Reef Resilience Symposium 2024

Event program

16–18 April | Great Barrier Reef | Cairns, Australia

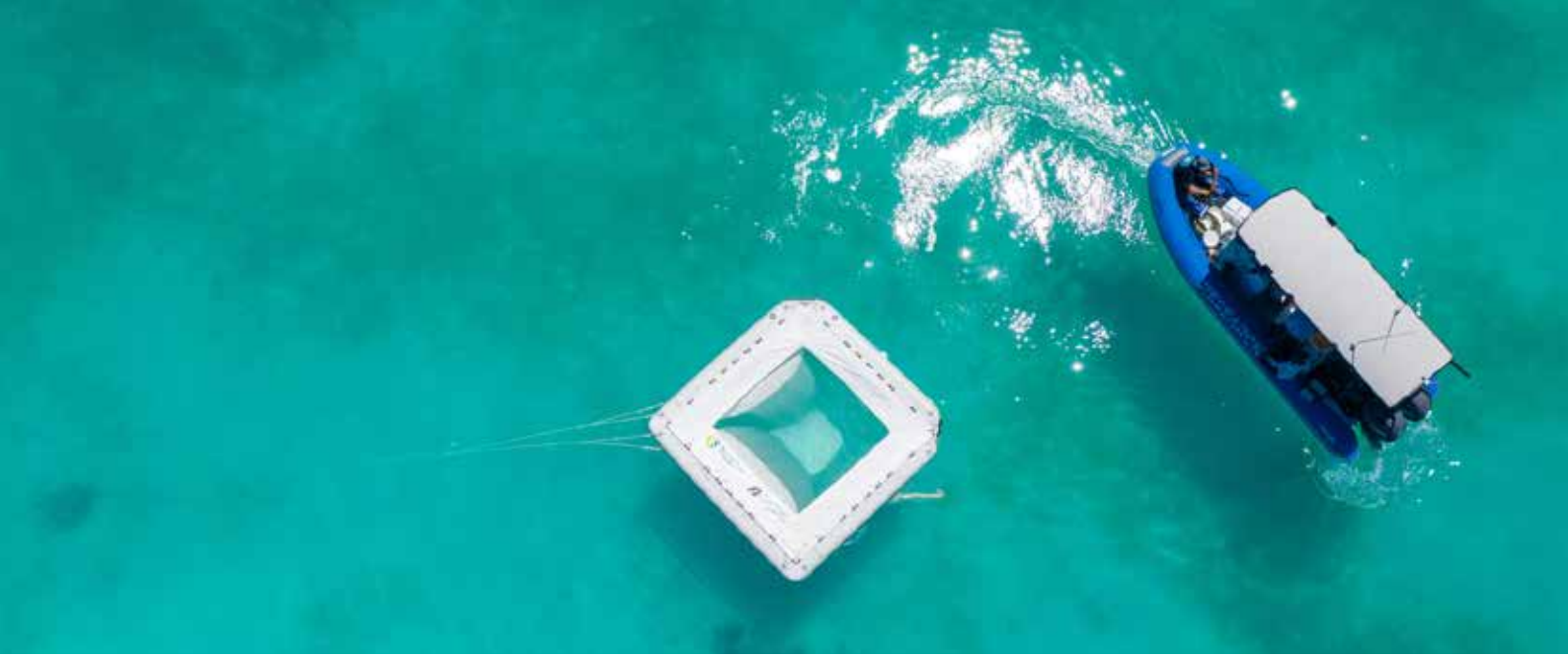
reefresiliencesymposium.org

Reef Resilience Symposium 2024

In the spirit of reconciliation, we acknowledge the Traditional Custodians of country throughout Australia and their connections to land, sea and community. We pay our respect to their elders past, present, and emerging and extend that respect to all Aboriginal and Torres Strait Islander peoples today.

Organisers


RRAP
REEF
RESTORATION
& ADAPTATION
PROGRAM
Australian Government
Australian Institute of Marine Science
Australian Government
REEF TRUST
Great Barrier
Reef Foundation
AMPTO
Association of Marine Park Tourism Operators
Australian Government
Great Barrier Reef
Marine Park Authority
Reef
Authority
Reef &
Rainforest
RESEARCH CENTRE
JAMES COOK
UNIVERSITY
AUSTRALIA
CSIRO
Southern Cross
University
QUT
Queensland
University
of Technology
The University
Of Queensland
AUSTRALIA



Welcome

Dear Reef Stewards,

On behalf of the Organising Committee we welcome all of you, both in-person and online, to the Reef Resilience Symposium 2024.

With global warming expected to surpass 1.5°C this century, coral reefs around the world are already struggling to cope with the rate of environmental change. The stakes have never been higher for the future of coral reefs and the communities that depend on them.

Rising to this challenge requires strong partnerships and innovative solutions that bring together diverse skills, perspectives and knowledges to deliver programs and initiatives that build resilience, both locally and globally.

Over the past four years, the Australian Government has invested in research and innovation that informs resilience-building actions through the Reef Restoration and Adaptation Program (RRAP) and the COTS Control Innovation Program (CCIP).

At the same time, managers, industry, Traditional Owners and communities have advanced a wide range of on-ground actions to monitor, conserve and restore coral reefs and coastal habitats, both in Australia and overseas.

This Symposium is a timely opportunity for us to connect with each other, share learnings, identify future priorities, and consider how we might work more effectively to meet current and future challenges.

We're excited to present an outstanding program of over 120 speakers from all sectors of our community, touching on cross-cutting themes including:

- Innovation in coral reef protection and restoration
- Cross-sector partnerships and collaboration
- First Nations leadership and local stewardship

Please join us with an open and solutions-focused mindset. We're all in this together and there's a lot to do. Let's get to work!

Your co-convenors,

Mia Hoogenboom, Acting RRAP Deputy Director

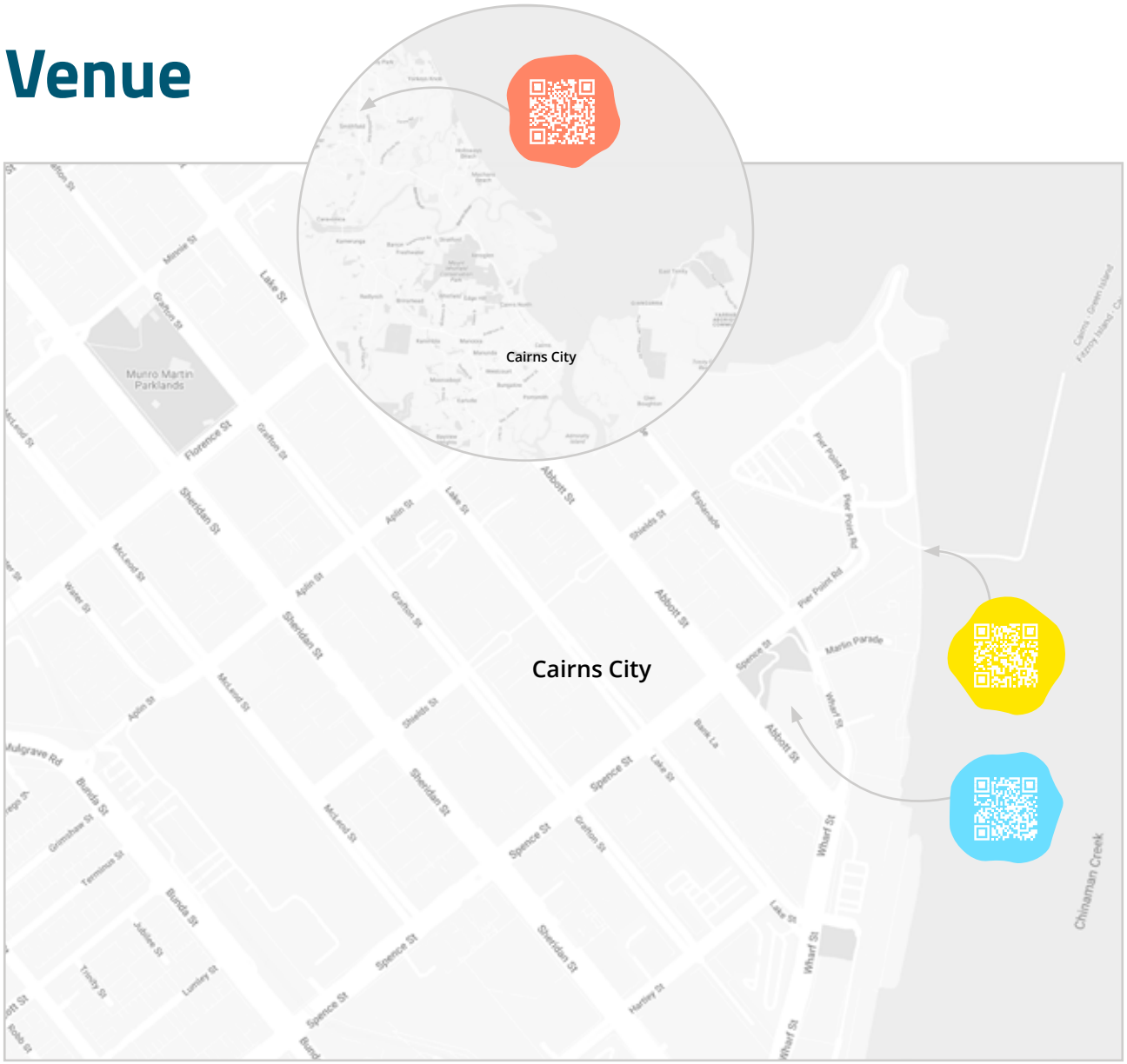
Mary Bonin, CCIP Program Director

On behalf of the Organising Committee:

- **Jim Higgs**
  RRAP Acting Program Director, AIMS
- **Suzanne Long**
  Senior Scientist, RRRC
- **Emily O'Regan**
  RRAP Project and Contract Administrator, AIMS
- **Eric Fisher**
  GBR Biology Manager, Experience Co
- **Emma Lawrence**
  Subprogram Director CCIP, CSIRO
- **Bob Muir**
  Indigenous Partnerships Coordinator, AIMS
- **David Williamson**
  Director Reef Interventions, Reef Authority
- **Roger Beeden**
  Chief Scientist, Reef Authority
- **Line Bay**
  Research Program Director, AIMS
- **Vanessa Haller-Bull**
  RRAP M&DS Subprogram, AIMS and ECR representative
- **Priscilla Peto**
  RRAP Executive Assistant (Minutes), AIMS
- **Manuwuri Forester**
  Indigenous Partnerships Coordinator, AIMS
- **Stewart Lockie**
  Distinguished Professor, JCU, and RRAP Engagement Co-lead, AIMS
- **Damien Burrows**
  Director, TropWATER JCU
- **Gareth Phillips**
  CEO, AMPTO

#reefresilience2024

Venue



The Reef Hotel Casino
Cairns City

35–41 Wharf Street

The Symposium will be held at The Reef Hotel Casino between Tuesday, 16 April to Thursday, 18 April.

James Cook University
Nguma-bada campus, Smithfield

14–88 McGregor Road

A shuttle service will be provided to workshops held on Monday, 15 April hosted at the James Cook University, Smithfield campus. (Limited capacity).

Reef Fleet Terminal
The Pier, Cairns City

1 Pier Point Road

Meet at the terminal at 8:30 am for the reef day tour on Friday, 19 April. (Bookings essential).


Program

Workshop 1

9:30 am – 11:30 am

JCU Smithfield Campus, Room A001-016

Crown-of-Thorns Starfish control

In this workshop you will learn about the latest science that underpins the control of crown-of-thorns starfish (*Acanthaster* spp.) on the Great Barrier Reef, and you will gain practical skills for using the state-of-the-art technologies that have been developed for COTS control. The workshop will include ~30 minute seminar presentation from leading COTS Control scientists and practitioners, ~30 minute Q&A, ~60 minute practical exercises focusing on setting-up and maintaining COTS injection devices, and reporting COTS sightings and cull activities via the Reef Authority's Eye-on-the-Reef.

Convenors
David Williamson (Reef Authority), Sam Matthews (Reef Authority), and COTS Program Divers

Shuttle bus transport to JCU

Getting there

Departing The Reef Hotel Casino for James Cook University at **9 am** and **2 pm**. Meet the shuttle bus at least 30 minutes before the workshop starts.

Getting back

Departing James Cook University for return to The Reef Hotel Casino at **12:15 pm** and **4:45 pm**.

Workshop 2

Workshops
Monday, 15 April

James Cook University (JCU)
(In-person attendance only)

2:30 pm – 4:30 pm

JCU Smithfield Campus, Room A004-130

Scaled production of corals for reef restoration

In this workshop you will learn about cutting-edge methods for up-scaled production of coral larvae and spat for reef restoration from some of Australia's leading researchers. The workshop will include a brief explanation of coral reproduction followed by a set of three ~30 minute interactive sessions about: 1) automated land-based spawning and fertilisation, larval rearing, and settlement of corals for reef restoration; 2) techniques and technologies for on-reef mass-production and deployment of coral larvae in the field (via larval pools and tanks); and 3) methods and equipment for large-scale deployment of settled corals into different reef habitats, taking into account reef ecology. The workshop will end with a brainstorming session with the panel around the future of sexual production of corals for reef restoration, a discussion about emerging methods and technologies, and a Q&A session.

Convenors
Mikaela Nordborg (AIMS), Carly Randall (AIMS), and Christopher Doropoulos (CSIRO)

2:30 pm – 4:30 pm

JCU Smithfield Campus, Room A001-013A and A001-013B

Coral reef monitoring technologies

Resilience-based management of coral reefs, and detecting the efficacy of reef interventions, requires large scale assessment of reef condition. New data collection technologies that rely on artificial intelligence for automated assessment of coral reef condition (coral cover and benthic composition) have been developed to solve data gaps for reef monitoring, In this workshop you will learn from the developers of the ReefCloud system about the underpinning science, and you will gain skills in how to access and contribute to ReefCloud. The session will include a comparison between ReefCloud and other similar platforms being used around the world. The workshop will end with a Q&A session. Computers are available but you may wish to bring a laptop with internet access.

Convenors
Manuel Gonzalez-Rivero (AIMS), and Emma Kennedy (AIMS)

10:00 am – 12:00 pm

JCU Smithfield Campus, Room A001-013A and A001-013B

RRAP Explorer: Modelling and decision support

RRAP Explorer is a modelling tool that integrates the latest Great Barrier Reef environmental datasets with models for coral population and community dynamics. RRAP researchers have created a web-based general user interface that will allow users to assess outcomes of different restoration scenarios. In this workshop, you will learn about the modelling and decision support tools used by RRAP and CCIP, and you will gain skills for using RRAP Explorer. The workshop will include: 1) ~30 minute presentation about the underlying science and an introduction to RRAP Explorer; 2) ~60 minutes interactive session learning how to use the GUI; 3) ~30 minute Q&A session about the application of the models and benefits and limitations of the approach. Computers are available but you may wish to bring a laptop with internet access.

Convenors
Peter Mumby (UQ), Arne Adam (UQ), Yves-Marie Bozec (UQ), and Tina Skinner (UQ)

12:00 pm – 2:00 pm

JCU Smithfield Campus, Room A003-002

Co-design of research with Traditional Owners

Two-way knowledge sharing between Indigenous communities and scientists is integral to our collective desire to conserve the marine environment for generations to come. Moreover, engagement with rights-holders and the public, along with robust governance (both Law and the Lore), is critical to achieving successful implementation of reef interventions. In this workshop, you will gain new understanding of Traditional Owner perspectives on sea country. The workshop will include: 1) ~30 minute presentation about the natural synergies that exist between reef research and the management and protection of sea country by Traditional Owners; 2) ~60 minute interactive session about how to co-create new shared research that weaves Indigenous Knowledge of sea country with other sciences; 3) ~30 minute Q&A session.

Convenors
AIMS Indigenous Partnership Team, and Crown-of-Thorns Starfish and RRAP Traditional Owner Technical Working Group

Symposium

The Reef Hotel Casino

Tuesday, 16 April

	Urchins Room		
7:30	Registration opens		
8:30	**Welcomes and conference opening** Welcome to Country by Gudjugudju – Gimuy Walubarra Yidinji Selina Stead, CEO, Australian Institute of Marine Science Richard Quincey, General Manager of Operations, Great Barrier Reef Marine Park Authority Matt Barwick, Director of Reef Restoration and Partnerships, Department of Climate Change, Energy, the Environment and Water		
9:00	*Plenary* **First Nations leadership in reef resilience** Bob Muir AIMS		
9:40	Morning tea		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Working models for co-design and cross-sector collaboration**	*Session* **Ecological intelligence and monitoring**	*Session* **Decision support tools and models**
10:00	*Keynote* **Connecting local students to Culture and conservation** Tarquin Singleton Reef Cooperative	*Keynote* **Ecological research and monitoring priorities to underpin coral reef restoration** Katharina Fabricius AIMS	*Keynote* **Ecological projections of Australia's Great Barrier Reef under an uncertain warming future** Yves-Marie Bozec UQ
10:30	**Traditional Owner partnerships for enhanced reef restoration outcomes** Cathie Page AIMS	**Ecological heuristics for site selection to maximise survivorship and growth of deployed corals** Juan Carlos Ortiz AIMS	**RRAP Modelling and Decision Support Design report – a plan for design and implementation of decision support** Peter Fitch CSIRO
10:45	**Partnering to build capacity of GMY Rangers to care, connect and support healthy Sea Country** Skye McKenna JCU	**Optimising coral larval recruitment through reef-based research on larval settlement and survival on various Crustose Coralline Algae.** Alexandra Ordoñez Alvarez SCU	**Interpretable rules for resilient reef futures with SIRUS** Pedro Ribeiro de Almeida AIMS

11:00	**Developing genuine partnerships with Reef Traditional Owners: Crown-of-Thorns Starfish (COTS) research and management in the Great Barrier Reef (CCIP-R-09)** Vincent Backhaus JCU	**Variation in coral thermal tolerance during a mild bleaching event: the role of holobiont taxa, colony sizes, and local environmental conditions** Mariana Alvarez-Noriega AIMS	**Modelling the influence of fishing and conservation zoning on the Great Barrier Reef ecosystem** Scott Condie CSIRO
11:15	**Sea Country mapping to manage Crown-of-Thorns Starfish outbreaks** Marycarmen Martinez Diaz CSIRO	**Allee effects in small coral populations: manipulating adult colony patches to assess fertilisation success** Peter Mumby UQ	**Predicting COTS dispersal in the GBR** Severine Choukroun JCU
11:30	**Spawning School: Fostering connection and capacity between Traditional Custodians and western science** Katie Chartrand JCU	**Highly resolved estimates of feeding rates for Crown-of-Thorns Starfish inform ecological projections and management decisions on the Great Barrier Reef** Josie Chandler JCU	**Validation of coral larvae connectivity modelling using observations of coral early life stages on the Great Barrier Reef** Robert Mason CSIRO
11:45	**Collaborative design in a marine science outreach program supports engagement of First Nations youth** Allison Paley JCU	**Predation rates on Crown-of-Thorns Starfish relative to fisheries management zones** Peter Doll JCU	**The hydrodynamic scales of marine dispersal** Clothilde Langlais CSIRO
12:00	**The Reef Catchments Science Partnership** Angela Marsh UQ	**Predator-prey dynamics of the Crown-of-Thorns sea star in their juvenile life stage** Peter Mumby UQ	**Predicting coral spawn slicks and dispersal of coral larvae to inform larval-based restoration interventions** Marine Gouezo SCU George Roff CSIRO
12:15	Lunch		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Working models for cao-design and cross-sector collaboration (cont.)**	*Session* **Ecological intelligence and monitoring (cont.)**	*Session* **Decision support tools and models (cont.)**
1:00	**Highlights from the Coral Restoration Consortium** Tali Vardi Coral Restoration Consortium	**Thinking outside the box: patterns and processes in the initiation of renewed population irruptions of Pacific Crown-of-Thorns Starfish (*Acanthaster cf. solaris*) on Australia's Great Barrier Reef** Morgan Pratchett JCU	**Evaluation of models for decision support in a changing environment** Barbara Robson AIMS
1:15	**Stakeholder and researcher partnerships to aid and improve coral restoration practices on the Great Barrier Reef** Lorna Howlett UTS	**A new coral reef monitoring tool: Species specific eDNA allows quantification and early detection of Crown-of-Thorns Seastar outbreaks** Sven Uthicke AIMS	**A platform approach to decision support for the Crown-of-Thorns Starfish Control Program** Cameron Fletcher CSIRO

1:30	**Operationalising resilience-based management in the Great Barrier Reef World Heritage Area** Mark Read Reef Authority	**Application of new technologies to coral reef monitoring and COTS detection** Zeeshan Hayder CSIRO	**Economic assessment of GBR management strategies** Gabriela Scheufele CSIRO
1:45	**From Theory to Application: The current status of scaling up RRAP Interventions** Deborah Foote and Kevin Erickson AIMS	**A comprehensive monitoring strategy for COTS in the GBR** Emma Lawrence CSIRO	**Does reef-scale modelling validate implementation of current coral-CoTS management?** Laura Blamey CSIRO
2:00	**Scaling out, up and deep: Lessons in collaborative planning from the Reef Restoration and Adaptation Program (RRAP) Community Panels** Samantha Stone-Jovicich CSIRO	**Improving the efficiency and effectiveness of COTS control decision making using deep learning** Md Zahidul Islam CSIRO	**Reef-Risk: A decision support tool for identifying vulnerable and resilient areas in the Great Barrier Reef** Alejandro Astorga Moar UQ
2:15	**The Great Reef Census: 21st Century Conservation for Monitoring and Management** Christopher Lawson UQ	**Juvenile waiting stage Crown-of-Thorns Starfish are resilient in heatwave conditions that bleach and kill corals and their response to chemosensory cues** Maria Byrne University of Sydney	**From Data to Decisions – a winding road** Karen Chong-Seng Reef Authority
2:30	Chair wrap up of session	Chair wrap up of session	Chair wrap up of session
	Urchins Room		
2:50	*Plenary* **Research and tourism partnerships for reef resilience** Mark Gibbs Reef Restoration and Adaptation Program Nicole Rosser ZigZag Whitsundays		
3:30	Afternoon tea		
4:00	**Panel discussion** Synthesis across sessions linked to cross-cutting themes		
4:50	Closing remarks		
5:00	**Welcome function** With address by Senator Nita Green, Special Envoy for the Great Barrier Reef and Member for Cairns and Queensland Tourism Minister The Hon. Mr Michael Healy		

Wednesday, 17 April

	Urchins Room		
7:30	Registration opens		
8:15	**Networking** Global Interventions World Café		
9:00	*Plenary* **Blueprint 2030: Managing the Great Barrier Reef under a rapidly changing climate** Roger Beeden Reef Authority		
9:40	Morning tea		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Resilience-based management: 2030 and beyond**	*Session* **Local stewardship for restoration and resilience**	*Session* **Ecological intelligence and monitoring (cont.)**
10:00	*Keynote* **Partnering with local communities, reef managers and resilience experts to respond to climate change and local threats** Ana Perez GBRF	*Keynote* **Evolution of local scale site stewardship on the Great Barrier Reef** Eric Fisher Experience Co	*Keynote* **A baseline of juvenile coral demographics across environmental gradients of the Great Barrier Reef** Christopher Doropoulos CSIRO
10:30	**Online Training to Support Resilience-based Management of Coral Reefs** Annick Cros The Nature Conservancy	**Empowering local scale stewardship actions by Great Barrier Reef tourism operators** Justin Bovery-Spencer Reef Authority	**Collaborative monitoring for assisted coral recovery: opportunities and potential benefits for large scale deployments and lessons from a pilot study at Moore Reef** Matt Curnock CSIRO
10:45	**Knowledge for resilient reef management: Reef Integrated Monitoring and Reporting** Melissa Lane Reef Authority	**Coral Nurture Program: A collaborative approach to coral propagation and out-planting on the Great Barrier Reef** Paige Strudwick UTS	**Beyond coral cover: An integrative approach to assess and report on the status and trends of coral reefs in the Great Barrier Reef** Manuel Gonzalez-Rivero AIMS
11:00	**Tourism Stewardship on the Great Barrier Reef** Johnny Gaskell Reef Authority	**Lessons learnt implementing mineral accretion and coral gardening at Agincourt Reef, Great Barrier Reef** Kailash Cook UQ	**Potential applications for the combination of Bathymetric LiDAR and Hyperspectral Imagery in mapping Marine Cloud Brightening/Fogging Plumes in coral reef systems** Peter Butcherine SCU
11:15	**Resilience Based Management in practice: A Keppel Islands case study** Neil Mattocks Reef Authority	**The Cairns-Port Douglas Reef Hub: An open, place-based collaborative network for local reef stewardship** Abbi Scott JCU	**Finding the right environment for the right taxa to inform restoration** Renata Ferrari Legorreta AIMS
11:30	**Community and stakeholder perceptions of resilience-based management in the Great Barrier Reef** Henry Bartelet JCU	**Cultivating capital: Enhancing communities through Great Barrier Reef adaptation and management** Gillian Paxton JCU	**What is rubble anyways? Opportunities and limitations to studying reef rubble substrates via remote sensing** Tanya Dodgen QUT

11:45	**Applying Indigenous and western science knowledges to inform the sustainable management of a dugong and seagrass hotspot in the Girringun TUMRA, Queensland** Phil Rist Girringun Aboriginal Corporation	**A local, "grass roots" collaboration for the restoration of tropical seagrass in north Queensland** Tim Smith JCU	**A synthesis of rubble bed dynamics to inform intervention site selection** Tania Kenyon UQ
12:00	**Coral reefs of Saudi Arabia's Red Sea – a resilience-based approach to management** Ian McLeod SHAMS	**Women in Marine Conservation** Kimberly Wong JARI Foundation	**Carbonate budgets induced by coral restoration of a Great Barrier Reef site following cyclone damage** Carmela Isabel Nuñez Lendo UTS
12:15	Lunch		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Resilience-based management: 2030 and beyond (cont.)**	*Session* **Local stewardship for restoration and resilience (cont.)**	*Session* **Business and financing of reef resilience**
1:00	**A structured approach to prioritising reefs for Crown-of-Thorns Starfish control on the Great Barrier Reef** Cameron Fletcher CSIRO	*Keynote* **Reefs of Hope: A Nature-Based Coral-focused Climate Change Adaptation Program Endorsed by UNESCO** Austin Bowden-Kerby Corals for Conservation	*Keynote* **Biodiversity credits as a sustainable financing option for scaling up coral reef restoration and adaptation** Cedric Robillot GBRF
1:15	**Effective management of Crown-of-Thorns Starfish (COTS) outbreaks protects the resilience of the Great Barrier Reef** Samuel Matthews Reef Authority		
1:30	**Ecological assessments of alternative Crown of Thorns Starfish control strategies using regional models of the Great Barrier Reef** Christina Skinner UQ	**Diverse coral larvae production from ocean-based nurseries that cater for warm water and wild weather** Ryan Donnelly Reef Restoration Foundation	**Funding for scale and impact** Theresa Fyffe GBRF
1:45	**Supporting the long-term resilience of the Great Barrier Reef through water quality improvement programs** Catalina Reyes-Nivia GBRF	**Could an inexpensive, low-tech, low-energy, small-scale intervention that reintroduces "normal" mixing of the water column improve outcomes for corals during acute mass bleaching events?** Dennis Stanley UWA	**Financing marine protected areas** Cabral Reniel JCU
2:00	**Building reef resilience through wetland restoration** Maximilian Hirschfeld Australian Marine Conservation Society	**Rebuilding the reefs of Peel Island, Moreton Bay, Queensland** Jodi Salmond and Mark Gibbs Reef Check Australia	**Using environmental markets to fund restoration of coastal wetlands and coral reef protection** Nathan Waltham JCU
2:15	**Title TBA** Karen Joyce JCU	**Building locally to scale globally** Andy Ridley Citizens of the Great Barrier Reef	**Nitrogen risk insurance and implications for fertiliser use and nutrient runoff to the reef** Russell Mehmet Willis Towers Watson
2:30	Chair wrap up of session	Chair wrap up of session	Chair wrap up of session

	Urchins Room
2:50	*Plenary* **Collaborative research and management drives innovation in COTS control on the Great Barrier Reef** Mary Bonin GBRF David Williamson Reef Authority
3:30	Afternoon tea
4:00	**Panel discussion** Synthesis across sessions linked to cross-cutting themes
4:50	Closing remarks
5:00	**Invitation only networking event with dignitaries**

Thursday, 18 April

	Urchins Room	Michaelmas Cay Room	Reef Room
7:30	Registration opens		
8:30	*Plenary* **Restoration at scale – legal barriers and enablers** Justine Bell-James UQ		
9:00	*Session* **KULBUL-BARRA – We are the Ocean** Gavin Singleton Yirrganydji Land and Sea Ranger Program Phil Rist Girringun Aboriginal Corporation Cass Hunter CSIRO Christabel Warren RRAP Steering Committee and Bromley Aboriginal Corporation		
9:40	Morning tea		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Managing risks, obtaining social license, and driving policy change**	*Session* **New technologies for restoration at scale**	*Session* **Adaptation, aquaculture and genetic tools**
10:00	*Keynote* **Intervention Risk Review: A commitment to independence and quality assurance** Sue Barrell AO RRAP	*Keynote* **Advancements in seeding coral spat and microfragments for reef restoration: defining drivers of survival from five years of experimental deployments and large field trials** Carly Randall AIMS	*Keynote* **Changing paradigms in the restoration of Florida's reefs: Novel interventions, transnational obstacles, and the urgent need to share genetic resources to maximize coral survival** Andrew Baker University of Miami

10:30	**An integrated approach to modelling and decision support for coral reefs in the Anthropocene** Ken Anthony AIMS	**Larger scale reef-based slick collection, culturing, and deployment of coral larvae from wild coral spawn slicks for reef restoration** Peter Harrison SCU Christopher Doropoulos CSIRO	**Hidden dimensions of coral biodiversity: cryptic taxa, hybridisation, and why it matters for restoration** Cynthia Riginos AIMS
10:45	**A social license to operate theory for existing and novel Reef interventions on the Great Barrier Reef** Henry Bartelet JCU	**Engaging technology to automate coral deployment for large-scale reef restoration across the GBR** Benjamin Moshirian AIMS	**Eco-evolutionary considerations and practices in coral reef restoration** Yui Sato JCU Annika Lamb AIMS
11:00	**Governing the COTS control program as a partnership – lessons from the last five years** Tim Moltmann GBRF	**Engineering the Future: Pioneering Marine Cloud Brightening Atomizer System – Concept to Regional Deployment for cooling and shading the reefs** Cheng Chen SIMS	**Characterising the chronic and acute effects of temperature on the growth of Great Barrier Reef's corals** Juan Carlos Ortiz AIMS
11:15	**The 2003 Zoning Plan – a global benchmark helping to maintain the resilience of the GBR** Jon Day JCU	**Co-development of coral enhancement technology utilising regional practitioner networks** Aric Bickel SECORE International	**Maximising the utility of cryopreservation as an enabling technology in coral reef recovery and resilience** Jonathan Daly Taronga Conservation Society Australia
11:30	**Research to support Indigenous-led decision making for Reef Restoration and Adaptation in the Great Barrier Reef, Australia** Kirsten Maclean CSIRO	**Semiochemical control of Crown-of-thorns starfish through scalable bioprocessing** Kuok Yap UQ	**Overcoming biological and technical bottlenecks in conservation aquaculture** Mikaela Nordborg AIMS
11:45	**The social benefits of stakeholder engagement: participant experiences in the Reef Restoration and Adaptation Program's Engagement Advisory Group** Jasmine Pearson QUT	**Evaluating the use of a high-throughput phenotyping tool to guide selection of coral material for restoration purposes** Christine Roper UTS	**Enhancing coral survival through nutrient supplementation** Jennifer Matthews UTS
12:00	**Governance Challenges and Recommendations for Marine Cloud Brightening** Rose Foster UQ	**Inducing out-of-season spawning of Great Barrier Reef corals to support active intervention efforts in reef restoration** Loni Koukoumaftsis AIMS	**Bridging the gap to using heat-tolerant coral photosymbionts in reef restoration** Madeleine van Oppen AIMS

AIMS	Australian Institute of Marine Science	RRAP	Reef Restoration and Adaptation Program
CCIP	COTS Control Innovation Program	RRRC	Reef and Rainforest Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation	SCU	Southern Cross University
		SIMS	Sydney Institute of Marine Science
GBRF	Great Barrier Reef Foundation	UQ	The University of Queensland
JCU	James Cook University	UTS	University of Technology Sydney
Reef Authority	Great Barrier Reef Marine Park Authority	UWA	University of Western Australia

12:15	Lunch		
	Urchins Room	**Michaelmas Cay Room**	**Reef Room**
	Session **Managing risks, obtaining social license, and driving policy change (cont.)**	*Session* **New technologies for restoration at scale (cont.)**	*Session* **Decision support tools and evolutionary models**
1:00	*Keynote* **A Monitoring, Evaluation, and Learning Strategy for engaging reef communities in large-scale assisted ecosystem adaptation** Karen Vella QUT	*Keynote* **Cooling and shading the Great Barrier Reef** Daniel Harrison SCU	**C~scape: a within-reef metacommunity modelling framework to inform reef management in an uncertain future** Juan Carlos Ortiz AIMS
1:15			**Bridge building between adaptation research and coral models** Vanessa Haller-Bull AIMS
1:30	**Research priorities and management reforms to meet international (CITES) obligations and secure social license for Australian coral fisheries** Morgan Pratchett JCU	**ReefCloud: automated image analyses and statistical modelling to support the integration of coral reef monitoring and sharing of actionable data** Emma Kennedy AIMS	**Fate of climate refugia in the Great Barrier Reef** Chaojiao Sun CSIRO
1:45	**Resistance of Restored Reefs to Cyclone Impacts in the Northern Great Barrier Reef** Freda Nicholson Mars Sustainable Solutions	**Coral reefs in 4D: Using novel technologies to inform and advance restoration** Sophie Gordon AIMS	**Context-dependent benefits of reef restoration: a simulation-based analysis** Arne Adam UQ
2:00	*Keynote* **Driving change to deliver improved outcomes for the reef – Jon Brodie Memorial Lecture** Sheriden Morris RRRC	**Coral shading through saltwater fogging: Contrasting modelled plumes against recent in situ observations** Joel Alroe QUT	**Synthetic data for exploring resilient reef futures** Rose Crocker AIMS
2:15		**Next-gen bioadhesives: helping shape the future of sustainable rubble stabilisation and reef restoration** Brett Lewis QUT	*Panel discussion* **Key knowledge gaps for incoroporating evolution/ adaptation into reef forecast models**
2:30	Chair wrap up of session	Chair wrap up of session	Chair wrap up of session
	Urchins Room		
2:50	*Plenary* **RRAP – Past, present, and future** David Mead AIMS Line Bay AIMS		
3:30	Afternoon tea		
4:00	**Panel discussion** Synthesis across sessions linked to future priorities		
4:50	Closing remarks		
5:30	**Public forum**		

Reef trip
Friday, 19 April

Reef Fleet Terminal

Book your spot here

GBR BIOLOGY
STORIES | KNOWLEDGE | EDUCATION | RESEARCH

Explore Reef Magic and the Reef Connect Program

Abstracts

Abstracts are presented in alphabetical order by the presenting author's surname

Plenary talks Keynote talks

Context-dependent benefits of reef restoration: a simulation-based analysis

Adam A, Bozec Y-M, Hedley J, Mumby P

As counterfactual model scenarios (the case of 'not intervening') predict challenging prospects for the survival of corals at most reefs at the Great Barrier Reef (GBR) over the coming decades, it is important to investigate how restoration strategies could boost the recovery of coral reefs at different spatial scales. However, identifying prominent reefs for restoration proves to be complex as intervention benefits are context dependent when the future of the GBR is unknown. Apart from restoration design, the state of the reef and the impact of disturbances occurring post-restoration highly influence the maximum achievable benefit over time. State-of-the-art ecological models such as ReefMod are considered valuable tools to investigate what factors affect restoration success. Here, we use ReefMod to examine restoration benefits for intervention scenarios of deploying corals at different stocking densities, proportions of the reef restored and heat tolerances under varying ecological and environmental conditions. Our results show that connectivity related factors such as external larval supply and self-retention as well as the timepoint of a disturbance post-deployment play an important role for restoration success. Overall, this study informs on important drivers of restoration benefits which could help us to better design intervention strategies across the GBR.

Arne Adam
The University of Queensland
a.adam@uq.edu.au

Coral shading through saltwater fogging: Contrasting modelled plumes against recent in situ observations

Alroe J

Shading to reduce solar radiation has shown potential for building temporary resilience to high water temperatures amongst coral communities. A leading technological innovation currently on trial within the Reef Restoration and Adaptation Program is the production of low-lying saltwater fog plumes to provide reef-level reduction in solar radiation. To assess viability and assist with deployment planning, models have been developed simulating the spatial coverage and shading effectiveness for a single plume. These modelling efforts suggest that, following a conventional Gaussian dispersion profile and under ideal conditions of low wind speeds and high humidity, the plume should offer up to 30% reduction in solar radiation over an area of approximately 2–3 km^2. A prototype fog plume generator was deployed to the southern Great Barrier Reef in March 2023. Below-plume measurements confirmed that the plume width agreed with the model out to a range of 1 km. The reduction in solar radiation averaged approximately 12–20% at 400 m from the ship and reached as high as 49% on one occasion. Further refinement of models and fog spraying technique are expected to yield closer agreement, however the trial clearly highlights the potential of this technique and has provided valuable insight for future development.

Joel Alroe
Queensland University of Technology
j.alroe@qut.edu.au

Variation in coral thermal tolerance during a mild bleaching event: the role of holobiont taxa, colony sizes, and local environmental conditions

Alvarez-Noriega M, Becker M, Fabricius K, Gordon S, Lechene M, Remmers T, Toor M, Ferrari R

Thermal stress threatens coral communities by disturbing the relationship between the coral host and their symbiotic algae, causing coral bleaching. Here, we used photogrammetry orthomosaics from 26 sites across four reefs in the central Great Barrier Reef collected during a mild bleaching event in 2022, to investigate how coral responses to thermal stress vary depending on factors such as their taxonomic identity, colony size, and local environmental conditions. Our results show that bleaching severity differed among taxa, with *Seriatopora hystrix* being the most severely affected taxon, while massive *Porites* was the least affected taxon, followed closely by tabular *Acropora*. We also found size-dependent differences in responses, with some taxa decreasing in bleaching susceptibility with colony size (e.g., corymbose *Acropora* and encrusting *Montipora* species), others increasing (e.g., tabular *Acropora*, *Goniastrea* sp., and *Platygyra* sp.), and others showing no size-dependence (e.g., *Lobophyllia* sp. and *Pocillopora verrucosa*). Similarly, the effect of depth on bleaching severity varied across taxa. Sites with faster water velocity tended to bleach less in inshore reefs, but not in offshore reefs. These findings can help optimise restoration interventions by identifying taxon-specific environmental conditions that might maximise the persistence of outplanted corals with enhanced heat tolerance in a warming climate.

Mariana Alvarez-Noriega
Australian Institute of Marine Science
m.alvareznoriega@aims.gov.au

An integrated approach to modelling and decision support for coral reefs in the Anthropocene

Iwanaga T, Adam AAS, Ani C, Baird M, Baker P, Bowen J, Bozec Y-M, Condie S, Cresswell AK, Crocker R, Haller-Bull V

The RRAP Modelling and Decision Support (M&DS) sub-program aims to provide credible and timely projections of reef futures and management advice for the Great Barrier Reef. The M&DS group are developing a suite of capabilities with a unique synthesis of environmental, ecological, and economic models alongside decision support tools, supported by an information system. Decision-making processes are then supported through the requisite blend of ecological models and dashboards that translate ecological information into a form accessible to partners and stakeholders. Here, we present a broad overview of current M&DS capabilities under development and ongoing activities to support the objectives of the sub-program. These include the development and integration of hydrodynamic and particle tracking models, climate change trajectories, spatial mapping layers, a suite of ecological models, advanced decision support capabilities, and engagement tools to facilitate communication. An open-source data management and provenance tracking system is adopted to ensure integrity and transparency of the underpinning data and information flow.

Ken Anthony
Australian Institute of Marine Science
k.anthony@aims.gov.au

Reef-Risk: A decision support tool for identifying vulnerable and resilient areas in the Great Barrier Reef

Astorga-Moar A, Deng W, Liu D, Kenyon T, Wuppukondur A, Harris D, Callaghan D, Baldock T

Reef-Risk is a new decision support tool developed as part of the Reef Restoration and Adaptation Program (RRAP) for the Great Barrier Reef (GBR). The tool utilises reef habitat maps and a twenty year hindcast wave climate to identify the regions of the GBR that are most vulnerable to coral breakage under typical storm wave conditions. Applying a deterministic (design) approach based on linear wave theory for bottom wave velocity calculations, Reef-Risk assesses the likelihood of reef breakage and coral rubble movement across diverse wave conditions. The analysis incorporates typical scenarios, maximum wave heights, and different return periods. This tool evaluates the impact on reefs hosting large or medium-sized coral colonies, incorporating the overall coral health (bio-erosion %) on the desired reef patch. The primary objective is to develop an end-user tool with a user-friendly graphical interface to identify both resilient and vulnerable areas within the GBR. Reef-Risk is a new asset for ongoing monitoring and management initiatives, providing important insights for strategic decision-making during coral reef restoration projects to ensure the long-term health and sustainability of the Great Barrier Reef.

Alejandro Astorga-Moar
The University of Queensland
a.astorgamoar@uq.edu.au

Developing genuine partnerships with Reef Traditional Owners: Crown-of-Thorns Starfish (COTS) research and management in the Great Barrier Reef (CCIP-R-09)

Backhaus V, Lockie S, Watkin Lui F, Dynevor T, MacleanK, Mann M, Shipton M

Traditional Owners have long understood the need to participate, contribute and share for the wellbeing and health of the Reef. The Heart of the Reef, Healing Country Statement (2021) states that 'The Reef is Country [...] She is our Family. The Reef is an extension of Us, and we are an extension of Her.' Yet there remains limited understanding of how to develop meaningful partnerships for management and research between Reef Traditional Owners and Reef managers. This presentation will share key findings of research conducted through the Crown-of-Thorns Control and Innovation Program in support of Reef Traditional Owner aspirations to exercise leadership in COTS monitoring and management. Research encompassed regional workshops and interviews with Traditional Owner partners interested in codesigning and developing local responses to COTS activities occurring across Sea Country. Through participatory methods of relationship building and connections between research and community priority and needs, core principles and activities were developed to contribute to the overall aims of the project. Case study material also contributed and, with permission of Traditional Owners, will be presented citing the long-term benefits of maintaining relationships between research and community.

Vincent Backhaus
James Cook University
vincent.backhaus@jcu.edu.au

Application of new technologies to coral reef monitoring and COTS detection

Armin A, Bainbridge S, Bonin M, Coleman G, Do B, Harvey D, Hayder Z, Lawrence E, Marsh B, Page G

A fundamental component in understanding the status and fate of reefs is the ability to effectively monitor them. Current methods, developed in the 1980's, are constrained by the ability of humans to collect and process data. Advances in technology, especially in Machine Learning and robotics, have open new approaches for scaling and improving monitoring. Under the COTS Control Innovation Program, funded under the Reef Trust Partnership, a new towed imaging platform has been developed that includes real-time Machine Learning identification of COTS and scars along with assessment of benthic cover. The system implements thruster-controlled depth and altitude hold to support operation in complex reef habitats, along with user interfaces and workflows to process and interpret imagery in remote operating environments. The goal is to mature the platform so that for most environments it is self-driving. The system delivers a step-change in starfish detection by delivering real-time in-field actional information. This allows for new operational logistics based on real time data on COTS and coral. Driven by a well-defined use case and developed through active engagement with the GBR COTS Control Teams, the system delivers an end-to-end solution for reef monitoring and provides a pathway for the adoption of new technologies.

Zeeshan Hayder
CSIRO
zeeshan.hayder@csiro.au

Changing paradigms in the restoration of Florida's reefs: Novel interventions, transnational obstacles, and the urgent need to share genetic resources to maximize coral survival

Baker AC

Coral reefs worldwide face an existential threat from climate change, whose effects will be most obvious during sporadic periods of prolonged high temperature stress, resulting in catastrophic episodes of bleaching and mortality. In Florida, the summer heatwave of 2023 exemplified the sudden nature of these events and highlighted the need for a comprehensive long-term strategic plan to explicitly manage for warming temperatures and progressively worse heatwaves. Such plans must include the development, testing, and implementation of novel approaches that are outside of historical practice and current regulatory frameworks. One such approach involves sourcing corals (and/or holobiont partners) from warmer sites in different national management jurisdictions across a species range, and introducing this genetic diversity to cooler sites via translocation and/or breeding. Such 'assisted gene flow' approaches have the dual value of allowing heat-tolerant corals to be used to build climate resilience in cooler areas, while also rescuing them from their current warm locations where they remain under threat from even more stressful conditions. In Florida and the wider Caribbean, opportunities exist to begin these efforts among 'nearest neighbours', but are challenged by existing regulatory frameworks, diverse stakeholder interests, and funding constraints. Ironically, the 2023 marine heatwave provided an opportunity to overcome some of these obstacles as the need to preserve genetic stock became apparent. However, much more rapid progress is needed, not only to facilitate the (relatively conservative) objective of sharing limited genetic resources to help buy time, but to also build the needed constituency for more aggressive interventions that may become needed in the coming years.

Andrew Baker
University of Miami
abaker@miami.edu

Intervention Risk Review: A commitment to independence and quality assurance

Barrell S

The RRAP Intervention Risk Review Group (IRRG) was established to provide independent guidance and advice on the assessment and management of risk associated with interventions being developed under RRAP. Mindful that risk assessment in the reef and climate change contexts necessarily embraces environmental, economic, social, cultural, and regulatory dimensions, the membership of IRRG is diverse, spanning subject-matter expertise and expertise in quality assurance, risk assessment, expert elicitation, and decision analysis. The RRAP and IRRG operate an interlinked process but with well-defined respective roles. IRRG engages with RRAP at key staging points to understand and query the RRAP risk and outcome assessment processes. While its near real-time advice may improve RRAP deployment proposals, the key attributes that span IRRG's work and its way of working are strict commitment to its independence and acknowledgment that its key role is framed around quality assurance. Ultimately, from a regulatory decision-making perspective, these attributes are critical to IRRG's credibility and value add. This presentation outlines the approach that the IRRG is adopting to meet its assigned responsibilities, and the principles it has embraced in developing and conducting its work, especially in its interactions with RRAP itself and in the communication of its findings and advice.

Sue Barrell AO
Reef Restoration and Adaptation Program
sue.barrell@barrellacumen.com

A social license to operate theory for existing and novel Reef interventions on the Great Barrier Reef

Bartelet H, Lockie S, Paxton G, Brooksbank L, Ritchie B, Sie L, Demeter C, Backhaus V

The limited knowledge we have about public perceptions of restorative and resilience-building action is a potential bottleneck for existing and emerging Reef management and restoration programs. In other sectors, novel approaches and technologies like carbon capture, windmills and genetically modified foods have encountered resistance from the public, affecting their deployment. To address this gap, we draw on in-depth interviews with 140 GBR community members and over 8,000 surveys with GBR residents and the Australian public to develop a better understanding of the social license for existing (COTS culling) and novel (adaptive, protective, and restorative) Reef interventions. We developed a grounded theory of the primary determinants of social license for COTS culling on the GBR, which can be helpful for environmental managers to identify potential ways to increase social license for Reef management programs. We cross-verified our grounded theory through survey data, which highlighted that the perceived ethical dimensions of culling, the manageability of culling risks, and trust in scientific knowledge and solutions were the primary determinants of social license. Although these findings are not directly generalisable to all Reef management scenarios, they suggest important considerations for policymakers and managers in the GBR and elsewhere.

Henry Bartelet
James Cook University
henry.bartelet@jcu.edu.au

Blueprint 2030: Managing the Great Barrier Reef under a rapidly changing climate

Beeden RJ, Flechett J, Nucifora F, Quincey R, Thomas J, and Walker I

The Great Barrier Reef is among the most well-known and loved world heritage areas. Like all of the world's coral reef ecosystems the future of the Great Barrier Reef is increasingly being influenced by climate change pressures. Established in 1975 and inscribed as a world heritage area in 1981, the Great Barrier Reef Marine Park is managed to protect the Reef for future generations. To achieve this goal Reef managers are increasingly looking to new interventions to amplify long-term actions such as marine park zoning compliance and water quality improvement identified in the joint Australian and Queensland Government Reef 2050 Plan. The Reef Authority's Blueprint 2030 identifies the key climate resilience and adaptation goals that are required to improve the Reef's future. Blueprint 2030 is based on our understanding of climate and other risks to the ecological, social, economic and cultural values of the Reef, that are evaluated in the five yearly Outlook reports. The intention of Blueprint 2030 is to empower and focus all of the Reef's constituents on the key actions that can be taken at local, regional, national and global scales. This plenary presentation will summarise the journey to Blueprint 2030 and how it can help guide actions to protect this iconic place for the benefit of all as the climate changes.

Roger Beeden
Reef Authority
roger.beeden@gbrmpa.gov.au

Restoration at scale – legal barriers and enablers

Bell-James J

Target 2 of the Kunming-Montreal Global Biodiversity Framework (GBF) calls for 30% of degraded ecosystems to be under effective restoration by 2030. If this obligation is interpreted in the spirit of the GBF, it demands rapid upscaling of restoration efforts across the globe. However achieving this rapid upscaling in the marine and coastal context will be challenging unless significant effort is made to dismantle the key obstacles to restoration. In a 2022 survey of Australian restoration practitioners and regulators, funding and legal frameworks were identified as the two main barriers to upscaling marine and coastal restoration (Saunders et al). This presentation will unpack the legal barriers to marine and coastal restoration, and highlight some enablers, solutions, and paths towards marine and coastal restoration at scale.

Justine Bell-James
University of Queensland
j.bell-james@law.uq.edu.au

Co-development of coral enhancement technology utilising regional practitioner networks

Bickel A, Miller M, Petersen D

Over the last 5 years, SECORE has built a comprehensive capacity building program and network of implementers running larval enhancement operations in the Caribbean; the network currently consists of organisations from 10 countries. As it has matured, we have increasingly seen the benefits of it to our biological research and technology development programs. The diversity of local reef and application contexts, and the variety of enhancement goals between the partners have been key to developing more successful design constraints, identifying bottlenecks, and understanding the best practices for translating effective technologies from one location to another. Single solutions to specific steps in the larval propagation process that work universally are rare, and SECORE has adopted a 'toolbox' approach to technology development aimed at creating a suite of options that can be adapted to suit the needs of a given location. Our focus has been on creating tools that work in low-infrastructure scenarios. These technologies include in situ rearing tools, mass collection devices, and a suite of settlement substrates tailored to multiple reef and outplanting scenarios. The network has enabled faster iteration on prototype technologies and the ability to quickly collect feedback in various implementation contexts.

Aric Bickel
SECORE International
a.bickel@secore.org

Does reef-scale modelling validate implementation of current coral-COTS management?

Rogers JGD, Plaganyi-Lloyd E, Blamey LK, Desbiens AA

We used an ecosystem model specifically designed to inform Crown-of-Thorn Starfish (COTS) management to investigate COTS culling strategies and to compare current with historical performance. Modelling different culling threshold implementations identified a dynamic we defined as an Effort Sink – a location that consumes more resources than expected which detracts from control capacity for other locations reducing overall outcomes. At a location, Effort Sinks emerged from low COTS culling thresholds, limited coral cover, and resurgent COTS dynamics. Modelling current thresholds defined to limit COTS impacts were found to balance coral protection with being able to control enough locations. Varying coral growth did not alter culling thresholds. Contemporary site selection approaches (which consider coral and COTS) substantially outperformed historical approaches that focused on high COTS densities. Our modelling indicates implementation of current COTS thresholds have improved since the last COTS outbreak and are fit for purpose if trying to limit COTS-coral impacts. Using COTS control to directly improve coral cover at all prioritised reefs is likely to require increased control capability. These findings are feeding into the current control program, helping to inform broader strategic modelling efforts. Moreover, our model framework allows incorporation of new data as they become available.

Laura Blamey
CSIRO
laura.blamey@csiro.au

Collaborative research and management drives innovation in COTS control on the Great Barrier Reef

Bonin MC, Williamson DH

Building on decades of scientific data, field intelligence and operational experience, the Crown-of-thorns starfish (COTS) Control Program has progressively developed and expanded into a core management action to protect coral and support the resilience of the Great Barrier Reef. It is the largest scale intervention program on the Reef, targeting approximately 200 reefs and protecting hundreds of hectares of reef habitat from COTS predation each year. The Program's evolution and effectiveness hinge on the strength of the research and industry partnerships that continue to drive innovation and inform strategic planning and tactical deployment of control effort. Here we provide an overview of the history, operations and outcomes of the Program, highlighting the importance of collaborative multi-disciplinary research that underpins our ability to predict, detect and respond to COTS outbreaks. Recent outputs from the COTS Control Innovation Program (CCIP) are delivering critical insights and demonstrating the value of research that is co-developed and co-delivered in partnership with management agencies. Our innovation comes not only from the scientific discoveries and capabilities developed, but also in the way that we work together to deliver research that directly informs management decisions and on-water actions. Proactive engagement and genuine collaboration can empower targeted research to deliver useful, deployable innovations that ultimately improve operational delivery and amplify conservation outcomes. We reflect on key lessons learnt and emerging opportunities for the future.

Mary Bonin and David Williamson
Great Barrier Reef Foundation and Reef Authority
mbonin@barrierreef.org

Empowering local scale stewardship actions by Great Barrier Reef tourism operators

Bovery-Spencer J

The Great Barrier Reef marine tourism industry is a fleet of over 350 vessels that traverse the entire 2300 km length of the Great Barrier Reef Marine Park. The operators that comprise this fleet visit hundreds of individual reefs, often returning to the same reefs and sites each day. These tourism operators have long played a role in the monitoring and protection of the Great Barrier Reef in partnership with the Great Barrier Reef Marine Park Authority. They act as the most frequent source of information on reef health and provide an early-warning system when threats to the reef arise. In 2020 the global pandemic grounded this fleet with no certain date of return to business. A government initiative to aid tourism operators in resuming monitoring and local scale stewardship actions resulted in not only a recovery, but an unprecedented increase in these actions. Spurned by this success, the Tourism Reef Protection Initiative now contracts tourism operators to conduct stewardship actions at high-value reef sites. Record survey efforts are contributing to management and targeted interventions are creating a network of highly resilient sites across the entire Marine Park. This initiative now empowers local-scale stewardship actions on a large scale.

Justin Bovery-Spencer
Reef Authority
justin.bovery-spencer@gbrmpa.gov.au

Reefs of Hope: A Nature-Based Coral-focused Climate Change Adaptation Program Endorsed by UNESCO

Bowden-Kerby A

Reefs of Hope is the first coral-focused adaptation program endorsed by UNESCO. Innovative strategies modelled on tropical forest restoration are used, rebooting natural coral reef recovery on reefs impacted by mass coral bleaching and cyclones. Corals used for the work are heat adapted, facilitating the adaptation of recovering reefs. The project trains indigenous Pacific Island communities and resorts to work with heat-adapted corals to reinforce fish habitat within MPAs. The goal is to facilitate natural restoration and adaptation processes at scale by rebooting natural coral recovery via patch nucleation and restoring reproduction to vulnerable species. Corals are sourced from unbleached survivors of mass bleaching and from pre-adapted coral populations located in hot nearshore waters, areas where they are jeopardised over the long term by rising temperatures. These bleaching resistant corals are translocated to cooler-water reefs offshore, helping secure their survival into the future, while facilitating adaptation to warming seas through sharing of bleaching-resistant symbionts with incoming coral recruits, increasing the resilience and functionality of MPAs. The intended results are prevention of coral species extinctions and associated fisheries habitat loss, securing resilient coral biodiversity, and prevention of the collapse of coral reef ecosystems that South Pacific cultures so greatly depend on.

Austin Bowden-Kerby
Corals for Conservation
abowdenkerby@gmail.com

Ecological projections of Australia's Great Barrier Reef under an uncertain warming future

Bozec Y-M, Adam A, Arellano-Nava B, Cresswell AK, Haller-Bull V, Iwanaga T, McWhorter JK, Anthony KRN, Halloran PR, Ortiz JC, Riginos C, Mumby PJM

Assessing future management needs and the effectiveness of resilience-based interventions on coral reefs requires baseline ecological projections at relevant spatial scales and for various climate change scenarios. We developed a simulation model of coral ecological-evolutionary dynamics to project the health of ~3,800 individual reefs of Australia's Great Barrier Reef (GBR) under warming. The model simulates the fate of coral colonies of multiple taxa by integrating key demographics, spatially-realistic stressors and mechanisms of genetic adaptation through selection by heat stress. Using bleaching projections from global climate models for different scenarios of carbon emissions, we present a portfolio of possible coral futures under conventional management (control of Crown-of-Thorns Starfish outbreaks) and evaluate the scope for coral adaptation across the GBR. Projections show that the most likely warming future leads to considerable coral loss with limited scope for genetic adaptation by 2100. More ambitious emission targets substantially improve the coral cover outlook, with spatial refugia from disturbances and larval connectivity promoting thermal adaptation locally and across the system. These projections allow us to evaluate the benefits of mitigating carbon emissions on the potential of coral adaptation. They also provide baseline scenarios (counterfactuals) for assessing ecological benefits and risks associated with new management interventions.

Yves-Marie Bozec
The University of Queensland
y.bozec@uq.edu.au

Potential applications for the combination of Bathymetric LiDAR and Hyperspectral Imagery in mapping Marine Cloud Brightening/Fogging Plumes in coral reef systems

Butcherine P, Medcraft C, Harrison D

Coral reefs globally are under significant pressure from environmental stressors, including climate change. Bleaching events are becoming more frequent as mean water temperatures increase. Solar radiation management techniques, such as marine cloud brightening or seawater fogging, could help reduce excessive light reaching coral reefs and mitigate some bleaching risks. However, it is still being determined how the 3D structure of artificially generated aerosols is distributed over reef systems. Here, we show that airborne remote sensing data, such as high-resolution LiDAR and hyperspectral imaging, can map the 3D structure of aerosol plumes and assess coral reef composition. Understanding the development of and spectral composition of generated plumes can help deliver more efficient reef coverage and enhance the effectiveness of solar radiation management interventions.

Peter Butcherine
Southern Cross University
peter.butcherine@scu.edu.au

Juvenile waiting stage Crown-of-Thorns sea stars are resilient in heatwave conditions that bleach and kill corals and their response to chemosensory cues

Byrne M, Clements M, Webb M, Selvakumaraswamy P

The accumulation of juvenile Crown-of-Thorns sea stars (COTS) in the reef infrastructure is an under-appreciated source of outbreaks. Their vulnerability to environmental stress may be amplified by climate change-ocean warming. We investigate the thermal tolerance of juvenile COTS in context with the degree heating weeks (DHW) model of coral bleaching. They had 100% survival in conditions that trigger bleaching (4 DHW), result in coral mass mortality (8 DHW) and beyond (12 DHW). Juveniles are far more resistant to heatwaves than the coral prey of adult COTS. In a warming world, juveniles in their crustose coralline algae (CCA)-coral rubble nursery may benefit from an increase in this habitat due to coral mortality. The behaviour underlying the shift from herbivory is not understood. We exposed juveniles to cues from CCA-rubble habitat, live coral and adult COTS to determine if waterborne cues influence decision making. When exposed to CCA-rubble and live coral (single cues), the juveniles moved to these cues and when presented in combination they moved to coral. However, when exposed to cues from adults they moved away. Exposure to food cues (live coral, CCA) in the presence of adult cues resulted in variable responses. This indicate the presence of negative density dependant feedback mediated by semiochemicals, whereby cues from adults may deter juveniles from switch to corallivory. As outbreaks wane, juveniles released from adult competition may serve as a source of outbreaks, supporting the juveniles in waiting hypothesis.

Maria Byrne
University of Sydney
maria.byrne@sydney.edu.au

Financing marine protected areas

Cabral R, Costa A

Marine Protected Areas (MPAs) are well known for their ecological benefits and for helping to replenish local fisheries. Sustainable financing is a key factor – and has been a limitation – in ensuring the success of MPAs. Here, we explore the potential of well-designed access fees for marine tourism in MPAs as a tool for generating revenue to fund MPAs and marine conservation. We test the idea using the scuba dive tourism industry and present two interrelated studies: 1) Synthesizing data from existing willingness to pay studies and using a global diver database, we map the global extent of scuba diving tourism, its current economic value, and estimate the potential economic benefits from scuba diving tourism if the protection status of all current dive sites are upgraded; 2) We conducted a willingness-to-pay survey in the Great Barrier Reef to quantify the amount of use fee recreational scuba divers are willing to pay for various biological and management attributes and better understand the drivers of this willingness to pay. Finally, we present our ongoing research effort to fill the gap in science and application of sustainable financing of MPAs and marine conservation.

Reniel Cabral
James Cook University
reniel.cabral@jcu.edu.au

Highly resolved estimates of feeding rates for Crown-of-Thorns Starfish inform ecological projections and management decisions on the Great Barrier Reef

Chandler JF, Figueira WF, Doll PC, Burn D, Caballes CF, Johandes A, Pratchett MS

Voracious feeding by elevated densities of Crown-of-Thorns Starfish (COTS; *Acanthaster* cf. *solaris*) continue to cause substantial coral loss on the Great Barrier Reef (GBR) with knock-on effects to both marine life and human livelihoods. Without a deep understanding of this feeding behaviour and its drivers, it is not possible to reliably predict COTS' impact on coral communities or establish meaningful ecological thresholds, which hinders the most effective management of outbreaks. In this study we used technological advances to produce highly resolved estimates of daily feeding and compared the feeding behaviour from over 1,500 individuals across 5 regions of the GBR. This large-scale study showed that COTS were consuming an average of 243 cm^2 of coral per day (± SE 12.17), however feeding rates were strongly driven by body size (~55% higher feeding rates for COTS >40 cm) and season (~30% lower feeding rates in winter). There was found to be little variation in feeding rates with respect to regional differences in COTS densities or the availability of different coral prey. This data, coupled with our improved understanding of population dynamics through the course of an outbreak, will enable improved ecological projections of COTS impact on coral communities and ultimately inform prioritisation processes required for management decisions on the GBR.

Josie Chandler
James Cook University
josie.chandler@my.jcu.edu.au

Spawning School: Fostering connection and capacity between Traditional Custodians and western science

Chartrand K, Cameron K, Scott A, Cameron G, Cameron J, Gunggandji-Mandingalbay Yidinji Land & Sea Rangers, Yirrganydji Land & Sea Rangers

The Cairns-Port Douglas Reef Hub seeks to deepen First Nations engagement through shared learning, knowledge exchange, and practical actions. This includes providing opportunities for communities to strengthen connections with their sea Country, through capacity-building and applied training in employable skills that support reef recovery. In late 2023, the CPD Reef Hub delivered the first Spawning School, a Traditional Owner-focused training and learning program on aquarium-based coral spawn collection and coral larvae aquaculture, to acquire skills in culturing large quantities of coral larvae for assisted reef recovery. First Nations Rangers and community members from the Cairns-Port Douglas region attended spawning nights and subsequent days for hands-on experience with the practical methods for raising coral larvae, building connection with this ancient process. A community day, co-led by Rangers, gave a multi-generational focus for shared learning about coral reproduction and the potential to harness spawning events for reef stewardship. Spawning School was held in a local, land-based facility, supporting connection for Elders and community members with limited access to the Reef. The knowledge and practical skillsets gained through Spawning School by each Ranger group align with needs for RRAP scaling-up future activities and provides the building blocks for First Nations-driven reef restoration projects.

Katie Chartrand
James Cook University
katie.chartrand@jcu.edu.au

Engineering the Future: Pioneering Marine Cloud Brightening Atomizer System – Concept to Regional Deployment for cooling and shading the reefs

Chen C, Harrison DP, Harrison L, Medcraft C, Holloway C, MacLennan S, Allum S

Marine Cloud Brightening (MCB) stands as a transformative technology, enhancing the albedo and resilience of maritime stratocumulus clouds to counter global warming and potentially reduce coral bleaching. This study emphasizes the efficacy of the effervescent spray method, introducing a ground-breaking MCB seawater atomizing sprayer system with 640 nozzles in the Great Barrier Reef Marine Park. This achievement resulted in an unprecedented droplet production rate exceeding 8.28×10^{14} per second, marking a pioneering engineering leap in cloud manipulation. The paper details significant engineering feats in system development and vessel deployment, evaluating crucial parameters such as mass flow rates, pressures, gas-to-liquid mass ratio, droplet production rate, and particle size distribution. The achieved particle size distribution, with a geometric mean of 49.53 nm and a GSD of 2.17, aligns with the recommended effective particle size for MCB. This underscores a comprehensive understanding of MCB's engineering parameters, affirming the practical viability of the effervescent atomizer in adeptly generating sea salt aerosols from seawater for MCB applications. Addressing a research gap, real-time energy consumption analysis exposes fluctuations linked to compressor operation. The Particle Production Efficiency Index (PPEI) introduces an innovative metric for assessing particle production efficiency per unit of power. Beyond advancing MCB engineering, this work establishes a robust foundation for future large-scale systems, significantly influencing climate intervention strategies.

Cheng Chen
Sydney Institute of Marine Science
cheng.chen@sims.org.au

From Data to Decisions – a winding road

Chong Seng K, Groves P, Webster E, Wilmes J

Decision-making across the Reef Authority benefits from an understanding of 'situational awareness', which relies on observational data and scientific models. These data and models can be overwhelming for managers in their raw form. To resolve this, the Reef Authority is developing tools to help streamline and synthesise data and models to support decision making. The aim is to future proof and flexibly adapt to changing scientific knowledge without too much expenditure. One such tool is the 'Resilient Reefs Network', which focuses on environmental disturbance data on coral reefs. A key objective of the tool is to help prioritise reefs or areas that may need more or less protection based on their environmental situation. To achieve this, it harnesses environmental pressure data (e.g. cyclones and thermal stress) from both observations and model outputs, combining them in a dashboard to enable reef-level detail, as well as broader summaries. An index can be calculated to help with prioritisation but requires the contextual, underpinning data to be transparent for decision-making. To reach its greater potential, it will be important for researchers and developers to engage with managers along the way, enabling the tool to be trusted, understood and used.

Karen Chong-Seng
Reef Authority
karen.chong-seng@gbrmpa.gov.au

Predicting COTS dispersal in the GBR

Choukroun S, Bode M, Stewart O, Mason L, Langlais C

The spread of Crown of Thorns starfish outbreaks on the Great Barrier Reef are driven by the dispersal of COTS larvae on ocean currents. These outbreaks involve rapid exponential population increase; on which early disruption is vastly more efficient than later actions. Understanding, measuring, and predicting how and where larvae move is therefore vital to both understanding COTS outbreak dispersal on the GBR, and controlling those outbreaks effectively and efficiently. However, modelling COTS larval dispersal is extremely challenging: knowledge of their biology and behaviour remains scarce and reef scale flow within the GBR lagoon is complex to model. This project has involved COTS larvae biologists, monitoring teams, biophysical modellers and stakeholders in the design phase. It has produced three key results and insights: 1) integrate up to date COTS larval biology into dispersal modelling and comparison to monitoring 2) identify that small differences in hydrodynamic modelling assumptions have stark effects on the resulting dispersal patterns; and 3) Increase usability and impact of the larval dispersal output for decision-making processes and GBR-scale COTS population models. Project outputs have been directly integrated into reef prioritisation decision-making for the on-water control program, used to answer ecological questions, and provided valuable parameterisation of GBR-scale COTS community population models.

Severine Choukroun
James Cook University
severine.choukroun@jcu.edu.au

Modelling the influence of fishing and conservation zoning on the Great Barrier Reef ecosystem

Condie SA, Barneche D, Ceccarelli D, Currey-Randall L, Porobic J

The Great Barrier Reef (GBR) is primarily managed through a zoning system that regulates where fishing is permitted. Zoning influences not only fish populations, but also the broader reef ecosystem through trophic cascades. Importantly, fish targeted by commercial and recreational fishers include predators of the Crown-of-Thorns Starfish (COTS, Acanthaster spp.), which can reproduce rapidly to form outbreaks capable of decimating coral populations. This has led to concerns that fishing pressure may increase the susceptibility of some reefs to destructive COTS outbreaks. We describe progress in modelling the effect of zoning on the GBR ecosystem using the Coral Community Network model (CoCoNet). This model represents food web interactions between fish, corals and COTS on reefs exposed to increasing cumulative pressures from tropical cyclones, marine heatwaves and COTS outbreaks. It also includes the influence of human activities, such as commercial and recreational fishing, as well as control of COTS. Ensemble simulations suggest that commercial fleet reductions and comprehensive zoning (fishing excluded from one third of reefs) introduced in 2004 significantly benefited reef health, and now potentially works synergistically with CoTS control. While current results are exploratory, the ultimate purpose of the model is to help integrate empirical data in a way that supports sustainable management of the Reef.

Scott Condie
CSIRO
scott.condie@csiro.au

Lessons learnt implementing mineral accretion and coral gardening at Agincourt Reef, Great Barrier Reef

Cook N, Cook K, Harris K, Songcuan A, Smith A

The health and diversity of coral reefs are vital for marine tourism but are heavily impacted by climate change and cyclones. In 2018, as part of the Australian Government's Reef Restoration and Adaptation Program, a trial investigated mineral accretion and coral gardening to enhance recovery on the Great Barrier Reef. We installed six artificial reef substrates where seven species of coral were transplanted. Mineral accretion through electrolysis had no positive impact on transplanted coral. After 13 months, a second transplant was done, discontinuing electrolysis. Over four years, live coral cover significantly increased at treatment locations, from 1.7% to 80.8%, and 0% to 75.8%, while control locations increased insignificantly from 5% to 14.2%. Mineral accretion technology proved challenging and ineffective for transplant growth but might find use in creating solid substrates. Artificial substrates, combined with coral gardening, demonstrated effectiveness in hard coral recovery.

Kailash Cook
The University of Queensland
kailashecocook@gmail.com

Synthetic data for exploring resilient reef futures

Crocker R, Robson B, Iwanaga I, Ani C, Anthony K

Synthetic data mimics the statistical properties of real-world datasets while removing reference to sensitive or confidential information in the original dataset (Quintana 2020). Synthetic data is often used for model testing and development, or where insufficient data is available for model training (Raghunathan 2021). In the context of reef modelling, synthetic data can be used to support model analyses that can be published without referring to specific sites, reefs, or study areas. Synthetic data also facilitates investigation of case studies not represented in observed data for model testing, validation and exploration. This talk will showcase a synthetic data pipeline developed for the ADRIA decision-support system (Adaptive Dynamic Reef Intervention Algorithms; ADRIA Synthetic Data Repository). The data's utility in model testing, method validation and exploring scenarios not represented in observational data is demonstrated. This talk will discuss how synthetic data can be produced from readily accessible Python packages and customised to explore key questions about the possible futures represented by reef models. The discussion will be illustrated with the example of creating a synthetic data set to support site selection for interventions to support reef resilience.

Rose Crocker
Australian Institute of Marine Science
r.crocker@aims.gov.au

Online Training to Support Resilience-based Management of Coral Reefs

Cros A, Maize K, Armstrong A

In 2023, the Reef Resilience Network (RRN) collaborated with the Resilient Reefs Initiative (RRI), to develop an online training on resilience-based management for reef managers and conservation practitioners. RRN is a learning community hosted by The Nature Conservancy. It has been a global leader for 18 years, empowering coral reef managers and practitioners to effectively manage, protect, and restore coral reefs and marine protected areas worldwide. During this session, we will outline the key structure of the free, self-paced online training, and provide our definition of resilience-based management (RBM) along with its three dimensions, ecological, social, and governance. We will highlight successes and challenges in applying the RBM process at various RRI and UNESCO reef sites, including Belize, Western Australia, and New Caledonia. Additionally, we will discuss key themes and address the most common questions raised by participants who have completed the course and attended different training sessions. We will also explore the next steps for tackling these questions and helping managers implement RBM.

Annick Cros
The Nature Conservancy
annick.cros@tnc.org

Collaborative monitoring for assisted coral recovery: opportunities and potential benefits for large scale deployments and lessons from a pilot study at Moore Reef

Curnock M, Scott A, Loder J, Forster R, Chartrand K, Fisher E, Donnelly R, Kish H, Murgha B, Taylor B

To achieve coral reef restoration goals at large scales, there is a need to engage and work with diverse groups of stakeholders and Traditional Owners, to build understanding, partnerships, capacity, and opportunities for new enterprises. Collaborative monitoring, with local partners and scientists working together in the evaluation of assisted coral recovery deployments, offers one pathway to further these goals, but how do such arrangements work in practice? In this presentation, we outline the design features and lessons learnt from a pilot program at Moore Reef, which brought together Traditional Owners, local tourism operators, restoration practitioners and RRAP scientists to observe, monitor and evaluate the performance of ceramic coral seeding devices, engineered by AIMS and deployed at six reef sites. The proximity of devices to tourist facilities also enabled us to conduct a survey of Reef visitors, helping to understand public perceptions and concerns about assisted coral recovery devices observed in situ. Outcomes from this study include insights on collaborative monitoring partners' motivations, requirements, and benefits associated with participation, an improved understanding of factors that influence Reef visitors' concerns about assisted coral recovery, and recommendations about the role and enabling conditions for future collaborative monitoring in scaled-up coral reef restoration.

Matt Curnock
CSIRO
matt.curnock@csiro.au

Maximising the utility of cryopreservation as an enabling technology in coral reef recovery and resilience

Daly J, Hobbs R, Severati A, Nordborg M, Bay L, Abdul Wahab M, Zuchowicz N, Hagedorn M, O'Brien JK

The loss of genetic and biodiversity caused by the impacts of ocean warming and acidification can reduce the ability of coral to adapt to the changing climate. Cryopreservation and biobanking can play a crucial role in supporting the large-scale production and deployment of coral recruits for reef recovery programs by facilitating genetic management of populations through selective breeding, reducing the dependence on synchronous spawning, supporting research, and preventing the extinction of coral species. We set out to optimise cryopreservation processing pathways for coral sperm, utilising a semi-automated approach to integrate and streamline existing protocols for fertility potential and concentration assessment, handling, and cryopreservation of coral sperm, as well as tracking of stored samples, including their Sea Countries of origin, in the Taronga CryoDiversity Bank. We also undertook a series of experiments to quantify the use of cryopreserved sperm for the production of *Acropora* coral larvae and spat, and showed that cryopreserved sperm can be used to produce coral recruits at a scale suitable for integration with aquaculture. The methodologies described will be applicable for coral cryopreservation and biobanking on reefs around the world to support the activities of scientists, reef managers, and Traditional Custodians in managing threatened reef ecosystems.

Jonathan Daly
Taronga Conservation Society Australia
jondaly@zoo.nsw.gov.au

The 2003 Zoning Plan – a global benchmark helping to maintain the resilience of the GBR

Day J

Twenty years after its declaration, the 2003 Zoning Plan for the Great Barrier Reef "…continues to pay dividends for the Reef and the industries and communities that the Reef supports", (Reef Blueprint 2030). When applied with other management tools, the GBR zoning plan provides a fundamental foundation for the overall management approach and remains a key tool to sustain the resilience of the GBR ecosystem as well as the dependent communities. The result of a controversial rezoning program between 1998–2004, the successful zoning outcome was primarily determined by four significant factors – a sound scientific basis, the unprecedented level of public engagement, an effective 'lattice of leadership' and the essential levels of political support and commitment. Political support was the most significant determinant for the success of the rezoning process, but all four factors were critical and were interrelated. Nevertheless, many lessons were learnt which should be considered, if and when an update of the 2003 Zoning Plan occurs (as predicted in Action 2.2 of the Reef Blueprint 2030). Considering the likely future challenges facing the GBR, zoning will always remain a key tool to help protect and conserve the values of the GBR Region.

Jon Day
James Cook University
jon.day1@jcu.edu.au

What is rubble anyways? Opportunities and limitations to studying reef rubble substrates via remote sensing

Dodgen T, Bryan S, Kim C, Kenyon T

Global efforts are underway to increase the scale of reef restoration in the face of climate change and other pressures. Areas of reef that have been degraded to rubble are an ongoing challenge to restoration efforts, due to low success of coral outplanting in rubble and to relatively sparse monitoring of rubble beds in general. Recent advances in satellite-derived reef-mapping and in automatic image classification provide a new opportunity for understanding rubble substrates on spatiotemporal scales that were not previously possible. However, descriptions of rubble are variable from study to study and accuracy around identification of rubble in some studies is below 25%. This talk will discuss how rubble is defined for the purposes of regional-scale mapping, which is distinct from the way that rubble is commonly described for the purposes of reef restoration at local levels. It will further present how improving automatic image classification for rubble substrates could help improve holistic reef management, which will be essential as we progress towards larger scale reef interventions in the future.

Tanya Dodgen
Queensland University of Technology
t.dodgen@hdr.qut.edu.au

Predation rates on Crown-of-Thorns Starfish relative to fisheries management zones

Doll P, Pratchett M, Ling S, Tebbett S, Hoey A

The removal of predators (through overfishing) is one of the foremost hypotheses to explain the destructive population outbreaks of Crown-of-Thorns Starfish (COTS). The ecological links between marine park zoning, predators and COTS abundance remain largely unresolved but could have major bearing on deciding appropriate management responses for increased reef resilience. We used standardised predation assays to quantify rates of in situ predation on adult COTS at reefs within different fisheries management zones in the central and northern Great Barrier Reef, including reefs where fishing is prohibited ('green' zones), restricted ('yellow' zones) and permitted ('blue' zones). Most of the predation events recorded, using time-lapse photography, could be ascribed to two known predatory fishes, the Spangled Emperor (*Lethrinus nebulosus*) and Starry Puffer (*Arothron stellatus*), with both observed to consume entire large adult COTS in many cases. Importantly, predation rates were threefold higher in 'green' (or no-take) zones compared to 'blue' zones, which corresponded with differences in the local abundance of key predatory fishes. These data represent a critical step to explain and model spatial heterogeneity in COTS abundance and the incidence of outbreaks. Moreover, our results highlight a potential role for fisheries management and zoning in moderating outbreaks and increasing reef resilience.

Peter Doll
James Cook University
peter.doll@jcu.edu.au

Diverse coral larvae production from ocean-based nurseries that cater for warm water and wild weather

Donnelly R, Bee C

The elusive challenge in our collective bid to assist coral reefs adapt to a changing environment is in the achievement of scalability, sustainability, and replicability. This has been the focus of development at Cairns-based Reef Restoration Foundation. How do we create an operational model that is manageable at a community level and achieves maximum output with minimum input? How do we do it with a high degree of species diversity and genetic diversity within species? And how do we speed things up without interfering in nature? The recent marine heatwave in the Caribbean put the global reef restoration effort on notice. It vindicated our thinking and prompted us to change things up. We moved away from outplanting corals to the reef and adopted a spawning hub approach. Success with scale, however, will stem from nursery design modification that retains the existing success factors but adds scope for multiple 'tree' frames on a single anchor line, double the number of 'branches' on each tree, and provides for easy lowering of every tree to sufficient depth for the corals to remain strong in times of thermal stress. Importantly, the move opens opportunity for more strategic collaboration with institutions and other groups.

Ryan Donnelly
Reef Restoration Foundation
ryan@rrf.org.au

A baseline of juvenile coral demographics across environmental gradients of the Great Barrier Reef

Doropoulos C, Alvarez-Noriega M, Fabricius K, Ferrari R, Noonan S, Orr M, Salee K

Demographic rates of juvenile coral communities are a key driver of reef recovery trajectories and often vary across environmental gradients. However, there has been limited assessment of juvenile coral demographic rates across the Great Barrier Reef (GBR). In a 3-year study as part of the RRAP Ecological Intelligence for Reef Restoration Subprogram, we examined juvenile coral demographic rates in five reef clusters spanning 14° of latitude, from inshore to offshore reefs. Annual average temperatures ranged from 24–28° C across latitudes, the Keppel Islands cluster was the most turbid, and the Capricorn Bunkers cluster had the highest chlorophyll a. Early results indicate similar community composition of major groups (*Montipora*, *Acropora*, Pocilloporidae, Merulinidae, and *Porites*) across reef clusters. Coral growth patterns were also consistent across clusters but highest for pocilloporids and acroporids. Coral survival, on the other hand, was generally highest in merulinid and poritid corals but this varied across reef clusters. Growth and survival were both positively correlated with size. These findings establish baseline vital rates of juvenile corals across the GBR's broad environmental range, offering valuable data for simulation models, and aiding the design and testing the effectiveness of interventions trials.

Christopher Doropoulos
CSIRO
christopher.doropoulos@csiro.au

Ecological research and monitoring priorities to underpin coral reef restoration

Fabricius KE, Doropoulos C, Ferrari R, Ortiz JC, Riginos C, Figueira W, Alvarez-Noriega M, Aston E, Gordon S, Hoey A, Lechene M, Noonan S, Mason R, Mumby PJ, Ricardo G, Toor M

Ecological, biological, environmental and genetic research and empirical data are essential for successful and cost-effective reef restoration. Here we outline how RRAP, through its subprogram, 'Ecological Intelligence for Reef Restoration' (EcoRRAP), is addressing major knowledge and data gaps to support future region-specific reef restoration. EcoRRAP established almost 100 Reference Reef sites covering a wide range of reef environments in the Great Barrier Reef and Torres Straits. We show some highlights and examples of the EcoRRAP outcomes to date, and demonstrate how the EcoRRAP research will help optimise restoration decisions, site dependent choices of taxa and restoration types, to maximise ecological success. Using photogrammetry based demographic monitoring, experimentation, and modelling, we obtain unprecedented information on coral vital rates, and the limitations to coral replenishment throughout early coral ontogeny. We address the conundrum of morphologically identical species, macroalgae and corallivory, and inform on ecological adaptation to a changing environment. We inform on unassisted reef recovery times across a wide range of environmental conditions, reveal environmental, taxon and size-dependent differences in bleaching susceptibility, and help parameterise ecosystem and decision support models. Finally we show how the EcoRRAP Reference sites serve to provide counterfactual data, once pilot deployments of corals for reef restoration commence.

Katharina Fabricius
Australian Institute of Marine Science
k.fabricius@aims.gov.au

Finding the right environment for the right taxa to inform restoration

Ferrari R, Aston E, Lechene M, Alvarez-Noriega M, Toor M, Gordon S, Noonan S, Figuera W, Fabricius K

Finding the right environment for specific taxa is crucial for improving restoration success. Different organisms have unique habitat requirements, and the lack of knowledge of how the spatial distribution, size and vital rates of dominant coral taxa relates to the environment, underpins wasted restoration efforts and dollars. The Ecological Intelligence for Reef Restoration and Adaptation (EcoRRAP) program informs future restoration trials through empirical observations across relevant spatial scales. EcoRRAP's Reference Reef sites spans the length of the Great Barrier Reef (GBR) and the Torres Strait, a cross-shelf gradient and varying depths and levels of wave exposure, making this the largest single in situ coral distribution and demographic study to date. We mapped and digitized over 20,000 coral colonies, developed corresponding distribution and statistical models, and produced spatially explicit within reef predictions. In doing so, we gained insight into the biophysical and environmental drivers of vital rates of the most important constituents of Western Pacific tropical reefs. The novel ecological intelligence generated establishes much needed baselines of suitable environments for specific taxa to thrive in, with the potential to save money and boost restoration success, to ensure coral reefs can continue their important contributions to nature and society worldwide.

Renata Ferrari Legorreta
Australian Institute of Marine Science
r.ferrarilegorreta@aims.gov.au

Evolution of local scale site stewardship on the Great Barrier Reef

Fisher EE

Local scale site stewardship has been practiced in the Great Barrier Reef Marine Park by tourism operators for several decades. Early efforts were unidimensional and often reactive to respond to immediate disturbance such as Crown-of-Thorns Starfish outbreaks. Today site stewardship efforts have evolved into a pro-active multi-dimensional approach to combat multiple and accumulative disturbances driven by anthropogenic climate change. I will present several local examples of site stewardship that highlight the critical steps to deliver efforts to assist reef resilience, protect diversity and the people that rely on coral reefs. The principal step is developing a high frequency monitoring program to create an intimate knowledge of multiple reef habitats. Secondly using long-term frequency data to predict trends of disturbance and recovery to decide the appropriate site assisted actions to promote reef resilience. Further examples will include how to build partnerships with the Traditional Custodians of the Great Barrier Reef and combine both Traditional Ecological knowledge with modern science to create a holistic approach to monitoring and site stewardship. Our work will highlight the importance of collaboration in local tourism between multiple stakeholders, which ultimately leads to large scale stewardship and the global conservation of coral reefs.

Eric Fisher
Experience Co
e.fisher@experienceco.com

RRAP Modelling and Decision Support Design report – a plan for design and implementation of decision support

Fitch P, Bowen J, Yu J, Sivapalen M

In 2021 at the commencement of the Reef Restoration and Adaption Modelling and decision support program feasibility phase, a design and roadmap were created. The purpose of these plans was to define the design requirements for M&DS, develop a conceptual framework to support an ensure quality decisions and to guide the implementation as the program set about meeting its objectives. In this talk, the main elements of the design report are presented, including the design principles and explanation of how a continuous improvement maturity assessment process has implemented to support the ongoing implementation. It has been 3 years since the completion of that plan, and we now undertake a critique of the utility of the proposed approaches, assessing how effective they have been in aiding delivery of the RRAP M&DS outcomes, as well as describing some lessons learnt.

Peter Fitch
CSIRO
peter.fitch@csiro.au

A platform approach to decision support for the Crown-of-Thorns Starfish Control Program

Fletcher CS, Waters EK, Chen C, Matthews SA

Crown-Of-Thorns Starfish (COTS) are a major threat to the Great Barrier Reef (GBR). The COTS Control Program removes COTS at key locations to protect coral and support the resilience of the GBR. To run the Program effectively, managers and on-water staff need to regularly make a series of decisions about which reefs to target for control, which sites within those reefs to control first, and when to cease control. They must also identify potential new outbreaks. The COTS Control Innovation Program has supported these decisions through the development of a flexible platform of decision support systems connecting researchers to managers and on-water operators. The platform is underpinned by an information system enabling dataset sharing across the Control Program and multiple research organisations. The information system was leveraged to develop reusable digital workflows to automatically process key data streams, which in turn enabled the empirical analysis of Control Program data to adaptively update key parameters of the Control Program. This system will enable research recommendations to be delivered to managers using Great Barrier Reef Marine Park Authority's internal PowerBI dashboards, and to on-water operators using a custom-built multi-platform app. This platform approach to decision support is enabling flexible connections across collaborators, and the efficient development of diverse and fit-for-purpose decision support.

Cameron Fletcher
CSIRO
cameron.fletcher@csiro.au

A structured approach to prioritising reefs for Crown-of-Thorns Starfish control on the Great Barrier Reef

Fletcher CS, Bode M, Matthews SA, Williamson DH

The Great Barrier Reef provides diverse ecological, cultural and economic values to a wide range of stakeholders. However, these values face multiple threats, including outbreaks of Crown-of-Thorns Starfish (COTS). The COTS Control Program strategically targets reefs with high ecological and economic value to suppress COTS outbreaks and protect coral reefs and the values they provide. However, in any given year, not all reefs are vulnerable to COTS outbreaks, and it is neither necessary nor feasible to protect all locations. As a result, the reefs targeted for control must be prioritised annually. Decisions around which reefs are prioritised are complex and must consider multiple values and stakeholder priorities. These decisions are informed by a range of data and information, and should be made in an inclusive and transparent manner. The Great Barrier Reef Marine Park Authority (the Reef Authority), in collaboration with COTS Control Innovation Program (CCIP) researchers and a range of other partners, have developed and implemented a structured prioritisation process to focus where COTS control actions will be targeted each year. CCIP researchers have developed a Multi-Criteria Decision Analysis framework to provide a structured and objective weighting of multiple values to inform prioritisation. The Reef Authority have leveraged this framework to build a strong culture of partnership with on-water operators in the prioritisation process. Together, these developments provide a foundation to broaden stakeholder participation in the prioritisation process while increasing transparency. A similar approach is likely to be of relevance to other reef interventions.

Cameron Fletcher
CSIRO
cameron.fletcher@csiro.au

From Theory to Application: The current status of scaling up RRAP Interventions

Foote D, Erickson K, Gibbs M

Over the past four years, hundreds of RRAP scientists and engineers have been conducting research as to the most effective interventions for reef restoration across the Great Barrier Reef at a range of costs. These interventions are now mature enough to begin to scale their implementation away from the research and development phase and into at-scale deployment. The RRAP Translation to Deployment (T2D) team has been tasked with scaling up these RRAP interventions through the Pilot Deployments in 2025–2030. To reach the deployment targets, there is a need to partner with outside contractors and industry to implement these interventions. External parties are now being engaged as contractors, partners, or stakeholders, with the nature of involvement varying between groups. The T2D team has commenced Pilot Deployments through engagement with industry via an RRAP Industry Briefing Day and begun building local capability through the Boats4Corals project. This presentation will summarise engagement of external parties to date and provide an overview of near-future plans for scaling of RRAP interventions.

Deborah Foote
Australian Institute of Marine Science
d.foote@aims.gov.au

Governance Challenges and Recommendations for Marine Cloud Brightening

Foster R, Shumway N, Harrison D, Fidelman P

This paper delves into the governance challenges and recommendations associated with Marine Cloud Brightening (MCB), a technology designed to mitigate climate change impacts by increasing the reflectivity of low-lying marine clouds. The findings are based on a systematic review of 27 publications that discuss the governance of MCB and Solar Radiation Modification (SRM), a broader set of technologies encompassing MCB. The study identifies 12 governance challenges and 13 recommendations, categorising them into three main themes: technical, legitimacy, and ethical. The implications of these findings are explored, particularly in relation to the design of effective MCB governance, with a focus on potential small-scale conservation applications like coral bleaching mitigation. The paper also underscores the existing knowledge gaps and potential avenues for future MCB governance research. Overall, it contributes to the burgeoning literature on the governance of innovative technologies aimed at addressing global environmental challenges.

Rose Foster
The University of Queensland
rose.foster@uq.edu.au

Tourism Stewardship on the Great Barrier Reef

Gaskell J, Groves P, Jones C, Merida F

Tourism stewardship efforts are increasingly being implemented at sites on the Great Barrier Reef. As tourism sites on the Great Barrier Reef have such a large geographical spread, operators are relied upon to gain valuable insights into current reef condition through constant visual assessment. This people led, industry driven stewardship conducted by High Standard Tourism Operators promotes reef protection while building resilience intended to combat the impacts of disturbances. With the intention of guiding fit for purpose stewardship actions, the Great Barrier Reef Marine Park Authority is developing a framework that will provide tourism permittees with the appropriate knowledge and monitoring tools to inform actions they implement at their sites. Currently, 26 tourism operators are in the process of developing a Site Stewardship Plan that will contribute to the development of the Framework. The Site Stewardship Plans incorporate a thorough ecological evaluation of the site, integration of knowledge from Eye on the Reef surveys and environmental models to inform site-based stewardship actions demonstrating best practice management. “Tourism Stewardship on the Great Barrier Reef” will provide insight into a broad range of outcomes achieved by tourism operators working towards building site resilience guided by the best available science.

Johnny Gaskell
Reef Authority
johnny.gaskell@gbrmpa.gov.au

Research and tourism partnerships for reef resilience

Gibbs M, Rosser N

A key challenge for reef restoration interventions or initiatives is how to scale up from micro or site-scale projects into regional scale projects. This applies to current and emerging intervention practices such as coral gardening or the deployment of artificial substrate and also those being developed in RRAP. A bottleneck for both current and emerging practices of intervention is on-water infrastructure and appropriately skilled human resources. To this end, the ability to upscale will be dependent upon the development of new approaches that are more labour and infrastructure efficient and have the ability to mobilise non-research provider labour and resources. The tourism sector is an obvious sector to participate in current and future reef restoration projects. Tourism operators have on-water infrastructure, including boats and crews, are already stewards of reefs and in some cases already participating in reef restoration projects. However, this does not automatically mean that every tourism operator will wish to, or have the capacity to, participate in every possible intervention. Based on our learnings from projects such as the Boats4Corals project in the Whitsundays, and international examples, this talk will discuss the essential and desirable conditions for, as well as barriers to, effective tourism industry participation in reef interventions.

Mark Gibbs
AIMS
m.gibbs@aims.gov.au
Nicole Rosser
ZigZag Whitsundays
nicole.a.rosser@gmail.com

Beyond coral cover: An integrative approach to assess and report on the status and trends of coral reefs in the Great Barrier Reef

Gonzalez-Rivero M, Thompson A, Johns K, Ortiz JC, Kim S, Fabricius K, Emslie M, Hoey A, Hoogenboom M, Barrios-Novak K, McClure E, Pandolfi J, Mumby PJ, Murray L, Staples SB

Coral cover is a critical indicator of ecosystem conditions because of the innate property of corals to engineer habitats and promote biodiversity and recovery. However, research has shown that cryptic or invisible loss of resilience through declining water quality, spatial homogenisation, and species loss. This indicates that without considering a wider range of attributes, coral cover may be masking fundamental and long-lasting ecosystem shifts. On the other hand, coral cover is a widely used and simple measure for reporting on the condition of reef habitats, whereas the multi-dimensional assessments are complex. Despite these challenges, the rapid rate of climate change disturbance has elevated the demand for immediate and innovative solutions to manage coral reefs. Therefore, comprehensive monitoring is pivotal for informing and tracking the success of innovative management interventions and requires heuristic, measurable, sensitive, scalable, and interpretable indicators. We present a quantitative framework for analysing essential indicators, setting expected thresholds that acknowledge spatial heterogeneity, and providing interpretative guidance to report on the condition of reef habitats across spatial and temporal scales. The framework outlines an approach to make data, information, and knowledge available in a relevant, integrated form that enables high-level reporting and supports decision-making at various management scales.

Manuel Gonzalez-Rivero
Australian Institute of Marine Science
m.gonzalezrivero@aims.gov.au

Coral reefs in 4D: Using novel technologies to inform and advance restoration

Gordon S, Toor M, Lechene M, Aston E, Remmers-Barry T, Smallhorn-West J, Noonan S, Bray P, Harianto J, Wyatt M, Boutros N, Watkin B, Bainbridge S, Figueira W, Gonzalez Rivero M, Fabricius K, Ferrari R

Ecological information on coral reef state and function is vital to inform effective reef restoration. Recent advances in imaging and AI-integrated technologies now enable a wide range of key reef metrics (e.g. coral cover, vital rates, and 3D habitat complexity) to be reliably measured via semi-automated photogrammetry pipelines. Here we present an overview of the EcoRRAP (Ecological information for Reef Restoration and Adaptation Program) photogrammetry workflow; an end-to-end protocol for monitoring coral reefs to inform on the 'where', 'when', 'how' and 'what/who' of coral reef restoration. We review developments in AI technologies, software, workflows, and online platforms and discuss how they can be applied to extract and share vital ecological data to inform restoration. Furthermore, we discuss the strong potential for these technologies to be applied by a range of users including communities, restoration groups, and researchers. Using case-studies, we provide examples of the diverse data that have been generated through photogrammetry-based pipelines within EcoRRAP and in collaborations and how they strengthen our understanding of reef function and resilience. Lastly, we discuss new technologies currently in development and their potential impacts for advancing coral reef restoration in the future.

Sophie Gordon
Australian Institute of Marine Science
s.gordon@aims.gov.au

Predicting coral spawn slicks and dispersal of coral larvae to inform larval-based restoration interventions

Gouezo M, Roff G, Langlais C, Beardsley J, Andrewartha J, Harrison P, Doropoulos C

Reef-based coral larval restoration involves collecting wild-spawned gametes, rearing them to competent larvae, and delivering them, 'en masse' onto impacted reefs to initiate early coral recovery. Reef-based operations for slick collection and larval delivery are strongly influenced by local wind and current conditions, which are highly dynamic over small spatio-temporal scales. As part of RRAP Moving Corals subprogram, fine-scale biophysical models were created for Lizard Island and Eyrie reefs. The modelling workflow aimed to predict the dispersal of wild spawn slicks from spawning corals and understand the dispersal potential of competent coral larvae when delivered onto reefs without using enclosures. Our simulations aim to improve the decision-making process by: i) maximising collections through determining optimal locations for deploying passive spawn catchers and identifying areas of convergence for active collection of slicks, and ii) amplifying the settlement of larvae on target reefs by identifying the optimal timing and location for larval delivery. Outputs of the dispersal model were used to parameterise a spatial model of larval restoration that quantifies how dispersal and larval behaviour interact to drive coral settlement on reefs, and to improve estimates of the spatial footprint of restoration by providing estimates of larval settlement densities following release.

Marine Gouezo and George Roff
Southern Cross University and CSIRO
marine.gouezo@scu.edu.au

Knowledge for resilient reef management: Reef Integrated Monitoring and Reporting

Schauble C, Cowlishaw M, Dyer M, Sobtzic S, Collier N, Groves P

The Reef Integrated Monitoring and Reporting Program has created a new paradigm for science for reef management. While scientists and reef managers have always collaborated, RIMReP operates on a shared governance model between reef managers and science providers to embed knowledge management architecture into adaptive reef management. This endeavour seeks to shift us from conventional management – in which we assume trends as usual for ecosystems and social systems, to managing under uncertainty, rapid change and radical social and ecological disturbance. As we contend with increasing patchiness of ecosystems and social-economic values we need to move from a knowledge system that concentrates on understanding state to focussing on system change. The RIMReP program to date has taken us partway down the track to having an adaptive operational knowledge system for the reef. We cannot plod in a linear fashion to a final end result. The rate of change for the reef and social systems demands innovation in monitoring and decision making. Do we know yet what next generation monitoring looks like for the reef?

Melissa Lane
Reef Authority
melissa.lane@gbrmpa.gov.au

Bridge building between adaptation research and coral models

Haller-Bull V, Cresswell A, Moore J, Ortiz JC

Models are important tools for predicting reef futures and allowing scenario testing to guide management decisions for coral reefs. As reefs experience repeated coral bleaching events due to climate change, there is potential for natural selection and genetic adaptation to change the thermal tolerance of the population, but this has only recently been considered in predictive models. We have developed C~scape, a mechanistic metacommunity model for corals to include mechanisms for selection and adaptation. However, during the development we experienced many hurdles from the mathematical representation of the adaptation and selection mechanisms to the parameterization of the components, resulting in a large amount of uncertainty around model predictions. Parameterizing selection and adaptation as accurately as possible is essential for predicting reef futures and assessing the potential of different restoration actions. As model predictions are only as good as the inputs provided, we rely on research investigating adaptation in the laboratory and the field to guide model structure and parameterisation. We will present how C~scape utilises past research and the key sources of remaining uncertainty, to build a bridge between the cutting-edge research conducted and how it is utilized within models to enable better collaboration and improved models in the future.

Vanessa Haller-Bull
Australian Institute of Marine Science
v.haller@aims.gov.au

Cooling and shading the Great Barrier Reef

Harrison DP, Abrego D, Alroe J, Baird M, Baker P, Braga R, Khan SB, Butcherine P, Chapman A, Chavez S, Chen C, Cleary M, Cravigan L, Deschaseaux L, Doss A, Eckert C, Ellis S, Eyre B, Fitzgerald S, Galindo S, Harper-Harris J, Harrison L, Haskell J, Henandez D, Hendrickson C, Holloway C, Horchler J, Huang Y, Hunt H, Jackson R, Jones I, Kelaher B, Kourmatzis A, Langlais C, Li Z, McGrath D, Medcraft C, Miljevic B, Mongin M, Pan Z, Pulik G, Reardon E, Richards L, Ristovski Z, Rosenfeld D, Ryan R, Schofield R, Scoble H, Seymour R, Siems S, Sturmberg B, Sun X, Tagliafico A, Virah-Sawmy D, Wang B, Wench C, Woodhouse M, Wu L, Yu D, Zhao W

The RRAP Cooling and Shading Subprogram aims to develop and assess technologies to mitigate bleaching stress on coral reefs by reducing the amount of solar radiation reaching the ocean surface. Modelling has indicated that cooling and shading interventions have potential to benefit the reef either at small scale sites (shading) or over large regions (cooling) providing that they can be successfully deployed at the scales required. Here we outline progress toward; 1) understanding of the pre-existing aerosol-cloud-radiation interactions over the GBR to model the impact of coral bleaching events and the most effective intervention strategy to limit coral bleaching; 2) assessing the benefits and potential risks of cooling and shading interventions to the GBR and surrounding environments; and 3) results from recent proof of concept lab and field testing for these interventions.

Daniel Harrison
Southern Cross University
daniel.harrison@scu.edu.au

Larger scale reef-based slick collection, culturing, and deployment of coral larvae from wild coral spawn slicks for reef restoration

Harrison PL, Doropoulos C, Gouezo M, Roff G, Langley C, Waters C, Carlin G, dela Cruz D, Hardiman L, Thomson DP

Recent years have seen a rapid advance in the research and application of active restoration techniques aimed at re-establishing populations and assemblages of habitat-building reef corals on degraded reefs. Many corals reproduce during synchronous mass spawning events and produce billions of gametes that can accumulate in wild coral spawn slicks that can be utilised for active restoration. Larval-based restoration has the potential to be one of the most scalable solutions for restoring diverse assemblages of corals with high adaptation potential and minimal impacts to remnant populations. Here, we provide a summary of work from the RRAP Moving Corals Subprogram, which aimed to develop methods to routinely produce 10s–100s of millions of genetically diverse coral larvae for scaling reef restoration. Specifically, we developed and tested coral spawn slick collection equipment to maximise the efficiency and operational handling of gametes for mass larval production; mass larval culture methods in situ and ex situ to enhance larval production for deployment; and, increasing the scale of bulk transfer of larvae to the reef using direct and substrate mediated deployment methods onto target reef areas.

Peter Harrison and Christopher Doropoulos
Southern Cross University and CSIRO
peter.harrison@scu.edu.au

Building reef resilience through wetland restoration

Hirschfeld M, Webster J, Rudischhauser F

Wetlands play a central role in building coral reef resilience. Long-term resilience of the Great Barrier Reef to multiple local and global pressures requires a combination of local and global management actions. On a local scale, poor water quality resulting from agricultural runoff is a major threat to coastal ecosystems such as inner and mid-shelf coral reefs and seagrasses. Water pollutants entering the reef catchments primarily originate from agricultural activities, including unsuitable land management practices, excessive fertiliser application, land clearing and modification of riparian and coastal wetlands. Natural, rehabilitated, and constructed wetlands are highly effective in mitigating impacts from poor water quality on coral reefs. Here we present a framework for restoring and constructing coastal wetlands as an economically and environmentally effective counterpart to regulation and voluntary practice change. The framework provides a roadmap for scaling-up restoration initiatives to form an effective and sustainable management solution to improve water quality in reef catchments. Wetland restoration and remediation should be considered an integral part of a long-term multiple-action approach to resilience-based management of our Reef.

Maximilian Hirschfeld
Australian Marine Conservation Society
maxhirschfeld@amcs.org.au

Stakeholder and researcher partnerships to aid and improve coral restoration practices on the Great Barrier Reef

Howlett L, Suggett, DJ, Edmondson J, Mattocks N, Hayward C, Camp EF

Active management methods are needed to facilitate reef recovery following declines in coral cover on reefs worldwide due to local stressors, such as reduced water quality, and global climate change. On the Great Barrier Reef (GBR), the Great Barrier Reef Marine Park Authority (Reef Authority), has supported the integration of coral restoration practices into new site-stewardship and management protocols. Since 2018, localised upscaling of coral restoration practices within the Cairns-Port Douglas region has been achieved through the integration of coral restoration into day-to-day tourism activities, via a world-first collaboration between tourism operators and researchers (Coral Nurture Program; CNP). From 2021, the CNP began collaborations with management agencies, including Queensland Parks and Wildlife Service and Reef Authority, and expanded to aid in site-stewardship at tourism sites in the Whitsundays region. Through these collaborations, >100,249 propagated corals have been out-planted over six years on reef sites from Cape Tribulation to Mackay. Monitoring has demonstrated survival of 41–93% for out-planted fragments, and significant increases in coral cover (up to 10.3%) over two years at some reef sites. Here, we discuss the benefits of collaborations between reef stakeholders in coral propagation and describe the scientific monitoring and support necessary for effective optimisation of these activities.

Lorna Howlett
University of Technology Sydney
lorna.howlett@uts.edu.au

Ecological heuristics for site selection to maximise survivorship and growth of deployed corals

Humanes A, Fabricius K, Ferrari R, Ortiz JC

Outplanting corals has been the focus of multiple research and development efforts to recover and maintain coral cover, with large-scale (hectares) deployments scheduled within the next few years. Given that it is logistically impossible to deploy corals across large reef areas (10s to 100s of hectares), reef and site selection for deployment is one of the most critical factors for sustaining coral populations. While it is also crucial to identify sites that will maximise long-term impact through reproduction of the deployed corals, ensuring that corals survive and grow where they are deployed can be the decisive factor for achieving shorter-and subsequently longer-term intervention goals. Here we developed a framework using a dynamic set of criteria to evaluate the ecological suitability of sites for coral deployment. Criteria are centred around heuristics informed by ecological knowledge of the critical conditions that favour coral survivorship and growth. This framework is a comprehensive and adaptable approach to guiding the identification of the ecologically most suitable sites to ensure population persistence and recovery by merging existing ecological knowledge, expert input, and new data.

Juan Carlos Ortiz
Australian Institute of Marine Science
j.ortiz@aims.gov.au

Improving the efficiency and effectiveness of COTS control decision making using deep learning

Islam MZ, Fletcher CS, Sun K, Chades I

On the Great Barrier Reef, managers controlling Crown-Of-Thorns Starfish (COTS) must make decisions about the most effective locations to target cull efforts to reduce COTS numbers and protect coral. To make effective decisions managers need information about the density of COTS around a reef. The COTS Control Program collects this information using periodic manta tow surveillance; however, manta tow uses resources that could otherwise be directed to culling. Balancing resources between surveillance and management is common to many environmental challenges on the GBR and globally. Here, we explore the promise of deep learning methods to reduce the need for surveillance by extracting insights from existing cull data. We developed a deep neural network model using both a Graph Convolution Network and a Recurrent Neural Network to predict COTS density from data already collected during previous cull actions. Our approach embeds spatiotemporal dependencies between sites and reefs to better estimate abundance over time and space, even at locations where very little data is available. Testing shows that our method produces more accurate abundance estimates than manta tow. The method is likely to be transferrable to other monitoring and management questions on the GBR, and other pest management systems globally.

Md Zahidul Islam
CSIRO
zahid.islam@csiro.au

ReefCloud: automated image analyses and statistical modelling to support the integration of coral reef monitoring and sharing of actionable data

Gonzalez-Rivero M, Kennedy EV, Chan YKS, Nand Y, Gainsford A, Golubuu Y, Mengersen K, Vercelloni J, Jupiter S, Boutros N, Logan M, Wyatt M

Despite technological leaps in our ability to map and monitor coral reef condition, our global tracking of benthic community composition change (as a proxy for reef health status) is still heavily reliant on compiling and sharing in-water observations made by snorkellers and divers. Temporal and spatial inconsistencies in field data collection and barriers to integration and data sharing limit our collective understanding of regional-to-global reef health trends. Here, we introduce the latest advances from ReefCloud. This newly developed open-access platform brings together automated image analyses, statistical modelling, and reporting tools to communicate on the condition of coral reefs more efficiently. Through ReefCloud.ai, machine-learning-enabled automated image analysis can replicate expert observations from photo quadrats with an 85–95% confidence to produce accurate estimations of benthic composition (3% mean error) at a rate that is 700-fold faster than manual assessment. Through partnerships with the GCRMN, academic and government institutions, and community groups, we highlight how ReefCloud is being used to facilitate regional reef monitoring and reporting. Together, these serve as potential means to help communicate monitoring data for timely conservation and management action, aiding in synthesising future global and regional GCRMN reef trend reports.

Emma Kennedy
Australian Institute of Marine Science
e.kennedy@aims.gov.au

A synthesis of rubble bed dynamics to inform intervention site selection

Kenyon TM, Paewai-Huggins R, Eigeland K, Sjahruddin F, Mumby PJ

The severity and frequency of rubble-generating disturbances is increasing on the GBR, and areas are likely to accumulate persistent rubble. Effectively upscaling RRAP restoration methods such as the larval re-seeding units and wild spawn settlement requires an understanding of benthos suitability. It is imperative to synthesise our knowledge of rubble dynamics moving into the future, and into the next RRAP phase. Our observational, experimental and predictive work shows that rubble is nuanced, and certain types of rubble beds (e.g., larger, interlocked) can be similar in coral recruitment outcomes to hard carbonate, suggesting a wider variety of suitable areas for these re-seeding methods. Furthermore, natural rubble stabilisation processes (binding) can occur within 4 months, but the degree of consolidation (strength) increases over time and is sensitive to rubble bed type, the diversity of binders, and environmental parameters including shelf location and hydrodynamic regime. In areas where rubble beds will stabilise naturally, re-seeding is likely to be suitable with no prior stabilisation intervention. This knowledge is currently being synthesised to inform site selection for restoration methods in future based on rubble bed type (fine-scale resolution) as well as natural binding potential (course-scale resolution at locations across the GBR).

Tania Kenyon
The University of Queensland
tania.kenyon@uq.edu.au

Inducing out-of-season spawning of Great Barrier Reef corals to support active intervention efforts in reef restoration

Koukoumaftsis LP, Salmon M, Everson G, Hughes DJ, Varkey D, Heyward AJ, Severati A, Humphrey C

Research into coral reproductive processes is a key component of the expanding toolbox to support active intervention efforts aimed at mitigating global reef decline. However, annual mass coral spawning events provide only a limited window of opportunity to access gametes during the year, which represents a major bottleneck to development of coral reproduction research. The ability to induce 'out-of-season' spawning to enable year-round supply of coral gametes represents a step-change in capacity for coral reproduction research and reef restoration efforts. Here we successfully induced out-of-season spawning for six Great Barrier Reef (GBR) coral species maintained in captivity at the National Sea Simulator (Australian Institute of Marine Science). To achieve this, micro programable logic controllers were used to apply 6-month offset temperature, day length, and moonlight profiles to F1 corals maintained in indoor aquarium facilities. During May/June 2022 and 2023, 106 coral colonies spawned across 6 species generating 1.9 million larvae. All coral species spawned close to predicted timings (i.e., nights after full moon and hours after sunset). Successful fertilisation, larval cultures, and settlement was observed for six species. Capacity to generate coral larvae at predictable timepoints over the year will accelerate investigations into the early life cycle of coral reproductive biology and recruitment and underpin future restoration efforts in the wider GBR. We discuss the application of these approaches within the landscape of restoration and scalability, as well as the intrinsic limitations in relation to scale and genetic management of broodstock.

Loni Koukoumaftsis
Australian Institute of Marine Science
l.koukoumaftsis@aims.gov.au

The hydrodynamic scales of marine dispersal

Langlais C, Choukroun S, Porobic Garate J, Thomson R, Mason R

Marine dispersal patterns are central to the mode of reproduction of marine species with pelagic larvae. Larvae are dispersed via ocean currents and will settle if they are carried towards a suitable substrate while competent. As a consequence, modelling larval dispersal and identifying potential source and sink areas for corals larvae and the Crown-of-Thorns Starfish (COTS) larvae aid in optimising resource allocation for restoration efforts. To adequately resolve larvae dispersal, numerical models used for simulating ocean currents should have a resolution that captures the relevant physical processes. Coral reef systems are often characterised by complex hydrodynamic features, including boundary currents, eddies, and tidal flows. The spatial extent of the model domain should also cover the relevant region where larvae are dispersed. Here we present multiple hydrodynamical model developed and used under eReefs, RRAP, ecoRRAp and CCIP projects. We discuss how their different hydrodynamic scales may be used to answer different connectivity questions : from GBR-wide identification of sources and sinks of larvae to identification of local patterns of larval supply at the scale of a reef; highlighting the advantages and limitations of the different methods.

Clothilde Langlais
CSIRO
clothilde.langlais@csiro.au

A comprehensive monitoring strategy for COTS in the GBR

Lawrence E, Foster S, Williamson D, Matthews S, Gladish D, Uthicke S, Doyle J, Bainbridge S, Pratchett M, Armin A, Bonin M

To mitigate impacts of Crown-of-Thorns Starfish (COTS) and support informed management, a well-designed and coordinated monitoring program that measures COTS populations across the entire reef system is essential. This presentation outlines a multi-faceted strategy for comprehensive COTS and coral monitoring on the GBR. The approach considers the objectives of a COTS monitoring program and how robustly to build on ongoing monitoring whilst also incorporating newer monitoring technologies like Reefscan (underwater towed video) and environmental DNA sampling. These tools are likely to improve the effectiveness of a monitoring program by increasing data robustness, facilitating monitoring of lower COTS densities and reefs that may not be suitable for in-water monitoring and decreasing the uncertainty surrounding the process of decision making. In addition to the monitoring plan, we will explain how we have calibrated these technologies with existing tools like manta tow based on field experiments – enabling an understanding of the output metrics relative to each other. The benefits of the proposed monitoring strategy include early outbreak detection, cost and resource optimisation, and improved coordination between monitoring and management actions across the Great Barrier Reef region. The presentation will highlight both the technological capabilities and collaborative frameworks necessary for successful large-scale implementation.

Emma Lawrence
CSIRO
emma.lawrence@data61.csiro.au

The Great Reef Census: 21st Century Conservation for Monitoring and Management

Lawson C, Chartrand K, Roelfsema C, Ridley A, Vozzo B, Senn N, Mumby P

Managing reefs requires strategic resource allocation, relying on broad-scale reconnaissance to understand which reefs are important for recovery. The Great Reef Census is a collaboration involving a not-for-profit, scientists, reef managers, and private corporations. Volunteers follow a simple methodology to capture reef-scape photos. These are then processed by other 'virtual' volunteers, supported by a purpose-built Artificial Intelligence, to quantify benthic categories. This virtual volunteer workforce is derived heavily from private corporations engaged in ESG efforts. The Great Reef Census has enlisted over 100 boats to capture 100,000 images from over 500 reefs in three years (most of which aren't surveyed by long-term monitoring) and onboarded 10,000 virtual volunteers from 70+ countries. The human-AI hybrid analysis system is achieving 97–99% accuracy compared to human expert analysis for estimates of total coral and key groups (branching, plating, and massive). Alongside being directly provided to reef managers, the results of the Great Reef Census will be available openly on a digital platform. Key metrics include total coral cover, key source reefs to prioritise for protection, and dominant coral type. Such a system can provide grassroots communities and managers a low-cost platform to protect important areas, while remaining responsive to threats or research questions.

Christopher Lawson
The University of Queensland
christopher.lawson@uq.edu.au

Next-gen bioadhesives: helping shape the future of sustainable rubble stabilisation and reef restoration

Lewis B, Bryan SE, Moghaddam L, Baker A, Barner L

The potential for increasing accumulations and persistence of mobile and unconsolidated coral rubble debris on reefs can hinder coral recruitment and prevent reef regeneration and recovery. Currently, no interventions exist specifically designed to stabilise and bind coral rubble, which can be scalable, cost-effective and eco-friendly by not introducing foreign materials permanently into the reef environment. Underwater bioadhesives are a novel technological solution with wide potential applications in marine environments, such as for rubble stabilisation. Conventional adhesives formulated for air curing have been applied in reef restoration efforts; however, they frequently exhibit long-term ineffectiveness underwater. This is mainly due to the challenges posed by encountering biofilms and the necessity for underwater adhesion to bond to wet surfaces while excluding the water or biofilm to ensure long-term strength. Since 2021, we have been designing and testing various underwater bioadhesives from plant waste that are degradable, eco-friendly and cost-effective to produce. Over the past 12 months, improvements have been made to the bioadhesives, including a reduction in micro-toxicity at the interface of the bioadhesive and attached objects. Additionally, we have strengthened the adhesion and cohesion properties, enabling the bioadhesive to withstand wave forces exceeding 150 N, wave bed velocities of 0.55 m/s (the maximum possible in our laboratory), and channel flume water velocities of 1.4 m/s, which exceeds measured natural rubble mobilisation thresholds (0.50 m/s) and initial natural rubble binding strengths (approx. 10 N). The bioadhesives also foster additional interlocking of loose rubble under dynamic wave conditions in larger-scale wave flume testing, showing the potential to accelerate rubble binding at scale. With multiple versions currently undergoing testing, these underwater bioadhesives can be a versatile toolbox for various applications within reef restoration. From rapid equipment repair to device securement, deployment, and coral fragment outplanting, the current generation of bioadhesives demonstrates promising adaptability across the reef restoration landscape.

Brett Lewis
Queensland University of Technology
bm.lewis@qut.edu.au

Community and stakeholder perceptions of resilience-based management in the Great Barrier Reef

Lockie S, Paxton G, Bartelet H, Ritchie B

Shifts toward resilience-based ecosystem management raise questions about the articulation of goals, prioritisation of actions, recognition of rights, and management of divergent perspectives and interests. This presentation takes a first step toward resolution of these questions by exploring what is currently known about community and stakeholder perspectives of resilience-based management in the Great Barrier Reef (GBR). It draws on quantitative surveys of Australian and GBR residents undertaken in 2019 and 2022 (n>8000) and in-depth qualitative interviews of over 140 Reef stakeholders, Traditional Owners, and community members undertaken 2021 to 2023. We examine what respondents believe to most threaten the health of the GBR and their support for a variety of actions including threat prevention, local restoration, large-scale restoration, research, and building reef resilience. Survey results reveal widespread recognition of the threat posed by climate change, strong support for resilience-building actions, and high levels of trust in science to develop solutions for Reef protection and repair. A majority of interview participants meanwhile believed that pragmatic measures to build reef resilience should be accompanied by both meaningful social change and grassroots protection and care. We conclude by drawing out the implications of these findings for public engagement in support of resilience-based management.

Henry Bartelet
James Cook University
henry.bartelet@jcu.edu.au

Research to support Indigenous-led decision making for Reef Restoration and Adaptation in the Great Barrier Reef, Australia

Maclean K, Muir B, Moran C, Taylor B, Schmitt K

This paper describes the co-development of a biocultural risk and opportunity assessment framework to be used by Traditional Owners to assess the risks and opportunities associated with reef restoration and adaptation technologies to their Culture and their Country. The concept and need for a framework was developed by the Great Barrier Reef Foundation's COTS and Reef Restoration and Adaptation Science Traditional Owner Technical Working Group, and, delivered through a partnership between the Indigenous Partnership Team (Australian Institute of Marine Science) and social researchers (CSIRO) working as part of the RRAP. The aim of the framework is to support Traditional Owner leadership of decision making about their Country in the Great Barrier Reef, Australia. Our work is informed by a strength-based narrative of Indigenous care and responsibility for social ecological systems undergoing change. This approach highlights different perspectives of what constitutes risk, opportunity, and appropriate governance structures. We discuss the origins of the project and the central role of partnerships in its evolution. Next, we present the methods used, and provide an overview of the draft framework. We end by articulating the current and potential connections between this work and broader Traditional Owner activities and governance processes in the Great Barrier Reef.

Kirsten Maclean
CSIRO
kirsten.maclean@csiro.au

Funding for scale and impact

Marsden A

Despite being a global wonder, investment in the Great Barrier Reef and broader ocean conservation efforts remains woefully low. In fact, SDG 24 (Life Below Water) receives the least amount of funding of all the Sustainable Development Goals. Over the last five years, the Great Barrier Reef Foundation, in its role as a lead charity for coral reefs, has driven a global fundraising effort and raised over $300m in non-government investment for research, on-ground and in-water activities to build the resilience of the Great Barrier Reef. A significant amount of this support has been directed towards science and innovation – underpinning breakthrough research and development collaborations in coral and coastal restoration, and protection of the ecosystem. In this session, the Foundation will delve into the strategies and insights gained through this campaign, navigating the intricacies of crafting and executing the case for support from domestic and international donors. It will consider the elements of a program that most appeal to donors and also look at the unique needs of donors across private and corporate gift markets.

Theresa Fyffe
Great Barrier Reef Foundation
tfyffe@barrierreef.org

The Reef Catchments Science Partnership

Marsh A, Turner RDR, Mann RM, Warne M St. J

The Reef Catchments Science Partnership is a unique collaboration tasked with improving methods for data collection and analysis related to the quality of water feeding into the Great Barrier Reef. This partnership is co-delivered by the QLD Department of Environment, Science and Innovation; the University of Queensland and James Cook University. As well as employing staff from these three institutions, close to 70 individuals from different stakeholder groups are engaged by the program to collect water quality data across the GBR catchments. Data collected by this program includes the water quality data collected manually and by autosamplers and real time water quality data captured at over 100 sites throughout the GBR catchment areas. The amount of data being captured and analysed now exceeds 10 million data points annually. Data scientists analyse this data to trace nutrient loads and pesticides back to source, to identify opportunities to improve water quality and subsequently improve the health and resilience of the reef. The partnership has been growing and evolving for over a decade, and the level of engagement and collaboration across so many individuals is unique and brings a wealth of benefits to the program. Having a distributed management team across three organisations whilst presenting challenges, allows for greater capacity and more widespread research and innovation which this presentation will showcase.

Angela Marsh
The University of Queensland
a.marsh3@uq.edu.au

Sea Country mapping to manage Crown-of-Thorns Starfish outbreaks

Martinez-Diaz M, Lyons P, Fletcher CS

The Great Barrier Reef (GBR) faces unprecedented threats, including cyclical outbreaks of Crown-of-Thorns Starfish (COTS). Addressing this challenge in a manner that is inclusive and accounts for multiple stakeholder perspectives demands innovative cross-sector collaboration. This project proposes a co-design partnership with Traditional Owners, to build the decision support tools they need to participate effectively in the prioritisation process for COTS control. Through dialogue, mapping, and workshops, novel digital decision-making tools will be co-developed based on Traditional Owners' needs, priorities, and the significance of their Sea Country. The project complements work underway with Traditional Owners within the COTS Control Innovation Program, and aligns with the Traditional Owner Implementation Plan, Reef 2050, and 'Heart of the Reef – A Call for Healing' emphasising Traditional Owners' commitment to nurturing the Reef. This research seeks to establish enduring partnerships between researchers and Reef Traditional Owners. It aims to co-develop relationships, capability and decision tools that can contribute not only to effective COTS control but also to inclusive marine spatial planning and broader reef conservation initiatives. The project recognises the unique value of Traditional Knowledge and emphasises the importance of healing the Reef through genuine collaboration, respect for cultural practices, and acknowledgment of Traditional Owners' aspirations.

Marycarmen Martinez Diaz
CSIRO
marycarmen.martinezdiaz@csiro.au

Validation of coral larvae connectivity modelling using observations of coral early life stages on the Great Barrier Reef

Mason RAB, Langlais C, Uribe-Palomino J, Tonks M, Coman F, Herzfeld M, Thomson R, Choukroun S, Doropoulos C

Accurate predictions of larval connectivity provide a basis for restoration planning on the Great Barrier Reef. Larval connectivity prediction is a challenging problem involving accurate resolution of hydrodynamic flows and appropriate integration of biological models. Differences in connectivity networks can result in vastly different optimal solutions in placement and resourcing of restoration, motivating the need for connectivity model validation. Hydrodynamic processes influence connectivity networks at two scales: intervention scale (10's m to 10's km), and long-distance dispersal scale (10's km to 100's km). We conducted local connectivity validation experiments in which the abundance of spawned coral larvae and larval settlement rates were compared against connectivity predictions. Predictions were generated using models whose domain and resolution had been tuned to approximate both scales. Simulations at 300m resolution around target reefs did not adequately capture field observations of connectivity. Simulations at 100m resolution around target reefs, though in a different domain, performed better in initial testing. Our results reveal both caution and promise in the potential of coupled high resolution hydrodynamic-biological models of larval dispersal. At the scale of intervention, the integrity of the connectivity modelling being incorporated into decision support systems requires validation prior to operationalisation of the resulting plans.

Robert Mason
CSIRO
robert.mason@csiro.au

Effective management of Crown-of-Thorns Starfish (COTS) outbreaks protects the resilience of the Great Barrier Reef

Matthews SA, Williamson DH, Beeden R, Emslie M et al

Resilience-based management is essential to protect coral reef ecosystems facing the increasing and cumulative impacts of climate change and human use. Crown-of-thorns Starfish (COTS, *Acanthaster* cf. *solaris*) are voracious coral predators that periodically reach outbreak densities and cause extensive damage to coral reefs. Here we evaluate the outcomes of the past decade of strategic COTS management in the Great Barrier Reef Marine Park, Australia. We drew upon long-term systematic reef monitoring data to assess the degree to which targeted COTS control suppressed starfish densities and protected coral across entire reefs and regions (sectors). Compared to the previous outbreak wave, COTS densities were up to six-fold lower and coral cover increased substantially (~44%) in sectors that received timely and sufficient cull effort, while sectors that received limited to no culling effort had sustained COTS outbreaks that caused significant coral losses. Outbreaking reefs that received higher levels of culling effort had net increases in coral cover, while the rate of coral loss was more than halved on reefs with lower levels of cull effort. Our findings demonstrate that proactive, targeted, and sustained COTS control is an effective and scalable tool for resilience-based management action that augments the benefits of Marine Park Zoning management to protect coral and support the Reef's resilience at regional scales.

Samuel Matthews
Reef Authority
sam.matthews@gbrmpa.gov.au

Enhancing coral survival through nutrient supplementation

Matthews JL, Bartels N, La Motta L, Boulotte N, Padula M, Hughes DJ, Crane Z, Humphrey C, Roper C, Suggett D, Raina JB

Coral larvae are crucial for reef vitality. Maternal and environmental nutrients influence larval fitness, and nutrient depletion remains a key contributor to larval mortality, challenging the effectiveness of reseeding initiatives. Constituting 70% of coral biomass, lipids serve as vital energy stores, supporting growth and minimising cellular stress. Our innovative nanotechnology study explores targeted delivery of diverse lipid supplements – triacylglycerols, wax esters, phospholipids, and sterols – to enhance coral larval survival under controlled and heat stress conditions. Survival rates without feeding under control conditions ranged from 37–45%, surging to 70–98% with lipid supplementation. After six months of heat stress, corals unfed during the larval stage exhibited a mere 30–39% survival rate, while those fed as larvae showed a robust 60–65% survival rate. In collaboration with local tourism industries and traditional owners, we implemented an in situ larval feeding strategy, delivering an optimised lipid supplement directly on the Great Barrier Reef. This approach aims to expedite recovery at tourism hotspots and high-value reefs and has the potential for global application, catalysing restoration initiatives. Our nanodelivery of nutrient supplements exhibits broader applicability to adult corals, presenting global opportunities to bolster coral resilience and cultivate collaborative partnerships for the conservation of these invaluable marine ecosystems.

Jennifer Matthews
University of Technology Sydney
jennifer.amtthews@uts.edu.au

Resilience Based Management in practice: A Keppel Islands case study

Mattocks N, Nicholson F

Since the 2017 publication of the Reef Blueprint, the Reef Joint Field Management Program (the Program) has been working with a range of stakeholders to expand its capacity in coral reef ecosystem resilience-based management (RBM). In October 2022 the Program worked with local tourism operators, key partners Mars Incorporated, and the Woppaburra Traditional Owners to construct three small reef rehabilitation sites on fringing reefs within the Keppel Islands area. Project development, training, installation, and ongoing monitoring provided opportunities for divergent stakeholder groups to work together on a project that addressed several RBM principles. This included investing in experimental approaches and the implementation of strategies to build social and ecological adaptive capacity. One site (Humpy Island) was an installation of fifty Reef Stars (using approximately 750 live coral fragments) within an area of unconsolidated rubble with a 90–100% macroalgae cover. The Reef Star (or Mars Assisted Reef Restoration System (MARRS)) has never been used in this type of inshore reef environment before. This talk will review some of the early results from the project and plans for ongoing management, monitoring, and site access and use over the next 3–5 years.

Neil Mattocks
Reef Authority
neil.mattocks@gbrmpa.gov.au

Partnering to build capacity of GMY Rangers to care, connect and support healthy Sea Country

Sands C, Mundraby D, McKenna S, Chartrand K

Gunggandji-Mandingalbay Yidinji (GMY) Sea Country, southeast of Gimuy (Cairns), is culturally rich with high biodiversity values. However, understanding reef and seafloor habitats (e.g. seagrass) and how healthy they are in GMY Sea Country is a critical knowledge gap to support ecosystem management and areas of cultural significance (e.g. Sudbury, Stevens, Noggin and Maori Reefs) for generations to come. Together, GMY with JCU TropWATER have worked hand in hand to establish baseline data in a manner GMY Rangers can understand, add to, and report against for the ongoing resilience of GMY Sea Country and the Great Barrier Reef. Our multi-step project progressed through discussions and stories, skill and capacity building, on-Country training and culminated with the creation of benthic habitat maps (seagrass and coral) and integration with Great Reef Census. Collecting current habitat information supports GMY's goals of caring for Sea Country, maintaining a strong connection to place, empowering Rangers and the community to make informed decisions, fostering collaborations with local partners and maximising employment and enterprise opportunities for Traditional Owners.

Skye McKenna
James Cook University
skye.mckenna@jcu.edu.au

Resilience-based management for the coral reefs of Saudi Arabia's Red Sea

McLeod IM

Saudi Vision 2030 is a transformative national strategy that aims to fundamentally reshape the nation's society, culture, and economy. Core objectives of the strategy include diversifying the economy to reduce dependance on oil, boosting tourism, and building new sustainable cities and resorts. The Red Sea is a global icon. Saudi Arabia has spectacular coral reefs, with some reefs potentially showing natural resilience to climate induced bleaching. However, there is a risk that these reefs, and the wider Red Sea, will be impacted by increasing regional pressures, associated with coastal development and population growth. The General Organization for Conservation of Coral Reefs and Sea Turtles (SHAMS) is a new government organization in Saudi Arabia. Our strategy focuses on five key objectives: (1) expand scientific knowledge on Red Sea coral reefs and sea turtles; (2) spearhead science-based conservation within the Red Sea; (3) promote Saudi Arabia's coral reefs and sea turtles as national icons, boosting awareness and sustainable enjoyment; (4) build partnerships to elevate conservation outcomes; and (5) establish world-class capabilities. Our priority actions include growing national, regional, and global partnerships and to adopt, adapt and improve upon best practices. This presentation will provide an update of progress in Saudi Arabia, introduce our organization, and describe the range of opportunities for collaboration.

Ian McLeod
SHAMS
ian.mcleod@shams.gov.sa

RRAP – Past, present, and future

Mead D, Bay LK

The Reef Restoration and Adaptation Program (RRAP) is the world's largest effort to help a natural ecosystem survive climate change. The Reef Restoration and Adaptation Program (RRAP) began in 2020 following a feasibility study emphasising the urgency of climate mitigation AND the need for new protection, assisted adaption, and restoration interventions to sustain critical reef functions and values. It was clear then that time is of the essence – research takes time and the longer we wait, the more expensive and difficult it will be to successfully intervene safely and effectively at any scale. A research and development (R&D) program was designed and over the last four years hundreds of people from over 20 organisations have worked tirelessly to commence addressing key program objectives. In this presentation we reflect on learnings, key achievements and challenges. We argue that the strength of the Program lies in its mission driven approach with cross disciplinary thinking and collaboration at its core. Rapid progress is enabling selected methods to move to @scale pilot deployments in 2025, and we outline a vision for the future of the Program. Further R&D is still urgently needed, and we present some ideas to increase international collaboration on what is one of the global challenges of our lifetime.

David Mead and Line Bay
AIMS
d.mead@aims.gov.au

Nitrogen risk insurance and implications for fertiliser use and nutrient runoff to the reef

Mehmet R, Thorburn P

There are many reasons for farmers to consider reducing nitrogen fertiliser application rates, from the goal to maximise on-farm profits to the desire to reduce discharges of dissolved inorganic nitrogen discharges to the Great Barrier Reef. However, an obstacle to that decision is the fear of reduced yields (and profits) if the coming weather favours high applications of nitrogen. Nitrogen Risk Insurance is a unique product that helps sugarcane farmers avoid a loss of yield revenue following lower application of nitrogen fertiliser. Unlike traditional crop insurance policies where claims are usually assessed on the physical impact of weather events on yield, Nitrogen Risk Insurance claim payments are based on yield outcomes simulated with the APSIM farming systems model using Bureau of Meteorology weather measurements including rainfall, temperature and solar radiation. The insurance is based on 20+ years of CSIRO's research into sugarcane production. Policies are tailored to specific fields and give farmers flexibility and control over their buying decision. Nitrogen fertiliser reductions facilitated by Nitrogen Risk Insurance have substantial public benefits by reducing the need to fund grants and incentives to achieve improved water quality. The funds saved could be in the order of $50M/year if the product was widely used.

Russell Mehmet
Willis Towers Watson
russell.mehmet@wtwco.com

Governing the COTS control program as a partnership – lessons from the last five years

Moltmann T, Fyffe T, Quincey R, Morris S, Bonin M

Under the Reef Trust Partnership (RTP), $57.8M was invested to boost the Crown-of-thorns Starfish (COTS) Control Program, including $41.5M for COTS control. A COTS Control Partnership Group (CPG) was established to govern this investment, with an independent chair and senior representatives from the Great Barrier Reef Foundation (GBRF), Great Barrier Reef Marine Park Authority (GBRMPA), and Reef and Rainforest Research Centre (RRRC), along with the COTS Control Innovation Program (CCIP) Director. This partnership approach was novel for COTS control. By all objective measures it has been successful. Lessons learnt include the importance of (1) establishing principles for working together, (2) defining roles and accountabilities, and (3) connecting strategy with operations. As we look beyond the RTP, on a 2050 timeframe, it will be important to build on current strengths. The CPG experience provides valuable lessons about the power of partnership in building reef resilience.

Tim Moltmann
Great Barrier Reef Foundation
tim.moltmann@utas.edu.au

Jon Brodie Memorial Lecture: Driving change for the future of the Great Barrier Reef

Morris S, Marsh H, Tanzer J, Zethoven I, Fernandez L

Dr Jon Brodie was not only a leading researcher but a bold and influential advocate for policy and investment to tackle water quality issues for the Great Barrier Reef. He was a fearless force for change at a time when he perceived that the scale of the problems facing the Reef far outweighed the solutions that were currently in place to tackle them. In this Jon Brodie Memorial Lecture, longtime colleagues reflect on over thirty years of managing risks, growing social license, and driving policy change for the better in the often highly contested Great Barrier Reef space. Co-authors include those who led the charge for rezoning in the Marine Park, engaged in the fishing wars, created the water quality agenda and introduced the impacts of climate change on the Reef to the general public; all in an era of science scepticism. Drawing on their collective experience, the authors analyse successful pathways from science to policy to outcome, different approaches, challenges, and roadblocks, including the need to adapt to new information and new situations. Their conclusions distill what has been learnt about how to drive change to successfully deliver improved outcomes for the Reef.

Sheriden Morris
Reef and Rainforest Research Centre
sheriden.morris@rrrc.org.au

Engaging technology to automate coral deployment for large-scale reef restoration across the GBR

Moshirian B, Foote D, Gibbs M

The Deployment Guidance System (DGS) is an ambitious, interdisciplinary project that seeks to deploy millions of coral devices across the Great Barrier Reef (GBR) over the coming years as a response to climate change. This project has three major characteristics: (1) translating and applying RRAP research on reef location and modelling frameworks to perform in real-time as a deployment decision framework which recommends and dispenses coral devices; (2) designing and manufacturing hundreds of modular DGS dispensing units that seamlessly integrate with and validate the coral device manufacturing pipeline; and (3) scaling the operational dispensing of these devices across the GBR by working with industry, tourist operators, researchers, and Traditional Owners. This talk will highlight our strategy and the opportunities and challenges that will undoubtedly arise from our ambitious project which will bring us closer to on-demand scalable reef restoration.

Benjamin Moshirian
Australian Institute of Marine Science
b.moshirian@aims.gov.au

First Nations leadership in reef resilience

Muir B, Forester M, Singleton B, Harrigan D, Backhaus V

The push to include and leverage Traditional Owner knowledge and science in the reef restoration and resilience space is being driven strongly through Reef Traditional Owner leadership and governance systems. Through the Reef Trust Partnership, the Great Barrier Reef Foundation (GBRF) has created leadership roles for Reef and Catchment Traditional Owners, forming the Crown-of-Thorns Starfish and Reef Restoration and Adaptation Science (COTS/RRAS) Technical Working Group in 2020. Drawing from our technical and professional expertise and lived experience as Traditional Owners, we are focused on removing barriers to Traditional Owner access to, and active participation and leadership in, RRAS projects and COTS control. We have co-designed GBRF's Traditional Owner COTS/RRAS Program agenda – working across scales from funding on-Country Traditional Owner-led projects, to creating system change and re-asserting Traditional Owner voices and calls to action. In doing this work we are being sought out for cross-sector collaboration opportunities, and are influencing key programs and processes for the benefit of Traditional Owners working towards healthy sea Country. This presentation will highlight how Traditional Owner governance of the program has delivered outcomes for Traditional Owners and the health of the reef through insights of our program's core work areas and learnings.

Bob Muir
Australian Institute of Marine Science
b.muir@aims.gov.au

Allee effects in small coral populations: manipulating adult colony patches to assess fertilisation success

Ricardo GF, Babcock RC, Buccheri E, Doropoulos C, Mumby PJ

As reefs degrade, coral populations become fragmented with few surviving adult colonies remaining on reefs. Fragmented populations of reproductive corals on degraded or restored reefs negatively affects the reproduction potential of spawning corals due to limited egg-sperm encounters from a loss of gamete abundance and larger distances between reproductive adults. To assess the influence of adult coral patch characteristics on fertilisation success, we conducted a series of manipulated field experiments using three common broadcasting *Acropora* species at two distinct locations (One Tree Island, GBR; and Nikko Bay, Palau). Between 8 and 20 colonies were configured in patches at 1 to 2 m intercolonial spacing and each generated slick was sampled after ~90 mins. Each patch resulted in low but notable fertilisation success, ranging from 4 to 7%. We further developed a mechanistic coral fertilisation model using independent data, with fertilisation predictions closely aligning with data collected during the experiments. Modelling results indicate adult patch densities need to be greater than 15 colonies per 100 square meters to prevent fertilisation failure. These coral density thresholds need careful consideration when planning small- and large-scale restoration programs to ensure functional reproduction from restored populations of corals.

Peter Mumby
The University of Queensland
p.j.mumby@uq.edu.au

Resistance of Restored Reefs to Cyclone Impacts in the Northern Great Barrier Reef

Nicholson F, Fisher E, Mattocks N, Camp E, Carman R

Climate change is increasing the frequency and severity of extreme weather events such as cyclones, impacting shallow coral reefs through wave action. Resilient reefs can adapt and recover from such disturbances, while resistant reefs are able to withstand these disturbances without yielding. Both traits will be valuable in an increasingly volatile climate. One active method of aiding recovery of impacted sites and building resilience into reefs, the Mars Assisted Reef Restoration System (MARRS), works by bringing new live hard corals into the degraded area while simultaneously accelerating stabilisation of unconsolidated rubble beds, providing stable substrate for corals to adhere to. As one of the most widely deployed active intervention techniques globally, it is imperative that we understand its ability to withstand high wave energy when installed correctly. In December 2023 Tropical Cyclone Jasper tracked north along the Queensland coast between Townsville and Cape Tribulation, outside the Outer Great Barrier Reef, causing destructive winds over the Reef which persisted for over 72 hours. Severe local impacts from both wind action and freshwater inundation have been observed on some reefs in the affected region. This presentation will provide both empirical data and observations detailing localized impacts of TC Jasper on 5 MARRS sites (with site ages ranging from 6 to 42 months) and surrounding natural reefs located in this region.

Freda Nicholson
Mars Sustainable Solutions
freda.nicholson@effem.com

Overcoming biological and technical bottlenecks in conservation aquaculture

Nordborg FM, Severati A, Abdul Wahab M, Negri AP, Flores F, Ramsby B, Diaz-Pulido G, Fong J, Antunes E, Randall C, Bourne D, Neil R, Hoj L, Rix L, O'Brien P, Tsai D, Haikola P, Abrego D, et al.

Coral reef restoration is emerging as a key part of the tool kit for maintaining coral reef ecosystem services and function following worldwide declines in coral reef health. However, to enable reef restoration at large enough scales to generate positive outcomes, significant changes to the methods and technologies used for coral propagation are necessary. Here we review the steps involved for using ex situ aquaculture in reef restoration, key biological and technical bottlenecks in coral aquaculture for conservation purposes, and synthesise learnings to date across RRAP coral aquaculture projects performed at the Australian Institute of Marine Science (QLD, Australia). Our work shows that successful coral aquaculture at scale requires incorporating ecological concepts (e.g. around benthic competition) and species-specific knowledge (e.g. preferences for chemical inducers of settlement) with novel technologies and processes, including substrate design, process automation, machine learning, robotics and high-throughput analyses for monitoring. While further research and incorporation of knowledge produced to date is required, we demonstrate that automated coral aquaculture systems combined with scientifically informed rearing conditions and husbandry procedures offer a pathway to upscaling of coral culturing to meet future demands of reef restoration projects.

Mikaela Nordborg
Australian Institute of Marine Science
m.nordborg@aims.gov.au

Carbonate budgets induced by coral restoration of a Great Barrier Reef site following cyclone damage

Nuñez Lendo CI, Suggett DJ, Boote C, McArdle A, Nicholson F, Fisher EE, Smith D, Camp EF

Coral reefs rely on coral carbonate production to form their primary framework, a crucial component supported by other reef calcifiers. The interaction between carbonate production and erosion processes shapes coral reef carbonate budgets, crucial for ecosystem services like wave attenuation. These processes also influence reef structural complexity, fostering biodiversity and productivity. However, the unprecedented loss of coral reefs has jeopardised these valuable services. Active rehabilitation, exemplified by the Mars Assisted Reef Restoration System (MARRS), aims to counteract degradation effects by deploying structures on denuded reef sites and seeding them with corals. The impact of such interventions on carbonate budgets and structural complexity remains unclear. Monitoring coral growth and reef complexity using a census-based approach alongside coral skeletal properties identified the contributions of carbonate producers and eroders. This study compared rehabilitated sites with natural unrehabilitated reefs and rubble patches, revealing how these interventions can accelerate coral reef carbonate framework recovery.

Carmela Isabel Nuñez Lendo
University of Technology Sydney
carmela.nunez@uts.edu.au

Optimising coral larval recruitment through reef-based research on larval settlement and survival on various Crustose Coralline Algae

Ordoñez Alvarez A, Moynihan J, Harrison PL

Understanding and optimising natural settlement substrata for coral larvae to settle, develop and survive is important for improving coral restoration outcomes. Coral larvae use settlement cues to guide them to substrata that are beneficial for their survival, and crustose coralline algae (CCA) and associated bacterial communities are known to release cues that induce metamorphosis and settlement. However, laboratory experiments have revealed that not all species of CCA promote coral larvae settlement at the same rate, and it is still unknown if laboratory outcomes are applicable to reef environments to assist restoration success at greater scales. Therefore, we explored the response of coral larvae settlement to a variety of CCA species, and CCA communities developed on reef-conditioned settlement tiles, in conjunction with large coral larval restoration field experiments supported by the Paul G. Allen Family Foundation. This presentation summarises the key larval settlement and survival outcomes on a range of CCA species, and highlights the importance of including the use of particular CCA species in coral reef restoration methods to improve coral larval settlement and survival.

Alexandra Ordoñez Alvarez
Southern Cross University
alexandra.ordonez.alvarez@scu.edu.au

Characterising the chronic and acute effects of temperature on the growth of Great Barrier Reef's corals

Ortiz JC, Alvarez-Noriega M, Marrable I, Crossman K, Cresswell AK, Ferrari Legorreta R, Fabricius K

Corals have evolved strategies over millennia to maximise their performance under their local environmental conditions. As temperature is increasing at a rate never experienced before by corals, understanding the relationship between temperature and performance is critical. We conducted a series of laboratory experiments never attempted at this scale before, over 3 years as part of EcoRRAP, to describe the relationship between coral growth and temperature for five taxa across the latitudinal gradient of the Great Barrier Reef. We found multiple evolutionary strategies among taxa, as well as variability across latitude. Importantly, thermal strategies appeared to be extremely conserved among individuals of the same taxa within a reef, suggesting a tight evolutionary relationship that may pose constrains to thermal adaptation. We found that acute thermal stress events (both hot and cold) could suppress growth by 50–100% for at least 6 months, suggesting that moving corals from warmer to cooler environments may compromise their performance over the entire reproductive season and influence their response to thermal stress on the following summer. These results have already been incorporated into one of RRAP's mechanistic ecosystem models, demonstrating the benefit of multidisciplinary programs with clear pathways for the uptake of information as it is generated.

Juan Carlos Ortiz
Australian Institute of Marine Science
j.ortiz@aims.gov.au

C~scape: a within-reef metacommunity modelling framework to inform reef management in an uncertain future

Cresswell AK, Haller-Bull V, Anthony K, Ani C, Alvarez-Noriega M, Barneche DR, Bozec Y-M, Condie S, Doropoulos C, Fabricius K, Gilmour JP, Gonzalez-Rivero M, Gordon S, Lechene M, Lyons M, Mumby PJ, Renata F, Robson B, Roelfsema C, Toor M, Ortiz JC

In the face of global coral decline, models that capture ecosystem dynamics across space and time by incorporating biological mechanisms are needed. Much focus has been on modelling variability between reefs, despite substantial variability also existing within-reefs. We developed C~scape, a coral metacommunity modelling framework that integrates the demography of corals with population-level responses to disturbance, to facilitate spatiotemporal predictions of coral dynamics across reefs at fine (100s metres) scales. We designed the framework to uptake data on coral demography and growth-temperature relationships being generated by EcoRRAP to establish a direct flow of information from newly generated data into mechanistic models. The framework combines information on suitable coral habitat from satellite-derived maps with demographic data from different environments to predict within-reef variability in coral community dynamics. With case studies from the Great Barrier Reef, we demonstrate the model's capability in reproducing observed coral cover dynamics. Furthermore, we explore future declines in coral cover and changes in community composition under different climate change scenarios. C~scape provides a valuable framework for predicting spatiotemporal dynamics of corals, offering a mechanistic approach to explore a range of management and restoration scenarios.

Juan Carlos Ortiz
Australian Institute of Marine Science
j.ortiz@aims.gov.au

Traditional Owner partnerships for enhanced reef restoration outcomes

Page C, Randall CJ, Giuliano C, Muir B, Evans-Illidge E, Cummins M, Ivey J, Molinaro G, Bay L

As management of the Great Barrier Reef moves into a more active phase, utilising a wide variety of interventions and restoration techniques, western scientists are increasingly partnering with Traditional Owners of sea Country to ensure consent for proposed interventions, but also improved restoration outcomes and benefits for Traditional Owners. The Woppaburra Coral Project is an example of a partnership between the Woppaburra Traditional Owners of the Keppel Islands, southern GBR, the Australian Institute of Marine Science and industry (BHP) that has had positive outcomes for both restoration science and Traditional Owners. Beginning in 2019, the project provided opportunities for increased Traditional Owner connection to sea County, two-way knowledge sharing, delivered training and capacity building, importantly positioning Woppaburra for potential future employment in the restoration sector. Restoration science has also benefited from Traditional Owner involvement in the project. The Woppaburra Coral Project provides a model for future reef restoration research partnerships. The Project has not been without its challenges, these and lessons learnt during the Project will be discussed.

Cathie Page
Australian Institute of Marine Science
c.page@aims.gov.au

Collaborative design in a marine science outreach program supports engagement of First Nations youth

Paley AS, Smit J

The popular program Aboriginals and Torres Strait Islanders in Marine Science (ATSIMS) is a progressive example of a collaboratively designed outreach program in the marine science and management industry spanning more than a decade of successful operation. Fundamental to the ATSIMS program is the continued commitment and collaboration between industry experts, Traditional Owners and Representatives, Indigenous Land and Sea Ranger Groups and our community's youth. As the ATSIMS program enters its 11th year of engaging First Nations year 10 students from the Townsville region, we reflect on the key partnerships, stakeholder engagement, and impressive amount of in-kind support leading to its success. Building a pipeline of engagement for First Nations youth between the ages of 15 and 24 years of age is a timely extension to the ATSIMS core program that we identify as instrumental to its lasting impact. A new branch of the program called 'Beyond ATSIMS', in collaboration with our partners, will help provide opportunities for motivated youth with further engagement in the marine sector through participation in pre-professional training, internships, paid work experience and network development. Beyond ATSIMS will further enrich the ATSIMS core program and help develop skills-ready, competitive, confident job-seekers entering the workforce.

Allison Paley
James Cook University
allison.paley@jcu.edu.au

Cultivating capital: Enhancing communities through Great Barrier Reef adaptation and management

Paxton G, Lockie S, Brooksbank J, Bartelet H

The future of a socio-ecological system as large and important as the Great Barrier Reef is not only contingent on the adaptive capacity of coral, but the cohesion, well-being and agency of the human communities that live in and work with it. As part of engagement conducted under the Reef Restoration and Adaptation Program, social scientists from the Cairns Institute, JCU conducted in-depth qualitative interviews with 140 people living and working in the Great Barrier Reef, including Reef Traditional Owners, tourism operators, Reef restorers, COTS managers, commercial and recreational fishers, artists, divers, kayakers and others. As participants spoke freely about their lives and experiences, their first-hand accounts demonstrate how the Reef offers collective opportunities that extend well beyond the satisfaction of material needs and desires. We discuss how life in the Reef generates multiple forms of 'community capital', which is cultivated to enhance socio-ecological well-being, political participation and influence, and collective stewardship and capacity to care for Reef systems. We discuss how closer attention to the flows of this capital can inform inclusive and equitable pathways towards resilience in the Great Barrier Reef.

Gillian Paxton
James Cook University
gillian.paxton@jcu.edu.au

The social benefits of stakeholder engagement: participant experiences in the Reef Restoration and Adaptation Programs Engagement Advisory Group

Piggott-McKellar A, Vella K, Eberhard R, Baresi U, Pearson J

Engaging with stakeholders and community members in large-scale ecosystem management is widely understood to be important to ensure robust and viable decisions, and ensure that decision-making processes meet standards of fairness and justice. But how do participants involved in engagement process experience and benefit from opportunities to engage, if at all? To unpack this question, this research draws on the experiences of members from the Engagement Advisory group in the Reef Restoration and Adaptation Program (RRAP). Drawing on in-depth interviews, alongside experiences and reflections on the Advisory groups activities, we unpack the diverse experiences of members with a view to understand the social benefits they have experienced. Early insights indicate that participants have: benefited from enhanced social networks and relationships; built individual levels of confidence: and gained new knowledge and skills. Key factors that have shaped these experiences include: diversity of members' backgrounds, knowledge bases and life experiences, and participation in collaborative processes; opportunities for face-to-face interactions within and outside of meetings; and a common and shared purpose. Outcomes of this research will provide important insights on the ways stakeholder and community engagement can be tailored to not only benefit programmatic goals, but have broader benefits for participants.

Jasmine Pearson
Queensland University of Technology
jasmine.pearson@qut.edu.au

Partnering with local communities, reef managers and resilience experts to respond to climate change and local threats

Armstrong A, Fyffe T, Perez A, Douvere F, Davis A, Lovecchio J, Maize K

Coral reefs are critically important to the survival of the planet, supporting 25% of all marine life but also providing food, wellbeing and livelihoods to nearly one billion people across the globe. Business-as-usual approaches to coral reef management are no longer enough to protect them from local stresses and climate change, with 75% of the planet's coral reefs currently under threat. Over the last six years, the Resilient Reefs Initiative (RRI) has responded to the call of action by proving a model for working with reef communities and local governments to connect, catalyse and implement solutions in four World Heritage coral reef sites in Western Australia, New Caledonia, Belize, and Palau. Led by the GBRF and funded by BHPF, this global partnership built local capacity to design and deliver resilience projects and institutionalise Resilience-Based Management (RBM). During this session, we will share the outcomes of RRI, which include the delivery of 30 resilience projects, funding four Chief Resilience Officer roles, training more than 750 Reef managers in RBM, and engaging more than 3,000 Reef stakeholders for developing a Resilience Strategy for each of the four sites. The session will then explore next steps as part of the second phase of RRI, which will kick-off this year and will build on the lessons learnt from the pilot.

Ana Perez
Great Barrier Reef Foundation
aperez@barrierreef.org

Research priorities and management reforms to meet international (CITES) obligations and secure social license for Australian coral fisheries

Pratchett MS, Pacey K, Caballes CF

The Queensland Coral Fishery (QCF) is the largest of four Australian coral fisheries, which permits annual harvesting of up to 200,000 kg of live coral from with the Great Barrier Reef World Heritage Area, mainly for export as aquarium specimens. The export and international trade in CITES-listed corals is contingent on assurances that harvesting will not be detrimental to wild stocks. There is also increasing scrutiny of coral harvest fisheries given widely reported coral bleaching and reef degradation. While prescribed harvest limits are increasingly being imposed for individual species, the sustainability and suitability of current harvest levels and limits are unknown. Critically, there is a lack of necessary information and data to allow for rigorous and ongoing stock assessments, which are necessary to clearly establish and implement sustainable harvest limits for heavily harvested and potentially vulnerable coral species. This talk will outline recent progress, but also critical research and management priorities, needed to secure the future of commercial coral harvesting against the backdrop of increasing threats and reef degradation.

Morgan Pratchett
James Cook University
morgan.pratchett@jcu.edu.au

Thinking outside the box: patterns and processes in the initiation of renewed population irruptions of Pacific Crown-of-Thorns Starfish (*Acanthaster* cf. *solaris*) on Australia's Great Barrier Reef

Pratchett MS, Caballes CF, Chandler JF, Chen CMC, Doll PC, Lang BJ, Matthews SA, Uthicke S, Williamson D, Choukroun S

Recurrent population irruptions of Pacific Crown-of-Thorns Starfish (COTS; *Acanthaster* cf. *solaris*) are one of the foremost contributors to coral loss and reef degradation on Australia's Great Barrier Reef (GBR). Effective and enduring management of COTS population is largely conditional on understanding when, where and why population irruptions start. Extensive recent surveys to assess inter-annual variation in the size and abundance of COTS, both inside and outside the putative 'initiation box', provide unprecedented insights into the patterns and processes involved in the initiation of renewed population irruptions. Critically, elevated densities of large (and highly fecund) COTS were detected in the far northern GBR well before apparent increases in COTS densities within reef areas traditional regarded to be the initiation zone. These results challenge the prevailing paradigms regarding the underlying cause(s) of population irruptions on the GBR, and necessitate a re-thinking of required management responses.

Morgan Pratchett
James Cook University
morgan.pratchett@jcu.edu.au

Applying Indigenous and western science knowledges to inform the sustainable management of a dugong and seagrass hotspot in the Girringun TUMRA, Queensland

Pryor J, Girringun Rangers, Carter A, Groom R, Cleguer C

Girringun Aboriginal Corporation (GAC) and ranger program provide an opportunity for Indigenous people from nine Traditional Owner groups to actively manage their land and sea country, with the ultimate goal to heal and restore Country in the Great Barrier Reef. GAC are concerned about reduced resilience for the coastal environment in their sea country. As part of a collaboration with seagrass and dugong experts from James Cook University and Charles Darwin University, GAC is working to address identified knowledge gaps around dugong and seagrass that are core to Girringun Traditional Owner's cultural identity and traditional values. The project uses a two-way knowledge approach, incorporating Indigenous knowledge and western science and technology to (1) enhance understanding of significant dugong populations and seagrass habitats, (2) build research and monitoring skills and employment opportunities for Girringun rangers, (3) communicate with local Traditional Owners and the broader community and support them in strengthening their relationship with Country, and (4) plan monitoring activities to ensure ongoing connection to Sea Country and understanding of ecosystem health. In this talk we describe our partnership and present recent results from surveys in the northern Hinchinbrook Island area, Queensland.

Phil Rist
Girringun Aboriginal Corporation
tumra@girringun.com.au

Advancements in seeding coral spat and microfragments for reef restoration: defining drivers of survival from five years of experimental deployments and large field trials

Randall CJ, Jurriaans S, Whitman TN, Page CA, Forester R, Lefevre C, Stephenson B, Giuliano C, Ferguson S, Sims C, Abdul Wahab MA, Hoogenboom M, Severati A, Negri A

The renewal of coral populations via natural recruitment is being impacted by ocean warming. Seeding sexually produced coral juveniles and asexually generated microfragments is a promising restoration technique to augment recruitment and accelerate natural adaptation. Yet, inherently low rates of survival during early ontogeny, particularly on degraded reefs, challenge the cost and scalability of this intervention method. Here we synthesise the results of four years of in situ coral-seeding experiments and upscaled field deployments on the Great Barrier Reef, to inform methods development in three key areas: (1) optimising seeding-device designs; (2) describing environmental drivers of survival and growth to inform deployment decisions; and (3) developing procedures for rapid and up-scaled deployment and censusing. Lastly, we identify current knowledge gaps and bottlenecks, which are the focus of on-going research, and present forward-looking plans for implementation at ecosystem-wide scales.

Carly Randall
Australian Institute of Marine Science
c.randall@aims.gov.au

Operationalising resilience-based management in the Great Barrier Reef World Heritage Area

Read MA, Contarino A

The Reef Joint Field Management Program (Program) is jointly funded by the Commonwealth and Queensland Governments to deliver field-based activities in the Great Barrier Reef World Heritage Area. This includes rehabilitation activities on islands and coral reefs with the aim of minimising threats to the World Heritage Area, build resilience for the Reef, islands and species, and deliver Reef Blueprint initiatives and Reef 2050 Plan objectives. In the increasingly contested and congested space of Reef rehabilitation, the Program makes deliberate decisions to invest time and resources in areas for which we are uniquely positioned to deliver beneficial conservation outcomes and enhance resilience, supported by a robust governance framework and evaluation of management effectiveness. Delivering this program of work relies on working with a broad range of partners (e.g. Traditional Owners, researchers, tourism operators) and incorporating innovative techniques and technologies to maintain a contemporary focus and enhance project delivery.

Mark Read
Reef Authority
mark.read@gbrmpa.gov.au

Supporting the long-term resilience of the Great Barrier Reef through water quality improvement programs

Reyes-Nivia C, Perez A, Gongora M, Trewin C, Oliver G, James C, Speed R

Improving water quality is one of the most critical actions to protect the Great Barrier Reef (GBR) and build resilience against threats like climate change, coastal development, and Crown-of-Thorns outbreaks. Thirty-five catchments drain into the GBR, with excess sediment, nutrient, and pesticide pollution from agricultural run-off the main sources of poor water quality impacting the health and survivorship of corals. Within this context, new regulations and significant investment by the Australian and Queensland governments are key resilience-based policy and management initiatives in support of the Reef 2050 Long-Term Sustainability Plan. As part of this process, the Partnership between the Australian Government Reef Trust and the Great Barrier Reef Foundation is the largest global effort to date with $200m allocated to address water quality issues in support of reef resilience and recovery efforts. Since 2018, the RTP Water Quality Program has accelerated on-ground actions towards water quality improvement targets through activities such improved farming practices, reduced fertiliser use, landscape remediation, protection of unique areas and uptake of new technology. The program has been able to achieve significant pollutant reductions that are expected to improve long-term local, regional and GBR-wide resilience and provide recommendations for future resilience-based management initiatives.

Catalina Reyes-Nivia
The Great Barrier Reef Foundation
creyes@barrierreef.org

Interpretable rules for resilient reef futures with SIRUS

Ribeiro de Almeida P, Iwanaga T

Managing complex systems such as the Great Barrier Reef is challenging due to the uncertainties at play. Current practice in Decision Making under Deep Uncertainty is to explore many modelled scenarios (potentially tens to hundreds of thousands) with its many – potentially competing – outcomes. The aim is to discover strategies that are robust to many plausible futures while also highlighting the conditions for success and failure. Understanding these conditions then enable the development of proactive adaptive management plans. Interpretation and assessment of results have often relied on an iterative process of data analysis and assessment. We apply the SIRUS (Stable and Interpretable RUle Set) classification algorithm based on random forests to induce or extract short lists of governing rules from the scenarios run. These rules aid in identifying the key factors – from environmental conditions to policy levers including interventions – which drive system behaviour towards resilient reef futures and the context in which they are important. Moreover, the produced rule sets are easily interpretable and explainable, easing the communication process to partners and stakeholders. The approach is included as part of the ADRIA decision support platform, an openly developed RRAP and AIMS initiative to guide reef restoration and adaptation.

Pedro Ribeiro de Almeida
Australian Institute of Marine Science
p.ribeirodealmeida@aims.gov.au

Hidden dimensions of coral biodiversity: cryptic taxa, hybridisation, and why it matters for restoration

Riginos C, Popovic I, Meziere Z, Garcia V, Howitt S, Byrne I, Briggs E, Lei C, Ishida H, Khan Clark V, Richards T, Bairos-Novak K, Prata K

It has long been recognised that morphological variation in corals does not align well to genetic variation. Multilocus population genetic surveys often uncover distinct genetic taxa within morphologically defined taxonomic species, so called cryptic species. Additionally, hybridisation among corals has often been suspected, with genetic studies confirming some examples. The emerging consensus, then, is that genetically distinct groups may commonly coexist within dispersal range and that these groups may be linked by low levels of gene flow. To investigate the prevalence cryptic taxa and hybridisation among corals, we focus on population genomic data. We undertook a structured literature review and re-evaluated published studies for evidence of cryptic taxa and hybridisation using stringent and reproducible criteria. We find that signatures of cryptic taxa are common across corals and hybridisation is frequent. The pervasiveness of these phenomena should influence how we approach coral conservation and restoration, and these implications will be discussed. We will also present best practice guidelines for population genomic studies such that their results can more readily guide conservation and restoration practice.

Cynthia Riginos
Australian Institute of Marine Science
c.riginos@aims.gov.au

Biodiversity credits as a sustainable financing option for scaling up coral reef restoration and adaptation

Robillot C, Anthony K

The impact of global warming on coral reefs is increasingly evident. Marine heatwaves and mass bleaching are no longer considered extraordinary events and managers are actively considering how technology options such as those developed by the Reef Restoration and Adaptation Program (RRAP) could be scaled up and become an integral element of ecosystem management. Assuming effective interventions can be developed technically, identifying sustainable funding models will be critical to take these interventions to scale, safely and fast. With support from the Australian Government and the L'Oréal Fund for Nature Regeneration, AIMS, GBRF and partners are leading a project to develop the core science needed to underpin coral biodiversity accounting and to establish a pathway towards a coral biodiversity credit that could streamline fair, equitable, transparent and sustainable investment in place-based restoration and adaptation projects. Opportunities and risks associated with the supply of and demand for biodiversity credits are discussed in the context of the Global Biodiversity Framework and efforts to drive corporate investment in the conservation and restoration of nature.

Cedric Robillot
Great Barrier Reef Foundation
crobillot@barrierreef.org

Evaluation of Models for Decision Support in a Changing Environment

Robson BJ, Bode M, Bozec Y-M, Condie S, Cresswell A, Iwanaga T, Langlais C, Marinovich M, Ortiz JC, Passaris N

RRAP M&DS has developed a suite of ecological models and decision support tools to facilitate informed decision-making for conservation and management of coral reefs. When using predictive models, it is important to communicate the expected reliability of their predictions, especially when they will be the basis for regulatory or financing actions. Assessing fitness for purpose requires a clear specification of purpose, including the context and the operational constraints (e.g., response time and computational resources) under which the model will be used. It is not always possible to specify in advance the details of the context in which our models will be used; nor is it possible to fully quantify predictive performance. Observational data for the GBR are sparse, and we need to make assumptions about how future environmental conditions will unfold and how ecosystems will adapt to these changes. Hence, we need a flexible model evaluation approach, opportunistically using existing data while more clearly defining future observational needs. We present a framework for evaluation of predictive models in the context of sparse data, poorly defined operational context, and an uncertain environmental future. The framework applies four levels of evaluation (conceptual, state, process and system evaluation) and explicitly considers operational issues.

Barbara Robson
Australian Institute of Marine Science
b.robson@aims.gov.au

Evaluating the use of a high-throughput phenotyping tool to guide selection of coral material for restoration purposes

Roper CD, Suggett DJ, Herdean A, England H, Howlett L, Edmondson J, Camp EF

As coral restoration efforts intensify worldwide, selection of coral material that has beneficial emergent phenotypes has been identified as a strategy to increase future reef resilience. However, any approach which filters source material, such as through selection of colonies with advantageous phenotypes, could unintentionally reduce genetic diversity, and thus it is important to understand the potential consequences of colony selection based on phenotyping. Furthermore, high-throughput tools that allow us to characterise phenotypic diversity rapidly and cost-effectively in the field are generally lacking. In this study, we apply a novel, high-throughput phenotyping device to examine differences in photophysiological performance of 186 colonies from 3 reefs and 7 sites across the continental shelf (250 km2) under a thermal gradient (24° –37°). Through a rapid (4 colonies/40 minute) assay, we assess maximum quantum yield, electron transport rate, saturating irradiance, and non-photochemical quenching. We further assess the genetic structure of the phenotyped corals to evaluate how emergent phenotypes related to the underlying genetics. Our work shows that photophysiological responses varied significantly across reef communities and did not align with genetic structure which revealed a single, highly connected population, suggesting that selection of corals based on their photophysiological performance would not impact genetic diversity. This work demonstrates the potential of high-throughput phenotyping to identify corals with differences in predicted thermal optimum for targeted use within restoration.

Christine Roper
University of Technology Sydney
christine.d.roper@student.uts.edu.au

Rebuilding the reefs of Peel Island, Moreton Bay, Queensland

Salmond JG, Schubert JM

Coral reefs in Moreton Bay are regarded as close to environmental extinction, so how do we save them? With low water clarity and high sedimentation challenges, corals struggle to settle and thrive on the existing substrate, particularly in areas of low current flow. Our project is utilising metal frames to lift corals above the sediment to understand the survival of transplanted fragments at different elevations off the existing substrate within inshore Moreton Bay. Whilst growing corals and healthy reefs are important, we believe it is equally vital to involve local communities in restoration projects to achieve success. Including communities in restoration activities allows more people to contribute to reef protection and promotes marine stewardship. The frames are located within an area adjoining a prime anchorage site, in an area with historically high coral cover. This easy-to-access site allows the observation and documentation of the survival of the transplanted coral, currently being monitored by local volunteers. Initial observations suggest survival varies between species of coral, with some showing evidence of growth whilst other species are subject to predation by other marine organisms.

Jodi Salmond
Reef Check Australia
jodi@reefcheckaustralia.org

Eco-evolutionary considerations and practices in coral reef restoration

Sato Y, Lamb A, Brunner R, Morgans C, Doyle J, Grimm CM, Barton J, McCutchan G, Smith H, Sedgwick A, Edmunds R, Elder H, Abdul Wahab MA, Stephenson S, Pavlova A, Sunnucks P, Negri A, Severati A et al.

Resilience is crucial to the survival of corals under threat. Reef conservation must therefore support the resilience of corals, which is influenced by their 1) genetic diversity and 2) tolerance to environmental changes. The Reef Restoration and Adaption Program (RRAP) is working to maximise the resilience of multiple key coral species by considering their genetic make-up when conducting 1) scalable conservation aquaculture, 2) targeted interventions such as assisted evolution, and 3) deployment of corals to suitable reef communities. Quality assurance and quality control (QA/QC) monitoring of the genetic make-up of produced coral is essential for ensuring that reef restoration efforts effectively support reef resilience. For example, sequencing data revealed that sexually-propagated coral spats can be genetically depauperate, which could be alleviated by selecting and breeding genotyped broodstock. QA/QC tools must be time-efficient to be useful in coral aquaculture practices, e.g. by employing rapid and scalable genetic sequencing techniques. Digital PCR-based eDNA assays are also established to ensure that corals grown in high densities in captive environments pose minimal risks of transferring microbial diseases and pests into wild reef environments. Under RRAP, we are developing interventions and tools that will help maximise eco-evolutionary impacts in our effort towards coral reef conservation.

Yui Sato
James Cook University
yui.sato1@jcu.edu.au

Economic assessment of GBR management strategies

Scheufele G, Skinner C, Fletcher CS

The Reef Restoration and Adaptation Program (RRAP) and the Crown-of-thorns starfish Control Innovation Program (CCIP) are focused on the development and deployment of management tools that support the resilience of the Great Barrier Reef. These management tools may differ in terms of inputs used, costs incurred, outputs produced, and benefits generated. An economic assessment framework was developed to assess these alternatives explored under RRAP and CCIP. The economic assessment framework enables the analysis of regional economic impacts, cost-effectiveness ratios, productive efficiency, trade-offs, and net social benefit. It adds to the decision support toolbox that has been developed under these two programs to optimise resource allocation for maximum impact. This presentation demonstrates the application of this framework within CCIP by showing the results of a cost-effectiveness, productive efficiency, and trade-off analysis of alternative manual CoTS cull strategies that aim to maximise live coral cover and minimise the number of outbreaking reefs. The economic assessment is based on estimates of ecological outcomes for each strategy estimated by a spatially explicit ecosystem model of the GBR. Scenarios examine the effect of spatial distribution of vessels, considering different regions, protected versus fished reefs, and dynamic responses to CoTS outbreak fronts.

Gabriela Scheufele
CSIRO
gabriela.scheufele@csiro.au

The Cairns-Port Douglas Reef Hub: An open, place-based collaborative network for local reef stewardship

Scott A, Chartrand K, Loder J, Laycock P, Lockie S, Singleton B, Iovanella P, Gaskell J, Mattocks N, Donnelly R

As the number and type of active Reef protection and rehabilitation efforts increase, so does the need for more collaborative, scalable and practical approaches. The Cairns-Port Douglas Reef Hub is a pilot project to strengthen and scale ways to deliver this work using a place-based network to learn, share and collaborate across First Nations, tourism operators, non-profits and scientists working and living in the region and beyond. The Hub was developed and designed with input from the local community and has used an action learning approach throughout design and delivery phases, working to build a valued network that meets a range of needs by continually learning and adapting. Since on-ground activity began in January 2021, the Hub has run capacity building workshops to enable growth and foster techniques that support assisted coral recovery projects and generate regional, open-source data. We have also worked to nurture connections across the Hub network and link active participants to relevant researchers and organisations. We will share some of the learnings from our activities using a place-based approach, discuss the benefits of a diverse network and look to the future of the Cairns-Port Douglas Reef Hub beyond the pilot phase.

Abbi Scott
James Cook University
abbi.scott1@jcu.ecu.au

KULBUL-BARRA – We are the Ocean

Singleton G

The Great Barrier Reef is an integral part of our culture, heritage, identity and wellbeing. It has been instrumental in our survival and resilience as coastal Traditional Custodians. Our land and sea has many stories to tell including how we must live, use, conserve and manage this special coastal landscape for the present and future. Today, our Great Barrier Reef faces many challenges. It is not only under threat by natural events, but also by multiple and accumulative impacts. This poses the question – is the Great Barrier Reef resilient enough to withstand these impacts in the long term? This is what our Great Barrier Reef community has been debating for some time. As one of the Great Barrier Reef's Traditional custodians, we are concerned about the future of our reef country. We, the Yirrganydji, have been active in doing our part in reef conservation, management and stewardship with the goal to enhance the resilience and both natural and cultural integrity of our Great Barrier Reef. Our presentation will provide a Yirrganydji First Nations perspective on reef resilience, management and stewardship, some of the challenges that we face, and potential solutions to enable effective and efficient action on the Great Barrier Reef.

Gavin Singleton
Project Manager, Yirrganydji Land and Sea Ranger Program (Dawul Wuru Aboriginal Corporation)
gavin@dwcorp.com.au

Connecting local students to Culture and conservation

Singleton TS, Thaiday DT

The Reef Cooperative is a group of colleagues with a shared vision coming together to look after Sea Country and to better understand the reef through the combination of traditional ecological knowledge and contemporary science. The Reef Cooperative Education Program weaves together Traditional Ecological Knowledge with cutting-edge 21st-century conservation initiatives, such as the Great Reef Census, within the local school curriculum. This pilot program complements Yirrganydji people's connection to the land and sea, promoting contemporary management of the Great Barrier Reef for future generations. Engaging schools in the Cairns and Port Douglas regions, this pilot program is led by First Nations education officers and includes lessons on Yirrganydji People and Country. The curriculum explores Yirrganydji perspectives on custodians, stewardship and caring for Sea Country, with a focus on coral reefs, reef habitats and marine life. Lessons extend to interventions, monitoring techniques and pathways into reef management. The program seeks to instil a sense of responsibility and connection to the Great Barrier Reef in the hearts of local students. This collaborative partnership provides a unique classroom that shows co-design, co-lead and co-manage approach, in hopes to opens their minds to a holistic solution to care for country.

Tarquin Singleton
Reef Cooperative
tarquin@citizensgbr.org

Ecological assessments of alternative Crown of Thorns Starfish control strategies using regional models of the Great Barrier Reef

Skinner C, Condie SA, Fletcher CS, Scheufele G, Mumby PJ

The Great Barrier Reef (GBR) is primarily managed through a zoning system that regulates where fishing is permitted. Zoning influences not only fish populations, but also the broader reef ecosystem through trophic cascades. Importantly, fish targeted by commercial and recreational fishers include predators of the Crown-of-Thorns Starfish (COTS, *Acanthaster* spp.), which can reproduce rapidly to form outbreaks capable of decimating coral populations. This has led to concerns that fishing pressure may increase the susceptibility of some reefs to destructive COTS outbreaks. We describe progress in modelling the effect of zoning on the GBR ecosystem using the Coral Community Network model (CoCoNet). This model represents food web interactions between fish, corals and COTS on reefs exposed to increasing cumulative pressures from tropical cyclones, marine heatwaves and COTS outbreaks. It also includes the influence of human activities, such as commercial and recreational fishing, as well as control of COTS. Ensemble simulations suggest that commercial fleet reductions and comprehensive zoning (fishing excluded from one third of reefs) introduced in 2004 significantly benefited reef health, and now potentially works synergistically with CoTS control. While current results are exploratory, the ultimate purpose of the model is to help integrate empirical data in a way that supports sustainable management of the Reef.

Christina Skinner
The University of Queensland
tina.skinner@uq.edu.au

A local, "grass roots" collaboration for the restoration of tropical seagrass in north Queensland

Smith T, Gimuy Rangers, Mandubara Rangers, Goondoi Rangers, Collins G, Scott A, Rasheed M, York P

Large-scale coastal restoration projects require the inclusion, coordination and collaboration of local community stakeholders for the best results. Inclusive and coordinated projects benefit from diverse knowledge bases including scientific, traditional and local ecological understanding of the location and ecosystem being restored. These projects also provide employment, engagement as well as economic and social benefits to local communities involved. Coastal seagrass ecosystems along the north-east coast of Queensland were severely impacted by a series of storm and flood events between 2007 and 2011. Meadow-scale losses of seagrass throughout the region showed variable recovery in the following decade with some meadows completely lost with no natural recovery, (e.g. Mourilyan), while others took between 2 years (Townsville) and over 10 years (Cairns) to recover. These results highlighted the need to develop robust and fit for purpose seagrass restoration methods for tropical species and habitats. In response a partnership between researchers, Traditional Owner groups, recreational fishers, resource managers and philanthropic bodies was established to develop techniques suitable for the harsh environmental conditions of tropical estuaries (e.g. crocodiles, marine stingers and deep mud). The program, built on three years of pilot studies testing different planting procedures, is in its first year and runs to mid-2027.

Tim Smith, Gimuy Rangers, Mandubara Rangers, Goondoi Rangers, and Geoff Collins
James Cook University, Gimuy Rangers, Mandubara Rangers, Goondoi Rangers, and OzFish
tim.smith2@jcu.edu.au

Could an inexpensive, low-tech, low-energy, small-scale intervention that reintroduces "normal" mixing of the water column improve outcomes for corals during acute mass bleaching events?

Stanley D, Long S, Fisher E, Morris S, Pattiaratchi C

Acute periods of low upper ocean turbulence create stressful conditions for corals by concentrating heat in the upper water column, reducing the aggregate water flow available to corals, and increasing the transparency of the water column due to reduced sediment resuspension. Temperature, irradiance and flow can thus be seen to be tied to a single parameter: upper ocean turbulence. Analyses of millions of IMOS ocean glider temperature data points collected through the water column of the Great Barrier Reef in bleaching and non-bleaching summers show that mass coral bleaching events are coincident with acute oceanographic conditions characterised by periods of low winds, leading to the formation of a stratified, low-turbulence upper ocean layer. These data are supported by models such as eReefs. Mass bleaching does not occur unless these acute oceanographic conditions are in place. This increased mechanistic understanding leads to the question of whether reintroduction of turbulence and resultant mixing of the water column adjacent to small valuable reef sites could reduce coral stress and improve outcomes during these forecastable acute stratification events. This potential intervention is an attractive option from an engineering perspective because the energy required to reintroduce turbulence is very low, and the infrastructure required to accomplish mixing need not be high-tech or expensive, and could be temporarily deployed (hours/days) during normal reef tourism activities. This presentation will use publicly-available ocean glider data to demonstrate features of the water column on the Great Barrier Reef during "normal" conditions and leading up to and during mass coral bleaching events. We will also demonstrate a prototype low-power mixer in operation at Moore Reef that successfully moved cool water to the surface from a depth of 20 m during the 2020 bleaching event.

Dennis Stanley
University of Western Australia
dennis.stanley@uwa.edu.au

Scaling out, up and deep: Lessons in collaborative planning from the Reef Restoration and Adaptation Program (RRAP) Community Panels

Stone-Jovicich S, Bohensky E

The Reef Restoration and Adaptation Program (RRAP) affords strong recognition of public involvement in deployment for proposed reef restoration interventions in the Great Barrier Reef (GBR). As RRAP shifts from R&D to deployment at scale, regional collaborative planning processes that provide two-way deliberations among different 'publics' (community members, stakeholders, and First Nations peoples), RRAP scientists, and regulators will be critical to ensure the relevance, credibility and legitimacy of decisions made regarding which, where, and how reef interventions are deployed. We discuss RRAP community panels (Townsville and Cairns) as an engagement mechanism with potential to guide RRAP's broader collaborative planning process. We focus on community panels' ability to "scale out, up, and deep" (Moore et al. 2015) through two-way knowledge exchange, deliberation, and relationship-building among community members, RRAP scientists, and regulators. Community panels can 'scale out' engagement and deliberation principles and design features to other collaborative reef engagement processes, both within RRAP and across the GBR. The panels also offer insights for reef policy, regulations and management, particularly on ways to integrate community engagement for improved reef outcomes ('scaling up'). Lastly, the panels provide a mechanism to foster a more deliberative culture around reef issues ('scaling deep').

Samantha Stone-Jovicich
CSIRO
samantha.stone-Jovicich@csiro.au

Coral Nurture Program: A collaborative approach to coral propagation and out-planting on the Great Barrier Reef

Strudwick P

Researchers, tourism operators, and reef stakeholders have joined forces along the Great Barrier Reef in a collaborative effort to enhance natural recovery of high-value reef sites through targeted coral propagation and out-planting. Coral Nurture Program encompasses this cohort of reef stewards and facilitates the timely integration of pioneering science into reef restoration activities. Surpassing the initial proof-of-concept phase Coral Nurture Program extends beyond the Cairns and Port Douglas region and has established activities with three high-quality tourism operators in the Whitsundays. We are now also working to maximise resilience in all practices. Building on tourism operator knowledge of site histories and using state of the art scientific equipment we aim to develop methods to select more tolerant individuals and boost resilience of reefs to sustain their ecological functioning and ecosystem services into the future. In October 2023 we established the first nurseries seeded with coral fragments from parent colonies which were phenotypically characterised. This study will garner knowledge required to inform selection of the most tolerant individuals for propagation and subsequent out-planting. Incorporating resilience building into practices is integral for reef restoration activities to be successful into the future while global stressors are mitigated.

Paige Strudwick
University of Technology Sydney
paige.strudwick@uts.edu.au

Fate of climate refugia in the Great Barrier Reef

Sun C, Steinberg C, Klein Salas E

Aerial surveys show some regions in the Great Barrier Reef have consistently escaped severe coral bleaching since 1998. A critical management question is why these areas avoid thermal bleaching stress and whether these refugia will persist into the future. Identification and protection of these refugia may help facilitate reef survival and related biodiversity by allowing corals time to acclimatise and adapt, and provide source populations to replenish the rest of the reef. Using dynamical downscaling with nested ocean models, we show that these climate refugia may persist into the future even under a high-emission scenario.

Chaojiao Sun and Craig Steinberg
CSIRO
chaojiao.sun@csiro.au

A new coral reef monitoring tool: Species specific eDNA allows quantification and early detection of Crown-of-Thorns Seastar outbreaks

Uthicke S, Doyle J, Gomez Cabrera M, Patel F, Doll P, Chandler J, Pratchett M, Lawrence E

Coral predation by Crown-of-Thorns Sea stars (COTS) is a major contributor to the coral reef crises in the Indo-Pacific Region, with the 4th COTS outbreak on the Great Barrier Reef ongoing for more than 14 years. To address this, early detection tools are essential for timely intervention and understanding outbreak initiation zones. Current monitoring methods only identify COTS once outbreaks are established. We present an innovative approach using environmental DNA (eDNA) using digital droplet PCR to detect and quantify COTS presence. Through several independent datasets, we established a significant relationship between COTS eDNA and densities, detecting COTS distinctively below outbreak levels. In addition, a five-year time series using eDNA confirms a developing 5th outbreak in the Lizard Island area. To support the COTS control program, we propose integrating eDNA monitoring into large-scale programs for early outbreak detection and efficient intervention. This method not only supports reef restoration but also safeguards explanted coral from restoration projects, and coral that survived bleaching events; possibly acclimatised to elevated temperatures. Our findings underscore the importance of proactive monitoring for mitigating the impact of COTS on coral reefs.

Sven Uthicke
Australian Institute of Marine Science
s.uthicke@aims.gov.au

Bridging the gap to using heat-tolerant coral photosymbionts in reef restoration

van Oppen MJH, Abrego D, Allen C, Alvarez Roa C, Boulotte N, Buerger P, Chan W, Fae Neto W, Ivory E, Johnston B, Meyers L, Velasquez CP, Peplow L, Perez T, Scharfenstein H, Nitschke MR

The heat tolerance of corals is largely determined by their microbial photosymbionts (Symbiodiniaceae, a.k.a. zooxanthellae). Therefore, manipulating symbiont communities may enhance the ability of corals to survive summer heatwaves. Heat-tolerant and -sensitive symbiont species occur naturally on the Great Barrier Reef (GBR), but corals that associate with the most heat-tolerant species in the genus *Durusdinium* tend to show slower growth rates at ambient temperatures compared with those harbouring more sensitive species in the *Cladocopium* genus. Further, even corals that harbour *Durusdinium* species have been observed to bleach during summer heatwaves. We employed experimental evolution (i.e., laboratory selection) of Symbiodiniaceae cultures under elevated temperatures, and demonstrate this approach can enhance their upper thermal tolerance in vitro and in hospite following their reintroduction into corals. Enhanced tolerance was observed across coral life stages, in taxonomically divergent corals and in the presence of native symbionts. Notably, coral growth under ambient conditions was not compromised when heat-evolved *Cladocopium* was present. Encouragingly, the new symbioses with heat-evolved symbionts were shown to be stable for at least two years in aquarium experiments. Field trails are underway to assess the risks and benefits of this intervention.

Madeleine van Oppen
Australian Institute of Marine Science
m.vanoppen@aims.gov.au

Highlights from the Coral Restoration Consortium

Vardi T

The Coral Restoration Consortium began in 2017 as a way to synthesize the best science and put it into the hands of practitioners. Since then the CRC has restructured and become a global community of practice – a place where people who care about solutions to the coral crisis convene regularly and improve the effectiveness of their conservation strategies. In 2023 we revamped how we do business, placing a greater emphasis on listening to what practitioners need, diversifying our leadership, and focusing on the exchange of knowledge within particular regions. During this talk we will articulate some of the actions we have taken under our new structure, and discuss current trends in coral restoration – including a realistic look at scale, available new technologies, and the state of small scale restoration world-wide. The talk will also show how CRC is looking to the future to analyze the permitting, policy, and regulatory landscape and what is needed to move the needle on interventions that ensure a future earth with coral reefs.

Tali Vardi
Coral Restoration Consortium
tali@crc.world

A Monitoring, Evaluation, and Learning Strategy for engaging reef communities in large-scale assisted ecosystem adaptation

Vella K, Baresi U, Eberhard R, Gooch M, Calibeo D, Piggott-McKellar A

Large-scale assisted ecosystem adaptation and restoration that involves novel interventions is often associated with social, cultural, economic, and environmental complexity and uncertainty. We present an original strategy designed to evaluate engagement in the stakeholder and Traditional Owner Engagement subprogram within the Reef Restoration and Adaptation Program (RRAP). RRAP, an unprecedented large-scale assisted ecosystem adaptation program involving the use of novel interventions, is still in a research and development phase. Because of this, our strategy combines elements of traditional performance monitoring and evaluation with a focus on learning what RRAP engagement needs, and how achieve it. A collaborative learning effort across the Engagement subprogram guided the conceptualisation of this strategy, leading to a set of operating principles, a program logic, and evaluation criteria. This strategy provides lessons and key findings on the effectiveness of engagement within RRAP and with external reef communities, as well as how impactful the Engagement subprogram has been on influencing RRAP decision-making. This strategy represents a pioneering approach to evaluating and learning how engagement with Traditional Owners can be done effectively to collaborate with interested communities and First Nation peoples towards managing risks and benefits of assisted ecosystem adaptation interventions, and collaboratively monitor impacts on the environment.

Karen Vella
Queensland University of Technology
karen.vella@qut.edu.au

Using environmental markets to fund restoration of coastal wetlands and coral reef protection

Waltham N, Sheaves M, Motson K

Coastal wetlands support incredible ecosystem services, in addition to holding cultural values. Their loss has wide-reaching and long-term implications to these services and values. Restoring wetlands has become an important strategy for governments in meeting local and international agreements (e.g. Kunming Global Biodiversity targets – 30 x 30). Restoration has the potential to mitigate climate change through the capture and long-term storage of carbon in the vegetation, soils, and sediments of marine ecosystems, known as 'Blue Carbon'. Working with industry, community, Indigenous groups, government and NRM groups, our research is examining land use change, restoration, and management opportunities, undertaken in accordance with government-regulated crediting methods (e.g. ACCU scheme methods) or non-government regulated but scientifically credible methods (e.g. Reef Credits for reduction in loads of dissolved inorganic nitrogen (DIN) reaching the Great Barrier Reef lagoon at end of catchment). Using case studies, we outline the possible opportunity to use environmental markets to fund restoration of coastal wetlands. The scale of restoration projects will be an important requirement in achieving regional and international targets, but this requires greater cooperation and partnerships to be formed.

Nathan Waltham
James Cook University
nathan.waltham@jcu.edu.au

Predator-prey dynamics of the Crown-of-Thorns sea star in their juvenile life stage

Wolfe K, Desbiens AA, Dworjanyn S, Uthicke S, Mumby PJ

Predator-induced mortality of the corallivorous Crown-of-Thorns sea star (COTS) during its herbivorous juvenile life-stage may be a bottleneck limiting population success and outbreak formation. We have documented a suite of novel predators of juvenile COTS in their rubble nursery and characterised susceptibility to predation owing to predator-prey sizes, prey density, and predator morphology. Maximum consumption varies (1–20 COTS d-1) dependent on predator species. The exceptional predator, *Schizophrys aspera*, consumed entire COTS up to 10 mm diameter and continued to injure juveniles large enough to transition to coral. Reef- and regional-scale distributions of these predators appear inverse to populations of adult COTS, suggesting appreciable top-down pressure on juveniles in their rubble nursery is a natural mechanism contributing to outbreak suppression. Manual and eDNA monitoring of juveniles and their predators in rubble may provide early warning signals of outbreak susceptibility, which this project has initiated through workshops and training with Traditional Owners, and engagement with tourist operators. Our project provides justification for how investment in a more holistic understanding of the biology and ecology of COTS across their life cycle can inform natural control of this species and the social and ecological resilience of coral reefs.

Peter Mumby
The University of Queensland
p.mumby@uq.edu.au

Women in Marine Conservation

Wong K, Nusantari H

Descendants of the Bajo People, nomads of the oceans, the dedicated women from the Women in Marine Conservation program (WMC) have made history in Poto Tano waters. With the help of JARI Foundation in collaboration with Australian New Colombo Plan (NCP) interns WMC was founded to enable women to enter a male dominated conservation scene through empowerment, inspiration and education. The women of WMC revealed that they rarely entered these waters and were intrigued by the beauty that was the coral reefs; they were also astounded by the effects of the plastic pollution and disappointed by the destruction left by the dynamite fishing. Upon discovering this newfound playground, they have been inspired to learn how to snorkel, SCUBA dive, conduct Coral Watch surveys and assist with coral restoration projects. Through regular lectures, these women learnt of the importance of healthy coral reefs and their role in the conservation of their health. Inspired and equipped with the skills and knowledge, these women have shared the revelations with their families and the local fishermen; now conducting regular coral watch surveys with the local fishermen group. The women of WMC have been exemplary in bringing village-wide awareness of the importance of the reef and inspiring others to assist with its conservation.

Kimberly Wong
JARI Foundation
kimiwg10@gmail.com

Semiochemical control of Crown-of-Thorns Starfish through scalable bioprocessing

Yap K, Motti C, Harris R, Degnan SM, Degnan BD, Wang CK, Craik DJ

The Great Barrier Reef is under threat by the Crown-of-Thorns Starfish (COTS), a voracious predator of live corals. Frequent COTS population outbreaks with densities of >150,000 COTS/km^2 have led to widespread destruction of corals. The current method of COTS bio-control relies on divers manually injecting COTS one-by-one. However, this method is labour intensive and only effective in small areas. This research aims to develop a scalable strategy to control COTS outbreaks by creating species-specific baits that can be effective on a regional scale. The precursor to producing these baits is identifying biomolecules involved in COTS communication. Here, a rapidly scalable and widely used bioprocessing method, tangential flow filtration, was used to fractionate COTS-conditioned seawater by molecular weight. The resulting fractions were tested in COTS behavioural assays to determine and identify attractants through mass spectrometry-based proteomics. These results will provide a greater insight into COTS communication, which can exploited in the development of baits population control.

Kuok Yap
The University of Queensland
kuok.yap@uq.edu.au

Acknowledgement

Delivering this Symposium during a time of crisis for the world's reefs, while seeking to genuinely reflect the views and activities of diverse stakeholders locally, nationally and worldwide, has not been a trivial task.

We would like to thank our local Cairns sponsors, whose interest in the mission of the Symposium and willingness to subsidise have greatly contributed to its impact:

Reef and Rainforest Research Centre
Experience Co
Pullman Reef Hotel Casino
Encore Event Technologies
Danae Jones Consulting

... and all of our presenters and participants, both in-person and virtually.

All proceedings from the Symposium will be freely available online via the Symposium website:

reefresiliencesymposium.org

Image credits: (Page 4 Clockwise from top) Moving Corals Field Trip 2021, SCU. Coral Spawning November 2021 at AIMS National Sea Simulator including egg and spawn collection and propagation, settlement, cryopreservation, SkyReef Photos, AIMS. Coral Spawning November 2021 at SeaSim, SkyReef Photos, AIMS. AIMS researchers and SeaSim staff utilising a specialised coral propagation system known as the Autospawner during coral spawning 2021, SkyReef Photos, AIMS. (Page 21 Clockwise from top left) Great Reef Census 2022 Far North citizen science field expedition from Lockhart to Lizard Island for reef habitat and COTS reconnaissance, Jennifer Loder. Underwater image of Crown-of-Thorns Starfish on white coral, Shutterstock. Releasing larvae from floating pools on Heron Island December 2020, SCU. Boats4Coral operators deploying coral larvae on Reefs in the Whitsundays, Jodi Salmond, Reef Check Australia. (Page 68 Clockwise from left) Coral Spawning November 2021 at AIMS National Sea Simulator including egg and spawn collection and propagation, settlement, cryopreservation, SkyReef Photos, AIMS. Resilient Reefs 2022 Solution Exchange – Five years in the making, the Resilient Reefs Initiative's global team and site partners travelled to Brisbane in October 2022 all the way from Palau, New Caledonia, USA, Belize, France, WA and New Zealand to collaborate on project designs and solutions that will build the resilience of the world's reefs and their communities, Bec Taylor. A coral seeding device on a reef, ready to help its young coral passengers through their first year of life, Saskia Jurriaans, AIMS. (Page 69) Anthias, Unknown spp., and Fusilier, Caesio spp., mixed school, Gary Cranitch. (Page 71 Clockwise from top left) Coral Larvae stained blue, SCU. Green turtle underwater, Amanda Cotton, Ocean Image Bank. COTS Crew Members onboard the Tura with the 2023 'Biodiversity' Banksia Award, Rick Abom. Coral Spawning in SeaSimulator, Carly Randall, AIMS.


TURA

Reef Resilience Symposium 2024

#reefresilience2024

reefresiliencesymposium.org