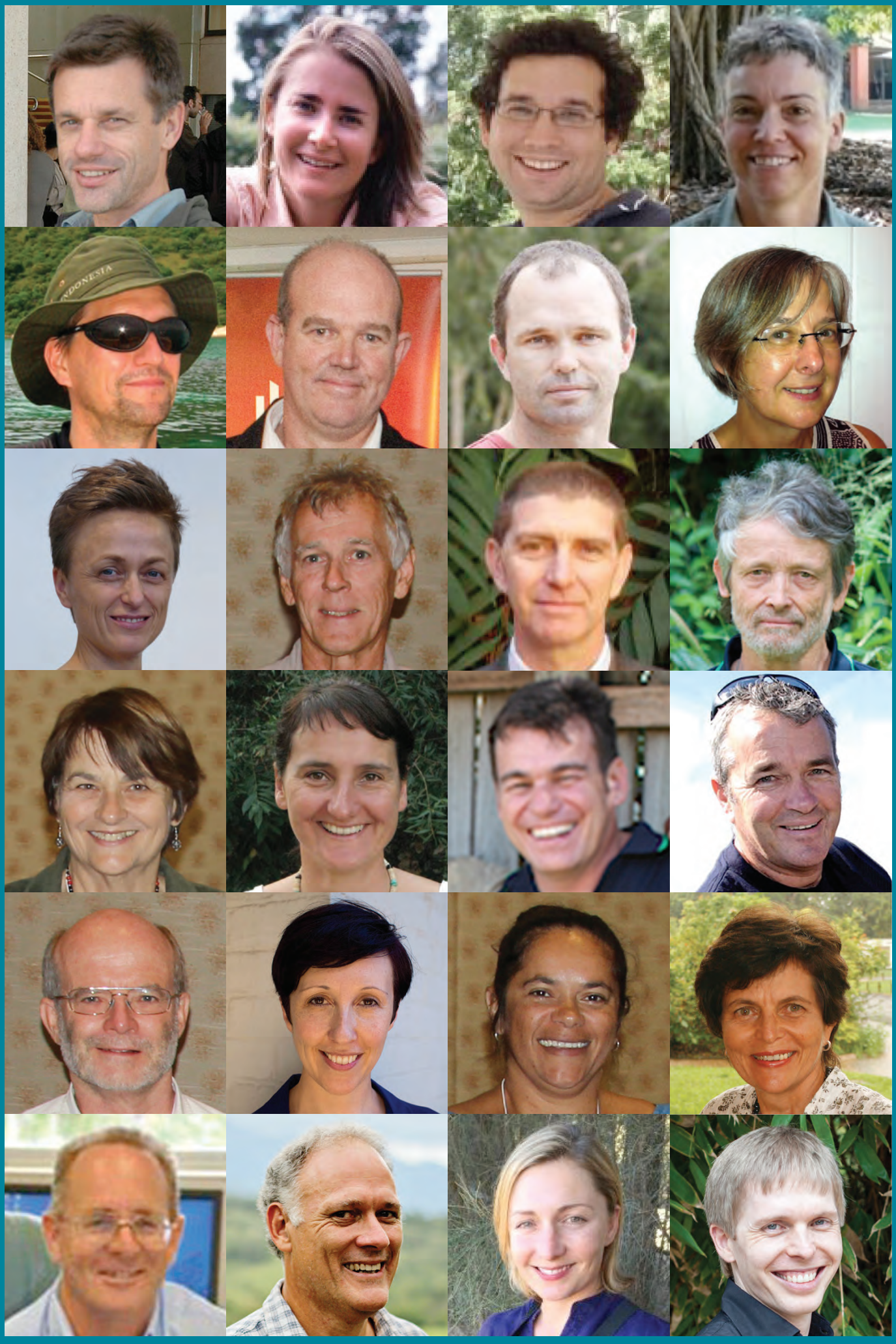
Tropical Water Quality Hub

National Environmental Science Programme

NESP Tropical Water Quality Hub Research Plan 1 Project Outcomes

1 July 2015 - 30 April 2016

The Tropical Water Quality hub is funded by the Australian Government's National Environmental Science Programme



About the NESP

National Environmental Science Programme

The National Environmental Science Programme (NESP) is a six-year $142.5m research funding initiative of the Australian Government to provide applied environmental science to assist decision-makers to understand, manage and conserve Australia's natural environment.

The Tropical Water Quality Hub

The NESP Tropical Water Quality Hub is a six-year $31.98 million environmental research hub administered by the Reef and Rainforest Research Centre Ltd, aiming to provide innovative research for practical solutions to maintain and improve water quality from catchment to coast under three key themes:

1. Improved understanding of the impacts, including cumulative impacts, and pressures on priority freshwater, coastal and marine ecosystems and species.
2. Maximise the resilience of vulnerable species to the impacts of climate change and climate variability by reducing other pressures, including poor water quality.
3. Natural resource management improvements based on sound understanding of the status and long-term trends of priority species and systems.

The key geographical focal area of the Hub is the Great Barrier Reef, Torres Strait and their associated catchments.

About this Publication

This publication is a summary of the outcomes of the NESP Tropical Water Quality Hub Research Plan 1 short-term funded projects for the period July 2015 to April 2016

Cover Photo: AIMS

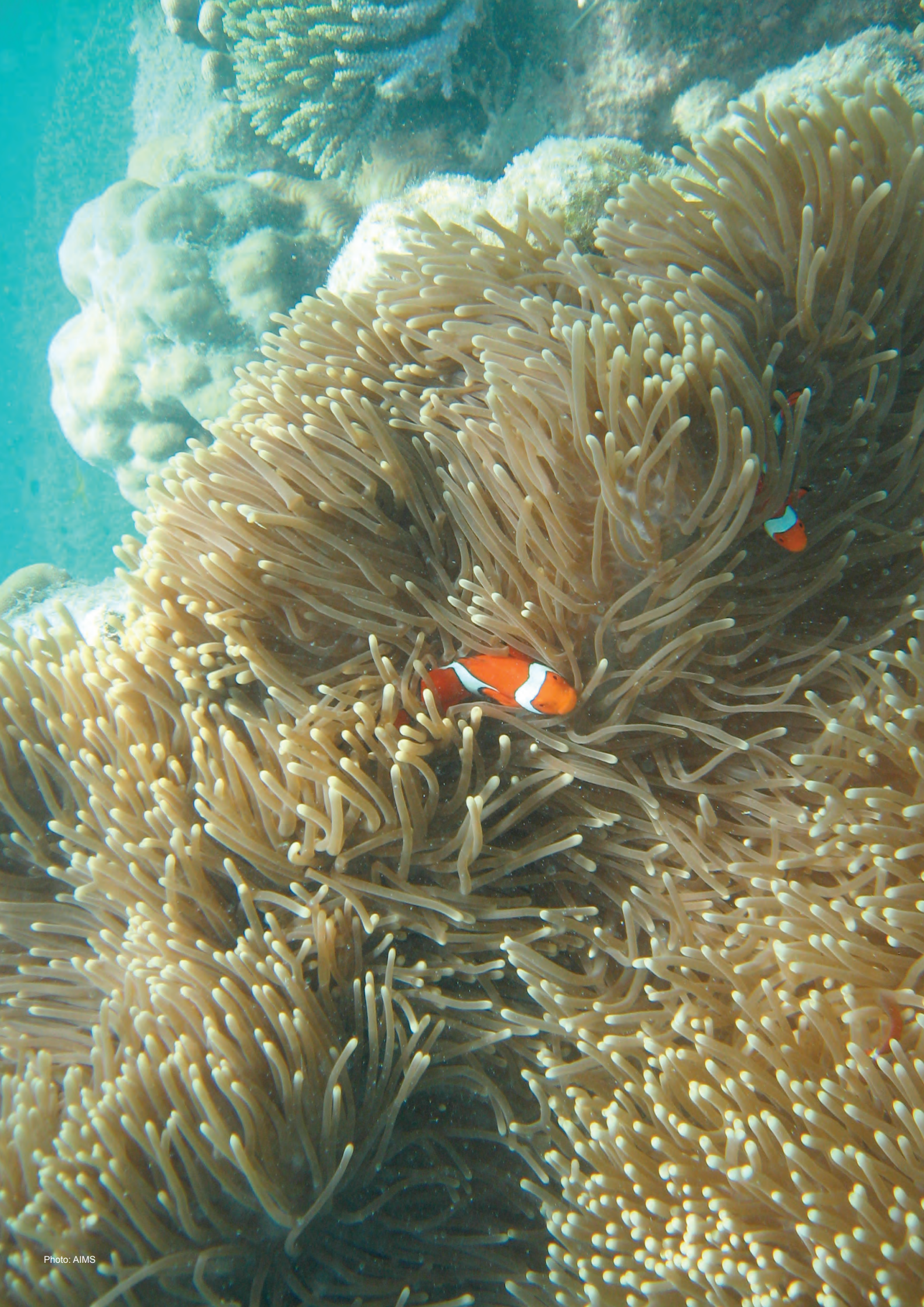


Photo: AIMS

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Acronyms

AIMS	Australian Institute of Marine Science
Ba/Ca	Barium to Calcium ratio
CQU	Central Queensland University
COTS	Crown of thorns starfish
CSIRO	Commonwealth Scientific Industry Research Organisation
DIN	Dissolved Inorganic Nitrogen
GBR	Great Barrier Reef
GBRCA	Great Barrier Reef Catchment Areas
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
GSA	Governance Systems Analysis
GU	Griffith University
ID	Identification
IPM	Integrated Pest Management
JCU	James Cook University
LTSP	Long Term Sustainability Plan
MBI	Market Based Instruments
MMP	Marine Monitoring Program
Mn/Ca	Manganese to calcium ratio
MTSRF	Marine and Tropical Sciences Research Facility
NERP	National Environmental Research Program
NESP	National Environmental Research Programme
NRM	Natural Resource Management
PNG	Papua New Guinea
RIMReP	Reef Integrated Monitoring Representative Program
TSRA	Torres Strait Regional Authority
TWQ	Tropical Water Quality
WAMSI	Western Australian Marine Institution
WQIP	Water Quality Improvement Plan
Y/Ca	Yttrium to Calcium ratio

Photo: Wayne Spencer

Project 1.1

Establishing the future NESP CoTS research framework including an ecologically-based approach to the management of CoTS at multiple scales

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Project Background

Developing appropriate strategies for incorporating surveillance into crown of thorns starfish (COTS) control activities at the local scale is a key point of intervention where research can improve management performance. Effective pest management strategies target investment based on an understanding of pest distribution, movement and population dynamics, such that key population events are targeted at critical locations and times with appropriately scaled management resources. This project provided the foundations for developing a reliable COTS surveillance and control program based on detailed understanding of: (i) COTS ecology, population dynamics and movement, (ii) control program capabilities and constraints, and, (iii) Integrated Pest Management (IPM) principles. In addition, the results will inform the COTS IPM Program to provide direction for COTS research under future NESP investment.

Project Outcomes

The project developed a management-focused qualitative model to determine the optimal trade-off between investment into surveillance versus investment into COTS control activities in the GBR. The outputs derived from the model offer significant potential improvement to the effectiveness of control operations by as much as 70% through appropriate investment in surveillance. The project identified six current and future management contexts: (1) control at sites and local areas; (2) protection of assets; (3) reduction of the spread of the current outbreak; (4) prevention of future primary outbreaks in the initiation box; (5) managing ultimate causes; and (6) the implementation of non-manual controls. For each context the knowledge gaps preventing implementation or limiting effectiveness were identified and classified into four clear areas for research investment:

1. Optimise control at sites and local areas.
2. Optimise control at regional scales.
3. Address outbreak causes.
4. Develop new control technologies.

These research areas were integrated into a research strategy that provides a sequence of work to deliver improved operations immediately and deliver improved pest management into the future.

Project 1.2

Developing an approach to evaluate the effectiveness of investments in riparian management in the GBR catchments

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Project Background

Streambank erosion is estimated to contribute approximately 30-40% end-of-catchment sediment yields in GBR catchments. However, understanding of the degree of alteration of bank erosion with the introduction of agriculture, and the success of methods for remediating bank erosion sites (using approaches such as riparian vegetation, fencing and stock removal) is limited. Without robust understanding it is difficult to target sites for remediation and to evaluate the costs and benefits of undertaking remediation in the riparian zone. The current tools used to estimate the contribution of bank erosion to the GBR (i.e. Source Catchments model), are based on empirical relationships using little or no data from tropical river systems. This project aimed to develop a revised methodology for estimating: (1) the natural or bench-mark rates of bank erosion in tropical rivers; (2) how this information can be coupled with improved data sets on channel morphology, site connectivity and sediment particle size to develop a more robust approach for identifying sites amendable to remediation; and (3) the effectiveness of remediation where riparian restoration has occurred.

Project Outcomes

The Fitzroy and Mackay Whitsunday catchments were used as case study sites to test the effectiveness of riparian vegetation for reducing streambank erosion. Using all known data on streambank erosion rates (or channel change) for these GBR catchments, this study specifically tested the hypothesis that sites with more riparian vegetation (>75%) will be more stable and undergo less change in channel width than sites with less riparian vegetation (<50%). Using historical aerial photos (circa 1950 to 2012) for measuring changes in channel width, it was found that remediation approaches implemented by NRM bodies was not directly but rather indirectly influencing riparian zones by removing stock, using fencing or installing off-site stock watering points. Results also showed that:

1. Effects of remediation would take between 2-18 years for water quality improvement.
2. Amount and condition of upstream riparian vegetation was important in reducing run-off.
3. Using historical aerial photos can provide important insights into how channels have changed over the recent (~50 year) past.

Riparian vegetation on its own will, at best, provide a local buffer to erosion and it is recommended that at least 10% of a project budget should be retained to evaluate the effectiveness of on-ground remediation works on water quality using monitoring points.

Project 1.3

A validation of coral geochemical records to reconstruct suspended sediment loads to the Great Barrier Reef lagoon

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JAMES COOK UNIVERSITY AUSTRALIA

Project Background

While coral geochemistry records are widely cited as evidence for increased suspended sediment loads delivered to the GBR since the 1850s, there has been little replication or quantification of the records. Indeed, most records are based on cores collected prior to the year 2000 when limited catchment monitoring data existed to 'validate' the interpretations that certain trace element ratios provided proxies of annual sediment loadings. This project analysed the geochemistry of coral cores collected in 2012 from sites in the central GBR and compare the ratios to measured sediment and particulate nutrient loads from the Burdekin River.

Divers coral coring on the GBR

Project Outcomes

Previous studies have speculated that the Ba/Ca, Y/Ca and Mn/Ca ratios in coral skeletons are related to land use change and sediment loading from adjacent river catchments to the GBR. A transect of coral cores collected from Magnetic Island, Havannah Island, Pandora Reef and Pelorus Island in August 2012 for the first time, directly examined the link between these trace element ratios in corals and measured sediment and particulate nutrient loads. These sites receive varying influence from the Burdekin River flood plume and provided an opportunity to compare the incorporation of trace elements in the corals from the different locations across single flood events. If a correlation could be established, this novel, independent technique would be able to quantify pre- and post-European suspended sediment loads to the GBR. Results of the analysis are currently withheld from publication.

Project 1.5

Legacy of the 2008 Lower Burdekin Water Quality Tender

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Project Background

The 2008 Lower Burdekin Water Quality Tender was the first NRM program in the GBR catchment to allocate funding for on-farm projects delivering water quality improvements through a competitive tender process. The water quality pilot tender was funded by the Australian Government through the National Market Based Instruments (MBI) in partnership with the NQ Dry Tropics NRM group and tender participants. The project aimed to review the design, operation, administration and other matters of the trial to evaluate the effectiveness of the tender in achieving long-term change and identify strengths as well as opportunities for improvement. The results are intended to inform economic theory and similar future tenders.

Project Outcomes

This project sought to explore the legacy of the Lower Burdekin Water Quality Tender, in particular its enduring benefits for water quality in the GBR and to summarise any lessons that could inform the design of future tender-based environmental funding programs. The research found a high level of persistence of investments and continuing functionality, meaning that water quality benefits continue to accrue. In particular, the Tender process:

- Engaged in an information and communications strategy that generated high levels of participant satisfaction during Tender implementation, but once funding decisions were made the level of transparency and communication became less satisfactory.
- Incentivised the participation of many farmers who had not previously addressed water quality or participated in any NRM programs.
- Effected learning about the impacts of agriculture on water quality – irrespective of the success of proposals – and thereby generated intrinsic motivation for many Tender participants to want to do more about improving water quality on their land.
- Sparked a series of subsequent investments into water quality improvements, many of which were entirely funded by the farmers while others were undertaken with the assistance of other NRM funding programs.
- Triggered and/or facilitated farming-systems change to more environmentally benign practices in some instances.

Project 1.6

Multiple and cumulative impacts on the GBR: assessment of current status and development of improved approaches for management

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Australian Government | Australian Institute of Marine Science

Project Background

Multiple local and global stressors from point source pollution to climate change affect the GBR. However, significant gaps remain in understanding how multiple stressors affect key reef components and processes, and how this varies spatially and temporally. These gaps have hindered the development of effective ecosystem models and management strategies, resulting in considerable uncertainty concerning critical thresholds, levels of interaction and cumulative impacts when making decisions about developments and activities in the GBR. This project synthesised experimental and field data from NERP, MTSRF and other research to produce a quantitative approach determining how multiple pressures lead to cumulative impacts on the GBR. Applying quantitative tools developed for ecotoxicology and water quality guidelines, critical interactive effects, environmental thresholds and their uncertainties and application in risk assessments were determined.

Project Outcomes

The project outcomes were: (1) a summary and synthesis of existing experimental work on cumulative stressors; (2) analysis of field data on stressors and thresholds; (3) testing statistical tools used in toxicology; and (4) investigating a novel tool for risk assessment. The project explored the relative importance of different drivers (e.g. climate change, run-off, sediment resuspension) and activities (e.g. dredging) in causing coral mortality risk under a set of environmental scenarios. Limitations were identified in the current interpretation of interactive effects of multiple stressors on reef components and processes, with the recommendation that a combination of tools from different disciplines – statistical, ecotoxicological, conceptual, semi-quantitative and quantitative mechanistic models, structured decision analyses – are essential to advance understanding of cumulative impacts. The project identified the generation of risk and exposure maps, together with the assessment of pressure and value thresholds, as key approaches to improving understanding of the accumulation of pressures on specific locations or ecological communities. This will better inform management decisions (e.g. for the purpose of assessing permit applications). A prototype is recommended for production of risk maps, by incorporating: (i) spatially explicit data (such as those available via eReefs and eAtlas) on the temporal variability of pressures; and (ii) improved mechanistic understanding of how multiple pressures interact and the ecological consequences. The project developed a roadmap that articulates the steps towards a management framework to assess and manage the cumulative impacts of multiple local stressors within the context of global pressures on the GBR.

Project 1.7

Reducing sediment sources to the Reef: testing the effectiveness of managing alluvial gully erosion

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Project Background

Alluvial gully erosion contributes 20-40% of fine sediment from the three largest sediment contributing catchments adjacent to the GBR, the large, dry, grazing-dominated catchments in the tropics – Burdekin, Fitzroy and Normanby. Yet there has been limited effort to manage this major sediment source. Cost-effective reduction of sediment from these alluvial gullies requires data on effective management strategies. The project documented a 'natural experiment' that occurred when tropical cyclone Ita passed over existing trial management sites in the Normanby catchment to evaluate the effectiveness of different management strategies in reducing erosion from alluvial gullies. To complement this, baseline data was collected at additional sites in the Normanby and Burdekin catchments.

The Burdekin River sends enough sediment to the reef each year to fill a line of dump trucks from Perth to Sydney and back

Project Outcomes

A series of four moderate scale (2-5 ha) cattle exclusion trial sites were established on Kings Plains, Springvale and Crocodile Stations in the Normanby catchment in 2011. A total of 117 vegetation survey plots were established both inside and outside these exclusion plots in 2011, and the sites were all resurveyed in November 2015. Qualitative assessment of the sites suggests that these treatments of sediment yield reduction (75% after 2 years) could be achieved and will withstand the onslaught of multiple cyclones, providing they are maintained as complete stock exclusion zones. This project further tested the hypothesis that surface and sub-surface soils from grazing lands could be highly significant sources of anthropogenically accelerated nutrients to the GBR. At each gully site in the Normanby catchment, samples were collected from the floodplain surface, the gully surface, the gully sub-surface and the material in the bed of the gully. Analyses of nutrient, physical and geochemical parameters on three sediment size fractions (whole soil, <63 um fraction and <10 um fraction) have been completed. Results of the analysis are currently withheld from publication.

Project 1.8

Sub-catchment scale monitoring, modelling and extension design to support reef water quality improvement

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Project Background

The catchment area adjacent to the GBRWHA contains 35 river basins, with numerous rivers discharging pollutants from agricultural, urban, mining and industrial land-based activities. In order to meet Reef Water Quality Protection Plan 2013 targets, there is a need for better spatial and extension targeting of management action change to reduce nutrient and pesticide runoff from cane lands. The aim of the project was to design a pilot sub-catchment scale monitoring, modelling and extension program, based on an end-user workshop, existing risk assessments, monitoring and modelling programs, for subsequent implementation with farmer support to identify reef pollutant "spikes/hotspots", their causes and the necessary areas for extension to improve management.

Project Outcomes

Recent GBR and global experiences increasingly recognise that despite its 'diffuse' nature, non-point source pollution still often originates in 'hotspots' or 'critical source areas' from a small portion of the landscape; areas which can be targeted for maximum intervention efficiency. Finer scale water quality monitoring projects integrating farm up to small watershed-scale monitoring-management frameworks (with a key emphasis on stakeholder collaboration and participatory learning processes) are now key mechanisms for achieving water quality improvements. A range of initiatives at the NRM regional level, particularly recently developed WQIPs, were synthesised to provide spatially explicit data on water quality 'hotspots' at a finer, catchment and sub-catchment scales. A monitoring program design framework presents a range of different 'gold, silver and bronze' standards to accommodate different program objectives, desired levels of integration with other monitoring-modelling initiatives, local capacities and levels available for investment. The range of 'bronze' to 'gold' standard program designs offer some flexibility in the level of investment required to meet different program objectives. These different levels of program design need not be mutually exclusive and even the implementation of an optimal 'gold standard' program will likely have to start modestly (bronze-silver level), which slowly evolves through a carefully staged, adaptive approach. Feedback loops to industry allow farmers to recognise themselves as part of the problem, but also part of the solution. The 'gold standard' of this hierarchy, would entail a stakeholder-guided collaborative approach that uses multiple targeted monitoring sites through a catchment to integrate stakeholder engagement in both the decision-making process and in the implementation of water quality management strategies. The monitoring design framework also provides options for integrating program outcomes into broader, concurrent water quality monitoring modelling programs currently underway in the GBRCA.

Project 1.9

The establishment of a future NESP dredging research investment framework

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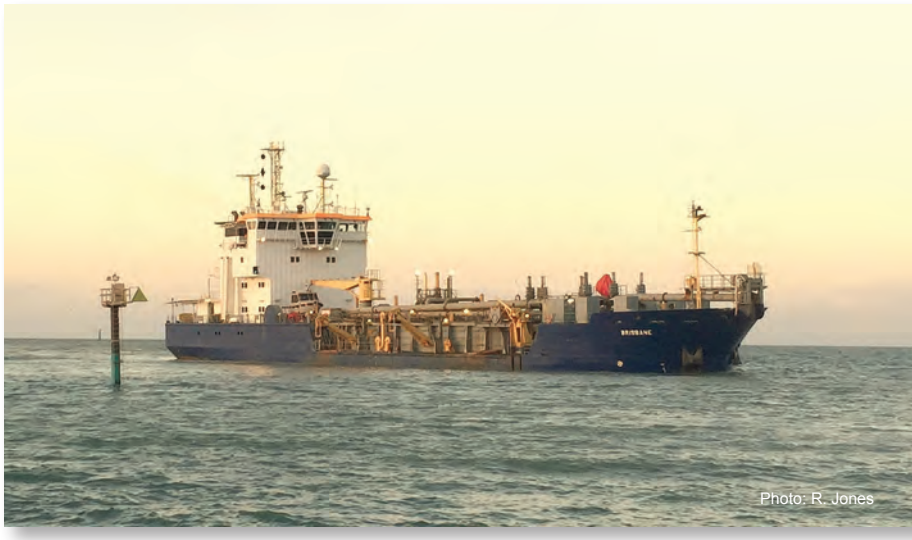
Australian Government | Australian Institute of Marine Science

Project Background

Port dredging and spoil disposal is an increasing issue that has received significant attention recently. An agreed research framework and coordinated research is essential to progress stakeholder-driven 'real life' solutions for the Ports Industry, while addressing water quality decline and ecosystem health impacts in the GBR. Improved certainty in the information utilised for management decisions on dredging projects in the GBR will result in less adversarial debate and more focus on innovative solutions. The recently completed report "Synthesis of current knowledge of the biophysical impacts of dredging and disposal on the GBR" outlined knowledge gaps important for the future improved management of dredging activities in the GBR. This document, together with the findings of the dredging science node of the Western Australian Marine Institution (WAMSI), will inform the future NESP TWQ Hub dredging research agenda prior to the investment of significant funding by the Australian Government.



The trailing suction hopper dredge 'Brisbane' in the Port of Townsville in 2015

Project Outcomes

The project synthesised a list of 21 potential research sub-themes for consideration and prioritisation by researchers and stakeholders from industry and government agencies. An initial online survey identified six high priority sub-themes, which were presented and debated among 30 diverse participants at a facilitated workshop. Distillation into a list of two high and one secondary priority research themes was achieved at the workshop with widespread support. The priority themes will address gaps in understanding of ecological thresholds caused by dredging-related pressures, dredging sediment transport pathways and research to understand the risks associated with disposal of dredge material on land. The resultant priorities to consider in subsequent funding calls were:

- Priority 1a: Develop critical ecological tolerance thresholds for light reduction, suspended sediments and sediment deposition to predict ecological impacts of dredging operations.
- Priority 1b: Better quantification of sediment transport pathways over relevant timeframe.
- Priority 2: Assessment of potential impacts and risks associated with disposal of dredge material on land and in reclamation areas.

Project 1.10

Identification, impacts, and prioritisation of emerging contaminants present in the Great Barrier Reef and Torres Strait marine environments

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Australian Government | Australian Institute of Marine Science

Project Background

Increased human activities in the GBR and Torres Strait regions are expected to increase the sources and diversity of contaminants in the marine environment. Current policy and management for marine water quality focuses on suspended sediment, nutrients and PSII herbicides. Other contaminants are known to be present in the marine environment, including new (alternative) pesticides, endocrine disrupting chemicals, coal dust, hydrocarbons, metals, microplastics, pharmaceuticals and personal care products. While emerging contaminants are a topic of intensive research internationally, little is known about their sources, role and fate in the GBR and Torres Strait regions. Furthermore, changes in agricultural practices and land uses, increasing coastal development including urban and industrial land uses and ports, and associated projected shipping increases are likely to result in new contaminants being released into marine ecosystems in the near future. This project aimed to: (1) determine the presence and locations of emerging contaminants based on monitoring data and the types of human activities present, and (2) prioritise the identified emerging contaminants based on their potential risk to receiving marine environments.

Project Outcomes

The project identified emerging contaminants likely to be present and of potential concern to the GBR and Torres Strait marine environments. These include heavy and trace metals, new (alternative) pesticides, hydrocarbons, coal dust, pharmaceuticals, personal care products, nano-particles, antifouling paints, and marine debris (including microplastics). Monitoring information on concentrations of most (but not all) of these emerging contaminants is either rare, not available or absent in the GBR and Torres Strait marine environments. The qualitative risk assessment determined that of the nine emerging contaminants examined, marine plastic pollution poses the highest risk to marine ecosystems, particularly in the Cape York and Torres Strait regions due to exposure to oceanic and local shipping sources. Compared to current pollutants of concern (sediment, nutrients and PSII herbicides), the risk assessment suggests that marine plastic pollution is likely to pose a higher risk to Torres Strait and Cape York marine ecosystems. The next emerging pollutants of concern are chronic contamination of water and sediments with antifouling paints, and exposure to certain personal care products, in regions south of Cape York. The qualitative risks of all other emerging contaminants are relatively low with some minor differences between regions. The project developed water quality guideline values for four alternative pesticides (2,4-D, Metribuzin, Imazapic, Isoxaflutole) commonly found in GBR waters. Recommended research areas include: (1) local, targeted monitoring for priority emerging contaminants where there is little or no recent monitoring data; and (2) examining the ecological impacts of marine plastic pollution, chronic contamination of antifouling paints, and certain personal care products on GBR and Torres Strait marine organisms and ecosystems.

Project 2.1

Assessing the cumulative impacts of climatic disturbances on inshore GBR coral reefs, identifying key refuges and testing the viability of manipulative reef Restoration

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Project Background

The Keppel Islands in the southern GBR, experienced successive climatic disturbance events in 2006 (coral bleaching), 2011 and 2013 (river flood plumes), and 2015 (tropical cyclone Marcia – Category 5). Long-term monitoring at 20 sites revealed significant declines in coral cover and fish abundance on both no-take reserve (green zone) and fished reefs. In 2013, most reefs in the Keppel Islands were severely degraded, however several reefs had retained moderate live coral cover and continued to support productive fish communities. In February 2015, tropical cyclone Marcia (Category 5) crossed the Keppel Islands. This project re-surveyed all 26 monitoring sites to quantify cyclone damage and identify remaining refuge areas that can support reef recovery and long-term resilience. A pilot-scale experiment was also conducted on degraded reefs in the Keppel Islands to assess the viability of active reef restoration.

Project Outcomes

Assessment of the current status of coral and fish communities in the Keppel Islands compared to the long-term monitoring dataset collected since 2004 revealed significant declines in live hard coral cover and fish abundances on both no-take (green zone) reserves and fished reefs between 2004 and 2015. Underwater surveys carried out at 20 monitoring sites in October 2015 documented a high degree of spatial patchiness in the condition of coral reefs. 21% of reefs surveyed were highly degraded, with <5% hard coral cover, >50% macroalgae cover, and low fish abundances and diversity. While 13% reefs retained at least 45% coral cover and are postulated to provide a refuge for coral (predominantly *Acropora spp*.) from cyclone and other damage. Overall in the Keppel Islands, hard coral cover is currently around 30% and coral community recovery is underway at a number of reef sites. The abundance of coral trout (*Plectropomus spp*.) has fluctuated considerably since 2004 and is highly correlated with the cover of live hard coral cover, habitat structural complexity and prey abundance. No-take (green) zone reefs continue to support higher abundances of larger coral trout than reefs that are open to fishing, however the magnitude of the difference is not as pronounced as it was 2004 and 2009, when reef health and productivity was at its highest. Protection of live coral and reef habitat structural complexity remain a high priority in the Keppel Islands, with reefs that support relatively high levels of live coral evidently the most resilient reefs within the island group. These refuge reefs provide important local stores of coral reef biodiversity, and contribute to the replenishment and recovery of degraded reefs through larval supply.

Project 2.2

A tradable permit scheme for costeffective reduction of nitrogen runoff in the sugarcane catchments of the Great Barrier Reef

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Project Background

Sugarcane production relies on the application of nitrogen fertiliser to enhance soil quality, and nitrogen is a highly mobile nutrient that is easily lost from the soil. Nitrogen runoff from sugarcane production is seen as one of the major sources impacting water quality in the GBR. An 80% reduction in the amount of dissolved inorganic nitrogen (DIN) by 2025 is the target in the Reef 2050 Long Term Sustainability Plan. Current methods to reduce nitrogen runoff from sugarcane production use an A-B-C-D best management practice framework which relies on voluntary participation. Despite considerable effort and expenditure, these approaches have produced only modest changes in runoff rates and water quality improvements. This project undertook a scoping study to design a pilot nitrogen trading scheme for key cane growing catchments draining into the GBR lagoon. The Tully catchment was used as the key case study with consideration given to the implications of the findings in the geographically different Burdekin catchment.

Project Outcomes

The key elements of a successful water quality-trading scheme identified are the establishment of a regulatory cap, clear identification of the pollutants to be traded and geographic trading area, development of trading rules and supportive institutional structures. Tradable permit simulation estimated the cost-effectiveness of the scheme for reducing nitrogen loads into the GBR, and the financial impact on sugarcane growers. Core enablers were identified and key steps for implementation were formulated, including governance structure and monitoring mechanisms. A spatially-specific model of a nitrogen-trading market was constructed for the Tully catchment by collating data on sugarcane area, soil class and the Tully drainage network. Nitrogen-trading was simulated using a grid of 4,020 ‘paddock-scale’ 250 m x 250 m cells, each trading as a separate entity in a centralised smart market. Trading of permits in the ‘Smart Market’ reduces the total cost impact on the cane growing section of the industry to achieve nitrogen reduction targets. As the cap tightens the market price for nitrogen increases and turning marginally productive cane land in key locations to wetlands becomes economically viable. Market simulation results suggest that reducing nitrogen fertiliser applications to 120 kgN/ha may be sufficient to achieve the 50% DIN load reduction target of the Reef 2050 Long Term Sustainability Plan.

Project 3.1

Seagrass mapping synthesis – A resource for marine park and coastal management

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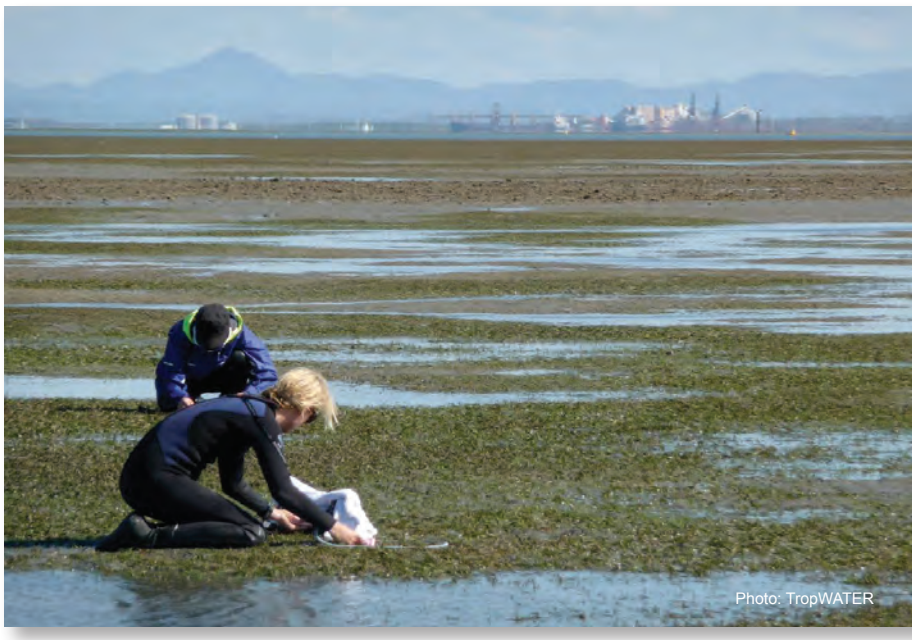
Project Background

Key to understanding the desired state of Queensland seagrasses is reliable data on seagrass distribution, abundance and species composition, and how this changes through time. Also valuable is the ability to reliably downscale from regional (World Heritage Area) to local-scale estuaries and meadows. Seagrass maps prepared by TropWater are part of Queensland's ecological "infrastructure". They are used to model connectivity, assist with zoning and management, understand change, assess the impact of poor water quality, and assess and predict vulnerability of turtle and dugong populations. However the seagrass mapping has not been updated since 2010 and as a result is missing data from important areas and events, and provides no meadow-specific information. This project re-compiled existing GIS layers, added 2010-2015 data, and provided meadow-specific information.



Sampling of intertidal seagrass at Gladstone

Project Outcomes

The project consolidated all available seagrass site and meadow-specific spatial data (approximately 320 separate data sets) for the GBR World Heritage Area (GBRWHA) collected by the TropWATER Seagrass Group and CSIRO into a Geographic Information System (GIS) layers database. The data includes species and meadow distribution and associated metadata. Twelve seagrass species from three families were included from 66,201 sites sampled in the GBR World Heritage Area between 1984 and 2014. Datasets now include multiple surveys for ports and shipping projects that have not been included in previous composite seagrass meadow layers. The project identified areas where much of the data available for management is more than 20 years old or where there are specific habitats unsurveyed. Large areas of central and northern Queensland require updating. Several key habitat types such as reef platform seagrass meadows are poorly represented in the data. The database will be made available on eAtlas.

Project 3.2

Improving historical estimates of abundance and distribution of dugongs and large green turtles in western and central Torres Strait

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Project Background

Accurate estimates of population size and distribution of dugongs and green turtles in Torres Strait are important for the Indigenous management of these species. Dugong aerial surveys and turtle sightings conducted since 1987 have identified that bathymetry and environmental conditions influence aerial observations. Recent studies attempting to address these issues estimated that there were ~400,000 adult-sized green turtles in central and western Torres Strait (Fuentes et al. in press), and that the dugong population was likely an underestimate since dugong in waters 5-12 m deep are less available to aerial observers than animals in shallower or deeper waters. This project aimed to improve the accuracy of aerial survey estimates of the size and distribution of dugong and green turtle populations in western and central Torres Strait by: (1) collecting and analysing data on their movements and diving behaviour, and (2) estimating the proportion of turtles seen during aerial surveys that are the large female green turtles harvested by Indigenous hunters. These data were analysed with historical data to (re)estimate the size and distribution of populations of dugongs and harvestable green turtles in Torres Strait.

Project Outcomes

The project has calculated improved estimates of dugong and turtle populations in the western and central Torres Strait. The Torres Strait dugong population is substantially higher than previously estimated because most dugongs in Torres Strait occur in water 5-20 m deep where they are out of the sight of aerial observers. The estimate of the foraging green turtle population in Torres Strait is less certain than for dugong. The fisheries independent data is limited, especially given mounting evidence of recruitment failure at Raine Island, the major rookery for the northern Great Barrier Reef green turtle stock.Tracking results have also provided valuable insight into the movement of dugongs and green turtles in the Torres Strait:

1. Dugongs range widely in western Torres Strait, crossing sea country boundaries and jurisdictional borders. One animal travelled twice between its capture site in Badu Sea country to waters around Boigu.
2. Of the nine green turtles that were tagged, most did not range outside the Torres Strait and three travelled from Badu sea country to Raine Island to breed, and then returned. The green turtles that ranged within the Torres Strait are unlikely to have bred in the 2015/16 season.

Results of the analysis are currently withheld from publication.

Project 3.3

Light thresholds for seagrasses of the GBR: a synthesis and guiding document for managing seagrass

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JAMES COOK UNIVERSITY AUSTRALIA

Project Background

Seagrass are dependent on light to maintain primary productivity, and when light levels become too low, seagrass loss occurs with considerable flow-on effects for GBR ecosystems and species (e.g. dugong and turtle mortality). In many cases, light levels (driven by water turbidity) can be managed to minimise seagrass loss. Recent attempts to define threshold levels of light required to maintain GBR seagrass state has resulted in a spectrum of recommendations with no single definitive guideline. This project aimed to define the amount of light (light thresholds) that seagrass require to maintain their status and develop a guiding document for managers and regulators. The guideline will draw on available data on light thresholds for some seagrass species, in particular *Zostera muelleri*, and will be broadly applicable to all seagrass species in the GBR, including those where there is limited data (e.g. *Enahlus acroides*).

Project Outcomes

The project developed a guideline that contains light thresholds for seagrass species in the GBRWHA. The thresholds can be applied to ensure protection of seagrass from activities that impact water turbidity and the light environment over the short-term, such as coastal and port developments. Thresholds for long-term maintenance of seagrass are also proposed. This guideline has utility for managers and regulators in generating relevant water quality guidelines and conditions for developments such as dredging programs. It also highlights research information needs and provides interim guidelines for immediate management application. The project identified a light thresholds framework that includes:

- Biological acute thresholds for 12 seagrass species, ranging from 2 mol m^{-2} d^{-1} to 6 mol m^{-2} d^{-1}, depending on species, measurement approach (e.g. experimental, in situ) and measurement indicator (e.g. abundance or growth).
- Thresholds are presented together with an integration time (1-14 days), time to impact (7-50 days) and confidence score (1-5).
- Colonising species that dominate in deep water habitat are the most sensitive to light reduction and therefore have the lowest light thresholds (2-6 mol m^{-2} d^{-1}) and shortest time to impact (14-28 days), depending on species.
- Opportunistic species have higher light thresholds (5-6 mol m^{-2} d^{-1}) and longer time to impact (28-50 days).
- Persistent species also had a high light threshold (5-6 mol m^{-2} d^{-1}), but with longer time to impact (50 days); however, there is very little information available on light thresholds for persistent species and they have the lowest confidence scores.
- Management thresholds for each species are more conservative than biological thresholds, and allow for error in estimation of thresholds, as well as some effects of cumulative or interacting factors.
- Long-term guidelines are based on long-term light thresholds, but these are not as clearly defined owing to a paucity of data. As an example, 10-13 mol m^{-2} d^{-1} is likely to prevent light limitation for the long-bladed species.

Project 3.4

Developing and refining biological indicators for condition assessments in an integrated monitoring program

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Project Background

The GBR Marine Monitoring Program (MMP) recently underwent a comprehensive review and is transitioning into reporting through the integrated monitoring framework. Refinement of biological indicators for condition assessment is an immediate priority under the Reef 2050 Long-Term Sustainability Plan, and this project focused on biological indicators for seagrass. Seagrass meadows are highly sensitive to climatic conditions and environmental pressures such as water quality, as seen through recent (past 10 years) changes in abundance in the GBR. Due to these impacts, GBR seagrass meadows underwent a period of decline from 2009 to 2011. Seagrass carbohydrate content is an early-warning indicator of water quality impacts, and analysis of samples collected quarterly since 2008 will be used to establish baselines and optimize protocols for applying carbohydrates as an indicator for future monitoring. Furthermore, calibration formulae to convert seagrass percent cover, the principal condition indicator, to biomass will be developed, allowing integration across programs critical for the Reef-wide Integrated Monitoring and Reporting Program.

Seagrass monitoring

Project Outcomes

Two indicators were examined: (1) carbohydrate stores in seagrass rhizomes, and (2) calibration formulae for integrating percent cover and biomass data. Carbohydrate results from 2008-2015 provided almost 1,000 samples that represent three seagrass species – *Halodule uninervis* (586 samples), *Thalassia hemprichii* (229 samples), and *Cymodocea serrulata* (177 samples). The sampling period (2008-2015) was affected by extreme weather events (high rainfall and flooding), which influenced seagrass abundance and composition, and resulted in some gaps in the long-term data set. Results show that there are differences among species in predominant carbohydrate storage form. Carbohydrate content was affected by seagrass condition; although further work is required to develop conclusively recommend carbohydrate content as a biological indicator. A preliminary exploration of results has demonstrated a good relationship between seagrass percent cover and biomass, which was improved when canopy height was factored into the calibration and continued refinement of biomass calibrations for other species and habitats will increase the utility of this indicator.

Project 3.5

Assessment of key dugong and turtle seagrass resources in the northern Torres Strait

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Project Background

Seagrass provide critical habitat and food for turtle and dugong in the Torres Strait, which supports the world's largest dugong population. However, seagrass remain inadequately surveyed in a large area of the Torres Strait between Deliverance and Boigu Island and extending to the PNG coastline and south to Orman Reefs. This area is the subject of considerable focus for dugong and turtle management and seagrass information is critical for successful planning and management. This project conducted a baseline assessment of intertidal and sub-tidal seagrass that will form the foundation for ongoing monitoring, and provide essential information to management for dugong and turtle management planning, complementing research studies and building skills and capacity of Traditional Owners and Rangers.

Project Outcomes

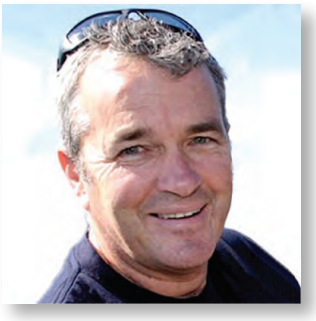
Over 853 sites were surveyed in intertidal and subtidal areas for seagrass presence/absence, percent cover, above ground biomass, species composition and diversity, as well as seagrass and habitat forming benthic macro-invertebrate communities. Project results from the field surveys have found:

1. Substantial areas of previously undescribed seagrass habitat in the northern Torres Strait, particularly in shallow and intertidal locations (area bounded by Deliverance, Turnagain and Boigu Islands), but sparse elsewhere likely due to strong currents south of Deliverance Island and high suspended sediments close to PNG.
2. Seagrass was present at 43% of sites and 60,263 ha across 34 meadows of seagrass area was mapped.
3. Ten seagrass species from three families were identified. The most dominant species in terms of contribution to mean biomass was *T. hemprichii* (35%), and *H. uninervis* was the most commonly occurring species.
4. Evidence that these areas are highly utilised by dugong, with extensive areas of dugong feeding scars present along the PNG coast and around Boigu Island.

Subtidal meadow distribution mapped in this study overlaps spatially with very high dugong and turtle density distributions recorded during aerial surveys.

Project 3.6

Establishing a research framework for future NESP investment into better understanding of the presence of Box-Jellyfishes (Irukandji) and risks in the Great Barrier Reef



Project Leader
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Project Background

Currently box-jellyfishes (Irukandji) are a growing issue in the GBR, particularly in relation to risks to swimmers and divers. Current information suggests that water quality can affect all life history stages of box-jellyfishes (this includes the benthic polypoid and medusoid phases) with changes in salinity triggering the release of small jellyfishes and if too low, killing jellyfishes, critical temperatures can affect jellyfishes, and nutrient levels can influence food availability that can in turn affect jellyfish survival. Issues raised by a number of key stakeholders regarding confidence in the information utilized for the safety of GBR users has resulted in an ongoing debate regarding the extent of the issue and a reduced focus on innovative solutions. The project aimed to resolve this debate by conducting a facilitated workshop with key researchers and stakeholders to establish the research framework for future NESP investment in box-jellyfishes research in the GBR to better understand their presence and risk to users.

Project Outcomes

The project team engaged with stakeholders to discuss scientific information already available, research gaps to be filled and develop a framework to guide future NESP research to meet end-user needs. The workshop focused on defining the scope of research required to: identify how species of Irukandji and other box-jellyfishes respond to changing water quality conditions, predictions of box-jellyfishes presence based on environmental conditions, determine ecological impacts, and innovative management options.

The key outcomes from the workshop include:

1. Early warning by forecasting (models), detection (e.g. with jellycams) and accurate identification when jellyfish are collected – the information would in turn be inputted to a revitalized alert system – including developing an ‘app.’
2. The development of risk models that are supported by good husbandry of jellyfish (and their benthic polyps) for experiments on the influence of water quality.

Continued engagement with stakeholders has developed a series of needs that focus on: (1) building a jellyfish database; (2) developing a forecast model to reduce the risk of stings; (3) test those models – including the use of Rangers; (4) providing on-beach quick ID of jellyfish using digital cameras; (5) delivering more accurate forecast of stings to stakeholders.

Project 3.7

Monitoring the effects of zoning on coral reefs and their associated fish communities in the GBR Marine Park

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Australian Government | Australian Institute of Marine Science

Project Background

Spatial management of human activities through zoning is the principal form of management of the GBR Marine Park. This project continues a program that monitors the effects of zoning, particularly fishing closures, on coral reef communities of the Marine Park. The program was established following the rezoning of the Marine Park in 2004. A recent survey of fish assemblages in 87 no-take reserves around the world considered that effects of past fishing were still evident after more than 10 years of closure. This project builds on the activities of the AIMS long-term program to monitor the effects of zoning on coral reef communities in the period July-October 2015. As well as forming part of the long-term monitoring program, these reefs are interesting as they are recovering from the effects of severe storms, notably tropical cyclone Hamish in 2009.

Trout and surgeonfish in the Great Barrier Marine Park

Project Outcomes

The AIMS monitoring team surveyed the effects of marine park zoning on reef communities – fish and corals – in the Capricorn-Bunker group in October 2015. The four pairs of reefs were chosen to be similar in size, setting, and underwater topography. One reef in each pair is open to fishing while the other was closed to fishing and zoned as a no-take (green) zone. The abundance and biomass of the primary target species of the reef line fishery – coral trout – were higher on no-take reefs in the Capricorn-Bunker group. However there were no consistent differences between open and closed reefs in the numbers of herbivorous fishes, which are considered to be important for reef resilience. These reefs were damaged by storms in 2008 and 2009 but coral cover is recovering rapidly, however, here were no consistent differences in cover of live hard coral or the abundance of juvenile hard corals between open and closed reefs. These results concur with the overall findings of long-term surveys on the GBR since 2006 that protection from fishing has a clear effect on target species, but few indirect effects on other components of the reef community.

Project 3.8

Towards an integrated monitoring program: identifying indicators and existing monitoring programs to cost-effectively evaluate the Long Term Sustainability Plan

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Project Background

As an initiative of the Reef 2050 Long Term Sustainability Plan (LTSP), an integrated monitoring program is being developed for the GBR. The specification of targets, objectives and outcomes in the LTSP elevates the importance of monitoring. The LTSP calls for an integrated monitoring and reporting program that will provide a comprehensive and up-to-date understanding of the GBR, its values, the processes that support it and the pressures that affect it. Further, the establishment of an effective integrated performance monitoring program is a fundamental precursor to enable adaptive management to protect and restore the GBR. The evidence of success (or failure) of meeting the targets, objectives and outcomes of the LTSP will be derived largely from the signal provided by an integrated monitoring program.

Project Outcomes

This project addressed a series of critical initial steps required to develop a cost-effective integrated monitoring program: (1) identified a suite of environmental, social and economic elements and indicators that could be monitored to enable an evaluation of the LTSP targets; (2) evaluated existing environmental, social and economic monitoring programs against the newly developed LTSP targets, to ensure that the relevant aspects of these monitoring program are considered for inclusion in an integrated monitoring program; and, (3) evaluated how the AIMS Long Term and Marine Monitoring Programs can cost-effectively contribute to the integrated monitoring program.

The project findings provide:

1. Breakdown of the LTSP targets and objectives to assist in the identification and/or development of appropriate and effective indicators to identify the environmental and socio-economic values and attributes that could be monitored to assess progress towards the LTSP targets and objectives.
2. Inventory of existing monitoring programs, and assessment of the relevance of the marine monitoring programs to measure the environmental and socio-economic values and attributes of the LTSP.
3. Assessment of the statistical power of the AIMS Long Term and Marine Monitoring Programs to determine their capacity to detect changes at scales relevant to the LTSP.

All project outputs, including a full monitoring program inventory, were delivered to end-users, including the Reef Integrated Monitoring Representative Program (RIMReP) Design working group, to assist in the development of an integrated monitoring and reporting program for the GBR.

Project 3.9

Indigenous capacity building and increased participation in management of Queensland sea country

Project Leaders
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Project Background

Traditional Owners over the last 20 years have been coming together, exploring and calling for a collective approach to achieving their aspirations for ownership, access to, and involvement in the management of sea country. Over these years, real progress has been made in people securing improved rights and the development of local capacities to govern and manage country. To date there has been a lack of Indigenous engagement in the development of the Reef 2050 Long Term Sustainability Plan (LTSP) and the research agenda within the GBR World Heritage Area. Through targeted community consultation this project analysed, scoped and prioritised the Reef 2050 LTSP Indigenous targets to develop an Implementation Strategy and investment framework to guide LTSP implementation and inform the NESP Tropical Water Quality Hub research priorities.

Sea country management planning

Project Outcomes

Investigation and analysis of the coordinated framework for increasing Indigenous engagement in sea country management is critical in taking forward co-management with the Australian and Queensland governments and the Great Barrier Reef Marine Park Authority. The key components identified were: (1) strengthen capacity of local Indigenous land and sea management organisations; (2) develop partnership frameworks for the engagement of government and non-government organisations; and (3) support open engagement with information and knowledge generation. At this time, the mechanisms for cohesive and coordinated implementation of the LTSP do not yet fundamentally engage Traditional Owners as real partners in the long-term management of sea country.

Project 3.10

Benchmarking costs of NRM improvements for the GBR

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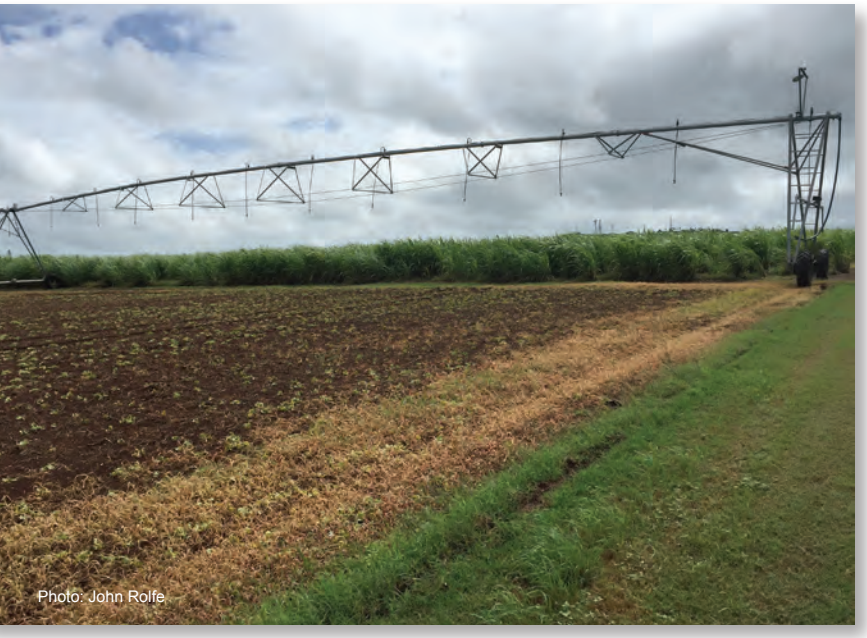
Project Background

Funding programs to improve the quality of water entering the GBR are difficult to evaluate and it is difficult to judge when particular proposals are too expensive, or how funds should be distributed between actions and regions. The objective of this project was to provide information on cost benchmarks for key management actions to improve water quality entering the GBR. The project involved a review and evaluation of summary data about NRM projects that have been funded recently to address water quality issues. By pooling the data across NRM regions and different activities, it was possible to identify the distribution of cost/outcome ratios. From this, potential benchmarks can be established (e.g. 75% of sediment reduction actions are less than $xxx/tonne, 95% are less than $XXX per tonne) and identification of the most cost-effective strategies across actions and regions.



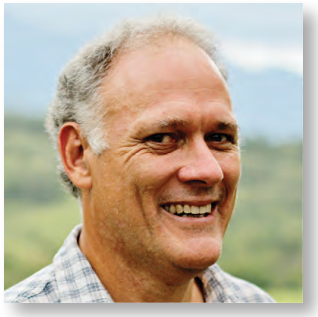
Boom irrigation within the GBR catchments

Project Outcomes

This project summarised and evaluated available data on the cost-effectiveness of improvements in agricultural water quality within GBR catchments to provide benchmarks on cost-effectiveness across the key pollutants to help prioritise future investments in water quality. Cost-effectiveness is the ratio of water quality improvements (such as reductions in sediment or nutrient loads) to the costs of achieving the change. Rigorous modelling indicates the approximate cost-effectiveness thresholds can be set at the average of achieved and predicted costs for end-of-catchment loads as sediment ($259/tonne); nitrogen (DIN) ($150/kg); and pesticide (PSII) ($8,351/kg). These benchmarks should be treated as average thresholds for allocating project funds, both between and within regions. It is likely that lower cost projects can be achieved through more targeted program design and better assessment of cost-effectiveness.

Project 3.11

Monitoring and adaptively reducing system-wide governance risks facing the GBR



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Project Background

Australian Governments have invested in water quality issues in the GBR for the last decade. While much has improved, more is needed. GBR environmental outcomes, however, depend on the interplay among diverse/fragmented governance activities (e.g. water allocation, ports planning, regional NRM). Despite being recognised in the Reef 2050 Long Term Sustainability Plan (LTSP), there is no coordinated system for benchmarking or monitoring the health of the overall GBR governance system and constituent activities. This project delivers both short-term influence over key Australian and Queensland government (i.e. GBR Taskforce) decisions regarding management and investment, and engages new LTSP implementation/review structures and stakeholders to build commitment to institutionalising this method over the longer term to be directly integrated into five-yearly Outlook reporting.

Project Outcomes

Using the GBR World Heritage Area as a case study of international significance, this project applied Governance Systems Analysis (GSA), a novel analytical framework that identifies, benchmarks and enables a more independent and integrated review of the key risks within the overall system of governance. The application of GSA enabled the identification of those governance themes, domains and subdomains most likely to influence environmental and related social and economic outcomes in the GBR. Overall, the implementation of the LTSP water quality improvement targets will remain unachievable if there is not a substantive focus on integrated reform of the key delivery-focused governance subdomains that deliver coordinative and on ground actions within GBR catchments. Three broad-scale dilemmas will affect the capacity of the LTSP in influencing the wider system of governance in mediating GBR outcomes: (1) the LTSP has little mandate or capacity to influence several high risk domains and subdomains not directly related to day-to-day GBR management; (2) the LTSP has significant governance challenges; and (3) the LTSP is not yet substantively guiding and aligning the efforts of other stakeholders, such as NRM bodies, to the effective delivery of effort at the catchment scale in the GBR. Progressing reform in these three areas will require a strong bilateral commitment between the Australian and Queensland governments to jointly monitor and adaptively improve the overarching system of governance affecting GBR outcomes.

Project 3.12

Development of an offset financial contribution calculator for Reef Trust

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THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Project Background

This project progressed an approach for incorporating environmental offsets into the Reef Trust through development of a prototype calculator to assist potential approval-holders and relevant agencies in determining appropriate financial payments as offsets under the Reef Trust. It extended the methodology currently used to calculate terrestrial offsets to the marine setting. It delineated the differences in applying such a calculator to the marine–catchment continuum and terrestrial settings. A draft prototype was tested for consistency with operational needs and practicality among key stakeholders.

Project Outcomes

'Biodiversity offsets' are a mechanism by which the permitted environmental impacts of development projects are compensated through conservation activities that yield a gain at least equivalent to the impact. Current offsets in Australia, while inclusive of the marine environment, were conceptualised primarily for terrestrial ecosystems and have most often been applied in terrestrial settings. The project team has developed an easy-to-use excel prototype calculator that is based on terrestrial offset calculators used in Australia and international best practice, but adapted for the GBR context. The prototype calculator is an easy-to-use excel tool that considers surrogates; surrogate condition factor; implementation costs; time delay; and administration fees. Results of the analysis are currently withheld from publication.

Project 3.13

eAtlas 2015 – NESP data management, Torres Strait NRM plan delivery platform and Torres Strait reef mapping

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Australian Government | Australian Institute of Marine Science

Project Background

The primary role of the eAtlas is to support researchers with the documentation, curation and publication of their research data and to ensure that this data is accessible and usable now and into the future. The eAtlas provides and develops the systems necessary for making the research data discoverable via the web. During July 2015 to March 2016, the eAtlas team were required to prepare, publish and visualise approximately 50 NERP Tropical Ecosystem Hub datasets that were submitted at the end of NERP; work with NESP Tropical Water Quality Hub projects to capture any new relevant data products; and continue to support and train Torres Strait Regional Authority (TSRA) staff in the new Torres Strait eAtlas for Torres Strait reef mapping and the new Land and Sea Strategy NRM plans.

Project Outcomes

Two significant outcomes have been achieved by the eAtlas during this short-term project. Firstly, all of the NERP Tropical Ecosystem Hub program datasets are now published on the eAtlas as high quality metadata records with accompanying downloadable data. The process of documenting and publishing datasets in the eAtlas from NERP was refined and updated providing valuable learnings for the first round of NESP Tropical Water Quality dataset submissions. Secondly, the eAtlas has extended the mapping of the GBR into Torres Strait to allow the creation of a single consistent dataset covering the islands and marine features of the entire GBR. Working with the TSRA, the new Torres Strait Reef and Island Features dataset was mapped at scale of 1:50,000 which is significantly finer mapping than the 1:250,000 scale of the *GBR Features* mapping of the GBR. This increased level of detail was important to capture the large number of small islands and reefs in Torres Strait. The final result is a highly detailed map dataset of the marine and island features of Torres Strait with permanent IDs that are compatible with the *GBR Features* dataset, allowing the compilation of a complete and consistent map of the entire GBR. This dataset is now available under a creative commons license from the eAtlas.


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