Australian Coral Reef Society

92nd Conference & AGM Program

TANGALOOMA RESORT, MORETON ISLAND, QLD
7 - 9th May 2019

Major sponsors

Australian Government
Great Barrier Reef Marine Park Authority

CSIRO

Australian Institute of Marine Science

Australian Coral Reef Society

Welcome to the 92nd Australian Coral Reef Society Conference.

Founded in 1922 the Australian Coral Reef Society (ACRS) is the worlds' oldest organization concerned with the study and conservation of coral reefs. The ACRS plays a key role by promoting scientific research on Australian coral reefs. It is a forum for discussion and information transfer among scientists, management agencies and reef-based industries that are committed to ecological sustainability.

Because it is not aligned to any vested interests, the Society's views are sought by government policy makers, conservationists and all those interested in coral reefs who need impartial and expert advice. The Society invests in the future by providing financial assistance for Australian post-graduate students.

This year, the ACRS Conference is being held at Tangalooma Resort, Moreton Island, QLD. Over the two days of **three** concurrent sections and a poster session the ACRS Conference is hosting over ***100*** delegates from across a number of universities, government organisations and international speakers.

Keynote Speakers

We have five keynote speakers at the conference. ***Dr Alana Grech, from the ARC Centre of Excellence for Coral Reef Studies, and Mr Russell Kelley, the recipient of the ACRS 2018 medal for science advocacy, will be our opening keynote speakers on Wedneday morning. Wednesday after lunch we have a special keynote presentation from GBRMPA, opened by GBRMPA CEO Josh Thomas. Thursday morning Professor Amatzia Genin from InterUniversity Institute for Marine Sciences will give a keynote, followed by Dr Pat Hutchings from the Australian Museum Research Institute after lunch.***

Dr Alana Grech completed her doctorate in Environmental Science at James Cook University. Currently she is the Assistant Director of the ARC Centre of Excellence for Coral Reef Studies, and leads research on the conservation and management of tropical coastal ecosystems. Alana was previously employed as a Senior Lecturer in spatial information science at Macquarie University, and Postdoctoral Research Fellow at the ARC Centre of Excellence for Coral Reef Studies, James Cook University. Much of her work explores spatially-explicit approaches to cumulative impact assessment (CIA), and the implications of CIA in environmental decision-making, policy and practice. Alana received the Queensland Young Tall Poppy Scientist of the Year Award in 2018 for her leadership in science and communication.

Mr Russell Kelley has been a member of the ACRS since the early 1980's when he started his career as a coral reef geologist at UQ working on the raised reef terraces of the Huon Peninsula, PNG. Subsequently Russell worked on programs at JCU and AIMS where he developed an interest in coral identification. In 1990 he left working-life and sailed all over the Great Barrier Reef and Torres Straits returning two years later to join an underwater film making group as science communicator and director / producer. After a decade working on high production-value factual documentaries he moved into science communication more broadly - work that continues today. In the 1990s / 2000s he produced a series of landmark print products focused on promoting a whole-of-system approach to reef management (e.g. the Blue Highway, the original Catchment to Reef). Later his interest turned to the fundamentals of ocean literacy and capacity building with the publication of the Coral Finder (3 editions) and the Reef Finder. Russell, in partnership with marine park manager Rachel Pears and others, have trained over 1000 people through the Coral Identification Capacity Building Program. Russell is the 2017 recipient of the ACRS medal for science advocacy for his exceptional role communicating coral reef science, and contributions to science education and conservation.

Professor Amatzia Genin is a marine ecologist and biological oceanographer. His major interest is in the coupling between physical and biological processes in the marine environment, focusing on the effects of water motion on fundamental ecological processes, including predator-prey relationships, competition, symbiosis, mass transfer, and behavior. Research at his lab is process-oriented and inter-disciplinary, addressing mechanisms that operate at levels ranging from the individual to the ecosystem.

The Cover: Photo by ACRS member Laura Puk. Taken while heading out to a field site in Palau, Micronesia.

#ACRS2019

Most of Amatzia's studies are based on field experiments involving advanced technologies and novel approaches. Amatzia completed his BSc (1977) and MSc (1981) at the Hebrew University of Jerusalem, Israel and his PhD (1987) at Scripps Institute of Oceanography, UC San Diego, USA. He has been a faculty at the Hebrew University of Jerusalem and a resident researcher at the InterUniversity Institute for Marine Sciences of Eilat (IUI) since 1987. During the past six years, he was the scientific director of the IUI. At present, he is on sabbatical leave at UQ in Ove Hoegh-Guldberg's lab.

Dr Pat Hutchings is a Senior Fellow, at the Australian Museum Research Institute, Australian Museum. Her research mainly focuses on the systematics and ecology of polychaetes which are dominant components of all benthic ecosystems. She also has an interest in wetland ecology and coastal zone management and has worked extensively on coral reefs especially with regards to bioerosion. In addition her work has explored how rates and agents of bioerosion are changing with increasing anthropogenic impacts on reefs around the world using experimental approaches.

Mr Josh Thomas was appointed Chief Executive Officer of the Great Barrier Reef Marine Park Authority in 2019 for a term of five years. Mr Thomas has more than 15 years' experience in the public and private sector in Australia and overseas. He has helped shape and lead environmental policy and programs for the Great Barrier Reef and in terrestrial natural resource management. Mr Thomas has worked in a number of senior public sector roles and across the environment, agriculture and finance portfolios, as well as in federal Ministerial offices. He has a strong track record of public engagement on matters affecting Australia's World Heritage sites, and through major environmental programs such as the Biodiversity Fund and Caring for our Country. Mr Thomas' policy experience in the marine environment extends across the Great Barrier Reef and its catchments, migratory and endangered species, whaling matters, marine parks and Antarctica. He is committed to enhancing Australia's natural environment and has been a strong advocate for incorporating both contemporary science and Indigenous traditional knowledge into environmental management throughout his career.

Sponsors Information

The ACRS would like to recognise and thank its current sponsors of the conference for their generous support, their contributions allow our important events to take place and ensure the conferences' success. Thank you to ***Great Barrier Reef Marine Park Authority (GBRMPA), Australian Institute of Marine Science (AIMS) and Commonwealth Scientific and Industrial Research Organisation (CSIRO).*** We would also like to recognise and thank our kind sponsor of the student workshop day ***ARC Centre of Excellence for Coral Reef Studies.***

Student Prizes and Prize Sponsors

Awards for best student oral and poster presentations will be presented at the Awards Dinner, with prizes kindly provided by Diversity Journal, Scuba Pro, One Tree Island Research Station and Lizard Island Research Station. Winners of the ACRS 2018 Terry Walker, Danielle Simmons and ACRS Research student awards, as well as the Conference photo competition winners, will also be announced on the evening.

Student Travel Awards

The ACRS provides assistance to student members to attend the conference. This year 22 students were awarded an ACRS travel award. We would also like to take this opportunity to thank the student recipients for their participation in running the conference.

Speaker and Poster Presenter Information

ORALS: Please arrive at your session at least 5 min before it begins to meet the chair. You will be able to load your presentation on the first morning from 7:00 am, Wednesday May 8th. Presentations can also be loaded during the first 15 minutes of each break during the conference. Please load your presentation in the break before the session prior to your own session at the VERY LATEST. Presentation time slots are 15 minutes, please plan to speak 12-13 minutes giving time for questions. Please remain in session till the final speaker, and note whether a discussion time slot is provided.
POSTERS: Please arrive at the Waterfront pavillion early on Wednesday May 8th to hang your poster. Posters will be on display throughout the conference. At 6pm on Wednesday 8th May there will be a poster session. ***At the end of the AGM on Wednesday 8th May, you will be asked to give a succicint 1 min pitch of your poster.***

Social Program

Tuesday 7th May – The Welcome Dinner will be held in the evening at the resort Wheelhouse room. The Welcome Dinner is from 7:30 pm onward. A buffet dinner has been organised.

Wednesday 8th May –The CSIRO poster session with drinks and antipasto platters will be held at the Waterfront Pavillion room from 6pm onwards. Poster presenters will give a breif description of their work at the end of the final keynote for the day, and be near their posters ready to discuss their work with delegates during the poster session.

Thursday 9th May – The Conference Awards Dinner will be held at the Waterfront Pavillion room. Delegates may arrive from 7pm to mingle, with the Dinner commencing at 7:30pm. The dinner will be an alternate drop, set menu.

Workshops

Friday 10th May - There will be two workshops held at Tangalooma resort: the ARC Centre of Excellence for Coral Reef Studies National Student Mentoring Day and AIMS data workshop, see further details below.

The ARC Centre of Excellence for Coral Reef Studies National Student Mentoring Day for graduate students will be delivered by Professor Joshua Cinner. The workshop is directed at early career scientists interested in learning how to navigate the publication process. The workshop will be in Kallatina Conference Room from 8:30am to 4:30pm.

AIMS data workshop – This workshop is to assist the scientific community to discover, access, download, use and understand the potential of the data being collected by a number of agencies on and around Coral Reefs. This includes IMOS and AIMS long term monitoring environmental and ecological data sets. The workshop will be in Waterfront Pavillion from 9:00am till 1:00pm.

Resort Area

3 - Reception & Tour Desk
3 - Cafes & Restaurants
B&B's Bar
Beach Cafe
Copper Grill
The Coffee Lounge
Tursiops Breakfast buffett
9 - Fire & Stone Restaurant

Conference Area

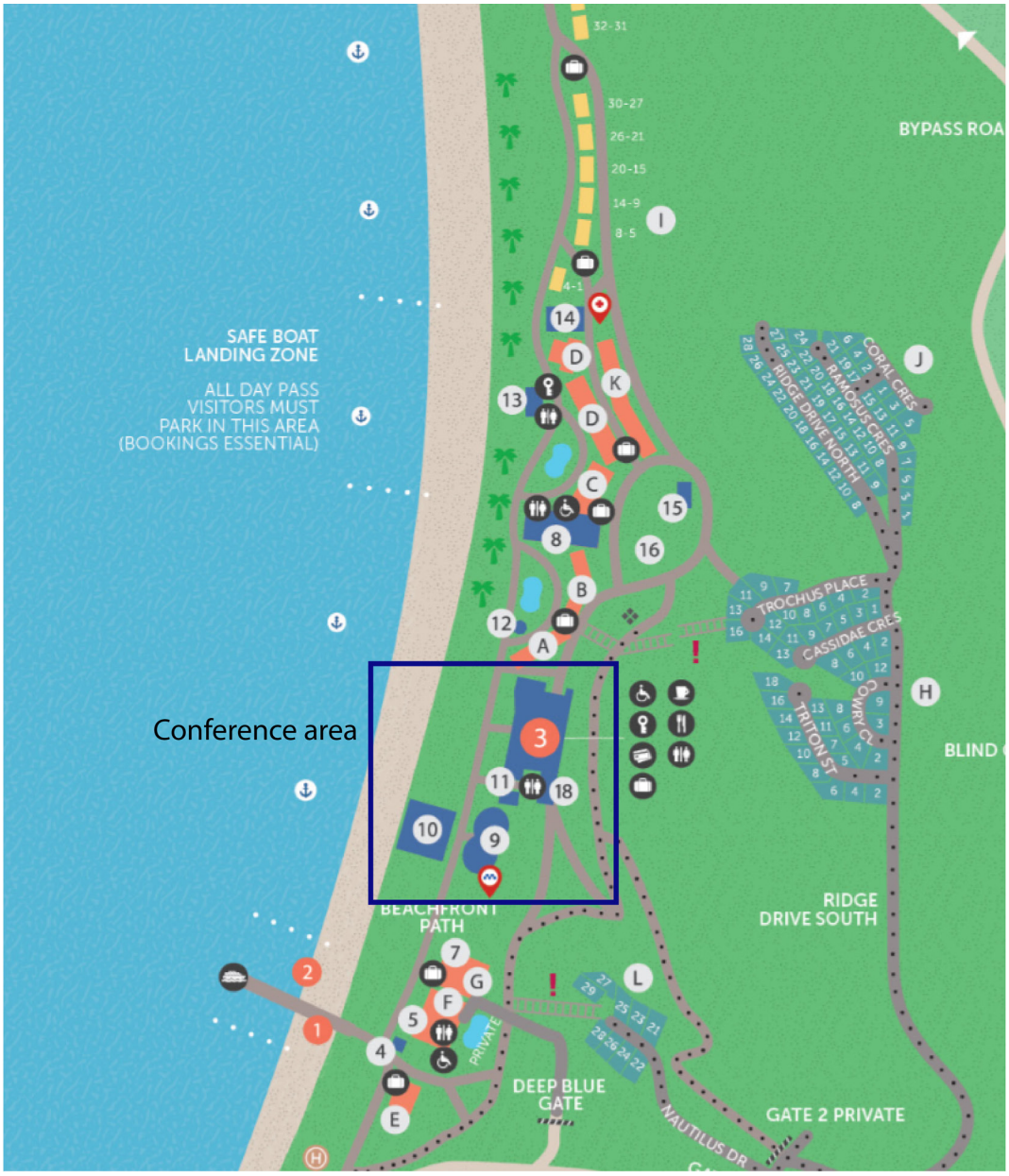
Welcome Dinner
3 - Wheelhouse (upstairs)

Speaker rooms
10 - Waterfront Pavillion: Keynotes and concurrent session talks
18 - Kallatina Room: concurrent session taslk
5 - Wadsworth Room: concurrent session talks

Poster session & Awards dinner
10 - Waterfront Pavillion

Catering
3 - morning/afternoon tea
10 - lunch

Workshops
18 - ARC CoE Student Day
10 - AIMS



The Venue

The Tangalooma Resort is located on Moreton Island, South East Queensland. The Welcome Dinner will be hosted in the Wheelhouse (3, upstairs) and is a sit down buffet. Speaker rooms include the Waterfront pavillion (10), Kallatina room (18) and Wadsworth room (5), keynote talks will be in the Waterfront pavillion. Catering during the conference will include morning and afternoon tea served in a seated/undercover area out the front of building 3, and sit down lunches will be served in the Waterfront pavillion (10). The final Awards Dinner will be hosted in the Waterfront pavillion. There are ample breakfast and dinner options at the Resort, you can also order delivery to your room.

Carbon Footprint

The ACRS makes every effort to reduce the carbon footprint of their conferences. As with previous years, we have made all our information available electronically including the call for papers, registration, travel award applications, photo competition entry, conference program and information on workshops. No print materials are handed out to delegates from sponsors but these can be picked up from the ACRS booth during the conference. Our meal choices for catering are considered with our carbon footprint in mind. Additionally, no disposables will be used during the catering. As such it would be wise to bring a water bottle and keep cup. We encourage those of you who have not done so already to offset your flights to the conference as well. Further, Tangalooma Island Resort are members of EarthCheck, a global eco accreditation program that assists corporations to lift their game when it comes to protecting the environment, through exemplary business policy and practices.

Moreton Island

Moreton Island sits just off the southeastern Queensland coast, on the eastern side of Moreton Bay. The island is 95% national park and has a World Conservation Union category of II. It is also the third largest sand island in the world. The island has only one resort on it, Tangalooma, and four small settlements. Moreton Island is the traditional home of the Ngugi tribe, and numerous shell middens can be found across the island. The protected sand island is known for its beaches and steep dunes, like Mount Tempest, where visitors go sand tobogganing. On the west coast, a group of sunken boats called the Tangalooma Wrecks features coral and tropical fish great for snorkelling or diving. A dolphin feeding spot is nearby and humpback whales can be viewed from Cape Moreton during their migration period. Moreton Island allows access by 4WD and camping with a permit (NB: delegates attending the conference must stay at the resort). Tangalooma resort was originally the site of Queensland's only whaling station between 1952 and 1962. Around 600 humpback whales were harvested each season. Some old sections of the station still remain at the resort. At Cape Moreton is Queensland's oldest lighthouse, Cape Moreton Light, which was first lit in 1857. The lighthouse was followed by at least four other lighthouse erected since the 1860s. Sites that are heritage listed on the island include Cape Moreton Lighthouse, Signal Station (25 Dorothy Newnham Street), and Fort Cowan Cowan.

The ACRS Conference would not be possible without the dedication and drive of its committee members. We thank them, as well as all ACRS Councillors, for their efforts in bringing this event together.

Again the ACRS Council welcome you and hope you enjoy the 92nd Conference.

photo by M Trapon

Program Overview

Tuesday 7th May

17:00	Registration open (Wheelhouse, upstairs)
19:30-22:00	Welcome Dinner at Tangalooma Resort (Wheelhouse, upstairs)

Wednesday 8th May

07:00 - 08:00	Registration open at Tangalooma Resort (Waterfront pavillion)
08:15 - 08:45	Welcome to Country and Opening Address (Waterfront pavillion)
08:45 - 09:45	Keynote addresses: Dr Alana Grech and Mr Russell Kelley (Waterfront pavillion)
09:45 - 10:15	Morning tea (front of Building 3)
10:15 - 12:00	Concurrent sessions
12:00 - 13:00	Lunch (Waterfront pavillion)
13:00 - 14:00	Keynote presentation: GBRMPA (Waterfront pavillion)
14:05 - 15:35	Concurrent sessions
15:35 - 16:00	Afternoon tea (front of Building 3)
16:00 - 17:00	Concurrent sessions
17:00 - 18:00	ACRS Annual General Meeting (Waterfront pavillion)
18:00 - 19:00	CSIRO Poster session (Waterfront pavillion)

Thursday 9th May

07:30 - 08:15	Registration open at Tangalooma Resort (Waterfront pavillion)
08:30 - 09:00	Keynote address: Prof. Amatzia Genin (Waterfront pavillion)
09:05 - 10:05	Concurrent sessions
10:05 - 10:30	Morning tea (front of Building 3)
10:30 - 12:30	Concurrent sessions
12:30 - 13:30	Lunch (Waterfront pavillion)
13:30- 14:00	Keynote address: Dr Pat Hutchings (Waterfront pavillion)
14:05 - 15:35	Concurrent sessions
15:35 - 16:00	Afternoon tea (front of Building 3)
16:00 - 17:30	Concurrent sessions
19:00 - 22:00	Conference Awards Dinner at Tangalooma Resort (Waterfront pavillion)

Friday 10th May

8:30 - 16:30	ARC CoE Student Mentoring Day (Kallatina room)
9:00 - 13:00	AIMS Workshop (Waterfront pavillion)

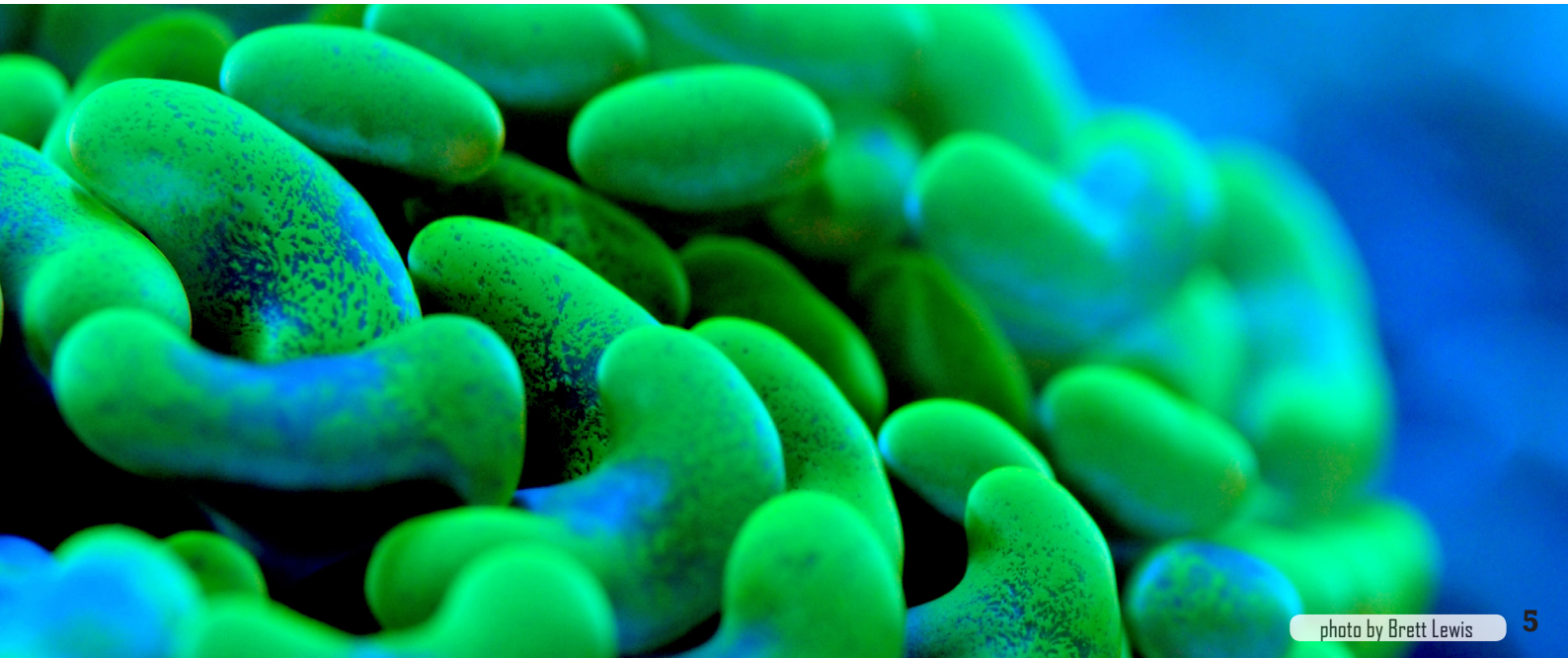


photo by Brett Lewis

Australian Coral Reef Society 2019 Conference

Conference Program

* indicates student presentations eligible for awards

Tuesday 7th May

17:00 Registration and presentation download opens

19:30 Welcome Function

Wednesday 8th May

TIME	Waterfront Pavillion
07:00	**Registration and presentation upload opens**
08:15	**Welcome to Country** **Opening**
8.45	**Opening Keynote Addresses** **Dr Alana Grech:** The Great Barrier Reef's changing coast **Mr Russell Kelley:** Adventures in Ocean Literacy and Science Communication: insights from wrangling scientists, stakeholders and training 1000 people
9.45 – 10:15	**MORNING TEA**

Australian Coral Reef Society

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	Waterfront Pavillion **Restoration of reef areas**	**Kallatina Room** **Coral reef resilience in a changing world – adaptation, acclimation and recovery**	**Wadsworth Room** **Water quality and coastal development**	
10:15	Great Barrier Reef Restoration: Identifying barriers and opportunities within the decision context Yolanda Waters*	Acidification is critically important to any conversation regarding reef futures Sophie Dove	Cross-shelf Heterogeneity of Coral Assemblages in Northwest Australia Molly Moustaka	
10:30	Motivations, success rates and costs of coral reef restoration Megan Saunders	Fifty years of sporadic coral reef calcification estimates at One Tree Island, Great Barrier Reef: Is it enough to imply long term trends Kay Davis*	The combined effect of ocean acidification and organic matter enrichment on coral reef sediment metabolism and dissolution Coulson Lantz*	
10:45	Supporting coral protection and recovery through ecologically-informed control of crown-of-thorns starfish on the Great Barrier Reef Cameron Fletcher	Consequential detriment to the mutual symbiosis of coral and dwelling gobies following cyclones and bleaching events Catherine Froehlich*	Responses and records from *Porites* corals: Spatio-temporal environmental changes in the Gladstone Harbour Yang Wu*	
11:00	Adaptive management in action – integrated pest management approach to crown-of-thorns starfish on the Great Barrier Reef David Westcott	Environmental predictors of Crown-of-thorns Starfish presence pervasiveness and outbreaks. Samuel Matthews*	Physical processes on coral reefs, understanding where, when and how nutrients and plankton originate and interact within the Great Barrier Reef Mathieu Mongin	
11.15	Crown-of-thorns movements and coral recovery Jacob Rogers*	Coral microbiome diversity reflects mass bleaching susceptibility Steph Gardner	Ingestion and retention of microplastics by reef filter feeders Mia Hoogenboom	

11.30	Desperately Seeking Substratum: optimal periods to release coral larvae to maximise rapid settlement Kerry Cameron*	Do we know what we're losing? Threats to soft bodied habitat builders and the implications for restoration Rosemary Steinberg*	The impacts of suspended sediments on coral fertilisation — pathways, thresholds, and risk probabilities Gerard Ricardo	
11.45	Operationalising techniques for industrial scale coral restoration Chris Doropoulos	Why corals in the northern Red Sea do not bleach despite ocean warming? Amatzia Genin	discussion	
12:00 – 13:00	**LUNCH**			
13:00	**Keynote presentation – Josh Thomas** **Building bridges between science and management: towards resilience-based management of the Great Barrier Reef.** GBRMPA session also featuring: Roger Beeden: Developing tools for resilience-based management Damian Weekers: Mind the Gap interactive session GBRMPA will run an interactive session using Sli.do. To join in the conversation, download the app on your device before the session or go to slido.com, then enter the event code #mindthegap			
	Waterfront Pavillion **Citizen science and management**	**Kallatina Room** **Cnidarian physiology**	**Wadsworth Room** **Eco-evolutionary dynamics of corals: Can we improve predictions of the future of coral reefs?**	
14:05	Help define resilience baselines for GBR corals with AIMS historic photo archive Terry Done	Partner switching and metabolic flux in a model cnidarian–dinoflagellate symbiosis Jennifer Matthews	The First Detailed Habitat Map of The Great Barrier Reef Chris Roelfsema	

14:20	A Sea Country learning partnership in times of Anthropocenic risk: Offshore coral reef education and our story of practice Marie Taylor	Going with the flow: do high water flow velocities mediate the impacts of thermal stress on hard coral species? Charlotte Page*	The Allen Coral Reef Atlas: where to begin with mapping the planet's reefs Emma Kennedy	
14.35	Building coral ambassador villages in the rural Pacific Igo Gari*	Diverse symbiont bleaching responses are evident as thermal stress intensifies in the coral holobiont Tracy Ainsworth	Spatial analysis of coral reefs Sarah Hamylton	
14:50	Using crime analysis techniques to improve compliance management planning and delivery in marine protected areas. Damien Weekers	Fatty acid biomarkers: trophic strategies of reef-building corals Veronica Radice	The real-time interaction of ecology and evolution in the sea: the curious case of reef building corals Greg Torda	
15:05	Expansion of the COTS Control Program as informed by Integrated Pest Management science Mary Bonin	Nitrogen cycling processes in Scleractinian coral microbiomes Tom Glaze*	Modelling three-dimensional growth and competition of a community of corals under different disturbance scenarios Anna Creswell*	
15:20	CoralWatch - from reef to outback Diana Kleine	Genomic responses to temperature, the lunar cycle, and daylight in a reef building coral Peter Vize	Blue light navigation and pulsed inflation phototaxis in Fungiidae coral *Cycloseris cyclolites* Brett Lewis*	
15:35	**AFTERNOON TEA**			

	Waterfront Pavillion **Reef community ecology**	**Kallatina Room** **Coral genomics**	**Wadsworth Room** **Symbiodiniaceae diversity and evolution**	
16:00	Local management actions can increase coral resilience to thermally-induced bleaching Brian Silliman	Will coral reefs be able to survive in our suffocating oceans? Rachel Alderdice*	Thermal stress results in variations in the Symbiodiniaceae volatilome – implications for thermal resilience, chemical signaling and the climate Caitlin Lawson*	
16:15	NESP 4.6: Recommendations to maintain functioning of the Great Barrier Reef Kennedy Wolfie	Sex specific Micro RNA in *Fungia fungites* Mila Grinblat*	The stability of photosymbiotic holobionts over time and during bleaching stress Melissa Pappas*	
16:30	Multiple habitat types in a tropical seascape influence coral reef fish communities Katie Sievers*	Symbiotic life-style triggers drastic changes in the gene expression of the algal endosymbiont, *Breviolum minutum* (Symbiodiniaceae); cellular pathways and membranal transporters Keren Maor-Landaw	Resolving the ecology of free-living Symbiodiniaceae through culturing, quantitative PCR, and eDNA metabarcoding Matthew Nitschke	
16:45	discussion	discussion	Genome evolution of Symbiodiniaceae as intracellular residents Raul González-Pech*	
17:00 ACRS Annual General Meeting - Waterfront Pavillion				
Poster Teasers				

18:00	**CSIRO POSTER SESSION**
	Steph Gardner: Homeward Bound: Women in leadership, towards a sustainable future
	Craig Steinberg: Back to back mass coral bleaching events on the Great Barrier Reef in 2016 & 2017: understanding the physical drivers
	Brett Lewis*: Citizen science project: sediment-rejection mechanisms of 30 species of Moreton Bay scleractinian coral
	Thea Waters: Enabling restoration on the Great Barrier Reef
	Brian Silliman: Harnessing biological partnerships to enhance marine restoration
	Nicole Hitchcock: The GBR Reef Protection Program Expansion Project
	Eric Fisher*: Tidal jets and fish aggregations
	Georgina Nicholson*: Microscopic analysis reveals dietary resource partitioning in Indo-Pacific Scarinine parrotfishes
	Maria Byrne: The seastar that never grows up, long term clonal propagation and stable demography in a geographically isolated population of Ailsastra heteractis at One Tree Island
	Lucy Tuley*: Investigating dietary responses by dugongs in relation to ontogeny, season and environmental stressors
	Tess Moriarty*: Coral Disease in the Extremes

Thursday 9th May

TIME	
07:30	**Registration opens**
08:30	**Keynote address – Prof Amatzia Genin:** Living in the flow: benefits, costs, and ecological consequences for corals and fish in exposed and sheltered reefs

	Waterfront Pavillion **Reef community ecology**	**Kallatina Room** **Marine mammals, sea birds, and sea snakes in coral reefs**		
09:05	Submerged pinnacles and small seamounts; deep, different and diverse coral reefs Gemma Cresswell*	Metabolic rate determination in wild dugongs, or how much seagrass does a dugong need? Janet Lanyon		
09:20	Assessing the sensitivity of coral connectivity modelling to mesh resolution in the Great Barrier Reef (or "How fine is fine enough?") Antoine Saint Amand*	Population structuring and connectivity of dugong (*Dugong dugon*) populations along the entire East Queensland coast Alex McGowan*		
09:35	Daily and seasonal fluctuations in the physiology of a marine sponge holobiont David Poli*	Modelled and observed Pacific South Equatorial Current Bifurcation in the current climate and projected changes in the future climate Chaojiao Sun		
09:50	DNA barcoding reveals cryptic functional diversity in a common coral reef macroalga (*Lobophora*, Phaeophyceae)	discussion		

	Laura Puk*			

10:05 – 10:30	**MORNING TEA**			
	Waterfront Pavillion **Trophic interactions and food web dynamics**	**Kallatina Room** **Early life history of reef organisms**		
10:30	Migrating herbivores and their role on sub-tropical and temperate reefs Shannen Smith*	Larval Cloning in the Crown-of-Thorns Sea Star, a Keystone Coral Predator Maria Byrne		
10:45	Temperature driven trophic mismatch between production and consumption of turf algae on a coral reef Alexia Graba-Landry*	The growth of herbivorous juvenile Crown of Thorns starfish (*Acanthaster cf. solaris*) on different algal diets Dione Deaker*		
11:00	Defining food resources for herbivorous and detritivorous fishes on coral reefs Kendell Clements	Incidence and severity of injuries among juvenile crown-of-thorns starfish on Australia's Great Barrier Reef Jennifer Wilmes*		
11.15	The response of parrotfish to reef ecosystem disturbances—Good and bad news John Howard Choat	Elevated temperature and CO_2 effect the aerobic and swimming performance of a larval reef mesopredators Shannon McMahon*		
11:30	Boomeranging around Australia: Historical biogeography and systematics of the anti-equatorial	Which receptors are responsible for coral settlement? Ramona Brunner*		

	fish *Microcanthus strigatus* (Teleostei: Microcanthidae) Yi-Kai Tea*			
11:45	Trophic separation in planktivorous wrasses: a new role for mucus? Victor Huertas*	Timing of mass spawning in corals: potential influence of the coincidence of lunar factors and associated changes in atmospheric pressure from northern and southern hemisphere case studies Jackie Wolstenholme		
12:00	Deception, mystery and exploitation: the diverse stories of endoparasitic trematode flatworms on the reef Storm Martin*	Neurobiology of pheromone detection: a comparison of teleost and elasmobranch olfactory systems Heather Middleton*		
12:15	The effect of habitat degradation on parasitism of herbivorous coral reef fishes Katie Motson*	discussion		
12:30 – 13:30	**LUNCH**			
13:30	**Keynote address – Pat Hutchings:** Australian Coral Reef Society – a brief history and its contribution to Australian coral reef conservation			
	Waterfront Pavillion **Conservation biology of coral reef organisms**	**Kallatina Room** **Coral reef resilience in a changing world – adaptation, acclimation and recovery**		

14:05	Understanding regulatory frameworks for large marine protected areas: permits of the Great Barrier Reef Marine Park Graeme Cumming	Evaluating adaptation pathways using a reef meta-community model of the GBR Scott Condie		
14:20	The contribution of Conservation Park Zones to the protection and management of reef fishes on the Great Barrier Reef April Hall	Coral populations carry genetic material to adapt to warming seas Emily Howells		
14:35	Bite sized chunks of change: Talking Reef Truth to Power Nick Heath	Cumulative impacts as drivers of the state and performance of GBR reefs Carolina Castro-Sanguino		
14:50	Mesophotic Coral Ecosystems of the World: where does Australia stand regarding research and conservation efforts Gal Eyal	Seventeen years of field data: A long-term observation of benthic composition dynamics for Heron Reef, Southern Great Barrier Reef, Australia (2002-2018) Eva Kovacs		
15:05	Building coral reef bioregions across the SW Pacific to support national marine spatial planning in five Pacific Island countries Leanne Fernandes	Modelling the impact of reduced solar radiation on reactive oxygen stress in corals Mark Baird		
15:20	Role of microbes in coral-algal interactions Grace Al Moajil-Cole*	Solar radiation interventions considered in the reef restoration and adaptation program Daniel Harrison		
15:35	**AFTERNOON TEA**			

	Waterfront Pavillion **Physical processes on coral reefs**	**Kallatina Room** **Coral reef resilience in a changing world – adaptation, acclimation and recovery**		
16:00	Applications of micro-CT data in studying skeletal porosity and microbioerosion Alexander Fordyce*	A mechanistic evaluation of cumulative impacts across the GBR, Yves-Marie Bozec		
16:15	Differential carbonate budgets shape geomorphological zones on a platform coral reef Kristen Brown	Cumulative impacts of sedimentation and climate change on *Acropora millepora* juveniles Christopher Brunner*		
16:30	Applying an attribute-based classification scheme to understand the seascape mosaic of the Central Queensland (CQ) coast Maria Zann	Coral reef resilience: a study of the complex regulatory space to aid resistance, repair and recovery of reefs Maxine Newlands		
16:45	An investigation of reef island landform dynamics in Isabel Province, Solomon Islands, using UAV-derived orthomosaics and digital elevation models Meagan Lowe*	Mangrove lagoons of the Great Barrier Reef house extreme coral populations Emma Camp		

17:00	Seasonal cross-shelf exchanges along the Great Barrier Reef Craig Steinberg	Impact of various increasing SST trajectories on *Pocillopora damicornis* bleaching response Jessica Bergman*		
17:15	discussion	Effects of warming and acidification on the physiology, behaviour and metabolome of polyps of the Irukandji jellyfish, *Carukia barnesi* Sheldon Rey Boco*		
19.00 Conference Awards Dinner				

KEYNOTE SPEAKERS

The Great Barrier Reef's changing coast

Alana Grech
Assistant Director of the ARC Centre of Excellence for Coral Reef Studies
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The Great Barrier Reef (GBR) World Heritage Area stretches along 2300 kilometres of coastline, and encompasses diverse seagrass, mangrove and coral reef habitats. The GBR's coast is exposed to cumulative and interactive stressors from multiple activities, including agricultural, urban and industrial development, commercial and recreational fishing and shipping. In addition, a changing global climate is leading to warming sea temperatures and increased intensity of tropical storms. In this presentation I will describe how coastal ecosystems of the GBR have responded to the interactive and cumulative effects of both global and local pressures, and provide insight on possible futures and management opportunities for the region. I will also discuss the importance of diverse and transdisciplinary teams of scientists, managers, policy makers and the community in developing environmental research with impact.

Adventures in Ocean Literacy and Science Communication: insights from wrangling scientists, stakeholders and training 1000 people

Russell Kelley
BYOGUIDES / ARC Centre of Excellence for Coral Reef Studies / James Cook University
russell@byoguides.com

Over the three decades I have been communicating coral reef science I have had the great fortune to work with dozens of gifted scientists, managers, media professionals and communicators. During that time the communication technologies and delivery platforms at our disposal for communicating science and marine conservation messages have undergone repeated revolutions. Yet despite these advances the fundamentals of good communication remain the same. In this talk I will review some of these fundamentals as they apply to the Ocean Literacy we all tend to take for granted in our audiences - popular, management, media etc. I will also outline successful, yet rarely used, training techniques for overcoming barriers to learning challenging subject matter like basic biology and coral identification. The talk ends with an update on progress towards Coral Finder 4.0 - the molecular version.

Living in the flow: benefits, costs, and ecological consequences for corals and fish in exposed and sheltered reefs

Amatzia Genin
The Hebrew University of Jerusalem and the Interuniversity Institute for Marine Sciences in Eilat, Israel
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Living in a stationary habitat, many coral reef organisms rely on the currents to provide essential commodities, to remove wastes and debris, to transport gametes and larvae, and

much more. Conversely, much due to the water's viscosity and momentum, the flow, or its lack thereof, can pose major limitations on some basic functions, such as photosynthesis and feeding. Here I will present a series of studies carried out in the coral reef of Eilat, northern Red Sea, demonstrating remarkable effects of flow on the following processes: (1) photosynthesis by algae, sea grass and corals due to flow-dependent efflux of excess oxygen from the tissues to the ambient waters; (2) recovery from lesions in stony corals; (3) inter-specific competition for space between aggressive (*Galaxea*) and subordinate corals; (4) predation rates on zooplankton by several species of coral-associated fish; and (5) the modulation of feeding postures in "anchored" fish (garden eels). I will also demonstrate the unique symbiosis between branching corals and damselfish, through which the fish enhance water motion in the otherwise nearly-stagnant space between the coral branches, thereby mitigating hypoxic conditions during the night and enhancing photosynthesis during the day. Similarly, some soft corals (Xeniidae) enhance the flow by themselves through perpetual (and quite captivating) pulsation, rendering their photosynthesis-to-respiration ratio the highest recorded for corals so far. Clearly, flow is a key dimension of the niche of many coral-reef inhabitants.

Australian Coral Reef Society – a brief history and its contribution to Australian coral reef conservation

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The Australian Coral Reef Society which traces its origins back to the Great Barrier Reef Committee which organised the Great Barrier Expedition to Low Isles in 1928 -29, and is the oldest coral reef society in the world. The Society has been very heavily involved in commenting on zoning plans for initially the separate sections of the GBR and subsequently was represented on the Resource Assessment Committee for Biodiversity and World Heritage-established by the Great Barrier Reef Marine Park Authority. This Committee provided input into the Representative Areas Program (RAP) which led to the rezoning of the entire reef and which increased the percentage of the reef and inter-reefal areas protected as green zones. While the Society has concentrated on the GBR we have also commented on zoning and management plans for other Australian coral reefs. The Society developed a handbook on the biology and geology of Heron Island way back in the 1970's by Mather and Bennett and which then morphed over the years into **The Great Barrier Reef: Biology, Environment and Management** edited by Hutchings, Kingsford and Hoegh-Guldberg published in 2008 by CSIRO, and a 2nd edition appeared earlier this year, considerably updated. The Society contributed to these editions and many if not all authors (49) are members of ACRS. So, this Society has a lot to be proud of and hopefully can continue to play an important role in the following decades as reefs become increasingly under stress.

KEYNOTE PRESENTATION

GBRMPA: Building bridges between science and management: towards resilience-based management of the Great Barrier Reef.

Opening: Josh Thomas
CEO, Great Barrier Reef Marine Park Authority

The Great Barrier Reef Marine Park Authority's Chief Executive Officer, Josh Thomas, together with the Authority's Reef Knowledge section will provide an overview of the agency's vision for resilience-based management of the world's largest coral reef ecosystem. The critical need for close collaboration between scientists and managers to address known and emerging pressures on the Reef will be discussed. A number of current projects that clearly demonstrate the benefits of close collaboration, including the Reef 2050 Integrated Monitoring and Reporting Program, crown-of-thorns starfish control and Marine Park compliance will also be outlined. This overview will be followed by a forum to discuss and capture how the Authority and scientists can most effectively foster current and future collaborations, which is essential to how we all best assist the Reef at such a critical point in its history. By focusing our efforts and working with partners, together we will give the entire Great Barrier Reef ecosystem the best chance of maximising its resilience as the climate changes.

Developing tools for resilience-based management

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Donna-marie Audas, Paul Groves, Joseph Street, Karen Chong-Seng

In this presentation we describe Resilience Network Project (RNP). This is a resilience network tool created by interrogating, modelling and combining data from a range of sources. The Great Barrier Reef ecosystem is functionally complex and characterised by regular periods of disturbance and recovery. The Reef has a naturally evolved resilient threshold to major disturbance events. However, the increased temporal frequency and spatial extent of a combination of different events threatens to exceed these boundaries and overwhelm the recovery capacity of the ecosystem. These include; coral bleaching, increasingly severe cyclones, crown-of-thorns starfish outbreaks and the legacy effects of degraded water quality. To create the RNP we worked with experts in each of the exposure fields to design the exposure model and thresholds. Our work then generated a reef biophysical exposure model by combining temperature stress, cyclone generated waves, crown-of-thorns starfish outbreaks and water quality stress. This tool can be used by reef managers to assist in making best available science-based decisions. Modelling these combined exposures provide a starting point towards an operational system for resilience-based management. It is critical to the future health and resilience of the Reef to reduce pressures by managing cumulative impacts and delivering decisions which improve the condition of values.

Mind the Gap interactive session

Weekers, Damian

GBRMPA will run an interactive session using Sli.do. To join in the conversation, download the app on your device before the session or go to slido.com, then enter the event code #mindthegap

ORAL PRESENTATIONS

Diverse symbiont bleaching responses are evident as thermal stress intensifies in the coral holobiont

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William Leggat, Sarah Gierz

Coral bleaching is the dysfunction of the coral-algal endosymbiosis and is characterized as a loss of *Symbiodinium* cells or photosynthetic pigments from host. This study characterized the cellular responses of *Symbiodinium* sp. (C3) within *Acropora aspera* exposed to thermal stress. We provide evidence for significant changes to the *Symbiodinium* morphology and rates of *Symbiodinium* cell division following exposure to temperatures equating to as little as 2 DHW thermal stress events; stressors below the corals bleaching threshold. While corals exposure to bleaching equating to an ecological thermal stress of 4-degree heating weeks (DHW) experience significant declines in *Symbiodinium* density and dark-adapted yield, we also find over 90% of the corals' *Symbiodinium* cells are degraded once corals are exposed DHW4. While sub-bleaching level thermal stress events do not trigger bleaching alerts, we show that these low-level thermal stress events, which are likely to increase on corals reefs, have substantial impacts to the coral endosymbiosis. It is therefore vital that we also begin to quantify sub-bleaching thermal stress events and the impact of mild stress events to the fitness of *Symbiodinium* populations, the coral host and reef health.

'Will coral reefs be able to survive in our suffocating oceans?'

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Nadine Boulotte, Katie Chartrand, Peter Harrison, David Hughes, Michael Kuhl, Mathieu Pernice, Christian Voolstra, David Suggett

Oxygen serves as the universal agent for fuelling metazoan life on earth. However, only recently has loss of oxygen (hypoxia) within coral reef systems been identified as a key regulator of mass coral mortality. As oceans continue to warm and coastal nutrient flushing persists, future dissolved oxygen availability will likely reach levels insufficient to meet biological oxygen demands in coral reef ecosystems. Despite research indicating corals endure routine intracellular hypoxia during the night, the extent of coral hypoxia tolerance and its mechanistic basis remains unknown. Here, we experimentally exposed two reef-building corals from the northern GBR (Moore reef), *Acropora tenuis* and *Acropora selago*, to acute hypoxic stress (<2mg O_2 L^{-1}), finding interspecific differences in the capacity to tolerate low ambient O_2 availability. Bleaching and tissue loss was observed in *A. selago*, whereas *A. tenuis* exhibited far greater hypoxia tolerance under comparable conditions. We discuss how hypoxia sensitivity may be related to heat stress bleaching sensitivity as a result of shared metabolic pathways. Tolerance to hypoxia also appeared to differ between life stages of *A. selago*, whereby larvae appeared physiologically active despite prolonged ambient hypoxic conditions. To understand differences in hypoxia tolerance, we present a comparative analysis of the genes

expressed between species and life stages, and discuss how this provides the first study to reveal potential biomarkers for coral hypoxia tolerance. Screening coral taxa for a responsive gene suite to better identify corals most likely to survive under future ocean conditions where ocean deoxygenation is coupled to ocean warming and acidification.

Role of microbes in coral-algal interactions

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David Bourne, Andrew Hoey

Tropical coral reefs are being degraded by anthropogenic stressors, and macroalgae can rapidly proliferate across areas of degraded reefs, occupying space and preventing coral recovery. Environmental feedbacks reinforce stable macroalgae regimes, causing a shift from a coral to macroalgae dominated state. Fluctuations in reef microbiomes due to changing environmental conditions have been shown to exacerbate reef degradation, and so describing the contribution of microbial communities could help unlock fundamental mechanisms underpinning macroalgae abundance. In particular, we explore how fluctuating macroalgae abundance mediates microbial coral-algal interactions, which may amplify macroalgae dominance. Sargassum, *Montipora aequituberculata* and seawater samples were collected from Geoffrey Bay, Magnetic Island at three time points for 16SrRNA bacterial community analysis. 5 replicates of Sargassum and *M. aequituberculata* were collected in isolation, direct contact and systemic proximity (5cm from the point of direct contact) to identify any microbial coral-algal interactions. Ecological surveys were conducted concurrently to establish a link between macroalgae abundance and changes in the coral and algae microbiomes. The Sargassum microbiome was separately profiled by conducting bacterial analysis on separate morphological components of the alga (leaf, biofilm, holdfast, primary axis and basal growth) to establish a comparative baseline for change when identifying coral-algal interactions. This project explores the relationship between microbial coral-algal interactions and macroalgae abundance to develop a mechanistic understanding of algal dominance and explore the influence of marine microbes on surrounding reef ecology throughout shifting environments.

Modelling the impact of reduced solar radiation on reactive oxygen stress in corals

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Mathieu Mongin, Élodie Bougeot

Reducing solar radiation impacting a coral community potentially reduces bleaching through a combination lowering the temperature of the water and reducing the light absorbed by the coral symbionts, thus reducing the build-up of reactive oxygen stress. In this study we assume the only mechanism for bleaching is the temperature-mediated light-driven build-up of reactive oxygen, and restrict our numerical experiments to investigating the effect of subsurface photosynthetically available radiation (PAR) on reactive oxygen stress. We setup twenty ~200 m resolution individual reef scale configurations of the eReefs coupled hydrodynamic – biogeochemical model to produce realistic conditions from the 2016/17 summer. Numerical

experiments are used to investigate the residence time of the water above the reef, and the change in build-up of reactive oxygen with reduced PAR. The outputs are spatially-resolved, allowing us to consider the optimal locations for deploying floating reflective films. The simulations show that in many locations the 30 % reduction in PAR can reduce reactive oxygen species (ROS) concentration to below a toxic level, but that the residence time on many of the reefs is only hours, greatly increasing the likely cost of deployments.

Impact of various increasing SST trajectories on *Pocillopora damicornis* bleaching response

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Bill Leggat, Tracy Ainsworth

Temperature anomalies on Australia's Great Barrier Reef (GBR) have been linked to the increasing severity of episodic coral bleaching events. The majority of experiments studying thermal stress and coral-algal physiology have utilized a single, direct increase to bleaching temperatures, but recent research has identified that exposure to sub-lethal temperature conditions preceding bleaching events on the GBR may confer thermal tolerance to corals. The present study exposed 18 colonies of *Pocillopora damicornis* to two historical summertime sea surface temperature (SST) trajectories seen on the GBR: protective, in which a sub-bleaching temperature pulse (32°C) precedes bleaching conditions (34°C); and single, where temperatures gradually increase to the bleaching threshold (34°C). To address the hypothesis that corals exposed to initial sub-lethal temperatures are better able to acquire short-term thermal tolerance during thermal stress than corals that directly reach bleaching temperatures, we measured photo-physiological parameters and densities of endosymbiont populations. Specifically, we measured the ability of *Symbiodinium* photosystems to recover from short-term light stress throughout each bleaching trajectory. The resulting data provide a better understanding of how coral symbionts adjust their photosystem function in response to variable levels of thermal stress, which is functionally important to determining acclimatory potential of corals to future SST trajectories.

Effects of warming and acidification on the physiology, behaviour and metabolome of polyps of the Irukandji jellyfish, *Carukia barnesi*

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Kylie Pitt, Steven Melvin

Ocean warming and acidification stress many cnidarian species but most experiments test responses to the most extreme climate scenarios, despite moderate scenarios being most likely to occur. We examined the interactive effects of warming and acidification on the reproduction, respiration, mobility and metabolic composition of polyps of the Irukandji jellyfish, *Carukia barnesi*. The experiment consisted two orthogonal factors: temperature (current 25 °C and future 28°C) and pH (current (8.0) moderate (7.9) and extreme (7.7)). All polyps survived the experiment but those in the pH 7.7 treatment produced fewer asexual buds, had higher

respiration rates and were approximately half as mobile as those in the pH 7.9 and pH 8.0 treatments, regardless of temperature. Several metabolites occurred in lower relative abundances in the lowest pH (i.e. acetate, betaine, glutamate, glycine, lysine, methylguanidine, sarcosine) and elevated temperature treatment (i.e. creatine, mannose, proline, trigonelline). The results suggest that *C. barnesi* polyps are unlikely to be affected by the more optimistic climate scenario and will tolerate, but perhaps not thrive in the most extreme climate conditions.

Expansion of the COTS Control Program as informed by Integrated Pest Management science

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What science is informing crown-of-thorns starfish (COTS) control program delivery? Is COTS control effective at reducing COTS numbers and protecting coral? Where and how are the COTS control vessels operating? In this presentation we address your burning questions about the expanded COTS Control Program. The goal of the Great Barrier Reef Marine Park Authority's COTS control program is to protect coral on high value reefs in the Marine Park. We cull starfish numbers to ecologically sustainable levels for coral growth and recovery that have been determined through scientific modelling. Progress toward achieving sustainable levels is measured using data from manta tow surveys and cull dives. In 2018 the control program expanded from two to six vessels. This has enabled COTS control work in the far north (e.g. Princess Charlotte bay) and far south (e.g. the Swains) of the Marine Park for the first time. Control vessel operations are guided by the best-available science from the Australian Government's National Environmental Science Programme Integrated Pest Management project. The Authority has been working closely with these scientists to implement improvements to on-water operations. Recent data collected through the expanded program illustrates that manual culling is effective at significantly reducing starfish numbers and maintaining coral cover at high value reefs in the Marine Park.

A mechanistic evaluation of cumulative impacts across the GBR

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Karlo Hock, Kenneth Anthony, Robert Mason, Scott Condie, Mark Baird, Peter Mumby

Australia's Great Barrier Reef (GBR) is facing an intensification of acute and chronic pressures, which challenge the ability of corals to maintain effective levels of ecosystem functions and services. Managing for reef resilience requires assessing the current state of coral populations and evaluating their exposure and ability to recover from the cumulative impacts of multiple disturbances. Yet the GBR Marine Park spans >2,000 km of coastline, so that only a limited portion of the Reef can be effectively monitored. To assess the current state of corals across the entire GBR and inform about recent impacts of disturbances, we developed ReefMod-GBR, a spatially-explicit model of coral demographics that enables reconstructing

past coral trajectories for different environments of the GBR. This mechanistic model simulates the recruitment, growth, reproduction and mortality of individual coral colonies over >3,000 individual reef environments. Following their geographic location, coral populations were exposed to temporally- and spatially-realistic regimes of acute (tropical storms, marine heatwaves, outbreaks of the crown-of-thorns starfish - CoTS) and chronic (water quality) stressors. The reconstructed trajectories of coral cover allow evaluating the relative importance of each stressor in the recent history and current health of each management section of the GBR Marine Park. These mechanistic projections can be used to identify priorities for spatial management and for exploring scenarios of intervention (CoTS control, water quality improvement, reef restoration) aiming at ensuring reef persistence in the face of climate change.

Differential carbonate budgets shape geomorphological zones on a platform coral reef

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Dorothea Bender-Champ, Michelle Achlatis, Rene van der Zande, Andreas Kubicek, Storm Martin, Carolina Castro-Sanguino, Ove Hoegh-Guldberg, Sophie Dove

Carbonate budgets are increasingly being used as a key metric to establish reef condition. To better understand spatial variations in platform reef framework development, we quantified in situ accretion and erosion rate across distinct geomorphological zones over a 23-month period at Heron reef on the southern Great Barrier Reef. Across eight locations, we quantified benthic community structure, habitat complexity, macro- and micro- bioerosion (including parrotfish, sponges, worms and clams). At a subset of four locations, we measured linear extension and calcification of two dominant coral species (*Acropora intermedia*, *Porites lobata*) as well as the bioerosion rate of clionaid sponges. Our results provide a comprehensive carbonate budget for Heron reef and demonstrate differences in reef carbonate budgets between geomorphological zones. The results of this long-term experiment improve our understanding of how net rates of reef carbonate production and accumulation range across spatial scales and provide a valuable baseline of reef accretion for high-latitude, comparatively undisturbed reef systems.

Cumulative impacts of sedimentation and climate change on *Acropora millepora* juveniles

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Andrew Negri, Mia Hoogenboom, Sven Uthicke, Gerard Ricardo

Coral reefs are globally threatened by rising water temperatures and ocean acidification. Locally, they are furthermore exposed to coastal development and associated sediment-runoff. The cumulative effects of climate change and sedimentation on adult coral colonies have been relatively well studied. However, comparatively less is known about their more vulnerable

post-settlement life stage, which represents a bottleneck in the successful reproduction of corals. In this study, the resistance to sedimentation of up to three months old *Acropora millepora* juveniles was tested in climate scenarios that are expected to occur by the end of this century (elevated temperatures and pCO_2). During the exposure to three different climate scenarios, coral juveniles were periodically exposed to environmentally relevant sediment concentrations (0, 5, 10, 20, 40, 80 mg/cm²) to simulate major sedimentation effects that may occur following floods or dredging operations. Preliminary results indicate that three months after settlement, coral juveniles smothered with the greatest sediment concentration (80 mg/cm²), which frequently occurs during dredging projects or flood plumes, demonstrated the lowest survival (< 10%) in all tested climates. In the highest climate treatment (29 °C, ambient + 1.2 °C), lowest survival was observed at all tested sediment intensities. This was followed by survival rates in medium and ambient climate treatments. These preliminary results demonstrate that recently settled coral juveniles suffer increasingly from elevated sedimentation rates in future climate scenarios. Further analyses will highlight climate-adjusted thresholds, which will support the improvement of water quality management guidelines to enhance coral replenishment on reefs in the future.

Which receptors are responsible for coral settlement?

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Aurelie Moya, Ira Cooke, David Miller

Coral reproduction is vital for reef recovery. Most corals reproduce by releasing gametes into the water column. Dispersed by the currents, embryos develop into larvae. Successful recruitment of these larvae depends on the ability to find suitable habitats for permanent attachment to the reef substrate (settlement). In this process, larvae follow environmental cues indicating appropriate settlement spots. While most research on coral settlement has focused on the identification of natural settlement cues, the cellular structures that coral larvae possess to sense these cues are still unknown. This study investigates the receptors responsible for coral settlement of *Acropora millepora* by combining gene expression analysis and pharmacological settlement assays. Gene expression analysis was performed on samples taken during larval development as well as on larvae bisected into oral and aboral halves. Receptors that play a role in settlement are expected to be upregulated in the time window before larvae become able to settle and are assumed to be exclusively located at the aboral pole where the larvae attach to the substrate. High-throughput RNA sequencing identified 68 receptors that are shortlisted to play a role in coral settlement. Validation of their importance in coral settlement will be achieved by pharmacological settlement assays. The identification of receptors and the associated cues responsible for settlement induction will have benefits for reef management since larvae can be efficiently settled for reef restoration and knowledge about settlement-inhibiting cues will be the basis for environmental legislations that limit the discharge of these compounds into the reef.

Larval Cloning in the Crown-of-Thorns Sea Star, a Keystone Coral Predator

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The crown-of-thorns starfish (COTS) is an iconic keystone predator whose population outbreaks have devastating consequences for Indo-Pacific coral reefs. We investigated the potential for larval cloning in COTS as this is a feature characteristic of other seastar species. Cloning occurs in the larvae which can be nearly instantaneous process with bisection of 'head' and 'body' clones and so catching cloning in the act is challenging. We tested the effects of algal food supply and larval density on the frequency of larval cloning by culturing the early bipinnaria larvae of under variable conditions. Larval COTS are able to clone themselves in both low and high food conditions, and that the frequency of larval cloning increased with levels of food but is unaffected by larval density. Across three density treatments (0.3, 1.0 and 3.0 larvae ml-1), cloning increased from 4.3% in low, oligotrophic conditions (0.17 µg Chl a L-1) to 7.9% in high food conditions (1.7 µg Chl a L-1). Recent research indicates that cloning may be a threshold response with respect to nutrient levels and may also influenced by maternal/parental effects and potentially the presence of predators. Larval cloning has the potential to increase both COTS larval supply and the dispersal distance of planktonic larval stages, both of which are critical factors in predicting the timing and location of outbreaks of this species. In addition, while the relationship between food supply and cloning frequency lends support to bottom-up hypotheses as contributing to outbreaks, cloning was also observed under the oligotrophic conditions characteristic of coral reefs indicating that this is an inherent trait of these larvae.

Desperately Seeking Substratum: optimal periods to release coral larvae to maximise rapid settlement

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Grant Cameron, Peter Harrison

Coral reefs are critically important ecosystems as centres of high biodiversity and for global biophysical processes. However, coral reefs are in decline around the world. While urgent action to reduce anthropogenic stressors remains the key priority to protect and conserve coral reefs, active restoration is also needed to preserve these important ecosystems at local scales. An emerging method takes advantage of the abundant release of reproductive material by broadcast spawning corals. Coral spawn is collected and reared to produce millions of genetically diverse coral larvae that are then transferred into mesh enclosures over degraded reef areas, for in situ settlement directly onto natural substrata. Initial results from this method have been very promising, with densities of settled coral spat and surviving colonies significantly higher in larval restoration sites than in control sites. New research is refining this technique, with recent experiments determining the optimal time to release "desperate" *Acropora tenuis* and *A. millepora* coral larvae to maximise rapid settlement and metamorphosis into coral polyps that are permanently attached to the substratum. We found that larval age was significant, as was the time of day for larval release. The highest rates of settlement and rapid

metamorphosis (< 2 hours) occurred when larvae were introduced to suitable substratum 7 days after coral spawning, during the middle of the day when light intensities were highest.

Mangrove lagoons of the Great Barrier Reef house extreme coral populations

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Annabelle Doheny

Declining coral cover on the Great Barrier Reef has increased the need to identify both coral refugia and intrinsically resilient coral populations. While research from other global locations have demonstrated that corals living in mangrove lagoons routinely experience reduced pH, reduced oxygen and elevated temperature that effectively parallel (or exceed) climate conditions predicted over the next 100 years, our understanding of such habitats on the Great Barrier Reef remain entirely unknown. We present data from two mangrove lagoon systems on the Great Barrier Reef that house numerous coral species living under some of the most extreme abiotic conditions reported for extant coral reefs. We identify that changes in coral associated microbes (bacteria and Symbiodiniaceae), along with physiological plasticity and skeletal adjustments support survival of these coral populations. Notably, a conserved physiological response was observed for corals persisting into the mangrove lagoon; however, this response was accompanied by highly divergent, species-specific microbiome flexibilities, suggesting that adaption to extreme conditions will likely require a multitude of microbiome readjustments across host populations. Together, the data reveal some of the key traits that corals will potentially require if they are to survive climate change. We also highlight that these present day coral populations could become central to future reef restoration programs.

Cumulative impacts as drivers of the state and performance of GBR reefs

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Juan Carlos Ortiz, Renata Ferrari, Sven Uthicke

The concomitant effect of multiple stressors on the Great Barrier Reef (GBR) has caused an overall decline in reef state. GBR degradation has been attributed to major acute disturbances such as coral bleaching, cyclones, and outbreaks of crown-of-thorns starfish (CoTS). Yet, coral reefs are simultaneously exposed to local chronic stressors. Poor water quality is a significant threat to the GBR impairing the recovery of coral reef communities. Therefore, understanding the contribution of acute vs chronic disturbances on the current state and performance of reefs is critical for successful management of the GBR. Here, we used 25 years of coral cover and CoTS data from the AIMS LTMP and the most comprehensive dataset currently available characterizing the exposure to local environment (eReefs) and disturbance regime along the GBR to compare the suit of variables that may drive reef state (cover of different coral types) and reef performance (difference between observed and expected state). With this comparison, we plan to unpack some of the ecological complexities associated with the cumulative effect of different type of disturbances on the GBR. Current advances in modelling strategies and data collection with unprecedented temporal and spatial resolution are improving our capability

to assess the variability in reef responses to cumulative environmental stress. While we still face many challenges for a full understanding of the complexity of coral reef dynamics, these advances offer important tools for the prioritization of local management interventions.

The response of parrotfish to reef ecosystem disturbances—Good and bad news

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The literature identifies declines in abundance and species richness of fishes following disturbances to coral reef ecosystems. The consequences of these disturbances include the reduction of living coral cover, the accumulation of coral (especially acroporid) debris and the provision of new space. This results in declines in the abundance of those species that use branching corals as sources of shelter or a food resource. This assemblage is dominated by pomacentrids, gobies, chaetodontids and the new recruits of a number of species. However, the literature also identifies a complex of large benthic feeding fishes, the herbivores that show consistent increases in numbers and biomass following disturbances, especially bleaching or cyclones. Many species of parrotfishes (especially large excavators) achieve their highest abundances on exposed reef fronts, habitats particularly vulnerable to disturbances arising from hydrodynamic forces. The mechanism appears to be increased abundances of microbial autotrophs that colonize freshly disturbed reef substratum and provide fresh substrata for protein-rich rapidly growing cyanobacteria. The presentation compares abundance patterns of large parrotfishes over geographically significant scales subject to different disturbance regimes on the northern GBR. *Chlorurus microrhinos* and *Cetoscarus ocellatus* benefit from a disturbance regime. However, cyclones and bleaching also impact on parrotfish recruitment especially in species with an inshore recruitment habitat. Long-term monitoring has demonstrated that significant disturbances drive increases in abundance of the former two species while the larger *Bolbometopon muricatum* has shown a 60% decrease in abundance on the northern GBR over the last 3 decades.

Defining food resources for herbivorous and detritivorous fishes on coral reefs

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Georgina Nicholson, J. Howard Choat

Herbivorous and detritivorous fishes are considered critical to ecosystem processes on coral reefs. However, the literature lacks a clear terminology for the different categories of resources used, i.e. macroalgae, turfing algae, detritus, cyanobacteria, diatoms, etc. In fact, there is not even clear agreement on what constitutes an herbivore. Fish taxa differ in their capacity to harvest, digest and assimilate these resources, and they appear to specialise to varying degrees. Arguably the literature to date has been dominated by what Oesterheld and McNaughton (2000) call a plant-based approach, where herbivores are defined in terms of plant removal. In contrast, an animal-based approach focuses on the nutritional targets of herbivorous species, and thus looks at resource use from the perspective of the herbivore. We will discuss the types of

resources present on coral reefs, and how these are processed by the major fish taxa involved. We will then show how these resources are partitioned by different taxa with a view to defining distinct categories. We will argue that a plant-based approach leads to conceptual problems when feeding and resource traits are examined across different spatial and temporal scales, highlighting the important of clarity in defining and quantifying categories of resources and the fish that target them.

Evaluating adaptation pathways using a reef meta-community model of the GBR

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On the Great Barrier Reef (GBR) regular outbreaks of coral-eating crown-of-thorns starfish (CoTS) have combined with tropical cyclones and coral bleaching to severely deplete coral cover. Managing the GBR to improve its general resilience has not stopped this decline and further deterioration is expected under projected climate change. Many management interventions have been suggested to help protect the GBR, and a small number have been implemented including CoTS control. However, evaluating the efficacy of alternative combinations of interventions (i.e. adaptation pathways) in a complex system experiencing major cumulative impacts can only be achieved through a systems-modelling approach. The Coral and CoTS Network (CoCoNet) reef meta-community model represents over 3800 reefs across the GBR, each supporting populations of corals and CoTS, and connected through ocean larval dispersal. The reef network is also exposed to tropical cyclones and bleaching events, the frequency and intensity of which change according to climate projections. A range of management interventions have been tested within this framework, allowing the effectiveness of alternative adaptation pathways to be compared.

Modelling three-dimensional growth and competition of a community of corals under different disturbance scenarios

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Damian P. Thomson, Michael Renton

Scleractinian corals, which grow solid living structures via the secretion of calcium carbonate, create complex three-dimensional habitats and support diverse ecosystems. There are a variety of growth forms of corals, which contributes to the structural complexity on reefs. Different growth forms have different advantages and disadvantages when corals compete for space and light and when they are exposed to hydrodynamic disturbances. We developed a three-dimensional functional-structural model, Coralcraft, to investigate how competition for space and light interacts with perturbations from a range of hydrodynamic disturbance regimes to drive the dynamics of a simulated community of corals. Using Coralcraft we first investigate the temporal dynamics of a community with five common growth forms of corals: encrusting, hemispherical, tabular, corymbose and branching (Fig. 1). Coralcraft captures the temporal dynamics using four metrics: number of colonies, percentage cover and volume of each growth form, and the topographical complexity (rugosity) of the community. We show how these metrics capture the dynamics of impact and recovery from disturbance in different but

complementary ways. Our findings illustrate the trade-off between being a fast growing marine sessile organism and occupying space quickly but being hydrodynamically vulnerable as a result. While there are already several models of coral growth, Coralcraft is the first to our knowledge to model the temporal dynamics of three-dimensional growth and competition of a community of multiple coral growth forms under different disturbance scenarios.

Submerged pinnacles and small seamounts; deep, different and diverse coral reefs

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Submerged features of the ocean's floor constitute a significant area of habitat available for coral reef ecosystems. Typically, deeper and more isolated than near-sea-surface coral reefs, bathymetric features like seamounts and pinnacles are highly understudied but are important biodiversity hotspots across global seascapes. Here, our study addresses multiple aspects of coral reef ecology on a series of shallow seamounts in the Bismarck Sea. Using a combination of stereo-video and ROV transects, direct capture and in-situ loggers, we sampled fish assemblages, individuals and environmental parameters across three distinct reef types; shallow nearshore, shallow offshore and submerged seamounts. Preliminary results show that our reef types are composed of topographically and hydrologically distinct habitats that support correspondingly distinct structures of fish community but also share many of the same species. There is also evidence of physiological differences between populations inhabiting deep and shallow reef habitats. These findings will lay the foundations for further study of submerged reefs in Kimbe Bay, informing spatial planning considerations for deeper coral reef habitats and enhancing knowledge of their ecological roles. More broadly, any resilience conferred by situation and depth would suggest that submerged patch reefs are likely key features in the global future of coral reefs.

Understanding regulatory frameworks for large marine protected areas: permits of the Great Barrier Reef Marine Park

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Increasing numbers of large marine protected areas (LMPAs) are being added to the global conservation estate, raising new challenges for marine governance and biodiversity conservation. To better understand the institutions that are involved in regulating the use of LMPAs, we undertook a quantitative, spatially explicit analysis of permit data from the Great Barrier Reef Marine Park. We geo-registered 10,030 permits from the period 2016-2017, extracted the information into a 2x2km grid, aggregated the data into six different permit types and explored spatial patterns by permit type and numbers. Permit numbers of different types were all strongly and significantly correlated; access and transport permits were the most

numerous. Commercial harvesting permit numbers were negatively correlated with those for research and education, but not for tourism. Apart from research permits, the influence of the immediate biophysical environment (coral reefs, proximity to shore) was low; permit numbers were more influenced by proximity to towns and population density. There was also a broad-scale latitudinal effect, with higher permit numbers in the south, independent of human geography. Permit numbers have been increasing exponentially over the last decade but due to time lags in the system it is still unclear whether, or how, spatial patterns of permit applications are responding to recent coral bleaching events. More generally, our analysis shows how permit data can offer useful insights into the governance and management activities and needs of LMPAs, while potentially providing a window into long-term shifts in use patterns and changing needs for conservation-oriented governance and management.

Fifty years of sporadic coral reef calcification estimates at One Tree Island, Great Barrier Reef: Is it enough to imply long term trends?

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Estimates of coral reef ecosystem calcification (Gnet) and productivity (Pnet) provide insight into coral community health and functionality in response to short- and long-term stressors, such as ocean warming and acidification. Here, we investigate spatial variability in calcification and organic production at One Tree Island (OTI) and compare our new observations to sporadic metabolic rates reported over the previous 50 years on the same reef flat. Gnet and Pnet estimates at the nearshore site were 55% and 112% lower than an offshore site with a shift in organic production from net productive to net respiratory. Contrary to expectations, calcification rates in 2017 (140.6 ± 3.4 mmol m-2 d-1) were comparable to the 1970's estimate (125.0 ± 12.5 mmol m-2 d-1) and > 190% greater than similar observations in 2014. Our results indicate only weak associations between Gnet and aragonite (Ωar) with no clear influence at any of the sites. A local increase in coral cover was the likely driver of increased calcification. A steeper TA – DIC slope in 2017 demonstrates a greater control of calcification on seawater carbonate chemistry. Overall, these results highlight the importance of site selection and replication when comparing metabolic datasets, and demonstrate major short-term variability in metabolic rates. Predictive capabilities of ecosystem metabolism studies may be constrained by using the available short-term datasets to represent long-term calcification trends.

The growth of herbivorous juvenile Crown of Thorns starfish (*Acanthaster cf. solaris*) on different algal diets

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The biology of the Crown of Thorns (COTS) juvenile stage remains largely unknown due to their highly cryptic nature, yet is key to understand the success of COTS that poses such a

severe threat to the health of the Great Barrier Reef. Like the juvenile phase of other predatory starfish, this species has an ontogenetic switch from a herbivorous to a predatory life stage. The juveniles are thought to be initially depend on crustose coralline algae. We sought to determine if there is any flexibility in the diet of the herbivorous stage. Growth of the juveniles was measured for 11 months on CCA, a biofilm and *Amphiroa sp*. Juveniles fed CCA grew at the same rate as those fed *Amphiroa sp.* until 43 days when CCA juveniles began to grow at a faster rate. Although their growth was minimal, juveniles were able to consume and survive on a biofilm diet. When juveniles were offered a choice between the three diets, they selected either CCA or *Amphiroa sp*. over biofilm indicating that they can identify preferred, more nutritious food. Herbivorous COTS juveniles may have a greater flexibility in their diet than previously recognised.

Help define resilience baselines for GBR corals with AIMS historic photo archive

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This proposed project would provide access to an important photographic archive of Great Barrier Reef (GBR) coral communities, compiled in thirty sites across the last two decades of the 20th Century. The sites include the full variety of reef-zones from sheltered nearshore reefs in turbid waters through to the slopes and surf zones of outer reefs, each of which has its own distinctive assemblage of corals. AIMS has developed protocols to put the digitized archive on-line and provide web-tools that will allow internet users to contribute to AIMS' resilience research, primarily through the Zooniverse interface (www.zooniverse.org).The sites exhibited substantial resilience (in terms of restoration of prior percent coral cover and composition) following disturbances such as floods, crown-of-thorns starfish and cyclone-generated waves. With this century's additional impacts of recurrent lethal coral bleaching, citizen scientists could support AIMS researchers by 'adopting a transect' through its entire time-series and applying Reef Check Australia's basic point-intercept and photogrammetric methods of data extraction in support of AIMS demographic studies of corals and resilience. Citizen participants would upgrade their skills though access to taxonomic labelling of corals and other benthos provided by the team's coral taxonomist and other guidance from the AIMS team. The project would provide the general public with graphic imagery of decadal changes in the recent past, citizen scientists with a hands-on 'virtual reef' experience, and researchers with a recent historic baseline for ongoing studies of reef resilience.

Operationalising techniques for industrial scale coral restoration

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Accelerating the recovery of coral populations is a global challenge that has been attempted on many coral reefs around the world. Previous restoration efforts have shown varying levels of

success at localised scales, but the development of techniques for large scale application is still in its nascent stage. We initially compared two large scale restoration approaches: the harvesting, development, and release of wild coral spawn slicks with the transplantation of fully fecund adult coral colonies. Comparisons incorporated the best available information on the demographic rates to estimate coral population growth beginning at settlement to maturity five years following deployment. Mechanistic modelling found the harvesting, development, and controlled release of coral spawn slicks is anticipated to achieve large-scale restoration of coral communities with low-impact technology at low cost per colony. We then conducted a field trial to evaluate the actual feasibility of harvesting wild coral spawn slicks for large scale restoration activities, incorporating technologies used in oil spill remediation, dredging operations, and land-based aquaculture. The trial focussed on containing, concentrating, collecting, and culturing coral spawn slicks until settlement competency, testing the potential for scalability to commercial vessels. To our surprise, each objective was achieved, with only one of five processes requiring further optimisation. Overall, this restoration tool has negligible impact on stock, allows for long-distance translocation of corals, and can be combined with other applications such as heat hardening if necessary. Most importantly, it can be scaled up further to produce billions of coral larvae for delivery to target reefs.

Acidification is critically important to any conversation regarding reef futures

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Future climate scenarios force novel environment on our coral reef ecosystems; environments for which we lack information regarding the reef's response. We attempted to fill this knowledge gap by exposing reconstructed mini-reefs to a range of future scenarios. The broad range of experimentally obtained in-tank light, temperatures, carbonate chemistries, and organisms cover estimates obtained in conjunction with incubations to determine mini-reef day and night calcification rates (across treatments that encompass daily and seasonal variability), provided an important dataset for evaluating the relative roles of the abiotic parameters on core ecosystem responses, whilst accounting for any significant treatment driven biotic effects. Our best fit models identified that the effects of temperature and acidification were interactive: temperature optima for mini-reef calcification declined as in-tank pCO_2 increased, but also the rate of calcification at that optimal temperature declined.

Mesophotic Coral Ecosystems of the World: where does Australia stand regarding research and conservation efforts?

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Mesophotic coral ecosystems (MCEs) are characterized by the presence of photosynthetically active corals, algae and associated communities at depths ranging from 30 to 150 m in tropical

and subtropical regions. Due to the increased awareness of the potential importance of these reefs as an integral part of the coral reefs ecosystem (i.e. deep reef refuge; specialized biodiversity; recreational and intrinsic values), interest from the scientific community has grown around the world over the last two decades. Many nations have already made management declarations and started to extend marine protected areas and fishery limitations to MCEs. Among these global efforts, where does Australia stand? The estimated potential area for Australian MCEs is approximately twice that of shallow reefs; however, these areas attract limited research effort. In this study, we explore the reasons for neglecting mesophotic research in Australian waters (e.g. senior researchers' involvement; diving regulations; prioritization of acute climate change effects). At the present time, research efforts on Australia MCEs are in decline and if we maintain this "biasness as usual" scenario, the global disparity between other major coral reefs areas around the world and their MCE counterparts will deepen sharply. Hence, we call for action from the coral reef community and decision makers toward a wider understanding of these important ecosystems in Australia.

Building coral reef bioregions across the SW Pacific to support national marine spatial planning in five Pacific Island countries

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Pacific Island nations are leading a global effort to do more in terms of ocean protection. Five nations in particular are moving forward with national marine spatial planning. As part of this planning, they wish to implement ecologically representative networks of Marine Protected Areas as per their commitment under the Convention on Biological Diversity. To do, we suggested the development of marine bioregions (both reef-associated and deepwater) at a scale useful to national planning to ensure “ecological representativeness” given the paucity of data. To develop the reef bioregions, the SW Pacific was divided into over 40 000 9x9km units covering the inshore areas. Presence/absence data for over 1000 species at more than 4800 sites across the Pacific were modelled against seven predictor variables and then extrapolated across the Pacific to locations where data were not available. Hierarchical clustering (Ward) was then used to identify 102 reef-associated bioregions across the SW Pacific at a scale useful for national planning. Complementary deepwater bioregions were defined using over 140 000 grid cells 20x20km in dimension. Thirty comprehensive and reliable environmental datasets were identified, after testing for cross-correlation, and used in an initial k-means clustering to reduce the dimensionality of the data due to computational limitations. A distance matrix was calculated using the centre of gravity of each k-means cluster using the dist function of R programming language and then hierarchically clustered using the hclust algorithm with default parameters in R. 262 deepwater bioregions were defined using this method.

Supporting coral protection and recovery through ecologically-informed control of crown-of-thorns starfish on the Great Barrier Reef

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Crown-of-Thorns Starfish (CoTS) population outbreaks are one of the major threats to coral on the Great Barrier Reef (GBR). Of the major threats to coral cover and its recovery following disturbances, CoTS are the most amenable to direct management. Active CoTS control can provide immediate impact reduction and help support net coral growth. On the other hand, the scale of the CoTS problem threatens to dwarf the resources available to combat it. To maximise coral resilience it is therefore vitally important that CoTS control activities are conducted as efficiently and effectively as possible. The effectiveness of current CoTS control activities can be maximised by ensuring that CoTS are removed efficiently from areas of ecological importance to coral growth, or areas which foster the growth and spread of the CoTS population. Identifying and prioritising the areas where the greatest impact can be achieved requires knowledge of the current distribution of CoTS from control and surveillance activities, and a detailed understanding of the ecology that drives the spread of their population. At the same time, it is vital that the effectiveness of control actions is monitored to ensure the desired outcomes are being achieved, and to know when the CoTS population at a site has been successfully controlled and resources can be redirected to another site. With input from on-water control staff, managers and Australian CoTS researchers, we have used such insights to design an ecologically-informed decision tree framework to underpin decision making in the CoTS Control Program on the GBR. This adaptive management framework uses the current best understanding of CoTS and coral population processes, along with targeted data collection during control activities, to make day-to-day reef-scale management decisions. It is being operationalised as the CoTS Control Centre, a tablet-based ecologically-informed on-water decision support system. The CoTS Control Centre uses the cull and surveillance data collected by the control program, coupled with ecological and management models, to recommend which sites control program staff should survey and which they should dive at, how often, and at what point they should move to the next priority site in order to achieve the greatest improvement in coral health and resilience on the GBR. It coordinates decisions across the fleet of control program vessels to optimise control strategies given current knowledge, while also generating the data required to improve our knowledge and decisions in the future.

Applications of micro-CT data in studying skeletal porosity and microbioerosion

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The physical framework built by hard corals underpins coral reefs' economic and ecological value. Increased bioerosion is an emerging threat to the stability of this architecture. A significant component of this is microbioerosion by skeletal endolithic microbes, who are one of the largest contributors to overall reef erosion. Due to their niche, this functional group is challenging to study. The application of micro-computed tomography (µCT) has the potential

to provide new insights into microboring. Historically µCT has been used to examine overall skeletal porosity, in pre-cut aragonite blocks from Porites sp., over several months or years. This limits the ecological relevance of these findings to massive corals from a single genus over long time frames. We present novel, high sensitivity applications of before-and-after µCT data obtained from two species of branching coral that were subjected to an eight-week severe bleaching and mortality experiment. We analyse variation in the number of pores, pore size, pore wall thickness, pore connectivity and overall heterogeneity in skeletal density. The magnitude of change in these parameters is regress against those in skeletal hardness and porosity, to compare their explanatory power to these common measures of bioerosion. Finally, the starting skeletal characteristics of each coral's µCT scan is regressed against changes in porosity and hardness. This is intended to be the first step in defining a general model that describes coral species' susceptibility to internal microbioerosion.

Consequential detriment to the mutual symbiosis of coral and dwelling gobies following cyclones and bleaching events

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The mutual symbiosis between corals and coral-dwelling gobies demonstrates a very delicate balance regarding the survival of both in the face of climate change. If gobies are facing drastic losses from climatic events, then reduced recovery potential for corals may exist without goby presence. This symbiosis is thus becoming fragile as climate change is directly threatening the persistence of coral hosts and indirectly their inhabitants. Recent cyclones and massive bleaching events have affected the northern Great Barrier Reef by deleteriously altering reef systems. The current study quantified the consequential loss to coral-dwelling Gobiodon populations and their Acropora coral hosts following these events at Lizard Island, QLD. Transect surveys were completed in 2014 (pre-events), 2015 (post-cyclone Ita 2014), 2016 (post-cyclone Nathan 2015), and 2018 (post-bleaching 2016 & 2017). Coral abundance and size have diminished by over 85%, and goby populations have accordingly dropped by over 90%, with bleaching producing the largest drop in these numbers. Several Gobiodon species were no longer observed, and instead of gobies associating in pairs or gregarious groups, the few gobies that were observed were almost exclusively alone after repetitive climatic events. The stress of consistent cyclones, and most importantly bleaching have been a massive loss to successful fish-host symbioses, as surviving corals were often left uninhabited by gobies. Thus, continued large-scale stressors are deteriorating both the existing populations of corals and gobies and their imperative symbiosis. However, with some reprieve between these events, there may be potential for recovery and resilience of gobies and their hosts.

Coral microbiome diversity reflects mass bleaching susceptibility

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Repeat marine heat wave-induced mass coral bleaching has decimated reefs in the Seychelles for 35 years, but how coral associated microbial diversity (microalgal endosymbionts of the family Symbiodiniaceae and bacterial communities) potentially underpins broad scale bleaching dynamics remains unknown. We assessed microbiome composition during the 2016 heat wave peak at two contrasting reef sites (clear versus turbid) in the Seychelles, for key coral species considered bleaching sensitive (*Acropora muricata, Acropora gemmifera*) or tolerant (*Porites lutea, Coelastrea aspera*). Over 30% of all corals bleached in 2016, half of which were from *Acropora sp*. and *Pocillopora sp*. mass bleaching that largely transitioned to mortality by 2017. Symbiodiniaceae ITS2-sequencing revealed that the two *Acropora sp.* and *P. lutea* generally associated with C3z/C3 and C15 types, respectively, whereas *C. aspera* exhibited a plastic association with multiple D types and two C3z types. 16S rRNA gene sequencing revealed that bacterial communities were coral host-specific, largely through differences in the most abundant families, Hahellaceae (comprising *Endozoicomonas*), Rhodospirillaceae, and Rhodobacteraceae. Both *Acropora sp*. exhibited lower bacterial diversity, species richness, and community evenness compared to more bleaching-resistant *P. lutea* and *C. aspera*. Different bleaching susceptibility amongst coral species was thus consistent with distinct microbiome community profiles. These profiles were conserved across bleached and unbleached colonies of all coral species. Further understanding such microbiome-environmental interactions is likely critical to target more effective management within oceanically-isolated reefs of the Seychelles.

Building coral ambassador villages in the rural Pacific

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Sustainability remains a challenge despite significant investments in developing countries and this research aims to examine the factors that contribute to or impede project sustainability from the perspective of project 'recipients'. Stakeholders have varied perceptions of what sustainability means and how to achieve it. Understanding sustainability in projects and using that understanding to bring maximum benefit to the recipients of a project would be the ideal option. The best and possibly the only way sustainability can be realised is through relevant projects that transform decision-making, community consultation and participation, and on-ground actions. Importantly, these projects need to demonstratively improve the standard of living for citizens. Furthermore, they should also have a lasting effect or continue beyond the formal completion of the project itself. This PhD case study on coral reef restoration in a MPA, Bootless Bay, PNG attempts to test 'true sustainability' in the rural livelihood context. The objective is to promote awareness, conservation, sustainable management of marine ecosystem and create local economic opportunities while ensuring food security and creating a platform for scientific research. The gap this research tries to address is lack of knowledge on what defines sustainability in rural development projects this research findings will increase

knowledge on sustainability and assist stakeholders in future decision-making processes. The study has the potential to influence policy and project management research.

Why corals in the northern Red Sea do not bleach despite ocean warming?

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The Gulf of Aqaba/Eilat (GoA), Red Sea, harbors a high-latitude (29°N), yet flourishing and diverse coral reef. Despite of warming (~0.035°C/yr) and sometime extremely hot summers, no mass bleaching has been reported for the GoA. The local corals appear to defy the otherwise universal "heating rule" of coral bleaching. On the other hand, mass coral mortalities occur due to algal bloom that follow extremely cold winters. Both phenomena are related to the unique geology and oceanography of the Red Sea, where a shallow sill (137 m) at the Straits of Bab el Mandeb controls the temperature and extent of water exchange with the Indian Ocean. Consequently, the deep Red Sea waters are unusually warm (21°C at 2500 m depth), stratification is weak, and vertical mixing during winter reaches depths that greatly exceed any other warm-water ocean on the globe (>800 m during extremely cold winters). Deep mixing generates extraordinary algal blooms that smother corals. In the past, during the peak of the last glacial period, when sea level was 120 m below present, the sill left little space for water exchange with the Indian Ocean, causing salinity to dramatically increase, eradicating corals reefs throughout the Red Sea. After sea level rose ~8000 yrs ago, corals entering the Red Sea form the Indian Ocean could not survive the passage through the straits unless they survived the local temperatures of 32-34°C. This warm-water barrier means that corals found today in the northern GoA are genetically selected to survive much higher temperatures than those occurring in the GoA during summer (~27°C). According to this scenario, under present rate of warming, it will take another ~100 yrs for corals to start bleaching in Eilat.

Nitrogen cycling processes in Scleractinian coral microbiomes

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Tropical Scleractinian corals accommodate a complex and diverse microbiome consisting of bacteria, archaea, fungi, protists and viruses. Microbiome associates may be stable or transient and engage in a range of inter-species relationships with the host. A large body of evidence suggests members of the coral microbiome play a significant role in host metabolic activities, including carbon, nitrogen, phosphorus and sulphur cycling. Nitrogen (N)-cycling counterparts may be of particular significance to corals, as N is generally limited in coral reef systems and is crucial in mediating the coral-*Symbiodinium* relationship. While N_2 fixation in coral microbiomes has been deemed ubiquitous through genetic and biogeochemical evidence, the role of other N-cycling community members such as those engaged in nitrification and

denitrification have been largely overlooked. In this study we conducted multiple isotope tracer incubation experiments on live fragments of seven Scleractinian coral species. Fragments were collected from wild colonies in the One Tree Island Reef lagoon, southern Great Barrier Reef. We present the first unequivocal biogeochemical evidence of denitrification activity in tropical coral microbiomes. Measured denitrification rates were significantly lower than those of N_2 fixation from all species tested, denoting corals as a net bioavailable N source to reef systems. Although the low rates suggest limited importance in host N removal, the collective contribution may account for as much as 11% of reef-scale gaseous N loss. Net nitrification was recorded in all species tested, with similarly low rates. Our data suggests a tight coupling exists between these processes in tropical coral microbiomes.

Genome evolution of Symbiodiniaceae as intracellular residents

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Symbiosis between corals and symbiodiniacean dinoflagellates is crucial for the survival of reef ecosystems. This type of symbiosis is different in the extent of permanence in and specificity to the host from one coral-algae ensemble to another. Although dinoflagellates are predominantly free-living, Symbiodiniaceae diversified mostly as symbionts. Recent studies demonstrate that symbiodiniacean genomes share gene functions associated with symbiosis and display high levels of sequence-divergence. Nevertheless, the evolutionary drivers of the transition from a free-living lifestyle to symbiosis remains largely unknown. In this presentation, we examine genome evolution of Symbiodiniaceae representing a wide range of symbiotic associations that this group exhibits, from free-living species to potentially obligate intracellular symbionts. Building on results from recent studies, we formulate fundamental questions regarding the impacts of the transition from free-living to a symbiotic lifestyle in symbiodiniacean genomes, and propose future research directions to enhance our understanding of coral-dinoflagellate symbiosis, and more broadly of eukaryote-eukaryote symbioses.

Temperature driven trophic mismatch between production and consumption of turf algae on a coral reef

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The effect of increasing temperatures on coral reefs is already evident with recurring mass coral bleaching events, followed by extensive coral loss and algal overgrowth. Herbivory is a critical process on coral reefs which mitigates algal dominance and facilitates coral reef resilience. Metabolism of both fish and algae are governed by environmental temperature, but the rate of change and thermal optima are likely to vary between species. Therefore, the effect of temperature on herbivory will depend on how production and consumption of algae scale with

temperature. We used seasonal variation in temperature to investigate the relationship between production and consumption of algal turfs on Lizard Island, northern Great Barrier Reef. We quantified individual feeding rates of eight herbivorous fish species with varied diets and the growth of turf algae over four seasons which ranged between 22ºC to 31ºC in temperature. We found that irrespective of diet, the feeding rate of all species slowed down significantly in the winter (22ºC). There was also no difference in feeding rates between autumn, summer and spring (26ºC-31ºC) for the majority of species suggesting that a thermal optimum has not yet been met for this trait. Growth of algal turfs however, showed an optimum in growth in the spring and autumn (26ºC -28ºC). These results suggest a current mismatch between production and consumption of algal turfs, with consumption exceeding production in the warmer season, which may have implications for coral reef health as temperatures continue to increase.

Sex specific Micro RNA in *Fungia fungites*

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Specific Double sex/Male-abnormal-3 (DM) domain genes control sex differentiation pathways in animals by encoding transcription factors that regulate the expression of downstream genes involved in sex determination. As previous work on cnidarians found sex-specific micro RNAs (miRNAs), it is reasonable to assume that miRNAs also function in the sex-determining pathways of corals and are expressed differently in different sexes of *Fungia fungites*. Total RNA and miRNA were extracted from *F. fungites* individuals (both male and female) collected in different months and miRNA expression profiles are compared and presented. The gonochorism (separate sexes) of *F. fungites* corals and their capability of sex change allow us to separate the sexes and study the upstream mechanism leading to sex determination. Different miRNAs are expected to be found in both sexes. As mRNA cleavage in cnidarians is achieved by nearly perfect miRNA-mRNA complementarity, the targeted genes will be revealed. Understanding the upstream mechanisms of the DM domain is crucial to developing a wider perspective on coral reproduction as it is a critical life-history function.

The contribution of Conservation Park Zones to the protection and management of reef fishes on the Great Barrier Reef

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Marine protected areas play a pivotal role in the conservation and management of marine ecosystems. On coral reefs, no-take marine reserves are fundamental to the conservation of key ecological processes, through protection of important functional groups such as predators. Although the benefits of no-take areas are well known, comparatively little attention has been given to complementary zoning types such as partially protected zones, which limit rather than prohibit fishing activities. Partially protected areas may act as a conservation middle ground, allowing limited extraction of fisheries resources whilst facilitating conservation benefits.

Conservation Park Zones (CPZs) are areas within the Great Barrier Reef Marine Park where partial protection is provided through restrictions on the type and amount of fishing gear permitted. Using a combination of ecological survey techniques, we examine the contribution of CPZs to conservation of coral reef fish communities on the Great Barrier Reef (GBR). Focus is given to the role of predatory fishes as a key ecological functional group, and the response of these fishes to partial protection in CPZs. This research provides insight into the ability for partially protected areas to contribute to conservation outcomes and will inform future management decisions around zoning on the GBR.

Spatial analysis of coral reefs

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Large volumes of complex information are now readily available in environmental research, including satellite and drone based remote sensing datasets. Innovative approaches to analysing big data, from machine learning algorithms to spatio-temporal models, are revealing patterns, trends and associations within this information that add valuable insight to our understanding of the natural world. How can we expand how we work with spatial information to address critical questions in coral reef environments? The disciplinary fields of remote sensing, spatial statistics, landscape ecology and morphometry collectively provide an exciting foundation for mapping, monitoring and modelling coral reefs. Here, I review some of the key opportunities that arise from the current spatial analytical paradigm for better understanding coral reef environments. These draw on examples from Australian reef systems, including: the development of robust frameworks for upscaling observations of important biophysical processes from the field and laboratory to geographically meaningful units (e.g. entire coral reefs), constructing spatial statistical models to explain and predict the behaviour of coral reefs, and developing novel spatial statistical frameworks for working with data gathered from new technologies to expand the boundaries of how we can better understand coral reefs.

Solar radiation interventions considered in the reef restoration and adaptation program

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Intervention to mitigate the threat of climate change to the universal values of the Great Barrier Reef is an immensely challenging task, largely due to the sheer scale and complexity of the ecosystem. A key class of interventions under exploration within the Reef Restoration and Adaptation Program are environmental engineering technologies designed to mitigate further damage by relieving the physical stressors of temperature and irradiance during marine heatwaves. Reducing the amount of solar energy during these periods could mitigate bleaching stress, scalable from individual reefs right up to the entire GBR. A mix of technologies has been identified which overlap to span this range in scale, each with apparent benefits, risks, and large uncertainties. Solar radiation management options can be grouped into two categories, atmospheric interventions which aim to reduce the amount of energy transmitted through the lower atmosphere, or surface interventions which reduce the transmission of light

by altering either the ocean surface or water column albedo. Atmospheric interventions considered include; cloud brightening, misting, and fogging, while surface interventions include reflective surface films, ocean microbubbles, and other forms of ocean whitening. The RRAP first stage analysis focused on assessing technical feasibility. Risk, societal and legal implications, social acceptability, and development pathways are to be more completely assessed in the next phase. Sophisticated hydrodynamic and atmospheric modelling techniques were utilized to assess potential benefits. The analysis has demonstrated that the potential benefits are significant, however each of the methods have significant unknowns, technology development requirements, and risks to be quantified.

Bite sized chunks of change: Talking Reef Truth to Power

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The Reef is under enormous, possibly existential threat, but we've already known that for far too long. What if getting bigger, faster action wasn't about making it bigger, but smaller? Requiring full-scale energy, catchment and fishing transition tomorrow is beyond the capacity of our often criticised but defensibly world-class democratic system. Obviously. But what is? One answer: Bite-sized chunks of change. And a persistent conveyor belt of them! If so, which reforms, when, how, why and how much should they cost, by and for who? How do we identify the orderly, economically rational, socially understood and most importantly, achievable, pathway out for our Reefs plight? Long-time fan of the ACRS, Nick Heath is working on it, imperfectly, with a few allies, and needs help from the incredible membership of the ACRS. We haven't cumulatively nailed the answer yet. He will report back an epistle from the visually unspectacular frontline of George St and Canberra, on what's working, what's not and ask some questions for the ACRS community on how we can unite together for Reefs once more. His presentation will cover combined efforts on overdue reforms addressing land based pollution, overfishing, threatened species bycatch and thermal coal transition.

Ingestion and retention of microplastics by reef filter feeders

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Microplastic pollution (plastic <5 mm in size) is ubiquitous in marine environments globally, and there is growing concern about the potential impacts of these tiny plastic particles on marine life. We conducted a series of microplastic exposure experiments to assess the ingestion and retention of microplastics for 6 hard corals (*Acropora tenuis*, *Pocillopora damicornis*, *Porites cylindrica*, *Dipsastrea pallida*, *Platygyra* sp., and *Duncanopsammia axifuga*), 2 soft corals (*Sinularia* sp., *Lobophytum* sp.) and 2 sponges (*Carteriospongia* sp. and *Cinachyrella* sp.). Using pulse-chase experiments where corals and sponges were dosed with fluorescent microbeads of varying sizes, we also aimed to establish whether microplastic ingestion and retention depended on particle size. Results showed that microplastic ingestion was highly variable among species, ranging from an average of 0.5 microplastics per cm^2 for *Sinularia* sp. to 32 microplastics per cm^2 for *D. pallida*. Microplastics were retained in the tissues of all

species for up to 6–12 days but, for most of the sampled species, microplastic counts declined decreased over the first four days after feeding. Microplastic ingestion also depended on particle size, with most of the sampled species ingesting more particles with diameters 27–75 µm compared with particles with diameters > 300 µm. Histology of coral tissues showed that microplastics are engulfed into tissues rather than simply being retained in the polyp cavity. By demonstrating microplastic retention over time, and the transfer of particles into tissues, this study identifies mechanisms through which microplastics potentially cause harm to reef organisms.

Coral populations carry genetic material to adapt to warming seas

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Bleaching and mortality responses to thermal stress can differ markedly among individual corals on a reef and some populations appear to have increased their upper thermal limits over recent timescales. The contribution of coral host genotypes to these observations has been rarely measured. Yet, standing functional genetic variation is critical to determining how fast populations can adapt to climate warming. Here we use a quantitative breeding approach to evaluate heritable genetic variation for heat tolerance in the common brain coral, *Platygyra daedalea*. Over a series of spawning events, 220 crosses were bred among individuals in populations from the Great Barrier Reef, Ningaloo Reef, Okinawa, Oman Sea, and Persian Gulf. The survival of >36,000 non-symbiotic larvae from these crosses was tracked at ambient (27-28°C) and elevated temperature (36°C). Among crosses, there was negligible mortality at ambient temperature, but considerable variation in survival at elevated temperature. Genetic and maternal effects explained up to 90% of the variation in heat survival, and the strength of the genetic effect within populations (R^2 = 0.03-0.36) was positively correlated with maximum monthly sea temperature (r =0.85). Interbreeding between comparatively warm and cool populations produced larvae with enhanced heat survival rates, that were, on average, equivalent to those from the warm population. These findings indicate that most coral populations have the raw genetic material to facilitate adaptive responses to warming, and that rates of adaptation can be accelerated by selective breeding.

Trophic separation in planktivorous wrasses: a new role for mucus?

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The feeding apparatus directly influences a species' trophic ecology. In fishes, our understanding of feeding modes is largely derived from studies of the rigid components (i.e. bones and teeth). Yet, a recently described lip innovation highlighted the role of soft anatomy in enabling specialized feeding modes. Similar diversification may also occur in the soft anatomy of the oral cavity. Using four key anatomical traits to classify 19 species (15 genera)

of wrasses, we evaluated the relationship between morphological specialization of the oral cavity and diet. Our data revealed a previously undocumented anatomical adaptation in fairy wrasses (Cirrhilabrus) that underpins a novel feeding mode: the oral mucosa is packed with goblet cells, enabling them to secrete large quantities of mucus; a trait absent in other wrasses. This disparity reflects diet differences, with mucus secretion found only in planktivorous Cirrhilabrus that feed predominantly on amorphous organic material (potentially cnidarians). This suggests a cryptic mucus-based resource partitioning in planktivorous wrasses.

The Allen Coral Reef Atlas: where to begin with mapping the planet's reefs

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Reliable and informative coral reef habitat maps not only capture the visible wonder of our planet but extend our scientific capability around these important ecosystems. Mapping any submerged environment is challenging, yet without maps we are more limited in our ability to design marine protected areas, model ecosystems in space and time, and even navigate to our field sites. Despite several notable attempts to map the planet's reefs since the 1800s, to date, there is no single detailed coral reef habitat map with complete and consistent global coverage. Advances in remote sensing, computing capability and our knowledge of reefs, has finally made the goal of producing an atlas of shallow tropical reef habitat achievable. The Allen Coral Atlas project, a multi-partner international and cross-disciplinary collaboration aims to produce consistent global coral geomorphic zonation and benthic cover map layers. We describe the mapping component of the project, including a) state-of-the-art input data from Planet's constellation of small satellites, derived physical oceanographic (depth, waves) information and ecological field data, b) the process of combining this data, defining map classes and generating outputs using cloud processing and object-based image analysis, and c) the calibration and validation of coral reef maps. The Allen Coral Atlas brings together remote sensing specialists, coral reef ecologists, geomorphologists, citizen science organisations and conservation agencies in an unprecedented collaborative effort. As well as sharing online interactive maps we hope Atlas' online home will be a hub for existing oceanographic data and a repository for future coral reef data.

CoralWatch - from reef to outback

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How do you get citizens around the world to love the reef and help to take care of it? CoralWatch, based at The University of Queensland, is a well-established citizen science program founded in 2002. It integrates global coral health monitoring with education and public outreach creating reef awareness using simple and engaging tools that provide people with accessible information about coral reefs and climate change, and hands-on experience

collecting scientific data on coral bleaching using the Coral Health Chart. The chart is an easy-to-use tool to quantify changes in coral colour associated with coral bleaching. Instructions are available in 13 languages and data on >2000 reefs from 78 countries is freely accessible. CoralWatch has successfully expanded its reach and focus in 2017 with the introduction of the CW Ambassadors program. The ambassador program invited engaged citizens from across Queensland to join our team, through their own ideas and initiatives, as official ambassadors. Through this and other initiatives, CoralWatch has successfully engaged with a wider spectrum of society, highlights include a recent 'Corals in the Outback Sustainability Tour'. CoralWatch travelled between Mt Isa and Longreach presenting the latest reef science, creating reef awareness through presentations, displays and Chasing Coral screenings. New virtual reality (VR) technologies provided a real-life reef experience connecting participants with the reef and motivated them to move towards a more sustainable future to help save reefs for future generations. CoralWatch produced factsheets about the GBR and provides practical solutions to "Save Money and the Reef".

Seventeen years of field data: A long-term observation of benthic composition dynamics for Heron Reef, Southern Great Barrier Reef, Australia (2002-2018)

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Annually over a 17-year period (2002-2018), 3,000 to 5,000 photoquadrats (approx. 60,000 total) were collected along the reef slopes (5 m contour) and across the reef flat at Heron Reef (28 km^2), Southern Great Barrier Reef, Australia. The downward looking photoquadrats each represented 1 m^2 of the benthos and were captured at regular intervals (3 m intervals) along transects (500-1500 m transects). Photoquadrats were automatically annotated using CoralNet to estimate benthic community composition, requiring an initial manual calibration of 5% of photoquadrats for a learning algorithm to analyse 92.5% of photoquadrats, with another 2.5% of photoquadrats reserved for validation. Classes were collapsed into functional groups, and Hard Coral types: branching, plate and massive. Trends in benthic composition were examined at four hierarchical scales: 1) "Reef Scale", all data; 2) "Zone scale", reef flat or reef slope (2x Zones); 3) "Cluster scale", geomorphic zones: north or south reef slope, and inner and outer reef flat (4x Clusters) and; 4) "Site scale", grouped within areas that shared common features (31x Sites). The major findings indicated an inverse relationship of Hard Coral to Rock at all scales; branching coral dominated the reef slope south and all reef flat clusters, and; branching coral was the driver of increased coral cover on reef slope sites after a storm event. Automated classification of photoquadrats enabled an unbiased analysis of the field data, and provided an unheralded description of temporal change in benthic composition and coral type over almost two decades, and following an environmental impact.

The combined effect of ocean acidification and organic matter enrichment on coral reef sediment metabolism and dissolution

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Ocean acidification (OA) and organic matter enrichment (due to coastal eutrophication) could act in concert to shift coral reef carbonate sediments from a present state of net calcification to a future state of net dissolution. However, no studies have examined the combined effect of these stressors on carbonate sediment metabolism and dissolution. This study used a series of 22-hour incubations in flume aquaria with captive sediment communities to measure the combined effect of OA and organic matter (OM) enrichment (in the form of phytodetritus) on coral reef sediment gross primary productivity (GPP), respiration (R), and net calcification (Gnet). Relative to control treatments, both OA (~ 1000 µatm) and OM enrichment (~ 20 µmol C L^{-1}) decreased rates of sediment Gnet to a state of net dissolution (Gnet < 0), but the mechanism behind this decrease differed. Under OA alone, the transition to net dissolution was geochemical, as rates of GPP and R were unaffected and dissolution was solely enhanced by an OA-driven decline in water column pH. In contrast, under OM enrichment alone, sediments transitioned from net autotrophy to net heterotrophy, thereby biologically reducing seawater pH due to the increased respiratory addition of CO_2. When combined, OA and OM enrichment worked in concert to enhance dissolution more than each stressor alone. Together, these data suggest that the OA-mediated increase in coral reef carbonate sediment dissolution will be exacerbated during periods of coastal eutrophication and subsequent OM-enrichment of coral reef waters.

Metabolic rate determination in wild dugongs, or how much seagrass does a dugong need?

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Metabolic rate and energy expenditure of wildlife is informative of food requirements. It has been assumed that herbivorous dugongs have low metabolic rates because in the related manatee, metabolic rates are only 25-30% of predicted values for large mammals. However, measured rates of metabolic water turnover have indirectly suggested that dugongs may either have a relatively high metabolism or practise mariposia (voluntary drinking of seawater). In this project, we conducted an experiment in which oxygen consumption of five resting adult dugongs was measured in a metabolism chamber. Oxygen consumption was converted to resting metabolic rate (RMR) and expressed in terms of specific body mass, and energy expenditure at rest was also calculated. Mean O2 consumption ranged from 2.4 to 2.9 mL kg-1min-1, and RMR from 29,943 to 40,799 kJ day-1. Energy expenditure at rest ranged from 0.81 to 0.99 W kg-1. Food (seagrass) intake rates were calculated based on energy turnover and seagrass energy content. RMRs in dugongs are higher than tin the related manatee, but are comparable to rates in similarly-sized marine and terrestrial mammals. The higher RMR in dugongs compared to manatees may explain discrepancies between behaviour, growth and

reproductive rates; dugongs have more active pelagic habits but have slow growth and reproduction. Whilst metabolism and energy expenditure are relatively high, grazing on a low nutrient, low energy seagrass diet means that dugongs use a high proportion of the energy extracted from the diet to power metabolism, and thus allocate a lower proportion to growth and reproduction.

Thermal stress results in variations in the Symbiodiniaceae volatilome – implications for thermal resilience, chemical signaling and the climate

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Terrestrial plants produce diverse consortia of biogenic volatile organic compounds (BVOCs). These "volatilomes" play a role in their health, resistance to stress, inter-species signaling, while also influencing local climate. Despite the documented importance of BVOCs in terrestrial ecosystems, these compounds remain mostly uncharacterised in marine ecosystems. Coral reefs are putative hotspots for BVOC production because of the large densities of Symbiodiniaceae present in coral tissues. Here, we subjected two prevalent Symbiodiniaceae strains to a temperature stress, a thermally tolerant *Durusdinium* (UTSD) and a thermally sensitive *Cladocopium* (SCF058), and measured their volatilomes throughout the experiment. We detected 89 different compounds, most of them being reported here for the first time in marine algae. In both Symbiodiniaceae strains, distinct shifts were recorded in the total volatilome between control (26°C) and treatment (32°C). Dimethyl sulfide (DMS), the most abundant volatile, was produced by both strains, but its concentration was much higher in the tolerant strain. Conversely, DMS became undetectable in the sensitive strain when the temperature reached 30°C. Interestingly, another sulfur compound, dimethyl disulfide (DMDS) increased dramatically in the sensitive strain at 32°C. The concentration of other compounds, such as toluene and hexanal, which are known to increase in response to thermal stress in higher plants, were not affected by thermal stress in Symbiodiniaceae. Changes in specific molecules, such as DMS and DMDS, and shifts in the overall volatilome may prove to be pre-emptive indicators of stress and provide new information for global emission models of climate-active molecules.

Blue light navigation and pulsed inflation phototaxis in Fungiidae coral *Cycloseris cyclolites*

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The Fungiidae coral *Cycloseris cyclolites* starts life budded to substrates in shallower waters (<20 m) before migrating to its preferred zonation in 20m to 35m water depth. The migration of Fungiidae to preferred water depths aids resilience during hyperthermal events and is a critical part of their life-history strategy. How corals navigate into their preferred zonation and the biomechanics of the process is poorly constrained. To study the phototactic response of *C.*

cyclolites experiments used specialised blackout aquaria with a single slit to focus the irradiance to one end of the tank while shading the opposite end. Samples were placed at the shaded end and either broad bandwidth light (shallow water, 400–700 nm) or narrow bandwidth (deep water, 480 nm) was introduced through the slit at the opposite end. Trials were recorded using standard, HD and SHD time-lapse videography and carried out over 24 hours (n = 30). All *C. cyclolites* had a positive phototactic response during the narrow wavelengths/blue light trials - migrating towards the blue light. In contrast, all but one broad bandwidth light trial had no response over the timeframe of the trial. Even when both light sources were simultaneously available and in equal measure *C. cyclolites* moved towards the narrow bandwidth light. Results suggests that *C. cyclolites* uses diffuse blue light emitted from deeper waters to infer general direction for migration to its preferred zonation (20–35 m). The project also documented a range of novel forms of locomotion driven by pulsed inflation.

An investigation of reef island landform dynamics in Isabel Province, Solomon Islands, using UAV-derived orthomosaics and digital elevation models

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Reef islands are formed as a result of wave-driven deposition of reef-derived carbonate sediments on coral reef platforms. These islands respond to environmental changes by adjusting their size, shape and position, and are often considered vulnerable to climate change and sea-level rise due to their low elevation. The ability to accurately detect changes in shoreline position and beach morphology on relevant spatial and temporal scales is essential for understanding reef island landform dynamics. This study analysed annual changes on five islands in Isabel Province, Solomon Islands, using UAV-derived orthomosaics and digital elevation models (DEMs) collected in November 2017 and October 2018. Planimetric (two-dimensional) and net volumetric (three-dimensional) changes on island beaches were quantified; volumetric changes greater than the vertical error of ±0.2 m were detected with confidence. The observed changes varied in pattern and magnitude; on some islands localised areas of erosion were offset by areas of accretion, while one experienced pronounced erosion associated with vegetation loss at its eastern end. Beach profiles derived from the DEMs showed complex changes, including shifts between concave and convex morphologies. Such analyses can assist in understanding reef island equilibrium states and landform responses to environmental stressors. The high resolution of UAV-derived orthomosaics and DEMs provides notable advantages over lower-resolution remotely sensed data; smaller changes can be detected accurately, and other geomorphic processes inferred. However, as a recent technological advancement, UAV-derived datasets have limited temporal coverage and require contextualisation with historical imagery to understand longer-term patterns of reef island change.

Symbiotic life-style triggers drastic changes in the gene expression of the algal endosymbiont, *Breviolum minutum* (Symbiodiniaceae); cellular pathways and membranal transporters

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The symbiotic relationship between corals and algae (Symbiodiniaceae) is crucial to coral reefs. Successful exchange of molecules underpins the mutualistic partnership, yet how nutrients are trafficked between symbiont and host is unknown. Symbiodiniaceae algae change their morphology, cell cycle, and life history attributes in hospite compared to their free-living state. We compared gene expression profiles of cultured, free-living *Breviolum minutum* with profiles of the same alga living symbiotically in the sea anemone *Exaiptasia pallida*, which is a model for corals. We looked for genes that are differentially expressed to better understand the cellular processes important to symbiosis. While the impact of algal symbiosis on coral host gene expression has been previously studied, the effect of symbiosis on algal symbiont gene expression is unknown. Our results demonstrated symbiosis significantly alters algal gene expression patterns. Enrichment analysis indicated up-regulation of protein translation and algal morphogenesis genes while inside a host. Intriguingly transmembrane transport, particularly ammonium transporters, were also substantially upregulated in hospite. We are now examining in more detail a list of differentially expressed transporters that we consider to be potential candidates for key symbiotic exchange. Using immuno-fluorescence microscopy with custom-made specific antibodies, we localized one of these, a sugar-like-transporter, to the plasma membrane of symbiotic alga, suggesting it could be involved in transferring sugars to the host. Our research provides some of the first molecular insight into how algal gene expression shifts might induce the drastic metabolic and morphological changes associated with the symbiotic life-style.

Deception, mystery and exploitation: the diverse stories of endoparasitic trematode flatworms on the reef

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The Trematoda is an exceptionally diverse and successful lineage of obligate, endoparasitic flatworms which exploit virtually all lineages of vertebrates as well as many groups of invertebrates. Endoparasitic organisms (and perhaps those who study them) are frequently misunderstood, overlooked or the cause of contempt and revulsion. However, these organisms are fascinating in their myriad morphological forms, ranging from unbelievably specialised to remarkably unremarkable, in their ingenious ploys of transmission and exploitation, and in the intimate relationships they share with their hosts, from gruesome to benign or intriguingly complex. Significantly, these parasites, especially benign and economically insignificant taxa, comprise a significant proportion of the metazoan biodiversity yet to be characterised. On the Great Barrier Reef, despite our concerted efforts to document the trematode fauna of fishes over several decades, the discovery rate of new taxa shows no sign of slowing. I will provide

an overview of the current state of knowledge on trematode diversity in the tropical Indo-West Pacific and will share the case studies of some of these species, highlighting some of the theoretical and practical challenges we currently face.

Partner switching and metabolic flux in a model cnidarian–dinoflagellate symbiosis

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Metabolite exchange is fundamental to the viability of the cnidarian–*Symbiodiniaceae* symbiosis and survival of coral reefs. Coral holobiont tolerance to environmental change might be achieved through changes in *Symbiodiniaceae* species composition, but differences in the metabolites supplied by different *Symbiodiniaceae* species could influence holobiont fitness. Using 13C stable-isotope labelling coupled to gas chromatography-mass spectrometry, we characterized newly fixed carbon fate in the model cnidarian *Exaiptasia pallida* (Aiptasia) when experimentally colonized with either native *Breviolum minutum* or non-native *Durusdinium trenchii*. Relative to anemones containing *B. minutum*, *D. trenchii*-colonized hosts exhibited a 4.5-fold reduction in 13C-labelled glucose and reduced abundance and diversity of 13C-labelled carbohydrates and lipogenesis precursors, indicating symbiont species-specific modifications to carbohydrate availability and lipid storage. Mapping carbon fate also revealed significant alterations to host molecular signalling pathways. In particular, *D. trenchii*-colonized hosts exhibited a 40-fold reduction in 13C-labelled scyllo-inositol, a potential interpartner signalling molecule in symbiosis specificity. 13C-labelling also highlighted differential antioxidant- and ammonium-producing pathway activities, suggesting physiological responses to different symbiont species. Such differences in symbiont metabolite contribution and host utilization may limit the proliferation of stress-driven symbioses; this contributes valuable information towards future scenarios that select in favour of less-competent symbionts in response to environmental change.

Environmental predictors of Crown-of-thorns Starfish presence pervasiveness and outbreaks.

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Outbreaks of the coral eating Crown-of-thorns starfish (COTS) occur in cyclical waves along the Great Barrier Reef (GBR), contributing significantly to the decline in hard coral cover over the past 30 years. One main difficulty faced by scientists and managers alike, is understanding the relative importance of the many contributing factors to COTS outbreaks such as increased nutrients, predator removal, larval connectivity and abiotic conditions. We analyse COTS abundances from the most recent outbreak (2010-2018) using both Boosted Regression Trees and Bayesian hierarchical models in a Species Distribution Modelling

approach to identify key environmental, larval connectivity, and spatial predictors of COTS outbreaks. We used this approach to predict the suitability of each reef on the GBR for COTS outbreaks at three different levels: (1) reefs with COTS present intermittently (Presence); (2) reefs with COTS widespread across a reef (Pervasiveness) (3) reefs experiencing outbreak levels of COTS (Outbreak). We also compared the utility of two auto-covariates account for spatial autocorrelation amongst observations, built using weighted inverse distance and weighted larval connectivity respectively. Boosted regression trees and Bayesian Hierarchical models were combined in an ensemble model to reduce the effect of model uncertainty on predictions of COTS presence, pervasiveness and outbreaks. Our results indicate that larval connectivity potential and flood plume exposure are strong indicators of reefs that are prone to outbreaks and COTS presence, while exposure to cyclones and lower maximum coral cover are the strongest predictors of the pervasiveness of COTS on a reef. Interestingly whether the reef was open or closed to fishing had no significant effect on COTS presence or outbreaks. This study provides the first empirical comparison of the major hypotheses of COTS outbreaks and helps to further clarify the specific areas of the GBR where COTS outbreaks are most likely, providing a useful aid to management of this pest species on the GBR.

Population structuring and connectivity of dugong (*Dugong dugon*) populations along the entire East Queensland coast

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The dugong (*Dugong dugon*) is a marine herbivore that inhabits shallow tropical and sub-tropical coastal waters extending from East Africa to Vanuatu, with Australia considered a stronghold of the species. Despite dugongs being mobile marine mammals, with a few individuals tracked making movements over long distances (> 500 km), analysis of microsatellite genotypes from Southern Queensland individuals indicates the presence of at least two distinct genetic populations separated by only a few hundred kilometres. This study expanded the previous project by examining genetic population structure and connectivity of dugongs along the entire Queensland coast. Skin samples were collected from live and dead stranded dugongs between Moreton Bay in the south and Torres Strait in the north, and encompassed all of the major dugong feeding grounds (Dugong Protection Areas). Bayesian clustering analysis using nuclear markers (22 microsatellite loci, n=293 genotypes) identified two main genetic clusters within the Queensland population, with an abrupt genetic break over a short geographic distance within the Whitsunday Islands region. In addition, STRUCTURE analysis of these two main clusters individually indicated more fine-scale population structuring than was found in the overall analysis. Factors affecting genetic structuring of dugongs may include distribution of seagrass meadows, sea temperature and ocean currents and tides: these and other factors are discussed. The outcomes of this study can help inform better management of dugongs in the central Great Barrier Reef region.

Elevated temperature and CO_2 effect the aerobic and swimming performance of a larval reef mesopredators

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As anthropogenically driven climate change advances, coastal marine ecosystems are predicted to experience increasingly frequent and intense heatwaves, which will occur in association with ocean acidification. Changes to temperature and CO_2 levels beyond the usual conditions can present significant stress to marine organisms, especially if they occur during critical early life history stages; however, their effects on ecologically and economically important mesopredators are relatively understudied. We used a fully cross-factored experiment to test the effects of elevated temperature (+4°C) and CO_2 (1000 µatm) on the aerobic physiology and swimming performance of juvenile snapper, *Chrysophrys auratus*. Both elevated temperature and elevated CO_2 increased resting metabolic rate, meaning elevated daily metabolic costs. By contrast, maximum metabolic rate was increased by elevated temperature and decreased by elevated CO_2. The differential effects of elevated temperature and elevated CO_2 on maximum metabolic rate resulted in the aerobic scope being reduced only in the elevated CO_2 treatment. Critical swimming speed also increased with elevated temperature and decreased with elevated CO_2, matching the results for maximum metabolic rate. Elevated CO_2/low pH events already occur in the coastal habitats that larval and juvenile snapper occupy, and these events will be exacerbated by ongoing ocean acidification. Our results show that elevated CO_2 in coastal habitats negatively affected a broader range of traits than heatwave conditions for juvenile snapper, which could reduce their overall fitness and potentially have negative consequences for population recruitment.

Neurobiology of pheromone detection: a comparison of teleost and elasmobranch olfactory systems

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Locating potential mates and recognising kin are fundamental tasks to the survival of a species. In a visually challenging environment, many aquatic organisms have evolved to detect chemical cues, or pheromones, from conspecifics to fulfil such a task. Pheromones are detected by olfactory receptor neurons (ORNs) within the olfactory system of these animals. The specific ORNs responsible for pheromones detection, and the underlying neural circuitry within the olfactory bulb and forebrain, have been studied extensively in a handful of ecologically and economically important teleost species. However, comparable studies investigating the olfactory system of elasmobranchs (sharks, skates and rays) in regard to pheromones and chemical cues remain untouched. Here I present a comparison of the teleost and elasmobranch olfactory systems using the epaulette shark, *Hemiscyllium ocellatum*, as a model. Using histological, immunohistochemical and neural tracing techniques, I highlight some key similarities including the presence of the elusive crypt neuron, a receptor neuron

known to respond to pheromones in teleosts, in the elasmobranch olfactory system. Additionally, the ORN projection patterns in the olfactory bulb, the organisation of the olfactory tract and their implications will be discussed to begin to answer the question "do sharks use pheromones?"

Physical processes on coral reefs, understanding where, when and how nutrients and plankton originate and interact within the Great Barrier Reef

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The eReefs information system is now in its operationalisation phase, it has throughout the years helped us to better understand the GBR over a wide range of issues. The entire system relies on a mechanistic understanding of the biogeochemical processes and on a wide range of in situ observations that allow for model skill assessment and forcing. In this study, the model outputs are used to extend knowledge gained from the inherently spatially and temporally coarse observations and explore regional variations in biogeochemistry within each reef of the GBR at seasonal, annual and inter-annual time scales. While most of the water quality assessment is considered within the GBRWHA regions, a similar analysis performed over each of the 3500+ reefs provides further insight. The overall flow of the GBRWHA rivers is often northward along the coast and some of the major rivers are on the border of these regions. Throughout all years, water quality decreases from the northern to southern reefs and from outer to inner reefs. Similarly, some of the inner reefs particularly in the southern regions of Whitsundays, Fitzroy and Burnett-Mary are specifically influenced by high turbidity rather than plankton dynamic. The northern reefs have clear waters, but the planktonic gradient from outer to inner reefs reveals a different zonation that requires consideration.

The effect of habitat degradation on parasitism of herbivorous coral reef fishes

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Habitat degradation is a growing and pervasive threat among terrestrial and aquatic ecosystems due to ongoing global change. Shifts in benthic composition because of habitat degradation can alter disease dynamics within an ecosystem, reduce biodiversity and negatively affect individual health. However, we have a poor understanding of how changes in benthic composition affect ecological processes and species interactions such as parasitism. This study investigated how different benthic substrates, representing a gradient of ecosystem health, affect the community composition, diversity and infection intensity of ectoparasite communities on coral reefs. Nine sites (n = 3 coral-, n=3 rubble-, n=3 macroalgal-dominated) were selected within the Palm Island Group, Great Barrier Reef. Eight cages, designed to prevent the entry of cleaner organisms, were placed at each site. Each cage contained a single *S. doliatus*, whose ectoparasites had been removed prior to caging. Cages were retrieved after

72 hours and the ectoparasitic fauna collected and identified. Differences in ectoparasite communities were driven largely by changes in the cover of live coral and rubble between sites. The ectoparasite communities in rubble habitats (representative of a degraded reef) were largely dominated by gnathiid isopods compared to coral and macroalgal habitats. Whereas the ectoparasitic gill fluke, *Dactylogyrus sp.* showed no variation in prevalence between habitats. Benthic composition also determined parasite prevalence, with individuals caged at low coral cover sites having a greater likelihood of parasitic infection than those caged in areas of high coral cover. As coral reefs are projected to experience further habitat degradation in the future because of anthropogenic activity and climatic change, we may expect a higher likelihood and intensity of parasitic infection in coral reef fishes, particularly by gnathiid isopods, in degraded rubble-dominated reefs.

Cross-shelf Heterogeneity of Coral Assemblages in Northwest Australia

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Understanding the spatial and temporal distribution of coral assemblages and the processes structuring those patterns is fundamental to managing reef assemblages. Cross-shelf marine systems exhibit pronounced and persistent gradients in environmental conditions; however, these gradients are not always reliable predictors of coral distribution or the degree of stress that corals are experiencing. This study used information from government, industry and scientific datasets spanning 1980–2017, to explore temporal trends in coral cover in the geographically complex system of the Dampier Archipelago, northwest Australia. Coral composition at 15 sites surveyed in 2017 was also modelled against environmental and spatial variables (including turbidity, degree heat weeks, wave exposure, and distance to land/mainland/isobath) to assess their relative importance in structuring coral assemblages. High spatial and temporal heterogeneity was observed in coral cover and recovery trajectories, with reefs located an intermediate distance from the shore maintaining high cover over the past 20 years. The abundance of some prominent genera in 2017 (*Acropora*, *Porites*, and *Turbinaria spp*.) decreased with the distance from the mainland, suggesting that inshore processes play an important role in dictating the distribution of these genera. The atypical distributions of these key reef-building corals and spatial heterogeneity of historical recovery trajectories highlight the risks in making assumptions regarding cross-shelf patterns in geographically complex systems.

Coral reef resilience: a study of the complex regulatory space to aid resistance, repair and recovery of reefs

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Coral reef restoration is gaining considerable momentum globally in response to the threat of climate change and associated coral bleaching. In Australia, as part of the Reef Restoration and Adaptation Program (RRAP), are investigating a range of interventions that could help the Great Barrier Reef (GBR) resist, repair and recover from climate change. Implementing any reef restoration research and development into a precious reef environment, requires adaptation of the current complex regulatory environment. Existing Australian regulatory work is beginning to address restoration, but the current multiple layered legislation and associated government agencies at federal and state levels, makes for a complex space. Whilst Australia's development of reef restoration permitting guidelines is a step forward, the International Coral Reef Society (ICRS), The Nature Conservancy (TNC), and SCORE's also realise the need for a global approach to solve a global problem. This paper looks at the complexity of creating a regulatory environment that is likely to be critical in determining the feasibility and viability of restoration interventions on the GBR and reefs around the world. Drawing on document analysis, scenario's and policy labs, this study investigates the regulatory, institutional and governance implications of reef restoration interventions. This includes mapping the existing regulatory controls on the proposed restoration interventions in Australia and internationally. Ultimately, this study provides important insights into the role of regulation and governance in enabling effective large-scale reef restoration. These may prove useful to other jurisdictions, where reef restoration has become an imperative under a rapidly changing climate.

Resolving the ecology of free-living Symbiodiniaceae through culturing, quantitative PCR, and eDNA metabarcoding

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Dinoflagellates of the family Symbiodiniaceae are characterized by prominent endosymbiotic life histories with corals but also persist as free-living populations in reef habitats. The uptake of free-living Symbiodiniaceae is a critical moment in the life-history of corals and as endosymbionts, these microalgae are essential for coral survival and ultimately the formation of entire reef systems. Yet, the ecology of free-living Symbiodiniaceae and the dynamics between free-living and symbiotic populations remains enigmatic. We combined culturing of single-cell isolates, eDNA metabarcoding, and qPCR to resolve free-living Symbiodiniaceae diversity and abundance in the water column, on macroalgal surfaces, and within sediments (epi vs endolithic) at Heron Island, Southern Great Barrier Reef. Culturing yielded several novel strains that we used to supplement reference databases. This approach considerably improved taxonomic assignments of eDNA sequences, which comprised all major Symbiodiniaceae lineages (excepting Effrenium), with clear niche-specific signatures in

composition. The composition of Symbiodiniaceae in the water column overlapped with host-related Cladocopium, while sediments were dominated by novel *Symbiodinium*, Fugacium, and Gerakladium sequences. Diversity of epiphytic Symbiodiniaceae was intermediate to that in the water and sediment but abundances were comparatively high, suggesting that Symbiodiniaceae thrive in this niche. New support for an endolithic niche for Symbiodiniaceae was found with diverse communities detected from within sediment grains. Overall, our study breaks new ground in resolving the relationships between free-living and symbiotic communities and highlights the exceptional genetic diversity of free-living Symbiodiniaceae on reefs.

Going with the flow: do high water flow velocities mediate the impacts of thermal stress on hard coral species?

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The function of tropical coral reefs uniquely hinges upon the maintenance of a symbiosis existing at the microscopic level. If we are to ensure the persistence of reefs under a warming climate, of particular importance is identification of drivers that may increase the resistance of this relationship, ultimately mitigating against coral bleaching and mortality. Underpinning this resistance is an interplay between biological and physical factors. One such physical factor identified as affecting coral responses under thermal anomalies is water velocity. Here we show that increased water flow velocities under a simulated bleaching event result in differences in symbiont photophysiology compared to a lower water flow treatment. We show that with the onset of stress at ecologically pivotal temperatures, high water flow velocities increase the recovery capacity of endosymbiont photosystems. The apparent mitigating effect of high flow is reduced after further accumulation of thermal stress, with equal reductions in endosymbiont populations being measured in both high and low flow treatments at the end of the heating period. Further understanding the physiological and hydrodynamic drivers of coral responses to thermal stress can improve our predictive capabilities and inform targeted management responses, thereby increasing the resilience of reefs into the future.

The stability of photosymbiotic holobionts over time and during bleaching stress

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Holobionts are multiple organisms in symbiosis, reacting as an entire unit or meta-organism. Climate change poses a serious threat to the symbiosis between the hosts and their algal symbionts which manifests as bleaching. Bleaching can occur in many marine invertebrates including corals and giant clams, which harbor the same algae in the family Symbiodiniaceae. This research aims to identify shifts of species abundance pre, during, and post bleaching as well as identify the baseline community of Red Sea giant clams. When compared to the baseline community of algal symbionts prior to experiencing thermal stress, it is clear that there was a

change in the structure of the symbiont community in bleached giant clams. Samples collected from giant clams in Thuwal reefs showed that seasonally, the symbiont community remained stable. To further this investigation of algal community shifts, we have designed and executed thermal stress experiments for corals of the GBR. Previous research indicates that corals can shift their algal community in response to their environment, but little has been done to identify the triggers and micro processes of the algal symbiont community shifts. Here we study the reef flat branching coral *Acropora aspera* on the GBR, and aim to determine the potential shifts of algal species dominance following exposure to different thermal stress regimes. We specifically examine the repopulation of algal symbionts during recovery to determine if thermally tolerant species remain dominant post bleaching. This research will provide insights into the symbiont population structure following thermal stress and bleaching.

Daily and seasonal fluctuations in the physiology of a marine sponge holobiont

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The marine demosponge *Amphimedon queenslandica* inhabits a low energy zone on coral reef flats, where tides, temperature, oxygen, and nutrients vary greatly along daily and seasonal time frames. Adults of *A. queenslandica* support a low abundance and low diversity bacterial symbiont community that is dominated by a sulfur-oxidizing gammaproteobacterium of the order Chromatiales (AqS1). The sulfide oxidation capability of this major symbiont may prevent sulfide toxification inside the holobiont that could arise from anoxic conditions caused by environmental fluctuations or by reduced pumping activity by the sponge. To test this hypothesis, we researched for temporal variations in the *A. queenslandica* microbial community structure and activity potentially related to seasonal environmental variability and *A. queenslandica* physiological status. Here we present fluctuations in sponge pumping activity compared with microbiome community composition and activity in response to daily and seasonal environmental variations. We show that, at the intertidal reef study site, water parameters such as salinity, temperature, pH and oxygen levels can fluctuate drastically, even within minutes. These changes affect *A. queenslandica* pumping activity along a day/night gradient and, as a consequence, the exhaled water oxygen saturation. Of particular interest are observed decreases in dissolved oxygen and redox potential, because these are generators of a more reductive environment in which sulfide might be produced. Furthermore, we show circadian and seasonal changes in the abundance or activity of few key microbial symbionts possibly involved in the putative sulfur cycle within the sponge holobiont. These data provide insights into how this marine sponge holobiont responds to summer-winter variability.

DNA barcoding reveals cryptic functional diversity in a common coral reef macroalga (*Lobophora*, Phaeophyceae)

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Coral reefs around the world are threatened by local stressors and mass mortality following thermal stress events. Increasingly, coral reefs are shifting towards macroalgal dominated states, which has implications for ecosystem function. In the Pacific, phase shifts are often dominated by a common macroalgal genus – *Lobophora*. While many ecological studies report a single species (*L. variegata*), recent advances in genetic approaches have documented a global cryptic diversity of over 100 species of *Lobophora*. Here, we sampled *Lobophora* specimens from twelve reefs around Palau at varying depths, wave exposure and herbivore assemblage structure. Using one mitochondrial gene (cox3) and two chloroplast genes (psbA, rbcL), we uncovered a striking cryptic diversity of 15 species, including five previously undescribed species. Exposure regime showed the strongest influence on *Lobophora* species composition but neither of the ecological factors explained much of the variation found. Widespread sampling indicates the presence of generalist species which were found in almost all sampled habitats, and specialists which occupy specific niches. Such high levels of cryptic diversity have important implications for ecological studies, as algae commonly identified as *L. variegata* using field identification may in fact be multiple different species. If cryptic species are functionally different in growth rates and competitive strengths, these results have broad implications for our understanding of herbivory and recovery following disturbance on coral reefs.

Fatty acid biomarkers: trophic strategies of reef-building corals

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The ecological success of shallow reef-building corals has been linked to the symbiosis between the coral host and its dinoflagellate symbionts (herein 'symbionts'). As mixotrophs, symbiotic corals depend on nutrients 1) transferred from their photosynthetic symbionts (autotrophy) and 2) acquired by host feeding on particulate organic resources (heterotrophy). However, coral species differ in the extent to which they depend on heterotrophy for nutrition and these differences are typically poorly defined. Here, a multi-tracer approach was used to evaluate the trophic strategies of three species of common reef-building coral (*Galaxea fascicularis*, *Pachyseris speciosa*, and *Pocillopora verrucosa*). The composition and various indices of fatty acids were compared, including applying established fatty acid indices in a novel context to examine the relative contribution of autotrophy and heterotrophy in corals. The total fatty acid composition and various fatty acid indices revealed differences between the more heterotrophic (*P. verrucosa*) and more autotrophic (*P. speciosa*) coral hosts, with the coral host *G. fascicularis* showing overlap with the other two species and greater variability overall. For the more heterotrophic coral P. verrucosa, the fatty acid indices and LDA results both indicated a greater proportion of copepod-derived fatty acids compared to the other coral

species. Overall, the LDA estimated that PUFA derived from potential particulate resources (copepods and diatoms) comprised a greater proportion (mean 83%) of coral host PUFA in contrast to the lower proportion of symbiont-derived PUFA (mean 17%). These estimates provide insight into the importance of heterotrophy in coral nutrition, especially in productive reef systems.

The impacts of suspended sediments on coral fertilisation — pathways, thresholds, and risk probabilities

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Sediments introduced to and disturbed within the marine environment near sensitive areas like coral reefs present a water quality concern for marine resource managers. Using an ecotoxicological approach, cause–effect pathways, concentration–response thresholds, and risk probabilities were determined to assess the implications of suspended sediments on fertilisation of broadcast spawning corals. We found that sediments containing mineral clays and sticky organic matter (extracellular polymeric substances) mediated the formation of sediment–sperm flocs that reduced the number of sperm available to fertilise the eggs. These sediments presented the greatest impact to coral fertilisation whereas sediments lacking these 'sticky' components resulted in higher effect thresholds. When effect thresholds were compared against in situ water quality data from three major dredging programs in Western Australia, the increase in risk probabilities during dredging compared with background conditions was limited, and occurred most notably within a few kilometres of the operations.

The First Detailed Habitat Map of The Great Barrier Reef

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The Great Barrier Reef (GBR) is a globally unique ecosystem and essential national resource for Australia. The most current comprehensive map of the GBR only shows the extent of each reef. Detailed maps representing several dimensions of coral reef habitat: geomorphic zonation, benthic cover type and predicted coral type are not available for each individual reef. This project will create these detailed habitat maps for the 3000 shallow offshore GBR reefs that occur between 0 – 20m depth. The habitat mapping approach combines: 1) field data; 2) Sentinel 2 satellite imagery3) reef bathymetry and slope; 4) wave climate; 5) object based image mapping to incorporate eco-geomorphological knowledge and 6) predictive models to estimate coral type occurrence. The approach was initially developed for 20 reefs of the Capricorn Bunker Group, and 237 reefs in the Cairns region. The field data used will be sourced from field expeditions in 2019, existing field programs and citizen science groups and crowd sourcing of other field data. The methods and the digital maps to be produced by 2021 will represent a significant advance in our capability to map, monitor and manage coral reefs in

Australia. These will support management and science for the conservation of the Great Barrier Reef or other reefs globally.

Crown-of-thorns movements and coral recovery

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Effective conservation of marine species and management of fisheries resources requires managing on-going exploitation in the face of natural and anthropogenic changes. Mathematical multispecies ecosystem models are well-suited to informing effective management strategies. Models of Intermediate Complexity for Ecosystem Assessment (MICE) provide information for strategic and tactical management advice through a restricted focus that allows them to handle uncertainties whilst preserving an ecosystem context. Here I will characterise my development and application of the MICE framework to the management of the crown-of-thorns starfish (CoTS) and coral on an individual reef within the Great Barrier Reef. I will provide an overview of the underlying model from which preliminary results suggest management culling of CoTS has a positive effect on coral recovery. However, incorporating CoTS movements indicates significant ramifications for management efficacy. Capturing and modelling these movements could enhance coral abundance through advising the development of more efficient CoTS management.

Assessing the sensitivity of coral connectivity modelling to mesh resolution in the Great Barrier Reef (or "How fine is fine enough?")

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Over the past decade, constant efforts have been put in modelling the connectivity between the 3000+ individual reefs composing the Great Barrier Reef (GBR). However, the computing cost of such models compared to the vastness of the GBR often results in using coarse-resolution models or to work on limited areas. In this study, we use the 2D unstructured-mesh coastal ocean model SLIM (slim-ocean.be) to assess the impact of mesh resolution on model results. SLIM uses unstructured meshes that offer the flexibility to vary the spatial resolution so that computational resources can be allocated where they are most useful: the level of detail is set at a high precision near reefs, islands and along the coast. On the other hand, resolution is coarser in deeper areas, where SLIM is coupled with eReefs model (3D, 4 km fixed resolution). In this work, we assess the effect of mesh resolution on connectivity estimates. For this purpose, we built five different meshes for which the maximum resolution ranges from 250 m to 4 km. For each setup, we model ocean currents to simulate larval dispersal over the whole GBR. We then compare the effect of mesh resolution on different connectivity indicators (local retention and self-recruitment, average connectivity length, community structure…). Our results suggest that with a too coarse resolution (typically >500 m), most of the local processes happening in the wake of reefs are missed by the model. Indeed, those local processes are more

likely to retain larvae close to the source reef. A too coarse resolution will thus lead to over-estimate long-distance connectivity and hence under-estimate local retention and self-recruitment.

Motivations, success rates and costs of coral reef restoration

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There is an urgent need for successful coral reef restoration to recover ecosystem services and to meet international agreements target ecological recovery. Information about what motivates reef restoration as well as its success and cost is not well understood but needed to inform restoration decisions. We systematically review and synthesize data on the motivations for coral reef restoration, the variables measured, outcomes reported, the cost per hectare of the restoration project, the survival of restored corals, the duration of the project and its overall spatial extent depending on the restoration technique employed. The main motivation to restore coral reefs was to further our ecological knowledge and improve restoration techniques, with coral growth, productivity and survival being the main outcome variables measured. The median project cost was 472,000 US$ ha-1 (2010 US$), ranging from 6,000 US$ ha-1 for the nursery phase of coral gardening to 3,911,000 US$ ha-1 for substrate addition to build an artificial reef. Restoration projects were mostly of short duration (1-2 years) and over small spatial extents (0.01 ha or 104 m2). Median reported survival of restored corals was 60.9%. Our findings and database provide data to inform coral reef conservation initiatives.

Multiple habitat types in a tropical seascape influence coral reef fish communities

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Habitat connectivity is a fundamental topic in ecology. Organisms often move between and interact with multiple habitats, consequently affecting community and population structure. With new and improved analytical methods, there has been a resurgence in research exploring the spatial relationship between habitats and species. Seascape ecology is one such field, where marine habitats, species, and their connectivity are explored in a spatial context. Using satellite imagery, spatial analytics, and coral reef community surveys, we explore the importance of multiple habitat types on driving coral reef fish assemblages in a dynamic reef system in the Philippines. Determining the relationships between coral reef fishes and multiple habitat types leads to a more holistic approach to understanding reef fish dynamics in a tropical seascape system. Here, we use satellite imagery of Siquijor Island in the Visayan region of the Philippines to create a detailed habitat map of a tropical seascape, mapping coral reef and non-reef habitat such as seagrass, mangroves, and macroalgal beds. Spatial metrics such as area, distance, and spatial connectivity measures are included in multidimensional scaling and regression analysis to identify spatial characteristics of multiple habitats that are important in

driving coral reef fish assemblage patterns and fish functional groups. In a location such as the Philippines, where fishing in non-reef habitat is a regular occurrence, understanding the intricacies of multiple habitats in driving coral reef fish dynamics is important when considering seascape wide conservation practices.

Local management actions can increase coral resilience to thermally-induced bleaching

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Recent large-scale analyses suggest that local management actions may not protect coral reefs from climate change, yet most local threat-reduction strategies have not been tested experimentally. We show that removing coral predators is a common local action used by managers across the world, and that removing the corallivorous snail *Coralliophila abbreviata* from Caribbean brain corals (*Pseudodiploria* and *Diploria* species) before a major warming event increased coral resilience by reducing bleaching severity (resistance) and post-bleaching tissue mortality (recovery). Our results highlight the need for increased evaluation and identification of local interventions that improve coral reef resilience.

Migrating herbivores and their role on sub-tropical and temperate reefs

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Global species redistribution is causing rapid changes in ecological community structure. For the east coast of Australia, the southern migration of coral reef species coupled with ocean warming is causing ‘tropicalisation’ of sub-tropical and temperate rocky reefs. For some mid-shelf reefs within the sub-tropical Solitary Islands Marine Park, there has been an increased presence of tropical herbivorous fishes as well as an observed decline in large habitat forming macroalgae. For such reefs, we show that by caging patches of rocky reef to exclude large herbivorous fishes: a) macroalgae is still able to recruit to these reefs and b) benthic community composition differs from control plots that are subject to herbivory. At the project’s halfway point, we provide evidence for the role of migrating coral reef fishes in interacting within higher latitude communities.

Do we know what we're losing? Threats to soft bodied habitat builders and the implications for restoration

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Octocorals and anemones are structurally complex animals that provide crucial habitat, food, and grazing substrate for a variety of fish and invertebrates, including endangered species and obligate symbionts. These soft corals exist worldwide and form reefs from warm, shallow tropical waters to the icy depth of the arctic. Despite this, they are often overlooked in studies of coral reef ecology, threats, and restoration. Here we review the ecology of, threats to, and restoration of octocorals and anemones using a systematic approach. We found evidence that octocorals and mixed octocoral-stony coral habitat provide complexity that hosts large fish assemblages in all climate zones, which challenges the long-held assumption that octocoral habitat is less favourable to fishes than stony coral. Further, we identified similar threats to octocorals and anemones as stony corals – bleaching, habitat damage, disease, collection, predation, etc. However, loss of soft corals is hard to quantify without long-term monitoring as most species have no hard structures that remain after a mortality event. Observational studies suggest that octocorals and anemones are more sensitive than stony corals to some stressors, such as bleaching, and less sensitive to others, such as predation from crown of thorns starfish, though rigorous experimental work is needed to confirm this. Our review suggests that in many cases octocorals and anemones may be more resilient to environmental stressors than hard corals because they are generally fast recruiting and fast growing, but exceptions do exist. As such, restoration is becoming increasingly necessary and here we provide two case studies of restoration practice for the Mediterranean red coral *Corallium rubrum* and the temperate Australian cauliflower soft coral, *Dendronephthya australis* to support our findings. In doing so we demonstrate that more research is needed on the ecology, threats, and restoration potential of octocorals and anemones.

Seasonal cross-shelf exchanges along the Great Barrier Reef

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A wide variety of processes have been observed and modelled that provide evidence of cross-shelf exchanges that affect the ecology of the Great Barrier Reef. Whilst at first it may seem that the along-shelf flows generated by the prevailing SE trades and boundary currents would dominate the circulation, cross-shelf flows are of fundamental importance and account for a significant proportion of the flushing and the introduction of nutrients. From spring to summer when the trades ease and the East Australian Current accelerates sub-surface intrusions of deeper Coral Sea waters make their way across the shelf. The complex reef matrices can channel these flows and mix them alleviating surface warming on the outer shelf. During a successful monsoon season or wet season river plumes can extend hundreds of kilometres along the shelf but also extend across the shelf into the Coral Sea. In one extreme case a freshwater

plume from the Burdekin can be seen to deflect the East Australian Current. In autumn as coastal waters cool Dense Shelf Water Cascades have also been observed to move across the seafloor across the shelf. The presentation will provide an overview of the processes from a mix of IMOS observations and eReefs modelling that includes an overview of the extraordinary monsoon of 2019.

Modelled and Observed Pacific South Equatorial Current Bifurcation in the Current Climate and Projected Changes in the Future Climate

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The South Equatorial Current (SEC) bifurcates at the Australian Coast and flows northwards as the Gulf of Papua Current (GPC) and southwards as the East Australian Current (EAC). The SEC bifurcation latitude marks the division of the warm tropical gyre and cool subtropical gyre at the western boundary. Recent studies have shown that there is a long-term southward shift of both SEC and North Equatorial Current (NEC) bifurcation latitudes in the Pacific over the last 60 years. Using the results from a high-resolution ocean downscaling experiment and direct observations from glider transects and mooring records in the Coral Sea, the modelled location of the SEC bifurcation latitude is compared with observations and demonstrated remarkable agreement. The downscaling experiments were run with the 1/10 degree OFAM3 model from 1979 to 2100, with the hindcast (1979-2014) forced by Japanese 55-year Atmospheric Reanalysis (JRA-55), the future projections (2006-2100) forced with CMIP5 RCP8.5 forcing. We show that the long-term poleward trend in SEC bifurcation continues for the next 100 years by about 1 degree. This has implications for the Coral Sea circulation and physical connectivity in the Greater Great Barrier Reef region, and could impact the health of marine ecosystems, and lead to disastrous ecological events such as coral bleaching. The shift of the SEC bifurcation latitude could induce stronger southward flows in the lagoon, south of the bifurcation. This may affect predictions of connectivity for both corals and COTS. Weakening of net transport of larvae from the north could have implications for rates of adaptation to warmer temperatures by coral populations in the southern GBR.

A Sea Country learning partnership in times of Anthropocenic risk: Offshore coral reef education and our story of practice

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Our approach to offshore reef education is influenced by the concept of learning civic environmentalism linking environmental learning with building community capacity. Civic environmentalism merges environmental and civic issues through processes that recognize the worth of all (self and others human and non-human), as opposed to the traditional top-down, expert-driven, individualist models of citizenship. The concept of people coming together in each community to participate in learning collectively for the environmental, economic,

cultural and social health of a national reef treasure, is an act of implicit civic environmentalism. And this is made even more important given the present pressures of the Anthropocene. Our educational intention is to physically connect young people and reefs; to encourage reef custodianship; enhance the capacity of education and science tertiary students to undertake reef education in their future professional practice and educate ourselves. What we aim for is the long tradition of indigenous peoples understanding of Sea Country to blend with western scientific understandings. Enhancing the power and beauty of the reefs themselves to form, new, mutual, and productive understandings. Our "community of learners" is composed of school aged students, their teachers and parents, pre-service teachers and their academics, science undergraduates (as intending teachers), marine biologists and local Sea Country guardians who are all taken to one of eight outer barrier reef locations or local islands, reached in a day trip from Cairns.

Boomeranging around Australia: Historical biogeography and systematics of the anti-equatorial fish Microcanthus strigatus (Teleostei: Microcanthidae)

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The geographic distributions of marine fishes have been shaped by ancient vicariance and ongoing dispersal events. Some species exhibit anti-equatorial distributions, inhabiting climatically cooler regions on both sides of the tropics while being absent from equatorial latitudes. The perciform fish genus Microcanthus exhibits such a distribution, with disjunct populations occurring in East Asia, Hawaii, Western Australia, and the southwest Pacific. These populations are regarded as being part of a single, widespread species: the stripey (*Microcanthus strigatus*). Here we examine the historical biogeography and evolutionary history of *M. strigatus*, based on more than 80 specimens sampled from the four major populations. We analyze 36 morphological characters, three mitochondrial markers, and two panels of 7120 and 12,771 single-nucleotide polymorphisms from the nuclear genome. Our results suggest that *M. strigatus* represents a cryptic species complex comprising at least two genetically distinct populations worthy of species-level recognition, with one population exhibiting strong genetic structuring but with intermittent gene flow. We provide evidence for a southwest Pacific origin for the ancestral Microcanthus, and explain how past connectivity between these regions might have given rise to the relationships observed in present-day marine fauna. Molecular-clock analyses and ancestral range reconstructions support a southwest Pacific centre of origin for Microcanthus, with subsequent colonization of Western Australia through the Bass Strait followed by trans-equatorial dispersals to the Northern Hemisphere during the Pleistocene. Our results detail an anti-tropical dispersal pattern that is highly unusual and previously undocumented, thereby emphasizing the importance of integrative systematics in the evaluation of widespread species.

The real-time interaction of ecology and evolution in the sea: the curious case of reef building corals

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The long-standing paradigm that ecology and evolution play out on different timescales is increasingly challenged by recent studies that show real-time interaction of the two. Similarly to terrestrial examples, it is expected that eco-evolutionary dynamics define both the population trajectories and adaptive capacity of marine organisms. But contrary to the relative simplicity of terrestrial ecosystems, the complexity of the natural history of many marine taxa pose significant challenges for our attempts to understand how ecology and evolution interacts on short timescales in the sea. I will demonstrate some of these challenges through the example of reef-building corals, that are the ecosystem engineers of one of the most biologically diverse, socially, ecologically and economically valuable, and environmentally sensitive ecosystems of the planet. Recent global-scale disturbances have decimated coral populations worldwide, and whether these populations will be able to recover in an era of ever more frequent and severe perturbations is at the focus of global interest. I will present the unprecedented ecological impact of the 2016/17 mass bleaching event on the Great Barrier Reef, during which over 50% of shallow reef corals were lost, and show how density dependent mechanisms, ecological feedback loops, connectivity that can drive both outbreeding enhancement or depression, complex reproductive strategies, and symbiotic relationships complicate ecological and evolutionary models that aim to predict the fate of this iconic reef system in the Anthropocene.

Genomic responses to temperature, the lunar cycle, and daylight in a reef building coral

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Genomic responses to environmental variables, such as temperature and daylight have been explored in a variety of species. However, no in-depth analysis has been performed on how interactions between such variables impact coral biology. Broadcast spawning corals integrate environmental inputs from water temperature, the lunar and solar cycles to set their annual spawning window. We performed long term sampling of diurnal cycles of transcription over an entire lunar month and at both summer and winter temperatures with the goal of identifying processes that link two or more of these variables. Deep sequencing of five clonal individuals across this time scale demonstrated that interactions between different variables have unique responses, with temperature/daily cycles impacting rhythmic and stress processes, temperature/lunar rhythms impacting transcriptional and developmental processes, and lunar/daily interactions regulating post-transcriptional systems. Interactions between all three variables also seem to be mediated by post-transcriptional mechanisms. The scale of change in expression patterns over this time scale, and these variables, is absolutely enormous, and many changes in gene expression previously reported are likely due to normal changes over time. These data identify processes that may mediate the integration of different environmental signals and allow corals to tell time from their milieu.

Great Barrier Reef Restoration: Identifying barriers and opportunities within the decision context

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Lorrae van Kerkhoff

A strong understanding of the decision context is vital for change to occur, particularly when planning climate adaptation responses. The values, rules, knowledge (vrk) perspective has been developed as a way to facilitate change by revealing barriers and opportunities within a particular decision context. To illustrate what an analytical framework of vrk might look like, this study applies the vrk perspective to the Great Barrier Reef (GBR) restoration decision context. By characterising the GBR restoration decision context as relevant sets of values, rules and knowledge and considering how these sets of vrk inform perceptions of risks and benefits, this study uses the vrk perspective to illuminate an important step towards the social acceptance and potential delivery of a restoration approach. Drawing on eleven semi-structured interviews, participant observation, published literature, and applying the vrk perspective, this study reveals that whilst the set of knowledge in the restoration decision context is expanding rapidly, it is currently constrained by socio-political barriers created through dissenting values and rules which no longer 'fit' the current state of knowledge. While there are no simple solutions, this analysis suggests that to overcome these barriers and work towards a climate-changed future on the GBR, efforts and resources could be most usefully directed at addressing the strong interactions between these sets of socio-political values and rules. This study suggests that addressing these interactions may involve increasing trust in restoration decision-makers. Conceptualising the decision context in this way shows that both barriers and opportunities to facilitate change can be identified.

Using crime analysis techniques to improve compliance management planning and delivery in marine protected areas

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Despite the rapid increase in marine protected area (MPA) coverage, concerns remain about the ability of nation states to fulfill their obligations under the Aichi Biodiversity Targets to effectively and equitably manage coastal marine areas. Notably, the capacity of governments to enforce compliance within MPAs has been shown to represent a critical element of their success. This presentation will explore the utility of extending environmental criminology and crime analysis (ECCA) theories and techniques to improve compliance management in MPAs. Established crime analysis techniques will be used to examine the spatial and temporal patterns and trends associated with illegal recreational fishing in no-take zones (poaching) in the Great Barrier Reef Marine Park. The results show that poaching is concentrated in a small number of places which share a set of common features, offenders tend to travel to the nearest no-take zone to offend, and the identification of space/time hotspots can be used to predict the likelihood of illegal fishing activity. The results will be discussed within the context of current compliance management planning and delivery strategies.

Adaptive management in action –integrated pest management approach to crown-of-thorns starfish on the Great Barrier Reef

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Crown-of-thorns starfish (CoTS) cause widespread loss of hard coral cover on reefs across the Indo-Pacific. CoTS outbreaks are considered to be one of the major threats facing the Great Barrier Reef (GBR). Despite a long history of CoTS management and research on the GBR there has been only slow improvement in CoTS control programs since the 1960s. In response to this, we have developed an integrated pest management strategy that links management and research and is firmly focussed on improving the design and performance of the CoTS control program. The strategy is based in the ecology of how CoTS outbreaks arise and spread, and from this identifies the management actions required and the scale at which these responses are required. This information is then used to identify the knowledge and technology gaps that prevent the implementation of effective responses. The resultant integrated pest management strategy has allowed us to identify key areas where research can contribute to successful management: 1) Control at sites, individual reefs, and local areas and its optimization; 2) Control at regional scales and its optimization; 3) Identifying appropriate management objectives for existing and new outbreaks; 4) developing new control and monitoring approaches; and 5) addressing ultimate causes of outbreaks. In this talk we describe the development of the management and research strategy, the process through which it is being implemented on the GBR, and the effectiveness of manual control relative to other management options, and future research needs.

Incidence and severity of injuries among juvenile crown-of-thorns starfish on Australia's Great Barrier Reef

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Outbreaks of crown-of-thorns starfish (CoTS) represent a major threat to coral reef ecosystems and there is significant interest in whether no take marine reserves moderate the frequency or severity of outbreaks. Herein, we investigate whether the incidence and severity of sublethal injuries among juvenile Pacific CoTS (max diameter=45mm) differs between areas that are open versus closed to fishing, microhabitats and/or with body size. The majority (91%) of juvenile CoTS had conspicuous injuries, presumably caused by predation. The incidence of injuries was negatively related to body size, but links between body size and severity of injuries was only evident in CoTS collected from dead coral microhabitats. Small (3mm radius) CoTS from dead coral microhabitats had injuries to 68.06% of arms, compared to 12.00% of arms in larger (12mm radius) CoTS from the same microhabitat. Juvenile CoTS associated with dead coral had a higher incidence (95 vs 87% respectively) and severity (21 vs 6%) of injuries,

compared to those associated with live corals. There was no difference in the incidence or severity of injuries between areas that are open versus closed to fishing. Our results show that small juvenile CoTS are extremely vulnerable to sublethal, if not lethal, predation, and predation risk declines as they grow and change their microhabitat. Predation during and immediately following settlement is, therefore, likely to have a major influence on population dynamics and ontogenetic changes in microhabitat use. Key predators at this life stage are, however, seemingly unaffected by fishing activities on reefs considered in this study.

NESP 4.6: Recommendations to maintain functioning of the Great Barrier Reef

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Conservation of biodiversity has historically been the focus of ecosystem-based management on the GBR, but it is increasingly recognised that a small subset of species can be particularly important to the maintenance of ecosystem functioning. This means that broad-scale habitat protection (e.g. marine park reserves), likely needs to be augmented with specific provisions for key species. But while the biology and ecology of tropical reef species are broadly understood, data on ecosystem functioning are weighted towards corals and reef fishes. This NESP Project (4.6) is the first of its kind to make a comprehensive assessment across a diverse range of taxonomic and functional groups – from microbes through to predatory fishes – to summarise reef functioning. A panel of GBR experts were elicited to identify key species using a novel framework developed to assess their (1) functional importance (a process-based assessment), (2) vulnerability, and (3) manageability on the Reef. In a combined model, these three tiers of information were used to guide a comprehensive review of the literature, and to outline groups with explicit and critical functional roles. Specific recommendations are presented for a range of key players (e.g. branching and tabular corals, microbes, turf algae), surprise outcomes (e.g. chemoautotrophic microbes, cleaner wrasse, coral-associated decapods), and where scientific certainty was particularly limiting (e.g. crypto-predators, deposit-feeding sea cucumbers, cryptic sponges), which can be adopted to shape novel management strategies and future research objectives in support of ecosystem functioning on the GBR.

Timing of mass spawning in corals: potential influence of the coincidence of lunar factors and associated changes in atmospheric pressure from northern and southern hemisphere case studies

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Synchronised multispecies mass spawning events are striking features of reproduction in corals. This synchronous gamete release of thousands of animals over vast stretches of reef is thought to be cued by rhythms of the Moon. However, the mechanisms are not fully understood. We propose an explanation that may contribute to understanding this mechanism, that spawning is triggered by the coincidence of two factors, each in different lunar rhythms. We investigate this proposal in case studies using seven years of coral spawning data from two locations: Kochi, Japan and Lizard Island, Australia. Our calculations show that a feature in a lunar synodic rhythm (the third quarter) will synchronise with a feature in a lunar non-synodic rhythm (the zero declination) usually once, although occasionally twice in a year. Supported by data on the date of spawning from the two locations, we suggest that this coincidence of lunar factors exerts an important influence on the timing of annual mass spawning in corals. This coincidence may be associated with low atmospheric pressure. Spawning at the time of the third lunar quarter may favour fertilisation success due to the reduced currents during neap tides associated with the lower gravitational pressure of the lunar quarters.

Responses and records from Porites corals: Spatio-temporal environmental changes in the Gladstone Harbour

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Gladstone Harbour, central Queensland, has undergone dramatic port development in the past decades. This large-scale industrial development, on the one hand, has benefited the local economy, but may have triggered adverse impacts on the coastal marine environment. For example, dredging has disturbed coastal sediment deposits and re-suspended aqueous metals and colloids. Alumina processing plants have also introduced excessive Al to nearby ecosystems. In the absence of continuous seawater monitoring we use coral skeletons to reconstruct seawater elemental variations. Utilizing laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), we have reconstructed century-long geochemical records from corals in and around Gladstone Harbour. This includes four sites adjacent to Gladstone Harbour (offshore control: Masthead Island, inshore control: Hummocky Island, inner harbor: RAT Island and South End Curtis, and outer harbour: Sable Chief and Seal Rocks). We have found that distinct geochemical signals have been recorded in these corals (e.g., Barium peaks due to river runoff, elevated trace metals from local industrial developments). This study clearly shows that massive Porites corals can be used as effective long-term recorders of environmental changes resulting from natural and anthropogenic influences. Results from this study can also offer guidance for the Australian governments in developing appropriate regulations to maintain sustainable coastal development in the Gladstone region.

Applying an attribute-based classification scheme to understand the seascape mosaic of the Central Queensland (CQ) coast

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Understanding the nature and extent of ecosystem in a seascape mosaic is fundamental for management, but marine datasets are disjointed and diverse. Classification provides a common language that harnesses biophysical attributes underpinning ecosystems. An intertidal and subtidal classification scheme was devised for Queensland, compatible with other ecosystems mapping, national and overseas classification standards. Attribute-based classification was applied in Central Queensland in three stages. From a pool of attributes, technical experts chose eight attributes underpinning Central Queensland ecosystems. During the typology stage, the experts devised rule-sets using combinations of these attributes to determine around 100 different ecosystem types. At the mapping stage, source datasets were translated to a common language, amalgamated into mapped attributes to which rule-sets were applied to map ecosystem types. Ecosystem types and attribute layers served multiple purposes. Coral types were diverse and connected e.g. rock, boulder, coffee rock reefs, carbonate, hard coral and octocorallians, branching / non-branching, rubbly reefal gardens, sponge, filter feeders. Coral knowledge gaps include - inshore regionalization, coral extent north of 1770, paucity of bathymetry / poorly known mesophotic coral ecosystems. A conservation assessment for the Baffle northward added values of flora, fauna, ecosystems and special areas. Mapping links to the attributes and ecosystem types are available on WetlandInfo website. Attribute-based classification is the 'Rosetta stone' enabling compilation of rich resources for diverse management purposes e.g. monitoring, field inventory, and representation. Seamless land and sea based ecosystem mapping is an integrative management tool.

POSTERS

The seastar that never grows up, long term clonal propagation and stable demography in a geographically isolated population of *Ailsastra heteractis* at One Tree Island

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Seastars of the family Asterinidae are well-known for their diverse life history strategies including sexual and clonal asexual reproduction. For at least 25 years, a population of the minute (radius ≤ 7 mm) fissiparous asterinid, *Ailsastra heteractis*, has been abundant in shallow water coral rubble habitat at One Tree Island, southern Great Barrier Reef. The population biology of this seastar was investigated over 15 years to characterise the pattern of asexual reproduction through fission (splitting in half) and to determine whether a size threshold is reached for the switch to sexual reproduction. Fission followed by regeneration was the dominant propagation mechanism generating individuals that varied in arm number (2–7) and length. Recently split individuals were present year-round with regenerating individuals being the most prevalent body form. There was a positive correlation between the incidence of fission and air and water temperature with a decrease in the proportion of recently split individuals in winter and an increase in summer. Fission was present in all size-classes with no evidence of a switch to a larger sexual morphotype with growth. Juvenile recruitment from sexual reproduction was also not evident. Clonality appears to be the only reproductive mechanism for the *A. heteractis* population.

Tidal jets and fish aggregations

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Tidal forcing was the principle driver influencing the hydrodynamics of a reef pass at Moore Reef, situated in the northern section of the Great Barrier Reef Marine Park. Several Marotte HS current meters and a Nephelometer (optical backscatter turbidity logger) were used to evaluate the fine scale hydrodynamic patters of the reef pass. Tidal jet formation was illustrated by the restriction in flow created by the reef pass and also the significant increase in current velocity and water movement. Other evidence of tidal jet phenomenon was the production of a separation point towards the entrance of the seaward side of the passage and current velocity on the outer reef slope increases further away from the passage. Tidal harmonics analysis of water height data demonstrated Moore Reef experiences a semi diurnal tidal pattern. Tidal changes in current direction were not synchronised with changes in tidal phase, with current changing direction two hours in advance to change in tidal phase. Flood and ebb bodies of water in the passage varied in turbidity and temperature and were generally 0.8°C cooler than ebb tides. In the passage daily average current speed ranged between 0.093 to 0.37 m/s with regular peaks and troughs in water velocity indicating lunar periodicity. Peaks in current velocity correlated with spring tides, and troughs with neaps. The Moore Reef pass is a known

fish aggregation site and tidal jet phenomenon influences where fish aggregations occurs in the pass.

Homeward Bound: Women in leadership, towards a sustainable future

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Two pressing issues facing the world today are climate change and gender equality and they are intrinsically linked. Research has shown climate change has a disproportionate impact on women and children, due to unfair distribution of roles, resources and leadership. Currently, less than 26% of the world's researchers are women and even fewer are in leadership roles. This under-representation comes at a time when women leaders could make a tangible difference in contributing to a more sustainable world. Similarly, research has shown that gender imbalance is widespread in academia, where women face unconscious bias, have fewer role models, under representation in editorial boards, committees and invited/plenary speakers and are two times less likely to win scholarly awards compared with their male colleagues. In order to give women the tools and training necessary to address the imbalance, the Homeward Bound program was founded in 2016 in Australia. Homeward Bound is a ground-breaking leadership program which aims to heighten the influence and impact of women in making decisions that shape our planet. There are four core components: leadership development, strategic capability, visibility and science communication and collaboration, woven together into an integrated program, delivered by an expert global faculty. Some of the main outcomes of the program include; practical ways for improving your ability to act as a leader in our world, understanding of the benefits of developing strategic capability in both the organisational and personal context, fundamentals of visibility and communication, establishing a global community of women in STEMM to collaborate towards impactful outcomes and shared goals.

The GBR Reef Protection Program Expansion Project

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Over the last 3 years, the Great Barrier Reef Joint Field Management Program has spent >$3M reducing localised direct impacts on the Great Barrier Reef through the expansion of the Reef Protection Program, essentially a network of public moorings and reef protection markers. Public moorings promote and provide safe, convenient and sustainable access at high use destinations by reducing the need for boat users to drop their anchor. Additionally, reef protection markers are used to clearly designate no-anchoring areas, mitigating the risk of anchor damage particularly on sensitive island fringing reefs. Together, they achieve ongoing protection and provide for sustainable use of the Reef's most popular diving, snorkelling and anchorage locations. This recent investment in expanding the Reef Protection Program involved localised in-water assessments of live coral cover, consultation with the public and relevant stakeholders, site planning and prioritisation processes and environmentally friendly infrastructure installation methodologies. Ranging from Lady Elliot Island in the south to Lizard Island in the north, there are now 256 public moorings and 48 no-anchoring areas in

place along the Great Barrier Reef helping to protect sensitive coral reefs and other habitats from anchor damage.

Citizen science project: Sediment-rejection mechanisms of 24 species of Moreton Bay scleractinian coral

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The marginal reefs of Moreton Bay, Queensland, occur in turbid environments subject to large sediment influxes from the adjacent urban fluvial catchments and frequent sub-tropical storms. With sedimentation increasing it is important to understand how corals adapt to turbid environments. This is a citizen science project aimed at investigating the mechanisms employed by 24 inner Moreton Bay corals to deal with a variety of sedimentation. This work adds to previous work by Stafford-Smith et al. (1992) who documented the rejection mechanisms of 42 corals on the Great Barrier Reef. High school students from IONA College is years 9, 10 and 11 used HD time-lapse microscopy to observe the coral tissue/sediment interface and observed corals employing a variety of adaptations to remove the sediment including pulsed inflation, mucus shearing, tissue undulations and tentacular activity. The students have also identified novel behaviours that aid unique morphologies deal with sedimentation and low light in turbid environments. Vase shaped *Turbinaria peltata* increased mucus release during sedimentation that agglutinated the sediments trapped on its surface, gas bubbles then formed under the mucus increasing the buoyancy of the sediments allowing for passive removal via water currents. In addition, the students documented species ingesting the sediments - suggesting that during turbidity events where light and thus nutrient acquisition is limited corals may be able to gain nutrients from the sediment itself. Improved understanding of sediment removal mechanisms in corals this project helps identify corals for effective inner reef restoration projects and assist with coral reef management in near shore environments such as Moreton Bay.

Coral Disease in the Extremes

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Coral reefs make up a mere one percent of our ocean, yet they attribute 25% of all marine life. This resource not only supports a rich biodiversity but also provides numerous ecological goods and services. Predicted climate trajectories threaten the existence of this entire ecosystem through anthropogenic perturbations sequentially leading to coral bleaching and coral disease outbreaks for example. Coral disease is one of the most threatening factors having detrimental impacts on coral reef health and coral community structure. Reefs which have experienced numerous coral bleaching events and sequential disease outbreaks have consequently undergone large restructuring and minimal recovery. The World Heritage Site, Lord Howe Island is a unique site exposed to subtropical and temperate waters, making it a

melting pot for marine life and illustrating a high level of endemism. Currently the reefs at Lord Howe Island are undergoing a coral bleaching event leaving the reef vulnerable to the onset of disease. This study aims at establishing coral disease prevalence and identification seen at Lord Howe Island. The study will examine the core microbiome to distinguish microbial community shifts in healthy and diseased coral colonies. These shifts will help determine disease identification and establish bio-indicators for healthy and diseased states. Coral disease prevalence was monitored in the lagoon indicating an overall prevalence of 10.5% across three sites. Higher prevalence of disease was seen in the Acropora and Isopora genera as well as larger coral colonies. Such work is crucial to establish current coral disease prevalence and track past and current coral disease patterns to help reef managers protect the unique and highly endemic coral reef system at Lord Howe Island.

Microscopic analysis reveals dietary resource partitioning in Indo-Pacific Scarinine parrotfishes

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Scarinine parrotfishes (Chlorurus and Scarus) are considered to be key 'herbivores' in coral reef ecosystems, although there is no clear consensus on their dietary targets. The prevailing view of Scarinines as 'ecosystem engineers' is based on the removal of turf, macroalgae and sediment. However, recent work synthesising multiple lines of evidence including behavioural observations, trophic anatomy, digestive physiology, stable isotope analysis and fatty acid analysis suggests that most Scarinine parrotfishes are "microphages" that target microscopic photo-autotrophs. Therefore, testing this microphage hypothesis, and thus developing an understanding of the functional roles of these parrotfish on coral reefs, requires dietary investigation at the microscopic level. We posed two hypotheses. First, a direct test of the "microphage hypothesis": do Scarinine parrotfishes target microscopic photo-autotrophs, and if so, what is the composition of the microscopic prey community? Second, does diet composition vary inter-specifically? To identify and quantify the dietary targets of Scarinines we followed five species of parrotfishes until focused feeding was observed. Feeding sites were photographed and a bite core (22mm diameter) was extracted and fixed for laboratory analysis. Bite cores were subsequently photographed at 5x-1000x magnification to identify and quantify the epilithic and endolithic biota, including rhodophytes, Phaeophyceae, chlorophytes cyanobacteria and diatoms. Tufting or biofilm-forming epilithic cyanobacteria were the most abundant biotic component on the cores in all five parrotfish species. Significant differences in bite core biota percentage cover were found between all five study species.

Harnessing biological partnerships to enhance marine restoration

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In coastal restoration efforts, managers overwhelmingly focus on reducing negative interactions (e.g. competition) among transplants. My research in marine wetlands challenges

this approach and reveals designs that focus instead on maximizing positive interactions (e.g. mutualisms) can double restoration yields. This project will consist of collaborative work to be completed in Australia with CSIRO scientists to test if incorporation of positive interactions into real-world restoration can increase success. I will globally disseminate these findings using a multi-faceted, education and outreach approach. These efforts have the high potential to greatly increase success of coastal wetland conservation.

Back to back mass coral bleaching events on the Great Barrier Reef in 2016 & 2017: understanding the physical drivers

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The Great Barrier Reef has suffered unprecedented coral bleaching and mortality following record breaking exposure to heat stress in 2016 and the first ever repetitive bleaching event for the region in 2017. Whilst the bleaching in 2016 reduced in severity from north to south, the bleaching in 2017 was most severe in the central GBR, increasing the overall extent of the ocean warming impacts on live coral cover. Seasonal outlook models by NOAA and BoM predicted the warming for 2016 but in contrast considered 2017 to be a lower risk. IMOS, BoM and AIMS contributed a wide range of observations from satellite observations feeding into ReefTemp to reef based weather and oceanographic sensor networks that provided real time observations as events unfolded. A glider was also deployed at short notice in 2017 after the 13 glider missions in the previous year to help understand how deep the thermal stress extended to. The combination of the extended summer time observations throughout the water column by multiple observing platforms and the application of the operational eReefs model is allowing the 2016 and 2017 bleaching event to be analysed in ways unprecedented since the last major event in 2002. Winds played a major role in keeping large sections of the reef cooler than others however there are also regions where the confluences of a number of oceanographic processes over a range of scales have resulted in persistently cooler waters. This indicates they may provide long term refugia for corals during marine heat waves.

Investigating dietary responses by dugongs in relation to ontogeny, season and environmental stressors

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Dugongs of the Great Barrier Reef (GBR) region exist as a series of genetic populations along the Queensland coast and are likely Critically Endangered. Dugongs rely on abundant healthy seagrass, and in the event of local seagrass degradation or loss (e.g., due to coastal flooding, cyclones), dugongs are vulnerable to starvation. How dugongs cope with degradation of seagrasses (e.g., by shifting diet or local feeding ground) is unknown. We do know that there have been mortality episodes associated with extreme weather events. This project used carbon

and nitrogen stable isotope analysis to investigate ontogenetic and temporal dietary shifts, through examining tusks of dugongs that had died in the Townsville region, central GBR. Dugong tusks are large, permanent and grow incrementally throughout a lifetime, with two growth layer groups (GLGs) laid down each year, corresponding to wet and dry seasons. Dugongs can be aged by counting GLGs, and if date of death is known, deposition of GLGs specifically associated with environmental events (e.g., cyclones) can be identified. Micro-samples of tusk tissue were drilled from a curated collection held at North Queensland Museum to investigate dietary shifts in terms of ontogeny (GLGs along tusks of individuals) and season (GLGs deposited in wet versus dry). The effects of a severe cyclone (Althea 1971) were investigated by comparing dietary variation in dugongs that had died pre-cyclone with those that survived the cyclone by up to five or ten years. Understanding how dugongs respond to food stress will be useful as adverse weather events intensify.

Enabling restoration on the Great Barrier Reef

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The condition of coral reef habitats within the Great Barrier Reef Marine Park has declined over the past 30 years. Due to multiple recent impacts and ongoing climate change, the capacity of existing management arrangements to support resilience is no longer enough. Consequently, the Authority has shifted its management approach to not only protect and mitigate, but to enable active restoration interventions where required. While strong efforts to mitigate climate change through emissions reduction are essential, the Authority considers that restoration and adaptation activities can help prevent decline, restore degradation or enhance recovery of species or habitat locations in order to increase the resilience of coral reef habitats. The objectives are to discuss the broad range of considerations around restoration and adaptation activities. The Authority has seen increased interest and new permit applications for restoration activities, including pilot studies. To assist applicants, the Authority has produced Guidelines for applications for restoration and adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park. The Authority is currently developing a reef restoration policy for the Great Barrier Reef Marine Park. A staged approach is being used to ensure that the risks of new and emerging techniques are fully explored prior to implementation. The Authority is taking into account the best available scientific knowledge and uncertainty (among other considerations) when deciding on restoration and adaptation activities for conservation gains going forward.