Tropical Water Quality Hub

National Environmental Science Programme

NESP TWQ Hub Impacts & Achievements Conference

Program & Abstracts

28-29 April 2021

Pullman Reef Hotel Casino, Cairns

#nesptwq2021

Welcome to the NESP Tropical Water Quality Hub Impacts & Achievements Conference

The NESP Tropical Water Quality (TWQ) Hub is one of six hubs established under the Australian Government's National Environmental Science Program (NESP). Like those Hubs, the Tropical Water Quality Hub has operated from 2015-2021. During that period, we have funded ~90 projects, mostly focused upon water quality and ecosystem condition of the Great Barrier Reef (GBR).

The Tropical Water Quality Hub has been administered and managed by the Reef and Rainforest Research Centre (RRRC) which has drawn upon more than 200 researchers, mostly from our six partner research institutions – James Cook University, CSIRO, Australian Institute of Marine Science, Griffith University, the University of Queensland and Central Queensland University.

Reflecting on the priorities for GBR water quality, Day One showcases our work in reducing nutrient, sediment and pesticide runoff to the GBR from both farm and catchment management, and also via restoring and managing coastal wetlands. Day Two showcases our work in the marine environment which receives catchment runoff. Here we share our demonstrated outcomes in reducing the impact of Crown-of-Thorns Starfish on the Reef, responding to the 2016-2017 mass coral bleaching events and improving the management and monitoring of the Great Barrier Reef.

NESP TWQ Hub research is driven by end-user needs and is thus highly applied, focusing upon delivering tangible on-ground outcomes for environmental management, policy development or social/behaviour change, within the timeframe of the program. We are proud of our achievements in this regard and this final event offers an opportunity to display and share with our partners and collaborators, many of the topics we have worked on and successes we have had, over the last six years. We have postponed this event several times during the 2020-COVID19 affected year but are pleased to be able to host this event before the Hub concludes all operations in June 2021.

Although the Tropical Water Quality Hub will shortly come to an end, we will continue on in a different but related guise, managing one of four NESP Hubs established under the next iteration (2021-2027) of NESP – the NESP Marine and Coastal Hub. The Marine and Coastal Hub will have a much broader geographical and topical remit than the current Tropical Water Quality Hub, encompassing all of Australia and potentially considering all coastal and marine issues. The experiences we have learnt during the Tropical Water Quality Hub will greatly benefit us in this new, larger endeavor. We will continue with the same applied, end-user driven ethos, working to ensure that this approach to research becomes embedded as a standard practice.

We do hope that you are enriched by what you hear, see and learn at this event and that the pathways to improved social, economic and environmental outcomes from the work of the TWQ Hub are evident. Thank you for taking the time to share this last major public event with us and are very grateful for your commitment and efforts working constructively with us over the last six years.

Leith Boully, ***NESP Tropical Water Quality Hub Steering Committee Chair***

Sheriden Morris, ***NESP Tropical Water Quality Hub Administrator & RRRC Managing Director***

Damien Burrows, ***NESP Tropical Water Quality Hub Leader***

Day 1 – Wednesday 28th April

07.45 **Registration opens**

08.15 **Introduction**
Sheriden Morris, *Reef and Rainforest Research Centre* (*RRRC)*

08.20 **Welcome to Country**
Gavin Singleton, *Yirrganydji* and Gudju Gudju, *Gimuy Walubarra Yidinji*

08.55 **Introduction to sessions**
Damien Burrows, *NESP TWQ Hub Leader*

Session One: Nutrient Management

09.00 **Engaging with farmers and demonstrating water quality outcomes to create confidence in on-farm decision-making ("Project 25")**
Aaron Davis, *James Cook University (JCU)* and Steve Calcagno, *CANEGROWERS*

09.15 **Smarter irrigation management in the sugarcane farming system using internet of things**
Eric Wang, *JCU* and Aaron Linton, *Cane Farmer*

09.30 **Can improved fertiliser technology allow reduced fertiliser N rates in sugarcane?**
Mike Bell, *University of Queensland (UQ)* and Julian Connellian, *Sugar Research Australia (SRA)*

09.45 **Enhanced efficiency fertilisers can reduce nitrogen runoff losses from sugarcane**
Tony Webster, *CSIRO* and Mark Savina, *Salmec Farming*

10.00 **Insights into farmer decision influencers towards behaviour change in Queensland**
Rachel Hay, *JCU*

10.15 **Overcoming barriers to reducing nitrogen losses to the Great Barrier Reef: A synthesis of NESP TWQ Hub research**
Jane Waterhouse, *C_2O Consulting*

10.30 **Session discussion**

10.45 **Morning Tea**

Session Two: Sediment Management

11.05 **Quantifying the effectiveness of gully rehabilitation on water quality: Results from demonstration sites in the Burdekin**
Rebecca Bartley, *CSIRO* and Scott Crawford, *NQ Dry Tropics*

11.20 **Research informing the estimation of sediment reductions for gully rehabilitation programs**
Scott Wilkinson, *CSIRO*

11.35 **Targeting the right gullies. Achieving the targets**
Andrew Brooks, *Griffith University (GU)* and James Daley, *GU*

12.00 **Implementation challenges of large-scale land remediation actions from an industry perspective**
Damon Telfer, *Fruition Environmental*

12.15 **Targeting Burdekin sediments through landholder monitoring and engagement alongside tracing and modelling**
Zoe Bainbridge, *JCU* and Rodger Walker, *NQ Dry Tropics*

Day 1 – Wednesday 28th April *continued*

12.30 **Examining the influence of the newly delivered sediment and associated particulate nutrients in the inshore Great Barrier Reef**
Stephen Lewis, *JCU*

12.45 **Session interim discussion**

13.00 **Lunch**

14.00 **Bioavailable nutrients from sediment – applications towards reducing risk to the reef and enhancing gully remediation practice**
Alexandra Garzon-Garcia, *Queensland Department of Environment and Science*

14.15 **Reducing end of catchment fine sediment loads and ecosystem impacts: a synthesis of NESP TWQ Hub research**
Mari-Carmen Pineda, *C_2O Consulting*

14.30 **Final sediments session discussion**

Session Three: Pesticide Management

14.40 **Pesticides and other contaminants: A conceptual model NESP TWQ Hub synthesis project**
Rachel Smith, *Queensland Department of Environment and Science*

14.55 **Improving water quality thresholds for alternative pesticides and future climate conditions**
Andrew Negri, *Australian Institute of Marine Science (AIMS)* and
Reiner Mann, *Queensland Department of Environment and Science*

15.10 **Session discussion**

15.20 **Afternoon Tea**

Session Four: Ecological System Repair

15.45 **Land use conversion to improve water quality in high DIN risk, low-lying sugarcane areas of the GBR catchments**
Nathan Waltham, *JCU*

16.00 **Empowering stakeholders to restore and care for reefs**
Adam Smith, *Reef Ecologic* and Ryan Donnelly, *Reef Restoration Foundation*

16.15 **Restoring natural values back to Great Barrier Reef wetlands: Costs and benefits and case study evaluations**
Nathan Waltham, *JCU*

16.30 **Two extreme ENSO-driven oscillations in mean sea level destabilise protective shoreline mangroves of Northern Australia**
Norm Duke, *JCU*

16.45 **Session discussion**

17.00 **Day 1 Close**

Social Function

17.30 - 21.00

Please join us at the **Pullman Reef Hotel Casino, Pool Deck,**
for social drinks, canapés and music

Day 2 – Thursday 29th April

08.00 **Registration opens**

08.25 **Welcome**

Session Five: Integrated Pest Management of Crown-of-thorns Starfish

08.30 **Session introduction**
Sheriden Morris, *RRRC*

08.35 **The NESP Integrated Pest Management COTS Control Research Program and its impact on COTS control on the GBR and the potential for successful control of the next outbreak**
David Westcott, *CSIRO*

08.50 **Step-change wanted: Biologically based technologies for innovative crown-of-thorns seastar**
Lone Hoj, *AIMS*

09.05 **Predation release by coral reef fishes predicts population outbreaks of corallivorous crown-of-thorns starfish**
Frederieke Kroon, *AIMS*

09.20 **Environmental DNA (eDNA) for early warning of crown-of-thorns outbreaks: Genetic detection of larvae and post-settlement individuals at extremely low densities**
Sven Uthicke, *AIMS*

09.35 **Implementing an ecologically-based operational strategy for crown-of-thorns starfish control on the Great Barrier Reef**
Cameron Fletcher, *CSIRO*

09.50 **The future IPM COTS Control Program – necessary evolution for future readiness**
David Westcott, *CSIRO*

10.05 **Session discussion**

10.20 **Morning Tea**

Session Six: Marine Monitoring and Management

10.40 **Crown-of-thorns starfish management to achieve Reef 2050 goals for the Great Barrier Reef**
Roger Beeden, *GBRMPA*

10.55 **Indigenous aspirations for the GBR going forward**
Duane Fraser, *Great Barrier Reef Marine Park Authority (GBRMPA)*

11.10 **Great Barrier Reef Indigenous tourism: Translating policy into practice**
Henrietta Marrie and Adrian Marrie, *Central Queensland University (CQU)*

11.25 **The genetic traits of corals that survived recent bleaching events**
Kate Quigley, *AIMS*

Day 2 – Thursday 29th April *continued*

11.40 **Monitoring water quality from space: Benthic light as a new indicator of water quality for corals and seagrasses of the Great Barrier Reef**
Barbara Robson, *AIMS*

11.55 **A new monitoring program design for Great Barrier Reef aesthetic values**
Matt Curnock, *CSIRO*

12.10 **Tools to support resilience-based management of the GBR**
Peter Mumby, *University of Queensland (UQ)*

12.25 **Improving coral reef condition through better-informed resilience-based management**
Johanna Johnson, *C_2O Consulting*

12.40 **Session discussion**

12.50 **Lunch**

Session Seven

14.00 **Defining desired state of seagrass as a management target to support ecosystem resilience in the Great Barrier Reef**
Alex Carter, *JCU*

14.15 **Risk assessing dredging activities**
Ross Jones, *AIMS*

14.30 **Strengthening the evidence: What is the influence of Fly River discharge on the Torres Strait?**
Jane Waterhouse, *JCU*

14.45 **Session discussion**

15.05 **A research hub's worth of data – lessons in making it accessible and reusable**
Eric Lawrey, *AIMS*

15.20 **Learnings from applied environmental research programs: Elements for success**
Suzanne Long, *RRRC*

15.35 **NESP 2 – The Marine and Coastal Hub**
Sheriden Morris, *RRRC*

15.50 **Session discussion**

16.00 **Conference Close**

16.30 **Venue Close**

ABSTRACTS

Abstracts are presented in the running order of the forum program timetable

Engaging with farmers and demonstrating water quality outcomes to create confidence in on-farm decision-making ("Project 25")

Aaron M. Davis

Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER), James Cook University, Townsville, QLD, Australia

Because of long-term challenges in fundamentally changing the behaviour of farmers, water quality monitoring is increasingly shifting to collaborative-participatory models involving landholders, scientists and other stakeholders. Using recent Great Barrier Reef catchment experiences from NESP 'Project 25' as an example, we highlight several emerging themes and opportunities in using stakeholder co-design and emerging technologies to increase the accessibility and relevance of monitoring data to catchment landholders. These models specifically support decision-making and consequent practice change on the part of farmers, and also in the spatial identification of nutrient generation 'hotspots' in intensive agriculture catchments. The importance of investment in building trust, maintaining research practice and data transparency with stakeholders, and the critical role of informal learning and training are essential components to achieving impact-based research outcomes. Results from Project 25 demonstrate that collaborative efforts between researchers and non-academic stakeholders increases legitimacy, ownership and accountability of environmental sustainability challenges, as well as for the identification of future solutions.

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Smarter irrigation management in the sugarcane farming system using internet of things

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The answers to "How much water does that crop need?" and "When should it be applied?", are vital to improving water quality leaving the farm and ensuring the sustainability of the Great Barrier Reef. However, these two questions must be complemented with a third, equally important, question, "How can I do this practically and effortlessly?".

The NESP Project 3.1.2 team designed, tested, and implemented a smarter irrigation system to apply the right amount of water at the right time by integrating automation with an irrigation decision support system using the Internet of Things technology. In this project, Uplink and Downlink were developed to automate irrigation record-keeping and scheduling, respectively. This smarter irrigation management platform provided an innovative and working solution to the above three questions.

The success and benefits of the platform have captured the attention of many farmers in the Burdekin, with Uplink running on six farms (over 576 ha) over two years and Downlink running on one farm over a year. Increasing the number of farmers who meet or exceed industry best practice irrigation management will make significant contributions toward meeting the Reef 2050 WQIP targets.

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Can improved fertiliser technology allow reduced fertiliser N rates in sugarcane?

Mike Bell[1], Julian Connellan[2], Danielle Skocaj[3], Bronwyn Masters[4], Tony Webster[5], Jayson Dowie[6], Nick Hill[7]

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The dominant form of nitrogen (N) lost from the sugarcane industry via surface runoff and deep drainage is dissolved inorganic N (DIN) derived from fertiliser applications. This N form represents an immediate risk to marine ecosystem health. Minimising DIN losses requires a combination of management strategies that collectively maximise the proportion of fertiliser N captured by the crop while minimising the risk of DIN loss in runoff or deep drainage. The large sugarcane N requirement, coupled with an extended period of crop N uptake that can coincide with the monsoonal wet-season, makes these objectives challenging.

Our NESP project explored the feasibility of combining new fertiliser technologies (Enhanced Efficiency Fertilisers – EEF's) with N application rates matched to historical records of productivity at the block scale as a way of maintaining productivity while improving fertiliser N recovery and minimising N loss. This work, at seven sites and focussed on high-risk times of fertiliser N application, was complimented by a much larger scale program (EEF60) funded by Reef Trust IV. This investment used a similar approach, although with a constant proportional N rate reduction of 20%, establishing 60 sites on different soil types and fertiliser application times across Reef catchments.

Our results show that using EEF's can reduce the risk of yield loss from reduced N rates, and reduce runoff losses in most instances, provided the crop is able to acquire the N as it is released. The higher cost of EEF products/kg N applied will be a driver for product choice in the industry.

Enhanced efficiency fertilisers can reduce nitrogen runoff losses from sugarcane

Tony Webster[1], Mark Savina[2]

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Fertiliser nitrogen additions provides good return on investment for sugarcane production. Fertiliser nitrogen is highly water soluble, and in the Wet Tropics is available to being lost in surface runoff where it can in turn negatively impact the Great Barrier Reef. Recently, attention has been focussed on the potential for Enhanced Efficiency Fertilisers (EEF) to help reduce nitrogen losses from sugarcane. EEF is a catch all term for a number of products which fall broadly into two categories; namely coated fertilisers and nitrification inhibitors. Both reduce the availability of water soluble nitrate. The downside is EEF cost more than the conventional fertiliser nitrogen source, urea.

Surface runoff is driven by the annual wet season, which starts immediately after the sugarcane harvesting and fertilising 'season'. For this reason, sugarcane fertilised late, closer to the start of the wet season, is particularly vulnerable to nitrogen losses. We hypothesised replacing urea fertiliser with an EEF for late season fertilising could reduce nitrogen lost from sugarcane in surface runoff water, without affecting sugarcane yield.

Here, we show EEF can reduce nitrogen losses from sugarcane in surface runoff and offer some insights as to the cost of those reductions. To facilitate broader adoption of EEF, some of these costs require mitigation, and we offer some thoughts on how that may occur.

Insights into farmer decision influencers towards behaviour change in Queensland

Rachel Hay

James Cook University, Townsville, QLD, Australia

Extension officers, researchers and other stakeholders have altered the way they market water quality improvement programmes to land managers using insights from a readability study that found communications materials were written in a language too complex for a substantial percentage of the Australian population. In addition, stakeholders implementing activities in water quality research programs used insights from farmer attitudes, behaviours and barriers to drive their approach to behaviour change projects in the region that aim to improve water quality and the heath of the Great Barrier Reef. This collaborative approach allowed stakeholders to access appropriate tools and implement them towards improvement of water quality projects. Insights into farmer decision-making factors may also guide extension officer's interactions with land managers in terms of communication and training programs. This presentation provides examples where stakeholders have adopted insights from the NESP 2.1.3 project to create behaviour change in water quality management.

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Overcoming barriers to reducing nitrogen losses to the Great Barrier Reef: A synthesis of NESP TWQ Hub research

Jane Waterhouse[1,2], Mari-Carmen Pineda[1], Peter Thorburn[3], Mike Bell[4], John Rolfe[5], Jim Smart[6], Nathan Waltham[2], Aaron Davis[2], Tony Webster[3]

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Land-based runoff is one of key threats to Great Barrier Reef (GBR) ecosystems, leading to poor water quality in many parts of the GBR, and particularly in inshore areas. Specifically, nutrient inputs can cause important ecological impacts including reduced coral diversity, increased algal blooms (that can also reduce light), enhanced outbreaks of coral-eating crown-of-thorns starfish, and increased susceptibility to coral bleaching and some coral diseases. Throughout the NESP TWQ Hub, several research projects have investigated solutions for reducing nutrient inputs to the GBR, with a particular focus on nitrogen management. This synthesis of research findings takes a 'sea to source' approach, beginning with the ecological impacts of nitrogen losses to the GBR, then summarising the outcomes for catchment-based solutions. A conceptual framework identifying the key stages for overcoming barriers to reduce nitrogen losses in the catchment structures the key findings: identifying actions, understanding participation, exploring new instruments and evaluating options. Finally, the synthesis provides advice on the practical on-ground actions for land and sea managers, policy implications and remaining gaps for future research and management investments.

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Quantifying the effectiveness of gully rehabilitation on water quality: Results from demonstration sites in the Burdekin

Rebecca Bartley[1], Aaron Hawdon[1], Anne Henderson[1], Brett Abbott[1], Scott Wilkinson[1], Nick Goodwin[2], Kahlytah Ahwang[1]

Contributors and collaborators on the project

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Gully erosion contributes ~40% of the excess fine sediment to the Great Barrier Reef from just ~0.1% of the catchment area, however, the approaches for reducing this erosion source were not well tested in the Burdekin Region. This study evaluated the water quality improvements following the implementation of a range of gully remediation options. The selection and design of sites were managed by NQ Dry Tropics as part of the Landholders Driving Change (LDC) Program. Evaluation of the effectiveness of the remediation in terms of improved vegetation, terrain and water quality response was undertaken by a collaborative team from the CSIRO and Queensland Government.

The monitoring sites allowed the LDC Program to (i) evaluate the performance of the remediation options and provide quantitative evidence of which techniques improved land condition and water quality; (ii) improve our understanding of erosion and remediation processes to support future site selection and the likely effectiveness of treatments (relative to other options); and (iii) help engage local landholders and provide accessible field sites, that were collecting real-time data, to demonstrate the benefits of the remediation efforts. The benefits of this multiple-partnership approach were that specialist groups were bought together to tackle previously intractable problems.

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Research informing the estimation of sediment reductions for gully rehabilitation programs

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Monitoring the effectiveness of gully rehabilitation is leading to better constrained estimates of the sediment reductions from gully rehabilitation. From water quality and other measurements across a range of treated and untreated gullies, recent research in the Burdekin confirmed that gully baseline sediment yields vary by orders of magnitude. This reinforces the importance of focusing on sites with large yields so that sediment reductions can be delivered efficiently. This research also found that several common gully rehabilitation techniques in use in GBR catchments can all be highly effective, provided that the appropriate technique is selected, that it is designed and installed well. The effect of long-term grazing exclusion on gully sediment yield in the upper Burdekin was quantified at more than 50% reduction in gully sediment yields. Diverting runoff away from gully headcuts was also shown to be effective if water can be either retained or safely delivered to the stream elsewhere. Gully reshaping and revegetation can be highly effective if livestock access is controlled, and surface erosion is controlled in the initial years. Translating site monitoring into effectiveness look-up tables requires accounting for the scale of monitoring (whether all parts of the gully were monitored), the duration of monitoring (short term monitoring results are sensitive to the climate), risk of extreme events, spatial completeness of works across a gully, control of livestock access and ongoing maintenance, independent technical review to validate the appropriateness of effectiveness estimates for sites. Some gaps in system understanding remain, in terms of certain soil types, treatments, climatic conditions and the persistence of outcomes. Research can continue to inform ongoing adaptive management of gully erosion rehabilitation programs by monitoring large erosion control sites.

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Targeting the right gullies. Achieving the targets

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Current estimates are that ~50% of the fine sediment load entering the GBR lagoon is sourced from gully erosion. In 2015, prior to the establishment of the NESP TWQ Program, there was little understanding of which gullies were the dominant sediment sources, how they should be remediated, what sort of sediment reductions could be achieved, how long it would take to achieve such reductions, and at what cost?

Research implemented through NESP between 2016 and 2020 addressed each of these issues, and we can report that most of these knowledge gaps have been largely resolved.

Key results:

- High resolution gully mapping shows us that in key gully hotspot areas, 30% of the fine sediment load is sourced from between 2–4.5% of the gully population. This now provides the means to identify which individual gullies should be targeted for remediation.
- Lifetime gully volumes derived from this mapping indicate that 156Mt (0.28 Sydharbs) were eroded from gullies over the last 130 years in the ~5300km2 mapped.
- It has been demonstrated that large scale (i.e. sites > ~1ha) remediation of alluvial gullies can achieve >95% sediment reductions in 1 – 2 years.

This research demonstrates that the ambitious Reef2050 water quality targets are now achievable, at substantially less cost than the previous estimate of $8Bn. However, substantial coordination and upscaling of effort is required to meet the targets.

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Implementation challenges of large-scale land remediation actions from an industry perspective

Damon Telfer

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The NESP 3.1.7 project has demonstrated that large sources of fine sediment from alluvial gully systems can be very effectively abated using a variety of fit-for-purpose remediation techniques.

The NESP research has both benefited from and assisted industry providers. Ongoing partnerships between researchers and industry operators should pay dividends in terms of improved cost-effectiveness through more effective targeting of remediation works and improved techniques.

However, the implementation of large-scale (tens of hectares) remediation projects in remote locations has significant challenges. Among these are the willingness of landholders to host intensive remediation programs, mobilisation of plant and equipment to remote locations, worker accommodation and safety, access to suitable remediation resources, contractor capacity, and high operating costs. These factors impact cost-effectiveness.

In terms of scalability, to give perspective, the projects funded at Strathalbyn Station in the lower Burdekin under Reef Trust, the Queensland Government's Reef Innovation Fund, Greening Australia's Reef Aid program, and the GBRF, represent works on less than 2% of the priority alluvial gully remediation sites identified in the Burdekin. Works at these sites reduced fine sediment pollution to the reef lagoon by approximately 10,000

tonnes per annum, or one third of a percent of the estimated annual total fine sediment export from the Burdekin, or roughly 1.2% of the Burdekin catchment's 2025 targets for fine sediment reduction. This is a massive achievement that relied on more than 50 individuals and local businesses.

However, at a total investment exceeding $3.4M for on-ground works for these projects alone the challenges of achieving the Reef 2025 targets under current funding and implementation arrangements are stark. Do the targets need revision or do implementation arrangements need to adapt to the challenge?.

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Targeting Burdekin sediments through landholder monitoring and engagement alongside tracing and modelling

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The novel application of the SediPump® instrument to capture sufficient sediment mass from low concentration flood plume waters has enabled catchment source tracing of Great Barrier Reef (GBR) flood plume sediment for the first time. Geochemical tracing of sediment captured in Burdekin secondary water types up to 160 km north-east from the river mouth reveal two clear sediment source contributions from this catchment: the Upper Burdekin and Bowen sub-catchments. Our flood plume sediment samples show that colloidal, clay and fine silt grains (<20 µm) from these two key sources travel furthest in the GBR lagoon, and are almost exclusively derived from sub-soil erosion sources. These data extend the current sediment transport understanding and linkages beyond the freshwater zone, and through the Landholders Driving Change Project are also being traced to tributary sediment sources within the key Bowen-Broken-Bogie (BBB) area. This strong collaboration formed between our project, NQ Dry Tropics Landholders Driving Change and importantly landholders within the BBB has led to improved characterisation of sediments within this area and enhanced local understanding of catchment to reef water quality connections. The new data have also been extended to the GBR Dynamic SedNet modelling team to refine the BBB sediment budgets, and are informing targeted remediation efforts within the catchment.

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Examining the influence of the newly delivered sediment and associated particulate nutrients in the inshore Great Barrier Reef

Stephen Lewis[1], Zoe Bainbridge[1], Thomas Stevens[1], Alex Garzon-Garcia[2], Chengrong Chen[3], Mohammad Bahadori[3], Joanne Burton[2], Mehran Rezaei Rashti[3], Cassandra James[1], Scott Smithers[1,4], Jon Olley[3]

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This presentation addresses the question: What is the influence of the newly delivered sediment (i.e. from flood plumes) on turbidity regimes at coral reef and seagrass locations of the inshore GBR? Our logger data reveal a clear influence of the newly delivered sediment from flood plumes on both the initial suspended particulate matter (SPM) concentration and exposure (and the resultant light) during the plume event and, at

some sites, in the resuspension events over the few months following the flood event. The particulate nutrients in association with the SPM also likely favour macroalgae growth at coral reef sites. The data also indicate that relatively small increases in SPM (~ 1 mg.L-1) can substantially reduce water clarity and light available to benthic autotrophs. Our new findings provide an enhanced process understanding for incorporation and validation to the eReefs model and help to better separate the influences of wave driven resuspension from dredging and newly delivered riverine sediment. The benefits of extensive end-user engagement and data sharing throughout the project life are also discussed.

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Bioavailable nutrients from sediment – applications towards reducing risk to the reef and enhancing gully remediation practice

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Our research shows that sediments have the potential to generate considerable loads of dissolved inorganic nitrogen (DIN) as they move through rivers and in flood plumes within the Reef lagoon, which can stimulate freshwater and marine algal growth. These sediments may continue to generate DIN once deposited on the marine floor or resuspended.

The full impact of gully remediation on achieving Reef water quality targets can be ascertained by including nutrients from sediment in addition to sediment quantity in gully prioritisation and catchment modelling. We show that the type of vegetation used in remediation as well as the soil amendment type, influences downstream particulate nutrient bioavailability. Monitoring gully nutrients at remediation sites is essential for developing a stacked sediment and nutrient Reef Credit method in grazing catchments. The methods developed for assessing bioavailable nutrient contributions from sediments and soil materials, and the database of bioavailable nutrients from sediment already developed in some catchments, can now be used to inform prioritisation, and assess the risk from this source of nutrients to the Reef.

This research highlights the need to progress the inter-operability of the paddock-to-reef and marine models to account for this source of nutrients and to monitor them at end-of-catchments.

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Reducing end of catchment fine sediment loads and ecosystem impacts: a synthesis of NESP TWQ Hub research

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Poor water quality is one of the big drivers of change in the GBR region which can be tackled by management measures at a local scale. Specifically, fine sediment inputs in the GBR lagoon can cause important ecological

impacts, such as reduction in benthic light, smothering of benthic organisms, direct disturbance by suspended particles or increased loads of bioavailable nutrients. Throughout the NESP TWQ Hub, a cluster of research projects have been developed around the research priority to seek solutions to sediment reduction.

This synthesis of research findings takes a 'sea to source' approach, beginning with sediment fate and impact in the GBR (i.e. impacts upon key marine habitats, such as coral and seagrass), the spatial extent of these impacts in the GBR, and new methods for measuring and reporting on reduced light availability as a result of catchment-derived sediment in the marine environment. This is then followed by an analysis of the delivery of sediments and transformation and mobilisation of nutrients attached to sediments, including fate and dispersion of catchment-derived sediments once in the marine environment. The synthesis concludes with an evaluation of the approaches for remediating the previously identified dominant sources of sediment (gullies and streambanks). Finally, this synthesis provides advice on the practical on-ground actions for land and sea managers, policy implications and remaining gaps for future research and management investments.

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Pesticides and other contaminants: A conceptual model NESP TWQ Hub synthesis project

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Pesticides are one of three key pollutant types entering waterways of the Great Barrier Reef including rivers, wetlands, and coastal areas. Through research and monitoring, our understanding of the sources of pesticides, their transport pathways, exposure to aquatic ecosystems and toxic effects has grown. Along with nutrients and sediment, reduction targets and management actions (through the Reef 2050 Water Quality Improvement Plan) have been developed to reduce pesticide impacts on Reef aquatic ecosystems. However, managing pesticide reductions faces unique challenges compared to nutrients and sediments; pesticides are generally found in complex mixtures and nowadays more than 50 pesticides are detected in waterways of the Reef's regions. Therefore, managing pesticides requires a different approach compared to nutrients and sediments, in which NESP and other research has contributed to the development these approaches.

In this conceptual model, focusing on research's role in informing environmental management, we present the foundational knowledge of pesticide sources, transport and aquatic ecosystems primarily at risk. In the same context, our burgeoning knowledge of emerging chemical contaminants is also illustrated. A case study provides a more in-depth look at the elements of pesticide management and how NESP and other research, as well as monitoring and evaluation, has built an evidence base that guides and continually improves our management actions to reduce pesticide impacts.

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Improving water quality thresholds for alternative pesticides and future climate conditions

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Assessing the risks posed by sediments, nutrients and pesticides to the Great Barrier Reef (GBR) requires an understanding of the effect thresholds of each individually, in mixtures and in combinations with other pressures such as heatwave conditions.

NESP TWQ Hub project 3.1.5 assessed the toxicity of 21 alternative pesticides detected in nearshore waters of the GBR on 16 tropical aquatic species in laboratory tests. The toxicity data from these tests are now being used to develop water quality guideline values (WQGVs) for the alternative pesticides.

NESP TWQ Hub projects 2.1.6 and 5.2 explored methods to develop climate adjusted thresholds for water quality, including quantifying the effects of future climate-change conditions on the sensitivity of tropical marine species to sediments and herbicides and developing a method to adjust current WQGVs for heatwave conditions. The project also built an interactive tool using the eAtlas platform illustrating issues of cumulative impacts and the consequences of alternate management interventions.

It is recommended that the toxicity data and methods to adjust thresholds to account for cumulative pressures are incorporated into future water quality risk assessments and targets for the Reef 2050 Water Quality Improvement Plan, Reef Water Quality report cards, Regional report cards and regional Water Quality Improvement Plans.

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Land use conversion to improve water quality in high DIN risk, low-lying sugarcane areas of the GBR catchments

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There is a need for innovative and cost-effective approaches to deliver further water quality improvement in Great Barrier Reef catchments. Transitioning low-lying, marginal sugarcane to alternative land uses that require lower or no nitrogen inputs, but still provide farmers with income streams, is an attractive solution. Here, a multi-criteria analysis identified sites suitable for such alternative land uses. The cost-effectiveness of DIN reductions from these land use changes were calculated accounting for reductions in annuity gross margins and land conversion cost. In certain locations (where conversion costs are low and DIN decreases are high) treatment wetlands and no-input grazing offer cost-effective DIN reduction in the range of 20–26$/kg DIN. This compares favourably with existing agricultural extension-based approaches (c. $50/kg DIN reduction). Ecosystem service wetlands (i.e., restoration for fish production) – again when appropriately situated offer the

prospect of even more cost-effective performance (11–14 $/kg DIN reduction). These results, in conjunction with best management practices, support the premise that alternative land uses are cost-effective options for improving water quality in certain areas of low-lying, low productivity sugarcane land. On-going investments by government in addition to private market funding could be appropriate for supporting such land use transitions.

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Empowering stakeholders to restore and care for reefs

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People care deeply about the health, impacts and future of the Great Barrier Reef. Many are very concerned about the impacts of global climate change and other stressors that have destroyed 50% of the Great Barrier Reef over the past 30 years. So what can or should they do about it? Until recently the recommended approach was citizen science. That is to collect information on the reef and report it to scientists and managers. A few years ago we collectively realised that we were monitoring the decline of the GBR and we needed a new approach, including new tools, interventions and positive actions such as reef restoration. It worked well overseas so it should work in our waters.

Adam Smith will discuss his experience within an IDEA framework and the tourism industry, conservation groups, indigenous stakeholders, scientists and artists to pilot several reef restoration projects between Port Douglas and the Whitsundays. The lessons learned include collaboration, competition, risk, methodology, training, funding, time and scaling.

As CEO of the Reef Restoration Foundation which has expanded from Fitzroy Island to several reef sites, Ryan Donnelly will share his experiences of normalising the notion that collectively we can act to increase the resilience of our patch while global leaders work on decarbonising economies. It can be achieved by galvanising community participation, forming business partnerships and attracting corporate sponsorship.

Restoring natural values back to Great Barrier Reef wetlands: Costs and benefits and case study evaluations

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Conservation and repair of Great Barrier Reef coastal wetland ecosystems have come into focus following media attention on reef health and resilience, with ecosystem protection and restoration cited as a key performance measure in long term strategic planning policies – e.g. 2050 Long Term Sustainability Plan. This NESP TWQ program worked closely with a multitude of NRM, NGO, government, industry and indigenous groups, to assess

and examine different restoration projects – a series of cases studies including feral animal management, bund wall removal, aquatic plant management, ponded pasture freshwater protection and constructed wetlands to improve water quality. More restoration projects are on the horizon, funded directly through government, though interest in private funded restoration schemes where major investment companies sponsor wetland restoration – projects focused on improving water quality, carbon additionally or biodiversity conservation. For new and future projects to be successful, we need to look back at past wetland restoration projects, in order to make informed decisions on investment in wetland restoration and maintenance for future projects.

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Two extreme ENSO-driven oscillations in mean sea level destabilise protective shoreline mangroves of Northern Australia

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Our investigations confirm over the last half century, there were two widespread instances of extremely low ENSO-related oscillations in mean sea level each causing catastrophic mass dieback and the sudden death of up to 80 km2 of mangrove forests along more than 2,000 km of shorelines of Australia's remote north. These previously unrecognised instances of severe desiccation in 1982 and 2015 created a longer-term cycle of shoreline collapse and recovery bringing enhanced vulnerability to already depauperate tidal wetland habitats across this semi-arid region faced with rapidly rising sea levels and other pressures. Accordingly, the impacted shorelines of the Gulf of Carpentaria displayed acute sensitivity to not only the extreme sea level lows but also accumulative damaging instances of locally-destructive cyclones combined with other damaging pressures from feral pigs, invasive exotic weeds and uncontrolled scrub fires. These factors together reduced landward migration of mangrove vegetation - much needed for coping with local rapidly rising sea levels. So, along with these things, the newly recognised extremes in atmospheric-driven ENSO processes seriously threaten the longer-term survival and recovery of otherwise enduring shoreline ecosystems and the beneficial services they offer - including their role in slowing down coastal erosion in their retreat across the drowning shorelines.

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The NESP Integrated Pest Management COTS Control Research Program and its impact on COTS control on the GBR and the potential for successful control of the next outbreak

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Crown-of-thorns starfish (COTS) are a significant contributor to hard coral loss on the Great Barrier Reef (GBR) and consequently has been a driver of management investment on the GBR and in the GBR catchment. In this presentation I review the impacts of the NESP IPM COTS Control Program research on management and its outcomes. This impact has been far reaching, from the overall strategic approach through to structuring of decision making in day to day operations. Perhaps the greatest impact, however, has been in the on-water outcomes of COTS Control itself. The COTS Control Program has been transformed from a program that was largely ineffective even at individual sites, to one that is successfully reducing COTS densities to below critical thresholds at entire reef scales and which has achieved this at hundreds of reefs. These changes clearly demonstrate that the IPM approach to COTS control is an effective management approach and demands a re-consideration of its potential in terms of meeting future COTS control needs.

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Step-change wanted: Biologically based technologies for innovative crown-of-thorns seastar

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Future integrated pest management strategies for COTS are likely to incorporate one or more biologically based technologies such as semiochemicals, predator control, traditional biological control, and genetic biocontrol. As part of the NESP TWQ Hub project on implementation of the COTS research strategy, we outlined the history and current use of these approaches in pest control worldwide, with special reference to their use in aquatic systems. We considered their potential role for COTS control on the GBR, analysing factors such as the scale of potential use, the need for repeated applications, reversibility, environmental risk, perception and regulatory risks, financial risk and critical knowledge gaps. On this basis, we made recommendations on their potential role in an integrated pest management strategy for COTS and estimated a minimum lead time until each could be application ready. Our analysis currently serves as a foundation for activities in the COTS Control Innovation Program (CCIP), which was established by the GBRF's Reef Trust Partnership to create a step-change and accelerate the development of innovative control and surveillance methods for COTS while continuing to improve current methods. The program is currently in its Design Phase, scoping and assessing research opportunities to produce a prioritised investment portfolio.

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Predation release by coral reef fishes predicts population outbreaks of corallivorous crown-of-thorns starfish

Frederieke Kroon

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The corallivorous crown-of-thorns starfish (*Acanthaster spp.*) have caused widespread loss of coral cover on Indo-Pacific reefs during periodic population outbreaks. Here, I examine the role of zoning and fish predation in mitigating outbreaks of the Pacific crown-of-thorns starfish (COTS; *Acanthaster cf. solaris*) in the Great Barrier Reef Marine Park. First, I review and confirm the role of reef zoning and find lower COTS abundance, density, and frequency of outbreaks on closed compared to open reefs. Second, I combine information from a review on fish predation on COTS, with new evidence from COTS DNA detected in fish faecal and gut content samples. I find that 80 fish species from 17 families consume COTS, indicating that direct fish predation on COTS might well be more common than is currently appreciated. Finally, I present preliminary results of statistical analyses exploring linkages between COTS densities, fish densities and fish biomass removal on the GBR. Combined, this work points to the need to reconsider management approaches that enhance predation on COTS by coral reef fishes, thereby contributing to the prevention of COTS outbreaks and reverse declines in coral cover.

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Environmental DNA (eDNA) for early warning of crown-of-thorns outbreaks: Genetic detection of larvae and post-settlement individuals at extremely low densities

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Innovative early warning tools are required for timely intervention of current crown-of-thorns seastar (COTS) outbreak spread and future outbreaks. We have developed environmental DNA (eDNA) methods that allow us to a) quantify COTS larvae in plankton samples and, b) detect post-settlement COTS on reefs with sensitivity greatly surpassing traditional surveys.

COTS larval eDNA work has been supported by tourism operators and COTS Control Vessels with > 7000 samples collected since 2014. This dataset can now be employed to i) elucidate spawning times and patterns, ii) investigate larvae distribution and connectivity, iii) examine relationship between COTS larvae and water quality (e.g. 'nutrient hypothesis of outbreaks'). In a monitoring context, detection of COTS larvae constitutes the earliest possible indicator for population build-up.

COTS post-settled eDNA work aims at identifying trace amounts of COTS eDNA in a small volume of seawater. We have demonstrated that COTS densities below those classified as 'outbreaks' can be detected and deviations from baseline (=population build-up) can be employed for early warning. In addition, we can detect exceedance of threshold levels with easy-to-use and fast methods.

We propose to integrate larval and post-settlement eDNA monitoring into a large-scale COTS monitoring program for early warning detection and to assist efficient COTS control.

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Implementing an ecologically-based operational strategy for crown-of-thorns starfish control on the Great Barrier Reef

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Crown-of-thorns starfish (COTS) are a major threat to coral on the Great Barrier Reef (GBR) and across the Indo-Pacific. Of the increasing threats faced by the GBR, such as physical damage due to increased cyclone severity or bleaching due to rising ocean temperatures, COTS are the only threat amenable to immediate control. Implementing management strategies that can reduce the impacts of COTS at ecologically-meaningful levels is vitally important to conserving coral cover and fostering the overall resilience of the GBR.

To achieve this under NESP, we designed decision tools to support a control program that: 1) targeted effort at high priority locations at an intensity sufficient to preserve coral cover; 2) provided a solid ecological underpinning for control program decisions; 3) allowed each key decision to be made by on-water staff and managers from the control program data itself; and 4) could robustly generate ecologically-meaningful outcomes even when some management and population processes could not be estimated accurately ahead of time.

This presentation will outline the decision tools we designed, how they were implemented on-water, how they have generated significant outcomes for the resilience of the GBR, and their effectiveness at controlling COTS populations at regional scales on the GBR.

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The future IPM COTS Control Program – necessary evolution for future readiness

David Westcott

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The IPM CoTS Control Program (IPM CCP) has now been demonstrated to be an approach that is capable of reducing COTS densities to levels that protect coral cover, and of achieving this outcome at scales from individual sites, to reefs and across hundreds of reefs. This demonstrates that the IPM approach is effective at achieving its objectives and of doing so at scales that are relevant to the management of COTS outbreaks at the scale of the GBR. While this demonstration is an encouraging and necessary step it by no means signals that the current IPM COTS control program can effectively meet the challenge of the next COTS outbreak. For that the program's strategy and operations will need to evolve even further. In this talk I consider these future needs and how the program must evolve to in order to meet them. I consider how the strategy will need to evolve, what this means for its objectives and operations, and consider the new tools that will required. While the challenge is great, there reason to be optimistic.

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Crown-of-thorns starfish management to achieve Reef 2050 goals for the Great Barrier Reef

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The Reef 2050 Plan identifies crown-of-thorns starfish (COTS) outbreaks as a significant threat to the health of the Great Barrier Reef ecosystem. It calls on us to work collaboratively across government, research and industry bodies to reduce the impact of COTS in the Great Barrier Reef World Heritage Area. These outbreaks compound the damage caused by tropical cyclones and coral bleaching events, and mitigating their impact is one of the most scalable and feasible on-ground management interventions currently available to enhance Reef resilience and recovery in the face of climate change. The COTS Control Program is delivered as part of the Great Barrier Reef Marine Park Authority's management strategy to address the COTS threat. The Program's manual in-water control component is delivered through a strategic partnership between the Great Barrier Reef Foundation (GBRF), Great Barrier Reef Marine Park Authority (GBRMPA) and the Reef and Rainforest Research Centre (RRRC). Since its inception, the COTS Control Program has been carried out in collaboration with tourism industry and research partners to ensure the best available science and local knowledge are incorporated into on-ground action. The goal of the COTS Control Program is to protect coral by culling starfish down to ecologically sustainable levels that promote coral growth and recovery. We are not attempting to stop the outbreaks or eradicate the starfish; these are not feasible goals given the limitations of current control methods. The Program strategically focuses its resources on individual reefs of high ecological and economic value across the Marine Park using dedicated vessels and trained crews. With the expansion of the program in 2018, we implemented an innovative new approach to pest management in collaboration with our research partners in the National Environmental Science Program (NESP). NESP investment has underpinned collaboration among the research, management and industry partners and has significantly enhanced the capacity of the on water control program to effectively target COTS outbreaks in the Marine Park. This collaborative, iterative approach enables crews on board the COTS culling vessels to use targeted surveillance, intensive culling, and reef health surveys to achieve sustainable starfish numbers that promote coral growth and recovery. To support this new approach, the Marine Park Authority has developed data capture apps and visualisation tools to support adaptive and data-driven decision making. The expanded COTS Control Program is protecting coral from COTS impacts on a network of >100 high value reefs across the Marine Park. The COTS Control Program has undergone significant improvement since its inception, and we strive to maintain this momentum, delivering world-leading, science-based, adaptive management of COTS on the Great Barrier Reef. The success of the COTS Control Program to date highlights the critical role that investment under the National Environmental Science Program has played in supporting the resilience of the Great Barrier Reef under a changing climate.

Indigenous aspirations for the GBR going forward

Duane Fraser

Traditional Owner

All research that is undertaken, irrespective of its nature, will have some sort of impact on Indigenous Australians. Indigenous engagement and participation is identified as a cross-cutting theme for all National Environment Science Program (NESP) Hubs in the development of research priorities.

Indigenous people have certain rights associated with and based on the prior occupation of country and water and activities (e.g. fishing, gathering) associated with the use and management of these. These include the right to maintain and develop cultural practices to address spiritual, cultural, social and economic needs, and right to determine courses of action in relation to use and management of aquatic and terrestrial biological resources. Indigenous engagement outcomes for the NESP Tropical Water Hub and future improvements will be focus of this presentation.

Great Barrier Reef Indigenous tourism: Translating policy into practice

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Tourism Australia identifies "Aboriginal Australia" as one of seven signature Australian Experience Themes, while Tourism and Events Queensland (TEQ) has the intention of making Queensland the country's number one destination for Aboriginal and Torres Strait Islander experiences. The Great Barrier Reef (GBR) is Queensland's greatest natural asset and major destination for both domestic and overseas tourists. It also forms part of the traditional estates of 41 Indigenous Traditional Owner (TO) groups with rights to "sea country" along the GBR. Although the opportunities might seem abundant, there is little participation by TOs in the GBR tourism industry. There are only a handful of Indigenous-owned businesses offering Indigenous-mediated experiences. The challenge is how to translate TEQ's policy objective into reality by working principally with TOs, Regional Tourism Organisations and tourism operators to find avenues to encourage Indigenous participation in GBR tourism. The 2020 report identifies a number of actions that could be taken, and the presentation considers some of the outcomes one year on.

The genetic traits of corals that survived recent bleaching events

Kate Quigley, Blake Ramsby, Patrick Laffy, Veronique Mocellin, Jess Harris, Line Bay

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The past five years have seen unprecedented coral bleaching on the Great Barrier Reef and temperatures continue to rise. It is clear that corals need to adapt to increasing temperatures to be able to persist into the future, but the potential scope for corals or their symbionts to adapt is not yet known. This project aimed to identify whether corals surviving the 2016 and 2017 bleaching events had genetic adaptations and symbiont populations that enabled them to better withstand these higher temperatures. Genomic sequencing showed that in the coral Acropora millepora, gene flow was high among the populations sampled at the peak of bleaching in 2017 and suggests that recovery of this species post bleaching is possible from other populations not affected by bleaching-related death. The presence of the sacsin gene was able to predict bleaching appearance in A. millepora. Symbiont communities also significantly changed before and after mass bleaching, with corals like A. millepora having a higher proportion of heat tolerant symbionts after bleaching. These data provide important benchmarks for managers to predict which corals may be vulnerable to bleaching given their genetic background or composition of symbionts.

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Monitoring water quality from space: Benthic light as a new indicator of water quality for corals and seagrasses of the Great Barrier Reef

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Reduced light due to poor water quality is a driver of chronic stress for corals, seagrasses, and the habitats that they create. We have developed a new water quality index to monitor the amount of light stress experienced by corals and seagrasses in any part of the GBR over the course of each year. We use satellite ocean colour observations to estimate the amount of light reaching benthic habitats across the whole GBR each day and relate this to the habitat requirements of corals and seagrasses. The new index is sensitive to interannual and regional variations in water quality. After accounting for variations due to acute stress from bleaching and CoTS outbreaks, it explains a greater proportion in change in coral condition over time than previously used river

discharge or satellite water quality metrics. Benthic light is also effective as an input to models that predict the distribution and community composition of seagrasses. We therefore conclude that the new index is suitable for use as an ecologically relevant indicator of water quality in the GBR.

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A new monitoring program design for Great Barrier Reef aesthetic values

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The aesthetic values of the Great Barrier Reef (GBR) are an important part of its World Heritage status, and are a key driver for recreational and tourist visitation. However, monitoring and assessment of such values has been a long-standing challenge, with no consistent framework or metrics available, until now. This presentation will outline the key findings and outcomes from NESP TWQ Project 5.6, which engaged 46 GBR managers, scientists and potential end-users in identifying program delivery requirements, and developed metrics and protocols to enable long-term scalable monitoring of GBR aesthetic values across its diverse habitats. Cost-effective implementation of this monitoring can be achieved through the adoption of minor add-ons by existing scientific and citizen science monitoring programs, while AI/ML algorithms (e.g. as developed by NESP TWQ Project 5.5; with appropriate training and benchmarking) offer analytical capability for large-scale and historic photographic archives. An important feature of this project was its action-oriented research design, which resulted in effective, targeted engagement among a diverse and industrious group of participants. Transferable lessons from this engagement process will be outlined, as well as the next steps for monitoring implementation and its end-uses.

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Tools to support resilience-based management of the GBR

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Resilience-based management (RBM) aims to target interventions where they can best enhance natural processes of recovery or minimise disturbance where its consequences are disproportionately high. Following GBRMPA's Blue Print on resilience, we collaborated with partners to help operationalise several concepts of RBM. To do this we used the 'best available' science on reef ecosystems. Three RBM approaches were developed and applied in various degrees of operation.

1) The identification of key sources of coral larvae. This approach combines predicted and observed reef state with coral larval connectivity. It finds those reefs that play an exceptionally important role in supplying new coral larvae where they are most needed; i.e., recently damaged reefs in early stages of recovery.
2) Priotities for compliance: Through collaboration with GBRMPA's Compliance team we have mapped both recreational and commercial fishing pressure and identified areas of high risk of potential poaching and where the impact of such poaching on reef recovery would be particularly problematic.
3) RBM Explorer. A software tool to simulate how water quality improvement, zoning, boat-related damage, and CoTS control improves the state of coral reefs. This allows users to examine strategies that might provide better outcomes.

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Improving coral reef condition through better-informed resilience-based management

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As climate change becomes the dominant driver of Great Barrier Reef (GBR) condition, there is recognition that major disturbance events, such as coral bleaching and severe cyclones, will become more frequent, placing extra pressure upon the natural ability of coral reefs to recover. The emphasis therefore is to maintain and enhance resilience through management efforts that support reefs and associated habitats to resist or recover from future shocks and cope with the uncertainty of future change. Several projects across the National Environmental Science Program (NESP) Tropical Water Quality (TWQ) Hub focused on delivering science that can quantify simultaneous and cumulative pressures to inform resilience-based management and decision-making. Projects investigated: the relationship between water quality and bleaching risk, as well as other cumulative impacts; the function of important species on the GBR and how values are connected and managed across jurisdictions; spatial variability of thermal stress and bleaching; methods for coral restoration; and the traits of corals that have survived bleaching. The NESP TWQ Hub also invested in developing a resilience-based decision-support tool for marine park managers. This research focus on the interactions between pressures and resilience-based indicators contributed towards an improved understanding of what pressures undermine reef resilience and what management strategies can support resilience of vulnerable ecosystems. Numerous projects contributed to the improvement of GBR monitoring through identification of: a) additional indicators for monitoring to populate cumulative risk maps, b) cost-effective indicators based on benthic light (IbPAR), c) observational gaps required for bleaching prediction tools, d) reef recovery rates through using carbonate budgets, and e) priority species for inclusion in monitoring and surveillance based on key ecological functions.

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Defining desired state of seagrass as a management target to support ecosystem resilience in the Great Barrier Reef

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The Great Barrier Reef supports extensive, diverse and essential seagrass ecosystems. What should they look like? Do desirable states vary among the diverse communities found on the reef? These are fundamental questions when setting ecological targets and assessing management success. For complex and dynamic habitats, the answer is not simple. We present a framework to define seagrass desired state for the Reef and adjacent estuaries. This ambitious project included: (1) synthesizing 35 years of survey data with >81,000 observations, (2) predicting potential seagrass habitat, (3) defining 36 seagrass communities within that habitat, and (4) determining the desired state of a key seagrass health indicator – biomass – for each community. This resulted in defining what seagrass habitat within the Reef should look like and where it should occur. In the process, we identified environmental thresholds that define seagrass communities and knowledge gaps. There has been a decadal cycle of decline and recovery for some coastal communities, but other coastal and estuarine communities have not recovered to their desired states in recent years. These research outputs can be used for marine spatial planning and management, including zoning in “representative areas”, hierarchical monitoring design (e.g. RIMReP) and setting ecologically relevant load targets.

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Risk assessing dredging activities

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Dredging to create and maintain safe, navigable shipping channels releases sediments into the water column and the increased water cloudiness (turbidity) can change the underwater light availability, potentially impacting nearby phototrophic marine communities. Whilst light reduction is an easily identifiable hazard, translating it into a risk is a much more complex task, and yet essential for managing dredging programs and informing proponents/regulators of conditions which could result in environmental impact. Risk characterization requires contextualising of any dredging-related light reduction against natural patterns and testing physiological responses of test organisms under environmentally relevant exposure scenarios. To that end, we describe results from several investigations including a 3-year study of underwater benthic light and turbidity levels in the inshore turbid zone coral communities of Cleveland Bay (inshore central Great Barrier Reef). Light availability was quantified as a daily light integral (DLI, mol quanta m-2 d-1) over different running mean periods from days to weeks and different percentiles (1%, 5%, 10% etc) calculated to describe what corals actually experience as a result of clouds, natural turbidity events and seasonal solar declination cycles. Multispectral irradiance time series measurements on the reef and hyperspectral depth profiles through sediment plumes were also made to describe how suspended sediment concentrations (SSCs) change (attenuate) light and also alter the underwater light spectrum (by preferentially attenuating the more photosynthetically useful shorter bluer wavelengths). The results from the studies were used to develop a simple, multiple component empirical spectral solar irradiance model to estimate the underwater light (and spectrum) as a function of solar angle, SSC and water depth. The model output was used in a series of laboratory-based experiments in the AIMS SeaSim (aquarium facilities) using computer controlled fully automated sediment dosing system and spectrally adjustable programmable custom-made LED lights. The tolerance levels of 3 coral species to elevated SSCs (with a corresponding reduction in light and change in spectral quality) were determined over 28-days. The result was a time integrated running mean DLI value for risk assessing dredging and use for water quality monitoring during dredging projects in turbid environments. The results are currently being used in the Port of Townsville Channel Upgrade capital dredging project in Cleveland Bay, as part of the dredge management plan.

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Strengthening the evidence: What is the influence of Fly River discharge on the Torres Strait?

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Mining began in the headwaters of the Fly River in 1984, resulting in significant impacts on the river system including contamination by copper, increased turbidity and modified geomorphology. It is estimated that mining operations have increased sediment discharge of the Fly River by 40%; the close proximity of the Torres Strait to the Fly River mouth has raised concerns that trans-boundary pollution may occur. The extent of this influence was our research focus. We confirmed that habitats located in the northeast of the Torres Strait including Bramble Cay, north of Masig Island, the northern Warrior Reefs and as far northwest as Saibai Island, are located in an area of higher exposure to brackish and turbid waters from the Fly River and local PNG river discharges. Water and sediment quality were generally very good across the region, however, increased metal concentrations in waters and sediments were observed in the same areas of the northern Torres Strait. The trace metal concentrations were relatively low, and hence the extent of

environmental risk is currently not of concern. The research highlights the important role of the 1993 Torres Strait Baseline Study in setting an environmental baseline for comparison. It highlights a multiple lines of evidence approach to exposure assessment in remote, complex and data poor marine environments such as the Torres Strait is essential.

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A research hub's worth of data – lessons in making it accessible and reusable

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A key objective of the National Environmental Science Program was to ensure that all data generated by program research projects were made publicly available in a reusable and accessible manner. The eAtlas is a web delivery platform for environmental research data and was responsible for coordinating and publishing data products from the NESP Tropical Water Quality (TWQ) hub. Data management is often an afterthought in environmental research, leading to only a fraction of the data ever being published, and often with only poor documentation that limits their potential reuse. To combat this the eAtlas introduced data discussions, data management plans, expanded metadata templates and a data review process as part of the NESP TWQ hub data management. These helped guide and engage researchers in data management, resulting in the successful delivery of a high percentage of project data with high-quality documentation that facilitates data reuse.

This talk will highlight where you can access these data products, highlight which data management processes were most effective, outline how experience from the eAtlas assisted GBRMPA with the development of their Reef Knowledge System and lessons learnt in delivering research project specific web portals that go beyond just data management.

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Learnings from applied environmental research programs: Elements for success

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The rate of change in Australia's environment, society and economy is currently rapid, and is only going to increase into the future. To meet the nation's needs, applied research programs therefore need to become more nimble, flexible and appropriate. They need to become more solution-focused on the problems of stakeholders, including regional stakeholders. In addition there will need to be changes in the way and the rate that resultant information, knowledge and solutions are implemented. The adaptation cycle (the rate at which new or refined solutions are accepted by policy/management and then implemented on the ground) must speed up if environmental, social and economic objectives are to be achieved.

Since the 1990s the Australian Government has invested in a series of applied environmental research hubs focused on north-eastern Australia. Each of these hubs has generally sought to deliver improvements in sustainability for the region, involving many of the same stakeholders and research organisations over time, while differing subtly in objectives, governance, operations and impact. In 2019 the then Department of Environment and Energy (DoEE) requested that a comparative study of these hubs be conducted (synthesis project 6.7) with the intention that the recommendations of this study be used to inform the design of future applied research programs, in northern Australia as well as further afield.

Analyses of the results indicated that while there is no doubt that sustained Australian Government investment in the form of this series of applied environmental research hubs has been beneficial for the region, several recommendations can be made for future hub design in terms of hubs' background and objectives, governance and operations, and outputs, outcomes and impacts.

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