



Marine and Tropical Sciences Research Facility

Proceedings of the 2009 Marine and Tropical Sciences Research Facility Annual Conference



Australian Government
Department of the Environment,
Water, Heritage and the Arts



Proceedings of the 2009 Marine and Tropical Sciences Research Facility Annual Conference

**28-30 April 2009
Rydges Southbank Hotel, Townsville**

Compiled by Shannon Hogan and Suzanne Long
Reef and Rainforest Research Centre Limited



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Opening Address

Edited transcript of opening speech by Dr Russell Reichelt, Great Barrier Reef Marine Park Authority

“Welcome to the third annual scientific conference of the Marine and Tropical Sciences Research Facility. I wish to acknowledge the Traditional Owners for their Welcome to Country, along with Mr Richard Ireland, Chair of the Reef and Rainforest Research Centre, VIPs, distinguished scientists and postgraduate students.

This is a very important forum for a number of reasons. It is a showcase for the tremendous growth in scientific knowledge of the Great Barrier Reef, the Wet Tropics rainforests and also Torres Strait. It is an opportunity for the research community to summarise the results of many millions of dollars worth of research work by the best science teams; and in that summary, showcase the returns to the Australian community who have funded the work also the returns to the industry and community partners who have co-invested either by cash or in-kind in support of this effort.

It's also an opportunity to consider forward plans and discuss the scientific solutions that can help put these valuable ecosystems on a path for ecological sustainability; and develop a scientific basis for dealing with the far-reaching impacts of climate change.

The Australian Government's Marine and Tropical Sciences Research Facility, through the consortium created by the Reef and Rainforest Research Centre, has made tremendous advances in the relatively short period it has been operating; in saying that, credit must be given to the knowledge base created by the thirteen years' work by the Cooperative Research Centres and even longer baselines of research created by James Cook University, the Australian Institute of Marine Science, the CSIRO and other science partners.

In addition to the work of the research partners, the industry, the government and the Traditional Owners are all end-users of the research – they have played an important role in defining the research investment strategy for the MTSRF; it is this overall strategy that defines the purpose of the work and provides a basis for accountability back to the Australian Government.

There are many end users involved in MTSRF research, but I want to particularly acknowledge the strong support for research work given by the tourism industry. I have no doubt that it is their continuing interest and support and partnership in the scientific work in this region that is one of the MTSRF's major success factors.

The MTSRF research program is extremely important for providing a scientific basis for the environmental management role of my own organisation, the Great Barrier Reef Marine Park Authority, and for my colleagues in the Department of the Environment, Water, Heritage and the Arts, who also play a major role in the region through, among other things, administering the Environmental Protection and Biodiversity Conservation Act and administering the Reef Rescue Marine Monitoring Program. In the Authority we are working hard to become more effective adopters and users of the research results provided by the work of MTSRF and other programs. The 'path of adoption' of scientific research is not a one-way street: the end users of research can always do better at building links into the research world. The Atlas project is a good example where such links are building rapidly to provide a more comprehensive repository for spatial data and a foundation for further scientific modelling and analysis.

The MTSRF results are being used right now for very important public reports: for example, many of the scientific results quoted in the Authority's forthcoming Outlook Report for the Great Barrier Reef will be credited to work by many of you present today. In the long term, the major challenge for environment management of the Great Barrier Reef is to develop mechanisms for coping with the impacts of climate change – more extreme weather events such as we've seen this summer – hotter summers, more severe flood events and more frequent very large cyclones.

Environmental management in this region revolves around the issues of ecological sustainability, and its corollary, the understanding and maintaining resilience of the ecosystems. MTSRF-funded work is critically important for problems such as reversing the decline in coastal water quality, preventing further losses of key habitats that sustain biodiversity and ensuring that all human uses are compatible with the long term ecological sustainability of these ecosystems.

No single organisation deals with all these issues at once – strong collaborations are essential. One of the Authority's key priorities will be to build on current collaborations and develop new ones, particularly with collaborative approach to management, especially with:

1. The Queensland Government and DEWHA, and the key departments and agencies of the Australian Government;
2. Native Title holders and Traditional Owners;
3. The key industry groups in the region; particularly tourism, fishing, ports and shipping;
4. The community – the people who are part of, and who live and work in and adjacent to the unique ecosystems in our region; and
5. Last but not least, the scientific research community who build the essential scientific knowledge base for good management by all these groups.

These partnerships are critically important to GBRMPA – without them we cannot do our job. I hope by listing all of these groups that the researchers here today will also appreciate the complicated set of relationships within which they are operating when they do environmental research in support of ecosystem based management.

Finally, I want to acknowledge the major contributors to the success of this meeting, and to the delivery of the MTSRF program.

Thanks to the research providers who have co-invested with the MTSRF and brought not only their institution's financial resources but their intellectual capacity to bear on these important problems; and thanks also to the industry and community groups who are key contributors.

Thanks to the Reef and Rainforest Research Centre for their planning, management and reporting of the MTSRF program and for their efforts to build effective research partnerships and links to end users.

Thanks to the DEWHA for their oversight of not only the MTSRF but the entire CERF.

If Minister Peter Garrett was here I am sure he would thank you for your scientific efforts, and reinforce the need to focus on solutions, to capture the research products into lasting information systems, and to maintain a strong dialogue with the managers and users of the systems that you are studying. Thank you."

Introduction

The Reef and Rainforest Research Centre (RRRC) hosted the third Annual Conference of the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) at Rydges Southbank Hotel, Townsville over three days in April 2009.

Over 160 registered delegates attended the meeting, in addition to invited guests and those who attended select conference sessions relevant to their industry.

The 2009 conference showcased the latest MTSRF-funded research outputs relevant to the Great Barrier Reef, the rainforests and landscapes of the Wet Tropics and the Torres Strait, along with the human communities that depend upon these ecosystems, plus special sessions on water quality and climate change.

Within the MTSRF, the Australian Government has conducted an innovative experiment in the management and delivery of applied research. In an organisational framework specifically designed to achieve maximum return on investment in applied research, the RRRC employs dedicated research program managers and knowledge brokers to facilitate the timely delivery of milestones that meet end-user needs, against a background of sustained management, robust science and fiscal transparency.

The message that well-managed scientific research can help to improve the sustainability of management and use of Australia's environmental assets is more important than ever. The MTSRF 'experiment' of management and delivery of applied science is already showing promising signs of success: the MTSRF is achieving a seven-fold improvement in project milestone slippage rates, compared to historical 'norms' of 20-25% milestone delivery failure.

Most research facilities measure their success in terms of the number of scientific and technical publications they have produced. However, the applied, solution-oriented objectives of the research conducted through the MTSRF mean that, in addition to quality science publications, performance is more appropriately evaluated through examination of the impact of this newly-generated information on policy and practice. As a step towards an innovative evaluation of this kind, the RRRC has produced an online booklet that briefly describes some of the many cases in which MTSRF-funded research has already impacted on policy and/or practice, and thereby increased the sustainability of management and use of Australia's environmental assets. These examples span the entire scope of the MTSRF – from more efficient ways to biosequester carbon in rainforests, through improved shark fishery management, to increasing the effectiveness of knowledge repatriation into Indigenous communities – and are presented in terms of their capacity to feed into the Australian Government's strategic priority information needs. To download a copy of the booklet, entitled 'Impacts of the MTSRF', visit: <http://www.rrrc.org.au/mtsrp/index.html>

With the fourth and final year of the MTSRF well and truly underway, the MTSRF research portfolio is particularly focused on delivering major outputs to address the key research priority areas identified in the MTSRF Research Investment Strategy for 2006/2010.

Community support for the Wet Tropics of Queensland World Heritage Area

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MTSRF [Project 4.9.2](#)(b)

Extended Abstract

The Wet Tropics of Queensland World Heritage Area (WTQWHA) plays a significant role in the life of the North Queensland community for recreational and cultural purposes. Since its establishment in 1988, the Wet Tropics Management Authority (WTMA) has worked with WTQWHA stakeholders to protect the rainforests whilst managing them for community and visitor recreational access and supporting the Traditional Owners of the region. Community views on the WTQWHA and its management are therefore important. To understand how the community views both the rainforests and their management the Wet Tropics Management Authority has funded an ongoing program of surveying of community attitudes, with the first survey undertaken in 1992. The latest community survey conducted in 2007 shows continued support for the Wet Tropics and its management.

Specifically, this paper focuses on the community's awareness of the World Heritage Area; support for its World Heritage listing; personal and community benefits of living within the bioregion; and levels of support for cultural heritage listing and Aboriginal co-management of the Area.

In 2007 there was a very high level of awareness of the World Heritage status of the Wet Tropics rainforests amongst the community, with 92% of respondents indicating that they were aware the Area was World Heritage listed and 82% supported the listing. This strong and continued support for World Heritage listing is tempered with only 7.4% of respondents opposing the World Heritage listing compared to the 2002 survey results (12.4%). Further, support for the inclusion of Aboriginal cultural heritage in a future World Heritage listing re-nomination has grown from 63% in 2002 to 71.8% in 2007 and support for some form of Aboriginal co-management of the Area has increased from 58.4% in 2002 to 66.0% in 2007. Opposition to Aboriginal co-management has fallen from 30.5% in 2002 to 20.6% in 2007.

The community survey asked respondents to consider a range of personal and community benefits that living near the Wet Tropics conferred upon them. Responses were very positive, indicating respondents considered living in the region provided both strong personal benefits and significant community benefits by contributing to the community's quality of life, enhancing environmental awareness and protecting the rainforest plants and animals. Overall, survey results show that there has been a considerable increase in the level of support that the WTQWHA and its management has enjoyed since community attitudes and perceptions were first measured in 1992.

Acknowledgements

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References

Bentrupperbäumer, J. M. and Reser, J. P. (2006) *The role of the Wet Tropics World Heritage Area in the life of the community. A survey of the North Queensland community*. Revised edition. Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns (182pp.) (http://www.rrrc.org.au/rfrcrc/downloads/55_community_survey.pdf)

Carmody, J. and Prideaux, B. (2008) Community attitudes, knowledge, perceptions and use of the Wet Tropics of Queensland World Heritage Area in 2007. Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre, Cairns (120pp.) (http://www.rrrc.org.au/publications/community_attitudes.html)

Use of a multiple criteria analysis (MCA) process to inform Reef Rescue regional allocations

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Abstract

Reef Rescue is a \$200 million, five-year component of the Australian Government's *Caring for our Country* initiative, and aims to improve the quality of water entering the Great Barrier Reef lagoon by assisting farmers to adopt improved land management practices that reduce the runoff of sediments, nutrients and pesticides from their land.

In Year 1 (2008/2009), Reef Rescue indicative funding allocations for each of the six Natural Resource Management (NRM) regions in the Reef catchment were determined by the Australian Government based on an analysis of key Reef water quality science. To guide Year 2 regional allocations, a multiple criteria analysis (MCA) process was conducted. The MCA process included the development of a decision support model based on the 'assets, threats and solvability' framework. Criteria were developed to populate the model where there were readily available data sets that provided coverage of the entire Reef or catchment. Reef Rescue stakeholders and key Reef scientists were invited to make written submissions on the draft criteria. The revised decision support model was further developed at a science workshop. Reef scientists supplied weights for each criterion to generate an MCA score for each NRM region. The outcomes of the science workshop were presented at stakeholder forums to inform proposal development for Reef Rescue Water Quality Grants and Partnerships funds.

The MCA process proved useful for the logical and transparent treatment of a wide range of data sets and facilitated the structured engagement of Reef Rescue implementers with Reef scientists and stakeholders to inform the investment decision. A major limitation of the decision support model was the lack of adequate data sets for solvability criteria.

The outcomes of the MCA process were informative, but not determinative for the allocation of Reef Rescue funds to NRM regions. Final funding allocations were made with consideration of additional factors, including the quality of the funding proposals received and the institutional capacity of the applicants. We propose that the decision support model should be improved through an iterative MCA process and be used to support adaptive management of the Reef Rescue initiative.

Introduction

Reef Rescue is a five-year, \$200 million component of *Caring for our Country*, the Australian Government's \$2 billion initiative to restore the health of Australia's environment and improve land management practices. Reef Rescue will increase the resilience of the Great Barrier Reef (GBR) to climate change by reducing the run-off of sediments, nutrients and pesticides from agricultural lands into the GBR lagoon (Johnson and Marshall 2007). This will be

achieved by providing training and financial incentives to land managers in the Reef catchment to increase their adoption of improved land management practices. The five year outcomes for Reef Rescue are a 25% reduction in the discharge of dissolved nutrients and agricultural chemicals, and a ten percent reduction in the discharge of sediments and particulate nutrients.

Given the size of the GBR catchment, and the magnitude of water quality issues, careful risk-based targeting of the funds is essential to achieve the best outcomes for Reef water quality (Hajkowicz 2007). Investments in Year 1 of Reef Rescue (2008/2009) were allocated across the six reef NRM regions based on a synopsis of current GBR water quality research (Brodie *et al.* 2008). The highest priorities identified were the reduction of run-off of soluble nutrients and pesticides from intensive agriculture in high rainfall coastal areas close to sensitive reef assets. A lower level of priority was given to the reduction of sediment and particulate nutrient run-off from extensive rangelands grazing. Based on these priorities and other factors, indicative regional allocations for Year 1 of Reef Rescue were \$5-7 million for the Wet Tropics, Mackay Whitsunday and Burdekin regions, \$2-4 million for the Fitzroy and Burnett Mary regions and up to \$1 million for Cape York.

To review and refine regional investments for Year 2 of Reef Rescue, a multiple criteria analysis (MCA) process (Hajkowicz 2002) was conducted with the support of Reef scientists and Reef Rescue stakeholders. MCA is an integrated decision support tool capable of informing choices guided by multiple objectives measured in monetary and non-monetary units. The MCA technique can be used to rank or score decision options, but its main value typically lies with its capacity to help decision makers learn about complex trade-offs. It also introduces transparency, auditability and robustness in what can often otherwise be unstructured or ‘fuzzy’ decisions. The MCA process typically involves three stages as shown in Figure 1. In brief, the decision required is clearly defined (in this case the relative funding priority of the 6 Reef NRM regions) and criteria are identified to permit the relative scoring of decision options. Criteria are limited to those where adequate datasets are available – in this case covering the entire Reef or its catchment. Criteria values are mathematically transformed to permit comparability and then weighted by an expert panel. The sum of the transformed and weighted criteria values determines the relative priority score for each option.

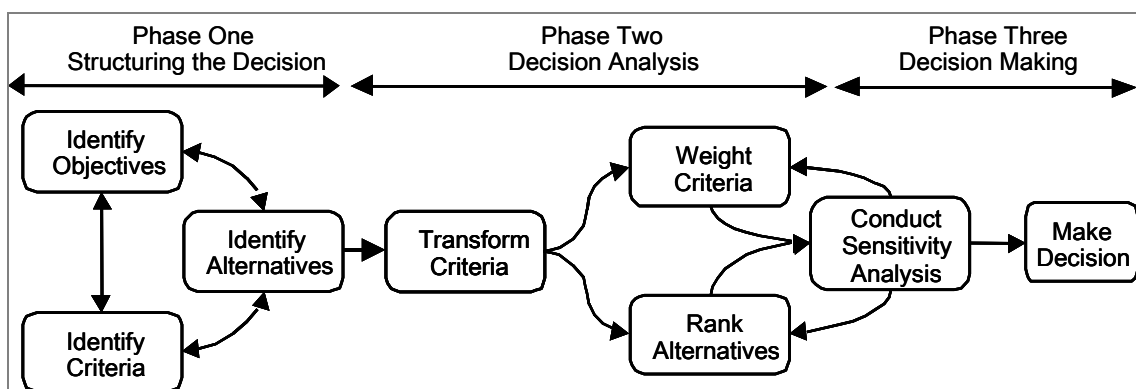


Figure 1: Multiple criteria analysis (MCA) process.

The ‘assets, threats and solvability’ Decision Support Model (DSM, Hajkowicz and McDonald, 2006) was used to select criteria for the MCA. This model directs investment towards high value assets (economic, social and environmental), facing severe threats, where there are feasible management solutions.

Methods and Results

Decision Support Model Development

A small workshop was held between project staff and six selected Reef scientists to develop a draft DSM structure and identify potential criteria and datasets. As a result of this workshop, a review of sediment and nutrient loads entering the GBR lagoon was undertaken (Brodie *et al.* 2009) to provide up-to-date information for pollutant load risk criteria.

The draft DSM was sent to a broad cross-section of Reef scientists and all Reef Rescue stakeholder groups identified through an expression of interest process with an invitation to provide written advice on the draft DSM structure, criteria and supporting data. Twenty-five submissions were received. As a result of this process the draft DSM was modified significantly.

A Science Workshop involving thirteen Reef scientists was held in Townsville on 16-17 February 2009 to: review the Reef Rescue transitional year investment profile across regions and land uses; ground-truth the draft DSM, including criteria and supporting information; review the 25 written submissions on the draft DSM received from scientists and stakeholders; obtain weightings of the final criteria by the scientists to input into the DSM; and seek feedback from the scientists regarding the process and outcomes to date.

The final DSM is shown in Figure 2. Key changes introduced as a result of the advice received at the science workshop included: introduction of area of protected marine zones, riparian buffer area, area of coastal wetlands and human use criteria (population, fishing value) under reef assets; replacement of the proposed modeled pesticide load criteria with an improved pesticide risk criterion based on modeling and monitoring, and developed during the course of the workshop; introduction of climate risk criteria; and simplification of solvability due to lack of supporting data for some criteria (e.g. improved management practice availability) and lack of support for the inclusion of others (e.g. wetland area, land vale).

The 27 criteria used in the DSM are described in Table 1. For presentation purposes, criteria values were mapped across the Reef catchments using the MCA-S spatial decision support tool (Lesslie *et al.* 2008). Maps of the criteria and histograms showing data values across NRM regions are shown in Figure 3.

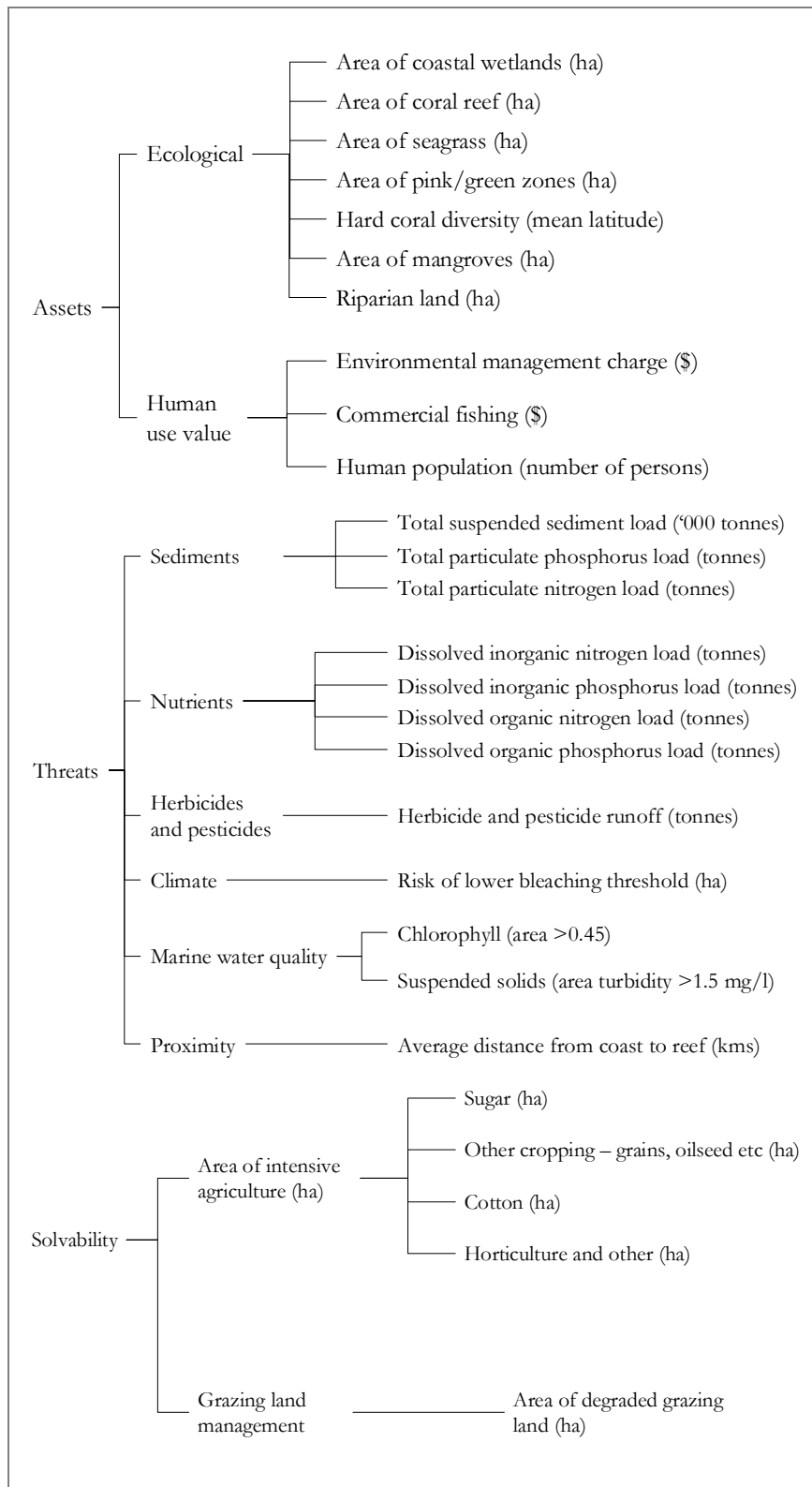


Figure 2: Final Decision Support Model structure.

Table 1: Description of criteria used in final Decision Support Model.

Reef Assets
<ul style="list-style-type: none"> ● Ecological Assets: Assets associated with NRM regions comprising the biophysical value of reef ecosystems: <ul style="list-style-type: none"> - A1 Coastal wetland area: The area (km²) of coastal wetland within marine zones adjacent NRM regions (Geoscience Australia 2006 data). - A2 Coral reef area: The area (km²) of coral reef within marine zones adjacent NRM regions (GBRMPA 2008 data). - A3 Seagrass area: The area (km²) of seagrass within marine zones adjacent NRM regions (Alana Grech, James Cook University, pers. comm. 2009). - A4 RAP protected zone area: The area (km²) of GBR Representative Areas Program protected (green and pink) zones within marine zones adjacent NRM regions. - A5 Hard coral biodiversity index: An index of hard coral diversity based on the latitudinal position of marine zones adjacent NRM regions (DeVantier <i>et al.</i> 2006). - A6 Mangrove area: The area (km²) of mangrove within NRM regions (Montreal Process Implementation Group for Australia 2008). - A7 Riparian buffer area: The area (km²) of riparian areas within an NRM region (Derived from BRS analysis of stream order, lakes, dams and wetlands). ● Human Use: Assets associated with NRM regions comprising human utility associated with the reef: <ul style="list-style-type: none"> - A8 Total Environmental Management Charge: The total EMC (\$) within marine zones adjacent NRM regions (GBRMPA 2007 commercial tourism operator data). - A9 Commercial fishing value: The total \$ value of commercial fishing associated with an NRM region (Productivity Commission 2003). - A10 Regional population: The total population within NRM regions (ABS 2005/2006 census). An indicator of recreational utility of the reef assets within the NRM region.
Reef Threats
<ul style="list-style-type: none"> ● Sediment Load: The current anthropogenic suspended sediment load discharged by reef catchments as calculated by Brodie <i>et al.</i> 2009. Anthropogenic loads were estimated by subtracting estimated pre-European loads from current best estimate loads: <ul style="list-style-type: none"> - T1 Total suspended sediment load: Anthropogenic load (tonnes ('000) per year) by catchment. - T2 Particulate nitrogen load: Anthropogenic load (tonnes per year) by catchment. - T3 Particulate phosphorus load: Anthropogenic load (tonnes per year) by catchment. ● Nutrient Load: The current anthropogenic nutrient load discharged by reef catchments as calculated by Brodie <i>et al.</i> (<i>Current loads of priority pollutants discharged from the Great Barrier Reef Catchments to the Great Barrier Reef</i>): <ul style="list-style-type: none"> - T4 Dissolved inorganic nitrogen load: Anthropogenic load (tonnes per year) by catchment. - T5 Dissolved inorganic phosphorous load: Anthropogenic load (tonnes per year) by catchment. - T6 Dissolved organic nitrogen load: Anthropogenic load (tonnes per year) by catchment. - T7 Dissolved organic phosphorous load: Anthropogenic load (tonnes per year) by catchment. ● T8 Pesticide Risk: An index based on estimates of the concentrations of the key pesticide discharges of reef catchment adapted from Brodie <i>et al.</i> (2009) with more recent data and modelling by Australian Centre for Tropical Freshwater Research, James Cook University. ● T9 Heating Risk: The mean risk of heating of marine waters predicted for climate change scenario for 2030 associated with marine zones adjacent NRM regions (Wooldridge 2008). ● Marine Water Quality Risk: The quality of marine reef waters based on key measures of nutrient and turbidity status, by NRM marine regions. It should be noted that these attributes are indicative of water quality risk associated with lowering of coral bleaching thresholds (Scott Wooldridge, publications pending): <ul style="list-style-type: none"> - T10 Chlorophyll: Area of chlorophyll 'a' greater than 0.45 ug/L within marine zones adjacent to NRM regions (Delean and De'ath 2008). - T11 Turbidity: Area of turbidity (<10m Secchi disk depth) within marine zones adjacent NRM regions (Delean and De'ath 2008). ● Proximity: The degree of exposure of reef ecosystems to the NRM regions: <ul style="list-style-type: none"> - T12 Proximity of reef to coast: The average distance of reef areas to the coast of adjacent NRM

regions (a higher value means a lower priority).
Solvability
<ul style="list-style-type: none">● Area of intensive agriculture: The extent of intensive agriculture; a proxy for the potential for targeting improvement of intensive land management practices:<ul style="list-style-type: none">- S1 Sugar area: The area (km²) under sugar within NRM regions (Queensland Land Use Mapping Program 1999-2004).- S2 Other cropping area: The area (km²) under cropping (excluding sugar, cotton and horticulture) within NRM regions (Queensland Land Use Mapping Program 1999-2004).- S3 Cotton area: The area (km²) under cotton within NRM regions (Queensland Land Use Mapping Program 1999-2004).- S4 Horticulture area: The area (total km²) under horticulture within NRM regions (Queensland Land Use Mapping Program 1999-2004).- S5 Area of grazing land: The extent of grazing lands; a proxy for the potential for targeting improvement of grazing land management practices: the area (total km² for grazing natural and semi-natural vegetation within NRM regions (Queensland Land Use Mapping Program 1999-2004).

* <http://www.nrw.qld.gov.au/science/lump/>

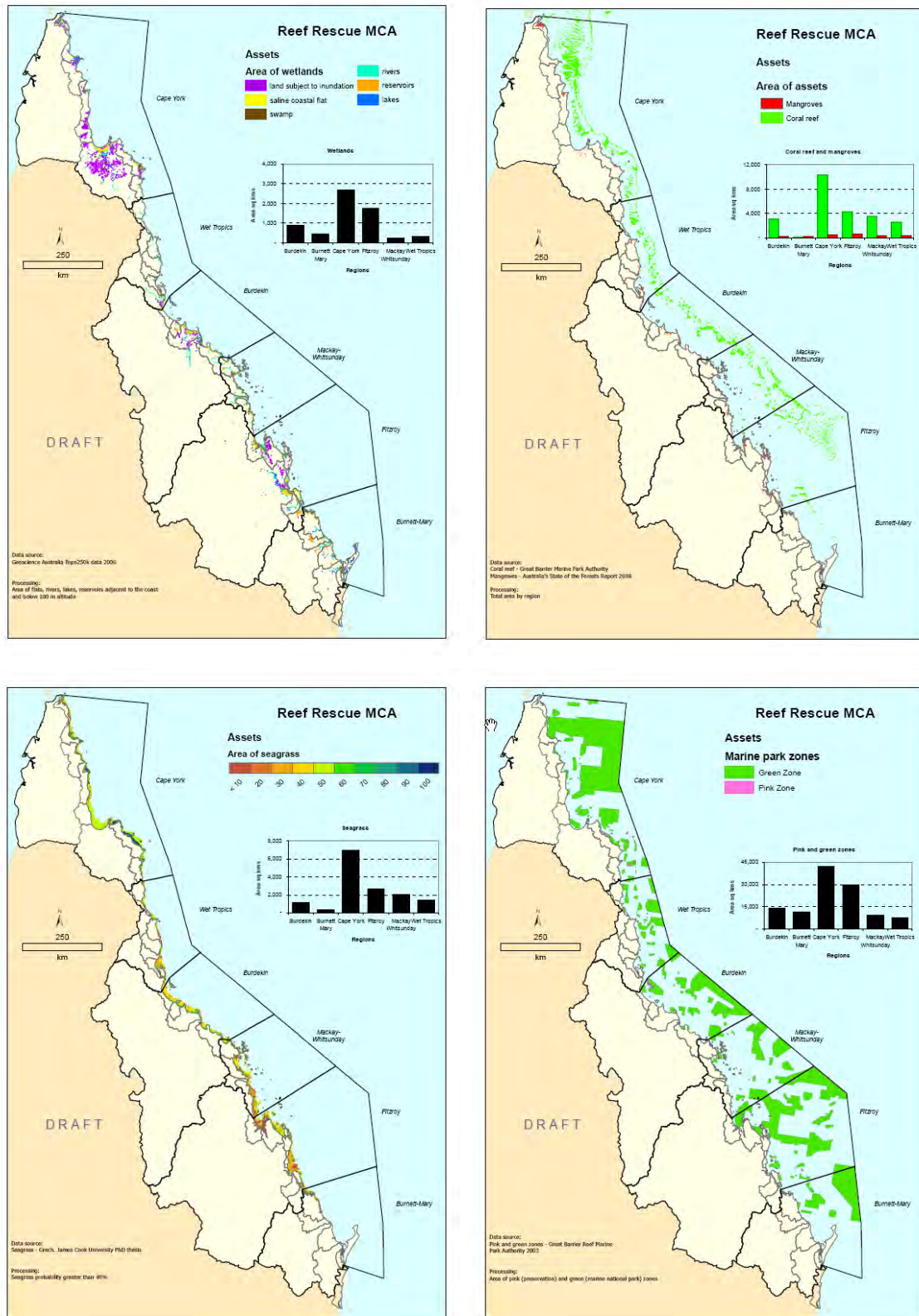


Figure 3A: Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Asset criteria.**

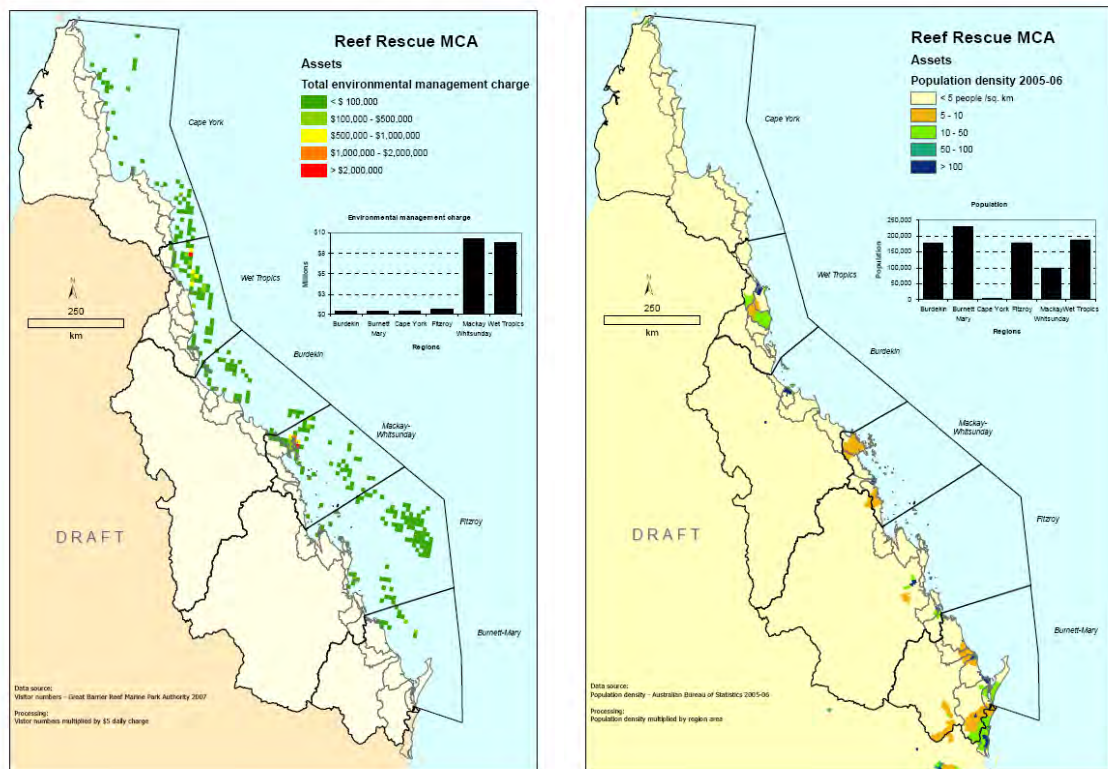


Figure 3A (continued): Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Asset criteria.**

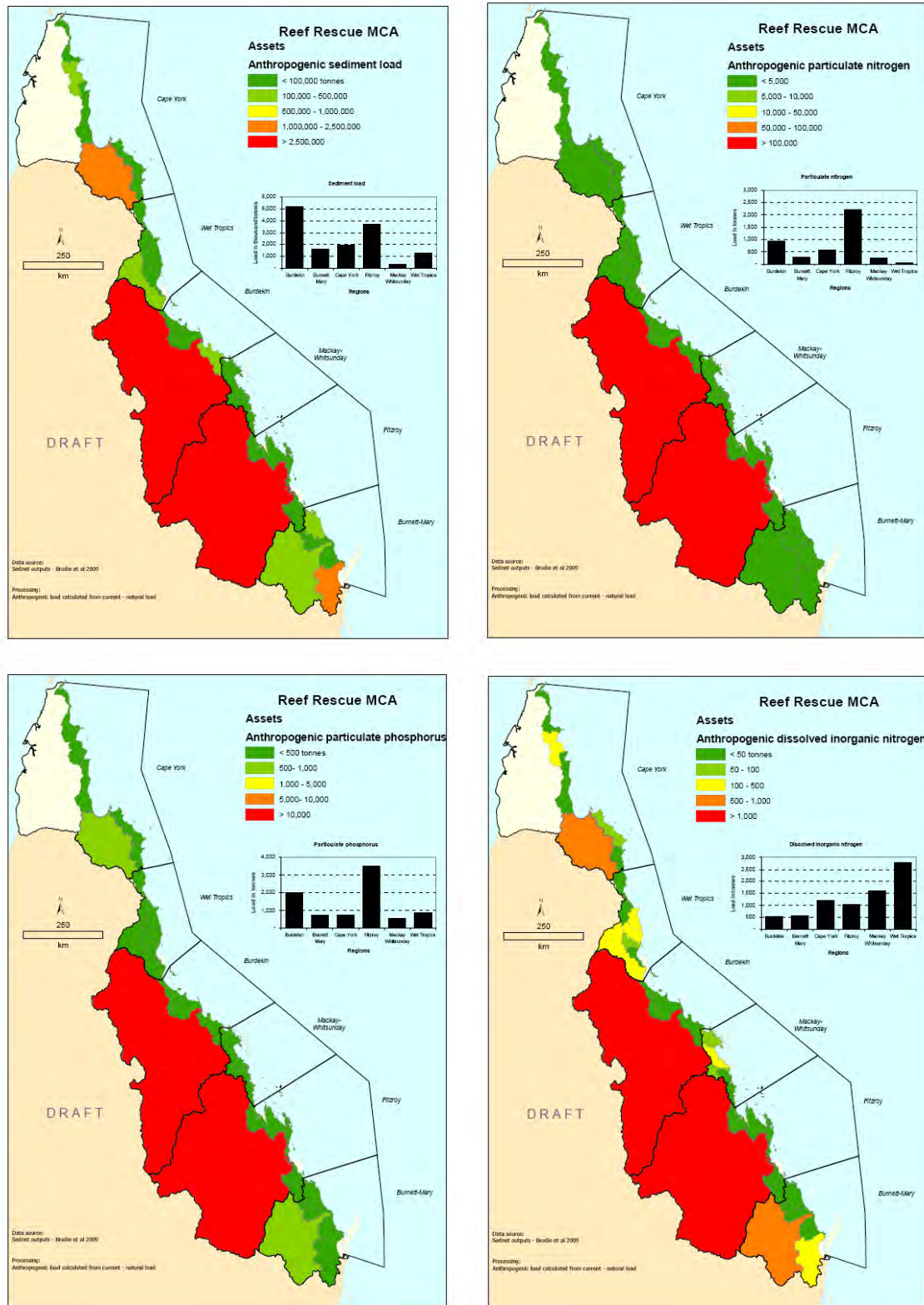


Figure 3B: Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Threat criteria.**

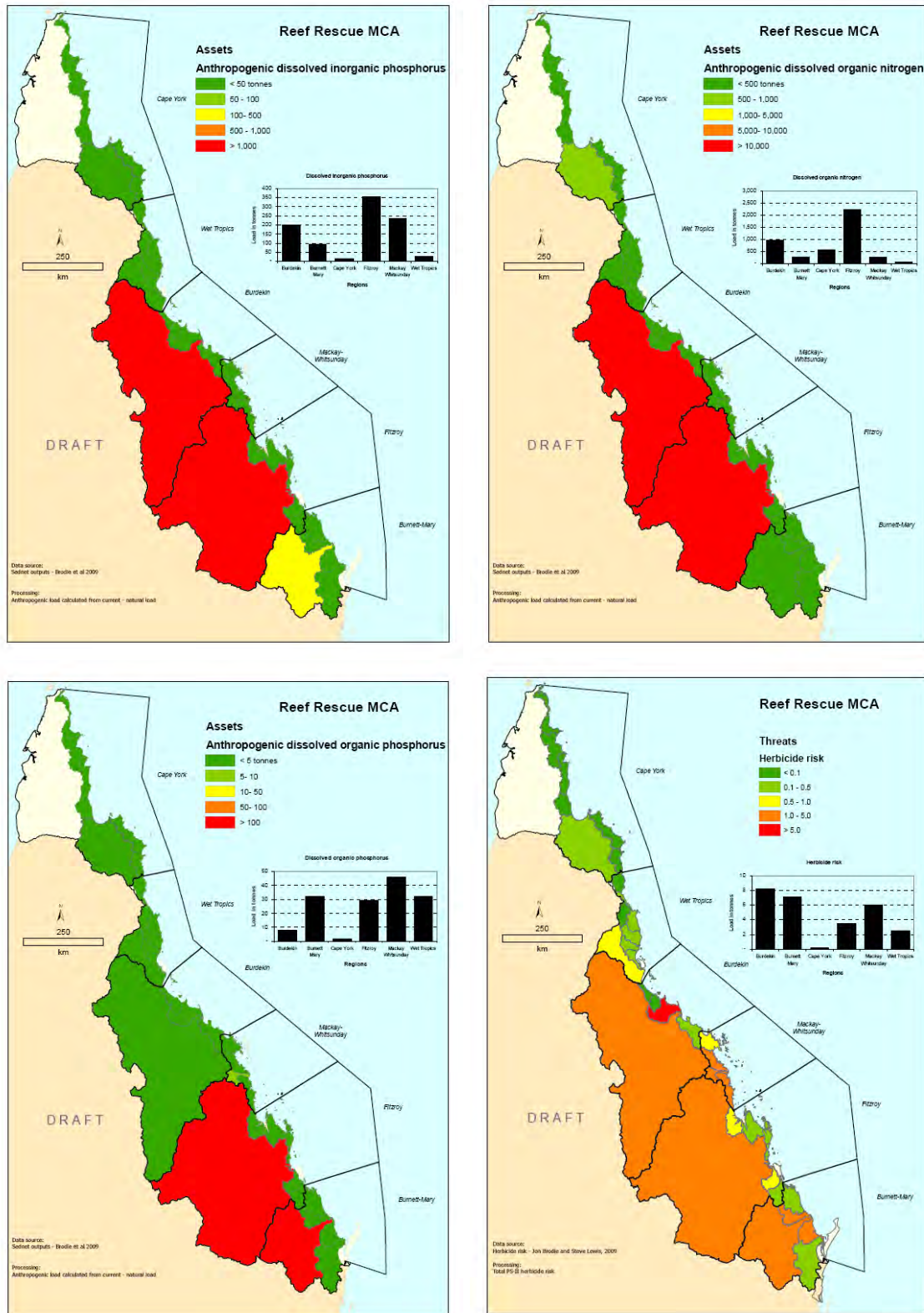


Figure 3B (continued): Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Threat criteria.**

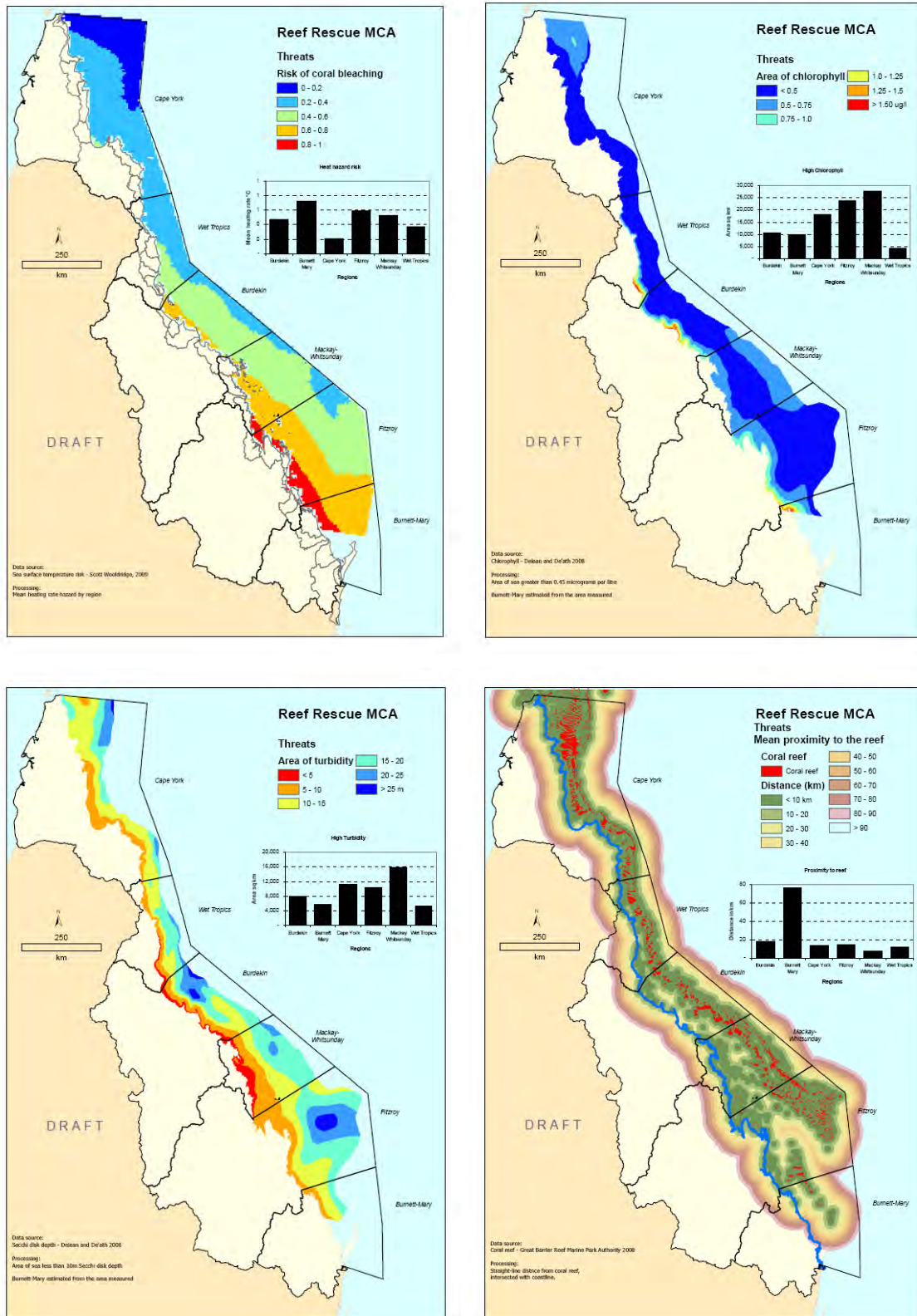


Figure 3B (continued): Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Threat criteria.**

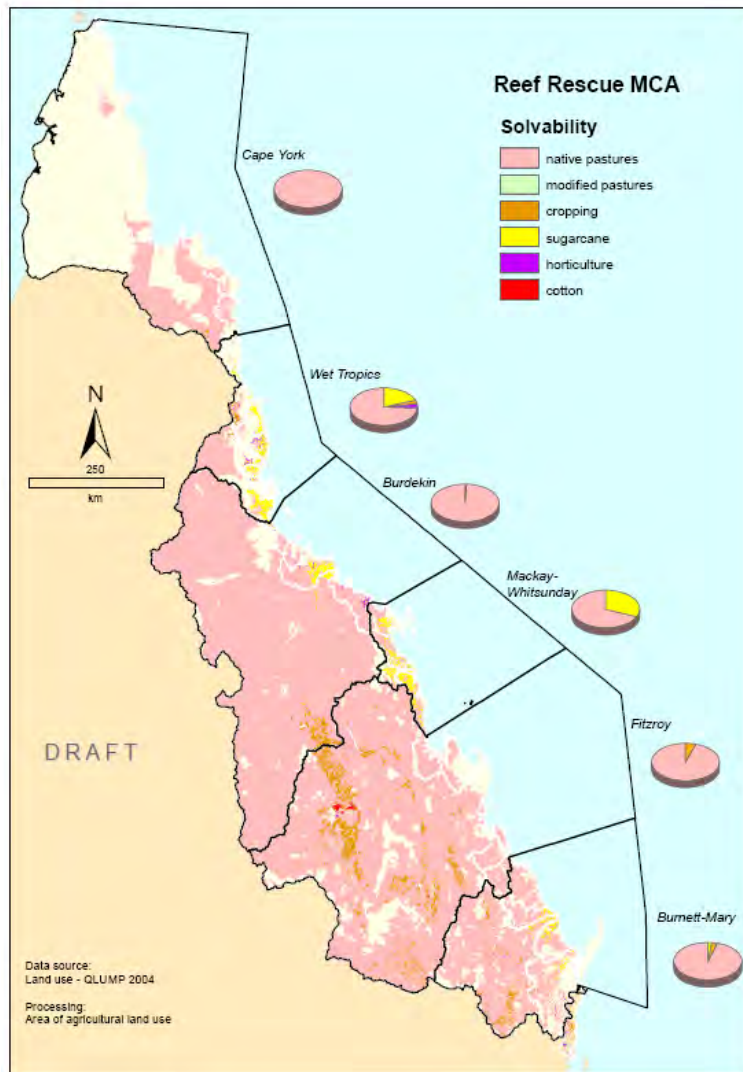


Figure 3C: Spatial presentation of final Decision Support Model criteria values and regional values for each criterion: **Solvability criteria.**

Weighting of DSM criteria

At the end of the Science Workshop, scientists were asked to weight each criterion in the DSM using a spreadsheet version of the model, designed so that the combined weights of each branch or sub-branch of the DSM equaled 100%. The output of the spreadsheet model, averaged across the thirteen scientists is shown in Figure 4. The regional MCA scores, derived by multiplying transformed criteria values by mean criteria weights, are shown in Figure 5A. The confidence limits of the MCA scores are shown in Figure 5B.

In addition to providing criteria weightings, scientists provided qualitative advice to Reef Rescue implementers on a number of critical issues relating to Reef water quality. This advice included the following key points:

- It was agreed that the investment profile was consistent with our current understanding of Reef water quality science as summarised in the Scientific Consensus Statement on Water Quality in the Great Barrier Reef (Brodie *et al.* 2008).
- The level of investment in the dairy industry was considered high in respect of the small extent and generally low water quality risk posed by this industry, as ground cover is generally maintained at high levels year-round.
- The level of investment in grazing in the high rainfall regions was considered high relative to the level of investment in rangelands grazing in the larger, drier catchments. It was suggested funding should be more targeted towards extensive grazing where ground cover is sub-optimal.
- The level of wetland rehabilitation was discussed. Whilst sedimentation ponds/artificial wetlands, riparian buffers and other bioremediation strategies were considered valid investments as part of a whole of system approach to water quality improvement, the protection or rehabilitation of sensitive or high value wetland ecosystems was considered not to be a valid water quality improvement option. Improved land management measures were generally considered to yield more cost-effective outcomes than landscape remediation measures.

Outcomes

Following the Reef Rescue science workshop and using the information received from scientists and stakeholders, regional MCA scores and other factors (see below), recommendations for regional funding allocations were presented to decision makers (Ministers for the Australian Government Environment and Agriculture portfolios). The recommended indicative regional allocations for Year 2 of Reef Rescue were: 2.5-7.5% for Cape York, 16-24% for the Wet Tropics, Mackay Whitsunday, Fitzroy and Burdekin regions and 7-13% for the Burnett Mary region, of \$23 million total available funding.

In addition to the provision of MCA scores, the DSM also resulted in ranking of the criteria supporting investment in each region (Figure 6). For example, the MCA score in the Cape York region was heavily influenced by Reef asset criteria, whereas MCA scores for Mackay Whitsunday and Fitzroy were determined largely by sugarcane and grazing related threat criteria respectively. This information was provided to stakeholders to guide the development of their 2009-2012 investment proposals.

Stakeholder forums

Following the science workshop, two stakeholder forums were held to: present and discuss the DSM, including criteria and supporting information; review the written submissions on the draft DSM received from scientists and stakeholders and the feedback on these received at the Science Workshop; and seek feedback from the stakeholders regarding the MCA process and outcomes to date. One scientist (Jon Brodie, ACTFR) attended the stakeholder

forums to help present the outcomes of the Science Workshop to stakeholders. A summary of the key issues raised at the stakeholder forums is provided below.

General issues

The issue of whether to include the entire marine zone adjacent to the Burnett Mary region was discussed. This zone contains ecosystem assets (reefs and sea grass meadows) that are outside the Great Barrier Reef World Heritage Area. It was suggested that for the next MCA, all environmental assets north of Fraser Island should be included.

Stakeholders considered that effective monitoring is essential to demonstrate the effects of land managers' efforts on ecosystem services and thus provide positive feedback. It was suggested that seagrasses are comparatively short-lived and their health and nutritional status may serve as bio-indicators of water quality. It was noted that there is currently no model to account for movement of pollutants within the marine ecosystem.

The current 'area of cane' dataset used in the DSM is different to cane production, which may be a better measure of risk. Area of cane as used represents maximum area and there are differences in intensity of cane production between regions. It was suggested that harvested cane area may be better measure, or harvested area x recommended fertiliser rate.

Asset criteria

A number of additional asset criteria were suggested, including deepwater sea grasses, inter-reefal benthos and commercial fishing value. The issue of the prominence of coral assets was discussed and it was noted that while other assets are also important, several criteria related to corals. It was concluded that the focus should be on assets at risk rather than assets *per se*.

Threat criteria

It was agreed that end of river pollutant loads are essential indicators of land-based pollutant threat to the marine ecosystem. The estimates of these loads are uncertain and need a continual improvement approach through monitoring and modeling. For example the current dissolved inorganic nitrogen load estimate used in the model does not account for loads from the lower Burdekin. Better catchment estimates will become available through ongoing research.

Average distance of reefs from river mouths was suggested as a more rigorous approach to assessing the regional proximity risk than average distance of reefs from the coast, as used in the current model.

Due to the high diversity of horticulture crops, it was suggested that only major crops (e.g. bananas, paw paws, pineapple and mangoes) should be the focus of investment, based on area, risk and availability of improved management practices.

The potential for water quality risk to be assessed using flood plume distribution was discussed. It was suggested that long term average water quality from remote sensing (e.g. chlorophyll and turbidity) could be used to account for plume distribution. This could include mapping of exceedence of water quality guidelines.

Solvability criteria

It was agreed that more work is required to identify solvability criteria and supporting data sets. Sensitivity analysis showed that removing solvability from the model had significant effects only on Cape York (increased ranking). Several solvability criteria were suggested for

which catchment-wide data sets are not currently available, including availability, effectiveness and cost/benefit of improved management practices for major land uses. Other suggested criteria included numbers of farmers and average size of farm per region, numbers of crops grown per farmer and private versus public benefit of available improved land management practices.

The suggestion was made that a temporal criterion should be included – for example the estimated time for improved management practice adoption to result in improved water quality for each major land use.

It was noted that relatively low ‘preventative’ investment in Cape York may have significant benefits in maintaining reef ecosystems in this region in relatively pristine condition compared to other regions where restorative activities are being funded.

Feedback from participants on the MCA process

Scientists and stakeholders gave positive feedback on the MCA process, and were generally appreciative of what had been achieved over a very short timeframe. Participants agreed that the process and outcomes could be improved given longer timeframes. Stakeholders appreciated the openness of the process and felt that it resulted in an improved understanding of priorities to be addressed in the development of their Reef Rescue funding proposals.

Other feedback from participants included:

- ‘The outcomes of the process reflect the obvious – dissolved inorganic nitrogen and total suspended sediment are equally important and are derived primarily from intensive agriculture and extensive grazing respectively, with herbicides (primarily from cane) ranked lower. There is still a need for more information on the relative impacts and solvability of different pollutant classes’.
- ‘Appreciate this is the first attempt to quantify regional herbicide risk and recognise transformation of particulate nutrients in marine ecosystem’.
- ‘The knowledge base for the MCA needs to include ‘grey’ literature and non-scientist knowledge’
- ‘There is a need to manage forestry and emerging land uses – now’.
- ‘Biophysical research gaps are small compared to socio-economic ones’.
- ‘Results of Stakeholder forums should be presented back to the science group to make the MCA an iterative process’.

Discussion/Conclusions

The MCA process facilitated structured engagement of Reef Rescue implementers with Reef scientists and Reef Rescue stakeholders. The MCA provided an opportunity for scientists and stakeholders to ensure the most relevant information and data sets across a broad range of biophysical and socio-economic criteria were considered in a logical and transparent manner. Although the DSM yielded a quantitative regional ‘MCA score’, this was not used directly to set NRM regional allocations. Final allocation ranges were set with consideration of MCA scores; key messages delivered by scientists and stakeholders to program implementers through the MCA process; and demonstrated institutional capacity of the regional proponents. Final funding subsequently awarded to regions also depended on the quality of proposals received and fit of proposals with Reef Rescue priorities.

Concerns were initially raised by decision makers and one stakeholder group regarding the potential conflict of interest arising from stakeholders, including regional NRM bodies, being

involved in a process to prioritise regions for investment. This issue was managed by reviewing stakeholder written input at the Science Workshop and seeking criteria weights from the scientists but not stakeholders.

The main result of the decision support process (Figure 5A) was to increase the priority given to the management of extensive rangelands grazing (primarily through ground cover management) in recognition of the extremely large pollutant loads delivered from these vast areas during periodic flood events. This resulted in equal investment priority being given to the Fitzroy region (grazing dominated) and the Burdekin (containing substantial cane and grazing industries) and the Mackay Whitsunday and Wet Tropics regions (dominated by cane with some horticulture and grazing). The Burnett Mary region was ranked lower due primarily to lower proximity and asset value scores. Cape York was ranked lowest, primarily due to low threat criteria scores. Priority was subsequently given to conducting further research into water quality risk in the Cape York region rather than investment in water quality improvement at this time.

A high degree of variation in weightings by scientists was evident (Figure 5B), especially for cane or grazing dominated regions, possibly reflecting a dichotomy in prioritisation of extensive and intensive agriculture by scientists. A lower level of variation was evident for regions with more mixed industries, such as the Burdekin and Burnett Mary.

We propose that the MCA process is repeated annually as an adaptive management tool to facilitate review and fine tuning of Reef Rescue investment priorities. This would involve revision of the DSM and supporting data. Further information is especially required to provide improved solvability criteria and it is envisaged that this could be achieved in part through the analysis of past investment performance. We support the inclusion of a temporal criterion, reflecting time lags between management actions and achievement of water quality outcomes.

The MCA process was conducted at a cost to the Reef Rescue program of less than one percent of the value of one year of program investment. We consider the MCA process to be a cost effective mechanism for capturing scientific and expert stakeholder knowledge to improve the return on NRM investment and engender a shared understanding of how investment priorities were established.

					Min	Max	Weight	
32%	ASSETS	68%	Ecological	13%	Area of coastal wetlands (units)	261	2,686	2.8%
				23%	Area of coral reef (sq km)	184	10,406	4.9%
				18%	Area of seagrass (sq km)	331	7,000	3.9%
				13%	Area of pink/green zones (sq km)	7,671	42,039	2.9%
				11%	Hard coral diversity (latitudinal ranking)	1	6	2.3%
				13%	Area of mangroves (sq km)	258	667	2.8%
				9%	Riparian land (sq km)	378	7,477	1.9%
				100%				
		32%	Human	39%	Total environmental charge (\$millions)	0	9	4.0%
		100%		23%	Commercial value (\$ millions)	7	31	2.4%
				38%	Population (number of persons)	2,239	230,096	3.9%
				100%				
42%	THREATS	16%	Sediments	85%	Sediment load (thousand tonnes)	292	5,164	5.6%
				7%	Particulate nitrogen load (tonnes)	1,552	10,205	0.4%
				8%	Particulate phosphorus load (tonnes)	508	3,474	0.5%
				100%				
		22%	Nutrients	60%	Dissolved inorganic nitrogen load (tonnes)	544	2,791	5.7%
				23%	Dissolved inorganic phosphorus load (tonnes)	14	357	2.2%
				10%	Dissolved organic nitrogen load (tonnes)	57	2,219	0.9%
				8%	Dissolved organic phosphorus load (tonnes)	2	46	0.7%
				100%				
		17%	Herbicides	100%	Herbicide risk (PS-II risk factor)	0	8	7.3%
				100%				
		18%	Climate risk	100%	Risk of bleaching (degrees celcius)	0	1	7.5%
				100%				
		18%	Marine water quality	57%	Area of high chlorophyll (sq km)	4,380	27,497	4.3%
				43%	Area of high turbidity (sq km)	5,226	15,801	3.3%
				100%				
		9%	Proximity	100%	Average proximity of reef to coasts (km)	7	77	3.8%
		100%		100%				
26%	SOLVABILITY	60%	Intensive agriculture	54%	Area of sugar (sq km)	0	1,967	8.3%
100%				14%	Area of other cropping - grains etc (sq km)	19	8,617	2.2%
				11%	Area of cotton (sq km)	0	250	1.7%
				21%	Area of horticulture (sq km)	0	248	3.2%
				100%				
		40%	Grazing land	100%	Grazing area (sq km)	4,035	127,272	10.4%
		100%		100%				

Figure 4: Weighting of Decision Support Model (DSM) criteria. The spreadsheet was designed so that each branch of the DSM summed to give 100%. Values represent the mean weights of thirteen Reef scientists (green boxes). Value range for each criterion is shown.

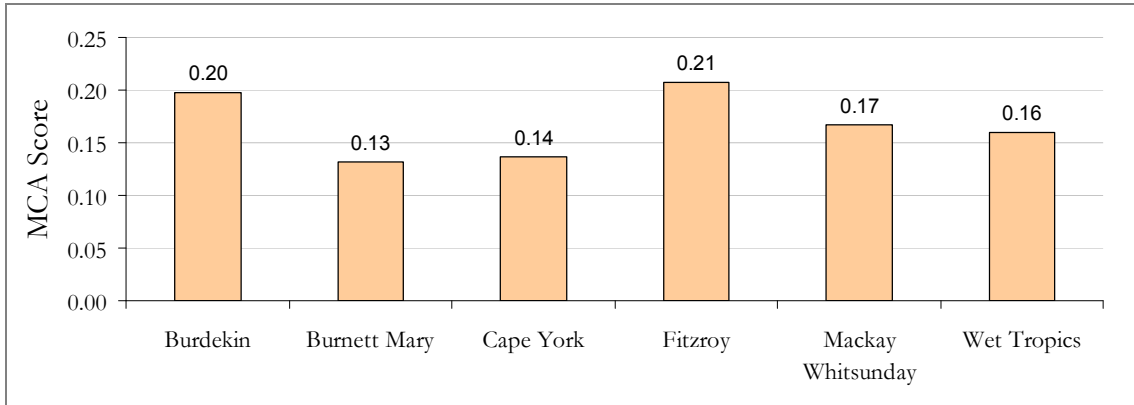


Figure 5A: Regional multiple criteria analysis scores.

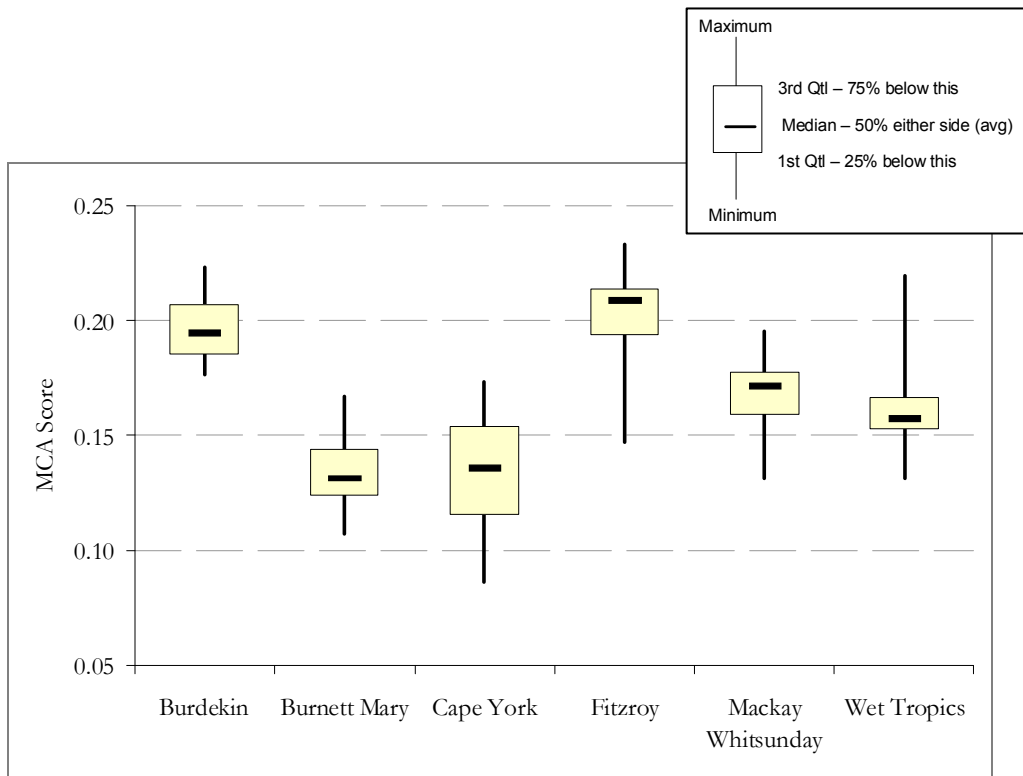


Figure 5B: Confidence limits for multiple criteria analysis scores.

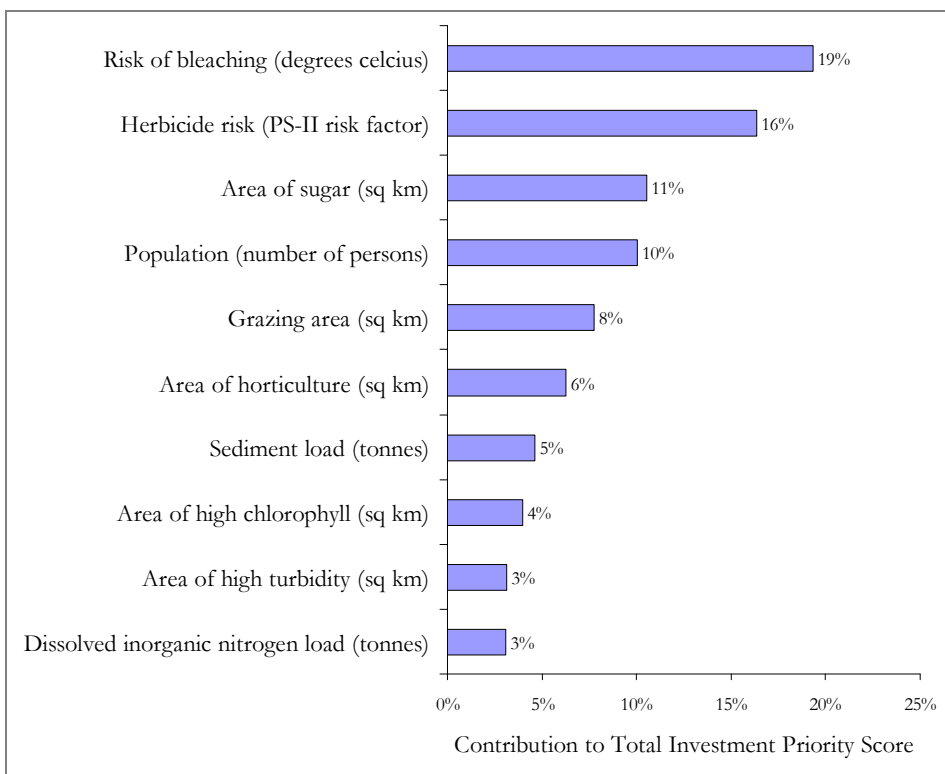
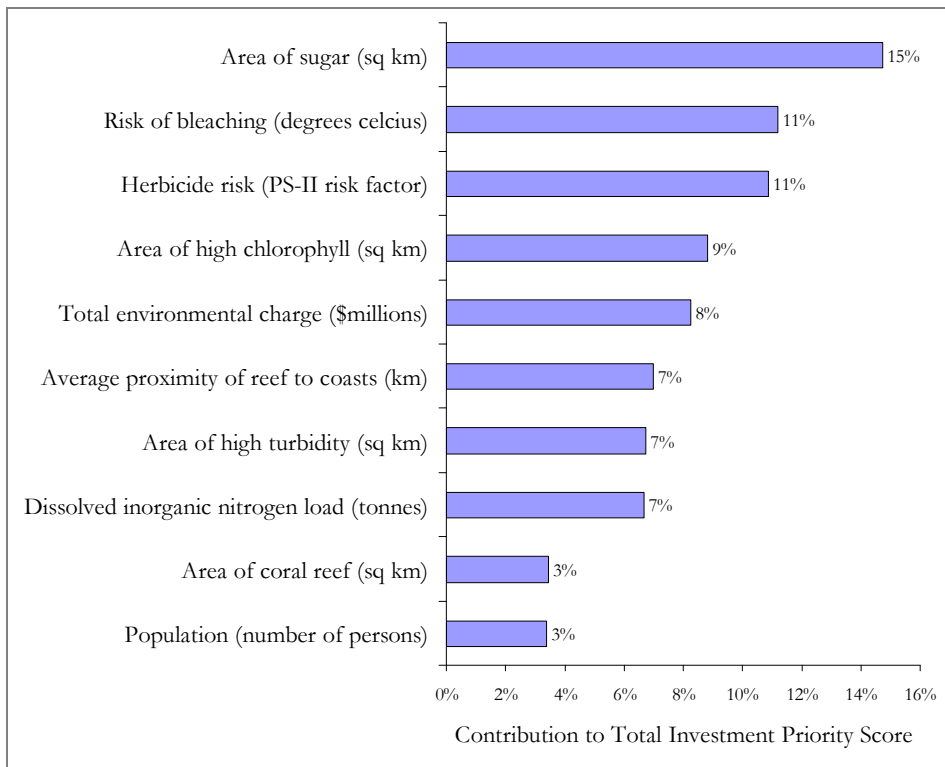


Figure 6: Criteria underpinning regional multiple criteria analysis scores for (top) Burnett Mary and (bottom) the Burdekin.

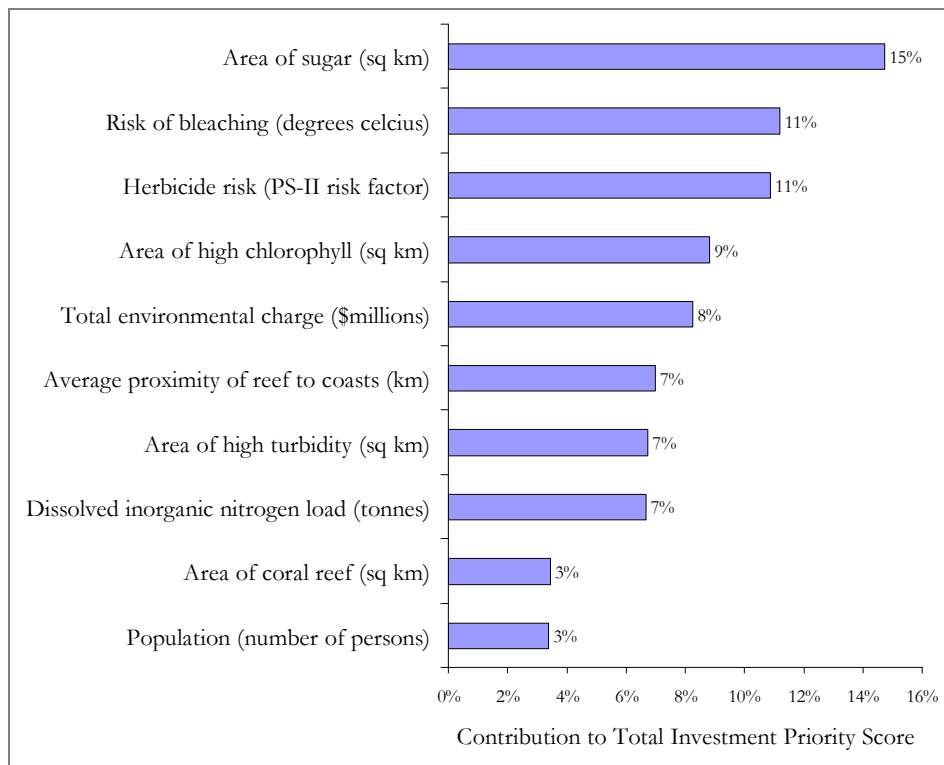
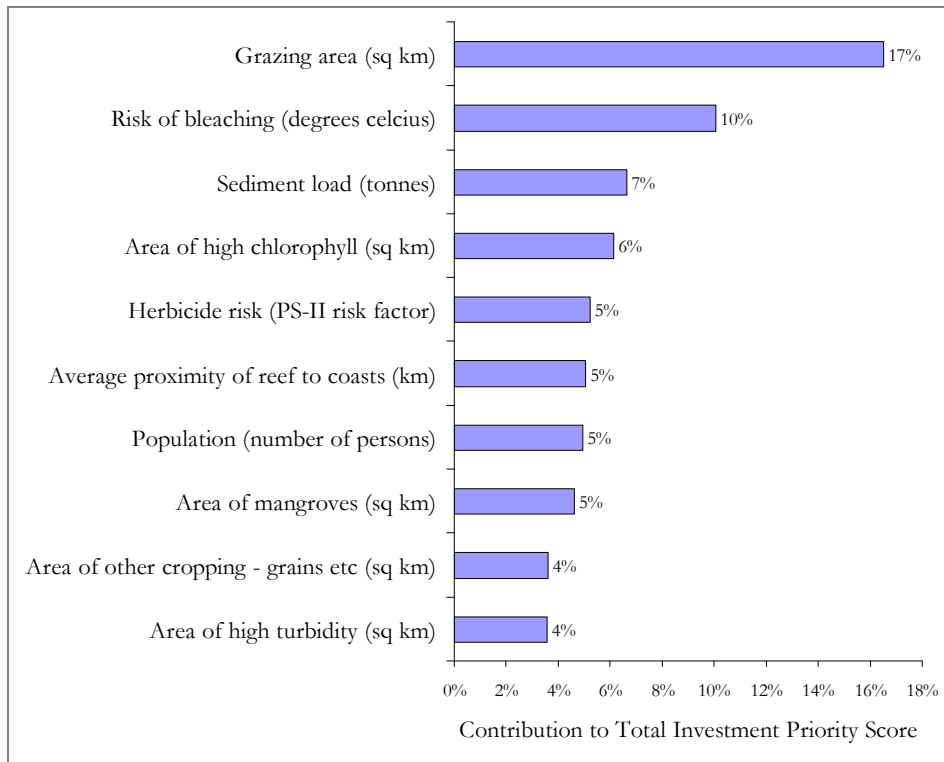


Figure 6 (continued): Criteria underpinning regional multiple criteria analysis scores for (top) Fitzroy and (bottom) Mackay Whitsunday.

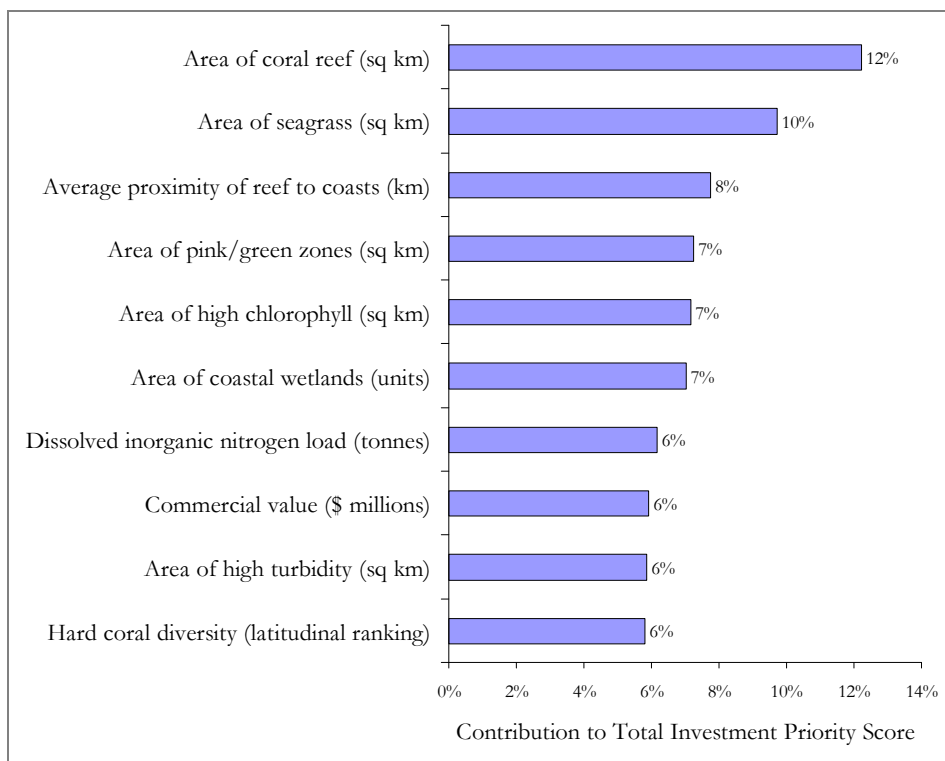
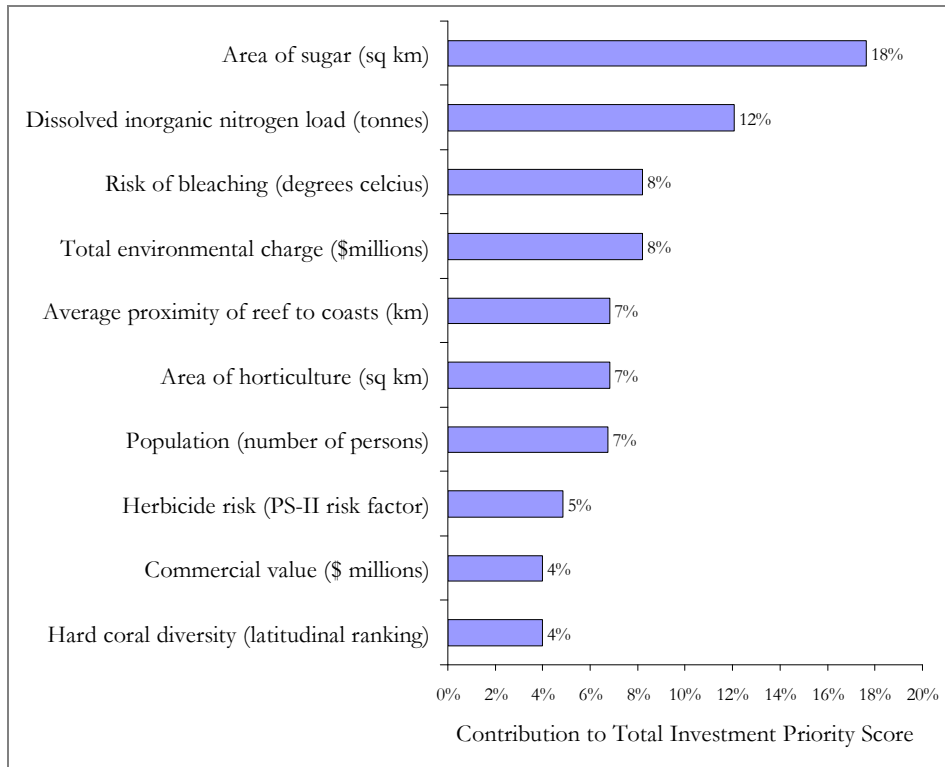


Figure 6 (continued): Criteria underpinning regional multiple criteria analysis scores for (*top*) the Wet Tropics and (*bottom*) Cape York.

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References

- Brodie, J., Binney, J., Fabricius, K., Gordon, I., Hoegh-Guldberg, O., Hunter, H., O'Reagain, P., Pearson, R., Quirk, M., Thorburn, P., Waterhouse, J., Webster, I. and Wilkinson, S. (2008) *Scientific consensus statement on water quality in the Great Barrier Reef*. A Reef Plan publication, Queensland Department of Premier and Cabinet.
- Brodie, J., Waterhouse, J., Lewis, S., Bainbridge, Z. and Johnson, J. (2009) Current loads of priority pollutants discharged from the Great Barrier Reef catchments to the Great Barrier Reef. Australian Centre for Tropical Freshwater Research (ACTFR) Draft Report No. 09/02.
- Delean, S. and De'ath, G. (2008) [*Spatial and temporal patterns of indicators of reef health on the Great Barrier Reef*](#). Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (116 pp.).
- DeVantier, L. M., De'ath, G., Turak, E., Done, T. J. and Fabricius, K. E. (2006) Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef. *Coral Reefs* 25: 239-340.
- Hajkowicz, S. A. (2002) *Regional priority setting in Queensland: A multi-criteria evaluation framework*. Queensland Government Folio 02/1311.
- Hajkowicz, S. A. (2007) Allocating scarce financial resources across regions for environmental management in Queensland, Australia. *Ecological Economics* 61(2-3): 208-216.
- Hajkowicz, S. A. and McDonald, G. T. (2006) The Assets, Threats and Solvability (ATS) Model for Setting Environmental Priorities. *Journal of Environmental Policy and Planning* 8(1): 87-102.
- Johnson, J. E. and Marshall, P. A. (eds.) (2007) *Climate Change and the Great Barrier Reef*. Great Barrier Reef Marine Park Authority and the Australian Greenhouse Office.
- Lesslie, R. G., Hill, M. J., Hill, P., Cresswell, H. P. and Dawson, S. (2008) The Application of a Simple Spatial Multi-Criteria Analysis Shell to Natural Resource Management Decision Making. In: Pettit, C., Cartwright, W., Bishop, I., Lowell, K., Pullar, D. and Duncan, D. (eds.) *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*. Springer, Berlin, pp 73-96.
- Montreal Process Implementation Group for Australia (2008) Australia's State of the Forests Report 2008. Bureau of Rural Sciences, Canberra.

Productivity Commission (2003) *Industries, Land Use and Water Quality in the Great Barrier Reef Catchment*. Research Report. Productivity Commission, Canberra.

Wooldridge, S. (2008) *Regional scale coral bleaching predictions for the Great Barrier Reef (1990-2050)*. Milestone Report 2 to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Ltd, Cairns, January 2008.

Quantifying wetland connectivity in the Tully-Murray floodplain using 1-D hydrodynamic modelling

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Abstract

Wetland connectivity has been quantified using hydrodynamic model results. Timing and duration of the connections between a wetland and the two main rivers were estimated for wetlands of different types in the Tully-Murray floodplain. Overbank flow connections during floods were previously estimated (Karim *et al.* 2008) using the 2-D MIKE 21 hydrodynamic model. In the second part of this study, we estimated round the year connectivity using a 1-D model as it requires substantially less computation time. This paper describes a methodology for analysing channelised flow connection during and after the overbank flooding using a 1-D hydrodynamic model. Location and size of the wetlands and the extent and size of the stream and drain network were quantified using high resolution LiDAR data; these estimates formed inputs to the hydrodynamic model. Connectivity between a wetland and the Tully and/or Murray Rivers was estimated for seven wetlands for the 2007 hydrological year. Results indicate that wetlands that are large in size and/or located near the rivers maintain longer connection times with rivers. This study provide a means of identifying the degree of connectivity of different wetlands, ranging from those wetlands that are more permanently connected with rivers and drains to those that are connected only when there are overbank floods.

Introduction

Habitat quality and ecological condition of a floodplain wetland depend on many factors, but a key determinant is how the wetland is connected to other wetlands, streams, rivers and the ocean over time (Paterson and Whitfield 2000; Bunn and Arthington 2002). Connectivity in this study is defined as the extent to which fish and other aquatic biota can move between different habitat types. It has major consequences for wetlands of different types and the habitats and biodiversity each wetland can support. The level of connectivity depends on the period of time water flows between wetlands and/or streams. In the Wet Tropics there are often permanent flows in rivers and large creeks that provide continuous connectivity to on-stream wetlands; however, off-stream wetlands may be isolated for long periods (Veitch and Sawynok 2005). A recent study by the Great Barrier Reef Marine Park Authority (GBRMPA) identified the wetlands of the Tully-Murray floodplain as being among the highest value from a fishery perspective. However, the connectivity of the wetlands in this catchment is yet to be explored (Veitch and Sawynok 2005). The Tully and Murray Rivers are the two main waterways that connect wetlands in this catchment directly or indirectly. The wetlands in these catchments are permanent, semi-permanent or ephemeral. Flooding is very common on the Tully-Murray floodplain, with the rivers going over bank several times a year on average (Wallace *et al.* 2008). Since the topography of the Tully-Murray floodplain is very flat

and the rivers are quite close, floodwaters often merge and connect the majority of the wetlands between the two rivers. Recently, Karim and others (2008) investigated overbank flow connection between a wetland and the Tully and Murray Rivers for the flood events of one- and twenty-year return periods using a 2-D hydrodynamic model. For round the year connectivity (i.e. channelised connection) analyses 2-D modelling is not feasible as it requires substantial computation time. Moreover, channelised flow can be well presented by a 1-D model. Therefore, in the second part of this study, we have investigated round the year connectivity using 1-D modelling.

Methods

The study first computed water depth information at a large number of points across the stream network in the Tully-Murray floodplain using a 1-D hydrodynamic model. Time-varying water depths through the streams were estimated by interpolating model outputs. This gave the temporal history of connection and detachment between a wetland and a main stream for a specified threshold water depth. By accumulating this information, timing and duration of connection for wetlands of interest were obtained. The method of hydrodynamic flow simulation and the techniques of connectivity analyses are briefly described in the following sections.

Hydrodynamic flow simulation

A one-dimensional river-creek-drain network (hereafter called stream network) model was developed using the MIKE 11 hydrodynamic model (DHI, 2008). We used colour contoured and shaded relief images of a 3m digital elevation model derived from LiDAR to manually digitise stream links representing all natural and man-made waterways (e.g. drains) and wetlands (lagoons) of significance in the Tully-Murray floodplain (Figure 1). To reduce computational complexity, the hydrodynamic model was developed by considering only streams that link a wetland directly or indirectly to the Tully River or the Murray River. The network model consists of 69 branches, seven upstream boundaries and two water level boundaries.

The main inputs to the model were stream cross-section, surface roughness, runoff sources and boundary conditions. Cross-section data (reporting heights at one-metre intervals across the river/drain section), were extracted from the raw LiDAR point data using customised code written in Python. The LiDAR survey was conducted in October when majority of creeks and drains were dry and the water depths in the river were low. However, in some river and wetland cross-sections, manual adjustments had to be made to estimate profiles beneath water where the LiDAR survey could provide no information. Initial roughness coefficients were estimated based on Chow (1959) and Connell Wagner (2006) and the coefficients were subsequently updated during the calibration process. Sources of rainfall-generated runoff were estimated at sub-catchment scale using a calibrated rainfall-runoff model. Runoff from the upper catchments was added to the model domain as boundary flow and runoff within the floodplain was uniformly distributed along stream links based on the drainage area associated with the individual stream link.

The schematised stream network model includes water level and flow computing points and boundaries (Figure 2). Water levels were computed at points where cross-section data were available and discharges were computed midway between consecutive cross-sections. There were 457 water level and 404 discharge computing points. Total schematised length was 104,684m with an average distance of 260m between two cross-sections. Minimum distance between two computing points was 47m in case of drains and 890m in case of rivers. We used relatively close computational points in case of drains to capture any changes in elevation and/or width of the drain.

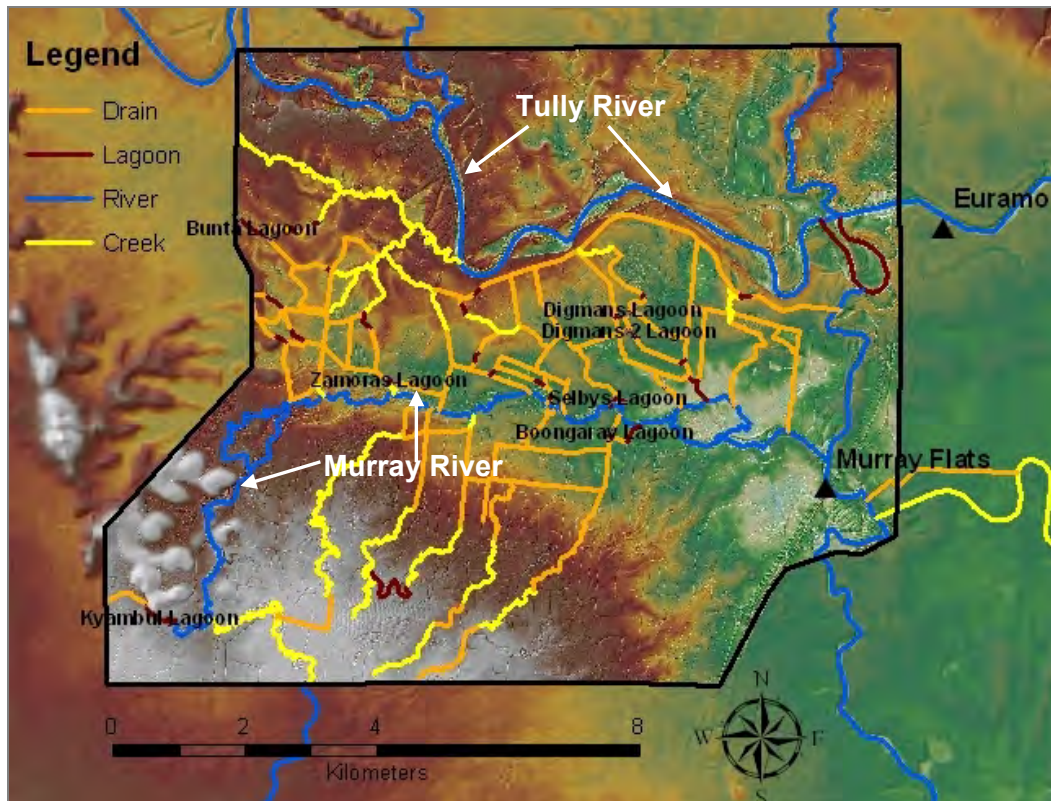


Figure 1: Stream network and location of wetlands in the Tully-Murray floodplain.

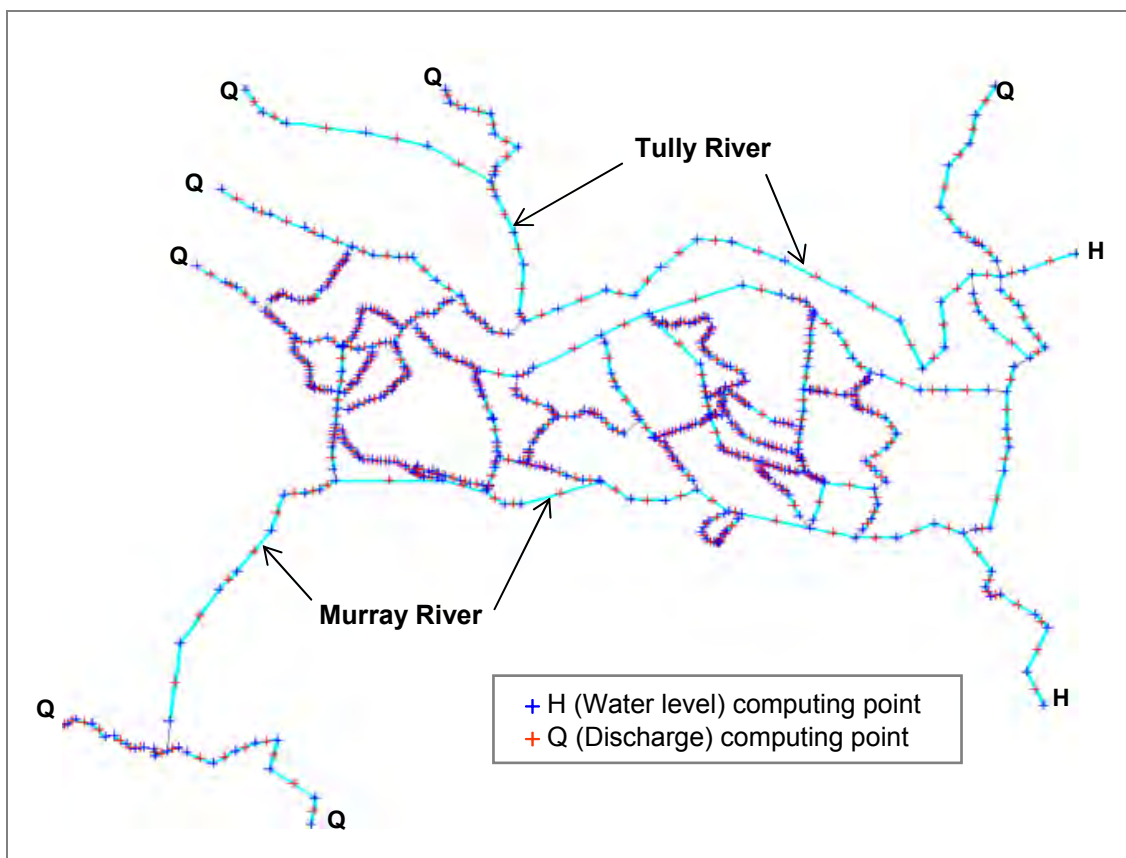


Figure 2: Schematised river-stream-drain network showing water level and discharge computing points and boundaries.

The model was run for the 2007 hydrological year by twelve interlinked runs, each of one month duration. To maintain the Courant stability criteria, a very small time increment (five seconds in most cases) was assigned. The Courant number is a function of flow velocity, distance between two computation points (Δx) and time step (Δt). It ensures the conservation of mass by limiting water movement less than Δx within Δt . A safety factor of 1.3 was maintained all through the simulation. Computed water depths were recorded for all water level points and the data were saved at daily intervals.

Connectivity analyses

For each day, water depths at computational points were formed into continuous depths across the stream network by interpolating between computed water level points from the model. A wetland was considered connected with a river when water depth along any pathway from a wetland to the river was equal or greater than a threshold depth. Connection of a particular wetland to the river system was firstly established by uniquely identifying all continuous water surfaces (exceeding the threshold depth) for each daily time step. By then comparing unique identifiers for each continuous water surface with those coinciding with wetlands and rivers for that time step it was possible to establish a time series of connection and disconnection for individual wetlands with the Tully and Murray Rivers. Connectivity was assessed for two threshold water depths, 5cm and 15cm.

Results and Discussion

A typical example of connectivity analysis by identifying connected stream links at each time step shows the connectivity status of wetlands on 2 May 2007 for 5cm water depth or more (Figure 3).

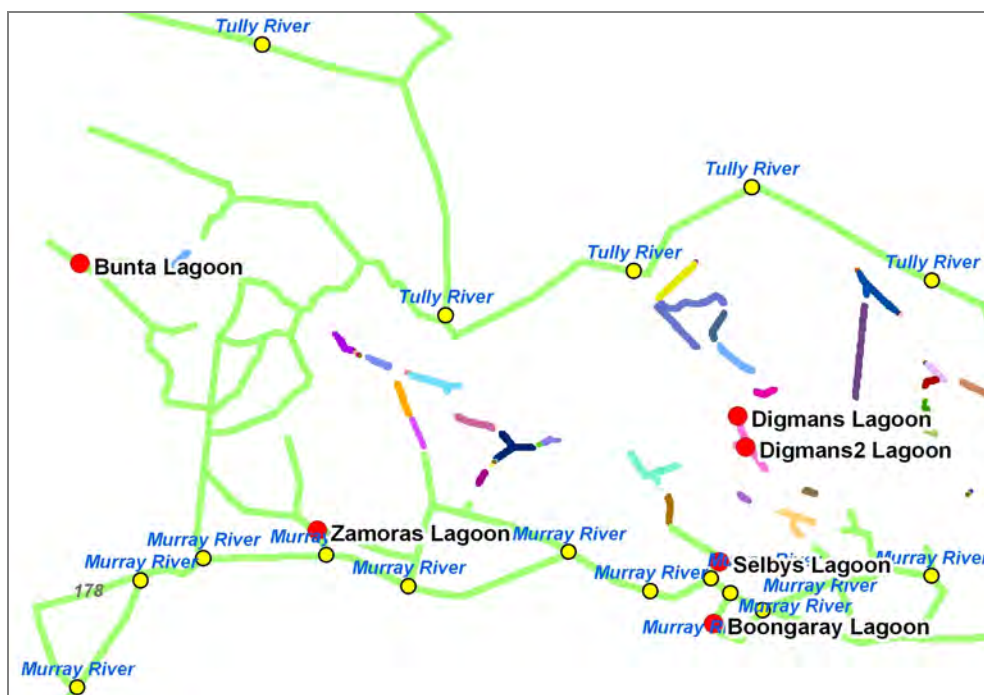


Figure 3: Method of connectivity analysis. Each colour shows inter-connected stream links at a particular time step (2 May 2007 in this case). In this analysis, Kyambul, Bunta, Zamora, Selbys and Boongaray are connected to the Tully and Murray Rivers [for a threshold water depth of 5 cm].

Each colour on this figure represents the interconnected stream links at that particular time step. It can be seen that Kyambul, Bunta, Zamora, Selbys and Boongaray lagoons are connected to the Tully and Murray Rivers (all green), but Digmans and Digmans 2 are connected to neither the Tully River nor the Murray River. However, connectivity may still exist through smaller cane drains not represented here. Digmans and Digmans 2 are artificial wetlands and are located relatively distant from the two main rivers. These two wetlands are small in size comparing with other five wetlands. The factors that control connectivity for a particular wetland include location and size of lagoon and its linkage with the stream network. It was found that wetlands that are large in size and/or located near the rivers maintain longer connection time with rivers.

We found that connectivity time varies with wetland size (Figure 4). It can be seen that Bunta, Kyambul, Selbys and Zamora lagoons maintain connection with the Murray River almost round the year. Among those, Bunta and Kyambul lagoons are very large in area, and the other two lagoons are very close to the Murray River (see Figure 1 for location). We summarised connection time and duration of connection of the wetlands to the Tully and Murray Rivers for two threshold depths (5cm and 15cm) for the hydrological year 2007 (Figure 5). It is noticeable that the connection times for all wetlands to the Murray River are the same as to the Tully River for 5cm threshold depth. The reason is that there exists a continuous connection between the Tully and Murray Rivers for that water depth (i.e. 5cm), so connection to one river would result in connection to both. In the case of the 15cm water depth threshold, most of the wetlands retain their connection to the Murray River for a longer period because they have direct or very short links directly to the Murray River. We would stress that these results are preliminary and are yet to be verified.

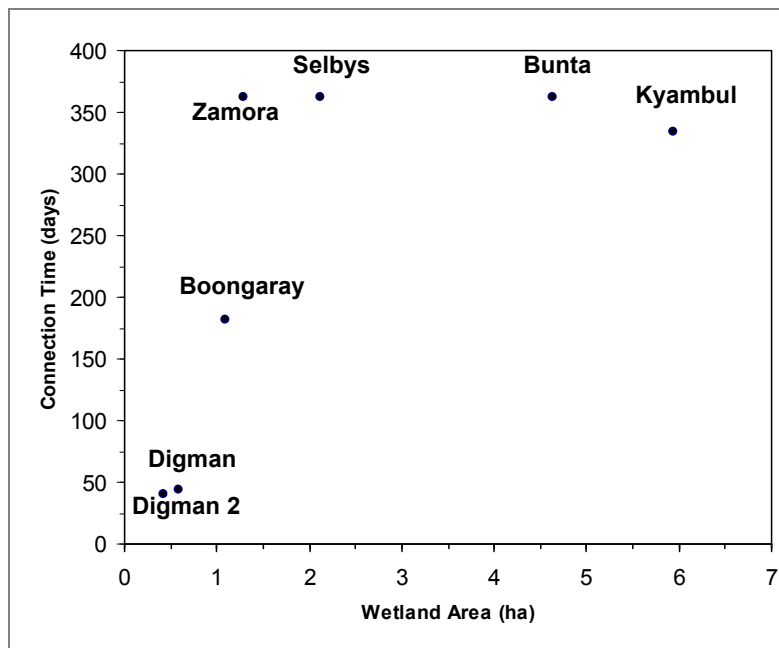
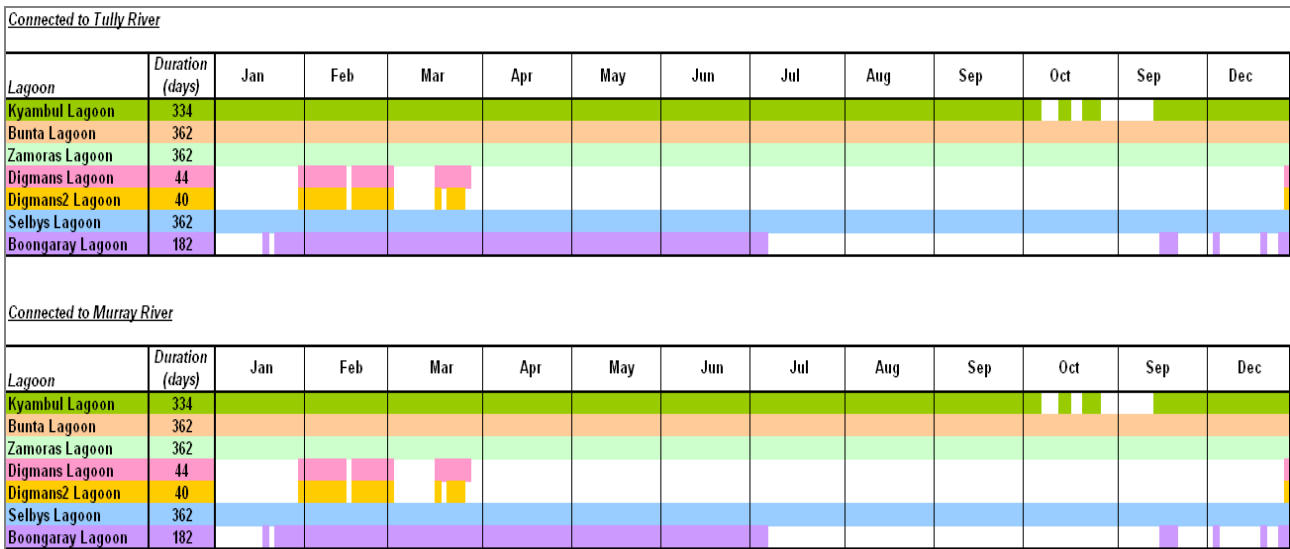


Figure 4: Relationship between wetland size and connectivity time for 5cm or more water depth.

(a) 5cm water depth or more



(b) 15cm water depth or more

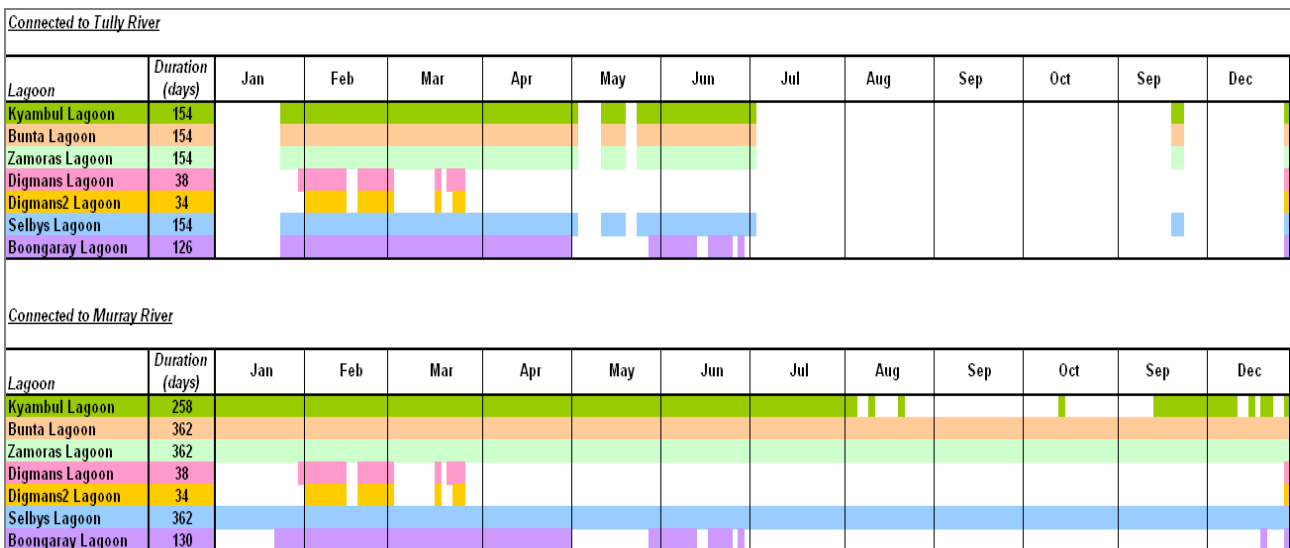


Figure 5: Summary of wetland connectivity to the Tully and Murray Rivers for the hydrological year 2007 for the threshold water depths of (a) 5cm and (b) 15cm.

Implication for end users

In this study we have demonstrated how the connectivity of different wetlands through the stream channel network can be quantified using hydrodynamic modeling. Results indicate that connection time and the duration of connectivity of each wetland to the major rivers differ according to wetland size and/or proximity to rivers. Some wetlands retain their connection with the main rivers all through the year, although water depth is very low during the dry season. Other wetlands, which are small in size and are located more distant from the main rivers, maintain connection with the main rivers during the wet season but will disconnect during the dry season. These results will be of significance to the potential movement patterns of aquatic biota during and after flood events, to the habitat structure and water

quality of individual wetlands over time, and to the potential for wetland processes to influence downstream water quality. The results are also useful to identify better locations for an artificial wetland if connectivity is considered important.

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References

Bunn, S. E. and Arthington, A. H. (2002) Basic principles and consequences of altered hydrological regimes for aquatic biodiversity. *Environmental Management* 30: 492-507.

Chow, V. T. (1959) *Open Channel Hydraulics*. McGraw-Hill International Edition, 680 pp.

Connell Wagner (2006) *Tully-Murray Rivers Flood Study Calibration Phase Report*. Prepared for the Queensland Department of Main Roads. Queensland Department of Natural Resources and Mines and Queensland Rail.

DHI (2008) MIKE by DHI (Danish Hydraulic Institute). MIKE 21 Flow Model, Scientific Documentation, 60pp.

Karim, M. F., Henderson, A., Wallace, J. S, Rash, P., Arthington, A. H. and Pearson, R. (2008) An assessment of wetland connectivity in the Tully-Murray floodplain using a hydrodynamic model. In: Taylor, R. and Long, S. (eds.) *Proceedings of the 2008 Marine and Tropical Sciences Research Facility Annual Conference*. Reef and Rainforest Research Centre Limited, Cairns, pp 64-70.

Paterson, A. W. and Whitfield, A. K. (2000) Do shallow-water habitats function as refugia for juvenile fishes? *Estuarine, Coastal and Shelf Science* 51: 359-364.

Veitch, V. and Sawynok, B. (2005) *Freshwater Wetlands and Fish*. Sunfish Queensland Inc. Report No: SQ200401, p136.

Wallace, J. S., Stewart L. S., Hawdon A. and Keen R. (2008) *The impact of floods on sediment and nutrient fluxes from the Tully-Murray catchments to the GBR lagoon*. Report to Terrain NRM Ltd and the Marine and Tropical Sciences Research Facility (MTSRF) for input to the Water Quality Improvement Planning process. CSIRO Science Report Y/07, p56.

Reflections on the value of MTSRF research for rainforest management

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Introduction

Queensland's World Heritage-listed Wet Tropics rainforests and its World Heritage neighbour, the Great Barrier Reef face considerable pressures. Climate change, the impacts of pests and weeds, development impacts, pressures from recreational and commercial uses and a host of other existing and potential risks need to be identified, addressed and managed. The wider Wet Tropics region is also under substantial development pressure with downstream impacts on the rainforests and the reef. The region is undergoing rapid population growth and this is forecast to continue (Queensland Government 2009). We have an opportunity to manage this growth within ecologically sustainable principles, but only if we have sufficient knowledge of the biophysical, social and economic nature of the region. Further, optimising the utilitarian benefits of regional environmental assets, particularly through tourism, requires a thorough understanding of the industry and its clients. We must continue to accumulate and communicate knowledge about these magnificent natural assets to meet our obligations to the Australian community and the wider world. These factors and others establish a very strong case for a continuing substantial investment in marine and tropical research in the region.

Governments have responded. The region has enjoyed substantial investment in research focussed on the reef and rainforest through two Cooperative Research Centres and latterly through the Australian Government's investment in the Marine and Tropical Sciences Research Facility (MTSRF). A strong and internationally recognised research capacity has been developed at James Cook University, the CSIRO, Australian Institute of Marine Science (AIMS) and in laboratories at other institutions. A very substantial body of knowledge has been created over several years. Importantly, much of this is transferable to analogous ecosystems elsewhere.

We are approaching the end of the third year of the four-year MTSRF investment and work is underway to secure and allocate a future round of investment. It is an appropriate time to reflect on the current arrangements and what we have learned about its value and application as a basis for future planning.

The MTSRF Concept

The mission of the MTSRF is to "plan, fund and coordinate the highest quality, cross-disciplinary research for public good to:

- "Ensure the protection, conservation, sustainable use and management of environmental assets of the Great Barrier Reef and its catchments, tropical rainforests including the Wet Tropics World Heritage Area and the Torres Strait;
- "Foster an understanding of the interactions of North Queensland's natural environment with the social and economic aspects of North Queensland's communities;
- "Support the adoption of science based knowledge in policies and practices for ecologically sustainable management; and

- “Facilitate capacity building for sustainable environmental management and environmental management research, in partnership with the community, environmental managers, research institutions, industry and policy makers.”

(Department of the Environment and Heritage 2006)

A number of principles were established:

- “The adoption of results by end-users of the research products will be accorded high priority...”
- “End user participation throughout the design, implementation, delivery ... will be expected and assisted
- “Research quality will be accorded high priority ... All research projects will produce appropriate peer-reviewed scientific publications as well as documents and data that are accessible and suited to the needs of [end users]”

(Department of the Environment and Heritage 2006)

Two further principles deal with management of intellectual property and support for post-graduate training.

Clearly, the MTSRF is concerned with not just what research is conducted, but how it is conducted and delivered. Our judgments of the value of the MTSRF will be influenced by both these dimensions.

A further distinctive feature of the MTSRF investment is that it is administered through a contract between the Department of the Environment, Water, Heritage and the Arts and the regionally-based Reef and Rainforest Research Centre (RRRC)[†]. The RRRC brokers between research partners in the design of collaborative projects and between research providers and users in interpreting and communicating research outcomes. So our judgment of MTSRF design and implementation will also be influenced by our perception of the RRRC and its performance, as well as that of the research community.

The Wet Tropics of Queensland World Heritage Area

The Wet Tropics World Heritage Area (WTWHA) is, by definition, one of the World’s outstanding natural features. It meets all four of the natural World Heritage criteria. It is a region of outstanding natural beauty, highly distinctive geomorphology, supports ancient plants demonstrating ongoing evolutionary processes and supports an extraordinary diversity of flora and fauna.

While listed for its natural heritage criteria, the WTWHA is also a region of great cultural and social significance. It lies within the traditional country of eighteen Rainforest Aboriginal tribal groups who maintain strong links and interest in the management of the Area. It is a major tourist destination, generating over \$425M annually in the regional economy (Prideaux and Falco-Mammone 2007). Its scenic values and opportunities for recreation add substantially to the quality of life for North Queensland residents.

Maintaining the values of the World Heritage Area requires that we understand the nature, distribution and interactions of key World Heritage values and also the nature, distribution and interactions of threats to these values. Threats almost always originate in the activities of humans, so to deal with them we must have knowledge not just of the scientific and technical nature of the identified threats but of their social and economic dimensions.

[†] The author is a director of the RRRC.

Managing threats means managing human behaviour – influencing the choices of communities and policy makers through regulation, education and persuasion. Importantly, success in maintaining the values of the World Heritage Area means promoting sustainability in the wider region through education, regulation, community action and incentives.

The outstanding value of the WTWHA attracts the World's attention. In this sense, it is a laboratory where we can generate knowledge about tropical rainforests and their management but also an exemplar, demonstrating how knowledge can be used to improve management. For example, knowledge of the impact of climate change on the Wet Tropics and of our policy and management response to it could be of value to the managers of other tropical forests around the globe. The World Heritage Committee has observed that the global network of World Heritage sites is ideally suited to building public awareness and support through sharing of information and effective communication on the subject, given the high-profile nature of these sites (UNESCO 2007).

Wet Tropics Management Authority

In signing the World Heritage Convention, the Australian Government, “recognised the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage of Wet Tropics” (UNESCO 1972). The Australian and Queensland Governments agreed to establish the Wet Tropics Management Authority (WTMA) as a means of ensuring the shared interests of the two Governments in the management of the World Heritage Area are achieved. The Authority's functions defined in the *Wet Tropics World Heritage Protection and Management Act 1993* (Queensland) include, “[to] gather, research, analyse and disseminate information on the wet tropics area” and “[to] monitor the state of the wet tropics area”. The Authority's Strategic Plan (WTMA 2008b) for 2008-2013 identifies that WTMA has a role as a “knowledge manager – directing, collecting, analysing and communicating knowledge of the World Heritage Area as a basis for change” and establishes related objectives and strategies. Clearly then, research is squarely within the Authority's role and purpose and it has a vital interest in the MTSRF program as well as research funded through other sources.

The WTMA has analysed the research needs for the WTWHA through its research and information needs report (WTMA 2000). Prepared after considerable consultation within the Wet Tropics community, the report reflects the interests of the WTMA, its partners in service delivery and the wider Wet Tropics community. It was revisited in a contribution to establishing priorities for the MTSRF investment but now requires more thorough review. This process has commenced and the WTMA Scientific Advisory Committee and its other consultation forums will be central to the review process.

As well as maintaining links with the research community, the WTMA works closely with partners in managing the World Heritage Area and its surrounding landscape. Partners include the Queensland Department of Environment and Resource Management and several other Queensland State Government agencies, local governments and the Commonwealth Department of the Environment, Water, Heritage and the Arts in its administration of the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). The WTMA also maintains networks with the tourism industry, the conservation sector and operates an active community engagement program. This network of relationships means the WTMA is well-placed to be aware of current and emerging management and policy issues confronting our partners so is well positioned to communicate advice based on research outcomes but also to identify research priorities based on management and stakeholder needs.

Reflections on implementation of MTSRF

MTSRF-funded research has made a valued contribution towards improving knowledge and management of the Wet Tropics bioregion, including the World Heritage Area. It has advanced and extended the programs established by the Cooperative Research Centre for Tropical Rainforest Ecology and Management (Rainforest CRC) and has created a strong platform for continuing research investment. While not intending in any way to derogate the hard work across all of the research programs, the following examples are highlights from the Authority's perspective:

- **Climate change predictions and impacts:** The Wet Tropics World Heritage Area is regarded by the Intergovernmental Panel on Climate Change (IPCC) (Hennessy *et al.* 2007) as one of the ecosystems most vulnerable to the impacts of climate change. MTSRF-funded research improving regional scale climate predictions and monitoring and forecasting impacts on habitats and wildlife is highly aligned with a key management challenge for the Wet Tropics. The work helps to maintain community and policy attention on the issue and provides a basis for investment into mitigation and adaptation. The research was particularly useful in the the WTMA State of the Wet Tropics Report for 2008 (WTMA 2008a), which focussed on climate change.
- **Tourism and visitor use:** One of our national obligations under the World Heritage Convention is to 'present' the World Heritage Area. The regional tourism industry, combined with public investment into visitor facilities is the major means of meeting this obligation. MTSRF-funded tourism research has helped to improve our understanding of the needs and preferences of rainforest visitors as a basis for better tailoring of commercial and non-commercial tourism services. The project is also generating practical resources that will assist tour operators and managers in presenting the rainforests to visitors and in ensuring sustainable management practices. These researchers have achieved a high standard of engagement and communication with management agencies and the tourism industry.
- **Cassowary DNA profiling:** While this is just one component of a wider project, the WTMA has been pleased to provide supplementary support for it because it is addressing a key issue – that of the numbers, distribution and population structure of cassowaries – but also because of the leadership the research team has shown in engaging community groups as volunteers. This aids community understanding, builds community capacity and smoothes the way for adoption of research outcomes.

The common features these projects share are their alignment to management and policy needs, the quality of the scientific work and the commitment the research teams have given to collaboration and communication with managers and stakeholders. These features create the core of their value to the WTMA.

Gaining increased value from future investment

A first point to be made about future investment is that a successor to the MTSRF is extremely important. While there is a very strong case for continuing Australian Government investment in the region for public good environmental research, we cannot take this for granted, especially in light of current economic conditions. In collaboration, the Wet Tropics research and management community need to create a very persuasive proposal for continued investment.

Secondly, the basic mission and principles of the MTSRF offer considerable promise and remain very relevant. A substantial solutions-oriented research program creates much value for land and resource managers. The WTMA would advocate that any future program carries forward these ideas.

Assuming another round of investment is secured, the following suggestions are offered as a means of increasing its current significant value to the WTMA and other Wet Tropics management agencies and in turn, to the wider community.

- **Clear links to policy and management outcomes:** If a future investment is to be explicitly solutions-oriented (and it should be), we must be clear about the management and policy questions that need to be solved. This responsibility falls firstly on the management agencies, and we need to do it better. If we see MTSRF-funded projects that are not clearly aligned with management needs, we may have a failure in policy analysis, not a failure in the conduct of the research project. This is not to say that we should expect that every research outcome will have immediate and profound management application, but we should at least be able to map the program logic that links the research to its anticipated applications. This process is another one requiring collaboration in the design of the research program and must happen at the start of the process and not be 'cooked up' half way through. We should also replace the notion of research themes (a directionless catalogue of related ideas) with the freshly-defined management and policy problems.
- **A more collaborative approach:** In the MTSRF lexicon, the WTMA, along with other management agencies, is an 'end user'. The term implies (no doubt, unintentionally) that we are passive recipients of the knowledge generated by the research community and further, that the transfer of knowledge stops with us. We should not lose sight of the point that the real 'end users' – the beneficiaries of the research – are, in the case of the WTMA, the wider Wet Tropics stakeholders and communities.

An IUFRO task force (Guldin 2003) concluded that collaboration is an especially effective way to build trust and influence policy. But reflections from the Rainforest CRC (Goosem *et al.* 2008) lead to the conclusion that cultural attitudes and external demands differ in the research and management communities, so collaboration is always going to be a challenge. We need to construct projects in a way that actively drives effective collaboration between researchers and managers. This sort of collaboration would mean that the management agencies are effectively *inside* the project and that there is a regular flow of formal and informal information between the research institution and its management counterparts. Under this arrangement, collaborating management agencies would be active learners, adapting and changing in response to the knowledge generated by researchers as it becomes available. This approach will create challenges for research project design, but also will demand more of management and policy agencies. Holmes and Clarke (2008) made the point that "policy makers need to become more intelligent customers, better able to define questions to science and reflect uncertainties appropriately in policy formulation".

Collaboration should not be limited to the relationship between researchers and managers in the conduct of the research. We need to ensure appropriate forms of structured engagement with stakeholders and communities in defining the problems that require research. Such collaboration would build confidence in research programs, related management solutions and ultimately in research and management institutions. Effective engagement will assist in stakeholder acceptance of research findings that challenge existing norms (see, for example, Joyce 2003).

- **A stronger role for management agencies in communicating research findings:** Natural resource managers use information as a contribution towards changing behaviour in communities and among policy makers. We strategically select, package, ration, target and time the release of information to gain maximum behavioural effect. If the MTSRF is to be a management oriented research program, it is vital that the release of research findings is done in a way that contributes to the objectives of management agencies. Accordingly, management agencies like the WTMA must be centrally involved in the communications process. It is not a role that we can comfortably delegate.

- **Reporting:** The tension between reporting research outcomes through the scientific literature and the need to make results available to managers in a timely and management relevant way should not be irreconcilable. But it won't happen without some effort. Put simply, papers published in the scientific literature normally come too late and are presented in a way that limits their utility for managers and policy makers. The knowledge of front-line service delivery staff, who may have limited professional experience with the scientific literature, and who are always under time pressure, is not likely to be enhanced by this form of communication. We need to respect the professional academic need for this form of reporting, but if that is all a research program intends to produce, it is not likely to gain the support of WTMA. Choi *et al.* (2008) advocate the use of brokers in particular circumstances to overcome the problem of knowledge transfer. But if we were to pursue a collaborative approach to project design and implementation, the WTMA and other management agencies could assist in the interpretation, communication and application of reports that meet their needs and the needs of stakeholders. This is a matter that we need to address in relation to the future role of the RRRC, which might create greater value in facilitating collaboration at the commencement of a project than brokering knowledge transfer at the end.
- **Project Management – matching resources to milestones:** Some of the disappointment we feel about some research projects that have not delivered all that we might have hoped for is because we hoped for too much in the first place. In assessing project proposals, we must be alert to the risk of seeking too much from research teams that have insufficient resources or capacity to deliver promised results. Incidentally, this risk is by no means confined to research projects. Once the initial investment is made into a project, it is difficult to reverse the decision for fear of losing any value from earlier investments. We instead tend to accept that we will not get the promised results, but grumble about it, with adverse consequences for future investment.
- **Meaningful milestones:** Milestone reports potentially provide an informal yet useful way of communicating progress to research users during the course of the project. Ideally, they will also stimulate some dialogue about management applications. Some of the current milestone reports under the MTSRF focus more on activity than outputs, limiting their value in knowledge transfer, but also limiting their value as a means of tracking project progress. We need to be vigilant about this in any future round of investment.
- **Broadened scope of research:** In some cases, environmental policy and management decisions are not constrained by a lack of knowledge of biophysical matters but by a lack of knowledge about economic and social issues. In fact, in most cases, all three branches of knowledge must be considered. There is a case for broadening the scope of future research investment to take this into account. The appropriate balance between investment in economic, social and biophysical research should become evident if we start the priority setting process with clearly-stated management and policy problems.
- **Evaluation:** Much of the discourse around the current MTSRF round concerns how we can best target, design and implement research projects that generate knowledge that is taken up and used by policy makers, managers and stakeholders. We can point to some successes but also to some examples where the link between researcher and manager is not as strong as we would wish. There would be merit in investing in a structured, parallel research project that analyses the uptake, usefulness, cost/benefits and engagement of end-users, in each of the funded research projects. This might have a catalytic role in encouraging collaboration and could result in on-going improvements in governance and other arrangements. A potential benefit for the researchers is that such an arrangement could justify a reduction in administrative reporting requirements. Investors and management agencies would benefit from an improved understanding and greater confidence in knowledge transfer pathways.

Conclusion

The MTSRF investment, building on and coordinating with other regional research investments, has made a vital contribution to the management of the Wet Tropics World Heritage Area and the surrounding bioregion. The research program, built on strong principles of end-user engagement with structured knowledge transfer and application, mediated by a regional hub, is a distinctive and regionally relevant means of ensuring research investment has real value for management and policy development.

Further investment into research about the values, uses and threats to the Wet Tropics World Heritage Area and its surrounding bioregion is essential if we are to maintain the world-class management standards expected by the international community under the World Heritage Convention and by Australian citizens with an interest in this outstanding landscape. In the development and application of any new research funding program, we need to ensure we retain the particular strengths of the MTSRF approach, but also to reflect on how we could improve as a basis for increasing the value of the investment.

High priorities for attention for a future round of investment are making more explicit the link between policy/management problems and research programs, projects that facilitates communication and knowledge transfer and improvements in project design and management. As an agency with a clear role and established interest in research for the Wet Tropics, the Wet Tropics Management Authority remains committed to play an active part in any future research program.

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References

Choi, B. C. K., Gupta, A. and Ward, B (2008) Good thinking: six ways to bridge the gap between scientists and policy makers. *J Epidemiol Community Health* 63: 179-180.

Department of the Environment and Heritage (2006) *Marine and Tropical Sciences Research Facility Research Investment Strategy*. Department of the Environment and Heritage, Canberra (<http://www.environment.gov.au/about/programs/cerf/publications/mtsrf-ris.html>)

Goosem, S., Stork, N. E. and Turton, S. M. (2008) Rainforest science and its application. In: Stork, N. E. and Turton, S. M. (eds.) *Living in a Dynamic Tropical Forest Landscape*. Blackwell Publishing, UK.

Guldin, R. W. (2003) Forest science and forest policy in the Americas: building bridges to a sustainable future. *Forest Policy and Economics* 5: 329-337.

Hennessy, K., Fitzharris, B., Bates, B. C., Harvey, N., Howden, S. M., Hughes, L., Salinger, J. and Warrick, R. (2007) Australia and New Zealand. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson (eds.) Cambridge University Press, Cambridge, UK, 507-540.

Holmes, J. and Clark, R. (2008) Enhancing the use of science in environmental policy making and regulation. *Environmental Science and Policy* 11: 702-711.

Joyce, L. A. (2003) Improving the flow of scientific information across the interface of forest science and policy. *Forest Policy and Economics* 5: 339-347.

Prideaux, B. and Falco-Mammone, F. (2007) Economic Values of Tourism in the Wet Tropics World Heritage Area, Cooperative Research Centre for Tropical Rainforest Ecology and Management (Rainforest CRC) and James Cook University, Cairns (<http://www.rrrc.org.au/publications/downloads/Wet-Tropics-Economic-Values-Report-Rainforest-CRC.pdf>)

Queensland Government (2009) *Far North Queensland Regional Plan 2009-2031*. Department of Infrastructure and Planning, Brisbane (<http://www.dip.qld.gov.au/regional-planning/regional-plan-3.html>)

UNESCO (2007) *Climate Change and World Heritage: Report on predicting and managing the impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses*. United Nations Educational, Scientific and Cultural Organisation World Heritage Centre (<http://whc.unesco.org/uploads/activities/documents/activity-393-1.doc>)

UNESCO (1972) *Convention for the Protection of the World Cultural and Natural Heritage*. United Nations Educational, Scientific and Cultural Organisation (<http://whc.unesco.org/archive/convention-en.pdf>)

WTMA (2000) *Wet Tropics Information Needs for Management*. Wet Tropics Management Authority, Cairns (http://www.wettropics.gov.au/mwha/mwha_pdf/rain_report.pdf)

WTMA (2008a) *Climate Change in the Wet Tropics: Impacts and Responses*. State of the Wet Tropics Report 2007-2008. Wet Tropics Management Authority, Cairns (http://www.wettropics.gov.au/media/media_pdf/annual_reports/2008sowt_report_climatechange.pdf)

WTMA (2008b) *Strategic Plan 2008-2013*. Wet Tropics Management Authority, Cairns (http://www.wettropics.gov.au/mwha/mwha_pdf/Strategies/WTMAStrategicPlan.pdf)

Understanding and indicating social resilience factors in the Far North Queensland region

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MTSRF [Project 4.9.7](#)(b)

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Abstract

The concept of resilience in social-ecological systems has attracted considerable interest as a foundation for natural resource management at regional scales, yet there is a distinct knowledge gap when it comes to the social dimensions of resilience. Meanwhile social and health sciences have developed a strong understanding of personal resilience, but this is yet to be scaled up for communities and regional-scale use, and does not recognise ecological and economic connections. This team views social resilience as how individuals, communities and societies adapt, transform, and potentially become stronger when faced with environmental, social, economic or political challenges. The challenge is to understand the nature of the social dimensions of resilience in far North Queensland, in the context of this region's many social-ecological systems, then to develop indicators of resilience to assist our partners in their planning, investment, management and reporting.

This paper reports the preliminary results of three sub-regional case studies of social resilience within two Far North Queensland catchments. They focus on: the restructure of the dairy industry in the upper Johnstone catchment area; the most recent outbreak of the crown of thorns starfish on the Great Barrier Reef area off Cairns; and urban expansion to date in the Cairns region. The resilience-building factors emerging from the analysis to date are knowledge generation and management, awareness raising, communication, physical infrastructure, willingness to change behaviour, developing a diverse economic base, engaged governance and partnerships. Indicators will need to reflect these attributes, in a way that is relevant to this region.

An understanding of social resilience factors will assist far North Queensland to take an innovative and integrative approach to planning, and to prepare for climate change and other major challenges. Investment in the resilience of individuals, groups and organisations should enhance societal adaptability and transformation in the face of regional change.

Introduction

This paper reports on a four-year qualitative social research project conducted in the Wet Tropics region of Far North Queensland, northeast Australia. The project questions how communities from the region adapt, transform and potentially become stronger when faced with environmental, social, economic and, or political challenges that impact upon their way of life. The research has implications for natural resource management and regional

development, particularly in the context of rapid regional change, policy imperatives for changed land and sea management practices, as well as the potential and cumulative impacts of climate change. Organisations with regional-scale responsibilities in natural resource management (including Terrain NRM Ltd, the Wet Tropics Management Authority, the Great Barrier Reef Marine Park Authority and Giringun Aboriginal Corporation) and the authors identified the need for a social resilience reporting framework and indicators to assist in considering and managing for social resilience within regional management approaches. This framework will assist managers to understand the social dimensions of resilience; to incorporate data on social resilience within their planning and monitoring activities; to consider the implications of their management decisions and interventions for regional social resilience; and to develop strategies to enhance social resilience into the future.

This paper provides an overview of the project and its findings to date. It introduces the social resilience conceptual framework, contextualises the research in the Wet Tropics region of Far North Queensland, describes the research design, provides preliminary results from three of the six case studies that ground the project in the Wet Tropics region, and ends with a summary of the future pathway of this work.

The project has two principal aims. The first is to develop an understanding of what constitutes social resilience at a regional scale, and the features of social resilience for the Wet Tropics region specifically. The second is to develop monitoring criteria and indicators for regional social resilience, to enable incorporation of social resilience thinking into monitoring and management arrangements by our partners and other bodies. The research has clear pragmatic and academic outcomes: a monitoring and evaluation framework for regional natural resource managers and strategic planners, as well as an improved academic understanding of the characteristics of the social resilience of specific social ecological systems.

We have argued in Cuthill *et al.* (2008) that while resilience is a well-recognised concept, there is a distinct knowledge gap when it comes to social resilience, and especially so at the regional scale in which we are interested. There is little communication or mutual influence between the two current bodies of literature on resilience. The social and health sciences literature concentrates particularly on fostering the resilience of individuals, in a strengths-based approach to mental health. Few studies have extended to the resilience of communities, however, or acknowledge relationships with the environments or economies of those communities (exceptions are Hegney *et al.* 2007; Kulig 2000; Kulig *et al.* 2005; Lalonde 2006). Meanwhile the body of work focusing on theory building concerning the nature of social-ecological systems and their resilience contributes excellent theory concerning the nesting of social ecological systems but remains predominately informed by ecological concepts. The choice of social concepts remains limited, and informed by an early interest in broad ecological and social scales. Institutional arrangements have thus been a core focus (Adger 2000; Folke *et al.* 2005; Gunderson and Holling 2002) and recent literature incorporates recognition of trust and cooperation, knowledge and learning capabilities (Berkes and Turner 2006; Gunderson and Folke 2005; Watson *et al.* 2003).

Our work uses both bodies of literature, broadening from the interests of the first, and seeking to enrich the social dimensions so far addressed within the second. Like the literature on social-ecological systems, we recognise the nested nature of social and social-ecological systems, with mutual influences between systems from individual to global scales (see Cuthill *et al.* 2008).

Methods

The research practices a participatory process at two scales. The first is collaboration with regional partner organisations (Terrain NRM Ltd, Wet Tropics Management Authority (WTMA), Great Barrier Reef Marine Park Authority (GBRMPA), WTMA Rainforest Aboriginal Advisory Committee and Girringun Aboriginal Corporation). This is essential to develop an understanding of the region's social resilience, and to jointly develop a set of indicators of social resilience tailored to management needs. The second scale is more localised, whereby participants in case studies help to develop an understanding of social resilience using their experience, and will share in interpretation of their results towards development of robust indicators that reflect the region's social resilience well.

The methods used include two literature reviews (the resilience literature and social reporting approaches – see Cuthill *et al.* 2008) and six in-depth case studies. The case studies provide a mechanism to consider what individuals from the regional community perceive as important characteristics of coping with change. Triangulation of the insights of our regional partners, conceptualisation from literature, and the case studies, will inform development of a new regional social resilience monitoring and evaluation framework, as well as increased academic understanding of what constitutes regional social resilience within social ecological systems.

The focus of each case study is upon a "change story" from a particular area within the region. This provides a way to consider how individuals coped with the particular change, and what this can teach us about resilience. The six foci were selected by the regional natural resource management partners. They are:

- Restructure of the dairy industry;
- Most recent outbreak of crown-of-thorns starfish on the Great Barrier Reef;
- Urban expansion in the Cairns region;
- The water allocation process on the upper zone of the Barron river;
- Declaration of the Wet Tropics World Heritage Area; and
- The role of Girringun Aboriginal Corporation in enabling people to cope with change.

A stakeholder analysis was conducted for each case study. A researcher met with each of the regional natural resource management partners to decide who should be interviewed for each case study, aiming for ten to fifteen individuals for each. Open ended semi-structured interview schedules were designed for each case study. These followed themes related to: what happened leading up to and during the change event; how did the interviewee and their community cope with the change event; and what would the interviewee consider useful to facilitate their coping with, adapting to and transforming as a result of changes into the future. Informed prior consent was obtained before each interview and a digital voice recorder was used to capture each interview. Interviews were transcribed and coded for emergent themes. All interviewees remain anonymous in the reporting process.

Results

Some preliminary results from three of the six case studies are presented here. The data reported focuses upon how interviewees from each case study coped with the particular change event.

Case study one: The restructure of the national dairy industry, the upper reaches of the North and South Johnstone rivers

This case study was chosen by the regional partners because dairy farms are an integral part of the region and have dominated the upper reaches of the Johnstone River since 1913. Also, water and water quality are pertinent issues for those involved with the dairy industry. Fifteen individuals from the Upper Johnstone River basin area were interviewed for this case study. These included individuals from the dairy and potato industry, from relevant government agencies, as well as Traditional Owners from the region. The case study illustrates the interdependencies between community, industry, local enterprise, environmental sustainability and regional identity. The dairy industry has been severely impacted by deregulation.

Preliminary findings show that individuals coped in a variety of ways. The following are some examples that interviewees highlighted as important during this change period.

- Important role of government advisors and extension officers (individuals lamented the loss of research stations and extension officers);
- Existence and development of community support networks;
- The need to stay positive;
- Development of and access to business knowledge; and
- Enterprise innovation.

Case study two: The most recent outbreak of the crown of thorns starfish (COTS) on Great Barrier Reef, Cairns inshore and marine area

This focus was chosen by the regional partners because biophysical changes in the reef have important ramifications for sustainable livelihood development as well as the management of the Great Barrier Reef World Heritage Area. Also, the Great Barrier Reef Marine Park Authority (GBRMPA) was closely involved with the Association of Marine Park Tourism Operators in the COTS eradication program. Eleven individuals from the Cairns, Port Douglas and Townsville areas were interviewed for this case study. These include individuals from the tourism and fishing industries, relevant government departments and Traditional Owners from the region. All individuals were able to speak about the inshore and near reef area off Cairns. The case study illuminates how changes to the Great Barrier Reef directly impact the Cairns and Port Douglas tourist industries because specific changes can reduce tourist visitation to the region. It discusses how tour operators coped with the challenges of the COTS outbreak. Integral to this was an innovative partnership between operators with assistance from GBRMPA and federal and state government funding. The resulting program was called the COTS eradication project.

Interviewees discussed how they coped with the outbreak. Some issues they identified include:

- The development of partnerships between tour operators, scientists and government;
- New technical knowledge;
- Local champions with extensive networks;

- Ability of tour operators to change core business with changing market conditions; and
- Government funding for innovative and unusual projects.

Case study three: Past and continuing urban growth and expansion in the coastal zone of the Barron River catchment

This case study was considered important by regional partners because urban expansion is an ongoing process closely linked to tourism. Also, there is a clear tension between the desire to protect the natural heritage values of the region and the development ethos (although this ethos and culture seems to be starting to take social and environmental values into account). Finally, there are links between development and the identity of the region (environmental battles, past culture, changes in land use from cane to housing, heritage). The twelve interviewees included representatives from relevant government and non-government organisations as well as a sugarcane farmer from the region. Interviewees highlighted the fact that urban expansion is an ongoing process. They identified a variety of issues that they regard as important during this change process. These include:

- A slow but growing environmental awareness in the region;
- The development of knowledge of appropriate and strategic language by community advocacy groups (to get their opinions heard);
- Conflict as beneficial to social process; and
- Collaboration and network building between government and non-government agencies to progress a shared agenda.

Discussion

Preliminary analysis of these three case studies shows that social resilience factors are collective as well as individual. They are also dynamic and cross many of the domains initially identified in Cuthill *et al.* (2008) (human, social, natural, physical, financial, cultural, and governance). Analysis of three further case studies is yet to be complete. As such this discussion is based upon 'emergent themes'.

Knowledge generation and management is identified as an important theme for maintaining and enhancing regional social resilience. This includes the use and inclusion of diverse forms of knowledge into natural resource management decision making and process, for example: seeking the knowledge of traditional Aboriginal elders as well as considering youth aspirations for the future; the development and generation of new knowledge in relation to natural resource management practice; sharing knowledge between and within different interest groups; and the development and promotion of system understandings.

Building and raising awareness of current and future challenges faced by natural resource managers from the region is another important factor in social resilience. This includes being honest and transparent about current and future impacts on the region, for example the real impacts of crown-of-thorns starfish on the Great Barrier Reef. It involves enhancing regional capacity so individuals and groups are empowered to seek, analyse and use information about current and potential biophysical and political changes that may affect local livelihoods. The building of capacity, development of systems understanding and breaking down of stereotypes were regarded as important for sustained regional social resilience. For example the stereotype that poor water quality is due only to farming practices and that all farmers put productivity above stewardship, was regarded as unhelpful as well as untrue. Avoiding such stereotypes will facilitate discussion and dialogue between different interest groups who ultimately share aspirations for a sustainable region.

Communication is a third theme important for regional social resilience. This includes the overt and explicit sharing of information and knowledge, and the strategic management by natural resource managers of the print and television media to present accurate regional stories as a potential medium for information and knowledge sharing to build social resilience. Physical infrastructure is another important theme for building and enhancing regional social resilience. This includes appropriate housing, the development and use of sustainable and tropical building codes, for example the potential for new developments to use world class technology including solar, local waste plants, energy generation; as well as resourcing suggestions made by the wider community via designated community engagement processes.

The willingness to change behaviour includes developing a culture that is innovation-orientated, that embraces and fosters change and recognises the importance of taking measured risks. Characteristics of measured risk-taking include anticipating the outcomes of potential biophysical and political events, being able to foresee trends and responding proactively in the face of change. A related theme includes maintaining and developing a diverse economic base, at regional, community and individual scales. This includes diversification of enterprise investment and maintaining a culture that is loyal to local brands (this is consistent with community economic development theory).

Engaged governance is another essential theme. It includes collaboration between potential community leaders, the investment of government in social process, and the ability of community groups to access knowledge and to be empowered to 'fight decisions' they do not agree with. Partnerships within and between government, industry and community groups were also identified as important. This includes the development of innovative partnerships (crossing sectors), genuine partnerships based on trust and reciprocity as well as the development of partnerships between holders of different kinds of knowledge (for example the scientific community, the Aboriginal community and industry).

Implications for end users

Aboriginal philosophy recognises that 'healthy country and healthy people' go hand in hand: that their Law is fundamentally about managing social-ecological systems. This recognition is also strengthening within environmental management, in the notions that a strong society with sufficient well-being will be most inclined to conserve the natural systems on which they depend, and that managing environments is really about managing people. The concept of social-ecological system thus offers our partners and other environmental (and social) management bodies a powerful way of considering their management aims and achievements. The concept of resilience prompts management bodies to focus on shaping the social-ecological systems they influence towards a capacity to meet the challenges and uncertainties we expect through climate and global change. Importantly, it emphasises building strengths, as opposed to correcting weaknesses.

The project enables our partners to focus on the social dimensions of building resilience within their planning, monitoring and management activities. It will provide them with the ability to monitor social resilience criteria relevant to their reporting requirements, and to develop indicators which show progress against key social resilience targets. The themes so far emerging from the case study analysis: knowledge, awareness raising, communication approaches, infrastructure, engaged governance, partnerships, the development of a diverse economic base and the willingness of individuals and communities to foster a culture that embraces and anticipates change, suggest that these will be qualities that future regional management should seek to enhance. As these concepts are qualitative, difficult to 'measure' and do not appear in current national data sets, the development of indicators will prove a challenge. It is important to ensure that the monitoring criteria and indicators developed by this project are specific, measurable, achievable, reviewable, timelined and

can talk (the SMARTT framework) to other indicator sets that may already exist. Future work involves investigation of data sources that could inform the social resilience monitoring criteria (for example, ABS data sets, SEIFA index of disadvantage data set, NRM agency information). The team will also explore collection methods for resilience concepts that are not yet represented in data sets. These may include social surveys, periodic qualitative case studies, and interactive forums between regional stakeholders.

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References

- Australian Bureau of Statistics [ABS] (2006) Census of population and housing. Retrieved 5 November 2007 from <http://www.abs.gov.au/websitedbs/d3310114.nsf/Home/census>
- Adger, W. (2000a) Institutional Adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers* 90(4): 738-358.
- Adger, W. (2000b) Social and ecological resilience: Are they related? *Progress in Human Geography* 23(3): 347-364.
- Berkes, F. and Turner, N. (2006) Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. *Human Ecology* 34(4): 479-494.
- Cuthill, M., Ross, H., Maclean, K., Owens, K. and Witt, B. (2008) Reporting social outcomes of development: An analysis of diverse approaches. *The International Journal of Interdisciplinary Social Science* 3(6):145-158.
- Folke, C., Hahn, T., Olsson, P. and Norberg, J. (2005) Adaptive governance of social-ecological systems. *Annual Review of Environmental Resources* 30: 441-473.
- Gunderson, L. and Folke, C. (2005) Resilience – now more than ever. *Ecology and Society* 10(2): 22 [online: <http://www.ecologyandsociety.org/vol10/iss2/art22/>]
- Gunderson, L. and Holling, C. (eds.) (2002) *Panarchy: Understanding transformation in human and natural systems*. Island Press: Washington D.C.
- Hegney, D. G., Buikstra, E., Baker, P., Rogers-Clark, C., Pearce, S., Ross, H., *et al.* (2007). Individual resilience in rural people: A Queensland study, Australia. *Rural and Remote Health* 620 [online: <http://www.rrh.org.au/articles/showarticlenew.asp?ArticleID=620>]
- King, D. and MacGregor, C. (2000) Using social indicators to measure community vulnerability to natural hazards. *Australian Journal of Emergency Management* Spring 2000: 52-57.
- Kulig, J. C. (2000) Community resiliency: The potential for community health nursing theory development. *Public Health Nursing* 17(5): 374-385.

Kulig, J. C., Edge, D., and Guernsey, J. (2005) *Community resiliency and health status: What are the links?* Lethbridge: University of Lethbridge.

Lalonde, C. (2006) Identity Formation and Cultural Resilience in Aboriginal Communities. In: R. J. Flynn, P. Dudding and J. Barber (eds.) *Resilience in Child Welfare*. Ottawa: University of Ottawa Press.

United Nations Conference on Environment and Development [UNCED] (1993) Agenda 21, Programme of Action for Sustainable Development United Nations, New York. Retrieved 5 February 2008: <http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm>

Watson, A., Alessa, L. and Glaspell, B. (2003) The relationship between traditional ecological knowledge, evolving cultures, and wilderness protection in the circumpolar north. *Conservation Ecology* 8(1): 2 [online: <http://www.consecol.org/vol8/iss1/art2/>]

Status and Trends – *State of the Environment* reporting and gap filling: Biodiversity condition of the Wet Tropics region

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MTSRF [Project 1.2.1\(c\)](#)

Abstract

As part of MTSRF Project 1.2.1(c) *Status and trends of biodiversity and ecosystem services: State of the Environment reporting and gap filling*, we present an analysis of native vegetation extent in the Wet Tropics region, which is an important indicator of the condition of biodiversity and ecosystem services. In the absence of ecologically-based thresholds of concern, we measure change in native vegetation extent against the Wet Tropics Regional Natural Resource Management Plan's Resource Condition Target 1 (RCT1) for biodiversity: '*No net loss of native vegetation extent across the region by 2014*'.

We assessed nine datasets that might provide suitable data for estimating native vegetation extent in the Wet Tropics region. For pre-European vegetation extent, we used the Queensland Herbarium's Pre-clearing Regional Ecosystem mapping. We chose the National Carbon Accounting System (NCAS) datasets from the Australian Government's Department of Climate Change to undertake this analysis for assessment of extent since 1988. While the data has a fine scale resolution (25m) and regular time series (1972-2006), it does not include more open and less forested native vegetation types. It also includes non-native tree plantations. In spite of these deficiencies the NCAS data set provides the most useful source of information for assessing native vegetation change at the spatial and temporal reporting scales required by the Wet Tropics Management Authority and Terrain NRM Ltd.

There has been a net loss of native vegetation across all four extents we assessed of 17.9% (MTSRF study area, pre-European to 2006), 2.0% (Wet Tropics Bioregion, 1988-2006), 0.2% (Wet Tropics World Heritage Area, 1988-2006), and 0.7% (Terrain NRM catchments, 2004-2006). The most recent year for our estimations is 2006, and it is possible that this decline has continued since then. We estimate that in order to achieve RCT1 by 2014, at least 33,719 Ha (1,663 Ha in the Wet Tropics World Heritage Area and 32,056 ha in the Wet Tropics Bioregion) of native vegetation will have to be restored to regain the 1988 extent, and at least 11,739 ha to regain the 2004 extent (Terrain NRM catchments). To regain pre-European native vegetation extent across the whole MTSRF study area, 476,054 ha would need to be restored.

Our analysis has highlighted the Tully (12%) and Herbert (9.5%) subregions as having lost the highest proportion of native vegetation since 1988 and thus may be considered as restoration priorities. This recommendation is based purely on the reported results, and does not consider other factors that the Wet Tropics Management Authority may consider important in restoration prioritisation such as areas within the World Heritage Area where infrastructure has been removed.

For Terrain NRM, over the shorter reporting period of 2004-2006 the South Johnstone catchment has had the highest relative loss (3.2%) of native vegetation. The Murray and North Johnstone catchments have also lost relatively large areas of native vegetation (1.7% and 1.4%, respectively) since 2004.

Introduction

Designing a framework that can generate data to meet multiple audience objectives must consider interactions across levels and multiple scales of interest (Kennedy *et al.* 2009). In this project we have strived to identify biodiversity targets that are discrete and measurable entities; are consistent across spatial, jurisdictional, temporal, and management scales as well as ecological systems. This paper presents a preliminary analysis of the first biodiversity target 'native vegetation extent in the Wet Tropics region', which is an important indicator of the condition of biodiversity and ecosystem services. In consultation with the project's end-users, the Wet Tropics Management Authority (WTMA) and Terrain NRM Ltd, we measured the change in native vegetation extent against the Wet Tropics Regional Natural Resource Management Plan's Resource Condition Target 1 (RCT1) for biodiversity: '*No net loss of native vegetation extent across the region by 2014*'.

What are Resource Condition Targets?

Natural resource management (NRM) plans apply a system of targets which must comply with the Australian Natural Resource Management Framework. For the biodiversity asset in the first Wet Tropics Regional NRM Plan (2004), six Resource Condition Targets (RCTs) were set:

- No net loss of the area of native vegetation across the region;
- Quality and extent of Regional Ecosystems currently with an 'endangered' or 'of concern' conservation status is maintained or improved by 2014;
- Quality and extent of riparian ecosystems maintained and improved by 2014;
- Progressive improvement in condition of coastal ecosystems by 2014;
- Increase in the area, conditions and integrity of areas of regional biodiversity significance by 2014; and
- No decline in the conservation status of any native species or Regional Ecosystem by 2014.

In the course of reviewing the 2004-2008 Wet Tropics Regional NRM Plan, and drafting the 2008-2012 Plan, discussions between Terrain NRM, the Wet Tropics Management Authority and CSIRO in 2008 resulted in the redesign of the asset framework. The RCTs for biodiversity were also revisited, and distilled from six to three:

- RCT1: No net loss of native vegetation extent across the region by 2014;
- RCT2: No net loss of native vegetation condition across the region by 2014; and
- RCT3: No decline in species of conservation significance and their habitats.

Ecosystem services and biodiversity asset

Previously in an expert panel workshop, six ecosystem services were identified for the biodiversity asset. These included:

- Features of natural beauty and magnificent sweeping landscapes (World Heritage Area Criterion iii);
- Iconic species of socio-cultural importance (World Heritage Area Criteria I and ii);

- Regulation of diseases and pests;
- Seed dispersal;
- Pollination; and
- Species of socio-cultural importance for hunting/gathering.

This paper describes the process and results relating to the analysis of the data layers, following feedback from stakeholders in relation to the initial results. These are preliminary results and are currently undergoing further analysis and refinement.

The MTSRF study area

The overall study area for this MTSRF project incorporates the Wet Tropics World Heritage Area, Wet Tropics Bioregion and parts of the Brigalow Belt and Einasleigh Bioregions and Terrain NRM region (Figure 1). It has a total area of 2,744,683 ha.

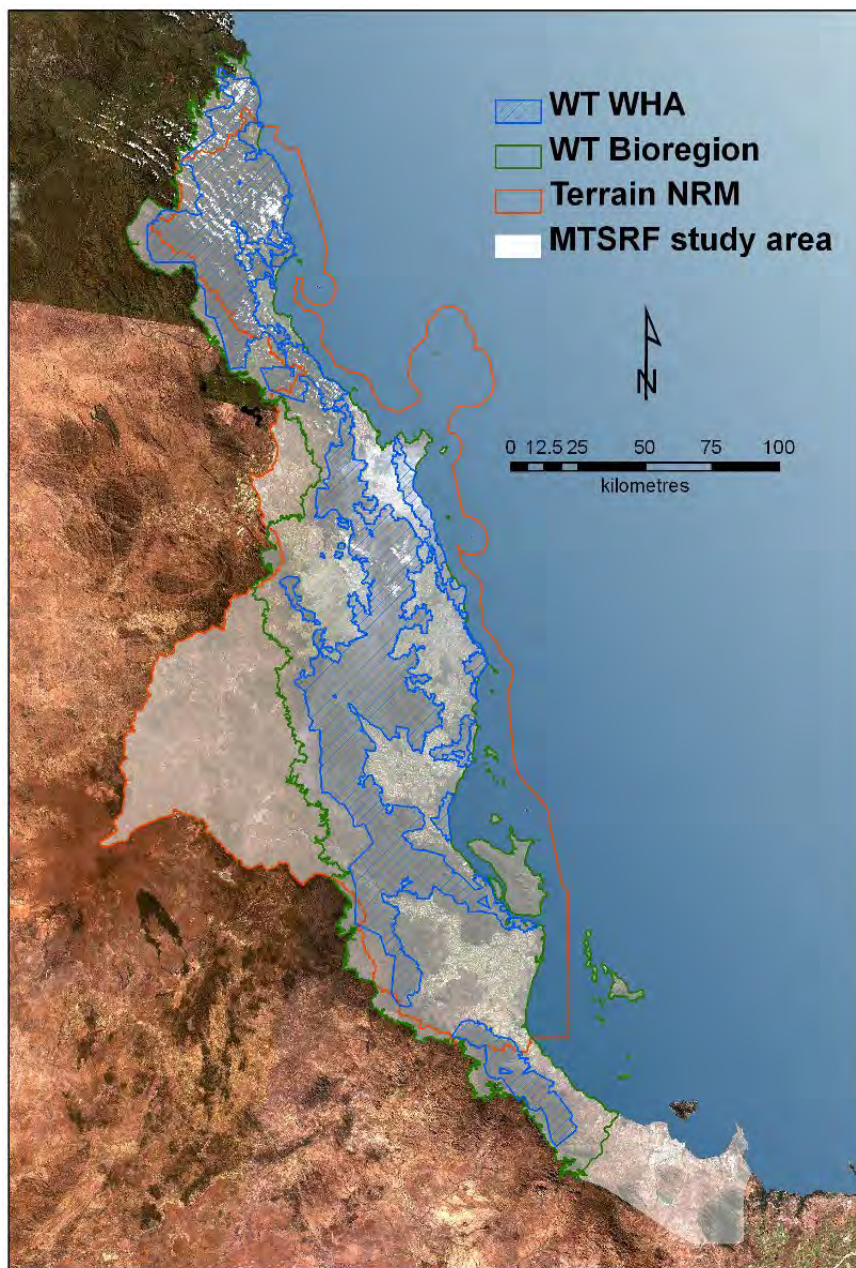


Figure 1: The MTSRF study area, North Queensland.

Methods

Reporting units included the MTSRF study area (Figure 1), the Wet Tropics World Heritage Area, Wet Tropics Bioregion (IBRA v 6.1) and Subregions/Provinces (v4.3), and NRW catchments within the NRM region from 1998-2006. Nine datasets sourced from different custodians were examined and compared to determine their suitability for measuring changes in native vegetation extent based on the following criteria:

- Attribute adequacy;
- Coverage across the MTSRF, WTMA and Terrain NRM reporting areas;
- Temporal resolution (i.e. the number of epochs or ‘timeslices’); and
- Spatial resolution.

Based on this, we selected the National Carbon Accounting System (NCAS) forest and regrowth monitoring datasets based on Landsat 7 satellite imagery. This provided a regular time series from 1972-2006 at a high spatial resolution (25m). To provide a pre-European comparison of native vegetation extent we used the Environmental Protection Agency’s pre-clearing Regional Ecosystem mapping.

Process

NCAS datasets selected for vegetation area analysis were converted to a standard format and projection suitable for GIS processing and statistics generation (ESRI shapefile, GDA94, UTM55). Data layers were then clipped to the reporting area boundaries and unioned with reporting unit layers (Bioregion, Subregions, catchments, Wet Tropics World Heritage Area). Maps were then generated for discussion with WTMA and Terrain NRM. During these discussions, concern was raised about the high occurrence of apparent clearing, particularly within the Wet Tropics World Heritage Area. Subsequent checking of these areas revealed that much of this ‘clearing’ was in fact incorrect due to shading/brightening and ephemeral changes. Masks were therefore created to ‘block out’ these errors and the GIS processes were re-run. All analyses and maps were generated using ESRI’s software ArcGIS 9.2. Area statistics were further derived using Microsoft Access and Microsoft Excel was used to generate graphs.

Results and Discussion

The change in area of native vegetation inside the MTSRF study area was calculated for the time period pre-European to 2006. Coverage has declined by 17.9% (476,054 ha) within this period (Figure 2), equating to a decline from 2,657,203 ha to 2,181,049 ha (Figure 2).

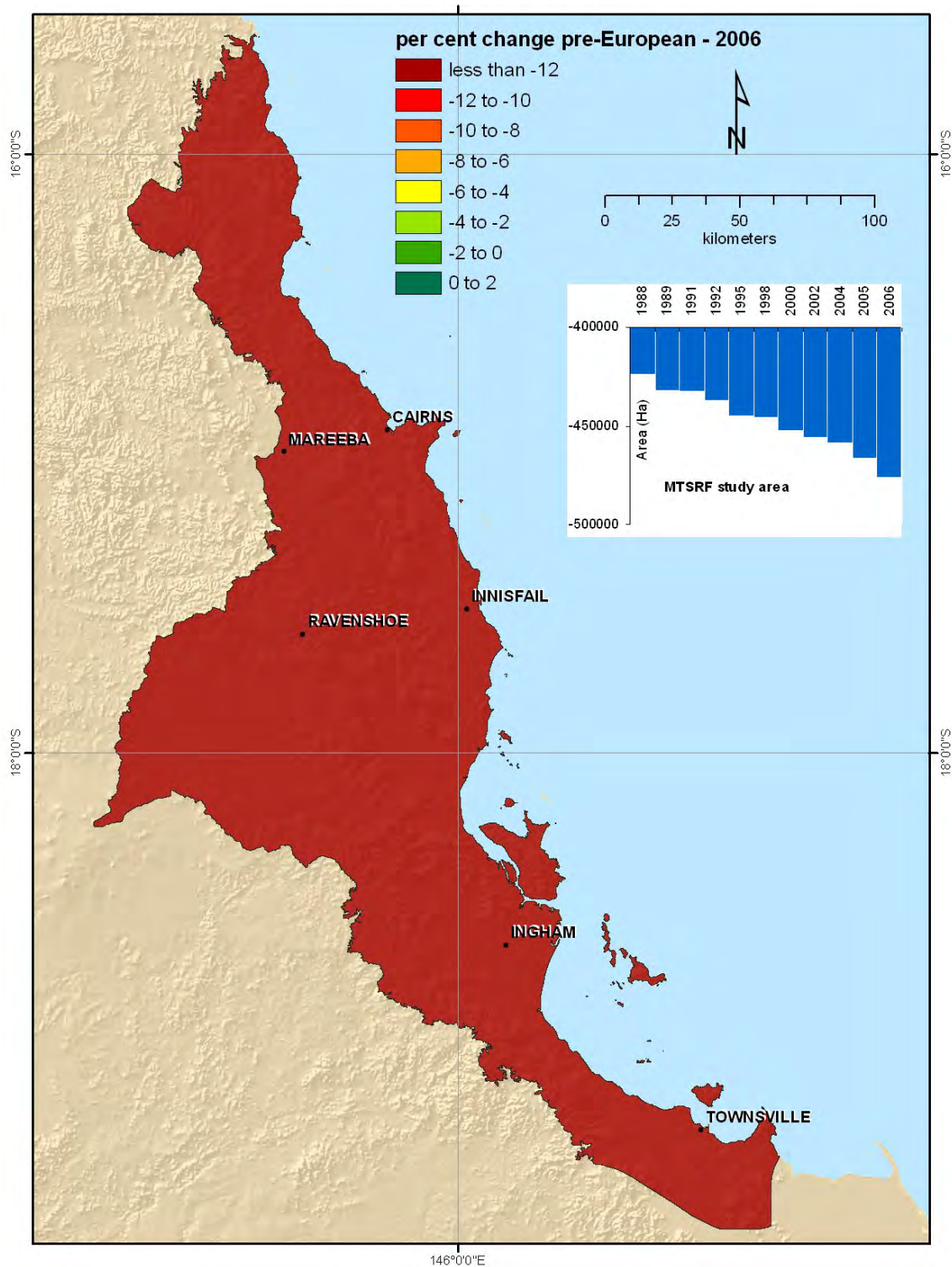


Figure 2: Change in the area of native vegetation for the pre-European to 2006 time period within the MTSRF study area. Map depicts percent change over the whole time period; graph depicts area change (ha) for individual years from the pre-European baseline.

Wet Tropics World Heritage Area

Native vegetation change inside the Wet Tropics World Heritage Area was calculated for the 1988-2006 period and showed a small but steady decline over this time. This equated to a loss of 1,663 ha from 884,539 ha, or 0.2% within the Area. This is less than the decline relative to the pre-European extent (a decline of 1,534 ha from 886,073 ha). This difference is more likely to be an artifact of attribute and scale resolution differences between the NCAS and pre-European datasets.

Bioregion

The change in the area of native vegetation inside the Wet Tropics Bioregion showed a steady decline over the period 1988-2006. There was a 32,056 ha (2.0%) loss across the Bioregion during this time. The decline in vegetation extent from the pre-European era to 2006 was more than ten times as great, with a loss of 365,105 ha (from 1,939,784 ha to 1,574,678 ha).

Subregions

For the nine subregions that occur within the Wet Tropics Bioregion, change in area (ha) of native vegetation was calculated for each year from 1988-2006. Area and percentage change values show an overall decline over the time period for all subregions. Decline in area from 1988 to 2006 was greatest in the Herbert (11,395 ha, 9.5%) and Tully (10,472 ha, 12%) subregions. Change in the Bellenden Ker-Lamb subregion was minimal (-60 ha, -0.0%). Relative to pre-European vegetation extent, both the Herbert and Innisfail subregions have lost the greatest areas (121,230 and 107,094 ha respectively).

Catchments

For the twelve catchments that fully or partly (Endeavour River) occur within the Terrain NRM area, native vegetation change was calculated for each year from 2004-2006. Overall decline across all catchments was 0.7% (11,730 ha). Declines occurred in all catchments with the Daintree (70 ha, 0.0%), Hinchinbrook (0 ha, 0.0%) and Mossman (152 ha, 0.4%) catchments only experiencing minimal change. Decline in area was by far the greatest in the Herbert catchment both within the 2004-2006 (3,762 ha) and pre-European to 2006 (112,512 ha) periods. The South Johnstone catchment however had the greatest percent decline between 2004 and 2006 with a loss of 3.2% of native vegetation extent.

Implications for End Users

This paper presents a preliminary analysis of change in native vegetation extent in the Wet Tropics region, which is an important indicator of the condition of the biodiversity asset, and the six ecosystem services supported by this asset. In agreement with the MTSRF, WTMA and Terrain NRM, the information has been analysed and presented in different temporal and spatial reporting units. For both of the WTMA (1988-2006) and Terrain NRM (2004-2006) reporting periods, it is clear that this RCT1 target is not being achieved. In spite of the designation of the World Heritage Area in 1988, and the introduction of the Wet Tropics Regional NRM Plan in 2004, there has been a continued decline in native vegetation, with a net loss of 0.2% across the Wet Tropics World Heritage Area since 1988, and 0.7% across the Terrain NRM catchments since 2004. The most recent year for our estimations is 2006, and it is possible that this decline has continued since then. Consequently we estimate that in order to achieve RCT1 by 2014, native vegetation will have to be restored by a total area of at least 32,056 ha (across the Wet Tropics Bioregion) and 1,663 ha (across the Wet Tropics World Heritage Area) in order to regain the extents present in 1988. In order to attain the extent present in 2004, the regrowth of at least 11,739 ha (across the Terrain NRM catchments) will be required. Across the whole MTSRF reporting region, 476,054 ha of native vegetation has been lost since pre-European times.

Priority areas for this restoration vary according to the spatial reporting unit concerned. For the WTMA, the data clearly show that since 1988 the majority of vegetation loss has occurred outside the WHA and within this region, the Tully and Herbert subregions have lost the highest proportion of native vegetation and may be considered as priorities.

However, it should be noted that the NCAS data we have used may not capture more open and less forested native vegetation types, and therefore underestimate the amount of native vegetation extent remaining. This may be counterbalanced by the possible inclusion of non-native tree plantations, which NCAS does not distinguish from native forest and regrowth. In spite of these deficiencies the NCAS data set provides the most useful source of information for assessing native vegetation change at the spatial and temporal reporting scales required by the WTMA and Terrain NRM.

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References

FNQ NRM Ltd and Rainforest CRC (2004) *Sustaining the Wet Tropics: A Regional Plan for Natural Resource Management 2004-2008*. Innisfail: FNQ NRM Ltd.

Kennedy, E. T., Balasubramanian, H. and Crosse, W. E. M. (2009) Issues of scale and monitoring status and trends in biodiversity. In: M. Birnbaum and P. Mickwitz (eds.) *Environmental program and policy evaluation: Addressing methodological challenges*. *New Directions for Evaluation* 122: 41-51.

WTMA (2008) *Annual Report and State of the Wet Tropics Report 2007-2008 Climate Change Impacts and Responses*. Cairns: Wet Tropics Management Authority.

Spatial habitat prioritisation and visualisation in Mission Beach

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MTSRF [Project 4.9.6\(b\)](#)

Abstract

Most conservation programs operate with limited resources and budgets. Competing demands for these resources among different species or regions can place further restrictions on conservation programs. The best means of utilising available resources and the highest priority locations to place these resources are topics of clear interest. Spatial models and visualisation tools can be used to help prioritise resource allocation to achieve conservation goals. This study aimed to provide a tool for natural resource management (NRM) practitioners to identify, in collaboration with stakeholders, the most suitable areas for investment for habitat retention, restoration and/or rehabilitation and to enable visualisation of these in the landscape. Our tool, the Collaborative Habitat Investment Atlas (CHIA) uses ESRI's ArcGIS9.3 and Placeways' CommunityViz™ software to support four interactive models: biodiversity importance, level of protection, threat and condition. The biodiversity model is at an advanced stage of development. Inputs to the biodiversity model were based on data from a biodiversity significance assessment and other GIS layers identified and refined through an expert panel process. A summed biodiversity importance map was created by combining several biodiversity significance attributes with different weightings. The next stage of the project will involve the development of the three remaining models: level of protection, threat and condition, which will then enable further prioritisation of areas and the development of a composite suitability map. The dynamic production of maps is useful in planning processes, facilitating negotiation and prioritisation of areas in an interactive workshop setting. Using this tool, local area planners are able to spatially prioritise areas for conservation corridors and target habitat for conservation and revegetation. The effective visual outputs generated by the tool, underpin its ability to support both generalists and specialists in making decisions about conservation action and implementation.

Introduction

Funds allocated for conservation are usually limited and are not sufficient to achieve every desirable goal in conservation (MacKenzie 2009). The intent is to make efficient use of what resources are available to achieve a state objective that will probably differ among conservation programs, but once defined as amenable for use in an optimal decision-making process. The more limited the resources, the greater the desire should be to use those resources as wisely as possible. Detailed maps of areas are needed to identify priority habitat, assess threats, assign priorities to future acquisitions, and evaluate previous and future investments for restoration and conservation (Rissman and Merenlender 2008). This study aimed to provide a tool for natural resource management (NRM) practitioners to identify, in collaboration with stakeholders, the most suitable areas for investment for habitat retention, restoration and/or rehabilitation and to enable visualisation of these in the

landscape. This paper describes the tool we developed, the Collaborative Habitat Investment Atlas (CHIA) and details the development of one component: the biodiversity importance model. We present the study in the following sequence. Firstly the history and geography of the case study is described. We then discuss the need for a participatory decision-support tool, the factors behind our platform selection, and its technical specifications. The results section presents the biodiversity importance model in detail. We conclude with a discussion of the further development of additional models and the utility of the tool for NRM practitioners for efficiently allocating resources to prioritized areas.

The Mission Beach case study: History and geography

The Mission Beach study area (Figure 1) is bounded by Maria Creek in the north, the Hull River to the south, the Walter Hill Range to the west and the Coral Sea to the east. The study area is well known for its outstanding biodiversity and supports an important concentration of the endangered southern cassowary (*Casuaris casuaris johnsonii*) in Australia (Latch 2007). It is one of the few lowland areas remaining with historically high cassowary numbers and lies adjacent to urban areas (Crome and Moore 1990). Mission Beach has been identified as a priority area for action on biodiversity conservation within the Wet Tropics. A planning process aimed at achieving protection of an ecologically viable habitat network that protects community values related to lifestyle, culture and the natural environment in Mission Beach commenced in 2006 (Hill *et al.* 2009a).

A Committee was formed at the commencement of the planning process to oversee and guide the development of the Mission Beach Habitat Network Action Plan (henceforth Action Plan, Hill *et al.* 2009a). The Committee is comprised of key actors from a range of government, industry and community groups. Many of these groups and individuals within them have been active within conservation for a long time, including through private efforts in habitat protection and restoration. It was considered that involvement of these key actors in voluntary governance roles would: facilitate community ownership of the Plan in partnership with Terrain NRM Ltd; provide a forum for guiding the plan implementation process; allow information sharing; ensure that there was a strong foundation for resourcing and implementation; and provide an opportunity for participation in the common aspiration of securing the natural and cultural values of Mission Beach.

Community engagement was integral to the habitat planning effort to: raise awareness of Mission Beach values; increase engagement and involvement in the planning process; understand community needs; respond to community input; provide feedback on their input; and to facilitate the development of implementation partnerships and networks (Hill *et al.* 2009a, 2009b, 2008). Terrain NRM employed a local area planning officer to promote and raise awareness of the project, develop partnerships and undertake community consultation and education activities.

A community workshop conducted by the CSIRO and Terrain NRM Ltd in 2007 identified many strategies and targets for the Action Plan. Participants identified several issues to focus on: (1) habitat protection and restoration; (2) traffic management; (3) tourism management; (4) residential management; (5) agricultural management; (6) management by Traditional Owners; (7) exotic species management; and (8) building community strength. During the workshop, community members also discussed threats to the activities and values they hold for Mission Beach and surrounding areas. The Action Plan identified the need to protect, connect and reduce critical threats in all remaining cassowary habitat at Mission Beach through a variety of measures, and to restore degraded habitat in key sites. An important premise was that protection of cassowary habitat ensures protection of other significant biodiversity and aesthetic/lifestyle and Djiru[‡] cultural values.

[‡] The Djiru Aboriginal people were the original inhabitants of the Mission Beach-Bingil Bay area.

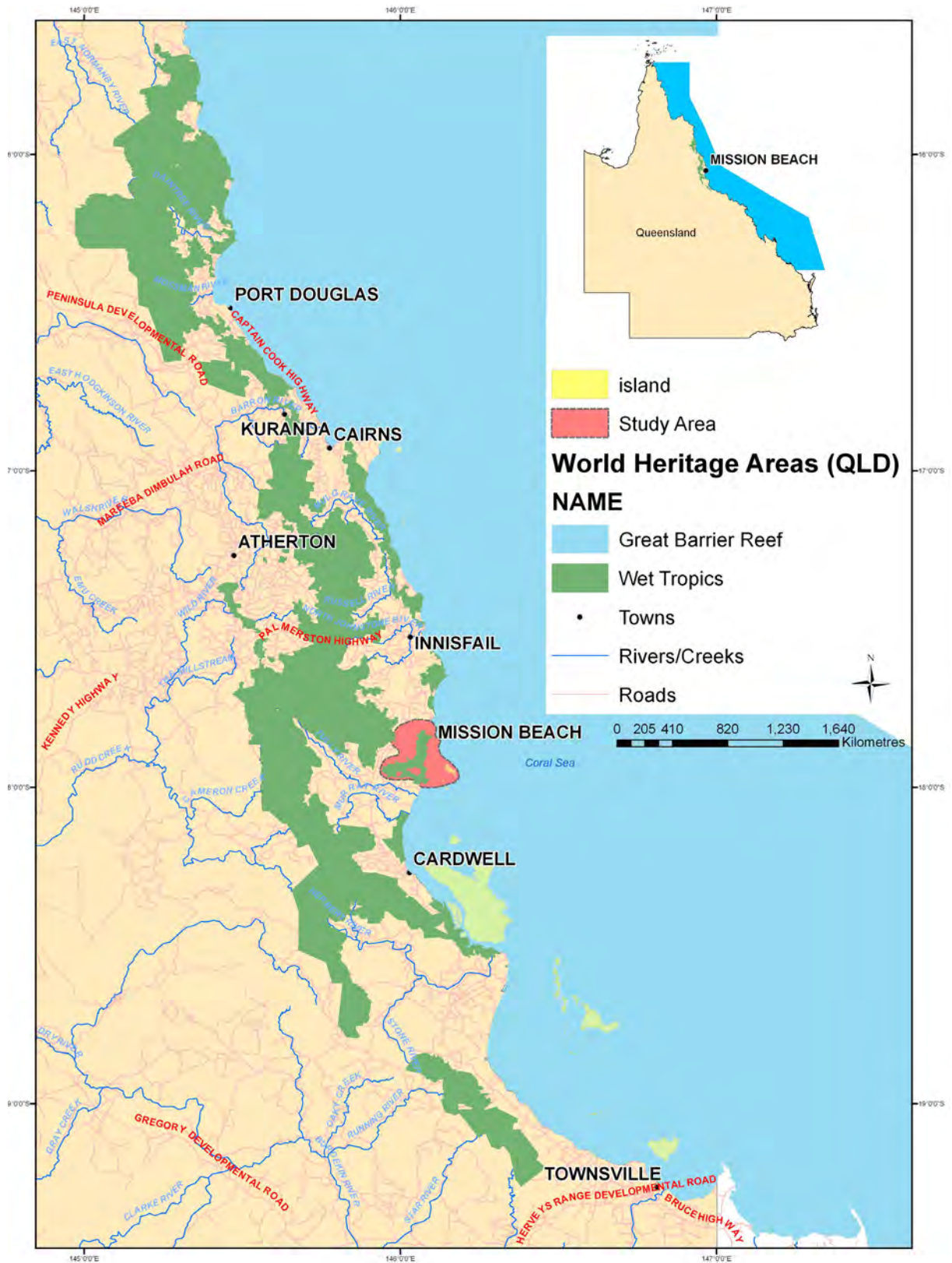


Figure 1: Mission Beach study area.

The Collaborative Habitat Investment Atlas (CHIA)

Requirement for participatory decision support tool

Although the Action Plan identified the need to protect, connect and reduce critical threats in all remaining cassowary habitat at Mission Beach, limited available resources and brief time-frames meant that priorities for immediate action needed to be identified. The CHIA was primarily developed as a tool to facilitate discussion about prioritisation among investment options, recognising scarcity of conservation resources, in an interactive setting. While optimal solution conservation prioritisation tools are available, participatory tools were required for the Mission Beach context, which has investment decision-makers at local, state and national government and non-government levels, each with different responsibilities and priorities (Joseph *et al.* 2009).

Participatory decision-support involves a variety of actors in priority definition and structuring, displaying of possible alternatives and consensus development. Flexibility, simplicity, visual strength, accessibility and technical capacity are keys to successful participation in decision-making (Jakku and Thorburn, In press 2009). For the Mission Beach project, we found that aspects of information relevant to the following variables were needed for inclusion into the CHIA as it was developed: biodiversity value, costs of land for acquisitions, costs of incentives, level/status of protection available through land-use planning, land-owner willingness to be involved, levels of entrepreneurship, social capital and burnout in rural communities (Knight and Cowling 2008). The CHIA currently brings together four relevant models: biodiversity importance, level of protection, threat and condition. The first of these, the biodiversity importance model, is at an advanced stage of development, and is the main focus of this report. The remaining models have been developed, but still require further refinement and stakeholder input.

Technical specifications of the CHIA

We investigated a number of potential platforms to provide NRM practitioners with a simple, interactive means to prioritise and visualise areas including various third party solutions for information management and analysis requirements. We chose ESRI's ArcGIS9.3 coupled with Placeways' CommunityViz™ software because it was designed to help people visualise, analyse and communicate important planning decisions and enables community interaction. Since its public release in 2001, CommunityViz™ has aimed to promote collaborative, informed decision-making (e.g. Salter *et al.* 2009; Lieske *et al.* 2008a, 2008b). CommunityViz™ is developed and supported in partnership with the Orton Family Foundation, a non-profit operating foundation that originated this visionary tool and continues to sponsor its ongoing development.

CommunityViz™ adds interactive analysis tools and a decision-making framework to ESRI's ArcGIS®. It works as an extension to the software modules ArcMap™ and ArcScene™. It is useful for a wide variety of applications however we chose the software primarily as it promotes dynamic interaction among stakeholders and allows users to change the weights and attributes in a model and visualise results immediately. For example, a variable assumption (an input to the analysis) can be readily changed using a slider bar as part of the analysis and following feedback from stakeholders (Figure 2). CommunityViz™ provides participants with the ability to interact dynamically with data. Formulas associated with the slider bar linked to features on a map drive recalculations and responsive changes throughout the entire analysis. This dynamic approach to data analysis allows participants to experiment with alternative levels of importance applied to different map features and view the outcome immediately. The use of CommunityViz™ encourages participation and collaboration by engaging colleagues and public audiences via visualisation and interactive media techniques.

Conceptually there are many layers of functionality in CommunityViz™ applied within the CHIA which are not discussed here and are still under development and refinement (Figure 4). The CHIA tool was primarily designed so that it could be readily updated with new information, allowing the final map of ‘prioritised areas’ to be dynamically updated and reviewed as needed.

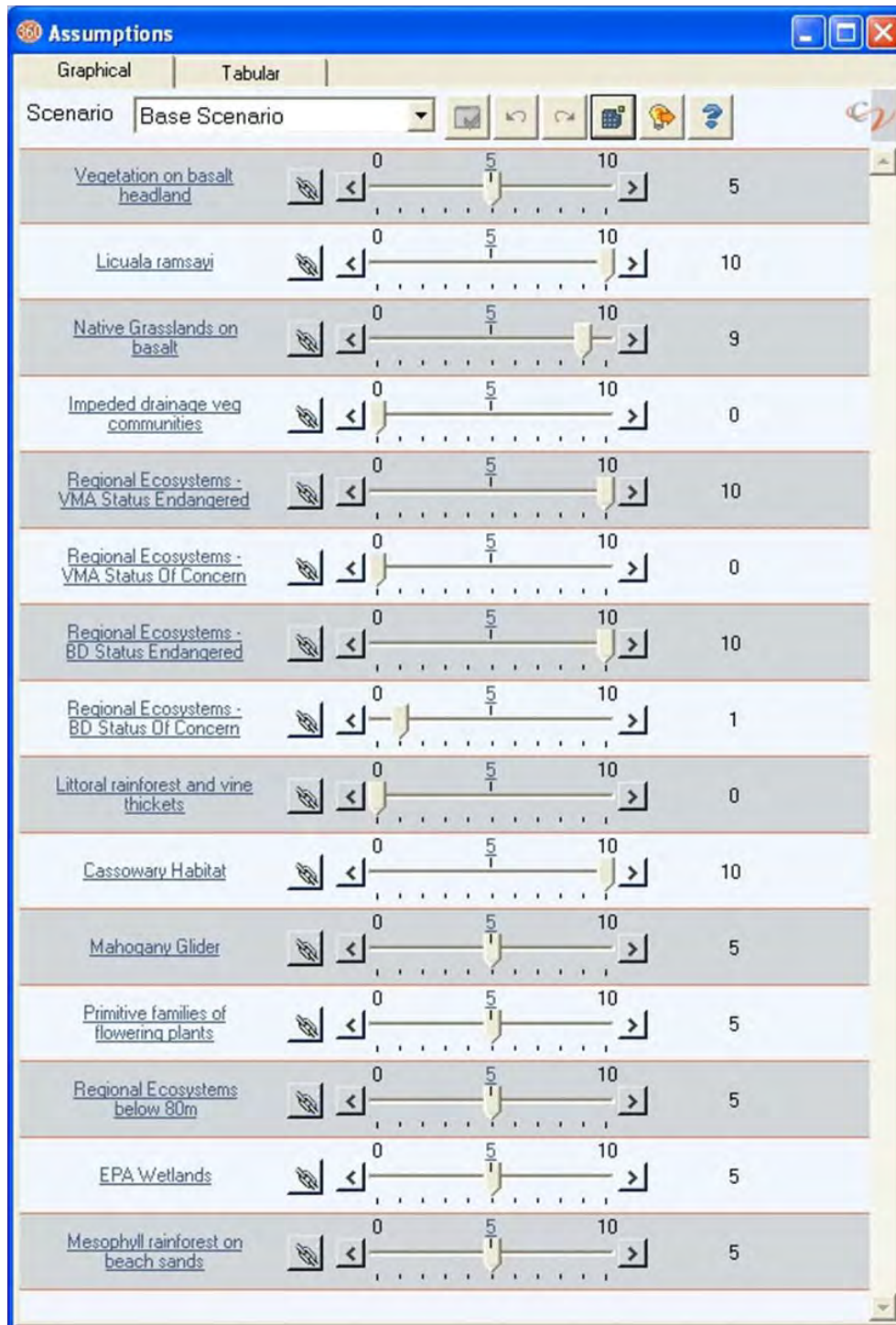


Figure 2: Variable assumptions used in the Biodiversity model.

Results

Biodiversity model

The biodiversity model is at an advanced stage of development. A six step process was used. The first step involved the formation of an expert panel, comprising representatives of key organisations and groups, with a scientific background and interest in the Mission Beach area. The second step was to distribute a list of biodiversity significance attributes to the expert panel and seek their feedback on these. The third step was to generate maps to spatially and visually represent these attributes and seek further feedback from the expert panel. These steps were conducted remotely. The fourth step involved bringing expert panel members together in a workshop setting to discuss the maps and obtain their input into the choice and weighting of attributes. The fifth step was to refine the visual representation of attributes (maps) and seek further data based on the feedback received. The sixth step was to compile all the attributes, weight these for importance according to expert opinion (Figure 2, Table 1) and produce a summed biodiversity importance map and to seek endorsement by those involved.

The resulting biodiversity importance model incorporated fifteen significant attributes as decided by the expert panel (Pert *et al.* 2009) (Figure 2). These were weighted (Table 1) and summed resulting in the biodiversity importance map (Figure 3). The biodiversity importance map indicates areas (in green) which contain areas of relatively high biodiversity importance and areas (in yellow) which contain areas of relatively low biodiversity importance.

The other models, level of protection, threat and condition are currently under development and require stakeholder interaction to define attributes and their weights.

Table 1: Biodiversity importance variables and weightings.

Biodiversity Significance Criteria (CEPLA 2007)	Biodiversity attribute	Rationale	Weight (default 5)
Geoevolution/ Geological diversity	Vegetation on basalt headland	Specific geological variations and diversity are good indicators of habitat diversity and ecosystem micro-variation. Mission Beach includes land systems that contribute to high biodiversity or individual species of significance.	5
Significant vegetation communities	<i>Licuala ramsayi</i>	The rarity of some vegetation communities contributes to their conservation value. Frequently rarity has been driven by human activities, but sometimes it is a result of unique geological and climatic conditions prevailing in a specific location. Integral patches of rare vegetation communities are regarded of significance.	10
	Native grassland on basalt	As above	9
	Impeded drainage communities	As above	0
	Regional Ecosystems – VMA Status Endangered	As above	10
	Regional Ecosystems – VMA Status Of Concern	As above	0
	Regional Ecosystems – BD Status Endangered	As above	10
	Regional Ecosystems – VMA Status Of Concern	As above	1
	Mesophyll rainforest on beach sands	As above	5
Scheduled species/ communities	Littoral rainforest and vine thickets	Scheduled species are those listed as Endangered, Rare or Vulnerable under the <i>Nature Conservation (Wildlife) Regulation Act 2006</i> or Endangered or Vulnerable under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> .	0
	Cassowary habitat	As above	10
	Mahogany Glider	As above	5
Wet Tropics World Heritage Values	Primitive families of flowering plants	By definition these areas are regarded of global importance.	5
Vegetation integrity	Regional ecosystems below 80m	Although portions of the forests of Mission Beach have historically been logged, much of the area is mapped as Remnant Vegetation. The presence of lowland vegetation communities is significant in largely cleared landscape.	5
Nationally important wetlands	EPA Wetlands	By definition its very definition areas mapped under this attribute are regarded as of National Significance.	5

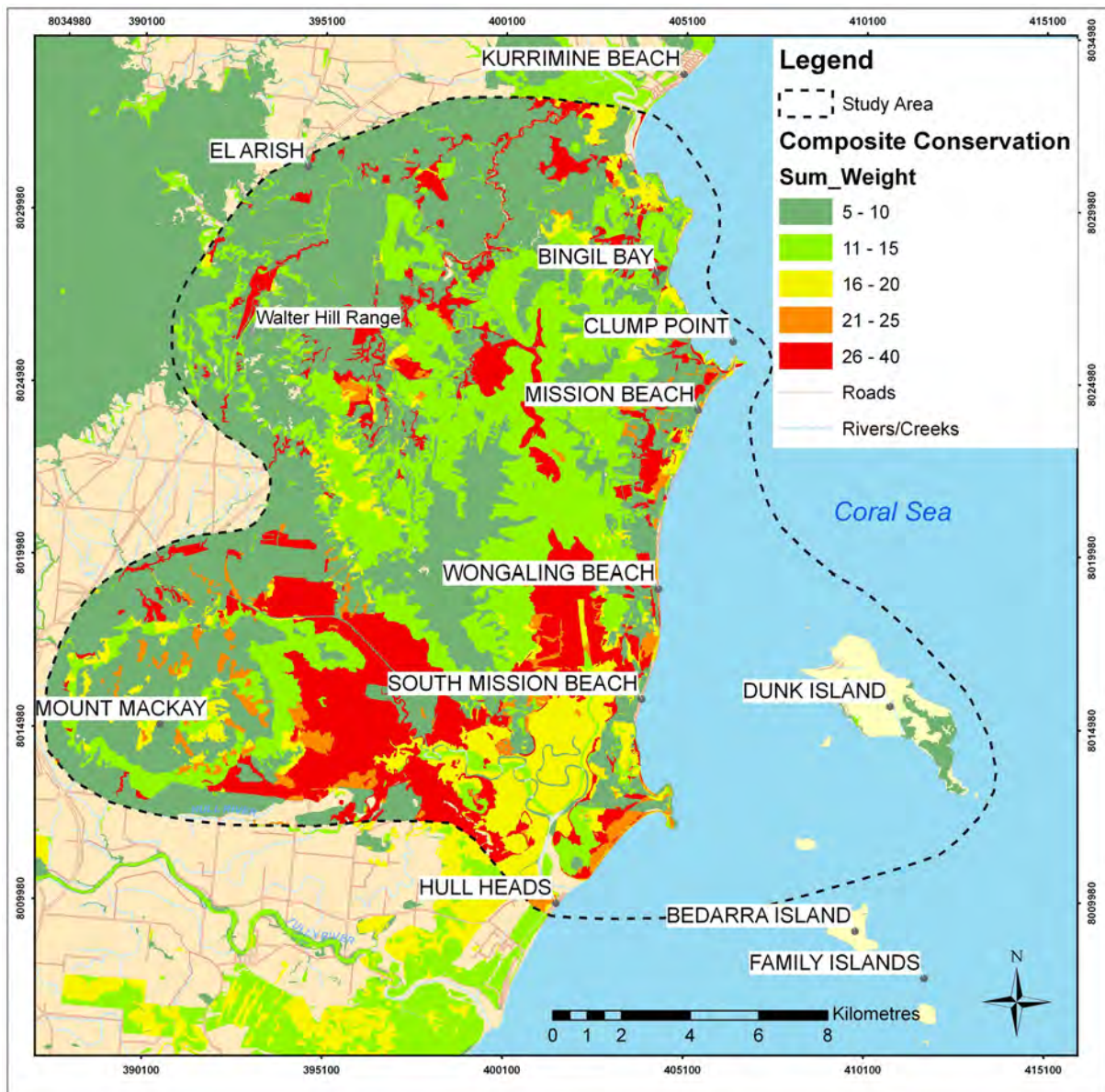


Figure 3: Summed weighted biodiversity map – includes the sum of all biodiversity attributes.

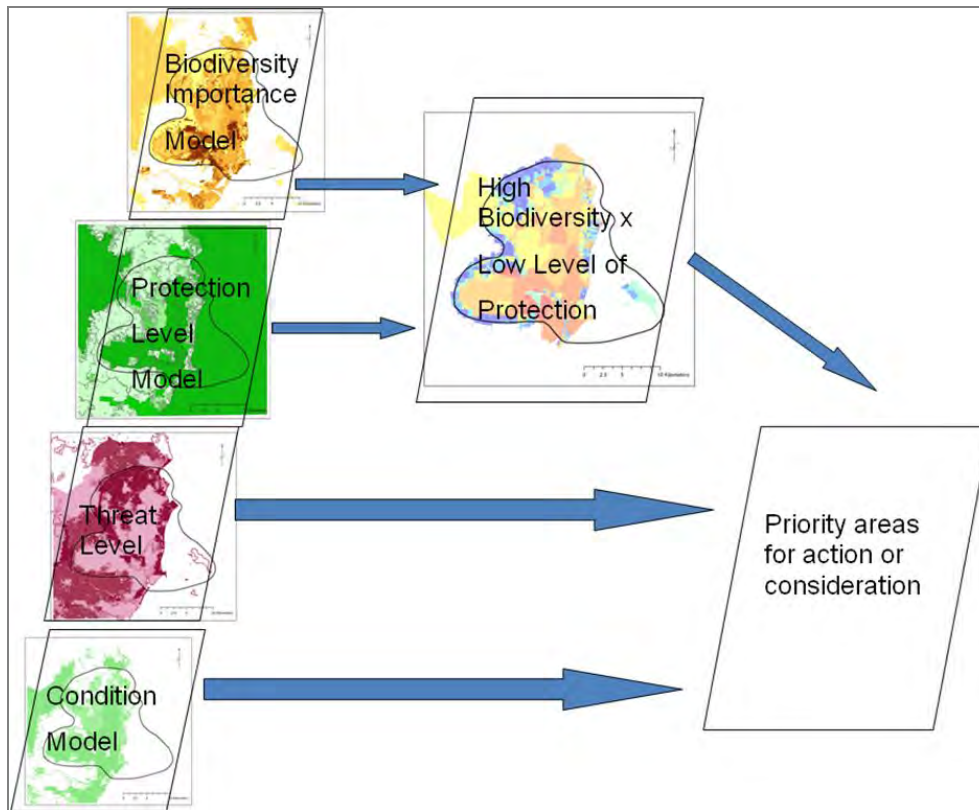


Figure 4: A schematic overview of the Collaborative Habitat and Investment Atlas (CHIA) and its models.

Discussion and Conclusion

Spatial decision support tools, such as the CHIA described in this paper, are intended to support decision-making in both the simple (one participant, one decision objective) and complex (multiple participant, multiple objectives) contexts. Together, CommunityViz™ and ArcGIS® have provided a powerful and unifying framework for managing the multiple and diverse spatial data sets required for future conservation and planning activities at Mission Beach. Collaborative expert input into a framework for integrating data from various planning layers and different biodiversity attributes proved to be a simple and effective way to set habitat priorities for local area planning at Mission Beach. The resulting composite map was designed to help guide regional conservation efforts and appropriate allocation of investment resources for on-ground action. In the future, once development of the CHIA has been completed, users will be able to use the tool to define spatially explicit scenarios that relate to the management of riparian, rural and urban land ('Management' scenarios).

This study has shown that once fully developed the CHIA will be able to perform several suitability analyses and create a conservation prioritisation map to help direct the management of habitat at Mission Beach. Despite their potential, such dynamic visualisation tools have not been widely adopted and used in real planning processes or have not been overly successful in informing and supporting decision-making (Feick and Hall 1999). We have aimed to minimise this risk by ensuring that the stakeholders have ownership of the tool and substantially contributed to its design and contents.

Using the weighted summation technique we were able to provide a sound measure of overall biodiversity importance, logically and simply which gained the acceptance of stakeholders. There can be many possible alterations of the weights depending on the preference of different evaluators including policy makers, scientific and technical experts

and the public. The tool allows participants to dynamically envision alternatives and understand their potential impacts. However, the weighted summation technique has a limitation of the compensatory problem (Jeffreys 2004). This means that an area with a low score on one criterion may gain from other criteria on which it scores highly. This may not reflect the concerns of the wider community and may result in poor decisions. The use of compensatory as well as non-compensatory multi-criteria analyses addresses this problem and is recommended by Jeffreys (2004) so as to alert decision-makers to presence of poor performing criteria. Continued work on the CHIA will focus on enhancement of its usefulness (through, for example, the utilisation of stakeholders in setting weights for remaining models) and involvement of decision-makers. In particular, efforts will be directed at improving the input data sets and finalising the component models.

Implications for End Users

In general the CHIA offers a powerful tool for land use planning and scenario visualisation due to its capability to process and integrate different layers of spatial data, once these have been identified and incorporated. The dynamic production of maps is useful in planning processes, facilitating negotiation and prioritisation of areas in an interactive workshop setting. Using this tool, local area planners are able to spatially prioritise areas for, conservation corridors and target habitat for conservation and revegetation. Because of the effective visual outputs generated by the tool, it could support both the generalist and specialists in making conservation decisions in regards to conservation action and implementation.

Acknowledgements

Funding was provided through the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) Project 4.9.6(b) *Biodiversity values in regional and local area planning*. The authors acknowledge the efforts of members of the expert panel who provided feedback to input maps; listed in Pert *et al.* (2009), the Mission Beach Habitat Network Action Committee, Terrain NRM Ltd, Scott Lieske (University of Wyoming) and Ken Lyons (Spatial Information Services Pty Ltd) for their guidance with CommunityViz™ software. We are also grateful to the reviewers for their comments and feedback on this paper.

References

- CEPLA (2007) *Biodiversity Significance of Mission Beach*. A Report to Terrain Natural Resource Management Ltd. Chenoweth Environmental Planning and Landscape Architecture (CEPLA), Brisbane.
- Crome, F. H. J. and Moore, L. A. (1990) Cassowaries in north-eastern Queensland: Report of a survey and a review and assessment of their status and conservation and management needs. *Australian Wildlife Research* 17: 369-385.
- Feick, R. D. and Hall, G. D. (1999) Consensus-building in a multi-participants spatial decision support system. *URISA Journal* 11(2): 17-23.
- Hill, R., Williams, K. J., Pert, P. L., Grace, R., O'Malley, T. and Jenkins, S. (2009a) *Mission Beach Habitat Network Action Plan Public Consultation Draft*. CSIRO and Terrain NRM, Cairns.
- Hill, R., Williams, K. J., Pert, P. and Harding, E. (2009b) Cassowary conservation through adaptive, collaborative planning at Mission Beach. In: R. Taylor and S. Long (eds.) *Proceedings of the 2008 Marine and Tropical Sciences Research Facility Annual Conference, 28 April – 1 May 2008*. Reef and Rainforest Research Centre Ltd, Cairns (pp. 51-63).

Hill, R., Williams, K. J. and Pert, P. L. (eds.) (2008) *Local Area Biodiversity Planning in the Wet Tropics Bioregion*. Mid-project Draft Synthesis Milestone Report. Mission Beach Habitat Network Action Plan. Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns (101pp.).

Jakku, E. and Thorburn, P. (In press 2009) A sociological framing of participatory development of agricultural decision support systems. In: Hatfield-Dodds, S., Van Kerkhoff, L. and Proctor, W. (eds.) *Reflecting on integrated mission directed research: Learning from experience in environment and natural resource management*. The Netherlands, Elsevier.

Jeffreys, I. (2004) The use of compensatory and non-compensatory multi-criteria analysis for small-scale forestry. *Small-scale Forest Economics, Management and Policy* 3(1): 99-117.

Joseph, L. N., Maloney, R. F. and Possingham, H. P. (2009). Optimal allocation of resources among threatened species: A project prioritization protocol. *Conservation Biology* 23(2): 328-338.

Knight, A. T. and Cowling, R. M. (2008a) Clearing the mud from the conservation opportunity debate: Reply to Pressey and Bottrill. *Conservation Biology* 22 (5): 1346-1348.

Latch, P. (2007) Recovery plan for the southern cassowary *Casuarius casuarius johnsonii* 2007-2011. Report to the Department of the Environment and Heritage, Canberra by Queensland Parks and Wildlife Service, Brisbane.

Lieske, S. N., Lyons, K., Hamerlinck, J. D. and Vock, N. (2008a) GIS-based evaluation of rural economic opportunity in Hunchy, Queensland. In: Proceedings of the 2008 Queensland Spatial Conference 'Global Warning: What's Happening in Paradise?' 17-19 July, Gold Coast.

Lieske, S. N., Lyons, K., Hamerlinck, J. D. and Vock, N. (2008b) Planning decision support – Australian examples. In: Proceedings of the 2008 Queensland Spatial Conference 'Global Warning: What's Happening in Paradise?' 17-19 July, Gold Coast.

Mackenzie, D. I. (2009) Getting the biggest bang for our conservation buck. *Trends in Ecology and Evolution* 24(4): 175-177.

Pert, P. L., Hill, R., O'Malley, T. and Williams, K. J. (2009) Conservation significance and biodiversity condition and status assessment for collaborative investment. Report on Mission Beach Expert Panel Workshop and Process. Unpublished report.

Rissman, A. R. and Merenlender, A. M. (2008) The conservation contributions of conservation easements: Analysis of the San Francisco Bay Area protected lands spatial database. *Ecology and Society* 13(1): 40.

Salter, J. D., Campbell, C., Journeay, M. and Sheppard, S. R. J. (2009) The digital workshop: Exploring the use of interactive and immersive visualisation tools in participatory planning. *Journal of Environmental Management* 90: 2090-2101.

Probability-based climate change projections for the tropical rainforest region of North Queensland

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MTSRF [Project 2.5ii.1](#)

Abstract

Temperature in the tropical rainforest region has increased steadily between 1950 and 2008, but shows strong decadal and inter-annual variations. Since 1950, the average maximum temperature of Australia's tropical rainforest region has increased by 0.76°C (0.12°C per decade), the minimum by 0.79°C (0.14°C per decade) and the average by 0.78°C (0.13°C per decade). Variations in annual and seasonal rainfall in the rainforest region of North Queensland during the past century show no clear trend, but indicate fluctuations on multi-decadal time scales. Decadal fluctuations in annual rainfall are dominated by rainfall variations of the wet season (January to March). The relationship between the Southern Oscillation Index (SOI) and rainfall is positive, but also shows decadal-scale variations. The relationship was weak during the 1930s and also during the 1980s. The tendency for a weakening relationship in recent years began after the mid 1970s.

The projections show that the inland areas of the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) study region will warm faster than the coastal areas. For a medium (AIB) emissions scenario, the best estimate of regional annual average temperature increase by 2030 is 0.8°C, with a range of uncertainty of 0.6 to 1.1°C. Higher increases are projected for 2050 and 2070. For 2050, the range of uncertainty for regional average temperature increases for the different scenarios and spans the range 0.7 to 2.2°C. The corresponding range for 2070 is 0.9 to 3.5°C.

Rainfall changes are more complex than temperature changes and show increases and decreases. For a medium emissions scenario, the best estimate or the 50th percentile regional average rainfall change for 2030 is -1% with a range of uncertainty of -8 to +6%. Changes by 2050 and 2070 are dependent on the emissions scenario. Projected changes in potential evaporation (PE) indicate an increase of 3% by 2030 with an uncertainty range of 0 to 6%. Increases are larger for 2050 and 2070.

A single fifteen kilometre resolution regional simulation over the tropical rainforest domain predicts a spatial variation in the rise of minimum screen temperature between 1.4 and 2.4°C and a spatial variation in the maximum screen temperature between 1.6 and 2.6°C, centered on 2075. The regional mean change of approximately 2°C is consistent with the global climate model results. The spatial variation in rainfall changes shows both increases and decreases, depending on location. However, in all cases the change in rainfall was not statistically significant at the 95% confidence interval when compared to the intra-decadal variability in simulated rainfall.

Preliminary modelling studies at CSIRO suggest a small decrease in the frequency of tropical cyclones, but increases in the intensity of severe storms in the east coast under climate change conditions.

Introduction

The tropical rainforest regions of North Queensland and the Great Barrier Reef area support a rich diversity of habitats, which sustain regional economies through fisheries, tourism and other industries. The rainforest covers less than one percent of Australia's landmass but contains a highly disproportionate amount of the biodiversity. This region contains plant taxa representative of the earliest stages of the evolution of vascular plants and a very large number of regionally endemic plant and animal species. Climate change is one of the major threats that could affect the spatial distribution of diverse fauna and flora in the future. Sensitivity of rainforest to climate change has been investigated by Hilbert *et al.* (2001). The extinction risk of some species due to climate change has also been reported by Thomas *et al.* (2004). If strategies are not put into place to minimise potential impact of climate change, increased population pressure along the coast may have repercussions for the health of tropical and coastal ecosystems in the region and the economies and communities that they support. Extensive research on climate impacts upon this biodiversity is being undertaken through a major research initiative, the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF), implemented in North Queensland by the Reef and Rainforest Research Centre Ltd.

Suppiah *et al.* (2007b) provided ranges of likely change in annual and seasonal temperature and rainfall averages for the 21st century for the tropical rainforest region of North Queensland and also for the northern and southern halves of Queensland. Methods used to select climate models and to construct climate change projections were given by Whetton *et al.* (2005) and Suppiah *et al.* (2007a). These projections were derived from simulations of fifteen global climate models (GCMs), selected from 23 GCMs on the basis of their reproduction of observed temperature and rainfall over Queensland and mean sea level pressure over the Australian continent averaged for the period from 1961-1990. Since then, CSIRO has developed new climate change projections for Australia using a probabilistic method that involves weighting the output of 23 GCMs according to the ability of models to reproduce the observed climate averages for the 1961-1990 period (CSIRO and the Australian Bureau of Meteorology 2007). The weighting method was developed by Watterson (2008). Following the release of probability based climate change projections for the Australian region in 2007, Suppiah *et al.* (2008) produced revised climate change projections for the tropical rainforest region using the method described by CSIRO and Australian Bureau of Meteorology (2007). Although future projections will be the main focus of this paper, a brief description of trends and variability of temperature and rainfall over the past century will also be given.

In this paper, first we provide a brief description of observed changes in temperature and rainfall in the tropical rainforest region. Secondly, we provide temperature, rainfall and potential evaporation projections for 2030, 2050 and 2070 for low, medium and high emission scenarios. Thirdly, detailed spatial results are given for temperature and rainfall changes, derived from high resolution modelling over the rainforest region. Fourth, changes to tropical cyclone characteristics from modelling are discussed.

Methods

This section provides a brief explanation of the generation of probabilistic projections for the tropical rainforest region. Changes in maximum, minimum and average temperatures, rainfall and potential evaporation for the years 2020, 2030, 2040, 2050, 2060, 2070 and 2080 were calculated relative to averages for the twenty-year 1980-1999 period. Although projections for selected variables were calculated for regions shown in Figure 1, detailed projections are given for 2030, 2050 and 2070 for the tropical rainforest or the MTSRF region. Since climate change projections are given for thirty-year periods or decades, changes in any individual year will be strongly affected by natural climate variability (variability on inter-annual to decadal scales is not easily predicted and has not been accounted for). Three main sources of uncertainty are accounted for:

- The uncertainty in the future evolution of greenhouse gases, sulphate aerosol emissions and other gases;
- The uncertainty in how much the global average surface temperature will respond to increases in atmospheric greenhouse gas concentrations and changes in sulphate aerosol emissions; and
- The uncertainty in how the climate of Australia will respond to an increase in global average surface temperature.

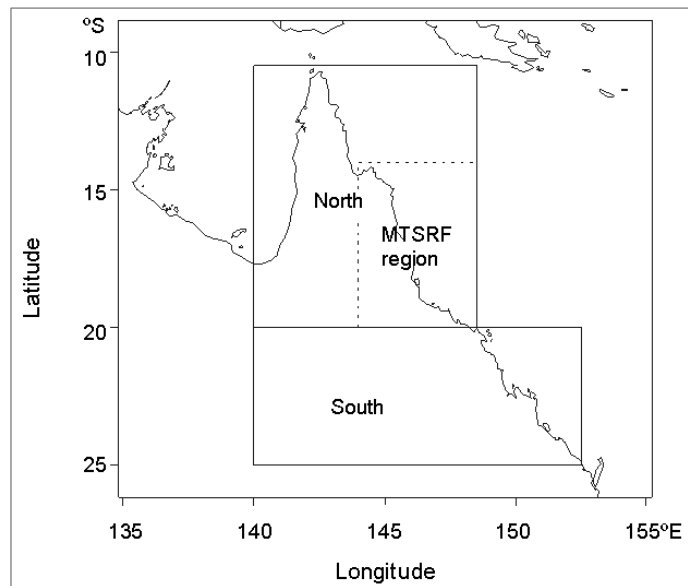


Figure 1: Regions for which climate change projections are provided by MTSRF Project 2.5ii.1.

The first uncertainty is addressed by considering six different scenarios for the future evolution of greenhouse gas and sulphate aerosol emissions described by the Special Report on Emissions Scenarios (SRES) (Nakićenović and Swart 2000) of the Intergovernmental Panel on Climate Change (IPCC). Each of the scenarios, denoted A1B, A1FI, A1T, A2, B1 and B2 in Nakićenović and Swart (2000) is based on a plausible storyline of future global demographic, economic and technological change in the 21st century.

The second uncertainty is addressed by considering information on the response of the global average surface temperature to the emissions scenarios from multiple climate models and the IPCC Fourth Assessment Report (Meehl *et al.* 2007b). Meehl and others (2007b) projected warming between 0.5 and 1.6°C by 2030 and between 1.1 and 6.4°C by 2100 relative to the average temperature for the 1980-2000 period, as summarised in Figure 2. Their study also suggested that simulated global average surface temperature anomalies for the 20th century agree well with observed anomalies on the timescale of several decades, giving us some confidence in the ability of climate models to accurately simulate anomalies on such a timescale.

For each period of interest and each scenario, the range of warming is described using a probability distribution, which comprises a set of probabilities assigned to the numerous plausible values of change.

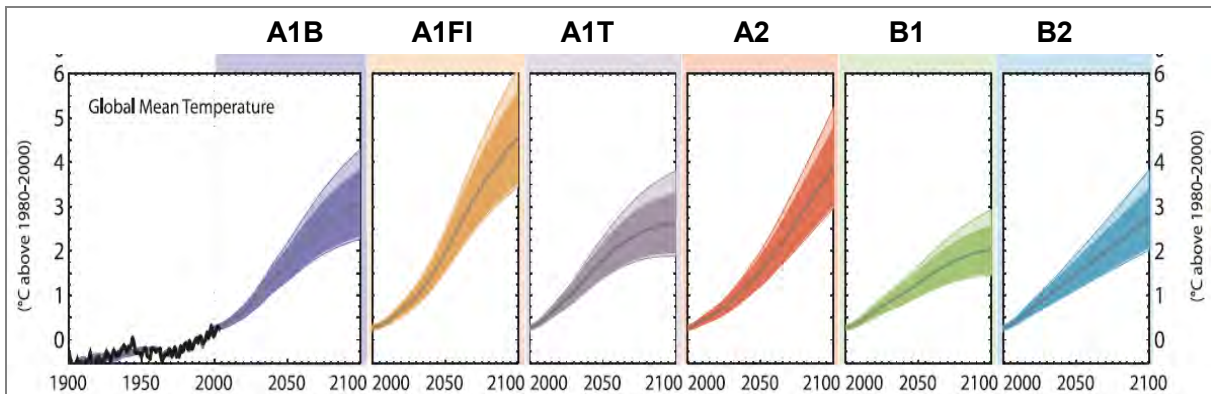


Figure 2: Changes relative to the average for the period 1980-2000 in global average surface temperature for the 21st century for the A1B, A1FI, A1T, A2, B1 and B2 SRES emission scenarios. The dark shaded areas represent uncertainties in changes based on the consideration of the response of nineteen climate models to the emissions scenarios. The light shaded areas represent uncertainties in changes based on the consideration of the response of the models to the emissions scenarios and uncertainty in carbon cycle feedbacks in the climate system. The coloured lines indicate changes based on the mean average response of the models and mid-range assumptions about carbon cycle feedbacks. The black line indicates changes recorded during the 20th century. Source: Meehl *et al.* (2007b).

The third uncertainty is addressed by considering the response of the climate of Australia to global warming in 23 climate models. Model output from the Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (see Meehl *et al.* 2007a) of the World Climate Research Programme (WCRP) was processed using the pattern scaling technique described by Mitchell *et al.* (1999), Mitchell (2003) and Whetton *et al.* (2005). From the simulations of the 21st century from each model, the trend in each variable at each model grid point was calculated, relative to the global mean warming. Projected regional changes in temperature are computed as degree of change per degree of global warming and rainfall changes are calculated as percentage change per degree of global warming. The results from the 23 models were then combined to form a probability distribution for local change per degree of warming. In this process, models were given differing weights (Watterson 2008), or emphasis, depending on their ability to simulate average patterns of temperature, precipitation and mean sea level pressure in the Australian region for the period, 1958-2001. An assessment of the simulations of mean sea level pressure, temperature and rainfall by 23 GCMs over the Australian region is given by Suppiah *et al.* (2007a).

Observed climate trends and variability

Temperature: We have analysed observed temperature data set from 1950 to the present which is available from the Australian Bureau of Meteorology. Temperature in the tropical rainforest region shows steady

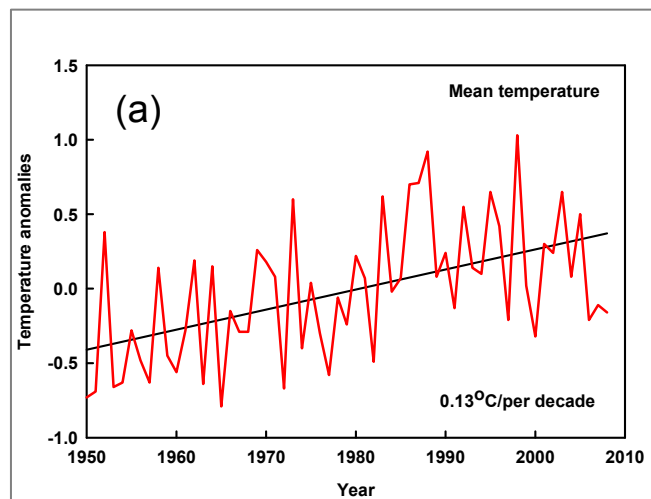


Figure 3: Trends and fluctuations in mean annual temperature anomalies over the MTSRF region from the climatological period (1961-1990) for the period 1950-2008. The long-term increasing trend in mean annual temperature anomalies is shown by a linear trend line.

warming between 1950 and 2000 and reduced warming after 2000. Observed records also show strong decadal and interannual variations. Since 1950, the tropical rainforest region's average maximum temperature has increased by 0.76°C (0.12°C per decade), the minimum by 0.80°C (0.14°C per decade) and the average by 0.78°C (0.13°C per decade). Figure 3 shows strong interannual variations in mean annual temperature over the tropical rainforest region embedded in an increasing trend since 1950. Compared to national trends, the tropical rainforest region's temperatures show slower increases during the last five decades. The year 1998 was the warmest on record in the rainforest region, as it was globally (Jones and Moberg 2003).

Rainfall: Rainfall data from the Australian Bureau of Meteorology for the domain have been analysed. Variations in annual rainfall in the rainforest region during the past century show no clear trend, but there are fluctuations on multi-decadal time scales as shown in Figure 4. In particular, the 1920s, 1960s and 1990s were drier decades and the 1970s was a wetter period. Decadal fluctuations in annual rainfall are dominated by the wet season (January to March) and the transitional season 1 (November and December) rainfall

variations. Rainfall in the dry season (August to October) shows strong interannual variability (not shown here). Rainfall in transitional seasons (transitional 1 – November and December; transitional 2 – April to July) also shows greater variability. Observed rainfall shows significant decrease in the south of the region compared to the north of the tropical rainforest region (Suppiah *et al.* 2007b).

El Niño-Southern Oscillation (ENSO) and Rainfall:

The El Niño-Southern Oscillation phenomenon has significant influences on the interannual variability of rainfall over northern and eastern Australia. Previous studies (McBride and Nicholls 1983) demonstrated that the relationship between rainfall and the southern oscillation is relatively stronger during spring compared to other seasons. The relationship between the Southern Oscillation Index (SOI), a measure of ENSO variability, and rainfall is positive, but shows multi-decadal variations. The relationship was weak during the 1930s and after the mid 1970s (Nicholls *et al.* 1996; Suppiah 2004). Such a weakening of the SOI-rainfall relationship is due to increasing pressure over the Western Pacific represented by Darwin, as pressure

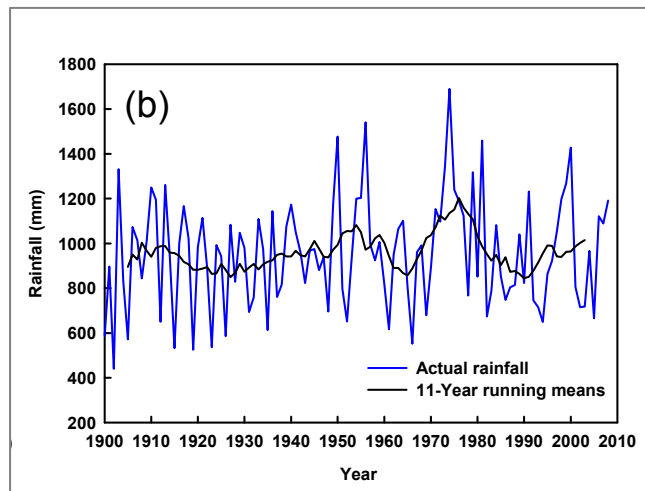


Figure 4: Variations in annual mean rainfall from 1900 to 2008 in the tropical rainforest region of North Queensland. Decadal-scale fluctuations in rainfall are shown by eleven-year running means.

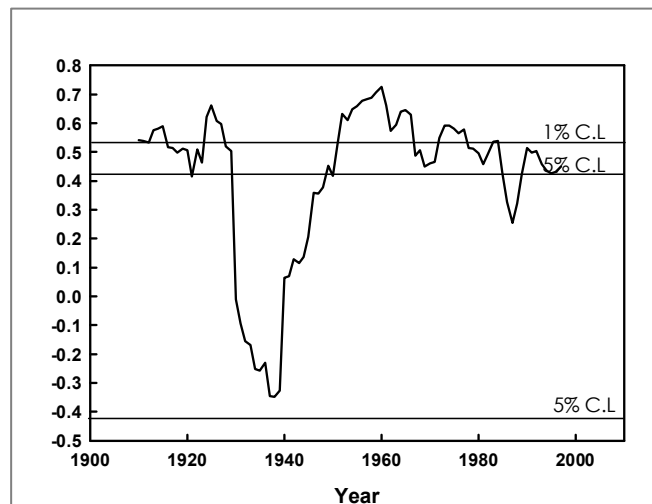


Figure 5: Variations of correlation coefficients with a 21-year sliding window between area-averaged annual rainfall over the tropical rainforest region of North Queensland and the annual SOI. The horizontal lines show the 5% and 1% significance levels.

records at Tahiti do not show clear trends (Suppiah 2004). The weakening of the relationship between the SOI and rainfall has led to more rainfall for a given value of the SOI after the mid 1970s, compared to previous periods. We have repeated the analysis shown in Suppiah (2004) using area-average rainfall for the tropical rainforest region of North Queensland. Correlations for wet, dry, transitional 2 and transitional 1 are 0.46, 0.52, 0.19, and 0.63. The correlation between annual rainfall of this region and the annual SOI is 0.46. Except for the transitional 2 seasons, all other seasons and the annual relationship are statistically significant at the 95% confidence level. However, the relationship has changes on decadal-time scales as shown in Figure 5. In particular, the relationship is strong between 1900 and 1920 and also between 1940 and the mid 1970s, weak between 1900 and the 1940s and also during the 1980s. The reason for very weak correlation between 1920 and 1940 needs further investigation. In particular, there is a tendency for a weakening relationship since the mid 1970s. Since the relationship between rainfall and ENSO shows decadal variations, it is necessary that future GCMs adequately simulate the observed pattern of this relationship and its low frequency variations, to help produce reliable climate change projections for the region.

Climate Change Projections

Temperature: Figure 6 shows the 10th, 50th and 90th percentiles of annual average temperature increase for low (SRES B1), medium (SRES A1B) and high (SRES A1FI) emissions scenarios for 2030, 2050 and 2070. This figure shows that inland areas of the tropical rainforest region will warm faster than coastal areas. Temperature increases by 2030 do not differ greatly between low, medium and high emissions scenarios. For a medium emissions scenario the best estimate (50th percentile) regional average temperature increase by 2030 is 0.8°C with a range of uncertainty of 0.6 to 1.1°C. Temperature increases by 2050 and 2070 increasingly diverge dependent on emissions scenario. For 2050, the ranges of uncertainty for regional average temperature increase for the different scenarios, and span the range 0.7 to 2.2°C. The corresponding range for 2070 is 0.9 to 3.5°C. Temperature increases for the different seasons are not greatly different from increases in annual average temperature. Projected changes in magnitudes of maximum and minimum temperature are very similar to those magnitudes for average temperature.

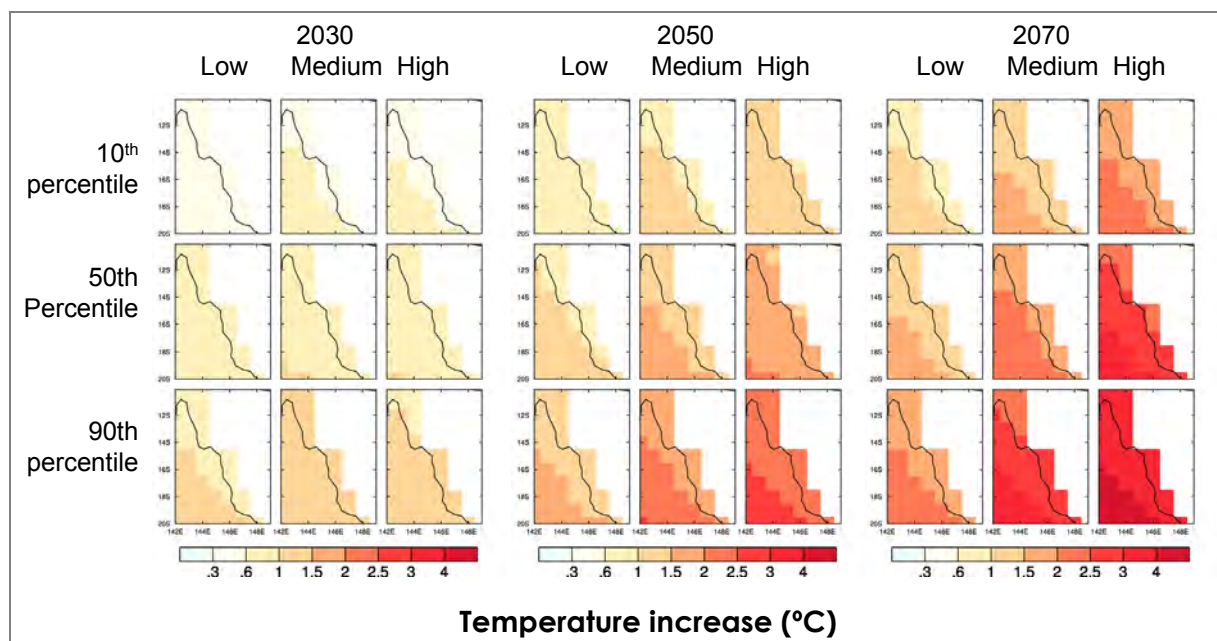


Figure 6: The 10th, 50th and 90th percentile increases in annual average temperature (°C) for low, medium and high emissions scenarios for 2030, 2050 and 2070.

Rainfall: Projected changes in the 10th, 50th and 90th percentiles of annual average rainfall for low (SRES B1), medium (SRES A1B) and high (SRES A1FI) emissions scenarios for 2030, 2050 and 2070 are shown in Figure 7. Rainfall changes are more complex than temperature changes, as their signs and magnitudes show strong spatial variations. Model to model variations in rainfall are also large. As for temperature, changes by 2030 do not differ greatly between low, medium and high emissions scenarios. For a medium emissions scenario the best estimate (50th percentile) regional average rainfall change for 2030 is -1% with a range of uncertainty of -8 to +6%. Changes by 2050 and 2070 are dependent on the emissions scenario. For 2050, the ranges of uncertainty for regional average rainfall change for the different scenarios span the range -16 to +11%. The corresponding range for 2070 is -26 to +18%. As mentioned earlier, projected changes in rainfall are based on a linear relationship between temperature and rainfall, and therefore, variations on inter-decadal scales are not easily predictable.

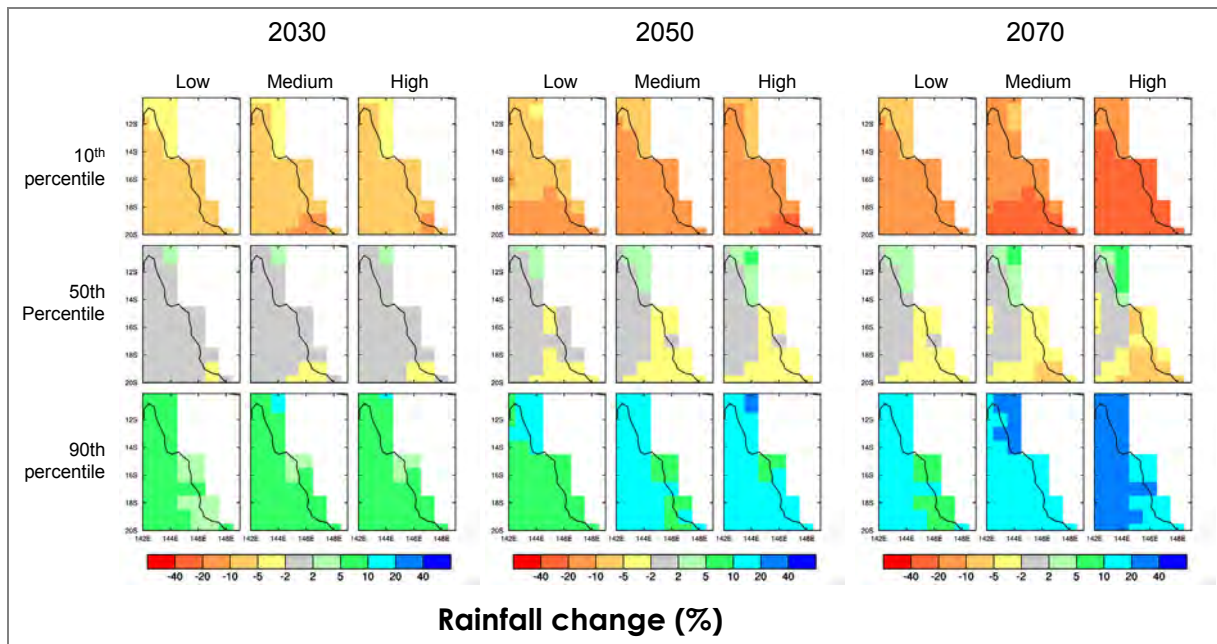


Figure 7: 10th, 50th and 90th percentile changes in annual average rainfall (%) for low, medium and high emissions scenarios for 2030, 2050 and 2070.

Potential evaporation: We had simulations only from eleven GCMs to construct projected changes in potential evaporation over the domain. Increases in temperature and overall decreases in rainfall lead to an increase in annual potential evaporation in the study domain. The potential evapotranspiration was derived using offline calculations from simulated monthly time series of climate variables using the Morton method (Morton 1983). Figure 8 shows that southern and central parts of the area show strong increases in potential evaporation. Increases of 2-8% by 2030 and 4-18% by 2070 are projected by the range of emission scenarios.

It is evident that the results, which were derived from global climate models, do not show detailed spatial variations of projected changes in temperature and the complex topographical areas of the tropical rainforest. Therefore, we have conducted experiments using the CSIRO high-resolution model, the Conformal Cubic Atmospheric Model, CCAM, to investigate the spatial variations of projected changes in climate variables in the tropical rainforest region.

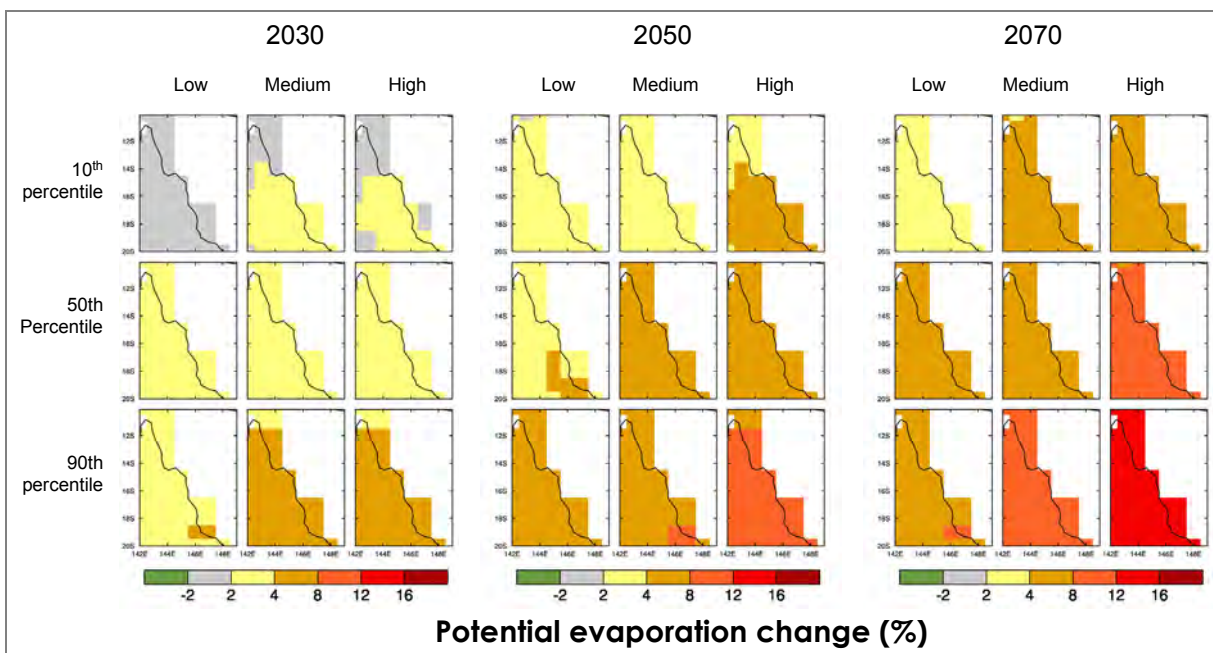


Figure 8: 10th, 50th and 90th percentile changes in annual average potential evaporation (%) for low, medium and high emissions scenarios for 2030, 2050 and 2070 in the region.

High-resolution modelling

In this section, we describe the results of a single 2060-2090 regional climate projection over northern Queensland (Thatcher *et al.* 2007), assuming an A2 emission scenario (see Figure 2). We use the CSIRO Mk3.5 GCM to simulate the future global climate at 200km resolution assuming an A2 emission scenario. At the time of experiment, we assumed that the A2 emission scenario was reasonably consistent with the current trends in GHG emissions. The Mk3.5 output is dynamically downscaled to 15km by CCAM using a multiple one-way nesting approach, where Mk3.5 output is first downscaled to 60km resolution. The output of the CCAM 60km simulation is then downscaled by CCAM to 15km resolution (see Figure 9) This two step process is used because the boundary condition data provided by Mk3.5 is too coarse to be used directly with the highly stretched 15km conformal cubic grid. Note that in the case of CCAM there is no need for two-way nesting since the stretched global grid accounts for the feedback between the high resolution region and the lower resolution host data. Detailed description of the experiment is given by Thatcher *et al.* (2007).

It is not possible to account for uncertainties arising from the GCM simulation or emission scenario using a single A2, Mk3.5 experiment. However, we can still quantify the statistical significance of predicted changes in climate relative to the simulated climate variability. Specifically we use Student's t-distribution to estimate the 95% confidence interval of changes in maximum, minimum and average temperatures and rainfall. In this way, the errors quantified in this paper are essentially dependent on the interdecadal climate variability as simulated by CCAM.

Predicted changes in maximum temperatures between 2060-2090 and 1970-2000 for the transitional season 1 (November to December), the wet season (January to March), transitional season 2 (April to July) and the dry season (August to October) are shown in Figure 10. These figures suggest that simulated maximum temperature will increase by approximately 1.6 to 2.6°C on average, with the increase showing a complex spatial dependence. The increase in average maximum temperature is greater than the 95% confidence interval at all locations and for all seasons, indicating that the projected change is statistically significant relative to the simulated climate variability. Note that a larger average increase in maximum temperature can be expected in the transitional season1 and the dry season, compared to the other seasons. In the case of the dry season, the increases in maximum temperature tend to be greater in the southern part of the domain compared to the northern part.

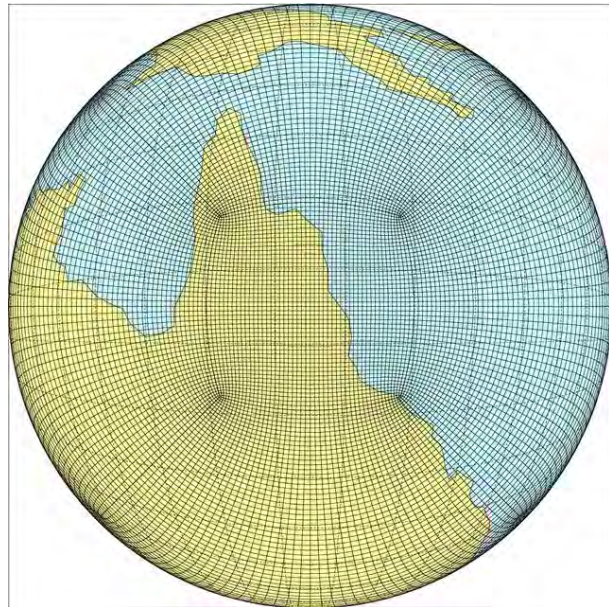


Figure 9: Example of the conformal cubic grid with a ~15km resolution grid over the MTSRF study region in North Queensland.

Figure 11 shows the corresponding predicted changes in average minimum temperature between 1970-2000 and 2060-2090 for A2 emission scenario, for four seasons. This figure shows the average minimum temperature increases between 1.4 and 2.4°C for the A2 emission scenario. The increase is greater in the south of the domain for all seasons. Also, note that the spatial dependence of the increase in average minimum temperatures differs from that predicted for maximum temperatures (see Figure 10). Again, the predicted average change in minimum temperatures is statistically significant (relative to the simulated

variability) at the 95% confidence interval for all seasons. A larger increase in minimum temperatures occurs for the transitional season 1 and the dry season, compared to the transitional season 2 and the wet season, as is the case for the maximum temperatures.

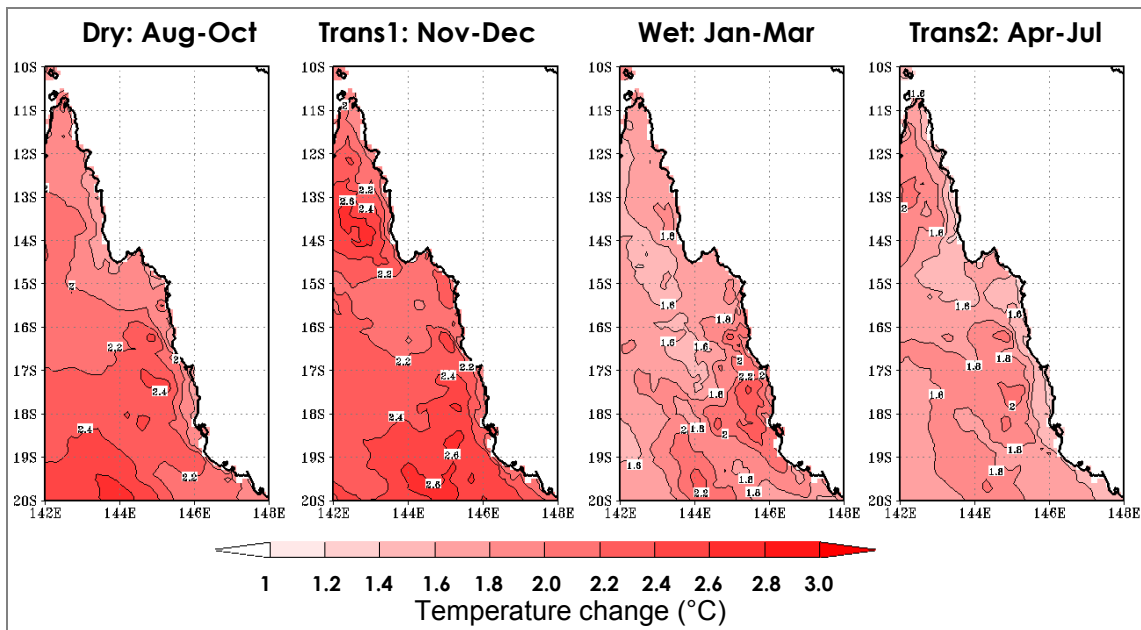


Figure 10: Projected change in average daily **maximum** temperature between 1970-2000 and 2060-2090, for transitional season 1 (top left), wet season (top right), transitional season 2 (bottom left) and dry season (bottom right). Units are degrees Celsius in all figures.

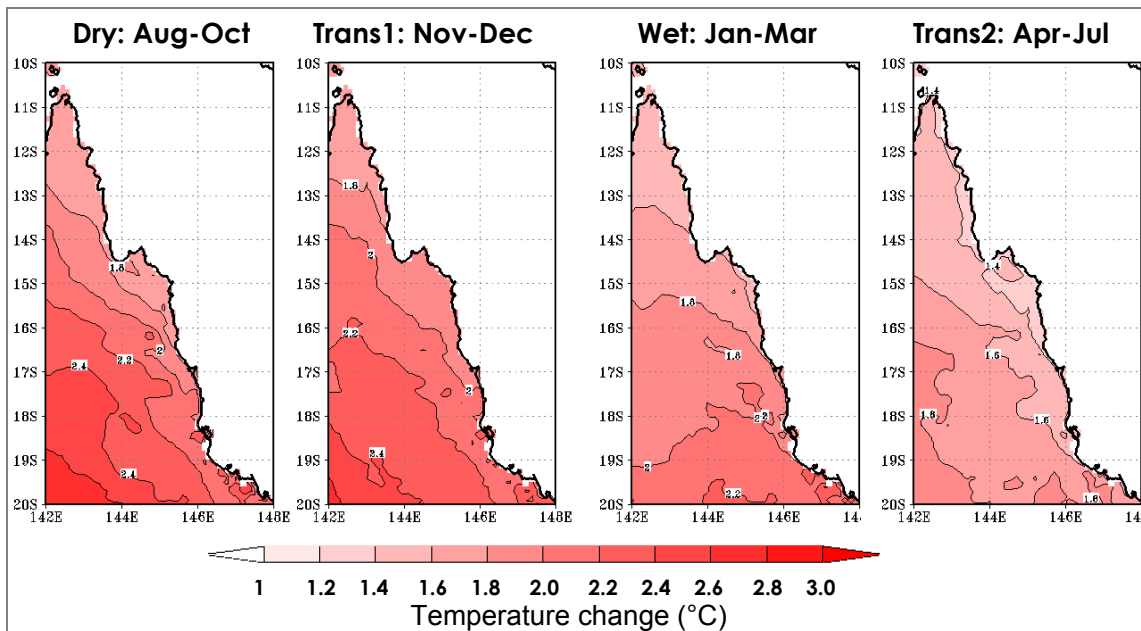


Figure 11: Projected change in average daily **minimum** temperature between 1970-2000 and 2060-2090, for transitional season 1 (top left), wet season (top right), transitional season 2 (bottom left) and dry season (bottom right). Units are degrees Celsius in all figures.

Projected changes in average temperature in the region in Figure 12 show larger increases inland compared to smaller increases along the coast, particularly during dry and transitional season 1. Typical changes in temperature are between 2.4 and 3.0°C inland and between 1.4 and 2.2°C along the coast. Wet season and the transitional season 2 show less warming compared to other seasons.

Changes in rainfall exhibit a more complex spatial pattern than temperature changes, as they show increases at some locations and decreases at other locations. The simulated change in average seasonal rainfall between 1970-2000 and 2060-2090 for each season is shown in Figure 13. However none of the simulated changes are statistically significant at the 95% confidence interval compared to the simulated variability in rainfall (i.e. we are less confident in the predictions of rainfall change than the predictions of temperature change). Nevertheless, the predicted increases in temperatures (i.e., increased evaporation) combined with no comparable increase in rainfall may have important implications for the availability of soil moisture, and therefore vegetation, in the MTSRF region.

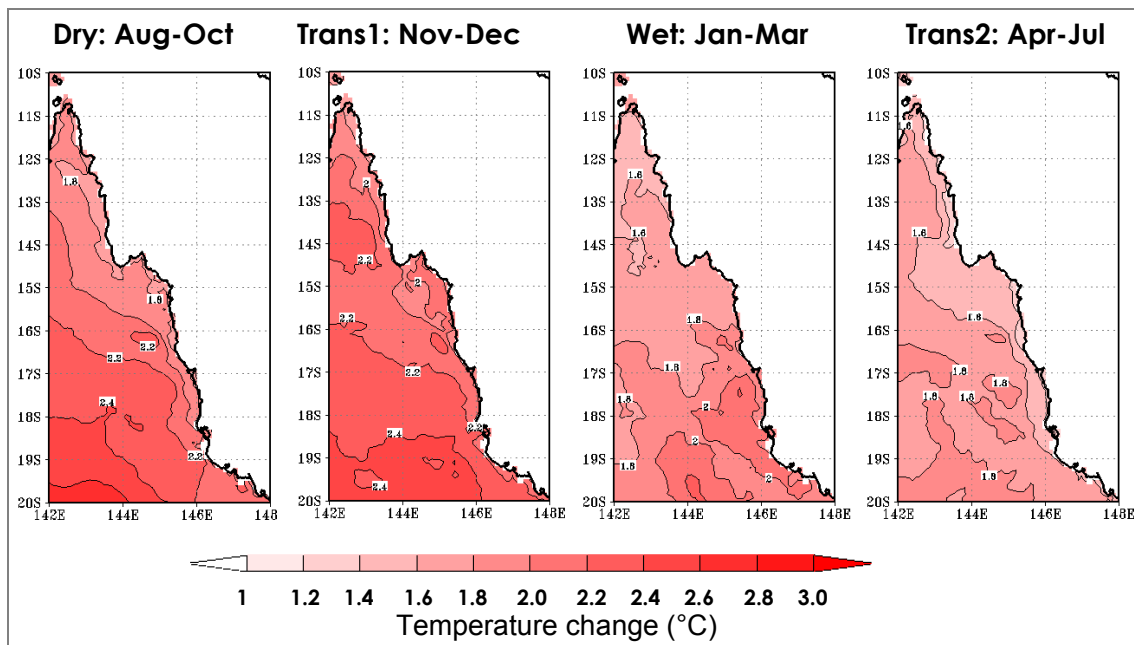


Figure 12: Projected change in average daily **average** temperature between 1970-2000 and 2060-2090, for transitional season 1 (top left), wet season (top right), transitional season 2 (bottom left) and dry season (bottom right). Units are degrees Celsius in all figures.

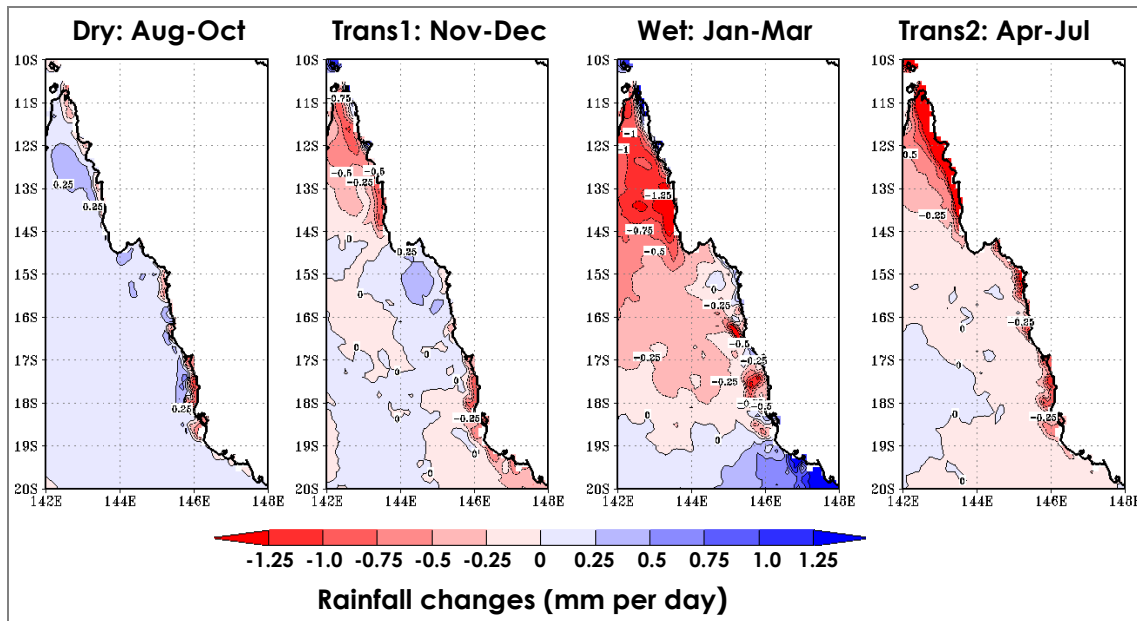


Figure 13: Projected change in average rainfall between 1970-2000 and 2060-2090, for transitional season 1 (top left), wet season (top right), transitional season 2 (bottom left) and dry season (bottom right). Units are mm/day in all figures.

Tropical cyclones

Tropical cyclones and slow-moving depressions, which produce a significant amount of rainfall, have significant impacts on the environment, infrastructure, economic activities and society in the Australian tropics. Severe tropical cyclones result in calamities for people, crops, wildlife and natural vegetation. The occurrence of tropical cyclones is highly seasonal and they are confined to the summer monsoon months. The tropical cyclone season extends from November to May, with a maximum frequency of occurrence in the months of January to March. Tropical cyclones and depressions form in three distinct areas; the western (105-125°E), the central or northern (125-145°E) and the eastern region (145-165°E). All these regions show maximum frequency of occurrence during the monsoon season. McBride and Keenan (1982) pointed out that 84% of the pre-cyclone cloud clusters first appear at the level (850 hPa) of the monsoon shear line, whereas 97% occur on the shear line at the point of development. Although individual cyclone development and Australian regional cyclone genesis locations coincide with the average location of the monsoon shear line, the monthly climatological positions of the monsoon shear line in the three regions and the locations of cyclone origins show considerable variations on intra-seasonal and inter-annual time scales. In particular, the points of origin in the western and central regions are found north of the monsoon shear line except during February and March, while in the eastern region the points of origin are located south of the shear line, an indication of southward penetration of warm water. Apart from these, the El Niño-Southern Oscillation has a strong influence on genesis, location and tracks of cyclones in the Australian region: few cyclones occur during El Niño years and more during La Niña years. Recent studies suggest a decline in tropical cyclone numbers in the Australian region, although the northeast coast has experienced a few very severe tropical cyclones, such as Tropical Cyclones *Larry* and *Hamish*. It is not surprising that El Niño events have dominated most of the inter-annual climate variability during the last two decades.

Recent observational and theoretical based studies on various basins of tropical cyclone origin (Emanuel 2005; Anthes *et al.* 2006; Koltzback 2006; Webster *et al.* 2005) suggest an increase in tropical cyclone numbers, duration and intensity, linked to a warmer environment.

It is unclear whether the occurrence of recent changes in tropical cyclones is a part of natural variability or due to warming environment. Tropical Cyclone *Larry* caused extensive damage to people's lifestyle, economy and environment of the northeast Queensland.

Since global climate models do not adequately simulate tropical cyclones, we have used simulations from a regional climate model to investigate possible changes to tropical cyclone characteristics under enhanced greenhouse conditions. Abbs *et al.* (2008) used simulations of the Conformal Cubic Atmospheric Model (CCAM) to investigate the characteristics of tropical cyclones in the Australian region. In their study, CCAM simulations at 65km mesh centred over the Australian continent, stretching to coarser grid spacings beyond the continent were used. The grid spacing over the tropical seas varied from 65-100km. In each set of simulations, tropical cyclones are identified and tracked using a modified version of the objective techniques described by Walsh *et al.* (2004). Results from this analysis show a significant decrease in tropical cyclone numbers for the Australian region especially in tropical cyclone numbers off the coastline of Western Australia. In that sub-region cyclone numbers are simulated to decrease by 44%; off the east Australian coastline small decreases of only nine percent are simulated. In contrast, a decrease is found in the number of long-lived cyclones for the west Australian coast. In common with most other studies they reported a marked increase in the frequency of the most severe storms. They also showed a change in the latitudinal extent of tropical cyclones, with a pole-ward shift of 0.7 degrees of latitude in the average tropical cyclone genesis region on both coastlines and a shift of almost 3 degrees latitude in the average decay location for east Australian cyclones.

An ensemble series of five thirty-year simulations, downscaled from the NCEP reanalysis dataset, has been analysed to investigate changes in circulation and warmer upper-level ocean temperatures. The end effect of these changes is difficult to predict. Making detailed comparisons between intensities of tropical cyclones over different periods in time is a process that is difficult to achieve in the observed world given the challenges in taking direct observations from storms, as well as the problem of methodologies for remotely determining storm intensity differing by both location and era. Numerical modelling provides us with a means of examining the potential effects on tropical cyclone intensities of human-induced climate change, and makes comparison between different tropical cyclone climatologies much easier.

Conclusions

Observed temperature in the study region has increased steadily between 1950 and 2008, but shows strong decadal and inter-annual variations. Since 1950, the tropical rainforest region's average maximum temperature has increased by 0.76°C (0.12°C per decade), the minimum by 0.79°C (0.14°C per decade) and the average by 0.78°C (0.13°C per decade). Variations in annual and seasonal rainfall in the rainforest region of North Queensland during the past century show no clear trend, but there are fluctuations on multi-decadal time scales. In particular, the 1920s, 1960s and 1990s were drier decades and the 1970s was a wetter period. The relationship between the SOI and rainfall is positive, but shows decadal-scale variations. The relationship was weak during 1930s and also during 1980s. The tendency for a weakening relationship in recent years began after the mid 1970s.

Probability-based temperature and rainfall projections were derived from the output of 23 GCMs and potential evaporation projections from eleven GCMs. Projections were given for the 10th, 50th and 90th percentiles of temperature, rainfall and potential evaporation changes for low, medium and high emissions scenarios, but projections for other decades from 2020 to 2080 are also available. Projected temperatures show that the inland areas of the tropical rainforest region and its surroundings will warm faster than the coastal areas. For a medium emissions scenario the 50th percentile regional average temperature increase by 2030 is 0.8°C, with a range of uncertainty of 0.6 to 1.1°C. For 2050, the ranges of uncertainty for

regional average temperature increase for the different scenarios, and span the range 0.7 to 2.2°C. The corresponding range for 2070 is 0.9 to 3.5°C.

Rainfall changes are more complex than temperature changes and show increases and decreases. For a medium emissions scenario the 50th percentile regional average rainfall change for 2030 is -1% with a range of uncertainty of -8 to +6%. Changes by 2050 and 2070 are dependent on emissions scenario. For 2050, the ranges of uncertainty for regional average rainfall change, for different scenarios, span the range -16 to +11%. The corresponding range for 2070 is -26 to +18%. Percentage rainfall changes in the dry season and transitional season 2 are greater than those for the wet season and transitional season 1. Projected increases in temperature and slight decreases in rainfall lead to increases in potential evaporation. Increases in potential evaporation of 2 to 8% by 2030 and 4 to 18% by 2070 are projected between low and high emission scenarios.

We have conducted higher resolution modelling experiments over the MTSRF region, as the global climate models are unable to resolve detailed spatial variations in climate variables in this complex terrain region. The changes in regional climate were simulated by CCAM at 15km resolution after dynamically downscaling from Mk3.5 output at 200km resolution. Projections were constructed for northern Queensland using the A2 emission scenario for 2060-2090.

Higher-resolution modelling over the tropical rainforest region indicates a spatial variability in the rise of minimum screen temperatures between 1.4 and 2.4°C and a spatial variability in the rise of maximum screen temperature between 1.6 and 2.6°C on average. There is a tendency for the average increase in minimum temperature to be smaller towards the northern part of the region compared to the south. Rainfall changes show a spatial distribution of both increases and decreases, but with no statistically significant changes at the 95% confidence interval compared to the simulated intra-decadal variability. Overall, predicted changes in temperature by CCAM agrees well with the changes produced by global climate models for the given period.

Preliminary modelling studies suggest a small decrease in the frequency of tropical cyclones, but increased intensity of severe storms in the east coast under climate change conditions.

Acknowledgements

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References

- Abbs, D., Rafter, T., Nguyen, K. and Thatcher, M. (2008) *The Impact of Climate Change and Climate Variability on Tropical Cyclones in the Australian Region*. Western Pacific Geophysics Meeting 2008, Cairns.
- Anthes, R. A., Corell, R. W., Holland, G., Hurrell, J. W., MacCracken, M. C. and Trenberth, K. (2006) Hurricanes and global warming – potential linkages and consequences. *Bulletin of the American Meteorological Society* [doi:10.1175/BAMS-87-5617].
- CSIRO and the Australian Bureau of Meteorology (2007) *Climate change in Australia*. Technical Report (140pp.).
- Emanuel, K. (2005) Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436: 686-688.
- Hilbert, D. W., Ostendorf, B. and Hopkins, M. S. (2001) Sensitivity of tropical forests to climate change in the humid tropics of North Queensland. *Austral Ecology* 26: 590-603.

- Jones, P. D. and Moberg, A. (2003) Hemispheric and land-scale surface air temperature variations: an extensive revision and an update to 2001. *Journal of Climate* 16: 206-223.
- Klotzbach, P. J. (2006) Trends in global tropical cyclone activity over the past twenty years. *Geophysical Research Letters* 33: L10805 [doi:10.1029/2006GL025881]
- McBride, J. L. and Keenan, T. D. (1982) Climatology of tropical cyclone genesis in the Australian region. *Journal of Climatology* 2: 13-33.
- McBride, J. L. and Nicholls, N. (1983) Seasonal relationships between Australian rainfall and the southern oscillation. *Monthly Weather Review* 111: 1998-2004.
- Meehl, G. A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J. F. B., Stouffer, R. J. and Taylor, K. E. (2007a) The WCRP CMIP3 multimodel dataset: A new era in climate change research. *Bulletin of the American Meteorological Society* 88: 1383-1394.
- Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, A. T., Gregory, J. M., Kitoh, A., Knutti, R., Murphy, J. M., Noda, A., Raper, S. C. B., Watterson, I. G., Weaver, A. J. and Zhao, Z-C. (2007b) Global Climate Projections. In: Solomon, S. D., Qin, M., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (eds.) *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Mitchell, T. D. (2003) Pattern scaling: An examination of the accuracy of the technique for describing future climates. *Climatic Change* 60: 217-242.
- Mitchell, J. F. B., Jones, T. C., Eagles, M., Ingram, W. J. and Davis, R. A. (1999) Towards the construction of climate change scenarios. *Climatic Change* 41: 547-581.
- Morton, F. I. (1983) Operational estimates of areal evapotranspiration and their significance to the science and practice of hydrology. *Journal of Hydrology* 66: 1-76.
- Nakićenović, N. and Swart, R. (eds.) (2000) *Special Report on Emissions Scenarios*. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK (599pp.).
- Nicholls, N., Lavery, B., Fredericksen, C., Drosowsky, W. and Torok, S. (1996) Recent apparent changes in relationships between the EL Niño-southern oscillation and Australian and temperature. *Geophysical Research Letters* 23: 3357-3360.
- Suppiah, R. (2004) Trends in the southern oscillation phenomenon and Australian rainfall and changes in their relationship. *International Journal of Climatology* 24: 269-290.
- Suppiah, R., Hennessy, K. J., Whetton, P. H., McInnes, K. L., Macadam, I., Bathols, J., Ricketts, J. and Page, C. M. (2007a) Australian climate change projections derived from simulations performed for the IPCC 4th Assessment report. *Australian Meteorological Magazine* 56: 131-152.
- Suppiah, R., Macadam, I. and Whetton, P. H. (2007b) [Climate change projections for the tropical rainforest region of North Queensland](#). Report to the Marine and Tropical Sciences Researchy Facility (MTSRF). Reef and Rainforest Research Centre Limited, Cairns (38pp.).

Suppiah, R., Macadam, I., Watterson, I. G., Page, C. M., Bathols, J. and Whetton, P. H. (2008) *Probabilistic climate change projections for the MTSRF region*. A CSIRO report to the Marine and Tropical Sciences Research Facility (36pp.).

Thatcher, M. J., McGregor, J. L. and Nguyen, K. (2007) [Regional climate downscaling for the Marine and Tropical Sciences Research Facility \(MTSRF\) between 1971 and 2000](#). Report to the Marine and Tropical Sciences Research Facility (MTSRF). Reef and Rainforest Research Centre Limited, Cairns (12pp.).

Walsh, K. J. E., Nguyen, K. and McGregor, J. L. (2004) Fine-resolution regional climate model simulations of the impact of climate change on tropical cyclones near Australia. *Climate Dynamics* 22: 47-56.

Thomas, C. D. and 18 co-authors (2004) Extinction risk from climate change. *Letters to Nature* 427: 145-148 [doi:10.1038/nature02121].

Watterson, I. G. (2008) Calculation of probability density functions for temperature and precipitation change under global warming. *Journal of Geophysical Research* 113: D12106 [doi: 10.1029/2007/JD009254].

Webster, P. J., Holland, G. J., Curry, J. A. and Chang, H-R. (2005) Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309: 1844-1846.

Whetton, P. H., McInnes, K. L., Jones, R. N., Hennessy, K. J., Suppiah, R., Page, C. M., Bathols, J. and Durack, P. (2005) *Climate change projections for Australia for impact assessment and policy application: A review*. CSIRO Technical Paper No. 001, CSIRO Marine and Atmospheric Research, Aspendale VIC (34pp.).

Assessment of ecological connectivity in corals: Implications for their recovery from major perturbations and their potential to adapt to climate change

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Abstract

We aim to obtain estimates of ecological connectivity and its temporal stochasticity for two common pocilloporid coral species on the Great Barrier Reef, *Seriatopora hystrix* and *Pocillopora damicornis*, by genetically characterising new recruits at a small number of locations in the Palm and Lizard Islands, and comparing these with the genetic characteristics of adult populations at a wider range of populations. Twenty unglazed terracotta tiles are horizontally attached to the substratum at each of sixteen sampling sites and sampled every two months for recruits. Species identification will rely on the use of genetic markers, such as DNA sequence variation in a non-coding region of the mitochondrial genome. Adult colonies are sampled on the same sites, as well as opportunistically throughout the Great Barrier Reef and recruits of the year are assigned to possible source populations using assignment tests. The genetic characteristics of different cohorts (recruits from different sampling time points and adults) are compared by calculating pairwise genetic differences in an Analysis of Molecular Variance framework and by estimating genetic diversity, such as expected heterozygosity and allelic richness. Spatial, ecological and genetic data are integrated in a Geographic Information System (GIS) to allow the detection of patterns of genetic divergence and/or selection on various spatial scales and finding links to relevant ecological parameters. Results will be cross-validated with circulation models of the region.

Introduction

The Great Barrier Reef (GBR) is an extremely large reef system, covering ~350,000 km² (of which ~21,000 km² consists of coral reef) and comprising ~2,900 separate reefs (Wachenfeld *et al.* 2007). Like most other coral reefs in the world, it is being affected by both natural and anthropogenic disturbances at scales that are increasing in both frequency and severity. As a result of this rapid degradation, processes of recovery will be fundamental to the long-term persistence of coral reefs and the high diversity communities they host. Recovery occurs through re-growth of surviving coral colonies and colony fragments and through new recruitment from local and external sources. As well as reducing adult densities, disturbances may reduce fecundity (Cantin *et al.* 2007; Michalek-Wagner and Willis 2001) and lower survival of eggs, larvae and juveniles (Negri *et al.* 2002; 2007). Hence, although some adult coral colonies survive severe disturbances, their presence does not guarantee replenishment. Recruitment from external sources is therefore likely to be extremely

important for recovery after severe but localised environmental perturbations. The extent of recruitment from external resources can be estimated by quantifying ecological connectivity, that is, the dispersal of individuals among populations over ecological time scales (the last few generations).

Assessment of ecological connectivity also provides insights into the potential of populations and species to change their distributional range (for example, towards the sub-tropical and temperate regions in response to global warming), and to whether adaptive alleles can spread and expedite local adaptation to a changing environment. Assessing temporal and small scale spatial genetic patterns may also help us understand the effects of site specific selection and adaptation, both of which need to be considered for the management and restoration of degraded coral reefs (Baums 2008).

Ecological connectivity of most marine populations, including reef corals, is poorly understood (Cowen *et al.* 2007) as few studies have specifically estimated contemporary dispersal. This limits our ability to evaluate the design and potential benefits of novel conservation and resource management strategies. Most population genetic studies on reef corals have estimated connectivity over evolutionary time scales (i.e. over thousands of generations) using conventional statistical methods (F-statistics), as statistical methods to estimate ecological connectivity from population genetic data have only recently been developed. One class of novel analyses, assignment tests, allows identification of recent migrants by mismatch of their multi-locus genotypes with the modeled distribution of genotypes of the populations from which they were sampled (Manel *et al.* 2005; 2007). Other novel methods focus on detecting genetic structure that may not be evident from allele frequency differences, on which the more traditional F-statistics approaches are based (Pritchard *et al.* 2000). These novel approaches have been applied to a small number of studies on reef corals and the results are promising (Baums *et al.* 2005; Underwood *et al.* 2007; Souter and Grahn 2008; van Oppen *et al.* 2008), but their performance for widespread marine species with overlapping generations and potentially many unsampled source populations remains to be shown.

Another approach to understanding ecological connectivity is to genetically characterise the 'young of the year' over the course of several years. This is the most promising approach, as it overcomes the confounding effects of analyzing multiple cohorts simultaneously and also addresses the potential temporal stochasticity of recruitment, which is largely unquantified in reef corals. A comparison with adult populations makes it possible to identify source populations of the recruits and allows selection on recruits and juveniles to be unveiled. This approach has been used only once in reef corals: Zvuloni *et al.* (2008) genetically characterised adults and recruits (< 5mm) of the brooding coral, *Stylophora pistillata*, from six sites (three in the north and three in the south, spatial scale ~10km) in the Gulf of Aqaba, Red Sea. The authors showed that although the adult populations were genetically distinct, recruits from both regions were genetically similar, suggesting that high levels of ecological gene flow occur between the regions (over a scale of ~10km) and that selection possibly accounts for the genetic differences between the adult populations.

Reef corals that brood their larvae internally and release mature larvae are generally believed to show little exchange of larvae over ecological times scales (Ayre and Hughes 2004). It is therefore expected that such corals are slow in recovering from large-scale perturbations. Pocilloporid corals fall in this group of corals, and form important components of reef systems on the GBR. The pocilloporid corals *Seriatopora hystrix* and *Pocillopora damicornis* are widespread and common on the GBR (Veron 2000), and are among the most sensitive species to coral bleaching (Marshall and Baird 2000). Hence, they are under severe threat from climate change related extreme weather events and it is unclear whether damaged populations can be repopulated from external sources. However, pocilloporid corals are also known to be effective colonizers on newly opened patches of reef and on

experimental settlement tiles (Mangubhai *et al.* 2007; Penin *et al.* 2007) and hence are important species to study in relation to recovery of degraded reefs. In addition, a recent study has shown that despite most recruitment in *S. hystrix* being highly localised, some regions in the GBR show stronger connectivity and recent recruitment has been supplemented by a considerable amount of long distance dispersal over tens to hundreds of kilometres (van Oppen *et al.* 2008). Similar results have also been found for *P. damicornis*, with dispersal occurring over hundreds of kilometres along the coast of East Africa (Souter *et al.* submitted).

Unlike mass-spawning corals which release gametes only once or twice a year over the course of a few nights (Harrison *et al.* 1984), most brooding corals, including *S. hystrix* and *P. damicornis*, release larvae over periods of several months (Harrison and Wallace 1990). However, the reproductive period may vary among conspecific populations depending on ambient temperature and hence latitude (Tanner 1996), as well as between years among the same populations (Ward 1992). As the exact mechanisms and timing of reproduction are not well documented for most species, it is difficult to predict connectivity from water circulation models, especially that such hydrodynamic models are not available at fine resolution for most of the GBR.

The main aim of this project is to estimate the ecological connectivity and determine the temporal stochasticity thereof for *S. hystrix* and *P. damicornis* on the GBR. The project also aims at estimating the potential of populations of these species to recover from major perturbations and shift ranges as needed in response to climate change, i.e. their chances for a long-term persistence.

Methods

S. hystrix and *P. damicornis* recruits are sampled in a nested fashion on a total of eight sites throughout the Palm Islands and at Lizard Island (Figure 1.). Twenty unglazed terracotta tiles are attached to the substratum at each sampling site as described in Mundy (2000) and sampled every two months for recruits. Pocilloporid corals are early successional species and generalist settlers that lack specific settlement cues (Baird and Hughes 2000) and thus unlikely to be biased by the use of settlement tiles (Babcock *et al.* 2003). However, to confirm that the use of settlement tiles does not bias the results, sampling of recruits from natural substrata will be attempted taking advantage of their luminescence. Recruits identified as belonging to pocilloporids based on morphology (Babcock *et al.* 2003) will be stored in ethanol until genetic processing. Species identification of recruits will rely on the use of genetic markers, i.e. DNA sequence variation in a non-coding region of the mitochondrial genome (Flot *et al.* 2008; Chen *et al.* 2008; Souter unpubl.).

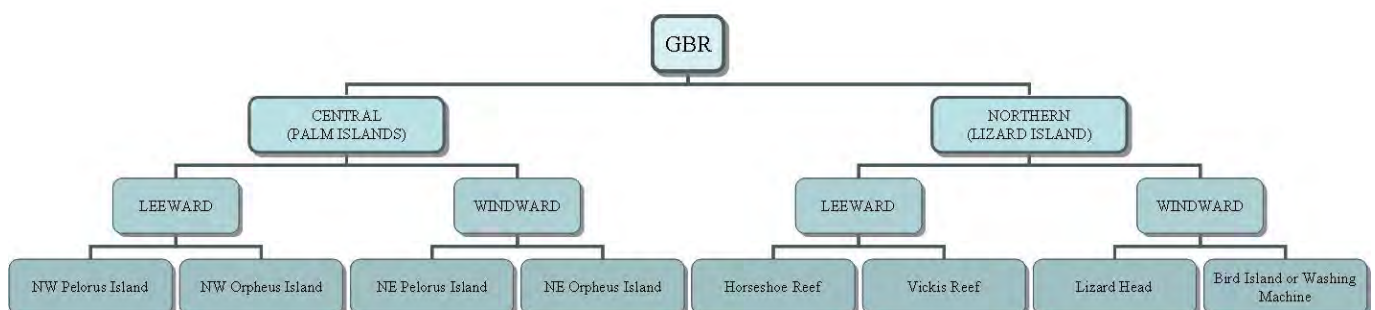


Figure 1: Sampling design. Recruitment of tiles are currently being deployed in a nested fashion at two leeward and two windward sites around Lizard Island and the Palm Islands, North Queensland.

Adult colonies are extensively sampled at and around the recruitment sampling sites and opportunistically GBR-wide. Colony branches a few centimeters in length are collected and stored in ethanol until genetic processing. Colonies are photographed and their depth is recorded along with their coordinates for integration into a GIS.

Samples will be genotyped using polymorphic DNA microsatellite loci. Such markers already exist for both study species (Underwood *et al.* 2006; Starger *et al.* 2008); however, to ensure adequate resolution, new markers are developed for both species.

Recruits of the year will be assigned to possible source populations using assignment tests as implemented in the software package GeneClass (Piry *et al.* 2004). The genetic characteristics of different cohorts (recruits from different sampling time points and adults) will be compared by calculating pairwise genetic differences in an Analysis of Molecular Variance framework (Excoffier *et al.* 1992; Excoffier *et al.* 2005) and by estimating genetic diversity, such as expected heterozygosity and allelic richness. Genetic landscapes will be generated by the software 'Alleles In Space' (Miller 2005) and ArcGIS 9.3 (ESRI) using inverse distance weighting and Kriging algorithms (Murphy *et al.* 2008), and will be correlated to ecological landscapes, which will be characterised on the basis of sea surface temperatures, salinity, currents and topography. The Australian Connectivity Interface (Condie *et al.* 2005), as well as other available circulation models and biophysical landscapes, will be used to explain observed patterns of genetic connectivity.

Results and Discussion

The project is in its early stages. Recruitment tiles have been deployed at each of the eight sites and more than two hundred adult samples have been collected from around the recruitment tiles. A further 2,000+ samples for both species from all around the GBR is available for analysis.

Recruitment tiles at and around the Palm Islands were sampled once since deployment, and 58 pocilloporid recruits were collected during the period between April and June 2009. Reproduction of pocilloporid species during late autumn on the central GBR has not been shown earlier.

Implications for end users

The project will add to the current data on genetic connectivity and adaptation being generated by MTSRF Projects 2.5i.3 and 2.5i.2. As such it will be linked to ongoing end user instigated activities such as the Reef Atlas and provide data that is relevant to reef managers (Great Barrier Reef Marine Park Authority), and reef users (tourism industry, diving industry, etc.).

It is foreseen that the detailed spatial and temporal genetic data for these two important hard corals on the GBR will lead to conclusions regarding the ecological connectivity of brooding coral populations and their potential to recover from major disturbances, and also help identify the main source and sink reefs. The results of this study will be used for validation of existing circulation models for the region.

Acknowledgements

This research is funded by the Australian Government's Marine and Tropical Sciences Research Facility, AIMS@JCU, the Australian Institute of Marine Science and James Cook University.

References

- Ayre, D. J. and Hughes, T. P. (2004) Climate change, genotypic diversity and gene flow in reef-building corals. *Ecol Letters* 7: 273-278.
- Babcock, B. C., Baird, A. H., Piromvaragorn, S., Thomson, D. P. and Willis, B. L. (2003) Identification of scleractinian coral recruits from Indo-Pacific reefs. *Zool Stud* 42: 211-226.
- Baird, A. H. and Hughes, T. P. (2000) Competitive dominance by tabular corals: an experimental analysis of recruitment and survival of understorey assemblages. *JEMBE* 251: 117-132.
- Baums, I. B., Miller, M. W. and Hellberg, M. E. (2005) Regionally isolated populations of an imperiled Caribbean coral, *Acropora palmata*. *Mol Ecol* 14: 1377-1390.
- Baums IB (2008) A restoration genetics guide for coral reef conservation. *Molecular Ecology*, doi: 10.1111/j.1365-294X.2008.03787.x
- Cantin, N. E., Negri, A. P. and Willis, B. L. (2007) Photoinhibition from chronic herbicide exposure reduces reproductive output of reef-building corals. *Mar Ecol Progr Ser* 344: 81-93.
- Chen, C., Chiou, C. Y., Dai, C. F. and Chen, C. A. (2008) Unique Mitogenomic Features in the Scleractinian Family Pocilloporidae (Scleractinia: Astrocoeniina). *Marine Biotechnology* 10: 538-553.
- Condie, S. A., Waring, J., Mansbridge, J. V. and Cahill, M. L. (2005) Marine connectivity patterns around the Australian continent. *Environmental Modelling and Software* 20: 1149-1157.
- Cowen, R. K., Gawarkiewicz, G., Pineda, J., Thorrold, S. R. and Werner, F. E. (2007) Population connectivity in marine systems: An overview. *Oceanogr* 20: 14-21.
- Excoffier, L., Laval, G. and Schneider, S. (2005) Arlequin (version 3.0): an integrated software package for population genetics data analysis. *Evolutionary bioinformatics online*, 1: 47-50.
- Excoffier, L., Smouse, P. E. and Quattro, J. M. (1992) Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. *Genetics* 131: 479-491.
- Flot, J. F., Magalon, H., Cruaud, C., Couloux, A. and Tillier, S. (2008) Patterns of genetic structure among Hawaiian corals of the genus *Pocillopora* yield clusters of individuals that are compatible with morphology. *CR Biologies* 331: 239-247.
- Harrison, P. L., Babcock, R. C., Bull, G. D., Oliver, J. K., Wallace, C. C. and Willis, B. L. (1984) Mass spawning in tropical reef corals. *Science* 223: 186-1189.
- Harrison, P. L. and Wallace, C. C. (1990) Reproduction, dispersal and recruitment of scleractinian corals. In: Dubinsky, Z. (ed.) *Ecosystems of the World: Coral Reefs*, Elsevier, Amsterdam
- Manel, S., Gaggiotti, O. E. and Waples, R. S. (2005) Assignment methods: matching biological questions techniques with appropriate. *Trends in Ecology and Evolution* 20: 136-142.

Manel, S., Berthoud, F., Bellemain, E., Gaudeul, M., Luikart, G., Swenson, J. E., Waits, L. P. and Taberlet, P. (2007) A new individual-based spatial approach for identifying genetic discontinuities in natural populations. *Mol Ecol* 16: 2031-2043.

Mangubhai, S., Harrison, P. L. and Obura, D. O. (2008) Patterns of coral larval settlement on lagoon reefs in the Mombasa marine national park and reserve, Kenya. *Mar Ecol Prog Ser* 348: 149-159.

Marshall, P. A. and Baird, A. H. (2000) Bleaching of corals on the Great Barrier Reef: differential susceptibilities among taxa. *Coral Reefs* 19: 155-163.

Michalek-Wagner, K. and Willis, B. L. (2001) Impacts of bleaching on the soft coral *Lobophytum compactum*. I. Fecundity, fertilisation and offspring viability. *Coral Reefs* 19: 231-239.

Miller, M. P. (2005) Alleles in Space (AIS): computer software for the joint analysis of interindividual spatial and genetic information. *Journal of Heredity* 96: 722.

Mundy, C. N. (2000) An appraisal of methods used in coral recruitment studies. *Coral Reefs* 19: 124-131.

Murphy, M. A., Evans, J. S., Cushman, S. A. and Storfer, A. (2008) Representing genetic variation as continuous surfaces: an approach for identifying spatial dependency in landscape genetic studies. *Ecography* 31: 685-697.

Negri, A. P., Marshall, P. A. and Heyward, A. J. (2007) Differing effects of thermal stress on coral fertilization and early embryogenesis in four Indo Pacific species. *Coral Reefs* 26: 759-763.

Negri, A. P., Smith, L. D., Webster, N. S. and Heyward, A. J. (2002) Understanding ship-grounding impacts on a coral reef: potential effects of anti-foulant paint contamination on coral recruitment. *Mar Pollut Bull* 44: 111-117.

Penin, L., Adjeroud, M., Pratchett, M. S. and Hughes, T. P. (2007) Spatial distribution of juvenile and adult corals around Moorea (French Polynesia): Implications for population regulation. *Bull Mar Sci* 80: 379-389.

Piry, S., Alapetite, A., Cornuet, J. M., Paetkau, D., Baudouin, L. *et al.* (2004) GENECLASS2: A software for genetic assignment and first-generation migrant detection. *J Hered* 95: 536-539.

Pritchard, J. K., Stephens, M. and Donnelly, P. (2000) Inference of population structure using multilocus genotype data. *Genetics* 155: 945-959.

Souter, P. and Grahn, M. (2008) Spatial genetic patterns in lagoonal, reef-slope and island populations of the coral *Platygyra daedalea* in Kenya and Tanzania. *Coral Reefs* 27: 433-439.

Souter, P., Henriksson, O., Olsson, N. and Grahn, M. (submitted) Contrasting large scale panmixia and small scale isolation in the coral *Pocillopora damicornis* in East Africa Coral Reefs.

- Starger, C. J., Yeoh, S. S. R., Dai, C. F., Baker, A. C. and Desalle, R. (2008) Ten polymorphic STR loci in the cosmopolitan reef coral, *Pocillopora damicornis*. *Molecular Ecology Resources* 8: 619-621.
- Tanner, J. E. (1996) Seasonality and lunar periodicity in the reproduction of Pocilloporid corals. *Coral Reefs* 15: 59-66.
- Underwood, J. N., Smith, L. D., van Oppen, M. J. H. and Gilmour, J. (2007) Multiple scales of genetic connectivity in a brooding coral on isolated reefs following catastrophic bleaching. *Mol Ecol* 16: 771-784.
- Underwood, J. N., Souter, P. B., Ballment, E. R., Lutz, A. H. and van Oppen, M. J. H. (2006) Development of 10 polymorphic microsatellite markers from herbicide-bleached tissues of the brooding coral *Seriatopora hystrix*. *Molecular Ecology Notes* 6: 176-178.
- van Oppen, M. J. H., Lutz, A., De'ath, G., Peplow, L. and Kininmonth, S. (2008) Genetic traces of recent long-distance dispersal in a predominantly self-recruiting coral. *PLoS ONE* 3(10): e3401 [doi:10.1371/journal.pone.0003401]
- Veron, J. E. N. (2000) *Corals of the world*. Australian Institute of Marine Science, Townsville.
- Wachenfeld, D., Johnson, J., Skeat, A., Kenchington, R., Marshall, P. *et al.* (2007) Introduction to the Great Barrier Reef and climate change. In: Johnson, J. E. and Marshall, P. A. (eds.) *Climate change and the Great Barrier Reef: A vulnerability assessment*. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville (http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/climate_change_vulnerability_assessment/climate_change_vulnerability_assessment)
- Ward, S. (1992) Evidence for broadcast spawning as well as brooding in the scleractinian coral *Pocillopora damicornis*. *Mar Biol* 112: 641-646.
- Zvuloni, A., Mokady, O., Al-Zibdah, M., Bernardi, G., Gaines, S. D. and Abelson, A. (2008) Local scale genetic structure in coral populations: A signature of selection. *Mar Pollut Bull* 56: 430-438.

Conference Program

The MTSRF is a \$40 million hub of the Australian Government's Commonwealth Environment Research Facilities program. The Reef and Rainforest Research Centre is a non-profit, North Queensland based company that manages and delivers the MTSRF on behalf of the Department of the Environment, Water, Heritage and the Arts.

The MTSRF does not fund research for research's sake. Instead, it focuses on using science to develop solutions to the problems facing North Queensland's key environmental assets – the Great Barrier Reef and its catchments, the Wet Tropics rainforests and the Torres Strait.

The 2009 Annual Conference aimed to showcase the many achievements of the MTSRF to date and to facilitate interactions among researchers and end users. The meeting also enabled the synthesis of MTSRF outputs across its Themes and Programs for more effective delivery to end users through targeted engagement activities coordinated by the RRRC.

Presentations marked with an asterisk (*) indicate the presenter is a student.

Day 1 – Tuesday 28 April 2009 – Morning Session

8.00am	Conference registration desk opens		
Water Quality Special Session (Main Room)			
8:30am	Welcome	Richard Ireland, RRRC Chair	Welcome on behalf of the Reef and Rainforest Research Centre
8:40am	Welcome	Manny Ross, Birri Gubba Nation - Bindal Clan	Welcome to Country
9:00am	Speaker 1	Richard Ireland, RRRC Chair	Introduction to the MTSRF
9:20am	Speaker 2	Sheriden Morris, RRRC	Introduction to the Water Quality Special Session and the e-Atlas: Converting knowledge into action
9:40am	Speaker 3	Katharina Fabricius, AIMS	The e-Atlas: A new system to map, access and share data and knowledge on Australia's Tropical Lands and Seas
10:00am	Speaker 4	Britta Schaffelke, AIMS	Spatial and temporal patterns of water quality in the inshore Great Barrier Reef lagoon
10:20am	Morning Tea		
10:50am	Speaker 5	Michelle Devlin, JCU	Comparison and definition of plume characteristics for the Wet and Dry tropics flood events
11:10am	Speaker 6	Thomas Schroeder, CSIRO	Remote sensing of flood plumes in the Great Barrier Reef: Extreme conditions for coastal ocean colour algorithms
11:30am	Speaker 7	Vittorio Brando, CSIRO	Satellite-based water quality (compliance) monitoring in the Great Barrier Reef World Heritage Area coastal and reef waters
11:50am	Speaker 8	Andrew Negri, AIMS	Herbicides and tropical marine organisms: Effects and thresholds
12:10pm	Speaker 9	Martijn van Grieken, CSIRO	Socio-economic consequences of the implementation of agricultural 'Best' Management Practices to improve water quality in the Great Barrier Reef catchment areas: A farm-household modelling approach in the Tully-Murray catchment
12:30pm	Lunch		
1:00pm	Launch of the Rainforest Revegetation Monitoring Toolkit		
1.00pm	e-Atlas metadata briefing session (during lunch)		

Day 1 – Tuesday 28 April 2009 – Afternoon Session

Rainforests Special Session (Main Room)				Water Quality Special Session (cont'd) (Room 2)	
1:30pm	Speaker 1	Steve Turton, JCU	Towards sustainable tropical forest landscapes: issues and challenges in the Wet Tropics region (MTSRF Program 9 Overview)	Kevin Gale, DEWHA	Use of a Multiple Criteria Analysis (MCA) process to inform Reef Rescue regional allocations
1:50pm	Speaker 2	Dan Metcalfe, CSIRO	Status and trends of species and ecosystems in the Wet Tropics rainforests (MTSRF Program 2 Overview) plus Biodiversity condition of the Wet Tropics region	Stephen Lewis, JCU	Assessing the risk of herbicides in the Great Barrier Reef lagoon
2:10pm	Speaker 3	Carla Catterall, GU	Reforestation of the landscape for biodiversity and carbon: Varied outcomes under different approaches	Joost van Dam*, UQ	Testing effects of herbicide on a wider range of coral reef species and possible herbicide-climate interactions on tropical marine species
2:30pm	Speaker 4	Nick Emtage, UQ	Targeting natural resource management policies and programs: A 'prime prospects' analysis of rural landholders' attitudes and practices in the Wet Tropics region of Australia	Fazlul Karim, CSIRO	Quantifying wetland connectivity during and after floods in the Tully-Murray floodplain using hydrodynamic modelling
2:50pm	Speaker 5	Julie Carmody, JCU	Community support for the Wet Tropics of Queensland World Heritage Area	Paul Godfrey, GU	Wetland connectivity as a factor in ecosystem health on the Tully-Murray floodplain
3:10pm	Afternoon Tea				
3:40pm	Speaker 6	David Westcott, CSIRO	Identification and impact of invasive pests in the Wet Tropics rainforests (MTSRF Project 2.6.2 overview)	Sven Uthicke, AIMS	An assessment of the use of benthic foraminifera as water quality indicators in conjunction with the Reef Water Quality Marine Monitoring Program (MMP)
4:00pm	Speaker 7	Frederieke Kroon, CSIRO	Reducing distribution and impacts of invasive fish species using environmental predictor variables	Petra Kuhnert, CSIRO	Reporting credible estimates of loads: Incorporating uncertainty and informing sampling regimes
4:20pm	Speaker 8	Dan Metcalfe, CSIRO	Rainforest threatened species and communities overview plus Fragment Futures: Decline trajectories of fragmented forests, and approaches for conservation prioritisation	Catherine Robinson, CSIRO	Institutional attributes for integrated water quality management in Great Barrier Reef catchments
4:40pm	Speaker 9	Dan Metcalfe, CSIRO	Mapping the distribution and abundance of weeds and feral animals in Far North Queensland	Iris Bohnet, CSIRO	Community visions for the future of the Tully-Murray catchment to reef system: A participatory planning approach informing natural resource management
5:00pm	Speaker 10	David Westcott, CSIRO	In the dead of night all is not what it seems: The resource use of a threatened 'rainforest specialist'	Tim Lynam, CSIRO	Social resilience to water quality change in the Great Barrier Reef region: A model and indicators
5:20pm	Speaker 11	Andrew Maclean, WTMA	The value of MTSRF research for Wet Tropics management	Helen Ross, UQ	Understanding and indicating social resilience factors in the Far North Queensland region
6:00pm	Cocktail Reception Poster Session Introduction to the MTSRF and RRRRC (Sheriden Morris, RRRRC)				

Day 2 – Wednesday 29 April 2009

8:00am	Conference registration opens		
The Great Barrier Reef and Torres Strait			
8:30am	Introduction	Ian Poiner, AIMS	Introduction to the Great Barrier Reef Session: Science informing management of the GBR
8:40am	Speaker 1	Peter Doherty, AIMS	Status and trends of the Great Barrier Reef (MTRSRF Program 1 Overview) <i>plus</i> Progress report on Project 4.8.2b
9:00am	Speaker 2	John Pandolfi, UQ	The history of mortality in Great Barrier Reef coral communities since European settlement
9:20am	Speaker 3	Hugh Sweatman, AIMS	Long-term monitoring of the status of GBR reefs and of the effects of rezoning the Great Barrier Reef Marine Park
9:40am	Speaker 4	Garry Russ, JCU	The effects of the 2004 zoning plan on inshore coral reefs of the Great Barrier Reef: Three years of protection
10:00am	Speaker 5	Michelle Waycott, JCU	Changes in seagrass meadows across the Great Barrier Reef
10:20am	Morning Tea		
10:50am	Speaker 6	Sophie Dove, UQ	Effects of temperature and CO₂ on the physiology of acroporids: Should we be looking beyond bleaching when assessing the health status of corals?
11:10am	Speaker 7	Rob Coles, QDPI&F	Modelling risk to seagrass meadows in coastal waters of the Great Barrier Reef World Heritage Area
11:30am	Speaker 8	Helene Marsh, JCU	Working with key stakeholders to inform the management of marine species of conservation concern (MTRSRF Program 4 overview)
11:50am	Speaker 9	Natalie Stoeckl, JCU	Live-aboard dive boats in the Great Barrier Reef: Their regional economic impact and the relative values of their target marine species
12:10pm	Speaker 10	Andrew Tobin, JCU	Shark catches in the inshore waters of the Great Barrier Reef World Heritage Area
12:30pm	Lunch		
1.00pm	e-Atlas metadata briefing session (during lunch)		
1:30pm	Speaker 11	Colin Simpfendorfer, JCU	Sustainable use and management of marine resources of the Great Barrier Reef (MTRSRF Program 8 Overview) <i>plus</i> Measuring the resilience of coral reef fish using biological data from the Effects of Line Fishing Project
1:50pm	Speaker 12	Arnold Mangott*, JCU	Attraction of dwarf minke whales (<i>Balaenoptera acutorostrata</i> subsp.) to vessels and their swimmers in the Great Barrier Reef World Heritage Area: Management challenges for an inquisitive whale
2:10pm	Speaker 13	Debora De Freitas*, JCU	Spatial assessment of the implications of the 2004 rezoning of the Great Barrier Reef for recreational fishers
2:30pm	Speaker 14	Kirsten Heimann, JCU	Analysis of recorded ciguatera poisoning incidents, distribution and seasonality
2:50pm	Speaker 15	Mike Kingsford, JCU	Abundance, population structure and forecasting risk of exposure to venomous cubozoan jellyfishes
3:10pm	Afternoon Tea		
3:40pm	Speaker 16	Alana Grech, JCU	Communicating with stakeholders builds capacity for spatial management

4:00pm	Speaker 17	Ali Coghlan, JCU	Australians and overseas reef visitors: Are there any differences?
4:20pm	Speaker 18	Vic McGrath, TSRA	Status, use and trends in the Torres Strait (MTSRF Program 3 Overview)
4:40pm	Speaker 19	Steve Whalan, AIMS	Sponge aquaculture in the Torres Strait
5:00pm	Speaker 20	Mark Hamann, JCU	Raine Island and Torres Strait: implications of fewer turtles
5:20pm	<i>Closing remarks</i>	Col McKenzie, AMPTO	Research and industry: an essential partnership
5:30pm	<i>Closing remarks</i>	Piet Filet, WWF	The usefulness of the MTSRF / RRRC for non-government organisations such as WWF
5:40pm	Poster Session (see page 12 for presentations) (cash bar in foyer)		

Day 3 – Thursday 30 April 2009

8:00 am	Conference registration opens		
Climate Change Special Session			
8:30am	Welcome	Russell Reichelt, GBRMPA	What GBRMPA needs to know to manage the GBR as the climate changes
8:40am	Speaker 1	Jozef Syktus, QCCCE	Queensland Climate Change Centre of Excellence (QCCCE): Research directions and challenges
9:00am	Speaker 2	Madeleine van Oppen, AIMS	Climate change threats, ecosystem impacts and mitigation for the Great Barrier Reef (MTSRF Program 5i Overview)
9:20am	Speaker 3	Scott Wooldridge, AIMS	Water quality and coral bleaching thresholds: Formalising the linkage for the inshore reefs of the Great Barrier Reef
9:40am	Speaker 4	Nikolaus Császár*, UTS	Estimating the potential for adaptation of corals to climate change
10:00am	Speaker 5	Ken Ridgway, CSIRO	Downscaling climate change to Heron Island on the Great Barrier Reef
10:20am	Morning Tea		
10:50am	Speaker 6	Craig Steinberg, AIMS	East Australian Current and upwelling influences on the thermal environment of the Great Barrier Reef
11:10am	Speaker 7	Catherine Collier, JCU	Temperature and seagrass death
11:30am	Speaker 8	Linda Tonk, UQ	Symbiodinium diversity on the Great Barrier Reef: biogeography, specificity, and patterns of host community sensitivity
11:50am	Speaker 9	Jeff Maynard, University of Melbourne	Predicting white syndrome outbreaks in northern Australia: Targeted monitoring and informed management
12:10pm	Speaker 10	Steve Sutton, JCU	Toward improved community engagement in climate change mitigation strategies for the Great Barrier Reef
12:30pm 1.00pm	Lunch e-Atlas metadata briefing session (during lunch)		
1:30pm	Speaker 11	Mariana Fuentes*, JCU	How will the largest green turtle population in the world be affected by climate change?
1:50pm	Speaker 12	Donna Green, UNSW	Building resilience and planning climate adaptation strategies in the Torres Strait

2:10pm	Speaker 13	Colette Thomas, CSIRO	An ecological-economic systems model for reef-based tourism in the Great Barrier Reef
2:30pm	Speaker 14	Suppiah Ramasamy, CSIRO	Probabilistic-based climate change projections for the tropical rainforest region of North Queensland
2:50pm	Speaker 15	David Hilbert, CSIRO	Studies of ecological patterns along an altitudinal gradient in the Wet Tropics inform likely changes with global warming
3:10pm	Afternoon Tea		
3:40pm	Speaker 16	Steve Williams, JCU	Towards an integrated framework for assessing the vulnerability of biodiversity to climate change: Prioritising research and adaptation strategies
4:00pm	Speaker 17	Steve Turton, JCU	Impacts of climate change in the Wet Tropics bioregion: Implications for the hydrological regime (MTSRF Program 5ii Overview)
4:20pm	Speaker 18	Mike Liddell, JCU	Climate change research in the Daintree Rainforest: The latest news
4:40pm	Speaker 19	Luke Shoo, UQ	Potential for mountaintop boulder fields to buffer resident species against extreme climatic events
5:00pm	Speaker 20	Ro Hill, CSIRO	Adaptive collaborative regional and local planning as an operational model for biodiversity conservation action: Saving the species of the Wet Tropics
5:20pm	<i>Closing remarks</i>	Allan Dale, Terrain NRM	Summary of the climate change session from an NRM perspective
5:30pm	<i>Closing remarks</i>	Sheriden Morris, RRRC	Presentation of student award, close of conference and thanks

Index of Presenting Authors

- An asterisk indicates the presenting author is a student.
- Links to abstracts are included here beside each presenting author.

A		Grech, A. Spoken	
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Presentation Abstracts

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A shitty thing about climate change: The dung beetle perspective

Marios Aristophanous*

Centre for Tropical Biodiversity and Climate Change, James Cook University
MTSRF [Project 2.5ii.4\(s2\)](#)

Preliminary monthly abundance data shows that some regions in the Wet Tropics harbour a significant quantity of native dung beetles. The manipulation and removal of animal waste, carcass, fruit and fungi by dung beetles provides many key ecosystem services including: reduction of micro- and macro-invertebrate parasites, facilitates nutrient cycling, contributes to soil conditioning and aeration and aids seed dispersal. Climate change may alter the abundance and distribution of dung beetles and so can have significant implications for the maintenance of key ecosystem processes. I provide evidence from the literature that dung beetle communities can be altered from a change in: (1) climatic variables; (2) mammalian community structure; and (3) habitat structure. All three are predicted to change with climate change thus leading to a restructured dung beetle community, which in turn has significant implications for the maintenance of key ecosystem processes.

Dung beetle diversity can also be used as a surrogate for the total biodiversity of an area. Using my future results on dung beetle species richness patterns and by identifying links between dung beetles, climate, mammals and habitat I aim to: (1) Use dung beetles to help identify new or reinforce known biodiversity hotspots within the Wet Tropics; and (2) propose that dung beetles, as a key-stone functional group for proper ecosystem functioning, should be incorporated into an existing Wet Tropics monitoring program since they are easier, more cost and time efficient, and much cheaper to sample than most vertebrate or plant groups.



Distributional modeling of the northern bettong (*Bettongia tropica*) under climate change

Brooke Bateman*, Christopher Johnson, Jeremy VanDerWal and Stephen Williams

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MTSRF [Project 2.5ii.4\(s1\)](#)

The northern bettong (*Bettongia tropica*) is a small endangered rat-kangaroo (Potoroidae) that is restricted to tropical North Queensland; an area that previous research indicates many species will be sensitive to climate change. There is a need to understand what constitutes suitable habitat of the northern bettong, in particular the role that climate has on its distribution. Predictive habitat modelling can be used to model species together with detailed environmental and climatic data to help identify suitable habitat. Such models are often pattern based, and do not incorporate the underlying processes that are actually driving species distributions. These models provide for poor prediction of a species distribution through time and space, including in altering climate scenarios. The incorporation of key

driving factors of distribution, such as food resources, will increase the predictive power of the model. Boosted regression trees and MaxEnt have been used here to integrate predicted suitable habitat models of the northern bettong and its main food resources. In order to fine tune the models, validation will be carried out through field trapping, resource sampling, and environmental surveys within predicted areas. Surveys will be conducted across gradients and boundary conditions and associated with weather data and soil moisture to gain an understanding of the mechanisms driving key resources. This will allow for more reliable predictions on what impact climate change may have on this species, including if known resources may be prevented from co-occurring in areas of suitable northern bettong habitat. The availability of such current and projected models of suitable habitat will aid managers in the conservation of this species.



The surface and acoustic behaviour of coastal dolphins in Queensland



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 MTSRF [Project 1.4.2](#)

Incidental entanglement in gillnets is one of the most serious threats to marine mammals worldwide. In coastal areas, bycatch can have dangerous repercussions on small populations of coastal dolphins. In Queensland Australia, government agencies are implementing different mitigation measures, such as acoustic alarms (pingers) to reduce the risk of entanglement. The response to pingers is species-specific and should be tested before they are implemented with the intent of reducing bycatch. We quantified the behavioural responses of Australian Indo-Pacific humpback dolphins to fixed frequency Fumunda pingers in Moreton Bay, Southeast Queensland using: (1) pre-during-post experiments to record surface and acoustic behaviours in response to pingers, and (2) tracking dolphins around a pinger array to measure changes between days when pingers were active or inactive. Multivariate analysis showed very subtle differences in specific behaviours when pingers were introduced in the water. However, no significant change in movement displacement occurred between days with active and inactive pingers. The study suggests that fixed frequency pingers will be ineffective in deterring Australian Indo-Pacific humpback dolphins from nets, but could affect their short-term behaviour.



Community visions for the future of the Tully-Murray catchment to reef system – a participatory planning approach informing natural resource management

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 MTSRF [Project 4.9.6](#)

The Tully-Murray catchment is located in the Wet Tropics of Australia adjacent to the Great Barrier Reef (GBR) lagoon. Sixty-four percent of the catchment is occupied by World Heritage listed rainforest. On the remaining 36% of the catchment economic pressures on primary industries coupled with the need to improve water quality provide a challenge for farmers, industry, and natural resource managers who have a responsibility to implement the Tully Water Quality Improvement Plan (WQIP). In response to this challenge, a participatory planning approach was chosen to develop community visions for the future of the Tully-Murray catchment which aim to achieve improved water quality as well as multiple

environmental, social and economic benefits. Interviews and workshops with a wide range of community members, including farmers, industry and conservation representatives, school students and indigenous and non-indigenous residents provided information on the social, cultural and economic values of water in the catchment and adjacent reef for inclusion in the Tully WQIP. In addition, the information was used to create a series of spatially explicit land use and management change scenarios, which were assessed and compared with the current situation using a range of agricultural, hydrological, ecological and economic models. Continued participatory planning and evaluation of land use and management change will be critical over the coming years to track progress towards halting and reversing the decline in water quality entering the GBR and to identify and implement further actions if required.



Satellite-based water quality (compliance) monitoring in the Great Barrier Reef World Heritage Area coastal and reef waters

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[Reef Rescue Marine Monitoring Program](#)

Coastal remote sensing can assist efforts to better manage and protect coastal waters by providing comprehensive monitoring capability that can report on the success of management strategies. One such area of application is the trend detection and compliance assessment of water quality objectives set to protect ecosystem health. Previous studies have shown that for the variability in optical properties leads to poor performance of standard algorithms to derive near-surface concentrations of suspended solids chlorophyll a and colored dissolved organic matter for the GBR. To account for the seasonal and spatial variability of the spectral shapes and the magnitude of the Specific Inherent Optical Properties (SIOP), a generic remote sensing algorithm was developed based on the inversion of a semi-analytical model with a variable SIOP parameterisation. The validity of this SIOP driven regional algorithm applied to MODIS data has been assessed using the Great Barrier Reef Long-term Chlorophyll Monitoring Dataset. There is good agreement between the in situ results and our regional algorithm estimates of chlorophyll.

From such valid and accurate daily remote sensed data it is possible to derive management relevant products such as compliance assessments, and alert or anomaly warning systems. Methods to enable the satellite derived information on water quality to be relevant to management of the Great Barrier Reef Waters will be discussed.



Mapping vegetation cover to determine changes in ecosystem service provision in the Wet Tropics



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MTSRF [Project 1.2.1\(c\)](#)

Recent research and public attention have focused on the role that ecosystem services play in maintaining the overall health of the planet, as well as of the economy and well-being of human populations. MTSRF Project 1.2.1 (*'Status and trends of biodiversity and ecosystem services: state of the environment reporting and gap filling'*) aims to map ecosystem services across the Wet Tropics region of North Queensland. We are approaching this process by using the Terrain NRM Resource Condition Targets as surrogates of ecosystem service provision. This poster presents results from the mapping of the first of these targets: "no net loss of native vegetation across the region by 2014". Native vegetation extent in the Wet Tropics region has been assessed to be an important indicator of the condition of the biodiversity asset, and six ecosystem services are supported by this asset. Our mapping of the extent of vegetation cover shows a decline over the period for which mapping is available. This indicates that the target is not being met and raises concerns that ecosystem services are not being maintained in the Wet Tropics region. Results are presented for both the Wet Tropics Management Authority (Wet Tropics Bioregion/Subregions/World Heritage Area, 1988 onwards) and Terrain NRM Ltd (Wet Tropics catchments, 2004 onwards) regions and areas of interest. These results have helped identify and prioritise particular catchments and subregions which require urgent management and action so as to meet the 2014 targets.



Distribution and environmental tolerances of exotic fishes in North Queensland and development of risk assessment methods for predicting invasiveness



Damien Burrows and Alan Webb

Australian Centre for Tropical Freshwater Research, James Cook University

MTSRF [Project 2.6.2\(s\)](#)

The waterways between Townsville and Cairns host more exotic freshwater fish species than any region in Australia, prompting greater public and environmental concern over their impact and further spread. Many more exotic species are available through the aquarium trade and via other, illegal sources that may also become pests in the future if released into our waterways.

This presentation examines the distribution of key exotic fish species in North Queensland and presents the results of a risk assessment methodology for identifying potential future high risk species. The approach adopted here is that species that are successful invaders have different life history and environmental tolerances to those species that are not successful invaders. Delineation of the key life history characteristics and environmental tolerances that separate successful from non-successful invaders then allows data on these key attributes to be used in risk assessment of any new species that might be introduced.

The model tested here thus compared a range of relevant attributes for species that have and have not established. Data on sixteen relevant species attributes were sourced from the literature. The model was run separately for all Queensland waters and for North Queensland waters only. The various model runs predicted attributes that can be used to predict which species are more likely to become invasive with classification accuracy of up to 92%.

For three key predictive attributes – tolerances to temperature, salinity and dissolved oxygen – it was considered crucial to obtain original laboratory-based tolerance data where such data was not available in the literature. Temperature tolerance was tested for sixteen species, salinity tolerance for fourteen species and dissolved oxygen tolerance for fifteen species. Successfully establishing exotic species were tolerant for all three variables, including being more tolerant of acute hypoxia than most native species.



Climate change threats, ecosystem impacts and mitigation for the Great Barrier Reef (Program 5i overview)

M. J. Caley and M. van Oppen

Australian Institute of Marine Science, Townsville
MTSRF [Program 5i](#)

Understanding the potential impacts of climate change on the Great Barrier Reef and management options for minimising its impacts is critical to the long-term sustainable use of this valuable natural asset. The MTSRF Climate Change Program for the Great Barrier Reef (Program 5i) consists of an integrated set of four projects designed to address specific information gaps of direct relevance and importance to users of the Great Barrier Reef and those charged with its sustainable management. The Program is focused on the development of regional climate models and scenarios of future change ([Project 2.5i.1](#)), an early warning and assessment system for thermal stress on the Great Barrier Reef ([Project 2.5i.2](#)), an evaluation of the resilience of coral reef ecosystems to climate change ([Project 2.5i.3](#)), and development of tools to support resilience-based management in the face of climate change ([Project 2.5i.4](#)). This program takes a large-scale, integrated approach in order to understand the best management options for minimising the risks of climate change to these reef communities.



Community support for the Wet Tropics of Queensland World Heritage Area

Julie Carmody and Bruce Prideaux

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MTSRF [Project 4.9.2](#)

The Wet Tropics of Queensland World Heritage Area (WTQWHA) plays a significant role in the life of the North Queensland community for recreational and cultural purposes. Since its establishment in 1990, the Wet Tropics Management Authority (WTMA) has worked with stakeholders of the WTQWHA to protect the forest whilst managing it for the community and visitor recreational access and supporting the traditional owners. Community views on the Area and its management are therefore important. To understand how the community views both the forest and its management the WTMA has funded an ongoing program of surveying community attitudes with the first survey undertaken in 1992. The latest community survey conducted in 2007 shows continued support for the Wet Tropics and its management. Specifically, this paper focuses on the community's awareness of the World Heritage Area;

support for the World Heritage listing; personal and community benefits of living in the bioregion; and levels of support for cultural heritage listing and Aboriginal co-management of the Area.

In 2007 there was a very high level of awareness of the World Heritage status of the Wet Tropics rainforests amongst the community with 92% of respondents indicating that they were aware the Area was World Heritage listed and 82% supported the listing. This strong and continued support for World Heritage listing is tempered with only 7.4% of respondents opposing the World Heritage listing compared to the 2002 survey results (12.4%). As well, support for the inclusion of Aboriginal cultural heritage in a future World Heritage listing re-nomination has grown from 63% in 2002 to 71.8% in 2007 and support for some form of Aboriginal co-management of the WTQWHA has increased from 58.4% in 2002 to 66.0% in 2007. Opposition to Aboriginal co-management has fallen from 30.5% in 2002 to 20.6% in 2007.

The survey asked respondents to consider a range of personal and community benefits that living near the Wet Tropics conferred upon them. Responses were very positive indicating that respondents thought that living in the region had both strong personal benefits as well as significant community benefits by contributing to the community's quality of life, enhancing environmental awareness and protecting the rainforest plants and animals. Overall, the results show that there has been a considerable increase in the level of support that the WTQWHA and its management have enjoyed since community attitudes were first measured in 1992.



Reforestation of the landscape for biodiversity and carbon: Varied outcomes under different approaches

Carla P. Catterall, J. Kanowski and K. Freebody

School of Environment, Griffith University
MTSRF [Project 4.9.5](#)

Restoration of rainforest to formerly-cleared land takes place through a variety of different pathways, including intensive ecological restoration ('biodiversity plantings'), lower-diversity timber plantations, and 'natural' regrowth. Our research has compared the outcomes of different types of tree-planting in the Wet Tropics, and is also investigating the rate of development of biodiversity within ecological restoration plantings. Results indicate that, when restoration plantings are well managed, they develop very rapidly within the first five to ten years, and their performance is superior to timber plantations in terms of not only biodiversity outcomes, but also resilience to cyclone damage, and ability to sequester above-ground carbon. They also have potential timber values, even though they were not designed with harvest in mind. However, the planting techniques which produce these outcomes are relatively expensive, and there can be considerable variation within each type of approach. This talk will review these issues, and consider the relative merits of different approaches to tree-planting as well as the potential for regrowth management as a less-costly, albeit slower, pathway to strategically increase forest cover.



The biology and ecology of *Carcharhinus melanopterus* and implications for management



Andrew Chin* and Colin Simpfendorfer

James Cook University
MTSRF [Project 4.8.4\(s\)](#)

The blacktip reef shark (*Carcharhinus melanopterus*) is a wide ranging reef shark found throughout the world's tropical reefs, including the Great Barrier Reef (GBR). While *C. melanopterus* is one of the most recognisable and commonly encountered sharks in the GBR, little is known about its biology or ecology on the Australian east coast. The species is one of the three shark species most commonly taken in the GBR coral reef line fishery, and is also taken in small quantities in the east coast inshore finfish fishery. Reef sharks are also iconic species in the GBR dive tourism industry. However the available biological data on the species are incomplete and sometimes contradictory. Additionally, the spatial ecology of blacktip reef sharks in inshore environments has not been investigated. This project will investigate the age and growth and reproductive characteristics of *C. melanopterus* in inshore environments in Cleveland Bay, North Queensland. Movement and habitat use in inshore environments (seagrass meadows, mangroves and coastal foreshores and inshore reefs) is being investigated using active tracking, acoustic monitoring and catch data. Sampling has recently begun and data collected to date (n = 66) suggest that *C. melanopterus* is relatively abundant in inshore environments and that a range of sizes (514 mm to 1540 mm) and sexes are present during the summer. Parturition probably occurs during early summer (December) although more samples are required. Tracking has begun and is continuing throughout 2009/2010. Age and growth data will support demographic analysis to inform fisheries risk assessments while data on movement and habitat use will assist managers in assessing how tools such as marine park zoning contribute to management of these species. These data will also increase our understanding the ecological roles and significance of inshore environments to the blacktip reef shark. The project sits within MTSRF Program 4.8 and operates in conjunction with other projects on the fisheries biology of inshore sharks and teleost fishes.



Development offsets in Mission Beach under the EPBC Act: Who is involved and how is it functioning?



Anthea Coggan and Stuart Whitten

CSIRO Sustainable Ecosystems
MTSRF [Project 4.9.6](#)

Development offsets are a tool intended to mitigate biodiversity impacts of development on the environment. Local and state governments as well as regional NRM managers have been exploring the potential for application in far northern Queensland for several years. The 2007 amendments to the *Environment Protection and Biodiversity Conservation Act 1997* (EPBC Act) moved offsets from possibility to reality by formally allowing offset conditions as part of development approvals for proposals impacting ecological communities of national environmental significance. Since this amendment, a number of EPBC Act offsets have been negotiated for developments in Mission Beach. The EPBC Act does not specify a formal process for proposing or considering offsets. In this paper we draw on extensive local and international literature on the theory and experience with offsets to:

- Describe the critical points in offset design and implementation;
- Illuminate the trade-offs in structuring a formal offset process; and

- Recommend a process for ensuring that offsets are cost-effective in protecting biodiversity.

Our conclusions emphasise the importance of biophysical information, transparency, and understanding transaction costs and where they fall within design, implementation and administration of offset schemes.



Australians and Overseas Reef Visitors: Are there any differences?

Ali Coghlan

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MTSRF [Project 4.8.6](#)

Understanding visitor characteristics is essential if destinations are to identify and respond to changes in visitor patterns, their preferences and their level of satisfaction with the destination. Visitors may be segmented in a number of ways ranging from socio demographic characteristics including gender, income and nationality to psychographic factors. One obvious, but not the only method of segmenting reef visitors is by origin, i.e. identifying domestic and international visitors. This segmentation approach has been adopted for this paper and follows the segmentation approach used by Tourism Australia and Tourism Queensland. Based on 5,077 surveys across 26 months' data collection, this study identifies differences in socio-demographic characteristics, travel behaviour and reef experiences between domestic and international tourists.

The percentage of domestic tourists who visit the reef shows variations on a seasonal and spatial basis. From a geographic perspective, respondents in the Southern region of the Great Barrier Reef (GBR) (the Capricorn Coast and the Whitsundays) are more likely to be domestic visitors. During the winter months of July to September the percentage of domestic respondents increases across the entire GBR region. In terms of socio-demographic differences, domestic respondents tend to be slightly older than international respondents, are more likely to be self-employed or professionals, and less likely to be students. Domestic respondents are more likely to travel in family groups or with their partner, and are less likely to travel with friends or alone. They frequently stay in holiday apartments and resorts, whilst international respondents chose to stay in hotels and backpacker accommodation. Visiting the reef was an important motive for visiting the area and achieved a mean of 4.54/5.00, slightly below the mean for international visitors (4.78/5.00). Compared to international visitors domestic visitors gave higher ratings to resting and relaxing (4.26 vs 3.72.) and family-time (3.65 vs 2.87).

Over half of domestic respondents (54%) had previously visited the GBR, whilst 41% had visited other reefs. Only 17% of international respondents were repeat visitors to the GBR, although 47% had visited other reefs. Domestic respondents were more likely to go snorkelling and swimming, but less likely to plan to go diving or actually go diving. They also used the glassbottom boats more frequently, and were more likely to report seeing marine animals during their trip. Their satisfaction scores with the experience were slightly lower than international respondents (8.46 vs 8.51), but they were just as likely to recommend the trip to others and feel they had received value for money as the international respondents.

As global tourism trends continue to shift, we envisage a decline in some traditional international markets visiting the GBR with Japan being the market that is most affected. It is not yet clear if emerging international markets including China and India will replace Japanese visitors, or if the industry will become more reliant on a strengthening domestic market. The results of this research will provide firms and Destination Marketing

Organisations working in the reef tourism sector with intelligence that may be used for marketing campaigns and product development as well as natural resource management agencies insights into different usage patterns of international and domestic visitors.



Modelling risk to seagrass meadows in coastal waters of the Great Barrier Reef World Heritage Area

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MTSRF [Project 1.1.3\(a\)](#)

Seagrass meadows in the coastal waters of the Great Barrier Reef World Heritage Area (GBRWHA) have been surveyed and mapped by the Northern Fisheries Centre since the mid 1980s. These maps have been extremely useful for Marine Protected Area (MPA) planning and coastal management, but their value is constrained by the physical limitations of field surveys and the costs involved. Surveys by their nature provide only a snapshot of the seagrass meadows characteristics in time and are spatially fragmented. It is impossible to survey at all seagrass locations during all times for an area the size of the GBRWHA.

We have employed a Bayesian modelling approach using a composite seagrass layer generated from all seagrass survey data and biophysical information to create a probabilistic surface of seagrass presence and distribution. The model identifies the key drivers of seagrass distribution as tide amplitude and relative exposure. Distributions of seagrass generated by the model differ from survey data and we discuss these discrepancies in the light of our knowledge of seagrass ecology. The modelled surface can be separated into varying probability thresholds and used to audit the protection afforded by present management protective zoning and to locate and identify areas of seagrass meadows exposed to risk from anthropogenic activity.



Temperature and seagrass death

Catherine Collier and Michelle Waycott

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MTSRF [Project 1.1.3\(b\)](#)

Exposure to extremely high water temperatures is common in tropical shallow water seagrass meadows, yet we know little about the importance of water temperature as a driver of changes in growth and seagrass meadow structure. This makes it difficult to interpret monitoring data and to predict the impact of future climate change on seagrass meadows. Temperature loggers deployed at four monitoring sites indicate that intertidal seagrasses are subjected to water temperatures ranging from 14 to 43°C. In addition temperature can vary by as much as 20°C in one day. We experimentally tested the effect of short-term temperature spikes on four species of tropical seagrasses. Water temperature was elevated for ~2.5 hrs to 35°C, 40°C and 43°C for six consecutive days. The physiological and growth responses of *Cymodocea rotundata*, *Halodule uninervis*, *Halophila ovalis* and *Thalassia hemprichii* were compared to plants maintained at ambient water temperature. We also measured the effect that small but long-term changes in water temperature had on the growth, morphology, physiology and sexual reproduction of *C. rotundata*, *H. uninervis* and

T. hemprichii by comparing plants grown at ambient (mean 23.2°C), 27°C and 30°C water temperature for 44 days under controlled light conditions.

The overall findings from both of these studies as they apply to monitoring are, (1) growth rates will increase at warmer water temperatures (27-30°C) and decrease from repeated exposure to short periods at 40°C or greater; (2) after a prolonged period at these temperatures biomass will reduce and this is probably due to higher respiration rates; (3) short-term temperature spikes of 35-40°C cause photosynthetic stress; (4) a change in species composition is likely to occur in response to elevated temperature as the species differed in their responses; and (5) at 43°C the seagrasses can become visibly stressed (turn brown) and die after only 2½ hours but no visible stress is apparent at lower temperatures. In natural conditions, seasonal increases in water temperature are usually accompanied by increases in sunlight and extra light availability may ameliorate some of these impacts. The next important phase of this work will be to investigate the interactive role of light and water temperature on these seagrass species. We will also continue to collect and analyse monitoring data to determine whether these experimental findings are also observed under field conditions.



Use of a Multiple Criteria Analysis (MCA) process to inform Reef Rescue regional allocations

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Caring for our Country – Reef Rescue

Reef Rescue is a \$200 million, five year program that aims to improve the quality of water entering the Great Barrier Reef lagoon by assisting farmers to adopt improved land management practices that reduce the runoff of sediments, nutrients and pesticides from their land. In Year 1 (2008/2009), Reef Rescue indicative funding allocations for each of the six Natural Resource Management (NRM) regions in the Reef catchment were made by the Australian Government based on an analysis of key Reef water quality science. To guide Year 2 Reef Rescue regional allocations, a multiple criteria analysis (MCA) process was conducted.

The MCA process included the development of a decision support model based on the 'assets, threats, solvability' framework. Criteria, including area of coral reef, end of river pollutant loads and area of intensive agriculture per region, were developed to populate the model where there were readily available data sets that provided coverage of the entire Reef or catchment. Reef Rescue stakeholders, including key Reef scientists, NRM bodies and relevant industry peak bodies were invited to make written submissions on the draft criteria. The revised decision support model was further developed at a science workshop. At the end of the workshop, scientists supplied weights for each criterion to generate an MCA score for each NRM region. The outcomes of the science workshop were presented at stakeholder forums for discussion.

The MCA process proved useful for the logical and transparent treatment of a wide range of data sets and facilitated the structured engagement of Reef Rescue implementers with Reef scientists and stakeholders. The MCA process was therefore a valuable mechanism for obtaining scientific and expert stakeholder input to inform the investment decisions. A major limitation of the decision support model was the lack of adequate data sets for solvability

criteria. The outcomes of the MCA process were informative, but not determinative for the allocation of Reef Rescue funds to NRM regions. Final regional allocations were made by the Australian Government with consideration of additional factors, including the quality of the funding proposals received and the institutional capacity of the applicants. We propose that the decision support model should be improved through an iterative MCA process and be used to support adaptive management of the Reef Rescue initiative.



Estimating potential for adaptation of corals to climate change

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⁴ Australian Museum

MTSRF [Project 2.5i.3\(s\)](#)

We have investigated the heritability of thermal tolerance traits in two Great Barrier Reef (GBR) populations of the coral *Acropora millepora*. One population was associated with thermo-tolerant clade D photosymbionts (zooxanthellae) and the other population with thermo-sensitive type C2 zooxanthellae (Magnetic Island (MI) and Orpheus Island (OI) respectively). We report the extent of the heritable genetic contribution (i.e. the broad-sense heritability, H^2) to the performance of two symbiont traits (photosynthetic efficiency – Fv/Fm, and thermo-protection of photosystems via the xanthophyll cycle), one holobiont (whole symbiosis) trait (coral growth rates), and four traits that are largely controlled by the coral host (stress gene expression rates for Ferritin, Hsp70, MnSOD, and Zn²⁺-metalloprotease).

The heritability for Fv/Fm under high temperature (32°C) was significant only for clade D symbionts ($H^2=0.5^*$) as opposed to type C2 symbionts ($H^2=0.3$). This suggests a higher adaptive potential for photosynthetic efficiency in zooxanthellae from the MI coral population. Both symbiont types/clades had an equally high and significant adaptive potential for the protection of photosystems ($H^2=0.53^*$ and 0.54^* for MI and OI, respectively) under temperature stress. Heritabilities for holobiont growth rates were significant for both coral populations, however, they were substantially higher for the MI ($H^2=0.59^*$) than for the OI ($H^2=0.19^*$) population. This suggests that the MI population has a higher potential to improve growth rates under temperature extremes. In either population, however, the coral host has only a limited potential to up-regulate some of its major stress and antioxidant genes. Heritability for expression patterns was only significant for one out of four genes in either population ($H^2=0.18^*$ for MnSOD in the MI population, and $H^2=0.33^*$ for Zn²⁺-metalloprotease in the OI population). These results suggest that the MI coral population has an overall higher potential for thermal adaptation than the OI population, and that the coral host is generally the weaker link in the coral-algal symbiosis in terms of the adaptability of corals to climate change.



Sustainability monitoring of swimming-with-whales tourism in the Great Barrier Reef: Developing objectives and indicators



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MTSRF [Project 4.8.6](#)

A swimming-with-whales tourism industry has developed in the northern Great Barrier Reef (GBR) based on the annual winter migration of dwarf minke whales (*Balaenoptera acutorostrata* subsp.). The sustainability of this tourism activity however is uncertain and there are widespread concerns about the impacts of swim-with programs on cetaceans. The remoteness of these human-wildlife interactions (occurring mostly along the Ribbon and Agincourt Reefs) poses additional challenges for monitoring this activity in the GBR. Effective evaluation of sustainability requires the long-term monitoring of key indicators, matched to clearly defined objectives, which are agreed by all stakeholders within a collaborative management framework. Using a Participatory Action Research methodology, this study evaluates the processes involved in the development of sustainability objectives and indicators for this marine tourism industry. An initial series of draft sustainability objectives were developed, using a Quadruple-Bottom-Line assessment framework, based on relevant literature and with input from scientists studying the whales and their interactions with dive tourists in the GBR. Key stakeholders (including tourism operators, the Great Barrier Reef Marine Park Authority and Queensland Environmental Protection Agency managers, cetacean scientists and representatives of wildlife conservation non-government organisations) were then interviewed to refine the objectives and explore issues relating to their implementation. The objectives were subsequently reviewed and fine-tuned in a series of facilitated stakeholder workshops and the resulting objectives formally agreed by workshop participants. A suite of indicators are currently being evaluated using industry and researcher-generated data, which must be reviewed and approved by key stakeholders prior to their implementation within an adaptive management framework. Outcomes and lessons from this ongoing process will be presented and discussed.



Spatial assessment of the implications of the 2004 rezoning of the Great Barrier Reef for recreational fishers

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MTSRF [Project 4.8.5](#)

In 2004, rezoning of the Great Barrier Reef Marine Park increased the amount of 'no-take' areas from 4% to 33% of the Park area. Recreational fishers are one of the stakeholder groups most affected by the changes in resources access under the new zoning plan. This study aimed to understand and document the spatial effects of the rezoning on recreational fishing activity and recreational fishers. Spatial data of previous and current fishing locations were collected throughout a series of face-to-face interviews that utilised maps to collect information and GIS for archiving and analysis. Indices of fishing displacement and pressure were calculated through spatial statistics analysis. Results suggest that many recreational fishers lost at least one of their primary fishing locations due to the new zoning plan. Most fishers reported compensating for lost areas by fishing more at other areas within the Park.

Fishing effort displaced from the new no-fishing zones tended to move inshore by approximately 25%, and to areas already heavily used by recreational fishers. Findings demonstrate the importance of considering the spatial implications of Marine Protected Area (MPA) zoning on recreational fishers and recreational fishing effort. Careful planning is required to minimize the impacts of MPA zoning on recreational fishers, and to ensure that displaced fishing effort does not negatively impact surrounding areas.



The economics of hunting and its long-term management



Aurélie Delisle*, Natalie Stoeckl and Helene Marsh

James Cook University
MTSRF [Project 1.3.3\(a\)](#)

Indigenous Australians highly value dugongs and marine turtles for their economic, social, cultural and spiritual significance and Torres Strait Islanders are allowed under Australian law to traditionally hunt dugongs and turtles for the purpose of subsistence. Management arrangements that seek to respect all these values will need to ensure the sustainable use of dugongs and marine turtles in the Torres Strait waters and cannot be developed without the strong involvement of Torres Strait Islanders. Optimally, this can be achieved if policy makers are given information on the full costs and benefits (market and non-market) that influence traditional hunting of dugongs and marine turtles in the Torres Strait. The objective of the project is to understand all those values and how they will be affected under the management plans developed by certain Torres Strait communities. The project also seeks to understand some of the extra costs and benefits associated with sea ranger programs that go beyond the management of dugong and marine turtles.



Comparison and definition of plume characteristics for the Wet and Dry Tropics flood events

Michelle Devlin, Jon Brodie, Stephen Lewis, Zoe Bainbridge and Jane Waterhouse

James Cook University
MTSRF [Project 3.7.2\(b\)](#)

Flood plume monitoring has now been carried out in a number of different catchments, (Burdekin, Fitzroy, Tully-Murray and Normandy) with depth and surface data collected through a number of sites over varying time periods. Data has been collected for a range of different parameters, including physico-chemical (salinity, pH, dissolved oxygen), dissolved and particulate nutrients, trace metals, pesticides, CDOM, chlorophyll and phytoplankton samples. This approach has given substantive information on the type of plume signal for each catchment and allows a first attempt at defining plume characteristics for each significant catchment event. This talk will present the details of each plume event, and defines the primary, secondary and tertiary characteristics of each plume related back to catchment. We have used a number of techniques to define the spatial and temporal parameters of plumes including surface water quality data, depth profiling and remote sensed images. The use of improved algorithms for the spatial analysis of chlorophyll and CDOM will be discussed in relation to our understanding of the spatial and temporal plume properties.



Status and trends of species and ecosystem in the Great Barrier Reef (MTRSF Program 1 overview plus progress report for Project 4.8.2(b))

Peter Doherty

Australian Institute of Marine Science
MTRSF [Program 1](#) and [Project 4.8.2\(b\)](#)

MTRSF Program 1 *Status and Trends of Species and Ecosystems in the Great Barrier Reef* consists of just five projects covering the condition of a few key indicators of biodiversity (seagrasses, corals and reef fish) with a focus on change. Two of the projects provide broad-scale monitoring of these selected groups. One of the projects is a definitional search for indicators of ecosystem health and thresholds of concern. Another provides an historical perspective on change in coral communities. The final project strives for synthesis and represents a journey within the MTRSF from a Great Barrier Reef Report Card to an [e-Atlas](#). In addition to the Program overview, I will report on the progress of a project looking into the effects of fishing in deep water habitats that has a direct link to the shallow water monitoring program (of fish and corals) on offshore coral reefs.



Effects of temperature and CO₂ on the physiology of acroporids: Should we be looking beyond bleaching when assessing the health status of corals?

Sophie Dove, Ken Anthony, Simon Dunn, Alicia Crawley, Rachael Middlebrook, Mathieu Pernice and Ove Hoegh-Guldberg

The University of Queensland
MTRSF [Project 2.5i.2](#)

Studying the effects of climate change on coral reefs has become synonymous with understanding the phenomenon of coral bleaching. Possible “adaptations” that inhibit bleaching are presented as a coral’s solution to future climate scenarios. Are we, however, justified in the assumption that a bleached coral is healthy whilst unbleached coral is unhealthy? And what key items are we failing to appreciate when we push forwards the notion that a reef that fails to bleach has successfully evolved to cope with a shift in climate? Here, we link physiology response to bleaching and where possible to long-term outcomes. The results indicate that in the absence of significant constraints the assumption is not valid.



Targeting natural resource management policies and programs: A ‘prime prospects’ analysis of rural landholders’ attitudes and practices in the Wet Tropics region of Australia

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MTRSF [Project 4.9.4](#)

A critical step in designing and implementing improved policies and programs to support improved management of natural resources is the better understanding the diverse nature of rural landholders, their circumstances and attitudes to natural resource management (NRM). The principles of Participatory Social Marketing were applied to examine the results of a survey of rural landholders in the Wet Tropics region of Queensland, Australia. Following the

application of principal component analyses to develop scales representing landholders' attitudes to various NRM issues, a series of indices were constructed to represent landholders' interest in NRM issues and engagement in recommended management practices. These indices were used to classify landholders into a series of groups using cluster analysis. Five separate groups were identified with varying levels of interest in NRM issues and engagement in the use of recommended practices. The groups were then profiled in terms of their socio-economic circumstances, communication behaviour and trust in outside agencies. These profiles are then used as the basis for recommendations on how to best to engage group members to improve NRM practices.



The effects of the 2004 Zoning Plan on inshore coral reefs of the Great Barrier Reef: Three years of protection

Richard D. Evans, David H. Williamson and Garry R. Russ

James Cook University
MTSRF [Project 4.8.2](#)

This report uses a BACIP design to investigate the effects of the new zoning plan on the major fish groups on the inshore coral reefs of the Great Barrier Reef. After three years of no-take marine reserve protection, the new zoning plan has affected the density and biomass of only the target fishery species, the coral trout (*Plectropomus* spp.). No other fish group, species, family or trophic group, has shown any significant change attributable to the establishment of the no-take marine reserves. Regression analysis has demonstrated some temporal changes in a predator-prey relationship that may, in time, indicate a secondary effect of zoning due to the increase of *Plectropomus* spp. density in the no-take areas. Benthic variables, hard coral cover, macro algal cover and structural complexity were not affected by the rezoning. This study has also demonstrated that reduction in live coral cover due to a coral bleaching event has had a larger impact on the fish community structure than the implementation of no-take status.



Application of modelling to *Miconia* management in Australia



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MTSRF [Project 2.6.2](#)

Miconia calvescens is a Class 1 weed in Queensland, Australia. There are only a small number of known infestations in Australia, which motivates hopes of effective eradication. On the other hand, work on frugivory in Australian rainforests suggests that *Miconia* seeds are likely to be spread up to 1,300 metres from reproductive adults. Such broad dispersal of extremely high numbers of long-lived seeds necessitates that management effort be allocated across those areas most likely to be invaded. We present modelling efforts aimed at understanding the spread of managed *Miconia* populations and supporting management in Australian rainforests.

We construct an individual-based model of frugivore-dispersed spread parameterised for *Miconia* in Australian conditions. The model captures the movement, parentage and growth of millions of individuals about the landscape. It accounts for habitat suitability and the movement of frugivores about the landscape. In addition, it incorporates information about

the actions of on-ground managers in their attempts to control known infestations. The resulting model therefore captures likely spread pathways for *Miconia* under current and future management scenarios, helping highlight areas insufficiently protected by current management strategies.



How will the largest green turtle population in the world be affected by climate change?

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MTRSF [Project 1.4.1](#)

Sea turtles are thought to be particularly vulnerable to climate change. Not only are they threatened globally by a range of anthropogenic activities – which reduces their resilience to climate change – but they also have life history traits strongly tied to environmental variables and nest in coastal areas vulnerable to sea level rise and cyclonic activities. Climate change can affect sea turtles in three broad ways, (1) their distribution; (2) foraging ecology; and (3) reproductive output. The broad aim of this study is to explore how sea turtles' reproductive output will be affected by (a) increase in temperature; (b) projected shift in cyclonic patterns; and (c) sea level rise. For this, the northern Great Barrier Reef (nGBR) green turtle population, the largest green turtle population in the world, is used as a case study. Nesting for this population occurs in the nGBR region and in Torres Strait. Our results to date indicate that:

- The sex ratio of hatchlings produced by this population will skew towards females;
- This population's exposure to cyclone disturbance will decrease by 25% by 2070; and
- Thirty-eight percent of available nesting area across all the rookeries used by this population may be inundated as a result of sea level rise.

An assessment of the combined impacts of the three distinct climatic variables on each of the nesting grounds used by this population is being conducted at the moment. This will be extremely important since re-building resilience to the most vulnerable marine turtle populations may require the protection of the most functional nesting areas as climate change progresses.



Wetland connectivity as a factor in ecosystem health on the Tully-Murray floodplain

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MTRSF [Project 3.7.3](#)

The ecosystem health of wetlands on the Tully-Murray floodplain is being investigated with a view to developing indicators of health and thresholds of concern for the Wet Tropics, and as a model for wetlands of the GBR catchment generally. The project has focussed on the relationships between land use, the physical environment, habitat quality, water quality and the aquatic biota, and has aimed to understand the dynamics of basic ecological processes

to underpin development of indicators. It has been determined that a key factor in the ecology of the wetlands is their degree of connectivity – that is, the distances between wetlands, rivers and the estuary, the frequency and duration of floods that connect all wetlands, and the frequency and duration of connections along natural channels and drains. Quantification of connectivity, reported in an accompanying paper by Karim et al. is providing a framework for understanding the dynamics of fish populations and communities, including breeding cycles, recruitment patterns to each lagoon, and eventual make-up of the assemblage. It is clear that understanding of this type of detailed hydroecological information is vital if we are to develop appropriate indicators of ecosystem health, as habitat quality and dynamics are as important to ecosystems as is water quality. We demonstrate that collaboration among scientists across the biophysical spectrum is required for proper understanding of key ecosystem processes.



Understanding and enhancing social resilience: Science and management integration project



Margaret Gooch, Donna Rigano, Hilary Whitehouse, Moni Carlisle*, Snowy Evans* and Renee Craft*

James Cook University
MTSRF [Project 4.9.7](#)

Project 4.9.7 began as a nested project involving three organisations: CSIRO (reef-wide perspective); the University of Queensland (regional or large catchment scale); and James Cook University (JCU) (community scale). The JCU team comprises staff and students from within the School of Education. We undertook a large literature review and interviewed over fifty people with a personal or professional interest in both water quality and education for sustainability. Through these activities, it became obvious that we needed to carefully target our efforts in relation to barriers and opportunities for building resilience at a community level. Thus, we developed three place-based sub-projects to try and operationalise concepts found in the literature about resilience and sustainability. We began our sub-projects with the underlying premise that reducing environmental stresses, through implementation of initiatives such as water quality improvement plans and/or sustainability initiatives in schools and local councils, builds resilience at a community scale. Each community scale project varies in approach, as we have each responded according to the particular circumstances and contexts in which we are working. We are finding common threads emerging from each that we hope will also resonate at other scales, and in other contexts. Two of our sub-projects focus on water planning initiatives, while the third investigates the influence of Education for Sustainability initiatives in school communities. Specific project objectives are to foster positive actions which can result in improved local water quality; to develop a set of indicators of community capacity for stewardship especially in relation to water quality issues for use by communities, natural resource management agencies; to investigate the influence of school-based sustainability initiatives on the resilience of school communities; to investigate the influence of natural resource management (NRM) initiatives on community-scale social resilience.

As a result of our efforts we should see: changes in personal behaviour regarding cigarette butt litter in the Townsville area; better management of sediment and reduction in sediment load into Townsville waterways, especially in the vicinity of new residential developments; greater understanding of how school based educators can contribute to a reduction of local environmental stresses; better arrangements for delivery of NRM management action targets (MATs), especially in relation to water quality; better understanding of community contribution to NRM implementation as participants in policy and not solely as consumers (in

relation to water asset); and increased understanding of NRM in practice, especially in regards to partnership arrangements.



Assessing the habitat quality of remnant and riparian vegetation



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MTSRF [Project 4.9.3](#)

In fragmented landscapes remnant and riparian vegetation may provide valuable habitat for a subset of native faunal and floral species as well as connectivity between larger habitat blocks. However, fragments are subject to edge effects and other disturbances that may diminish the quality of habitat, both for resident species and for transient faunal use as corridors or 'stepping stones' through the cleared matrix. In late 2007, we commenced habitat quality assessments in the urbanizing and agricultural landscape of Mission Beach, northeastern Queensland. We used a novel Anaglyph technique that allows stereoscopic examination on the computer screen to classify aerial photographs flown 6 months after Cyclone Larry into vegetation polygons on the basis of canopy cover and vegetation type. Easily-assessed habitat quality classes were created by combining vegetation quality class with remnant area or riparian width. These combined factors have previously been found to form an excellent surrogate of field-determined habitat quality in rural areas unaffected by cyclones. Field-truthing of the remotely sensed data included rapid transect assessments of vegetation structure and disturbance variables, as well as assessment of microclimate parameters. Bird surveys provided an indicator of faunal habitat quality. We analyse the degree to which the field assessment agrees with the remotely-sensed habitat quality and compare with results of an assessment in a region without cyclone damage. The final outcome of the project will be a map of the region which outlines habitat quality throughout the cleared landscape and suggests priority areas for maintenance and/or restoration of connectivity.



Indigenous Knowledge and the development of Aboriginal enterprises based on natural resource management in the Wet Tropics



Monica Gratani* and James Butler

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MTSRF [Project 2.6.2\(s\)](#)

Many Australian regions face the twin issues of environmental degradation and low well-being level of Aboriginal people. Enterprises based on practices of environmental management traditionally used by Aboriginal communities may represent a solution for both issues: such enterprises can provide incomes for Aboriginal communities and enrich environmental management practices, which are usually based on Western perspectives. By valuing the Indigenous perspective against the prevalent Western perspective this kind of enterprise also encourages the retention of Indigenous Knowledge (IK) associated with traditional environmental practices and its transmission to the younger generation. Despite the advantage of this approach, how to incorporate traditional Aboriginal practices into environmental management plans and actions is still subject to debate and there is no universally accepted procedure. Such outcomes are largely dependent on the institutional frameworks in which environmental managers and indigenous people operate.

An investigation of how to integrate IK and Western knowledge in environmental management, whilst producing economic advantages for disadvantaged Aboriginal communities, is the aim of a CSIRO/JCU/ACTFR 'Focal project' funded by MTSRF. The present project represents a case study of this main focal project and has three main identified aims, (1) to develop a strategy on how to incorporate freshwater management practices of an Aboriginal community of the Wet Tropics in environmental management strategies, with a focus on invasive fish and riparian habitat management; (2) to analyse the institutional framework to enlighten limits to this approach; and (3) to evaluate costs and benefits associated with this approach.

The project is in an early stage. Preliminary results consist in: engagement of the Aboriginal community, development of a collaborative research protocol with the elders of the community, development of the experimental design, attainment of human and animal ethics clearances, review of the literature and desk top analysis of institutional framework. A laboratory experiment to 'validate' one element of the IK has been planned and agreed with the elders. This involves the use of exudates from native plants to capture fish. Further steps consist of involving environmental managers in a social learning framework and conducting a cost-benefit analysis associated with this kind of approach.



Communicating with stakeholders builds capacity for spatial management

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MTSRF [Project 1.1.3\(a\)](#)

In partnership with governments, remote Indigenous communities in Torres Strait are challenged with making a variety of decisions about the management of dugongs and turtles. Because of the primacy of Traditional Ecological Knowledge to Indigenous peoples and the primacy of Western Scientific Knowledge to governments, management of Indigenous sea country including dugong and turtle harvesting must be based on both knowledge systems.

Our first objective was to empower communities in the Torres Strait to work with government in accordance with the National Partnership Approach and make decisions about the management of dugong and turtle by increasing their capacity to integrate their Indigenous Knowledge with information collected by western scientists. To achieve our objective, we conducted GIS and GPS training and community mapping workshops with eight communities participating in the NAILSMA and Torres Strait Regional Authorities (TSRA) Cross-regional Dugong and Marine Turtle Management Project.

Our second objective was to explore with stakeholders the benefits of and challenges associated with using spatial closures as one of the tools for community-based management of dugongs and turtles in the Torres Strait. We conducted a workshop in October 2008 with the TSRA, dugong and turtle project officers, and representatives from NAILSMA and DEWHA. The workshop consisted of presentations on: TUMRAs, legal issues associated with spatial closures, spatial closures as a management tool for dugongs in Torres Strait, tools for managing sea turtles in Torres Strait, the history of the Torres Strait Dugong Sanctuary, how the information required for spatial closures could be managed in a GIS, and an update on ranger programs in Torres Strait. Group exercises included discussions on: a 10 year vision for the turtle and dugong fisheries in Torres Strait, features of an effective dugong and turtle management tool, spatial closures in the context of customary tools for managing turtles and dugongs in Torres Strait, the strengths and weaknesses of the Dugong Sanctuary, and lessons learned from the workshop. Outcomes of the workshop included

building capacity for spatial management of dugong and turtle in Torres Strait and an increased mutual understanding between researchers, Torres Strait Islanders, and Government agency staff.



Building resilience and planning climate adaptation strategies in the Torres Strait

Donna Green

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MTRSF [Project 1.3.1](#)

Torres Strait Islanders are concerned about how climate change will impact their ability to live on their land in the near future. These concerns relate to direct biophysical impacts – such as storm surge inundation, to indirect impacts – such as increases in certain vector borne diseases, e.g. dengue fever. This presentation will discuss the progress of the first year and a half of the MTRSF-funded project Building resilience and planning adaptation project that seeks to encourage culturally appropriate adaptation strategies by documenting traditional knowledge of past adaptation strategies to inundation and environmental change. To date this project has run several climate impact workshops on the Islands, developed educational posters and compiled a scientific paper that brings together the current state of the science for this region. The project has also begun video knowledge recording on several of the Islands. With local Islander engagement to build local capacity, this stage in the project aims to enable cultural knowledge to be recorded both for future generations to access, and also to inform climate adaptation strategies.



Raine Island and Torres Strait: Implications of fewer turtles

Mark Hamann

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MTRSF [Project 1.4.1](#)

Raine Island, a small coral cay in the northern Great Barrier Reef, is the most important rookery for the largest green turtle population in the world. This coupled with its global importance as a sea bird rookery and place of significant Australian indigenous and modern heritage makes it one of the most significant islands in Australia. However over the last decade research groups from the Queensland Parks and Wildlife Service have noticed declining nesting success of female turtles and consequently fewer hatchlings being produced. Several causes have been speculated, but not empirically tested. Among these are changes to the islands reef structure, hydrology and geomorphology. Needless to say the issue has become of interest to many sectors of community, especially Indigenous people in northern Australia and Government agencies. In 2007 we initiated a project to (1) investigate whether other islands for the green turtle population were showing similar declines in nesting success and hatchling production and (2) begin a population scale assessment on island geomorphology and climate change. We have found that hatchling production at Torres Strait green turtle rookeries is variable, but higher than Raine Island. At foraging areas we have found low juvenile recruitment into the population and a possible shift in the genetic structure of juvenile turtles. Importantly, our work with Torres Strait Islanders indicates that their access to turtles for cultural purposes could be extremely compromised should management intervention not be undertaken. In this talk I will provide an overview of the issue from the perspective of researchers interested in both species ecology and maintenance of livelihoods of Indigenous people. I will discuss the most recent data and

research directions and consider the implications for Torres Strait Islanders and the short and long term implications for the green turtle population.



Insights to *Miconia calvenscens* invasion in Australia through genetic inference



Britta Denise Hardesty, Suzanne Metcalfe, Helen Murphy and David Westcott

CSIRO Sustainable Ecosystems, Atherton
MTSRF [Project 1.4.3](#)

Miconia calvenscens was listed as a Class 1 pest under the Land Protection Act of 2002 in Queensland, Australia, due to its highly invasive status and the degree of ecological damage it has been known to confer in tropical systems. The CSIRO is working with management teams that are actively eradicating *M. calvenscens* and we are spatially mapping and collecting leaf material from a large number of samples across multiple infestation sites, wherever possible. In conjunction with modelling efforts and understanding life history parameters that may assist in the spread and persistence of *M. calvenscens*, we are using molecular tools to understand the invasion process of this transformer species. Genetic diversity within individual populations is remarkably low, which is consistent with nearly complete self-pollination leading to high levels of reproductive success (i.e. seedling recruitment). While genetic diversity in *M. calvenscens* is low across Australia, we find novel alleles and similar genetic diversity to that observed in Tahiti, Hawaii, and New Caledonia populations, where *M. calvenscens* has occurred for a much longer period. Furthermore, we are inferring the number of different introduction events based upon genetic signatures. We are also comparing genetic diversity of *M. calvenscens* with other invasive Melastomes in the wet tropics region to understand whether genetic bottlenecks constrains invasion in these weedy species.



Estimating population numbers of threatened species using molecular approaches



Britta Denise Hardesty, Suzanne Metcalfe, Dean Jones, Adam McKeown and David A. Westcott

CSIRO Sustainable Ecosystems, Atherton
MTSRF [Project 1.4.3\(a\)](#)

Successful management of threatened species is almost always reliant on information derived from field studies of populations of distinguishable individuals. This information includes ranging patterns, life-history parameters and population sizes and trends. For cryptic species such as the Southern Cassowary, collecting such information using traditional field ecology methods has proven challenging. With recent technological advances, the application of molecular markers to the remote identification of individuals based on faecal material and shed tissues, e.g. feathers, has become increasingly feasible and cost effective. We have recently trialled a genetic fingerprinting approach to identify individual cassowaries from across their Australian range based on faecal DNA. We are able to extract DNA from fresh faecal material and use sex-specific and microsatellite markers to distinguish among individual birds. This enabling technology has the potential to make a range of detailed ecological and behavioural studies possible. We describe its application to monitoring population trends at a variety of spatial scales as well as to studies of population processes.



Life history of two species of hammerhead sharks from the inshore region of the Great Barrier Reef World Heritage Area



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MTSRF [Project 4.8.4](#)

Sphyrna lewini and *Sphyrna mokarran* (Carcharhiniformes, Sphyrnidae) are two large, wide-ranging species of shark that occur in tropical to warm-temperate seas circumglobally. Both occur throughout Queensland waters and together they make up approximately 30% of the total shark catch in the Queensland East Coast Inshore Finfish Fishery. The life history of *S. lewini* has been studied extensively in other parts of the world, with parameters showing considerable variation between different regions. Few studies have focused on the life history of the less abundant *S. mokarran*. The primary objective of this study was to determine age and growth parameters for both species in Australian waters – specifically growth rate, age at maturity and maximum longevity. Additional objectives were to determine the reproductive parameters of *S. lewini* and *S. mokarran* particular to Queensland waters – specifically size at 50% maturity, size at birth, fecundity, and timing of the reproductive cycle. Overall, the study aims to provide sound life history data upon which future stock assessments and risk assessments can be based. Vertebral and reproductive samples were collected using fishery-dependent sampling by placing observers on-board commercial gillnet vessels between Princess Charlotte Bay and Hervey Bay. Age validation has been attempted using a fishery-independent mark, tag and recapture study in Cleveland Bay. Preliminary results of this life history study are presented.



Analysis of recorded ciguatera poisoning incidents, distribution and seasonality

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MTSRF [Project 2.6.1](#)

Two existing, publicly accessible information sources were examined for their ability to provide analysable information on ciguatera incident distributions (nationally and globally), the potential seasonality of outbreaks, the identification of high-risk ciguatera fish groups, and their potential to define trophic links between ciguatera-causing dinoflagellates, lower order trophic vectors and ultimately fish. The sources were, (a) reports published by the OzFoodNet Working Group between 1995 – March 2008; and (b) the fishbase.org database which incorporates ciguatera information gathered by the South Pacific Commission (SPC, now known as the Secretariat of the Pacific Community). The study confirms that these information sources are by and large suitable for geographic analyses of ciguatera outbreaks and the identification of high-risk fish groups. However, the current data sets provide little information on seasonality of outbreaks or trophic transfer routes. In particular, distribution and abundance patterns of ciguatera-causing dinoflagellates and lower order trophic vectors cannot be established using these data sources. This highlights the need to establish a publicly accessible super database to collate all available information. We propose designing upgraded ciguatera questionnaires to source required detailed information such as months of outbreaks, local knowledge of risk areas, temperature at times of incidents. It is essential to superimpose seasonal abundance and distribution patterns for all trophic participants in ciguatera transmission, to obtain a clear image of risk areas at a seasonal and geographic

scale. To achieve this aim, the project will need to be well funded for a period of at least five years and will require interdisciplinary and inter-institutional collaborations.



Studies of ecological patterns along an altitudinal gradient in the Wet Tropics inform likely changes with global warming

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MTSRF [Project 2.5ii.3](#)

Funding from the Marine and Tropical Sciences Research Facility enabled the establishment of twelve rainforest monitoring plots in the central Wet Tropics at elevations from 30 to 1,200m. The plots are 0.1 hectare in area, differ in altitude by approximately one hundred metres, and with two exceptions, occur on oligotrophic substrates. The plots were surveyed, permanently marked and all trees >10cm diameter were recorded, given a unique identification tag and spot painted so that the diameters could be re-measured at the same point in the future. Full vascular plant surveys were also completed in all plots. Leaf herbivory rates were also quantified in nine of the plots in late 2008.

Several clear ecological patterns are evident that correspond to changes in mean annual temperature across the plots. As mean annual temperature increases (decreasing elevation), forest basal area decreases, tree species endemism decreases and leaf herbivory increases. The cooler upland forests tend to have more very large trees than the warmer lowlands. Tree species richness and tree density do not change along the temperature / altitudinal gradient. These observations suggest a number of likely responses to global warming in the Wet Tropics' forests, including reduced basal area (C stock), increased leaf herbivory rates and possible expansion of generalist lowland species, with concomitant decreases in more cool-climate adapted upland endemics.



Adaptive collaborative regional and local planning as an operational model for biodiversity conservation action: Saving the species of the Wet Tropics

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MTSRF [Project 4.9.6\(b\)](#)

The challenge of developing operational models for the implementation of biodiversity conservation plans remains urgent, with recent recognition that more than two-thirds of conservation plans in the scientific literature have not resulted in real-world conservation actions (Knight *et al.* 2008). On the other hand, many plans that have been implemented have not benefited from the full integration of up-to-date scientific research. In the wet tropics, a globally significant biodiversity region, the 2005 regional natural resource management (NRM) plan achieved an unprecedented level of alignment between the over one hundred plans and strategies for aspects of biodiversity conservation in coasts, catchments, local government areas, endangered species, national parks and world heritage areas. An operational approach for implementation of this NRM plan based on local-scale adaptive collaborative biodiversity planning has since been developed through a case study. However, the biodiversity of the wet tropics is particularly sensitive to climate change, and the recommended response requires a regional-scale approach (Wet Tropics Management

Authority 2008). The Australian Government's new environmental policy *Caring for our Country* also identifies the need for a regional-scale response to achieving conservation of the numerous threatened biota in the wet tropics. Knight *et al.* (2006) suggest three foundations to effective operational models for biodiversity conservation: (1) empowering individuals and institutions; (2) ensuring systematic conservation assessment; and (3) securing effective action. The regional initiative "saving the species of the wet tropics" is piloting an operational model that responds to these aspects through: (1) a collaborative focal species approach, incorporating the cultural keystone concept, to recognise multiple human values and empower individuals; (2) brokering as the explicit means of building institutional capacity; (3) systematic assessment through a fine-scale interactive biodiversity mapping package; and (4) securing effective actions by multiple local biodiversity adaptive collaborative planning initiatives. The results from this initiative, measured through both program and on-ground monitoring, will help to develop the theory and practice of implementing biodiversity conservation in the real world.



Quantifying wetland connectivity during and after floods in the Tully-Murray floodplain using hydrodynamic modelling

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MTSRF [Project 3.7.4](#)

The connectivity between a wetland and other water bodies in the floodplain is a major determinant of its habitat quality and ecological condition. In this study, connectivity was quantified both during and after floods using hydrodynamic models to calculate the timing, duration and spatial extent of the connections between ten different wetlands in the Tully-Murray floodplain. Connectivity during floods was estimated using the 2-D MIKE 21 hydrodynamic model. Once the flood waters had receded, connectivity via the network of streams and sugar cane drains on the floodplain was estimated using the 1-D Mike 11 hydrodynamic model. The location and size of the wetlands and the extent and size of the stream and drain network were quantified using high resolution LiDAR data. Connectivity between the wetlands and the Tully and Murray Rivers was assessed for the flood events of one-year and twenty-year recurrence intervals. Post flood connectivity was estimated throughout the wet and dry seasons during 2007. The results of these simulations provide a means of identifying the degree of connectivity of different wetlands, ranging from those wetlands that are more permanently connected with streams and drains to those that are connected only when there are overbank floods.



Abundance, population structure and forecasting risk of exposure to venomous cubozoan jellyfishes

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 MTSRF [Project 4.8.7](#)

Envenoming jellyfish are found in tropical waters of Australia. Although there are multiple cubozoan species, little is known of the ecology of stingers or species causing Irukandji Syndrome. Our approach has been to use ecology, genetics and elemental chemistry to provide greater resolution of the ecology of jellyfishes with the intention of reducing risk of exposure to the public. Here we report on cross-shelf patterns of distribution of cubozoans attracted to lights in 2008 and 2009. Jellyfishes were sampled near reefs at inner, mid and outer distance strata across the Great Barrier Reef and at multiple latitudes. In addition, we have used spatially and temporally explicit sampling designs to sample stingers in near shore waters. Patterns of abundance suggest highly localised concentrations and we expect to elucidate these patterns further with microsatellites and elemental chemistry of the statoliths. Outcomes of the research will include risk maps, the sophistication of which will increase with knowledge.



In the dead of night all is not what it seems: The resource use of a threatened 'rainforest specialist'

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 MTSRF [Project 1.4.3](#)

Pteropus conspicillatus has the dubious distinction of being listed as a threatened species as well as being widely considered to be a pest and a threat to human health and safety. Key to understanding the species' management needs, as well as the causes of its conflict with humans is knowledge of its habitat requirements and use. Traditionally the species is thought to be rainforest specialist and is managed based on this assumption, however, recent studies suggest that it uses a wide range of habitats. In this work, we used stable isotope analysis to examine the contribution different habitat types make to the assimilated resources of this highly mobile species. We classified vegetation into broad habitat types which were distinguishable based on the isotopic signatures. The long-term isotopic signatures exhibited by a hundred *P. conspicillatus* suggest that far from relying on rainforest resources, *P. conspicillatus* utilises resources from a broad range of habitats including orchards, mangroves, wetlands and sclerophyll forests. Across all of the scenarios considered, the contribution of rainforest remained relatively constant and in the vicinity of 35% of assimilated resources. A range of non-rainforest habitats provided the remainder. These results, and their application to the management of a threatened species, a pest and an airport, highlight the risks of relying on 'current knowledge' in environmental management; sometimes we really do need to know more.



Reducing distribution and impacts of invasive fish species using environmental predictor variables

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MTSRF [Project 2.6.2](#)

Understanding the distribution and abundance of invasive fish species in landscapes enables prediction of those landscape features that may drive invasion. Specifically, the ability to spatially predict presence and abundance of invasive fish in landscapes based on (combinations of) environmental variables can be used to (i) highlight the most probable locations for inspection and remediation, and (ii) provide recommendations for landscape rehabilitation and management to prevent and reduce spread. Our project attempts to identify those environmental variables that can be used to predict the (potential) distribution and abundance of invasive fish in the Wet Tropics bioregion. To this effect, we are modelling the relationship between environmental variables and presence/ abundance of invasive fish at stream, sub-catchment and regional scales. The data underpinning this effort are derived from past and new field collections, as well as from available spatial data on landscape features.

First, our project has provided a proof-of-concept the presence of invasive fish can be predicted based on environmental variables at individual sampling locations in three Wet Tropic streams. Second, data on environmental variables and fish presence and abundance at a sub-catchment scale have been collected in the Mulgrave catchment and are currently being processed and analysed. Third, at the regional scale, we have collated spatial data on landscape features, including an audit of fish barriers in the Wet Tropics bioregion, to commence our regional analysis. We believe that the outcomes of this combined field work and modelling exercise will contribute significantly to the development of targeted management strategies to control, contain and prevent spread of invasive fish species at the landscape level in the Wet Tropics bioregion.



Reporting credible estimates of loads: Incorporating uncertainty and informing sampling regimes

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MTSRF [Project 3.7.7](#)

Estimating loads is not a new topic. There are numerous load estimation methods available, some of which are captured in various online tools. A primary problem with the way in which loads are reported is that the measured uncertainty is difficult to calculate. Without it, the load estimate is difficult to interpret, trend detection is difficult to determine and sampling regimes are almost impossible to assess. We propose a statistical framework for incorporating uncertainty in the form of bias due to the way in which concentration and flow are measured. Where there are sufficient data, we propose an extension to the popular regression approach that incorporates uncertainty and includes additional predictor variables which capture unique features in the flow data, namely the concept of a “first flush”, the location of the event on the hydrograph (e.g. rise or fall) and a weighted cumulative flow where the weighting is based on the time lag between events. The approach will be demonstrated on two case studies, the Burdekin and Tully catchments.



The e-Atlas: A new system to map, access and share data and knowledge on Australia's tropical lands and seas

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MTSRF [Project 1.1.5](#)

The objectives of the e-Atlas are to develop the tools and mechanisms to, (1) provide a web-based portal to access and contribute data, metadata and information (<http://e-atlas.org.au/>), and to (2) map and visualise spatial data sets and the outcomes of spatial analyses. The e-Atlas is based on an open-source philosophy, with the e-Atlas team developing the tools, and the experts (data owners) contributing the content. The primary components of the e-Atlas are now ready and can be populated by experts, although some aspects of the system still require further refinement. Twelve of the most important Great Barrier Reef (GBR) data sets comprising over six hundred variables (layers within the e-Atlas) have been compiled and uploaded as maps, reports and text pages. The metadata system is easy to use and compliant with Australian standards hence fulfilling MTSRF metadata requirements. The backbone of the system are the (1) tools so users can upload data, metadata, reports, create web pages and add images without having technical or programming knowledge, (2) interactive mapping system (including side-by-side mapping and panning of several data sets), (3) statistical tools for spatial interpolation of point data and to relate data, (4) automated work flow system, and (5) incorporation of data feeds from external mapping servers. Experts are responsible for which topics are covered and for the accuracy of the information they contribute, but uploads will be screened by the e-Atlas team for appropriateness before publication. The long-term success of the e-Atlas will depend on user uptake, and we are seeking feedback to make the system as user-friendly and useful as possible for our target audience, namely scientists, managers, NGOs, industry and the informed public.



Assessing the risk of herbicides in the Great Barrier Reef lagoon

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MTSRF [Project 3.7.2](#)

Several herbicide residues (e.g. diuron, atrazine, ametryn, hexazinone, tebuthiuron) have been commonly detected in waterways of the Great Barrier Reef (GBR) catchment area and in the GBR lagoon. Concentrations of some herbicides exceed lowest observable effect levels for relevant marine plants and also exceed locally derived marine ecological trigger values developed for the GBR. However, the risk of herbicide runoff to the GBR is poorly quantified due to a lack of monitoring/modeling data of herbicide loads and concentrations delivered to the GBR, a lack of ecotoxicological studies, and relatively poor knowledge of the cumulative/synergistic effects of various combinations of herbicides (and coupled with other contaminants such as elevated nutrients, etc.).

We will present a simple model to quantify herbicide loads from the GBR catchment area and normalize these data to produce a toxicological equivalent (based on marine plankton studies) herbicide load. Therefore we can model the GBR catchments which have the highest risk to marine ecosystems. We then use these modeled data to compare with available catchment monitoring data to validate the model and examine its limitations.

Finally we normalise flood plume concentration data (to a toxicological equivalent for marine plankton) of herbicide samples collected in the Great Barrier Reef lagoon to determine the areas of highest risk in the Great Barrier Reef lagoon.



Climate change research in the Daintree rainforest – the latest news

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MTSRF [Project 2.5ii.2](#)

The lowland rainforests in far northern Queensland are expected to become stressed under the new climate conditions predicted for 2050-2080. How this stress will reflect itself in the forest biodiversity of the region requires an in depth understanding of forest performance. MTSRF Project 2.5ii.2 is carrying out a long term detailed study in a typical lowland rainforest site (Cape Tribulation) where early results have indicated that water availability in the drier and hotter months of the year are important in allowing the forest trees to perform at normal levels. Isotopes and leaf-level measurements have indicated that not all trees are able to cope with water stress in a similar fashion. Leaf litter beetle abundance has been correlated with litter abundance which has in turn been correlated with climatic conditions. Hence there is a cascade of events that are driven at the outset by the changes in the incoming rainfall. Monitoring the changes in the water availability in the soil profile has shown that the forests are highly reliant on surface water. New results will be presented from the phenology project which is working at the SkyRail site as well as the James Cook University Canopy Crane site. The flux sub-project is also now working at two sites, the canopy crane site and the Discovery Centre at Cape Tribulation. In both these sub-projects there is a strong coupling developing between the tourist operation and the research teams, results are made available to the public in some cases in real-time, helping involve the public in the science that is underpinning our understanding of potential climate change effects on these forests.



Sponge diseases in the Torres Strait and Great Barrier Reef

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MTSRF [Project 1.3.2\(s\)](#)

Sponges form a highly diverse and significant component of benthic communities, often aiding in important functional roles such as bioerosion, consolidation and benthic-pelagic processes. Therefore, the loss of sponge communities can have significant impacts on the surrounding environment. Previous disease epidemics throughout the Caribbean and the Mediterranean caused widespread sponge mortalities. To date, the Great Barrier Reef (GBR) and Torres Strait have not experienced the catastrophic mortalities observed in other places; however, anecdotal reports suggest an increasing prevalence of sponge disease in these regions. Based on these reports, *lanthella basta* was selected as a model species to investigate sponge disease on the GBR and Torres Strait. Disease prevalence surveys were conducted at sites around Masig Island (eight sites) and the Palm Islands (twelve sites). Surveys from both locations revealed relatively healthy communities, with 50-75% of the sponges showing no signs of disease. However, sponges displaying some signs of disease

were recorded at every site, with a higher percentage of sponges showing more advanced stages of disease found in Torres Strait. Initial signs of disease in *I. basta* include discolored, necrotic spots in which sponge skeletal fibers are just becoming apparent. Sponges in advanced stages of disease exhibit tissue degradation with completely exposed skeletal fibers and, in some cases, increased fouling. With the proposed additions of commercial sponge farms in Torres Strait and the GBR, the need to understand disease processes in sponge populations is vital. Outputs from this study will be beneficial to marine managers in constructing risk assessments for sponge disease onset and transmission.



Social resilience to water quality change in the Great Barrier Reef region – a model and indicators

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CSIRO

MTSRF [Project 4.9.7](#)

We do not know how either water quality changes in the Great Barrier Reef (GBR) region or the corrective actions policy or management agencies take to improve water quality, will positively or negatively impact the people and communities of the region. What, for example, are the likely social implications of investments of the order of \$125 million in the Mackay-Whitsunday region to achieve water quality objectives? What are the likely social implications of Queensland government's proposal to regulate water quality management if market-based incentive schemes do not work? Of interest to practitioners in the region, and hence the focus of this project, is the concept of social resilience, or the degree to which social systems can absorb change whilst retaining or improving their essential structure, function or identity. We used three information sources to develop a conceptualisation or model of social resilience: available theory, documented case studies and end user perceptions. In the paper we describe our conceptual model and also show how the conceptual model is consistent with the case study data and user perceptions. We then describe a Bayesian Belief Network (BBN) model of social resilience and discuss how the model may be used and improved. Finally we discuss caveats and next steps in the process of developing and using theoretically robust and practically useful models of social resilience for use in the GBR region.



The value of MTSRF research for Wet Tropics management

Andrew Maclean

Wet Tropics Management Authority

The MTSRF program has enabled the continuation of a strong tradition of world-leading rainforest research in the Wet Tropics World Heritage Area and the surrounding bioregion. The Wet Tropics Management Authority (WTMA) has, since its establishment, played an active role in research coordination and communication and intends to continue and further develop this role. The research legacy MTSRF builds on reflects the outstanding significance of the World Heritage Area and the need to ensure we are well equipped with information to monitor and manage pressures and impacts arising from human uses and climate change. Continuing investment is vital if Australia is going to demonstrate to the World that it is meeting its obligations under the World Heritage Convention.

As the final year of the four-year MTSRF investment approaches and work is underway on a possible future investment, it is timely to reflect on what we have learnt in implementation of

MTSRF and how we can make improvements that will ensure any future investment provides even further value to management agencies like WTMA. The fundamental concept of MTSRF – that of solutions based research – remains relevant and important for any future investment aimed at assisting improvement of policy and management practice. Also important is delivery through a regional project management, coordination and communication hub. This will enhance uptake and relationships between research providers and users.

Areas for future improvement or particular attention include ensuring widespread and effective engagement of researchers, management agencies and stakeholders in the establishment of research investment priorities; project design that facilitates engagement between researchers and managers, including adaptive management approaches; greater involvement of management agencies in the communication of research findings relevant to their responsibilities; and clearer links between policy and management problems and associated research programs so that uptake logic is widely understood.



Understanding and indicating social resilience factors in the Far North Queensland region

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MTSRF [Project 4.9.7](#)

The concept of resilience in social-ecological systems has attracted considerable interest as a foundation for natural resource management at regional scales, yet there is a distinct knowledge gap when it comes to the social dimensions of resilience. Meanwhile social and health sciences have developed a strong understanding of personal resilience, but this is yet to be scaled up for communities and regional-scale use, and does not recognise ecological and economic connections. Our initial views on social resilience are that it relates to how individuals, communities and societies adapt, transform, and potentially become stronger when faced with environmental, social, economic or political challenges. Our project's challenge is to understand the nature of the social dimensions of resilience in Far North Queensland, in the context of this region's many social-ecological systems, then to develop indicators of resilience to assist our partners in their planning, investment, management and reporting.

This presentation reports the results of three sub-regional case studies of social resilience within two Far North Queensland catchments. These case studies are part of a four year MTSRF project being conducted in collaboration with Terrain NRM Ltd, the Wet Tropics Management Authority, Great Barrier Reef Marine Park Authority, Rainforest Aboriginal Advisory Committee (to the Wet Tropics Management Authority) and Giringun Aboriginal Corporation. Here catchment management challenges are compounded by the diversity of social-ecological systems, involving urban, rural, extractive, production, protection and multiple use landscapes, associated with a rapidly growing population and high levels of tourist visitation.

The case studies explore the nature of the local social-ecological systems and social resilience factors. Approximately thirty stakeholders were invited to describe how they and their communities or organisations met the challenge of a specific event or process that impacted upon their resource base or livelihood. These case studies focus on include: the restructure of the dairy industry in the upper Johnston catchment area; the most recent outbreak of the crown of thorns starfish on the Great Barrier Reef area off Cairns; and urban expansion to date in the Cairns region. Participants emphasised, for example, innovation,

networks, leadership, and knowledge sharing as central to their ability to cope with the challenges. Indicators will need to reflect these qualities, in a way that is relevant to this region. An understanding of social resilience factors will assist far North Queensland to take an innovative and integrative approach to planning, and to prepare for climate change and other major challenges. Investment in the resilience of individuals, groups and organisations should enhance societal adaptability and transformation in the face of regional change.



Attraction to dwarf minke whales (*Balaenoptera acutorostrata* subsp.) to vessels and their swimmers in the Great Barrier Reef World Heritage Area – management challenges for an inquisitive whale

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MTSRF [Project 4.8.6](#)

Swim-with cetacean tourism is increasing rapidly throughout the world. Negative behavioural impacts on cetaceans associated with whale watch and swim-with tourism industries have been identified for odontocetes; little is known about the potential impacts of such industries on baleen whales. A diffuse aggregation of dwarf minke whales occurs in the northern Great Barrier Reef World Heritage Area (GBRWHA) during the austral winter months. The whales voluntarily approach dive tourism vessels and their passengers and maintain contact for several hours. This study investigated the distribution of interacting whales around the vessel and examined the passing distances of individual whales to swimmers in order to explore potential short and longer-term behavioural changes. The whales clumped around the boat, surfaced significantly more often within a sixty metre radius of the vessel than expected, and aggregated around swimmers. The mean whale-swimmer passing distance was 6.8 metres and individual whales significantly decreased their passing distance over both the course of an in-water interaction and over the seven week research period. In both cases approach distance was significantly influenced by group size; the larger the group, the closer individuals approached. Increased familiarity with the vessel and swimmers also positively influenced approach distance. The inquisitive behaviour of dwarf minke whales contrasts with most free-ranging wildlife interacting with humans. The closeness of their approaches, the prolonged contact and the change in behaviour with increased familiarity with vessels and swimmers raises concerns about habituation, and presents several challenges for the sustainable management of this industry.



Working with key stakeholders to inform the management of marine species of conservation concern (MTSRF Program 4 overview)

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MTSRF [Program 4](#)

The marine component of Program 4 aims to work with end users to contribute to inform the management of marine wildlife of conservation concern in the Great Barrier Reef and Torres Strait, with an emphasis on sea turtles, dugongs, coastal dolphins and minke whales. The marine program comprises two projects that aim to: (1) enhance information on the condition, trends and projected futures of sea turtles and dugongs including an evaluation of the key threats and management options; (2) inform the sustainable use of coastal dolphins, sea turtles, dugongs and minke whales. Partnerships with end users have been developed using

a variety of approaches: (1) delivering information on research findings in person at individual meetings, workshops that have representation from all stakeholders, and stakeholder specific workshops; (2) writing material on research findings for a range of specific audiences: written reports, publications, newspaper articles, on-line material, fact sheets; (3) delivering presentations at conferences – such as CERF and MTSRF conferences and discipline specific conferences, e.g. 2009 International Sea Turtle Conference; (4) conducting training workshops (e.g. community GIS and Decision Support Systems and monitoring; workshops with minke whale operators); (5) contributing to relevant steering committees and Technical Reference groups, e.g. GBRMPA Conservation Reef Advisory Committee through researcher membership; and most importantly (6) involving stakeholders especially Torres Strait Islanders (including Traditional owners) in the research as counterparts. The marine component of Program 4 has a major investment in research training and contributes to the support of the projects of seven research students. The program's progress against its objectives will be discussed in the context of the involvement of end users and students.



Predicting white syndrome outbreaks in northern Australia: Targeted monitoring and informed management

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MTSRF [Project 2.5i.3\(a\)](#)

Following the exceptionally warm summer of 2002, average abundance of white syndrome was higher than any in other year that reefs have been surveyed for coral diseases by the Australian Institute of Marine Science (AIMS) Long-Term Monitoring Program. Although white syndrome abundance varied widely in 2002, our results indicate that most (>85%) of the variability can be explained by the rate at which heat stress accumulated during summer months that year and by the cover of white syndrome's predominant host, coral species in the genus *Acropora*. Of the 45 sites surveyed annually for the last ten years, only four sites with greater than 40% *Acropora* cover experienced heating rates greater than 0.55. Significantly, outbreaks (>200 white syndrome cases) occurred at all of these sites in 2002. Based on retrospective calculations of heating rates, we have produced an image for each summer from 2002 onwards that colour-grades white syndrome outbreak risk as low, moderate, or high. The images will be made available online and include reef, park, and marine reserve boundaries to facilitate interpretation. The images will also be made available for viewing through Google Earth™ enabling users to search for, navigate to, and store locations of interest. The capacity to predict where white syndrome outbreaks are likely to have occurred, as well as where they are likely to occur, will enable targeted research and monitoring in order to answer questions that have been difficult to address using available datasets. The resulting improved understanding of white syndrome outbreaks may help managers understand whether actions can be taken to reduce both susceptibility to white syndrome and recovery timeframes. To this end, predictive tools, like the one described here, will form a critical component of early warning systems within a Great Barrier Reef wide coral disease response plan.



One with 'nature'? Visitor knowledge, attitudes and behaviours in the rainforest



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MTSRF [Project 4.9.2\(a\)](#)

Historically, there have been a number of studies conducted on visitation patterns to the Wet Tropics rainforests. Of scarcity however has been an in-depth exploration of visitor knowledge of, attitudes towards and behaviours in the rainforest. This papers sets out to advance research in this area by drawing on over one thousand surveys conducted with domestic and international visitors in various sites in the rainforest throughout 2008. Moreover, this paper also compares the broad environmental practices undertaken in visitors' day-to-day life with their knowledge of, attitudes towards and behaviours in the rainforest while holidaying in Tropical North Queensland.

Broad trends emerged that illustrated visitors' limited knowledge of the rainforest prior to visiting with only 61.9% of respondents being aware of its World Heritage status. Once on site however, visitors tended to learn greatly from the environmental and cultural information relevant to these rainforest sites. For instance 76.6% of visitors indicated that they strongly agreed or agreed that the information helped them understand the ecological processes of the site. In terms of activities, visitors participated in a range of passive and active rainforest activities, the most popular of which included walking (76.4% of respondents), viewing scenery (72.6%) and viewing wildlife (59.3%). Visitors also considered tourism and recreation to be of moderate threat to the rainforest, moreso than community infrastructure and farming. These findings are important when exploring how a sustainable and viable rainforest tourism industry might be developed further in the region.



The importance of physiology and microenvironmental information in predicting climate change impacts



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MTSRF [Project 2.5ii.2](#)

At present, most attempts to predict climate change impacts on biodiversity have relied on correlative methods. This approach uses environmental information based on the macroenvironment and species presence data to predict species distribution under different climate change scenarios. However, we know that not all species are directly exposed to macroenvironmental conditions (e.g. some organisms use shelters during part of their circadian cycle). Additionally, these models do not include information about species specific physiological requirements and tolerances, that is, their fundamental niche. The Microhylidae frog family has been predicted to be one of the most threatened groups of vertebrates by climate change in the rainforest of the Wet Tropics Bioregion, northern Queensland. The predicted susceptibility is primarily inferred from restricted geographic distribution to cool, wet and aseasonal upland environments. Previously, correlative models have predicted changes in the extent and location of microhylid distributions, even with minimal increases in temperature. During the day, these frogs take refuge under logs, rocks or epiphytes fallen from trees. These refuges provide a buffer from external daytime environmental conditions.

Here, we quantify differences between macroenvironmental information used in previous models and information on real conditions experienced by microhylid frogs in the rainforest. We also present preliminary physiological information (water loss rate, preferred temperature, and maximum and minimum thermal limits) for different species of microhylid frogs and discuss implications for future scenarios of climate change. Mechanistic distribution models are expected to produce more realistic prediction of climate change impacts and thus to improve the future conservation and management strategies on threatened vertebrates.



Plant community data gap filling



Daniel J. Metcalfe and A. J. Ford

CSIRO

MTSRF [Project 1.2.1](#)

Our understanding of species distributions and community composition is largely based on survey and collection data collected in a haphazard manner across the landscape. Analyses of the locations of collections showed an uneven distribution of sample data across the landscape, with some key areas, particularly those with limited access, being un-surveyed or only superficially studied. We have attempted to fill a number of these survey gaps in order to provide a better baseline understanding of distributions from which to monitor future changes. We have also made attempts to increase our understanding of the areas thought to have provided refugial habitat in previous periods of changed climatic conditions, and may well provide a similar role in the future. We discuss our findings to date, our plans for the future, and the impacts our data have on approaches to managing connectivity and resilience in natural vegetation communities.



Fragment futures: Decline trajectories of fragmented forests, and approaches for conservation prioritisation

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CSIRO

MTSRF [Project 1.4.3](#)

Lowland rainforest communities are under a range of threats to their persistence as functioning rainforest, including ingress of weeds and ferals, changed environmental conditions and loss of important pollinators and seed dispersers. We have been looking at the impact of age, isolation and size on fragments in the Tully-Murray-Johnstone catchments and at methods of prioritising which fragments might be best targeted in restoration efforts or for corridor linkages. We present the data collected so far on the health and richness of fragments compared to continuous forest analogues, and on the analytical approaches taken and preliminary results derived. We discuss the future of this project and how it might be replicated in other catchments.



Mapping the distribution and abundance of weeds and feral animals in Far North Queensland

Daniel J. Metcalfe, T. Lawson, J. Butler and C. Frazao

CSIRO, Atherton

MTSRF [Project 1.2.1](#)

The Wet Topics Bioregion hosts more than five hundred naturalised exotic plant species and at least 28 species of feral vertebrates. Few of these species are systematically surveyed to monitor changes in their abundance or distribution, and we are concerned that this undermines the understanding of a key threatening process. Consequently we are attempting to map the distribution of weeds and ferals across the Bioregion in order to (i) highlight clusters of pest species or potential pest species, (ii) relate the distribution of weeds and ferals to environmental and socio-economic variables, and (iii) investigate the gaps in understanding of distributions that may represent significant shortcomings in current monitoring arrangements. We are collating data from Federal and State agencies, from local councils and NRM bodies, and from projects funded by MTSRF, CSIRO and the Australian Weeds Research Centre. We present the completed feral mapping compiled to date and hosted on the FNQROC website, and discuss the progress of mapping target weed species to date. We also discuss our aspirations for the development of this mapping approach into a live tool available to all stakeholders.



Weeds of the Wet Tropics: Functional groupings to improve prioritisation



Daniel J. Metcalfe and H. T. Murphy

CSIRO

MTSRF [Project 2.6.2](#)

The Wet Tropics Bioregion of Queensland supports over five hundred naturalised plant species. Most of these are weeds of disturbed areas and agriculture, but a small proportion are capable of growing in vegetatively complex rain forest habitats, and a very small number of aggressively colonising rain forest during gap phases and persisting after canopy closure. Invasive species management faces the constant challenge of how to best target small amounts of funding on an ever growing list of invasive or potentially invasive species. A number of elegant weed assessment tools have been developed to better identify which species in cultivation are most likely to become naturalised and invasive. We are interested in refining the list of characteristics that contribute to invasive potential to identify those which may help to identify the species with the greatest likelihood of invading intact rain forest. We have compiled a functional attribute database for 537 naturalised species, collating published and field-sourced data for a variety of life history, ecological and physiological traits. Legislative status and inferred threat categories have also been considered. We present analyses focussed on identifying characteristics associated with the most aggressive and persistent invaders of rain forest. We discuss the value of our observations for targeting future research and management priorities.



Herbicides and tropical marine organisms: Effects and thresholds

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[Reef Rescue Marine Monitoring Program](#)

Recent water quality monitoring has revealed the widespread distribution of herbicides in river mouths and nearshore environments of the Great Barrier Reef (GBR). Here we present an overview of the temporal and spatial patterns of herbicide concentrations in the GBR region and a summary of the known effects of herbicides on a range of tropical organisms from benthic microalgae isolated from rivers to nearshore seagrasses and corals. We discuss the relevance of using tools such as pulse-amplitude modulation (PAM) fluorometry as a measure of sub-lethal stress in these organisms. In particular we describe relationships between the inhibition of photosynthesis and the growth and mortality of algae and the energy budgets, bleaching and survival of corals. The toxic threshold concentrations of a range of current herbicides are described for each species and these are compared with the known concentrations reported in recent monitoring programs.



Ecological and trophic relationships within Wet Tropics freshwater turtle communities and their sensitivity to climate change and habitat alteration



Amanda O'Malley*

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MTSRF [Project 1.4.1\(s\)](#)

The aim of this study is to investigate the ecology and biology of freshwater turtles in the Wet Tropics World Heritage Area (WTWHA). From this it will be possible to infer how habitat modification, brought about indirectly through climate change, or directly through physical alteration for agriculture, may be affecting populations and communities of freshwater turtles. The study will focus on co-occurring species found in the WTWHA: *Elseya stirlingi*, *Wollumbinia latisternum* and *Emydura krefftii*. The latter two are widespread generalist species while *E. stirlingi* is a recently described habitat specialist endemic to the WTWHA. The specific objectives of this study are to, (1) accumulate data on freshwater turtles within the WTWHA (abundance, population structure and critical habitat); (2) investigate community interactions and dynamics, particularly overlaps in diet and habitat use; (3) determine the climatic “envelope” of each species within the WTWHA and compare this to climate change scenarios for key features (e.g. temperature, flow regime); and (4) investigate how current and planned land use and water infrastructure may affect critical freshwater turtle habitat in the Johnstone River Catchment.



The history of mortality in Great Barrier Reef coral communities since European settlement

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MTSRF [Project 1.1.4](#)

Trajectories of decline of coastal marine ecosystems, resulting in long term losses of abundance, diversity and habitat structure, have been documented throughout the world. However, little is known about the historical ecology of the Queensland coastline before the first European encounter of Captain James Cook in 1770. We examined historical change in coral reef habitats from the tropical Great Barrier Reef (GBR) using coral community structure and frequency of partial mortality, in order to quantify the magnitude and rate of ecosystem response to anthropogenic interaction through time. Accurate estimates of past historical mortality events of inshore reef coral communities over broad spatial and temporal scales can be achieved through the application of high-precision thermal ionisation mass spectrometry (TIMS) uranium-series (U-series) dating of dead coral skeletons. In the inshore regions of the GBR, significant temporal shifts in coral community structure are associated with European settlement of the adjacent Queensland coast around 1864. Historical mortality events resulted in the loss of branching 'acroporid' communities, shifts in community composition, and loss of diversity. U-series dating of partial mortality events in massive poritid corals indicated contemporaneous episodes of mortality. This mortality is significant in that it occurred prior to the mass bleaching episodes in 1998 and 2002 AD and prior to the advent of long-term monitoring. These recent and dramatic ecological changes in GBR coral communities are associated with decreased water quality and huge increases in resource exploitation, urbanisation, pollution and coastal development. They provide evidence of widespread habitat degradation since Captain Cook's initial austral encounter, and illustrate historical ecology's plea for silencing the notion of 'pristine' ecosystems. Moreover, they provide managers with a history of the natural state of ecosystem variability, a baseline incapable of shifting. Thus management actions can be formulated using goals consistent with natural ecological variations, and managers can judge the success of these actions on the degree to which they alter or reverse trajectories of decline.



Attitudes and perceptions of recreational fishers to Conservation Park (Yellow) Zones in the Great Barrier Reef Marine Park



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MTSRF [Project 4.8.5](#)

The Great Barrier Reef Marine Park (GBRMP) is managed with the primary goal of preserving and protecting biodiversity while allowing for sustainable use. In July 2004, the GBRMPA implemented a new Zoning Plan for the GBRMP that increased the amount of

protection from various activities in the Park. Conservation Park (Yellow) Zones were introduced, which place strong restrictions on commercial fishing but allow recreational fishing to occur. Although Yellow Zones only cover one percent of the Park in total, the majority are inshore, and are essentially recreational only fishing areas (ROFAs). Research prior to the new zoning plan demonstrated 76% of North Queensland recreational fishers would like to see more ROFAs implemented. A recent survey investigating recreational fishers' perceptions about the Zoning Plan indicated most recreational fishers believe the new Yellow Zones will lead to better recreational fishing in the marine park (59%), reduce the impact of commercial fishing on the GBR (56%), and that the benefits of restricted commercial fishing in yellow zones outweigh the costs to recreational fishers (64%). There was a strong positive relationship between fishers' support for Yellow Zones and support for the Zoning Plan in general. Although Yellow Zones were not implemented specifically to enhance recreational fishing, most recreational fishers believe these zones will benefit recreational fishing, and this perception has helped foster positive attitudes among recreational fishers towards the rezoning in general. Incorporation of small ROFAs in Marine Protected Areas could help increase recreational fishers' support for MPA creation and management.



Status and trends – *State of the Environment* reporting and gap filling: Biodiversity condition of the Wet Tropics region

Petina L. Pert, James Butler, Dan Metcalfe and Caroline Bruce

CSIRO

MTSRF [Project 1.2.1\(c\)](#)

As part of MTSRF Project 1.2.1(c), '*Status and trends of biodiversity and ecosystem services: State of the Environment reporting and gap filling*', we present an analysis of native vegetation extent in the Wet Tropics region, which is an important indicator of the condition of biodiversity and ecosystem services. In the absence of ecologically-based thresholds of concern, we measure change in native vegetation extent against the Wet Tropics Regional NRM Plan's Resource Condition Target 1 (RCT1) for biodiversity: 'no net loss of native vegetation extent across the region by 2014'.

There has been a net loss of native vegetation across all four extents we assessed of 17.9% (MTSRF study area, pre-European to 2006), 2.0% (Wet Tropics Bioregion, 1988-2006), 0.2% (Wet Tropics World Heritage Area, 1988-2006), and 0.7% (Terrain NRM catchments, 2004-2006). The most recent year for our estimations is 2006, and it is possible that this decline has continued since then. We estimate that in order to achieve RCT1 by 2014, at least 32,056 ha (Wet Tropics Bioregion) and 1,663 ha (Wet Tropics World Heritage Area) of native vegetation will have to be restored to regain the 1988 extent, and at least 11,739 ha to regain the 2004 extent (Terrain NRM catchments). To regain pre-European native vegetation extent across the whole MTSRF study area, 476,054 ha would need to be restored.

Our analysis has highlighted areas such as the Tully subregion (12%) and Herbert (9.5%) subregion that have lost the highest proportion of native vegetation since 1988 and may be considered as recommended restoration priorities. This recommendation is based purely on the reported results, and does not consider other factors that the Wet Tropics Management Authority may consider important in restoration prioritisation such as areas within the World Heritage Area where infrastructure has been removed.

For Terrain, over the shorter reporting period of 2004-2006 the South Johnstone catchment has had the highest relative loss of native vegetation (3.2%). The Murray and North

Johnstone catchments have also lost relatively large areas of native vegetation (1.7% and 1.4%, respectively) since 2004.

We assessed nine datasets that might provide suitable data for estimating native vegetation extent in the Wet Tropics region. For pre-European vegetation extent, we used the Queensland Herbarium's Pre-clearing Regional Ecosystem mapping. We chose the National Carbon Accounting System (NCAS) datasets from the Australian Government's Department of Climate Change to undertake this analysis for assessment of extent since 1988. While the data has a fine scale resolution (25m) and regular time series (1972-2006), it does not include more open and less forested native vegetation types. It also includes non-native tree plantations. In spite of these deficiencies the NCAS data set provides the most useful source of information for assessing native vegetation change at the spatial and temporal reporting scales required by the WTMA and Terrain.



Spatial habitat prioritisation and visualisation in Mission Beach



Petina L. Pert¹, R. Hill¹, K. Williams¹ and T. O'Malley²

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MTSRF [Project 1.2.1](#)

The location of and threats to biodiversity are distributed unevenly, so prioritisation is essential to minimize biodiversity loss. Spatial conservation prioritisation concerns well-informed and efficient allocation of the resources available for conservation. A method was developed to identify future habitat conservation priorities in the Mission Beach area. Maps depicting land desirable for habitat protection and restoration were created using CommunityViz© software. In this desirability-suitability analysis, habitat is colour coded as suitable (green) or not suitable (red) for protection and/or restoration based on the summed biodiversity significance, threat, condition and protection indices. The system provides a simple means to alter the variables to allow prioritisation in a range of different contexts—for example prioritisation for inclusion in the formal protected area estate, or for investment in habitat rehabilitation for weed removal. CommunityViz© has been used because of its technical simplicity and possibility to apply in community settings designed particularly for community applications where efficiency and cost-effectiveness are the key drivers.

In order to explore these opportunities for restoration and/or protection, CommunityViz© is used in conjunction with a community engagement process to develop a series of options for exploration of rehabilitation/restoration options. Using CommunityViz© software in the Mission Beach case study area showed that it was possible to clearly, objectively and transparently determine and identify priorities dynamically, and visualise these priorities in response to changes in criteria and policy settings. The use of this application will allow natural resource planners and managers to better identify conservation priorities and appropriate strategies for moving forward across a whole range of their responsibilities in habitat restoration and protection.

This type of analysis enables identification of those habitat areas that most contribute to overall landscape connectivity, and evaluate the outcomes for overall connectivity from targeted protection, rehabilitation and restoration in those critical habitat areas. Our results will become part of an interactive biodiversity mapping platform and help guide investments in habitat protection and restoration through the Mission Beach Habitat Network Action Plan.



Implications of climate change for the oceanography of the Great Barrier Reef ecosystem



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An understanding of the oceanographic environment of the Great Barrier Reef is vital to understanding its biological response, and for comprehending how broad scale changes associated with climate change will impact its marine ecosystem. The oceanographic dynamics determine critical factors such as the temperature or nutrient availability, and any changes to the oceanographic environment, whether human-induced or natural climate change, affect the coral reef ecosystem in several ways.

The Great Barrier Reef is a complex system encompassing a range of meteorological and oceanographic conditions that operate on different temporal and spatial scales - from broad scale global circulation patterns to complicated regional and local scales. Currently, our understanding of the oceanographic dynamics of the Great Barrier Reef has been poorly documented and described. This project will focus on the dynamics of temperature, light, currents and other key variables to the Great Barrier Reef that underlie the major variability in oceanographic conditions related to phenomena such as coral bleaching events. This project will produce an increased knowledge of the connectivity between global change and the waters of the Great Barrier Reef, as well as to provide an in depth understanding of how these phenomena relate to biological responses such as mass coral bleaching events.



Institutional attributes for integrated water quality management in Great Barrier Reef catchments

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MTSRF [Project 4.9.6](#)

The achievement of proposed water quality targets to halt the decline of water entering the Reef from diffuse sources relies on an effective system of governance capable of facilitating the necessary co-operation and coordination between multiple environmental decision-makers and activities. This paper presents a 'SMART partnership' assessment framework that is currently being tested and developed to help identify and monitor the key institutional issues and attributes that constrain and enable the delivery of voluntary water quality management programs. The framework uses inter-institutional indicators to monitor the performance of integrated water quality management as well as intra-institutional indicators to assist in the self-assessment of industry, government and community stakeholder capacity to enable this integration to occur. Results from preliminary testing of this framework are presented and key issues affecting the institutional capacity to adaptively 'fit' the purpose of proposed water quality management programs are identified.



Spatial and temporal patterns of water quality in the inshore Great Barrier Reef lagoon

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[Reef Rescue Marine Monitoring Program](#)

Coastal areas of the Great Barrier Reef (GBR) receive substantial amounts of material from adjacent developed catchments, which can affect the ecological integrity of coral reefs. Large-scale data sets show elevated values of most water quality variables near the coast. Since 2005, data are collected under a Marine Monitoring Program (MMP) to track trends in ecosystem status and water quality. High turbidity levels and elevated chlorophyll a and phosphorus concentrations are the main water quality issues in the coastal GBR, based on observed exceedances of recently developed water quality guideline values. Other water quality variables exceeded guideline values during flood events. Ratios of carbon, nitrogen and phosphorus deviate from expected levels indicating organic enrichment of the coastal lagoon, at least temporarily after massive nutrient inputs during the tropical wet season. The Reef Rescue MMP is moving from traditional 'snap-shot' sampling to high-frequency instrumental monitoring of chlorophyll and turbidity, to resolve short-term variability and distinct 'events' in water quality at coastal and inshore reefs. This will provide a better understanding of conditions faced by coral reefs and whether any locations or regions require management intervention.



Reef Check Australia: Community coral reef monitoring of the Great Barrier Reef

Marie-Lise Schläppy

Reef Check Australia

MTSRF [Project 1.1.2](#)

Reef Check Australia is an environmental non-profit organisation that engages the general public in monitoring the health of Australia's coral reefs. Under the MTSRF program, community volunteers monitor 25 key dive sites on the Great Barrier Reef with the support of dive tourist operators. Surveys are conducted from February to June each year which is the low season for tourism operators. Key outputs include a measure of coral cover, algae blooms and abundance and size-class of crown-of-thorns starfish which are reported as observations and digital images. Outputs are presented in a Google Earth™ layer which enables managers and community members to keep track on the status and trends of Reef Check sites. Other program outputs include community awareness and education initiatives such as community service announcements, a national photo competition and interpretation material for dive tourism operators.



Remote sensing of flood plumes in the Great Barrier Reef: Extreme conditions for coastal ocean colour algorithms

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[Reef Rescue Marine Monitoring Program](#)

There are strong indications episodic river flood plumes can significantly influence water quality in the Great Barrier Reef (GBR). Water quality is a key issue for the health of the GBR and for the communities, industries and ecosystems that rely on good water quality. Remote sensing is becoming a cost-effective method to determine spatial and temporal information about water quality parameters, such as chlorophyll-a (CHL), total suspended solids (TSS), coloured dissolved organic matter (CDOM) and diffuse light attenuation (Kd). The objective of this work is to assess the spatial and temporal variation of the near-surface concentrations of these parameters during the 2008 and 2009 GBR flood events using satellite remote sensing data. Global ocean colour algorithms frequently fail to estimate CHL, TSS and CDOM in coastal waters, especially during flood events. To enable a reliable mapping of these parameters we developed advanced coastal ocean colour algorithms for the Moderate Resolution Imaging Spectrometer (MODIS) on-board of the NASA Earth Observation Systems (EOS) Aqua satellite sensor platform. We present first results of the development, validation and application of these algorithms for remote sensing of flood plumes in the GBR.



Potential for mountaintop boulder fields to buffer resident species against extreme climatic events

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MTSRF [Project 2.5ii.4](#)

One possible way species may circumvent or minimise impacts resulting from climate change is to utilise microhabitats that buffer against extreme climatic events (eg. peak daily or monthly temperatures). We aimed to investigate the potential for micro-scale habitat characteristics to buffer a mountaintop endemic nursery-frog from exposure to heat stress in the summer and moisture stress in the dry season. The Beautiful Nursery-frog (*Cophixalus concinnus*) is predicted to be the first vertebrate species to go extinct in Australia's diverse tropical rainforests as a result of contemporary climate change. Boulder fields are a prominent feature of the landscape occupied by this geographically restricted species. Data were obtained from weather sensors maintained for a period of twelve months in both an exposed and forested boulder field. Ambient summer temperatures above exposed and forested boulder fields were found to reach 34 and 24°C respectively. However, temperatures were much cooler and more stable within the boulder fields themselves. For example, at a depth of just 1.8m, summer temperatures varied as little as seven degrees (i.e. between 16-23°C) in exposed and four degrees (ie. between 16-20°C) in forested boulder fields. Relative humidity was typically high throughout the year (i.e. >80%) within forested boulder fields. In the critical dry season period, relative humidity did not fall below sixty percent and quickly returned to more saturated conditions. We also provide evidence of regular and persistent surface wetting due to non-precipitation inputs of water (e.g. mist and condensation). Combined, these results demonstrate that boulder fields provide heterogeneous environments capable of ameliorating exposure to stressful climatic conditions. Physiological and behavioural data are now needed to determine whether *C. concinnus* is already living close to its thermal limits and whether individuals are able to

take advantage of the buffering potential of boulder fields by actively shuttling between microhabitats in direct response to changing, unfavorable environmental conditions.



Measuring the resilience of coral reef fish using biological data from the Effects of Line Fishing Project

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MTSRF [Project 4.8.3](#)

The Effects of Line Fishing (ELF) Project collected samples (otoliths and reproductive samples) and life history information from more than fifty fish species on the Great Barrier Reef from 1995 to 2005 using commercial line fishing techniques. The majority of samples and information came from four families (Labridae, Lethinidae, Lutjanidae and Serranidae), with sufficient from 29 species to provide detailed life history data. Life history data collected included size and age composition, length weight relationships, size and age at maturity, maximum size and age, von Bertalanffy growth parameters, total mortality, spawning season and size and age at sex change (if applicable). These data were used to identify life history patterns within and between families using multivariate statistics. Life history data were also used to develop yield per recruit analyses as a measure of resilience to fishing pressure, and identify species at greatest risk of over-exploitation. The results of these analyses will be used to help inform the management of coral reef fisheries. Preliminary results of these analyses will be presented.



The value of photo-identification data on dwarf minke whales (*Balaenoptera acutorostrata* subspecies) collected by whalewatching tourists in providing critical information for sustainable management



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MTSRF [Project 4.8.6](#)

We evaluated the potential of whalewatching tourists to supply underwater photographs that provide photo-identification data for dwarf minke whales (*Balaenoptera acutorostrata* subspecies) in the Great Barrier Reef. New educational and interpretive material as well as intensified crew and researcher effort facilitated an increase in the quantity of donated pictures from c. 2,500 to >7,000 to >10,500 to >20,000 in 2005-2008. The complete 2006 data set was scored for picture quality and information content on a five point scale. Three groups of photographers were classified: (1) 'Researchers', (2) 'Professionals' and (3) 'Passengers'. In 2006, the target group 'Passengers' provided 44% and 43% of all pictures available in the higher categories (3-5) of picture quality and information content, respectively. 'Passengers' onboard one vessel in 2006 took pictures of 78% of the whales identified from researcher data, but this 'passenger sampling fraction' varied considerably between different encounters and photographers.

Data provided by non-researchers greatly enriched the re-sightings data, contributing to the identification of 56 within season re-sights in each year, 2006 and 2007 (total of 132 and 122

complete IDs obtained, respectively). These results indicate a relatively small interacting population, which raises the issue of potential cumulative impacts of the swim-with program on individual whales. Such information will be critical for the sustainable management of this activity in the Great Barrier Reef Marine Park.



DNA-based biomarkers for thermal tolerance in corals



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 MTSRF [Project 2.5i.2\(c\)](#)

Novel techniques for large-scale DNA sequencing have recently become accessible for non-model organisms such as corals. This advancement allows examination of the genetic code for thousands of genes, enabling biomarkers that can be linked to variations in thermal stress tolerance to be identified. In this study, three thermally distinct populations, harbouring two different types of symbiotic algae, have been sampled: Miall Island in the Keppel Islands (cool climate/type C2), Magnetic Island off Townsville (warm climate/type D), and Wilke Reef in Princess Charlotte Bay (warm climate/type C2). By pooling eight samples from each population we are able to detect differences in frequencies of specific gene variants of the coral host that correlate with the thermal environment in which they live. Experiments will be conducted to determine whether coral colonies harbouring different gene variants differ in their thermal tolerance. The outcomes of this work should allow the distribution of alleles, and therefore thermal tolerance, across the Great Barrier reef to be mapped using resources such as the Reef Atlas. Such integration of ecological data with functional and neutral genetic variation will improve predictive models regarding the future of the Great Barrier Reef.



Downscaling climate change to Heron Island on the Great Barrier Reef

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MTSRF [Project 2.5i.1](#)

A coarse-resolution, climate change global ocean-atmosphere model will provide scenarios of future climate change in the oceans around Australia. Its high-resolution, eddy-resolving version will provide information about climate change on a horizontal scale of ten kilometres around Australia. Further downscaling with a suite of three increasingly higher-resolution, nested models will allow simulation of climate change scenarios at the reef-scale (<100m horizontal resolution).

The suite of models focused on Heron Island in the Capricorn Bunker group in the Southern Great Barrier Reef will be calibrated against an intensive physical oceanographic array of instrumentation. The field study was undertaken in the Capricorn Bunker region over 2005-2006 and coincided with a mild bleaching event. A sister project (MTSRF [Project 2.5i.2](#)) is analysing this data together with remotely sensed observations in order to characterise the current state of local oceanography.

Ten austral summers for the period 2060-2070 will be modelled in order to discern any changes in circulation, temperature response, and mixed layer depth and ocean-shelf interactions. A review of impacts of climate change on the physical oceanography of the Great Barrier Reef is providing a basis upon which we can explore what processes may be affected by climate change when analysing the different scenarios. Key processes that may be affected are the circulation, temperature response, mixed layer depth and ocean-shelf interactions.



East Australian Current and upwelling influences on the thermal environment of the Great Barrier Reef

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MTSRF [Project 2.5i.2](#)

This task aims to explore the basis for the link between bleaching and upwelling by investigating the relationship between the activity of the East Australian Current (EAC) and in particular, its intrusion into the Great Barrier Reef (GBR) matrix. This project initially focused on the Capricorn Bunker group in the Southern GBR and we are now targeting the Palm Passage off Townsville in the Central GBR.

Upwelling and intrusions of EAC waters have been the subject of a number of process studies along the GBR, however they have been of limited duration. Long term measurements from the Australian Institute of Marine Science's automatic weather stations, temperature logger programme, current meter moorings and together with the University of Queensland's Centre of Marine Studies MODIS satellite imagery of SST and Chlorophyll climatologies will be presented. The spatial-temporal variability of the physical dynamics will be investigated to determine the biological response, and also whether particular reef systems may be heated or cooled (flushed) and hence likely to experience coral bleaching and mortality or not.

The Integrated Marine Observing System's (IMOS) GBR Ocean Observing System (GBROOS) is now significantly enhancing and expanding the climate change monitoring programmes that are essential to identifying how the GBR climate is changing and which parts of this unique ecosystem maybe more or less susceptible to the evolving consequences of a rapidly warming world.



Live-aboard dive boats in the Great Barrier Reef: Their regional economic impact and the relative values of their target marine species

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MTSRF [Project 4.8.6](#)

Using data collected from more than 1000 tourists on live-aboard dive boats operating in the Cairns/Cooktown management area of the Great Barrier Reef, this paper estimates the regional economic impact of that live-aboard industry. It also uses a sub-set of those data (247 respondents) to investigate some of the relative 'values' of key marine species seen on

those trips that included the Coral Sea location of Osprey Reef. It finds that (a) each year, the live-aboard dive boats are directly responsible for generating at least \$16 million worth of income in the Cairns/Port Douglas region; that (b) visitors participating in different types of trips gain their highest levels of 'satisfaction' from interacting with different types of species; and that (c) visitors to Osprey Reef would be willing to pay more for a 'guaranteed' sighting of sharks, than they would be for a 'guaranteed' sighting of large fish, marine turtles or a 'wide variety of species'.



Can logs buffer species from climate change? Creating regional climate layers and making future predictions of microhabitat temperature



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MTSRF [Project 2.5ii.4](#)

Global climate change poses a threat to the biodiversity of the Australian Wet Tropics. Predicted changes in maximum daily temperature, rainfall seasonality, and cloud interception may have profound effects on species which cannot adapt or seek refuge from sub-optimal weather conditions. Understanding the buffering characteristics of microhabitat conditions is then critical to predict the effects of global climate change on species.

An array of data loggers (n = 26) have been positioned across latitude and altitude, from Paluma in the South, to Mt. Windsor in the North, ranging from near sea level to 1,600 metres in elevation. These loggers have recorded ambient temperature under the rainforest canopy as well as temperature underneath logs (a critical diurnal refuge for many endemic frogs and skinks) at hourly intervals since 2006. These data have been compiled to form regional climate surfaces of under log temperature and under canopy ambient temperature for the entire Wet Tropics. By examining the relationship between these regional climate layers and above canopy temperature (from Australian Bureau of Meteorology observations) we can directly quantify the temperature buffering capacity of logs as a microhabitat. Once the temperature buffering capacity of logs is determined by this comparison, we can predict the temperature underneath a log based on future climate scenarios. This information will be invaluable in predicting how log-sheltering rainforest species will be affected by increasing temperature.



Probabilistic based climate change projections for the tropical rainforest region of North Queensland

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MTSRF [Project 2.5ii.1](#)

One of the major requirements of the Project 2.5ii1 (*Regional climate change projections for tropical rainforests*) for the Marine and Tropical Sciences Research Facility (MTSRF) is the ongoing development of climate change projections for the tropical rainforest region for impact assessment studies. Accordingly, we have developed probabilistic climate change projections for maximum, minimum and mean temperatures, rainfall and potential evaporation using simulations from global climate models performed for the IPCC Fourth

Assessment Report. Simulations from 23 GCMs were used to project mean temperature and rainfall, eight for maximum and minimum temperatures and eleven for potential evaporation. Projected temperatures show the inland areas of the tropical rainforest region will warm faster than coastal areas. Temperature increases by 2030 do not differ greatly between low, medium and high emissions scenarios, but increases beyond 2030 show marked differences between low, medium and high values. For a medium emissions scenario the median annual temperature increases by 0.8°C by 2030 with a range of uncertainty of 0.6 to 1.1°C. Increases in temperature for 2050 and 2070 are dependent on emissions scenarios and also show larger ranges. Rainfall changes are more complex than temperature changes as they show both increases and decreases. For a medium emissions scenario, the best estimate of annual average rainfall change for 2030 is -1% with a range of uncertainty of -8 to +6%. For 2050, the range of uncertainty for regional annual average rainfall change for different scenarios spans -16 to +11%. The corresponding range for 2070 is -26 to +18%. Projected changes to potential evaporation are typically +3% by 2030 with an uncertainty range of 0 and +6%. For 2050, potential evaporation increases by +6% with an uncertainty range of +3 to +10% and for 2070 it increases by +8% with a range of +3 to +14%.

High-resolution simulations are being performed, having 14km and 20km resolution over the MTSRF region. These simulations are dynamically downscaling several GCMs for the A2 emissions scenario for the periods 1971-2000, 2041-2060 and 2081-2100. Preliminary results will be presented for the simulated changes to temperature and rainfall. Indicated changes to tropical cyclone characteristics under enhanced greenhouse conditions will also be discussed.



Toward improved community engagement in climate change mitigation strategies for the Great Barrier Reef

Stephen G. Sutton and Renae C. Tobin

School of Earth and Environmental Sciences, James Cook University
 MTSRF [Project 4.8.5](#)

Climate change is the largest threat facing the Great Barrier Reef (GBR), with severe impacts predicted under even moderate climate change scenarios. GBR climate change reduction and mitigation strategies will require significant changes in human attitudes and behaviors. We surveyed 1,622 Australian residents to understand the potential for engaging the community in GBR climate change reduction and mitigation strategies. Eighty-nine percent of respondents were concerned about the effects of climate change on the GBR, and 75% believed that climate change will have a major impact on the GBR over the next 25 years. Eighty three percent of respondents were interested in helping reduce the impact of climate change on the GBR, but only 21% said they were very likely to take some action in the next twelve months to help reduce the impacts of climate change on the GBR. The strongest constraints preventing individuals from doing more than they currently do to reduce the impact of climate change on the GBR were: not knowing what else they can do (69% of respondents), having more important priorities (51%), lack of time (47%), and inadequate understanding of the climate change problem (34%). Results suggest there is high potential for improved engagement of communities in actions to reduce the impact of climate change on the GBR if agencies can develop programs and strategies that help people negotiate these constraints.



Long-term monitoring of the status of GBR reefs and of the effects of rezoning the Great Barrier Reef Marine Park

Hugh Sweatman

Australian Institute of Marine Science
MTSRF [Project 1.1.2](#)

The AIMS Long-term Monitoring Program has surveyed 47 reefs regularly since 1992 in odd-numbered years, and surveys a different set of reefs to look at effects of rezoning the Great Barrier Reef Marine Park in 2004 in even-numbered years.

Recent results from reefs that have been surveyed since 1992 showed loss of coral cover in the Capricorn-Bunker reefs in the southern Great Barrier Reef (GBR) from storms, and a suggestion of increased crown-of-thorns starfish activity north of Cairns. A second survey of the pairs of reefs that have been selected to examine the effects of the new GBR zoning plan four years after its implementation show that differences in numbers and biomass of exploited species between reefs that are open to fishing and reefs that were closed in 2004 have been maintained, but found no evidence yet of trophic cascades involving changes in abundance of prey species.



Queensland Climate Change Centre of Excellence (QCCCE): Research directions and challenges

Jozef Syktus and Lynne Turner

QCCCE, Department of Environment and Resource Management

The Queensland Climate Change Centre of Excellence (QCCCE) is a specialist whole-of-government unit based within the Office of Climate Change part of newly created Department of Environment and Resource Management. The QCCCE was established in March 2007 and its role is to ensure that the Queensland Government policies, programs and initiatives are informed by the best available climate science. The talk will outline the structure of the QCCCE, research activities and scientific challenges facing Queensland. In particular, the presentation focuses on the collaborative linkages with national and international science partners as well as on the climate system research undertaken by the Centre.



An ecological-economic systems model for reef-based tourism in the Great Barrier Reef

Colette R Thomas and Iain J Gordon

CSIRO Sustainable Ecosystems
MTSRF [Project 4.8.6](#)

A prototype Bayesian belief network (BBN) that integrates data across ecological and economic components of the Great Barrier Reef (GBR) social-ecological system is described. The probability of climate-driven coral bleaching can be reduced by improvements in river water quality; however these improvements may come at some cost to the agricultural industry – these costs have been quantified in previous work. In contrast, failure to protect the Reef from increased bleaching frequency may also come at a cost to reef-based industries such as tourism and recreational fishing.

Reef degradation is hypothesised to reduce tourist demand for reef experiences, resulting in loss of income to local communities and increased risk of industry failure in the long term. The mechanisms by which reef condition is related to reef demand are complex and under-researched in the GBR. The prototype model presented here is a first attempt at quantifying the key processes and costs to tourism of reef decline associated with coral bleaching.

In conjunction with previous and continuing work, this model helps in determining whether the costs of mitigating reef degradation through land-based activities will outstrip the benefits to tourism. The information generated in the project will therefore identify the net costs/benefits to the human community of coral bleaching mitigation efforts, as well as the distribution of costs/benefits between different sectors of the community under a range of scenarios. By making these trade-offs explicit, the BBN will help decision-makers minimise risks and maximise benefits across the wider system.



Shark catches in the inshore waters of the Great Barrier Reef World Heritage Area

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MTSRF [Project 4.8.4](#)

The take of sharks in fisheries in the Great Barrier Reef World Heritage Area have become increasingly controversial in recent times. To provide scientific information to inform the consideration of this issue, fishery-dependent surveys have been conducted throughout the area to document species and size composition of various sectors that take sharks. These data show that commercial net fishers catch over 25 species of sharks and ray, with the main species being Australian blacktip, spottail, scalloped hammerhead, milk, whitecheek and spinner sharks. Species composition, importance and size vary between different sectors of the commercial fishery. Discarding practices were also examined and varied by operator and sector, with some species (e.g. milk sharks) more likely to be discarded than others. Post-release survival of discards is unknown, but may be an important consideration in relation to the impact of the fishery. The majority of sharks taken were less than 150cm in length. Data from recreational fishers was not able to provide detailed species composition data, but did demonstrate release rates >90%. The use of these data in an ecological risk assessment will be discussed.



Symbiodinium diversity on the Great Barrier Reef: Biogeography, specificity and patterns of host community sensitivity

Linda Tonk¹, E. M. Sampayo² and O. Hoegh-Guldberg¹

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² Department of Biology, Pennsylvania State University, University Park, PA, USA
MTSRF [Project 2.5i.2\(a\)](#)

The identity of endosymbiotic dinoflagellates (Symbiodinium) living in a wide variety of reef organisms, including stony corals and soft corals, is of major importance because physiological differences between Symbiodinium types partly determine the response of their host to increased water temperatures and bleaching. We have compiled the current state of knowledge of Symbiodinium diversity on the Great Barrier Reef (GBR), establishing a database that comprises approximately 3,500 samples from 60 locations and spans multiple

host taxa. Whilst five different Symbiodinium clades (A, B, C, D and G) are identified on the GBR, the majority of taxa contain clade C with a vast variety of subcladal C types. Our database revealed numerous areas of the GBR that are still largely understudied. Therefore additional collections of the Mackay/Capricorn area and the Far Northern section of the GBR are being performed and ITS2-DGGE is being used to assess the symbiont diversity of these new locations. Here we present the first results on Symbiodinium diversity of Alcyonacea and Scleractinia of reefs near Lizard Island. Preliminary findings of these samples have shown that a wide diversity of subcladal symbiont types exists. Approximately fifty different subcladal types were identified across 27 genera of soft and hard corals. Subcladal symbiont types were largely host-specific although some types were shared between closely related host genera. The abundance and host-specificity of the subcladal symbiont types identified suggests that identification at the highest possible taxonomic level is ecologically relevant and will help to increase our understanding of the complex responses displayed by each distinct host-symbiont combination. The outcomes of this large-scale project will be assessed in relation to a wide range of environmental factors obtained from satellite imagery and on site long-term monitoring efforts, and the combination of these data-sets is envisaged to yield a valuable tool to improve our ability to predict sensitivity risks on the GBR in response to future climatic change.



Assessment of ecological connectivity in corals: Implications for their recovery from major perturbations and their potential to adapt to climate change (Project outline and first results)



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MTSRF [Project 2.5i.3](#)

Assessment of ecological connectivity in corals: implications for their recovery from major perturbations and their potential to adapt to climate change – project outline and first results. This presentation is the outline of an ongoing PhD project, that aims to obtain estimates of ecological connectivity and its temporal stochasticity for two common pocilloporid coral species on the Great Barrier Reef (GBR), *Seriatopora hystrix* and *Pocillopora damicornis*, by genetically characterising new recruits at a small number of locations in the Palm and Lizard Islands, and comparing these with the genetic characteristics of adult populations at a wider range of populations. Twenty unglazed terracotta tiles are horizontally attached to the substratum at each of sixteen sampling sites and sampled every two months for recruits. Species identification will rely on the use of genetic markers, such as DNA sequence variation in a non-coding region of the mitochondrial genome, developed during the initial stages of the project. Adult colonies are sampled on the same sites, as well as opportunistically throughout the GBR and recruits of the year are assigned to possible source populations using assignment tests. The genetic characteristics of different cohorts (recruits from different sampling time points and adults) are compared by calculating pairwise genetic differences in an Analysis of Molecular Variance framework and by estimating genetic diversity, such as expected heterozygosity and allelic richness. Spatial (geocoordinates of samples and settlement tiles), ecological (temperature, habitat, depth, relative shade, turbidity) and genetic data are integrated in a Geographic Information System (GIS) to allow the detection of small scale patterns of genetic divergence and/or selection and finding links to relevant ecological parameters.



Towards sustainable tropical forest landscapes: Issues and challenges in the Wet Tropics region (Program 9 overview)

Stephen M. Turton

JCU/CSIRO Tropical Landscapes Joint Venture, James Cook University
MTSRF [Program 9](#)

MTSRF Program 9 is focused on sustainable use, planning and management of environmental assets of North Queensland's tropical rainforests and adjacent Wet Tropics production and urban landscapes that constitute significant catchment areas for the Great Barrier Reef. The approach is to consider these landscapes as linked social, ecological and economic systems. The main objective is to provide the knowledge base that supports the management of the Wet Tropics World Heritage Area, as well as supporting sustainable economic activities (notably agriculture, agroforestry, tourism and Indigenous enterprises), while enhancing biodiversity and maintaining essential ecosystem services across the entire Wet Tropics landscape. This is a large cross-institutional and multi-disciplinary Program that hosts seven project areas that align directly with research needs for the Commonwealth Department of the Environment, Water, Heritage and the Arts, Wet Tropics Management Authority, Terrain NRM Ltd, Indigenous groups, tourism industry and other key stakeholders based in the Wet Tropics bioregion and Natural Resource Management region:

- Indigenous landscapes of the Wet Tropics World Heritage Area: Use, planning and management;
- Sustainable nature based tourism: Use, planning and management;
- Impacts of urbanisation on North Queensland environments: Management and remediation;
- Integrating ecology, economics and people in forest landscapes;
- Restoring tropical forest landscapes;
- Strategic natural resource management and landuse planning; and
- Tools and processes for social engagement.

This presentation will present some of the research highlights from 2008/2009, together with a synthesis of planned research activities for the final year of the MTSRF Program.



Impacts of climate change in the Wet Tropics bioregion: Implications for the hydrological regime (Program 5ii overview)

Stephen M. Turton

JCU/CSIRO Tropical Landscapes Joint Venture, James Cook University
MTSRF [Program 5ii](#)

MTSRF Program 5ii focuses on delivering strategic knowledge on the impact that climate change is having and will have on North Queensland's tropical forests, and management options for how to mitigate against the negative impacts. Research provides early identification of the risks and threats posed by climate change to North Queensland's key terrestrial environmental assets and early advice on options to mitigate and better manage these threats and reduce the risks. We are also providing advice on the resilience or lack of resilience of different terrestrial ecosystems and biodiversity to climate change.

Global climate model projections for the region indicate that the water balance of heavily forested catchments in the Wet Tropics region is expected to change in the future. This presentation will consider likely synergistic effects of climate change on the hydrological regime in the Wet Tropics bioregion over the next ten, forty and sixty years. Factors and processes to be considered include:

- More severe cyclones, sea level rise and increased area of freshwater systems affected by storm surges;
- Temperatures are expected to increase by 1-3°C. by 2050, with corresponding increases in evaporation and transpiration;
- Rainfall is expected to increase slightly in the wet season depending on the state and frequency of El Niño-Southern Oscillation (ENSO) and to decrease markedly in the late dry season;
- Rainfall variability is expected to be higher from year to year, especially for the wet seasons; and
- Effects of elevated CO₂ on transpiration rates of forest canopies.

The cloud stripping process is expected to be less effective with warming due to predicted increases in the average height of the condensation lifting level, resulting in less water yield from this (occult) process in the dry season.



An assessment of the use of benthic foraminifera as water quality indicators in conjunction with the Reef Water Quality Marine Monitoring Program

Sven Uthicke, Britta Schaffelke and Angus Thompson

Australian Institute of Marine Science, Townsville
MTSRF [Project 3.7.1](#)

As for most coral reefs, a decline in water quality is a concern for health of Great Barrier Reef (GBR) inshore reefs. The Reef Plan Marine Monitoring Program was initiated in 2005, encompassing coral reef assemblage analysis and water quality measurements. As the first of the indicators developed under MTSRF Project 3.7.1 we field-tested the utility of benthic foraminifera as water quality indicators in the GBR. Sediment samples for analyses of foraminiferal assemblages were sampled during the annual coral reef surveys under Reef Plan Marine Monitoring Program. Water quality measurements confirmed that many parameters (e.g. chlorophyll a, suspended solids) were higher at inshore areas of the GBR when compared to offshore reefs, and distinct differences exist between individual reefs and regions. Higher concentrations of most parameters were measured during the wet season, but regional differences in water quality were more distinct in the dry season. Regional differences in coral cover and community composition were pronounced. A substantial proportion of the variation in coral community composition was explained by differences in the hydrodynamic conditions, with several genera resilient to sedimentation attaining consistently higher relative abundance in areas where fine sediments predominate. However, coral cover estimates mostly reflect recent disturbance history rather than water quality conditions. Along a distinct water quality gradient, the FORAM index, as previously developed and applied in the Caribbean, showed a high correlation with water quality. Foraminiferal communities also showed distinct regional differences. While the FORAM index did not predict coral cover, one symbiont-bearing species was positively correlated with high algal/low coral cover. Because of the vulnerability of corals to other disturbances we suggest that foraminifera are more specific indicators for water quality. Combined analysis of

the water quality, coral- and foraminiferal community data from the MMP provided a validation of water quality indicators based on individual foraminiferal species' abundance or the combined FORAM index.



Net Primary Productivity (NPP) in the Australian Wet Tropics: Estimates from two field methodologies and real-time climate data



Vanessa Valdez-Ramirez*, Luke Shoo, Collin J. Storlie and Stephen E. Williams

Centre for Tropical Biodiversity and Climate Change, James Cook University
MTSRF [Project 2.5ii.4](#)

Until now, Net Primary Productivity (NPP) measurements have been obtained through estimates of aboveground productivity from one or various field methods. Most of the data collected in previous studies comprise specific time intervals in small areas, coupled with climatic data from long-term averages. Spatial variability of forest productivity may pose a problem when trying to estimate NPP for an entire region, and without real-time climate data there might be unaccounted temporal and spatial shifts due to inter and intra-annual changes. This study will be the first to close the gaps in NPP research by using monthly measurements of two separate field methods to estimate aboveground productivity coupled with site-specific, real-time climate data. These include concurrent data of fine litterfall and tree growth collected from September 2006 to September 2008. We present some of the first comprehensive estimates of NPP for the Australian Wet Tropics bioregion, including changes across latitude and altitude in a tropical rainforest ecosystem. We will quantify and test the relationships between field estimates of NPP with real-time climate, with implications for predicting primary productivity under climate change scenarios.



Testing effects of herbicide on a wider range of coral reef species and possible herbicide-climate interactions on tropical marine species

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MTSRF [Project 3.7.1\(s\)](#)

Previous research into the effects of herbicides on coral reef organisms has primarily yielded single dose-response relationships and focussed on a single group of target organisms (reef building corals). In addition to corals, foraminifera and crustose coralline algae (CCA) represent key primary producers that are potentially sensitive to both herbicides and thermal stress. Studies to date do not address the likelihood that field herbicide exposures will occur in combination (for significant periods) with other potential stressors such as high temperatures, illumination, sedimentation or lower salinity. Thus, we aimed to contribute to the development of threshold values by investigating a wider range of target organisms and testing for potential climate and herbicide interactions. Initial experiments revealed that CCA and foraminifera [eleven species representing all major groups of endosymbionts known in these organisms (diatoms, dinoflagellates, red algae and green algae)] are sensitive to PS(II) herbicides and clearly vary in their sensitivity to a variety of pesticides. However, the general range of concentrations affecting the photosynthesis is similar to that previously found in corals. A series of laboratory studies also examined the potential for thermal stress to impact

upon the toxic thresholds of photosystem II (PSII) of corals, foraminifera and CCA. This was tested using the herbicides diuron, atrazine and hexazinone. While corals have received most of the popular and scientific attention, these results indicate a more widespread vulnerability of various types of coral reef organisms to pesticide exposure and suggest that this may be exacerbated by climate change.



Socio-economic consequences of the implementation of agricultural 'best' management practices to improve water quality in the Great Barrier Reef catchments areas: A farm-household modelling approach to in the Tully-Murray catchment

Martijn van Grieken, I. Bohnet, T. Webster, P. Thorburn, J. Biggs and A. Fakes

CSIRO

MTSRF [Project 3.7.5](#)

In this study we analyse the socio-economic consequences of the implementation of agricultural 'Best' Management Practices (BMPs) to farmers in the Tully Murray Catchment. In more detail, we aim to determine the private economic consequences of BMP implementation to farmers and the effectiveness of these BMPs in reducing Dissolved Inorganic Nitrogen (DIN) loads to the end of the river.

We integrate (1) plot level benefit-cost analysis of management practices in sugarcane, grazing, banana and forestry industries with a (2) private-economic Farm Household Modelling approach at the farm level and a (3) catchment based hydrological model. This approach not only provides insight in the likelihood of adoption of best management practices by agricultural producers and subsequent private-economic consequences and water quality effects, but could also enable the identification of incentives and regulations that are likely to be most (cost-) effective in promoting the adoption of best management practices.



Changes in seagrass meadows across the Great Barrier Reef

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MTSRF [Project 1.1.3](#)

Seagrasses are present along the east coast of Queensland, buffering the Great Barrier Reef from coastal influences. The Reef Rescue Marine Monitoring Program (MMP) includes monitoring of intertidal seagrass meadows for parameters which give an indication of their health, in particular with respect to changes in water quality. Overall, seagrasses examined within the Reef Rescue MMP over the last monitoring period were in a good to fair condition on a GBR wide scale. Seagrass distribution has changed little since monitoring was established. Some localised changes have occurred, but there is no overall general trend. Seagrass meadow distribution over the 2007/2008 sampling period declined at some locations due primarily to natural physical disturbance (sediment movement). The declines observed, at two locations, have relatively large seed banks and low epiphytes/macro-algal loads and seagrasses are expected to recover rapidly.

Monitoring parameters include seagrass tissue nutrients and although at the scale of the whole GBR tissue nutrient concentrations are the result of their local nutrient environment,

we do observe trends at the NRM scale. The Wet Tropics show seagrasses are nutrient replete. The Burdekin Dry Tropics show a separation between habitat type, coastal and reef. In the Mackay-Whitsunday region, coastal sites are replete or P limited suggesting saturating levels of nitrogen. The Fitzroy also show a dichotomy between habitat types. The Burnett Mary region are N limited. Sediments associated with seagrass meadows were found to detect Diuron, the only herbicide, of the thirteen analysed, found above detectable limits during the late Monsoon 2008. Diuron was detected in the sediments at all Townsville sites and coastal sites in the Mackay-Whitsundays, Fitzroy and Burnett-Mary. All concentrations were below levels reported to inhibit seagrass growth, the highest were found in Sarina Inlet. However samples were not collected during river flow events so most likely reflect a more resident herbicide component that persists for some time associated with sediments rather than in the water column.

Within canopy temperatures over the past twelve months were slightly warmer at northern locations and cooler at southern locations than compared to the previous monitoring period. The only location to experience peaks in maximum temperatures above 40°C during the past twelve months was Yule Point. Seagrass meadow resilience as evidenced by seeds and reproductive structures were more common in coastal as opposed to offshore locations. The region with the greatest seed banks and reproductive effort was Burdekin Dry Tropics followed by the Wet Tropics and Mackay-Whitsunday NRMs.

With the monitoring approach applied, an augmented Seagrass-Watch program actively involves community volunteers and allows the large number of sites to be monitored for the cost expended. Monitoring indicates intertidal seagrasses are influenced primarily by the availability of light and nutrients for primary production when temperatures stay below 40°C, and research activities are being undertaken to understand the thresholds of these limiting factors to allow more effective monitoring and prediction of change.



Sponge aquaculture in the Torres Strait

Steve Whalan, Libby Evans-Illidge, Carsten Wolff and Alan Duckworth

Australian Institute of Marine Science, Townsville
 MTSRF [Project 1.3.2](#)

Sponges are conspicuous components of invertebrate benthic communities and play functional ecological roles in aquatic ecosystems. Several species are also commercially important for their use as bio-materials. Previous research efforts conducted by the Australian Institute of Marine Science, in association with CRC Torres Strait, MTSRF, Torres Strait Regional Authority, Yorke Island Council and Kailag Enterprises, has identified *Coscinoderma mathewsii* as an ideal bath sponge candidate for culture at Masig Island in the Torres Strait. The CRC funded research provided key information on sustainable sponge-farming methods that can be taken up by Torres Strait communities. Experimental trials using traditional pearl (mesh) panels demonstrated *C. mathewsii* explants can survive and double in size in twelve months. An additional focus of ongoing MTSRF-funded research continues to provide pivotal knowledge on the ecological role and potential value of sponges to Torres Strait by elucidating the population demographics and dynamics of *C. mathewsii* and other benthic invertebrates. This research further strengthens the sustainable management and culture of this sponge providing critical ecological information related to the distribution, abundance, population connectivity and recruitment of sponges in habitats surrounding Masig Island. Progress to date from past (CRC Torres Strait) and continuing MTSRF projects will be summarised. In addition, new research proposed for 2009, which will build upon the existing knowledge framework and link it more closely with Australia's first sponge farm being developed at Masig Island, will also be outlined. More specifically, the

proposed experimental research will aim to optimise growth and survival of cultured sponges by quantifying the effects of different harvesting, handling and farming techniques.



Towards an integrated framework for assessing the vulnerability of biodiversity to climate change: Prioritising research and adaptation strategies

Stephen E. Williams

Centre for Tropical Biodiversity and Climate Change, School of Marine and Tropical Biology,
James Cook University
MTSRF [Project 2.5ii.4](#)

Global climate change is the most significant current threat to biodiversity in the rainforests of the Australian Wet Tropics. Impacts on biodiversity, both negative and positive, will be diverse, complex and interactive, as will the biotic responses. It is now necessary to prioritise and integrate future research and management in order to minimise impacts. We provide a framework to assess the vulnerability of species to global climate change that considers the diverse factors that determine the key elements of sensitivity and exposure. Sensitivity of a species is mediated by the potential for ecological and evolutionary responses as well as species and ecosystem resilience. Sensitivity is then balanced against exposure where changes to regional scale conditions may be tempered by habitat buffering at finer spatial scales. The framework is then completed with explicit recognition of adaptive management and feedback mechanisms that will follow any realised impact. All of these components affect the relative vulnerability of a species and need to be considered in any comprehensive assessment of the impact of climate change on biodiversity. Objective prioritisation of vulnerability is the first step towards planning efficient adaptation strategies that maximise benefits and avoid wasting management resources on unnecessary, or lower priority, actions. I will present this framework and illustrate with examples from our MTSRF-funded research within the Wet Tropics.



Water quality and coral bleaching thresholds: Formalising the linkage for the inshore reefs of the Great Barrier Reef, Australia

Scott Wooldridge

Australian Institute of Marine Science
MTSRF [Project 2.5i.4](#)

The threats of wide-scale coral bleaching and reef demise associated with anthropogenic climate change are widely known. In this presentation, I consider the additional role of poor water quality in lowering the bleaching 'resistance' of symbiotic reef corals. In particular, I establish a quantitative linkage between terrestrially-sourced dissolved inorganic nitrogen (DIN) loading and the upper thermal bleaching thresholds of inshore reefs on the Great Barrier Reef, Australia. Significantly, this biophysical linkage provides concrete evidence for the oft-expressed belief that improved coral reef management will increase regional scale resilience of coral reefs to global climate change. Indeed, for the most disturbed inshore areas it is shown that the potential benefit of this 'local' management imperative is equivalent to ~2.0°C in relation to the upper thermal bleaching limit; though in this case, a potentially cost prohibitive reduction in end-of-river DIN of >50-80% would be required. To highlight the socio-economic tradeoffs that the water quality/coral bleaching linkage presents, I consider a case study application from the Tully River catchment.



Ongoing development of the interactive identification and information system to Australian tropical rainforest plants



Frank Zich

Australian Tropical Herbarium
MTSRF [Project 1.2.1\(a\)](#)

Australian Tropical Rain Forest Plants – Trees, Shrubs and Vines is a CD-based interactive identification and information system for 2,154 species of trees, shrubs and vines of northern Australian rainforests. MTSRF support has enabled further work on the system to, (1) add modules for grasses and forbs (almost 270 additional species); and (2) transform the whole system into Lucid 3 software to enhance functionality and enable web publication. Simultaneous projects are underway to produce fern, orchid, palm, pandan, parasite and saprophyte modules. Once completed, the entire vascular plant community will be covered by a single extensively illustrated identification key and information system, a unique achievement for any rainforest in the world, and an invaluable tool for researchers, students, public, managers and decision makers.

Further Information

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