

Reef Rescue Research & Development

Final Program Report: Overview of research findings and program outcomes, 2011-2015



Prepared by the Reef & Rainforest Research Centre



Australian Government
Department of the Environment



**Reef Rescue Water Quality
Research and Development Program
Final Program Report: Overview of research findings
and program outcomes, 2011-2015**

Prepared by the Reef & Rainforest Research Centre



Australian Government

Department of the Environment

Supported by the Australian Government's
Reef Rescue Research and Development Program



© 2015 Reef and Rainforest Research Centre.

This report should be cited as:

Reef and Rainforest Research Centre (2015). Reef Rescue Water Quality Research and Development Program Final Program Report: Overview of research findings and program outcomes, 2011-2015. Reef and Rainforest Research Centre Limited, Cairns (pp. 54).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's Reef Rescue Water Quality Research & Development Program.

The Reef Rescue Research and Development Program (Reef Rescue R&D) was funded in 2011 under the Australian Government's Caring for our Country program, and consisted of 18 projects. Reef Rescue R&D is designed to improve our understanding of the link between land management practices and environmental impacts, and improve water quality across the Great Barrier Reef by informing on-ground projects to reduce the amounts of nutrients, pesticides and sediments reaching the Reef from agricultural lands. The program was extended for one year in 2013-14 under the Australian Government Reef Programme.

This publication is copyright. The Copyright Act 1968 permits fair dealing for study, research, information or educational purposes subject to inclusion of a sufficient acknowledgement of the source.

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment. While reasonable effort has been made to ensure that the contents of this publication are factually correct, the Commonwealth does not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this publication.

This report is available from the Reef Rescue R&D website: <http://www.reefrescueresearch.com.au>

Contents

Contents.....	ii
Purpose	ii
Acknowledgements	ii
Executive Summary	1
1. Introduction.....	2
2. Key findings and management implications for the GBR ecosystems and agricultural practices.....	4
3. Priority knowledge needs and future directions	11
Knowledge gaps and future directions for <i>Reef Rescue</i> R&D projects	11
Priority needs to support water quality improvement in the GBR: Learning from Reef Rescue R&D	18
4. Enhancing collaboration.....	19
Evaluation of progress.....	20
5. Conclusions: Success and challenges	24
Program highlights	24
Lessons learned for program delivery	27
Appendix 1: Overview of <i>Reef Rescue</i> R&D.....	28
Appendix 2: List of publications	30
Appendix 3: Summary of <i>Reef Rescue</i> R&D communication.....	38

Purpose

This report provides an overview of the final outcomes of the Australian Government's Reef Rescue Water Quality Research and Development Program (*Reef Rescue R&D*).

The key findings and achievements and future research directions have been summarised from the Final Project Reports and Research Outcomes Reports submitted by Program Leaders between September 2013 and February 2015. The achievements of the Reef and Rainforest Research Centre (RRRC) in delivering the Science Coordination and Integration role for *Reef Rescue R&D* is also summarised.

Note that within this report, the Project Management staff in the Reef Programme team within the Department of Environment is referred to as the 'Reef Programme team' and the staff contracted through the RRRC to undertake the science coordination and integration role are referred to as the 'Science Coordination team'.

Acknowledgements

The RRRC would like to thank the Australian Government Reef Programme for their continued support in *Reef Rescue R&D*. In particular, Kevin Gale, Peter Chase and (formerly) Billy Quinn, have provided excellent guidance in the implementation of this research program. The researchers involved in *Reef Rescue R&D* have made outstanding efforts to ensure that the research is relevant and applied by managers involved in management of water quality issues for the Great Barrier Reef. We would also like to thank Adam Knapp and (formerly) Val Sapin from the Reef Rescue Water Quality Grants and Partnerships program for maintaining a collaborative approach with us throughout *Reef Rescue R&D*.

Executive Summary

The Reef Rescue Water Quality Research and Development Program (*Reef Rescue R&D*) was established to improve our understanding of the link between land management practices and environmental impacts for the Great Barrier Reef (GBR). It has been a highly successful component of the Australian Government's Reef Rescue and Reef Programme investments. The program commenced in May 2011 and a majority of the 18 projects were completed in September 2013. An additional year of funding was provided to six projects to continue components that would significantly benefit from additional time and resources, particularly in the completion of critical field work. These projects were completed at the end of 2014.

The research has delivered results directly related to the adoption and development of sustainable management practices that have water quality benefits, understanding pesticide dynamics, transport pathways and management practice efficiencies, and new approaches to monitor and report on the outcomes of investments in GBR water quality improvement. The key findings of the program are summarised in Section 2 of this report, with program highlights in Section 5. The outputs have informed other aspects of the Reef Rescue / Reef Programme and the broader Reef Plan initiative, including the on-ground water quality grants, and monitoring and reporting initiatives. *Reef Rescue R&D* has delivered a comprehensive suite of publications including 21 journal publications with a further 10 articles in review, and 35 *Reef Rescue R&D* Technical Reports. The project teams have also convened around 65 field days or industry forums and given over 100 conference and stakeholder workshop presentations about the projects.

The next steps for further R&D in this field must provide the foundation for the extension of investment for GBR water quality. We have identified the following key areas of inquiry in the GBR catchments (refer to *Section 3 Priority knowledge gaps and future directions*):

- i. Nutrient management for cropping industries.
- ii. Transitioning to non-residual herbicides and understanding pesticide risks to GBR ecosystems.
- iii. Manifesting erosion management in grazing lands.
- iv. Understanding and prioritising estuarine and inshore ecosystem repair.
- v. Prioritising investment through cost benefit analysis and enhancing past and present investment outcomes.

The success of the *Reef Rescue R&D* is attributed to the development of targeted research and development priorities, the outstanding scientific rigour and commitment of the research teams and importantly, the commitment to a dedicated independent coordination and integration role for the program undertaken by the Reef and Rainforest Research Centre (RRRC). The strong integration role maintained by RRRC, linked directly with the research teams and users of the research has enabled the program to deliver highly applicable results in just two years. The RRRC fostered inter-project communication, sharing of data, links to other programs and encouraged a joint vision between the researchers and research users. Section 4 provides further information on evaluation of the delivery of *Reef Rescue R&D*.

In conclusion, the outputs of *Reef Rescue R&D* have demonstrated that an integrated program and goal orientated R&D delivers more value for reduced transaction costs. The model adopted in this first investment provides a good foundation for the implementation of future investment in GBR water quality R&D.

1. Introduction

Reef Rescue was a five year, \$200 million investment by the Australian Government under its Caring for our Country¹ initiative which commenced in 2008. As part of Reef Rescue, the Water Quality Research and Development Program (referred to as *Reef Rescue R&D*) was established to improve our understanding of the link between land management practices and environmental impacts. The program began in 2011 and included 18 research projects, and a program coordination and integration role undertaken by the Reef and Rainforest Research Centre (RRRC). A majority of the projects were completed by September 2013, and additional funding was provided to continue critical field work for six projects during 2013-2014.

The portfolio of research in *Reef Rescue R&D* is illustrated in Figure 1 and included:

1. **Adoption and development of sustainable practices that have water quality benefits:** The development, trial and validation of land management practices that are sustainable and have improved water quality outcomes in the sugar, beef grazing, horticulture and dairy sectors;
2. **Pesticide threat, delivery and management:** Investigation of pesticide management in the sugar, beef grazing and horticulture industries and pesticide transport pathways in freshwater and marine ecosystems; and
3. **Tracking change:** Development of robust and cost effective techniques for measuring and reporting key monitoring indicators.

These are described further in Appendix 1.

A whole of program approach to managing and reporting the outcomes of the program was adopted from the outset. The *Reef Rescue R&D Research Linkages* report² was a strategic effort to document the linkage between individual projects and with related initiatives such as the Reef Plan Paddock to Reef Program. The document identified strategies to foster synergies between these initiatives. A number of communication strategies were adopted to deliver these linkages (see *Reef Rescue R&D Communication Plan*³). The most successful activities included the development of a dedicated program website www.reefrescueresearch.com.au, annual conferences, representation at various policy and industry forums, and regular participation in Reef Plan R&D Coordination meetings.

All *Reef Rescue R&D* research projects were required to submit a Research Outcomes Report that summarised their research findings. These have been prepared as part of a technical series for the program (visit <http://www.reefrescueresearch.com.au/resources/research-outcomes-reports.html>), and provide the basis of the technical content of this report; this report was circulated to all Project Leaders for review in 2014.

¹ <http://www.nrm.gov.au/>

² <http://www.reefrescueresearch.com.au/images/documents/Reef-Rescue-Research-Linkages-v101111.pdf>

³ <http://www.reefrescueresearch.com.au/images/documents/Reef-Rescue-Communication-Strategy-v101111.pdf>

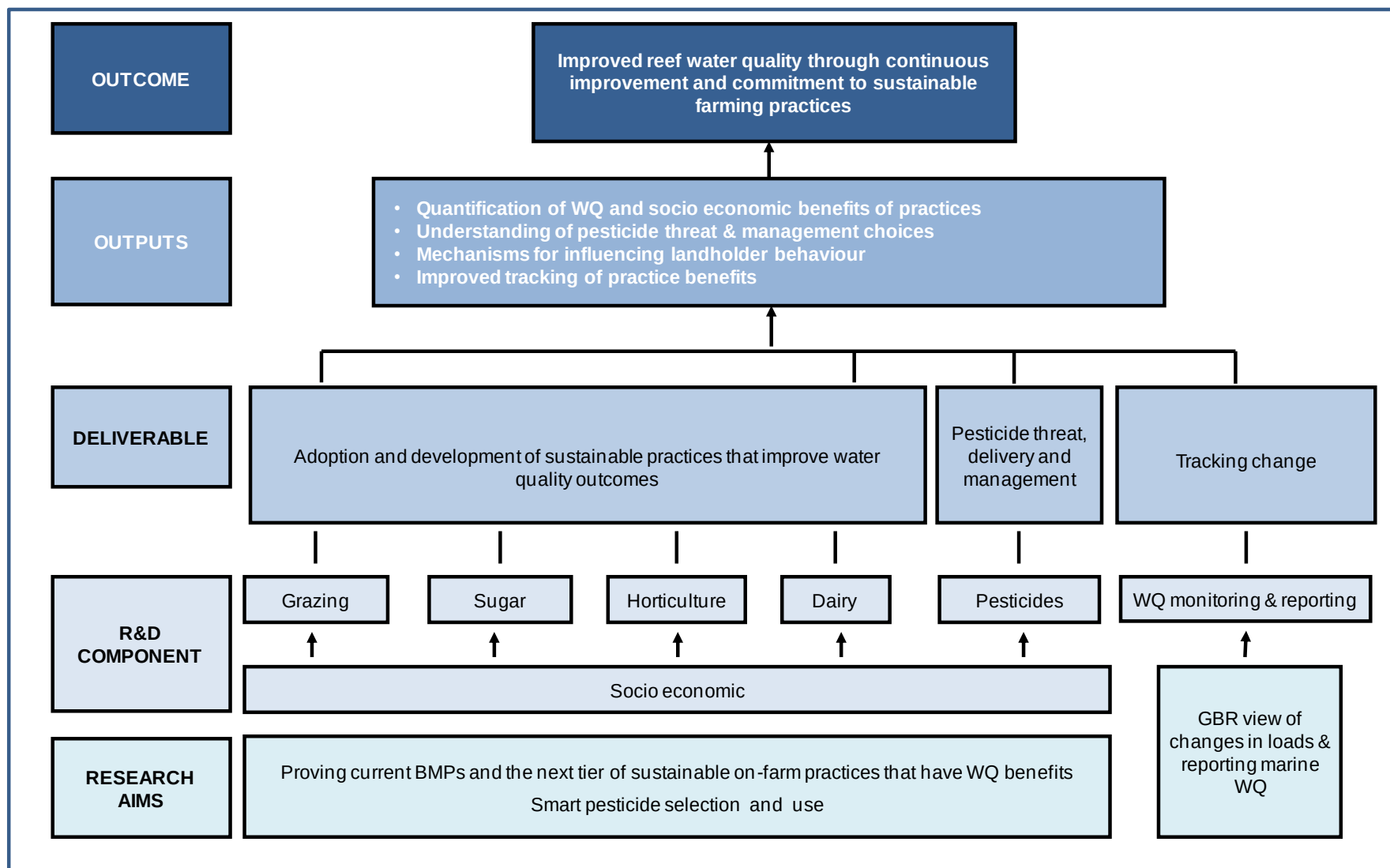


Figure 1: Structure of the Reef Rescue Water Quality Research and Development Program (Reef Rescue R&D).

2. Key findings and management implications for the GBR ecosystems and agricultural practices

The following section provides a summary of the science within each of the three main sub programs of *Reef Rescue R&D* and an overview of management applications.

Adoption and development of sustainable practices that improve water quality outcomes

Grazing industry related projects (RRRD024, 027, 032, 009). **RRRD024** has demonstrated that the success of rehabilitation of D-condition, severely eroded grazing lands was highly correlated to seven key aspects: (1) a high degree of mechanical disturbance (intervention) is required (deep ripping, blade ploughing or, adding mulch after heavy disturbance) to increase water holding and infiltration; (2) selecting the most suitable and responsive soil types (non-sodic clays, clay-loams and loams); (3) sowing well adapted pasture species (tropical grasses and legume cultivars); (4) long-term total grazing control to allow for rainfall-dependent pasture establishment, seeding and spread over the first 3-5 years depending on rainfall; (5) conduct mechanical disturbance and seeding rehabilitation programs in years of predicted above average seasonal rainfall conditions (la Niña years preferably); (6) start rehabilitation before all topsoil is lost, and exposing more serious chemical and physical constraints to pasture development; and (7) plan and monitor grazing management strategies early to prevent the development and spread of bare D-condition areas by maintaining healthy soils and pastures. Grazing land management training is desirable. Aggressive disturbance with successful pasture establishment can greatly increase infiltration, ground cover and pasture productivity, and reduce sediment and nutrient losses, for at least ten years on better quality soil types. There are sodic soil types that cannot be rehabilitated effectively by current methods. Results of successful rehabilitation can be included in education and training packages for the grazing Best Management Practice programme to encourage improved land management in the future.

A new fractional groundcover algorithm was developed to estimate ground cover more robustly than the previous Ground Cover Index, allowing better separation of over storey and ground cover as part of **RRRD027**. The project produced a new generation of spatially validated, multi decadal mapping of grazing land condition for the Burdekin and Fitzroy regions. These data suggest that grazing land condition has improved in both regions since the mid - 1990s drought. Analyses were also conducted to develop a number of tools that will allow users to better understand how ground cover levels relate to landscape and GBR water quality outcomes. These products have been packaged and distributed via a number of channels, including the seasonal cover time series in the VegMachine® software and training 32 on-ground staff to use the software. This has resulted in assessments of landscape state and change on over 300 grazing properties to help direct NRM funding and extension work, and to directly provide land managers with landscape monitoring data.

Monitoring and assessment of grazing management practices at 10 case study sites throughout the Burdekin and Fitzroy regions was undertaken to validate the relationships between land cover and condition, pasture productivity, grazing practices, and erosion rates (**RRRD032**). The results demonstrate that cover can be used to predict land condition (as previously found), and also the practices and erosion outcomes. It was concluded that reducing stocking rates across the two-thirds of properties in each soil type having medium and low cover levels would lead to reduced runoff volumes and increased soil stability in the long term, and also increased forage production. The magnitude of these responses will increase with the magnitude of reductions in stocking rates, up to at least 50% reductions in stocking rates on low cover properties. In addition, the resources required to grow forage were more efficiently retained on high cover sites than low cover sites. Scenario modelling indicated that increasing ground cover at the property scale can result in large reductions in long-term hillslope soil loss and associated nutrient losses. For example, increasing the minimum Ground Cover Index (GCI) during drought by 20–25% (change in mean-annual GCI of 7–12%) can reduce hillslope fine sediment loss by up to and exceeding 30% in the long term. In addition, in the long term, higher cover levels will help to maintain or improve land condition and soil water holding capacity, reducing runoff volumes and so reducing gully and streambank erosion rates. The pasture modelling also highlighted several situations

where time series of cover data can be misleading, particularly when pasture composition changes. Scenario modelling revealed that over-estimating the recovery rate following heavy grazing can result in over-estimating the safe stocking rates which will sustain land condition through drought period.

The project also developed guidelines for applying the recently developed Dynamic Reference Cover Method as a means of assessing differences in past grazing practices and land condition between properties, at regional scale and across rainfall gradients. A large scatter in grazing-induced cover deficit across properties within each region was demonstrated, highlighting the importance of targeting properties with greatest potential for improvement. The assessment is an additional line of evidence, which should be confirmed with on-ground observations such as land condition assessment.

Historical water quality datasets were collated for the Brigalow Case Study Site (**RRRD009**) and average event mean concentrations (EMCs) of total nitrogen runoff from different pastures were established for comparison to the project trials. During the 2010-2012 sampling period a number of conclusions were drawn: total suspended solids (TSS) and nitrogen loads (totals and species) from grass and grass-leucaena pasture were typically equal to or lower than virgin brigalow scrub; phosphorus loads (totals and DIP) from grass and grass-leucaena pasture were typically equal to or higher than virgin brigalow scrub; loads of all parameters from butterfly pea ley pasture were equal to or higher than virgin brigalow scrub. It was also demonstrated that land use effects on water quality can still be seen even in extreme wet seasons. In years with no runoff from virgin brigalow scrub, all loads from agricultural land uses are an absolute increase compared to the natural system. Runoff during 2013 supported the 2010 to 2012 result that clearing brigalow scrub for either cropping or grazing increased runoff. Grass pasture continued to display this trend in 2014; however, butterfly pea ley pasture had similar runoff to brigalow scrub. Loads of total, oxidised and dissolved inorganic nitrogen from butterfly pea, grass and leucaena pastures were all lower than virgin brigalow scrub. However, the greatest load of dissolved inorganic phosphorus came from butterfly pea in both years. No temporal trends were detected in the event mean concentrations of nutrients or sediment during 2010 to 2014 from brigalow scrub, grass pasture or leucaena pasture. However, a declining trend was observed for total, oxidised and dissolved inorganic nitrogen and total suspended sediment from butterfly pea ley pasture. Direct comparison of runoff totals for 2010 to 2014 support the observation that clearing brigalow scrub for either cropping or grazing increases the runoff component of the water balance.

These findings have been synthesised into a series of values and trends suitable for use in model development and validation to further refine estimations of the impact of changed land use, management and the adoption of leguminous pastures on water quality.

Sugar industry related projects (RRRD056, 004, 020). **RRRD056** used a combination of field measurements, simulation modelling and economic analyses to evaluate nitrogen losses from A-Class practices in sugarcane. It showed that A-Class practices can reduce losses of nitrogen from sugarcane fields and that universal adoption of A-Class practices may meet water quality targets, whereas adoption of B-Class practices may not. The reduced nitrogen losses from A-Class practices come about primarily from reduced nitrogen inputs to fields. Further, reducing tillage and practicing controlled traffic are predicted to reduce losses of nitrogen (and sediments) through runoff. However, nitrogen losses may be increased through other pathways in this situation. Inputs of nitrogen to sugarcane fields from mill mud need to be balanced by reduced nitrogen fertiliser applications. Achieving this balance is likely to require mill mud being applied to sugarcane fields at lower rates. These principles should apply to other organic nitrogen sources, such as legumes. Finally, it was demonstrated that flood irrigation can be managed to minimise nitrogen losses, through increasing irrigation efficiency. Other irrigation systems, like overhead low pressure systems, inherently have efficiencies and nitrogen losses similar to well managed furrow irrigation systems. Thus, they eliminate the nitrogen losses that come from sub-optimally managed furrow systems.

Crop water management and water quality outcomes were investigated in **RRRD004** with a focus on runoff water quality from furrow and drip irrigation (optimised with scheduling) in sugarcane (near Ayr in the Burdekin region). It was found that there was greater nutrient use efficiency in drip irrigation techniques, with significant control of run-off

(dry top soil- opportunity for storage of rainfall). Similarly larger herbicide loads were detected in furrow compared to subsurface drip irrigation water. Deep drainage is noted to be substantial (as much as one third of the total crop water inputs) in furrow and drip irrigation systems. Herbicides were detected in the deep drainage samples under both irrigation systems. There are a number of factors associated with optimizing irrigation that provide further benefits. For example, the pulsing of drip irrigation results in greater control of deep drainage which reduces the load of nitrogen loss and also leads to reduced contamination of ground water. The optimised subsurface dripper irrigation also kept the soil surface drier, allowing for a greater interception of rainfall that potentially lowers the run-off from subsurface dripper irrigation compared to furrow irrigation. However, there is a need to optimise the use of drip irrigation for sugarcane to make the system capable of offering achievement of full yield potential.

A survey was conducted with 60 respondents (stakeholders in the sugarcane industry) in the Burdekin and Burnett Mary (Bundaberg) regions to understand the drivers and barriers for adoption of drip irrigation technologies. The main drivers were saving of water, land dimensions, topography and soil types unsuitable for furrow irrigation, and the capability of the system to deliver small amounts of water and agro-chemicals. The barriers for adoption are high cost of installation, regular maintenance required, issues with clogging, and the need for specialised technical knowhow for the installation, operation and maintenance of drip and sub-surface drip irrigation systems. It was concluded that many of the current barriers for adoption of drip irrigation could be overcome by training and demonstration.

Growing legumes as a break crop is a common practice for sugarcane growers. However, questions remain about the amount of nitrogen available for sugarcane to plant and ratoon crops following legume fallows and whether nitrogen applications to these crops can be reduced. **RRRD020** aimed to investigate aspects of nitrogen release from legume break crops in sugarcane rotations and implications for water quality. Although these trials, and previous investigations, have indicated some carry-over of mineral nitrogen from fallow legume crops to the first ratoon sugarcane crops, it is highly dependent on rainfall conditions. In the Herbert district (Wet Tropics region), the 'good' legume fallow supplied enough nitrogen for the sugarcane plant crop, but insufficient nitrogen to meet the needs of the first ratoon crop. In Bundaberg, marked differences in the rainfall pattern experienced in two separate sugarcane crop cycles, indicated that we cannot easily predict what nitrogen will be available after the sugarcane plant crop following a legume fallow. The results of the pot experiments have indicated that legume nitrogen is more slowly available for plant uptake than urea nitrogen, but once it is in the mineral- nitrogen form, it is just as susceptible to loss as mineral nitrogen derived from urea nitrogen (if mineral nitrogen supply exceeds the rate of crop nitrogen uptake). Because of the uncertainty associated with predicting seasonal weather conditions, and the key role they have in determining the magnitude of mineral N loss, further refinement of the discounts applied for legume-derived nitrogen is not practical, and therefore the current management guidelines in the SIX EASY STEPS approach are recommended to remain unchanged to encourage assessment for a particular site / block when decisions are being made about possible reduced nitrogen applications.

Horticulture and dairy industry related projects (RRRD049, 054, 055). The banana trial at South Johnstone, Wet Tropics region (**RRRD049**) evaluated five different nitrogen fertilisers (urea, the industry standard, and 4 controlled release fertilisers) for their effect on crop production and on nitrogen loss in deep drainage below the root zone. The results showed that there was no clear advantage in using controlled release nitrogen (N) fertiliser compared to the industry standard of urea applied at the recommended rate of 250 kg N/ha/crop cycle. Loss of nitrogen in deep drainage was lowest for polymer-coated urea applied at 175 kg N/ha. However, leaf nitrogen concentrations were lowest in this low nitrogen treatment. While these were not associated with a lower bunch weight or other plant parameters, it is likely subsequent crops would have had reduced productivity. The controlled release products, Entec and polymethylene urea, when applied at rates of 187-200 kg N/ha, had similar losses of N in deep drainage to urea at 250 kg N/ha. The high rate of urea had the highest losses of nitrogen in deep drainage. The data indicates that controlled release products may be useful during the wet season for continued nutrient release for crop uptake when wet weather restricts application of conventional fertilisers, and by reducing labour costs as a single application may supply nutrient for months.

A component of **RRRD004** also involved comparison of drip irrigation and micro-sprinklers in banana plots in Bundaberg. A sizeable reduction in deep drainage and surface run-off volumes, and therefore a reduction in the loss of nitrogen, were evident for drip irrigation compared to micro-sprinkler irrigation. Reduced deep drainage also led to reduced contamination of ground water by applied agrochemicals.

RRRD054 has developed modelling capacity by adding a banana module to the APSIM framework to predict nitrogen exports in banana crop harvest, leaching, runoff and denitrification using experimental results generated in RRRD049. The module was developed through a combination of published (and unpublished) data, and field experimentation at South Johnstone Research Station. Data was used to calibrate the APSIM model for phenology, leaf area development, biomass accumulation and partitioning, and for harvest. APSIM is used in the Reef Plan Paddock to Reef Program to determine the economic and water quality impacts of ABCD management practices in sugarcane, and ultimately to develop Great Barrier Reef water quality report cards. APSIM is also used to inform NRM groups on incentive funding. The development of a banana module for APSIM provides the ability for the Reef Plan Paddock to Reef Program to model the water quality and economic impact of ABCD management practices in the banana industry. This information will be useful for catchment modelling to improve the validity of reporting and for regional NRM groups (particularly Terrain NRM in the Wet Tropics region) to provide better information on incentive funding decisions.

Dairy field trials in tropical (Ravenshoe in the Burdekin region) and sub-tropical (Gympie in the southeast) Queensland were conducted to quantify the N loss from fertiliser application, and management practices that might reduce these losses (**RRRD055**). The on-farm research presented several challenges, particularly due to the extreme seasonal variability, however some important findings emerged. At both sites there was a significant increase in biomass with DMPP (3, 4-dimethylpyrazole phosphate) applied at half the industry standard rate compare to urea at the same rate. At Gympie the yield was 20% higher than in the urea only treatment and similar to that observed from the higher N rate treatments. At Ravenshoe the biomass from the lower rate when combined with DMPP was greater than the higher N rate treatments. These findings will be of most interest for farmers looking to maximise their productivity at the lowest possible cost. The use of lower rates of urea nitrogen fertiliser should also reduce the potential risk of losses via other pathways, including leaching and runoff. The results also show surprisingly low N₂O losses compared to other studies. It is unknown if this was due to a lack of rainfall during the fertilisation period, or some unknown mechanism suppressing N₂O losses.

Socio economic projects (RRRD010, 011, 039). **RRRD010** has addressed a number of knowledge gaps in understanding the nature and importance of multi-dimensional factors (socio-demographic, economic, cultural and support services) affecting the adoption of land management practices that have water quality benefits at paddock level. The project focused on sugar cane farming within the GBR catchments through case studies from the Burnett Mary (Bundaberg) and the Mackay Whitsunday NRM regions. Survey results from 112 farmers and 17 stakeholders found that cane farmers are more interested in nutrient and herbicide management practices compared to soil and erosion management, and water and irrigation management practices within both regions. The study found nine factors that heavily influence the farmers' decision to adopt a management practice that has water quality benefits. Long-term profitability of the farm is a primary factor, with other factors including access to and availability of cash flow, whether farmers work full-time or part-time, and self-desire to protect natural resources. Half of the factors are economic and half are socio-cultural. The study also found that some farmers place high importance on economic factors while others place high importance on socio-cultural factors. Future investment should therefore be directed towards subsidies of practice(s) as well as social and cultural change that affect the rate of adoption. Understanding these factors has application for other industry sectors in the GBR catchment, such as horticulture, grazing, cotton and cropping.

RRRD011 captured and synthesised over 130 studies dealing with hydrology-water quality related to land use and management, predominately at the paddock scale. These studies are all relevant to estimating changes in hydrology and water quality associated with various management practices in the GBR catchments. A hierarchical data structure was used to summarise experimental sites with sufficient detail that audiences such as the GBR catchment modellers can add value to current and future modelling exercises. Time-series of hydrology and water quality data were used to

produce ‘best bet’ vegetation and soil parameters across a variety of land uses and regions. A protocol for pragmatic water quality modelling was established that estimates hydrology and water quality for a range of environments with reasonable accuracy. Synthesised studies, datasets and best bet vegetation and soil parameter files are published on a publicly available database: <http://www.Howleaky.net/index.php/library>. The project successfully captured several datasets that would have inevitably have been lost, yet such studies represent significant past effort and can provide useful physical evidence to support future management and modelling activities.

Existing information on farm scale net costs or benefits of adopting improved land management practices combined with the effectiveness of practice on pollutant exports is limited to a very few practices and contexts. **RRRD039** addressed this knowledge gap by providing estimates of a wide range of relative costs of practice changes across a variety of contexts. Further, these consistent estimates were scaled to support investment decisions about the adoption of improved practices from the paddock scale to the whole GBR. A recurring conclusion across the project was the pervasiveness of heterogeneity (variation) in both the costs of changing management and in the benefits delivered from changes to management. The very significant differences in costs and benefits (which are not necessarily correlated) drives the potential for targeting of low cost – high load sources to achieve pollutant reductions and improved water quality. Evidence of very large variations in the net costs of practice change and in the benefits to water quality across three dimensions was found. At the property scale the economic implications of individual management practices and their effectiveness in improving water quality varies widely; there is variability in the costs of practice change by enterprise scale (and most likely by other dimensions not explored in this study); and at the sub-catchment, regional and GBR wide scale there are wide variations in the benefits and costs from spatial targeting.

Across the grazing industry evidence of three different dimensions of variation in the net costs of practice change was found: (1) within land condition class according to pasture utilisation, (2) across land types and land classes, and (3) via improvements across condition classes within a land type. A similar degree of variation was apparent across the cane industry although the dimensions to influence water quality differ. The key property scale variations are across financial indicators from management practices within a farming system, financial indicators across combinations of management practices, nutrient and sediment outcomes and influences of soil types. It was demonstrated that the costs of making identical sediment and nutrient reductions can vary by more than one order of magnitude across the relatively small ranges of heterogeneity and are likely to vary across two orders of magnitude when all factors are taken into account. This has major implications for the cost-effectiveness implications of targeting investment in practice change.

Finally, the research suggested there are several overlapping drivers that explain poor adoption rates for some practices related to profit (and limitations in the ability to assess profit), risk and uncertainty around management changes and profit outcomes, the complexity of management changes and incompatibility with enterprise management, attitudes or lifestyle factors, making it difficult to adopt without major changes to the operation of the enterprise.

Pesticide threat, delivery and management

Several aspects of pesticide characteristics, transport and management in the GBR catchments were investigated in RRRD037 and 038. **RRRD037** investigated the half-lives in soil of commonly used pesticides in the sugarcane industry to assist in modelling pesticide runoff from sugarcane paddocks. The results showed considerable variation in herbicide degradation rates between the different herbicides (half-lives vary from 20 days to 530 days) and also in comparison with published values. The inclusion of these new data in paddock-scale modelling will considerably improve herbicide load predictions for the GBR. Little is known on the characteristics and benefits of new/alternative products available to the industry (e.g. Flame, Balance, Krismat, Stomp, Soccer, Dual Gold). A series of rainfall simulation trials across the Burdekin, Mackay Whitsunday and Burnett-Mary regions were undertaken to compare the runoff behaviour of these products. The results showed that much less of the ‘knockdown’ herbicides (glyphosate, fluroxypyr) were lost from the paddock compared to the ‘old’ PSII inhibitors (diuron, atrazine, ametryn) and the new/alternative herbicides (isoxaflutole, metribuzin, metolachlor), which displayed similar loss rates from the paddock. The loss of pendimethalin

was comparable to the 'knockdown' herbicides. Of the new/alternative herbicides, imazapic and pendimethalin were strongly bound to particulate materials while the others (isoxaflutole, metribuzin, metolachlor) were predominately transported in the dissolved phase. A series of spot spray rainfall simulation trials were conducted across the Burdekin, Mackay Whitsunday and Burnett Mary regions to examine the potential of improved spray technology (i.e. weed seeker, banded/shielded spraying) to reduce the losses of herbicides from the paddock. The results showed that the application of less herbicide on the paddock translated to a proportional reduction in the losses of herbicides from the paddock. Another trial examining the effectiveness of banded spraying in the Burdekin region was conducted to determine the reduction of PSII inhibitor herbicides (atrazine and diuron) where furrow irrigation was applied to the paddock. These results showed that for these irrigation systems diuron and atrazine loads leaving the paddock could be reduced by more than 90%.

An assessment of the persistence of herbicides in freshwater and marine environments (**RRRD038**) showed concerning results. A total of 37 different pesticide residues (not including metabolites of these pesticides) were detected in the Barratta Creek Complex (Burdekin region) during the 2-year research program, although a number of these residues were detected infrequently (< 5 / 27 deployments) and at seemingly low levels (i.e. below available ecological guidelines). The results provide valuable insights on the pesticides in common use in this region. The herbicides, diuron and atrazine regularly exceeded ANZECC and ARMCANZ (2000) ecological protection guidelines for several months (5-7 months of the year) at all four sites including in the Ramsar wetland. While concentrations of both atrazine and diuron progressively decreased towards the lower reaches of the Creek system (e.g. in the Ramsar wetland site concentrations were ~ 1/3 to 1/2 of the values measured at the upper site), they still exceeded the 99% species protection value for 6 months of the year. The degradation of priority PSII herbicides under tropical seawater conditions was very slow (over 500 days). Similar (preliminary) results were observed in unfiltered coastal water. Here the presence of light slowed degradation for the PSII herbicides while the presence of sediments increased their degradation rates. Metolachlor and 2,4-D generally exhibited lower persistence under most conditions. Very little degradation of diuron, atrazine, hexazinone, tebuthiuron, simazine, and ametryn would be expected during flood plumes lasting months. These results help explain the year-round detection of herbicides in the GBR lagoon.

The behaviour of tebuthiuron, used in grazing lands for woody vegetation control, was also investigated at the plot and small catchment scale (**RRRD038**). At the plot scale, the maximum load of tebuthiuron in the 'surface' soil (from 0 to 5 cm deep) occurred 28 days after application. Maximum loads in the 'sub surface' soil (from 5 to 20 cm deep) occurred between 56 and 98 days after application. At the small catchment scale, runoff 100 days after application showed high concentrations of tebuthiuron (averaging 103 µg/L); however, the total lost in runoff was only 0.05% of the amount applied to the catchment. Concentrations of tebuthiuron throughout individual hydrographs were consistent indicating high solubility rather than transport adsorbed to suspended sediments. Concentrations between the hydrographs declined exponentially with time.

Two herbicides, Basta (glufosinate-ammonium) and Glyphosate 450 (glyphosate), and the fungicide Penncozeb 75DF (75% mancozeb) were monitored in runoff and deep drainage from a banana plot at South Johnstone from 2011-2013 (**RRRD038**). Results showed that both herbicides were present in surface water runoff throughout both wet seasons. Importantly, glyphosate – thought to be a short-lived product - and its breakdown product AMPA were detected in all runoff events, despite runoff occurring as long as 6 months after application. Furthermore, glyphosate was also detected in deep drainage (below the root zone at 1 m) on two occasions in the month following 700 mm of rainfall over 4 days in late January 2013. This was regardless of below average rainfall and application in June the year prior. These results not only have important implications for the management and use of these herbicides in banana cropping, but other crops such as sugarcane, as many other industries use glyphosate for 'knockdown' control, and as an alternative to PSII inhibitors. The fungicide, mancozeb, was below detectable limits.

To detect impacts of herbicides, **RRRD058** have devised a new biomonitoring index based on freshwater benthic diatoms (a common group of micro photosynthetic algae with a cell wall made of silica) to detect impacts of herbicides. This new index, called SPEAR_{herbicides}, is based on similar principles as the macroinvertebrate-based SPEAR_{pesticides}. Rapid

toxicity tests were designed to test the sensitivity of large number of diatom taxa collected from rivers draining into the GBR and were used to classify diatom taxa as either SPEcies At Risk (SPEAR) or SPEcies not At Risk (SPEnotAR) from herbicides. Results showed that the relatively sensitivity of diatom genera was independent of herbicide type, light intensity, nutrient level and collection sites making them a useful tool for complementing pesticide monitoring in the GBR catchments.

Tracking change - water quality monitoring techniques and reporting

Two projects were conducted to support **monitoring and reporting** (RRRD030, 016) of Reef Rescue investments in the GBR. A technique for integrating several sources of information relevant to estimating suspended sediment loads was developed in **RRRD030**. Using a case study approach in the Upper Burdekin, the framework provides: a more realistic estimate of the sediment load, that takes into account measurement error, as well as error in our process level understanding of the pollutant; different summary measures of loads (e.g. daily, monthly, annual, event based) with estimates of the certainty; methods for quantifying hillslope, gully and streambank erosion processes within this framework, which provide information about the sources of the loads; scenario analyses based on changes to cover and rainfall (for example) with estimates of error; an exceedance probability curve or exceedance probability map relating to current condition, which enable managers to plan for events that lead to high probability of exceeding a load of a given magnitude; and more scientifically defensible targets based on exceedance probability curves or maps in response to changes in rainfall and/or cover; a forecast of concentration, flows and loads in the Upper Burdekin one year out with estimates of the certainty in those predictions. These outcomes can assist in prioritising areas within a catchment to reduce pollutant loads, identify the main erosion sources, and target the areas of greatest uncertainty in knowledge and decision-making.

RRRD016 developed an approach for an integrated assessment metric for reporting water quality in the GBR lagoon. To aggregate multiple sources of data across various spatial and temporal scales in the reporting framework, a spatio-temporal statistical process model was developed. A small reporting region around the Tully mouth/Rockingham Bay (Wet Tropics region) was selected for the proof of concept of the reporting framework as this area has the greatest spatial and temporal data from direct water sampling. For the proof of concept of the reporting framework, two parameters were selected: (1) TSS measured by remote sensing, direct water sampling both during floods and ambient conditions, and water quality instruments on coral reefs, and (2) DIN and PN values measured only by direct water sampling both during floods and ambient conditions. The approach was demonstrated to be fully compatible with the current Paddock to Reef reporting and builds on the current model of tiered reporting across regional areas. The implementation of the proposed framework would need to be considered in the context of potential future changes to the Paddock to Reef monitoring and reporting structure.

3. Priority knowledge needs and future directions

Knowledge gaps and future directions for *Reef Rescue* R&D projects

Each project has identified future directions for their field of research that builds on the results of their research projects. These are outlined below.

Adoption and development of sustainable practices that improve water quality outcomes

Grazing industry related projects (RRRD024, 027, 032, 009)

Rehabilitation of D-condition grazing lands:

- A detailed on-ground survey of mechanical methods, grazing management and conditions of successful landholder rehabilitation sites to expand rehabilitation knowledge across the two catchments. Incorporate rehabilitated sites on multiple land types in the Burdekin and Fitzroy regions, field measurements of pasture cover, composition, and soil surface conditions to better define what methods and management produces adequate rehabilitation.
- Maintenance and continuation of the Burdekin rehabilitation trial site located on the Spyglass Research Facility, Charters Towers, to evaluate longer-term rehabilitation, maintenance and management requirements over a range of annual rainfall and grazing conditions.
- Undertake trials on soil physical and chemical amelioration methods to establish pastures on the difficult soil types such as the sodic dermosol at the Spyglass Burdekin trial site and similar saline or sodic soil types in the Burdekin and Fitzroy catchments.
- A study to identify and map the soil types with bare, eroded D-condition patches requiring rehabilitation across the Burdekin and Fitzroy catchments and their extent.
- A review and on-ground pasture/soil condition assessment of regional funded rehabilitation works on properties (for example, in the Fitzroy and Burdekin regions) to expand knowledge of what makes successful rehabilitation would provide a better analysis of costs involved and attitudes to, and effectiveness of, external financial incentives.
- Investigate alternative and less costly methods of rehabilitating D-condition bare patches that are likely to appeal to landholders. One approach with cattle producer interest is to use high density herd impact (hoof impressions) on bare patches with added pasture seed, and timing at an appropriate soil moisture content. This method is suggested by some land management consultants with little or no local proven successful examples but it appeals to cattle producers who do not have ready access to machinery for aggressive mechanical disturbance, and it may be an economical approach.

Getting ground cover right:

- Secure ongoing funding for the Queensland Ground Cover Monitoring Program. The ground cover data is the fundamental landscape monitoring dataset in the GBR catchments and is fundamental to many aspects of Reef Rescue 2 and Reef Plan 3. Given the value it has demonstrated, and the wider implications of its potential loss/restriction, there is a clear priority in ensuring the ground cover program and its data acquisition and processing capacity is secure into the future.
- Progress VegMachine to an online delivery platform to provide direct access for land managers. This would radically change land manager ability to monitor, document and understand their impacts on the grazing landscape.
- Continue to leverage the ground cover data. The ground cover data and its associated products are the most detailed dataset of physical change in the GBR catchment. There have been many examples of these data informing understanding of the landscape and roles and options within it. Future research should look for novel ways to leverage this dataset.

Linking groundcover, land condition and water quality outcomes:

- Extend the cover deficit assessment to all rangeland grazing properties in GBR catchments. We have demonstrated the potential of cover deficit to monitor recent grazing impacts by removing rainfall gradient effects. Cover deficit should be used to assess the relative potential of each property in each catchment for forage management to be improved. It can also be used to evaluate the direction and magnitude of past and future property cover changes resulting from extension and water quality improvement programs such as Landcare, Stocktake and Reef Rescue. Cover deficit has the potential to improve assessments of grazing stress nationally.
- Monitor the land condition responses to practice change. There have been many more studies of land degradation than recovery, yet the latter is a primary objective. Current understanding of land condition recovery rates is poor. Yet we have identified that sustainable stocking rates are sensitive to recovery rates, and recovery is expected to vary between land types. Reducing sediment loads to the GBR will require increases in ground cover. However, it will also require reducing the runoff that feeds the gully and streambank erosion dominating sediment loads in many areas. Sustainable change will require increases in forage productivity. Cover alone can mis-represent the changes to forage composition and hydrologic function that are required to improve productivity and reduce runoff.
- Maintain a long-term land condition field monitoring program to: (i) evaluate the benefits of practice change, (ii) define rates of pasture recovery across different land types, (iii) enable more detailed interpretation of time series cover data, and (iv) inform stocking rate guidelines. The monitoring program should include pasture productivity, species composition, nutrient pool, soil infiltration capacity and water storage. The COSMOZ soil moisture probes (<http://www.ermt.csiro.au/html/cosmoz.html>) appear highly relevant to this purpose. Extensions to cover by remote sensing should also be explored to map the degradation of pasture composition and establish baselines for recovery. Combining land condition field surveys with cover deficit has potential to better define land condition mapping across climate zones than using ground cover directly.
- Map the cost-effectiveness of practice change investment. There is an increasing need for a more detailed technical basis for investment priorities in terms of the relative cost-effectiveness of different practice changes, including forage management and remediation of erosion features. The cost-effectiveness of investment will also be improved by considering spatial patterns in environmental drivers of all erosion processes, such as soil type, terrain and climate. Broader adoption of improved forage management would be assisted by further case studies of productivity and economic outcomes.

Nitrogen loss from pasture legumes:

- The dynamics of dissolved inorganic nitrogen in runoff from grazed catchments, and from established legume and non-legume pastures in particular, is still not clear. The risk posed to water quality is likely to be of concern given the concentration of dissolved inorganic nitrogen in runoff from butterfly pea is equal to that reported for some sugar cane systems. However, these concentrations are typically an order of magnitude less than those from brigalow scrub.
- Continue to invest in the Brigalow Catchment Study site to test a range of grazing management issues. This continuation avoids expenditure on development of new sites; assists with getting research activities on-ground in a short time period as management practice treatments are already imposed and monitoring equipment is installed; is supported by 50 years of data; and can be tailored to meet specific research needs. Examples of the management priorities best suited for investigation at this site include erosion management in the Burdekin and Fitzroy regions, DIN management in cropping in the Fitzroy region, and pesticide reduction in grazing lands in the Fitzroy region.

Sugar industry related projects (RRRD056, 004, 020)

A class management practices in sugarcane:

- More extensive field studies of the water quality outcomes of A-class practices to better test and, possibly refine A-Class practices (to expand field studies beyond three sites, two of which we were unable to determine yield in

the A-Class and conventional treatments). Outputs determined through simulation studies need to be confirmed experimentally.

- Develop a targeted research program to assess and demonstrate how to increase nitrogen use efficiencies. To date approaches to managing nitrogen have either been tested at relatively high rates of nitrogen (i.e. at or above recommended rates) and/or in 'demonstration' trials and greater certainty is required to encourage widespread adoption of the practices to reduce nitrogen loss.
- Initiate a program to develop management 'rules' that would guide N management in precision agriculture in parallel with the technology development (e.g. development of a commercial yield monitor).
- Desktop evaluation of nitrogen losses through new fertiliser technologies.
- Further cost-effectiveness and sustainability (socio-demographic and cultural factors) study to examine adoption of A-Class practices.

N mineralisation following legume fallow crops in sugarcane:

- Investigate the use of 'longer-term' weather forecasting to adjust N inputs to improve the current ability to predict how much nitrogen derived from a legume fallow will be available to the first ratoon sugarcane crop and facilitate modification / refinement of the current nitrogen management guidelines.
- Continued work to better quantify nitrogen release and cycling from fallow / rotational crops.

Irrigation techniques in sugarcane:

- Investigate optimal techniques for pulsing of water and injection of fertiliser under drip irrigation to improve overall yield whilst still achieving significant reduction in runoff.
- In consultation with irrigation business/industries and growers, critically examine the opportunity for optimisation of drip irrigation and use the optimised drip/subsurface drip for improvements in yield, water use efficiency and nutrient use efficiency that generate positive reef outcomes including an assessment of the associated economic implications.
- Investigate the use of slow-release nitrogen fertiliser in irrigated sugarcane to measure water quality runoff and impact on NOx emissions.

Horticulture and dairy industry related projects (RRRD049, 054, 055)

Fertiliser management in bananas:

- Further develop on-farm use of controlled release nitrogen fertilisers. This includes the assessment of how controlled release nitrogen fertilisers can be integrated with normal fertiliser practices, including paired comparisons with grower's standard practices for demonstration purposes.
- Develop/extend previous work on nutrient management strategies (integrated management of N and P nutrition) that can be adopted by industry. This would be complemented by further development and release of Bananaman® decision support software to help banana growers better manage their crop nutrition.
- The total N pool in banana crop soils is vast with 11 tonnes (surface 0.6 m) measured at the start of the trial. A better understanding of what factors affect N release may improve management of soil N and minimise losses to the environment in the plant crop. This includes the use of permanent bed systems where cultivation (and associated release of nitrogen) may be reduced to approximately 20% of the paddock.
- Quantify the potential of controlled release nitrogen fertilisers to reduce losses of nitrous oxide.

Simulation of growth, development and nitrogen balance of banana in APSIM

- To better allow the banana model to capture nitrogen dynamics within a paddock it is necessary to understand the breakdown of crop residue. Currently the banana model uses general terms described from other crops to simulate residue breakdown. An experimental study is underway to better understand banana residue

breakdown, and cycling of carbon and nitrogen from residue into the soil. Banana is a large biomass crop, and leaves are constantly being added to the soil, so understanding how they contribute to soil nitrogen is important.

- The APSIM banana module simulates banana phenology for a point (equivalent of a single plant). Banana plantations have a spread of flowering time, which can be over a number of months. It was necessary to model the 'average' phenology. Further development may be sought at a later time to allow APSIM to better simulate the spread of phenology through the use of crop cohorts.

Fertiliser management in dairy pastures:

- Continue field assessment of nutrient loss pathways in dairy pastures to factor in seasonal variability. These assessments should include: leachate analysis including more detailed investigations of the dissolved inorganic nitrogen component of leached N, more detailed measurement of NH₃ losses from pastures and urine patches, and the influence of N and P present in the DMPP (3, 4-dimethylpyrazole phosphate) product on pasture growth.
- Further research is required to validate the preliminary pasture growth results documented in this study. For dairy producers, measurements of the pasture yield response to inhibitors are required for multiple years to account for climatic variation. Before recommendations are made to farmers, a more detailed cost-benefit analysis, which incorporates other measures of pasture quality, is required. Research should focus on not only maximising yields and reducing N losses directly from pastures, but examine the system holistically.
- Given that DMPP is not yet commercially available in north Queensland, significant further research, in a variety of agricultural settings, is required to evaluate its potential. Future trials in other production systems which drain into the GBR (e.g. sugarcane, bananas) would help to improve our understanding of N loss under fertilised crops in the Wet Tropics region, and the effectiveness of management practices seeking to reduce those losses.

Socio economic projects (RRRD010, 011, 039)

Capturing historic management practice effectiveness data:

- Document experimental outcomes of another 20 management practice assessment study sites in the current web-based database.
- Develop another ten "supersites" which will be analysed and published to support model development and use.
- Synthesise and summarise paddock scale studies providing a consolidated view of the impact of management on water quality. The studies will be used to confirm or update conceptual models of water quality.
- Some studies identified as suited to further analysis are identified below, with the lead investigator:
 - Grazing: Glentulloch (Waters), Springvale (Silburn) and Wambiana (O'Reagain)
 - Sugarcane: Wet Tropics (Prove) and McKay (Rohde)
 - Horticulture: South Burnett (Stork), Imbil (Ciesiolka) and South Johnston River (Prove)
 - Cropping: Emerald and Gatton (Silburn and Tullberg)

Factors affecting adoption of management practices:

- Adoption of improved management practices does not solely depend on economic factors and using financial incentives to drive adoption is not sustainable. Further research to develop a robust and integrated multi-factors led adoption model and tool that can direct adoption policies and funding decisions.
- A qualitative and detailed study on the regional differences in adoption rates of management practices and the key factors affecting adoption decisions.
- A further study on supply chain of any new management practices that need to be adopted.
- A catchment wide integrated socio-economic model for key agricultural practices (sugarcane, grazing, horticulture and cropping) to understand the similarity and differences in adoption rate across the regions and agricultural practices as well as the factors affecting adoption decisions.

Cost effectiveness of management practices and socio economic outcomes:

High level opportunities to improve targeting or quantifying aggregate costs and benefits:

- Link to 'Source' export models for improved calibration; inclusion of additional pollutant reduction costs
 - Link additional pollutant reduction costs already available from other projects – e.g. Costs of pesticide reduction in cane, grazing land in condition class D, horticulture etc.
 - Identify ways to bring gullyng into the grazing cost estimates. We do not have good economic costs for gullyng because of the way gullyng itself interacts with farming systems (removing or dewatering the relatively fertile flats) and the interaction with preferred treatments of fencing them out and complicating stock movements etc. Note that the estimates in RRRD039 relate to sheet erosion which is now regarded as relatively less important than gullyng and bank erosion, although the existing costs are probably a good surrogate for the costs associated with avoiding the start of gullyng in high risk areas.
 - Review and improve highly uncertain cost estimates where these are likely to be high investment priorities (which should be prioritised can be identified by either the supply curve approach or alternative approaches);
 - Develop benchmarks for project selection to generate higher returns for public investment, particularly when information is incomplete; and
 - Focus on the costs and benefits of increasing participation in schemes as a separate issue to the drivers for landholder adoption; testing for take up in order to validate adoption.
- *Opportunities that would support wider reef policy:* Examine institutional/organisational and political impediments to effective delivery (across scales); and explicitly work with partners to convert the targeting and impediment knowledge from RRRD039 into innovation in delivery.
- *In the longer term there is a need to understand the industry scale implications of change:* The most important examples are sustainability of mills as improved practices in cane production are adopted, e.g. if production were to decline at what point do mills become unviable because economies of scale in supply chains fail in either sugar cane or grazing settings (there may also be opportunities to identify ways to improve economies of scale in supply chains and support industry viability, for example a particular interest in sugar cane is the use of sub-contractors and harvest groups to capture economies of scale in particular management practices).
- *Understanding the industry scale implications of change – paddock scale:* Assess emerging improved practices in sugar cane or grazing (many A Class practices for example) for which there is little or no information on the costs and benefits to landholder adoption; and the financial economic and pollutant export implications of precision agriculture for practices such as variable rates within blocks based on mapping.
- *Understanding the industry scale implications of change – whole of farm scale:* Understanding the implications of risk and uncertainty in explaining landholder choices to adopt or not for sugar cane. Note: a small subsequent project has been conducted to provide risk modelling of nutrient rates and yield responses, but have not tested it with landholders so information is required on how it accords with landholder expectations / beliefs.

Pesticide threat, delivery and management

Pesticide related projects (RRRD058, RRRD037, 038)

Pesticide management in sugarcane:

- *Collection/collation of high quality usage data:* Presently there are very little accurate data on pesticide usage in the basins of the GBR catchment. This limits our ability to assess pesticide losses (to amount applied) and to model pesticide loads at a catchment scale.
- *Compare runoff of different pesticides:* Further rainfall simulation sites, in particulate and dissolved phases, especially some of the widely used products like glyphosate that seem to behave variably in different scenarios (may need to be even more comprehensive in mixed applications). While a valuable dataset has been produced on pesticide runoff from paddocks where their runoff can be compared relative to each other, this work has only been conducted on limited soil types and regions and not all common pesticides have been examined.
- *Evaluate available weed/pesticide management practices:* Some work has been conducted on banded/shielded spraying and other similar practices (e.g. spot spraying), however, runoff trials on a commercial farm have only

occurred in the lower Burdekin region (under irrigation). While demonstrations have been carried out in other regions using rainfall simulation, assessing the difference in pesticide losses (e.g. between conventional and banded) in rainfall-runoff event from the Wet Tropics and/or Mackay Whitsunday regions on a commercial/demonstration farm would be highly desirable.

- *Develop a decision-support tool for weed management and pesticide application in paddocks:* With the knowledge currently available on pesticide runoff, soil half-lives, relative toxicity and the efficacy (i.e. knowledge of extension officers), a simplified decision support tool could be developed to help farmers better manage weeds (and pesticides) on their property as well as reducing potential pesticide losses.
- *Examine the efficacy of alternate pesticides for a range of soil types and climate conditions (better linkages with agronomic efficacy research):* Some of the alternate pesticides that have been promoted as viable replacements for the more commonly used products have yet to be properly trialled in different regions in terms of their efficacy (i.e. ability to suppress weeds) and runoff potential.
- *Assess the scope for optimising management of irrigation scheduling:* Investigate optimal days delay between application and irrigation application and choice of pesticide in irrigated systems like the Burdekin.
- *Investigate pesticide transport in groundwater:* While transport via groundwater pathways is usually considered very slow (decades), in the coastal plains of the GBR there are large areas of sugar cane cropping with constructed drains designed to remove deep drainage leachate within weeks, to prevent water logging of the cane. There is also some (minimal) evidence that some pesticides will dissipate slowly in sub-soils/regolith (no light, low organic matter, low oxygen, certain pH's). Baseflow (returned groundwater) is a large component of streamflow, for instance in the Wet Tropics region. Thus there may be a large persistent load of pesticides at low concentrations.
- *Longer term field studies of whole-of-crop cycle approaches:* Including fallow and plant cane management, and subsequent ratoons with improved liaisons with industry and growers to map out long-term pros/cons of shifts away from regulated PSII herbicides.

Pesticide management in grazing lands:

- Expand the tebuthiuron work in grazing lands beyond studies in the Fitzroy region, incorporate assessment of different soil types and at a range of timing after tebuthiuron application. Opportunities exist for replicating the small catchment scale work in additional catchments of the Brigalow Catchment Study. Repeating this experiment will add confidence to the findings of this project. It would also provide an opportunity to determine the movement of tebuthiuron in large runoff events soon after application, which was unable to be achieved in this project due to seasonal conditions.

Pesticide management in banana cropping:

- Continue monitoring pesticides in runoff and drainage sampling over a range of seasons in banana crops to: understand release glyphosate into leachate (deep drainage); determine how susceptible glufosinate is to runoff if applied outside the wet season; and determine partitioning of these herbicides in runoff.
- Determine if the spray-out of crops with glyphosate (a common practice in many other crops also) can also be a risk to runoff losses.
- Determine glyphosate dissipation in soils (i.e. Dermosol) and plant matter in wet and dry conditions (not just in banana cropping regions but other industries that use these products e.g. sugarcane farming).

Pesticide persistence in aquatic environments:

- Continue monitoring the Barratta Creek system (at least at the uppermost and lowermost sites) as these data provide important information on pesticide use in the catchment area and insights into changing product use in the Burdekin region.
- Establish monitoring at another wetland site in the Wet Tropics region within a wetland of national or international significance to allow examination of the exposure of pesticides in a rain-fed system and be a direct

comparison to the irrigation tailwater runoff system. The exposure of pesticides in such systems has not previously been examined in the GBR catchment area.

- Expand the GBR pesticide ecotoxicity database to include all 38 pesticides detected in GBR catchments and the GBR lagoon (and additionally emerging pesticides, breakdown products and commercial pesticide formulations) such that ecological risk can be modelled for all of these pesticides.
- Quantify the sensitivity of species/communities of the highest conservation value, under conditions relevant to freshwater, estuarine and nearshore marine environments, to priority pesticides – ensuring guideline concentrations protect species and communities that we value the most.
- Assess the impacts of: (i) multiple pesticides, (ii) additional stressors related to flood plumes (e.g. low salinity, nutrients and light) and climate change (e.g. high temperature, increased OA), and (iii) repeated pulses (flood plumes) and chronic exposures on organisms/communities of high conservation value towards incorporating these influences in species sensitivity distributions and future water quality guidelines.
- Biological and chemical monitoring (for example: ecogenomics, biomarker, SPEAR, passive and grab sampling) of areas where pesticides are at their highest risk, i.e. in freshwater and estuarine ecosystems, to: (i) determine the extent of impairment to these ecosystems and what effects they have on Reef resilience (e.g. through their connectivity with the Reef), and (ii) clearly demonstrate to farmers and industry representatives the impact that pesticides are having on aquatic ecosystems. For example, Barratta Creek and Bowling Green Bay.
- Improve biological and chemical monitoring (e.g. community structure, passive sampling and grab sampling) of nearshore GBR habitats of high conservation value to evaluate the success of land management policies to protect the GBR.
- Examine the implications of current pesticide loads on the GBR in terms of risk and determine if there is a relationship between pesticide load reduction and a reduction in pesticide risk.
- Establish an ongoing role for the Pesticide Working Group to facilitate communication between researchers, managers, regulators and end users.

Biological monitoring techniques for pesticides:

- Determine SPEAR_{herbicides} and SPEAR_{pesticides} at the pesticide monitoring sites before and after wet-seasons and use it as a biomonitoring tool to add value and confidence in the findings of the Paddock to Reef pesticide monitoring program. Consideration should be given to measuring these indexes at a greater number of sites on rivers draining into the GBR to provide greater spatial coverage at relatively modest additional costs.
- Conduct research to increase the confidence in the SPEAR indexes. In particular, mesocosms experiments could establish causality between the response of the SPEAR_{herbicides} and SPEAR_{pesticides} indexes and herbicides and insecticides, respectively. Mesocosm experiments could also establish whether factors confound SPEAR_{herbicides} and SPEAR_{pesticides} indexes. It would also be useful to conduct seasonal sampling of the diatom flora at selected sites to establish seasonal trends in SPEAR_{herbicides} and to show how quickly the diatom flora recovers at polluted sites following the ending of significant pesticide pollution.

Tracking change - water quality monitoring techniques and reporting

Addressing uncertainties in pollutant load estimation techniques:

- Validate both models (Weany Creek and Upper Burdekin) to ensure they are fit for purpose. This requires omitting periods where we have data, refitting the model and estimating concentrations, flows and loads for the periods that were missing to determine how good the model captures the measurements.
- Extend the model to incorporate erosion processes. This requires specifying a multivariate process as discussed in Cressie and Wikle (2011) which includes concentration, flow and each of the erosion processes.
- Translate the methodology across to a faster platform such as the CSIRO developed LibBi package. This package has been developed specifically for state-space modeling constructed in a BHM framework using particle Markov Chain Monte Carlo methods. The advantage of moving to LibBi is the fast implementation of the methodology and ability to use parallel processing for the computational aspects of the modeling.

- Undertake scenario evaluation of the Upper Burdekin catchment to examine the changes in loads with changing cover.
- The approach is applicable to other catchments and other constituents, which can also be modelled using the Bayesian Hierarchical Model framework. Furthermore, other types of measurements and methods (e.g. tracing techniques) that lead to a better understanding of load generation could be incorporated. Although each catchment and constituent is expected to exhibit unique characteristics and processes, the lessons learned about the implementation of the BHM approach will greatly benefit future applications.
- *Linking catchment models with receiving waters:* Link catchment model outputs with marine models to understand how the sources of loads in the catchments are impacting the GBR lagoon and whether certain scenarios of environmental change or management intervention in the catchments can lead to a change in the marine life in the lagoon. One of the models developed within CSIRO and part of eReefs is a Marine biogeochemical model. The framework for this model is similar to the one presented here, as it is a BHM that attempts to “blend” measurements with model outputs. As the frameworks are similar, the linkage of the two is conceptually straightforward where the outputs from the catchment BHM (posterior probability distributions) can feed into the marine biogeochemical BHM through prior probability distributions. Through this linkage, it is envisaged that scenario investigations occurring in the catchments can feed into the prior distributions for the marine model to examine changes to the marine environment. This approach has the potential to highlight hotspots where load exceedance probabilities are high and lead to more informative and scientifically defensible targets in the marine region.

Development of a marine water quality reporting metric:

- Define smaller reporting regions, based on the decision-making criteria proposed in the assessment framework, to provide a better reporting basis for water quality assessments based on the influence of the river flow and water quality associated with that water flow.
- Future application of this approach needs to consider the weighting of the different water quality variables based on ecological understanding of relevant thresholds for GBR ecosystems such as corals and seagrasses. Weighting and/or thresholds need to be considered in both seasonal and geographical context. In the present framework, all variables are normalised and no weighting is applied to the combination of the water quality variables.
- The issue of the overlapping influence of the waterbodies requires detailed analysis of the influence of river flow and plume formation from individual rivers.
- Further development of water quality guidelines for the GBR to account for regional characteristics and /or for coral reef and seagrass environments.
- In order to integrate the approach, other water quality indicators such as pesticides implementation issues such as the definition of ‘extreme case scenarios’ and spatial and temporal aggregations need to be investigated.
- For this case study, we have focused on a small reporting area (Tully marine area) as it the most data rich in the GBR. To be able to achieve full GBR implementation of this approach it will be necessary to assess whether the Marine Monitoring Program sampling design provides a sufficient spatial and temporal support for the statistical integration model.

Priority needs to support water quality improvement in the GBR: Learning from Reef Rescue R&D

The outcomes of the *Reef Rescue R&D* projects have been valuable in guiding on-ground action for reducing pollutant runoff, particularly from agricultural lands, in the GBR catchments and establishing new methods for monitoring and reporting. It is necessary to continue research of this nature to guide future management decisions, and to continue to improve our knowledge of the best approaches to water quality management in the GBR, in an adaptive way. The information contained in the [Research Outcomes Reports](#), and the outcomes of the [2013 Reef Rescue R&D conference](#) and [Regional Science Forums](#) were used to inform the *Reef Plan Research Development and Innovation Strategy 2013-*

2018. Drawing on this information, we have identified a number of priority R&D themes in the GBR catchments arising from *Reef Rescue R&D*:

- i. **Nutrient management for cropping industries:** This is especially important given the high priority of nitrogen management from the 2013 GBR water quality risk assessment, and is relevant for the sugar cane, horticulture and dairy industries. Most of the benefit is likely to come from a major initiative in innovative approaches to managing nutrient application. The effort must be supported by better understanding of the sustainable path of adoption by understanding farmers behaviour about adoption decision, testing behavioural scenarios and investigating more delivery options to accelerate uptake of recommended approaches.
- ii. **Transitioning to non-residual herbicides and understanding pesticide risks to GBR ecosystems:** The focus should be on the effectiveness, practices and economic benefits of the transition to more benign pesticide use and should build on several existing projects as well as link in to the incentives to be offered under the Australian Government Reef Programme. Assessment of pesticide risk needs to extend into freshwater and coastal ecosystems that are most likely to be at greatest risk from pesticide toxicity.
- iii. **Manifesting erosion management in grazing lands:** This should consolidate existing knowledge of maximising grazing management for improved land condition and productivity, and therefore the emphasis should be on the social and economic aspects of adoption of improved practices in grazing lands. A portion should be allocated to continue trialling cost effective options for rehabilitation of grazing lands in poor condition (especially gullies). Clarification of the relative importance of the management of particulate nutrients (which can be derived from erosion in grazing lands) for the receiving environments of the GBR and its catchments will be useful for guiding future investment priorities.
- iv. **Prioritising estuarine and inshore ecosystem repair:** There are multiple trade-offs and variable returns on investment from the actions required for ecosystem repair, and our present knowledge of the implications of restoration options is relatively limited. Gaining an understanding of which actions deliver the most benefits for overall GBR health will inform further management priorities identified in the regional Water Quality Improvement Plans and the Reef 2050 Long Term Sustainability Plan.
- v. **Prioritising investment through cost benefit analysis and enhancing past and present investment outcomes:** This involves a cost benefit evaluation of past investments to inform future approaches, and progression of improved techniques to optimise monitoring, evaluation and reporting activities for ongoing Reef Plan related initiatives. This theme needs to be supported by the development of a range of synthesis products that answer specific management questions. These outcomes would add substantial value to past investment by learning from the success and challenges of previous investment.

4. Enhancing collaboration

The RRRC was engaged to coordinate and integrate *Reef Rescue R&D* research. A key responsibility of the RRRC has been to ensure that, to the extent practicable, the work undertaken through *Reef Rescue R&D* and related programs are complementary and successfully integrated. The objectives for the integration of *Reef Rescue R&D* were to:

1. **Facilitate and document project linkages** across the *Reef Rescue R&D* portfolio of projects to foster collaboration between researchers and develop integrated outputs that meet the needs of end users;
2. **Understand and communicate** how *Reef Rescue R&D* links to and builds on companion research to deliver research efficiencies; and
3. **Foster synergies** between *Reef Rescue R&D* and related research, management and policies that contribute to Reef health so that there is a higher return on investment, targeted knowledge transfer and more likelihood of enduring outcomes for reef water quality and sustainable agriculture.

The strong integration role maintained by RRRC, which has linked directly with the research teams and users of the research, has enabled the program to deliver highly applicable results in just three years. The RRRC fostered inter-project communication, sharing of data, links to other programs and encouraged a joint vision between the researchers and research users.

Since commencement in 2012, *Reef Rescue R&D* has contributed to all aspects of the Reef Rescue investment and has important findings relevant to design and implementation of the Reef Programme and beyond (see Figure 2). Importantly, it contributed to achievement of the *Caring for our Country* five-year outcomes and targets by informing the effective and efficient delivery of the *Water Quality Grants Program*, and scheduled evaluations of the program's effectiveness and achievements through linkages with the *Water Quality Monitoring and Reporting* program. It utilised the mechanisms established through the *Reef Partnerships Program* coordinated by QFF and the RGC to ensure that the research was conducted in collaboration with landholders and managers, and that the results were communicated efficiently and effectively.

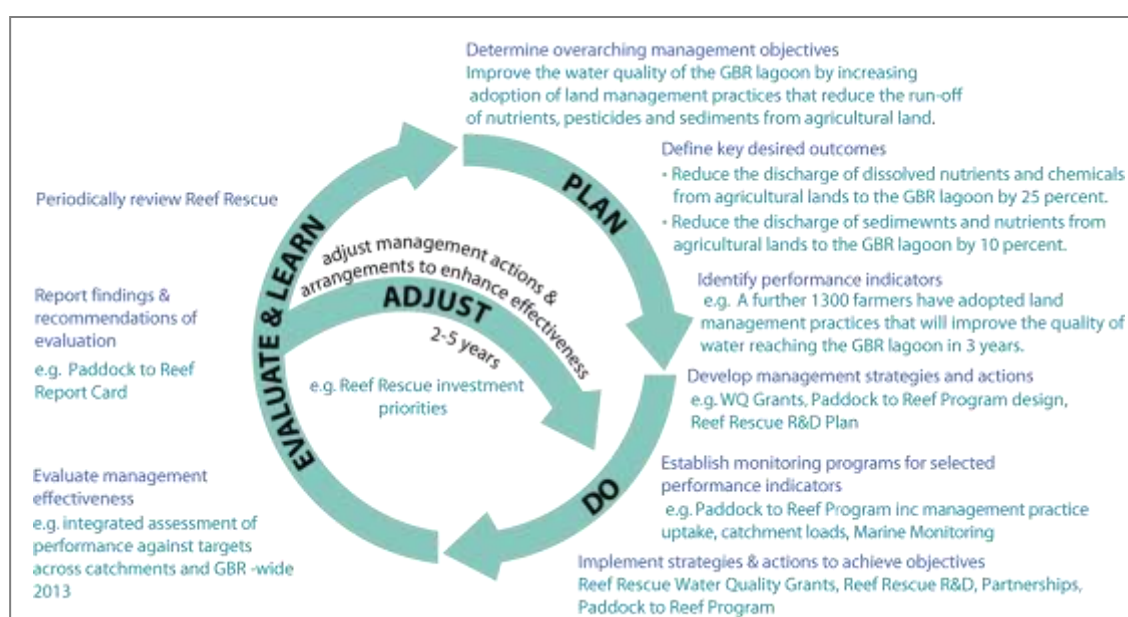


Figure 2: Schematic showing how the components of Reef Rescue / Reef Programme interact and contribute to an adaptive management approach. The blue text shows the overarching actions, the green text indicates how the components of Reef Rescue are achieving these actions.

Evaluation of progress

1. Facilitate and document project linkages

The RRRC has documented the linkages that exist between *Reef Rescue R&D* projects and with other initiatives. These were captured in the [Reef Rescue R&D Research Linkages](http://www.reefrescueresearch.com.au/images/documents/Reef-Rescue-Research-Linkages-v101111.pdf) report⁴ and were further developed in collaboration with other programs. Direct data sharing and exchange between projects was also documented and facilitated between projects. For example:

- Two of the socio-economic projects (RRRD010 and RRRD039) had regular meetings/workshops and shared some information and the analytical framework of adoption nature and factors.

⁴ <http://www.reefrescueresearch.com.au/images/documents/Reef-Rescue-Research-Linkages-v101111.pdf>

- The experimental trials for projects RRRD038 and RRRD049 have benefited from co-location with Paddock to Reef banana projects on the South Johnstone research facility, with access to metrological data, security and research maintenance facilities a few of the benefits.
- Linkages between the two banana projects (RRRD049 and RRRD054) has enabled validation of modelling results and additional trails to be added to the experimental schedule.
- Project RRRD011 undertook extensive liaison with water quality projects under various programs, including Reef Rescue and Paddock to Reef to access historic datasets that could be added to their online data portal. Other examples of collaboration include assistance with JCU honours student Jack Koci with modelling hydrology and water quality at the Atherton tablelands grazing site. Jack Koci utilised soil and vegetation parameter sets developed in RRRD011 for the Kairi cropping and pasture study (Cogle et al. 2011) for input into his water quality model. Further, Grant Fraser utilised many datasets and best bet parameter files published on the HowLeaky? website (website and parameter files developed in RRRD011) to model water quality in Far North Queensland.
- Strong linkages occurred between the pesticide projects (RRRD037, RRRD038, RRRD058) and other initiatives through the Pesticide Working Group. This was a joint program initiative between Reef Rescue R&D, NERP and the Paddock to Reef Program which involved scientists and policy stakeholders to share outputs from all projects on a regular basis. Discussion was held between the three projects on current data needs with advice from RRRD037 project leader on how RRRD058 could source pesticide loads.
- Discussions held between the three sugar projects (RRRD056, RRRD004, RRRD020) led to utilisation of new outputs into model platforms tested under RRRD056.

Summary of actions undertaken to facilitate integration between Reef Rescue R&D projects

- The [Reef Rescue R&D website](#) provides details of the program and individual projects. It has a searchable information base for the whole program, with individual pages for each project containing information on the scope of the project and linkages to other research, both within the program and to other programs. Additional information on project outputs is added to the site as it is generated. The website also provides overviews of the conferences, conference presentations and related resources including a page for the Reef Rescue Partnerships program. New pages have been added to capture the outcomes of the Reef Rescue Regional Forums held in September and October 2013, and a final listing of the Research Outcomes Reports. All of the project outputs are available through the project pages.
- **Annual forums** of Project Leaders, project teams, research partners, industry representatives and other key stakeholders were conducted to share updates on project progress and linkages to other research including:
 - [Reef Rescue R&D Inception Workshop June 2011](#)
 - [Reef Rescue Forum August 2012](#)
 - [Joint Reef Rescue R&D and NERP Tropical Ecosystems Hub Conference May 2013](#)
 - [Reef Rescue R&D Regional Science Forums, September to October 2013](#)

These have all been written up in yearly progress reports, and all of the presentations and outcomes are available on the Reef Rescue R&D website.

- We have now circulated fourteen editions of the *Reef Rescue R&D email newsletter* commencing with the first edition in November 2011. The newsletter is now distributed to around 180 recipients. The structure includes a feature article on a researcher, project snapshots and a news and events section.
- Development of a **data management protocol** and identification of requirements for formal data exchange between projects in terms of datasets to be provided between projects, and the timing and format of exchange (incorporated into the project MERI Plans).

- **Reef Rescue R&D Communication Guidelines** which form part of the Strategy were updated and circulated to all Project Leaders in April 2012 and more recently in July 2013. The intent of these guidelines is to ensure that appropriate members of the environment portfolio and Reef Rescue R&D participants are provided with a timely opportunity to consider scientific papers, technical report, media releases and media-related activities prior to public release. This will allow for the potential involvement of the Minister and Department in any media activities that may arise from the public release of Reef Rescue R&D research outputs and outcomes.
- **Coordination of meetings of groups of related projects** (e.g. industry based meetings or sub programs) including the establishment of the Pesticide Working Group to facilitate linkages between pesticide related research in *Reef Rescue R&D*, Paddock to Reef Program, NERP and the Reef Protection Science Program.
- Identification of mechanisms for facilitating collaboration between project teams were also built into the *Reef Rescue R&D Communications Strategy* developed at the beginning of the program and have been applied where possible.

2. Understand and communicate how Reef Rescue R&D links to and builds on companion research to deliver research efficiencies

Several research and monitoring initiatives related to water quality management in the GBR are directly relevant to *Reef Rescue R&D*, so collaboration and linkages with these initiatives were critical. Figure 3 shows a summary diagram of the broad scope of each of the key related initiatives. This was also established at a project level and is now maintained by the Reef Plan Secretariat. This diagram has been utilised more broadly to communicate linkages across research that supports Reef Plan implementation.

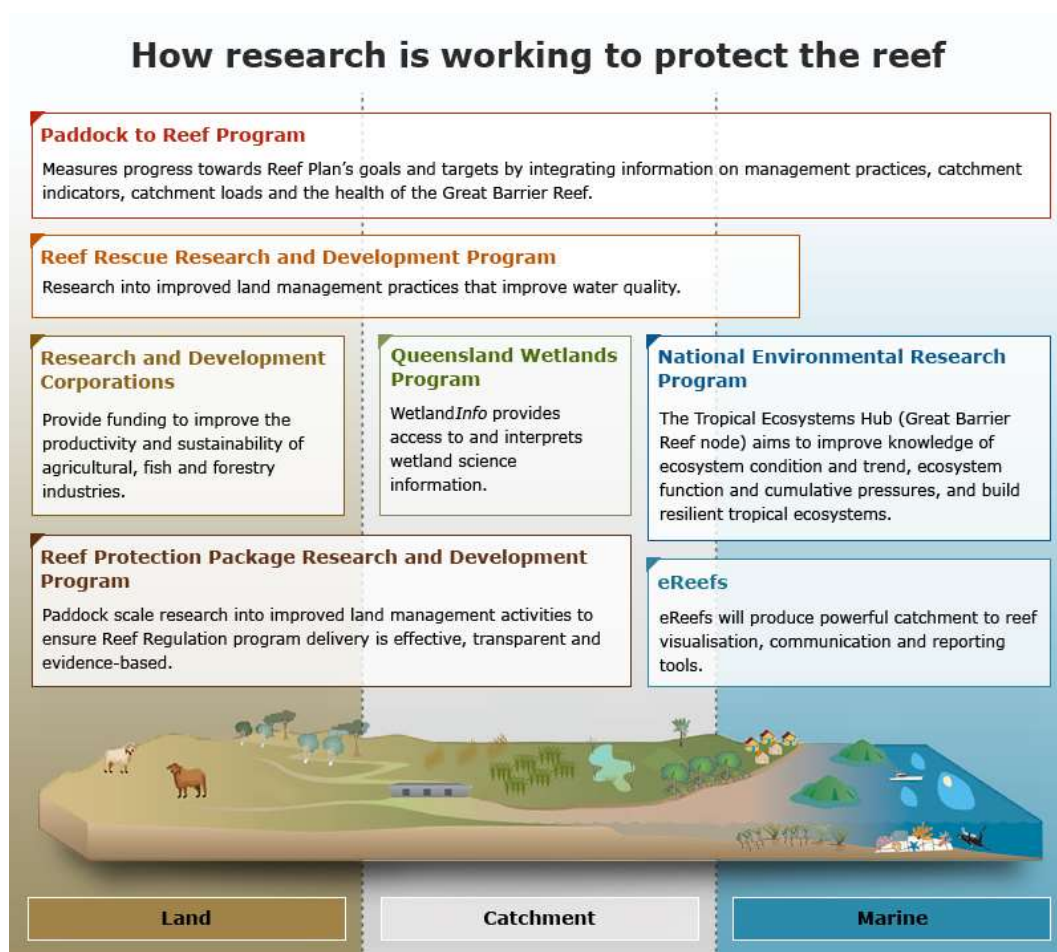


Figure3: Illustration of the links between research initiatives developed to inform Reef Plan implementation.

Summary of actions undertaken for facilitating integration and synergies with related research initiatives, management actions and policies

- Assisted in the facilitation of the establishment of a Reef Plan R&D Coordination Group in conjunction with the Queensland Government Reef Plan Secretariat to maintain links and share updates with program leaders of other research initiatives (shown in Figure 3). This group led to the commitment of the establishment of a formal coordination group under Reef Plan 3.
- Engagement with a variety of established extension networks for disseminating new information to farmers, particularly the considerable and effective extension officer programs run by industry, NRMs and government departments. For example, RRRC staff participated in the Reef Protection Package extension and education forums conducted for the sugarcane and grazing industries in the Wet Tropics, Burdekin and Mackay Whitsunday regions.
- Coordination of a *Reef Rescue R&D* forum each year with the objective of maximising opportunities for two-way communication between researchers and end-users of that research. Provision of opportunities for informal conversations at these workshops has been important for building and maintaining useful two-way relationships between researchers and those in a position to use the new information.
- Coordination of the joint *Reef Rescue R&D* and NERP Tropical Ecosystems Hub conference in May 2013.
- Coordination of five regional workshops during September and October 2013 in Mackay, Rockhampton, Cairns, Bundaberg and Townsville, coordinated by the RRRC and facilitated by regional NRM groups in each region.
- Regular liaison with a range of stakeholders in three primary phases: Introduction to *Reef Rescue R&D* (July to September 2011), progress updates throughout the program (September 2011 to June 2013) and final outcomes / future directions (May 2013 to September 2013). Targeted groups include:
 - Leaders of the Paddock to Reef Program, Reef Protection Package Science Program, NERP and eReefs;
 - Representatives of industry organizations including CaneGrowers, AgForce, Queensland Farmers Federation, GrowCom and the Australian Dairyfarmers Association;
 - Industry Research and Development Corporations including Sugar Research and Development Corporation, Meat and Livestock Australia and Horticulture Australia Limited;
 - Regional NRM groups including Terrain NRM, NQ Dry Tropics, Reef Catchments, Fitzroy Basin Association and Burnett Mary Regional Group; and
 - Other interested organisations such as WWF.
- Participation in events or meetings of related programs and industry groups (see schedule of meetings in Appendix 3).
- Presentation of the progress of *Reef Rescue R&D* to relevant committees including the Paddock to Reef Program Coordination and Advisory Group and the Reef Rescue Operatives (see schedule of meetings in Appendix 3).
- Presentation of the progress of *Reef Rescue R&D* to Department of the Environment under a NERP funded science visit to Canberra. Outputs from RRRD037 and RRRD038 were presented as part of the water quality session under NERP Research informing policy —Tropical Ecosystems Hub —Water Quality, Pesticides and Seagrass Workshops.
- Contribution to the Pesticide Working Group described above for encouraging collaboration between related pesticide research projects.
- Participation of the Science Coordination team and representatives of specific projects, where appropriate, at a range of events including communication and planning events of related initiatives (see schedule of meetings in Appendix 3).
- Participation of the Science Coordination team in planning for the next tier of investment in research that supports the objectives of Reef Plan.

This consultation and stakeholder engagement involved representation and participation of members of the Science Coordination team in more than 70 meetings and workshops through the duration of the program, with over 25 formal presentations delivered for Reef Rescue R&D.

The *Reef Rescue R&D Communication Strategy* contains further details of the plans and actions for delivering the outcomes of *Reef Rescue R&D* to a wide range of interest groups, and also incorporates a timeline of relevant events. The program has delivered a comprehensive suite of publications including 21 journal publications with a further 10 articles in review, and there will be a total of at least 35 Reef Rescue R&D Technical Reports. The project teams have also convened around 65 field days or industry forums and given over 100 conference or stakeholder workshop presentations about the projects. A full summary of the communication activities is provided in Appendix 3.

3. Foster synergies between *Reef Rescue R&D* and related research, management and policies

This action has been delivered through a combination of the actions described for task 1 and 2 above. A number of additional communication initiatives identified in the *Reef Rescue R&D Communication Strategy* have been undertaken to facilitate uptake of the research outcomes. These include:

- Release of the Research Outcomes Reports for each project using the email newsletter platform.
- Supported the development of [project fact sheets](#), initiated by the Project Leaders.
- Participation of the Science Coordination Team and researchers in a series of regional management practice synthesis workshops coordinated for the Paddock to Reef program in December 2011 to May 2012.
- Development of a catalogue of photos from the project teams has been established for use on website and for other communication products.

5. Conclusions: Success and challenges

Program highlights

Reef Rescue R&D has been a highly successful component of the Reef Rescue and Reef Programme investment. The program commenced in May 2011 and has delivered valuable outcomes in this relatively short period of time. The research has delivered results directly related to the adoption and development of sustainable management practices that have water quality benefits, understanding pesticide dynamics, transport pathways and management practice efficiencies, and new approaches to monitor and report on the outcomes of investments in GBR water quality improvement.

The success of the program is attributed to the development of targeted research and development priorities, the outstanding scientific rigour and commitment of the research teams and importantly, the commitment to a dedicated independent coordination and integration role for the program undertaken by the RRRC. The strong integration role maintained by RRRC, linked directly with the research teams and users of the research has supported the program to deliver highly applicable results in a relatively short timeframe. The RRRC fostered inter-project communication, sharing of data, links to other programs and encouraged a joint vision between the researchers and research users.

All of the projects are now complete and the outputs are readily accessible to the public via the program website. A selection of **research highlights** from the program is provided below.

- Field studies demonstrated that A-Class practices in sugarcane farming can reduce losses of nitrogen from sugarcane fields primarily from reduced nitrogen inputs to fields. Further, reducing tillage and practicing controlled traffic are predicted to reduce losses of nitrogen (and sediments) through runoff.

- Guidelines for nitrogen applications to the first ratoon crop following legume fallows were investigated, and it was confirmed that nitrogen applied to the first ratoon sugarcane crop after a good legume fallow can possibly be reduced. However, this reduction in applied nitrogen will be dependent on several factors which include legume residue management (surface or incorporated), soil type, position in the landscape, weather and climate, and tillage practices. These factors need to be assessed for a particular site / block when decisions are being made about possible reduced nitrogen applications.
- A trial conducted on irrigated sugar paddocks in the lower Burdekin showed that diuron and atrazine losses in drainage water could be reduced by 90% when applied to the raised beds only via the banded spraying technique.
- Continuous monitoring of pesticide residues in the Barratta Creek drainage system indicated that concentrations of diuron and atrazine residues decreased as they moved towards and into the estuary, however, they remained above ecological guideline values for approximately 6 months of the year even at the Ramsar wetland/estuarine site.
- Economic and socio-cultural factors that heavily influence cane farmers' decisions to adopt a management practice with specific water quality benefits have been identified. Long-term profitability of the farm is a prime factor, with other factors including access to and availability of cash flow, whether farmers work full-time or part-time, and self-desire to protect natural resources.
- An assessment of runoff water quality from furrow and drip irrigation in sugarcane and banana crops found that there was greater nutrient use efficiency in drip irrigation techniques, with significant control of runoff (dry top soil- opportunity for storage of rainfall) compared to furrow irrigation. While the yield of sugarcane with sub-surface drip irrigation was always lower compared to the furrow irrigation full optimisation of subsurface drip irrigation is likely to improve yields.
- Investigation of nutrient losses from banana crops showed that the plant crop phase is important for N loss in deep drainage from full ground preparation. Nitrogen released from the soil organic pool overwhelmed fertiliser effects on N lost in deep drainage during the first 3 months after planting. Management to reduce large release of N during the plant phase may be achieved with permanent beds and associated minimum tillage practices. Decreased cultivation is likely to reduce the loss of N to the environment by up to 50%.
- Trial of controlled release fertiliser in bananas indicated that the products may be useful during the wet season for continued nutrient release for crop uptake when wet weather restricts application of conventional fertilisers. The application may also reduce labour costs as a single application may supply nutrient for months.
- Investigation of surface runoff and deep drainage loss of glyphosate and glufosinate from banana plots showed that these pesticides could be detected in surface runoff, and glyphosate was also occasionally detected in deep drainage. Glyphosate could also be detected in both surface runoff and deep drainage following application 6 months earlier.
- Investigation of N loss pathways in dairy farming identified that Improved nitrogen use efficiency (NUE) can be achieved during the drier, cooler fertilisation period by better matching N fertiliser application to plant N demand. Reducing N application during periods of high water deficit is an effective strategy for improving NUE. The results indicate that fertiliser N inputs can be reduced from the standard commercial rates with no economic or yield penalty when urea is used in conjunction with a nitrogen inhibitor.
- The development of a banana module for APSIM provides the ability for the Reef Plan Paddock to Reef Program to model the water quality and economic impact of ABCD management practices in the banana industry.
- Examination of the movement of tebuthiuron in runoff and in soil from Brigalow lands showed that mean concentrations in runoff up to 472 days after application always exceeded the current ecological protection guidelines. These data also indicate that tebuthiuron was largely transported in the dissolved phase.
- A new fractional groundcover algorithm was developed to estimate ground cover, allowing better separation of over storey and ground cover.
- Reducing stocking rates across the two-thirds of properties in each soil type having medium and low cover levels would lead to reduced runoff volumes and increased soil stability in the long term, and also increased forage production.

- Scenario modeling indicated that increasing ground cover at property scale can result in large reductions in long-term hillslope soil loss and associated nutrient losses. In the long term, higher cover levels will help to maintain or improve land condition and soil water holding capacity, reducing runoff volumes and so reducing gully and streambank erosion rates.
- Multi decadal mapping of grazing land condition for the Burdekin and Fitzroy regions suggest that grazing land condition has improved in both regions since the mid - 1990s drought.
- Studies that trialled various mechanical disturbance treatments in the assessment of rehabilitation techniques for bare, eroded D-condition grazing land at Burdekin and Fitzroy catchment sites concluded that aggressive disturbance with successful pasture establishment can greatly increase infiltration, cover and pasture productivity, and reduce sediment and nutrient losses, for at least ten years on better quality soil types. There are soil types that cannot be rehabilitated by current methods. However, direct costs of rehabilitation can be high relative to the grazing value of the new pasture on all but most favourable soil types and are dependent on climatic conditions.
- Data from the Brigalow Catchment Study show that significant loads of suspended solids and dissolved inorganic nitrogen are lost from virgin brigalow scrub, indicative of the broader landscape in its pre-European condition. In an assessment of nitrogen runoff from different pastures, sediment and nitrogen loads from grass and grass-leucaena pasture were typically equal to or lower than virgin brigalow scrub. It is expected that loads of sediments and nutrients from newly established ley pasture will decline over time as pasture biomass and groundcover increase. Direct comparison of runoff totals for 2010 to 2014 support the observation that clearing brigalow scrub for either cropping or grazing increases the runoff component of the water balance.
- Estimates of a wide range of relative costs of practice changes across a variety of contexts have been developed, emphasising the significant variation in both the costs of changing management and in the benefits delivered from changes to management from paddock scale to GBR wide scale. These very significant differences in costs and benefits (which are not necessarily correlated) drive the potential for targeting low cost – high load sources to achieve pollutant reductions.
- Across the grazing industry, variation in the net costs of practice change are found within land condition class according to pasture utilisation, across land types and land classes, and via improvements across condition classes within a land type. A similar degree of variation was apparent across the cane industry although the dimensions to influence water quality differ.
- It was demonstrated that the costs of making identical sediment and nutrient reductions can vary by more than one order of magnitude across the relatively small ranges of heterogeneity and are likely to vary across two orders of magnitude when all factors are taken into account. This has major implications for the cost-effectiveness implications of targeting investment in practice change.
- The details of over 130 studies dealing with hydrology-water quality related to land use and management, predominately at the paddock scale were captured and synthesised into a publically available database <http://www.Howleaky.net/index.php/library>.
- To detect impacts of herbicides on freshwater organisms, a new biomonitoring index was devised based on freshwater benthic diatoms (a common group of micro photosynthetic algae with a cell wall made of silica). This new index, SPEcies At Risk from herbicides, or SPEARherbicides,, is based on similar principles as existing macroinvertebrate-based indexes for pesticides. Both indexes appear to be promising tools to complement chemical monitoring of pesticides in the catchments of the GBR, if used in conjunction with the chemical monitoring program before and after subsequent wet-seasons.
- A technique for blending several sources of information relevant to estimating suspended sediment loads was developed using a case study approach in the Upper Burdekin. The framework provides a more realistic estimate of the sediment load that takes into account measurement error, as well as error in our process level understanding of the pollutant.
- The Marine Monitoring Program collects water quality information using several techniques. A spatio-temporal statistical process model was developed to aggregate these multiple sources of data across various spatial and temporal scales into an integrated metric in the Paddock to Reef reporting framework.

Lessons learned for program delivery

The Science Coordination team has evaluated several aspects of the program, and considers that the greatest potential improvements to the program could be achieved by extended delivery of the research results to a wider range of audiences. Collaborating scientists, government policy officers, regional NRM staff involved in Reef Rescue delivery and industry body representatives were clearly identified as the target audiences for the Science Coordination team when the program commenced (as defined in the *Reef Rescue R&D Communication Strategy*). This was considered to be achievable with the resource allocation, and assumed that these audiences have a role in disseminating the information to their own audiences of greatest interest, including landholders. Policy officers, NRM operational staff and industry representatives have had regular opportunities to receive information on the results of the Reef Rescue R&D projects through various committees and the science forums, however, it is not evident that the information is reaching wider audiences. The project arrangements were set up so that much of the funding for communication sat with individual project leaders through their MERI Communication Plans, however, in many cases it is concluded that this approach was not effective and could be improved with greater resourcing to support the coordination of communication outputs. The program website is accessible to the general public and contains information suitable for a wide range of audiences. However, with the enhanced role of extension and education supported through Reef Plan 3, it is obvious that more effective means of communicating the research findings to landholders is required, and should be considered in the design and implementation of further R&D funding. However, it is not yet clear what the most successful mechanism is to extend the results through these audiences. The feedback from many stakeholders is that short video clips that communicate the project results are currently a very attractive form of media which warrants further exploration for future programs.

Following the final Reef Rescue R&D annual forum in May 2013, it was agreed by the Science Coordination team and Reef Programme teams that better synergies from the actual event would have resulted if the event had have been organised with the Paddock to Reef or Reef Rescue on-ground programs. This learning was taken in consideration in the proposal to run a series of regional science forums in September and October in 2013. The cross-interest of participants was greater, and allowed for more discussions about application of R&D results with regional managers.

While there scope for improvement of delivery of the research results, feedback from a range of stakeholders has indicated that the availability of project outputs and access to researchers through various forums has led to successful uptake of the research findings of Reef Rescue R&D projects.

Appendix 1: Overview of Reef Rescue R&D

Reef Rescue R&D includes 18 research projects⁵ and a program coordination and integration role. The projects were selected from an Expression of Interest process, and assessed by a Technical Advisory Panel using set evaluation criteria. The total value of the Program is almost \$9 million, to be carried out between May 2011 and June 2013, with final reporting due in September 2013. Research priorities were determined in consultation with the Queensland Government, universities and research organisations, and other key stakeholders in the development of the *Reef Rescue Research and Development Plan* (December 2009).

The overall objective of *Reef Rescue R&D* is to improve our understanding of the link between land management practices and environmental impacts and improve water quality across the Great Barrier Reef by supporting a reduction in the amount of nutrients, chemicals and sediments reaching the Reef from agricultural lands. The structure of comprises three main sub programs:

1. Adoption and development of sustainable practices that improve water quality outcomes;
2. Pesticide threat, delivery and management; and
3. Tracking change.

These are summarised below.

1. Adoption and development of sustainable practices that improve water quality outcomes

A total package of \$1,575,000 is allocated to understanding the social and economic motivations for practice improvement and potential constraints to the adoption of improved practices due to impacts on profitability and sustainability. The research will build on the experiences of NRM groups and draw upon existing knowledge about water quality outcomes and economic/profitability and sustainability aspects in order to inform the delivery of *Reef Rescue* incentives. An analysis of what worked, what didn't, key motivations and directions for any next tier of activities in improving practice for the GBR catchments and as a flow on, implications for Australia, will also be delivered.

Further development, trial and validation of sustainable management practices that improve water quality outcomes in the sugar, beef grazing, horticulture and dairy sectors will also be investigated.

Grazing – A total package of \$1,870,000 has been allocated across four projects that address the major issues in improving grazing practice: rehabilitating degraded lands, improving ground cover and reducing sediment loads and evaluating introduced pastures from a nutrient loading perspective.

Sugar – \$1,585,000 has been allocated to a package of three projects that will focus on proving up the water quality benefits and sustainability of 'A-class' practices while also filling gaps in knowledge on smarter irrigation and fertiliser systems and the role of fallows in reducing the need for the application of fertiliser.

Horticulture – On a Reef-wide scale, bananas are the main horticultural crop based on areal extent, pesticides and fertilisers used that contributes to GBR water quality. A total of \$450,000 has been allocated to two projects that foster smarter pesticide use and fertiliser practices for the banana industry.

Dairy – Dairy, the main intensive animal industry, is generally established on the volcanic soils of the Atherton and Eungella Tablelands and the Burnett region, and is managed very differently to the more extensive beef grazing that has

⁵ A brief description of each of the projects including the research objectives and outputs is provided for download at http://www.rrrc.org.au/reefrescue/downloads/project_overviews_220611.pdf

its own subprogram of R&D (see above). The greatest impact of dairy operations on water quality is from increased discharge of nutrients, however, intensive animal industries in high rainfall catchments can also increase sediment loads if cattle are not excluded from creek lines and watercourses. A total of \$467,000 has been allocated to a single project that will foster smarter fertiliser practices for the dairy industry.

2. Pesticide threat, delivery and management

A total package of \$1,650,000 has been allocated across three projects. These projects combined will deliver a far better appreciation of the magnitude of the chemical pollution issues for the GBR and the contributing sources and land uses. They will also establish systems, protocols and practices for routine monitoring.

3. Tracking change: water quality monitoring techniques and reporting

A total of \$714,000 has been allocated through two projects for improving reporting of two primary indicators for *Reef Rescue*: pollutant loads and marine water quality. The research will develop techniques for reporting end of catchment pollutant loads entering the GBR lagoon (catchment by catchment) with uncertainty estimates. It will also develop a metric for reporting marine water quality using datasets collected from remote sensing, and *in situ* monitoring.

Appendix 2: List of publications

Adoption and development of sustainable practices that improve water quality outcomes

Grazing related research

RRRD024

Hall, T. 2013. Recovering bare eroded grazing land in the Burdekin. Poster presentation and paper at the Northern Australia Beef Research Update, Cairns August 2013.

Hall, T.J. 2013. Rehabilitating degraded frontage soils in tropical north Queensland. Poster presentation and paper at the 22nd International Grasslands Conference, Sydney October 2013.

RRRD027

Beutel, T.S., Tindall, D., Denham, R., Trevithick, R., Scarth, P., Abbott, B and Holloway, C. 2014. [Getting ground cover right: thresholds and baselines for a healthier reef](#). Report to the Reef Rescue Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (64pp.). ISBN: 978-1-925088-20-5.

Bastin, G., Scarth, P., Chewings, V., Sparrow, A., Denham, R., Schmidt, M., O'Reagain, P., Shepherd, R., Abbott, B. 2012. Separating grazing and rainfall effects at regional scale using remote sensing imagery: A dynamic reference-cover method. *Remote Sensing of Environment*, 121, 443–457.

Star, M., Rolfe, J., Donaghy, P., Beutel, T., Whish, G., Abbott, B. (2012). Targeting resource investments to achieve sediment reduction and improved Great Barrier Reef health. *Agriculture, Ecosystems & Environment*, 180, 148-156.

RRRD032

Bartley, B., Wilkinson, S.N., Hawdon, A.A., Corfield, J.P., Abbott, B.N., Nelson, B., 2011. From Beef to Reef: challenges and triumphs in reducing runoff and sediment yields at hillslope and watershed scales in Australian Rangelands. *International Rangelands Congress Argentina*.

Bartley, R., Corfield, J.P., Hawdon, A.A., Kinsey-Henderson, A.E., Abbott, B.N., Wilkinson, S.N., Keen, R.J., 2014. Can improved pasture management reduce runoff and sediment loss to the Great Barrier Reef? The results of a 10 year study in the Burdekin catchment, Australia. *Rangeland Journal* 36: 67-84. <http://dx.doi.org/10.1071/RJ13013>.

Bartley, R., Bainbridge, Z.T., Lewis, S.E., Kroon, F.J., Wilkinson, S.N., Brodie, J.E., Silburn, M.D. 2014. From Coral to cows – using ecosystem processes to inform catchment management of the Great Barrier Reef. In: 7th Australian Stream Management Conference. Vietz G, Rutherford ID, Hughes R (Eds.), pp: 9-16.

Johnson, J.E., Maynard, J.A., Devlin, M.J., Wilkinson, S., Anthony, K.R.N., Yorkston, H., Heron, S.F., Puotinen, M.L., van Hoodonk, R., 2013. Resilience of GBR marine ecosystems and drivers of change, Chapter 3. In: Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M., Warne, M., McKenzie, L. (Eds.), *Land use impacts on Great Barrier Reef water quality and ecosystem condition: 2013 Scientific Consensus Statement*. The State of Queensland, Brisbane, p. 39. <http://www.reefplan.qld.gov.au/about/scientific-consensus-statement/resilience-of-marine-ecosystems.aspx>.

Kinsey-Henderson, A.E., Wilkinson, S.N. 2013. Evaluation of slope gradient estimates from contour-interpolated and Shuttle Radar digital elevation models, and consequences for erosion modelling *Environmental Modelling & Software* 40: 128-139. <http://dx.doi.org/10.1016/j.envsoft.2012.08.010>.

Kroon, F., Turner, R., Smith, R., Warne, M., Hunter, H., Bartley, R., Wilkinson, S., Lewis, S., Waters, D., Carroll, C. 2013. Sources of sediment, nutrients, pesticides and other pollutants in the Great Barrier Reef catchment, Chapter 4. In: Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M.,

Warne, M., McKenzie, L. (Eds.), Land use impacts on Great Barrier Reef water quality and ecosystem condition: 2013 Scientific Consensus Statement. The State of Queensland, Brisbane, p. 35. <http://www.reefplan.qld.gov.au/about/scientific-consensus-statement/sources-of-pollutants.aspx>

Silburn, D.M., Wilkinson, S.N., Whish, G., Stokes, C.J., O'Reagain, P., Thornton, C., Hawdon, A.A., Kinsey-Henderson, A.E., Dougall, C., In review. Paddock to Reef Synthesis of Management Practice Effectiveness in Grazing. The State of Queensland, Brisbane.

Thorburn, P.J., Wilkinson, S.N. 2012. Water quality benefits of improved agricultural management practices (abstract). In: International Coral Reef Symposium.

Thorburn, P.J., Wilkinson, S.N. 2013. Conceptual frameworks for estimating the water quality benefits of improved land management practices in large catchments. *Agriculture Ecosystems & Environ.* 180, 192-209: <http://dx.doi.org/10.1016/j.agee.2011.12.021>.

Thorburn, P.J., Wilkinson, S.N., Silburn, D.M. 2013. Water quality in agricultural lands draining to the Great Barrier Reef: Causes, management and priorities. *Agriculture Ecosystems & Environment* 180, 4-20: <http://dx.doi.org/10.1016/j.agee.2013.1007.1006>.

Thorburn, P., Rolfe, J., Wilkinson, S., Silburn, M., Blake, J., Gongora, M., Windle, J., VanderGragt, M., Wegscheidl, C., Ronan, M., Carroll, C., 2013. The water quality and economic benefits of agricultural management practices, Chapter 5. In: Brodie, J., Waterhouse, J., Schaffelke, B., Kroon, F., Thorburn, P., Rolfe, J., Johnson, J., Fabricius, K., Lewis, S., Devlin, M., Warne, M., McKenzie, L. (Eds.), Land use impacts on Great Barrier Reef water quality and ecosystem condition: 2013 Scientific Consensus Statement. The State of Queensland, Brisbane, p. 45. <http://www.reefplan.qld.gov.au/about/scientific-consensus-statement/agricultural-management-practices.aspx>.

Wilkinson, S.N., Bastin, G., Stokes, C.J., Hawdon, A.A., Kinsey-Henderson, A.E., Nicholas, D.M., Chewings, V.H., Abbott, B.N., McKellar, K., Kemei, J. 2014. [Improving grazing management practices to enhance ground cover and reduce sediment loads](#). Report to the Reef Rescue R&D Program. Reef and Rainforest Research Centre Limited, Cairns (85 pp.).

Wilkinson, S.N., Dougall, C., Kinsey-Henderson, A.E., Searle, R., Ellis, R., Bartley, B. 2014. Development of a time-stepping sediment budget model for assessing land use impacts in large river basins. *Science of the Total Environment* 468–469: 1210–1224. <http://dx.doi.org/10.1016/j.scitotenv.2013.07.049>.

Wilkinson, S.N., Stokes, C.J., Hawdon, A.A., Nicholas, D.M. 2014. Fat cows improve water quality: the benefits of higher forage levels in GBR rangelands. In: 7th Australian Stream Management Conference. Vietz G, Rutherford ID, Hughes R (Eds.). pp: 116–122.

Wilkinson, S.N., Hancock, G.J., Bartley, B., Hawdon, A.A., Keen, R.J. 2013. Using sediment tracing to assess processes and spatial patterns of erosion in grazed rangelands, Burdekin River basin, Australia. *Agriculture Ecosystems & Environment* 180: 90-102. <http://dx.doi.org/10.1016/j.agee.2012.02.002>.

Wilkinson, S., McKellar, K. 2013. RRRD032 Project Factsheet: Land condition outcomes from grazing land management. Reef and Rainforest Research Centre.

RRRD009

Thornton, C., Buck, S. 2011. Beef production from buffel grass pasture compared to leucaena-buffel grass pasture in the brigalow belt of Central Queensland. In: Proceedings of the Northern Beef Research Update Conference, Holiday Inn, Esplanade, Darwin, 3 & 4 August 2011.

Buck, S., Thornton, C., Dixon, R. 2011. Comparison of beef cattle diet quality on grass-only and leucaena-grass pastures in central Queensland. In: Proceedings of the Northern Beef Research Update Conference, Holiday Inn, Esplanade, Darwin, 3 & 4 August 2011.

Robinson, J.B., Shaw, M., Silburn, D.M., Roberts, A., Viagak, O., Thornton, C., McClymont, D. 2011. An improved model for linking phosphorus loads in runoff to climate, soil and agricultural management. In 'MODSIM 2011 - 19th International Congress on Modelling and Simulation - Sustaining Our Future: Understanding and Living with Uncertainty'. pp. 2620-2626.

Shaw, M., Silburn, D.M., Thornton, C., Robinson, B., McClymont, D. 2011. Modelling pesticide runoff from paddocks in the Great Barrier Reef using *HowLeaky*. In 'MODSIM 2011 - 19th International Congress on Modelling and Simulation - Sustaining Our Future: Understanding and Living with Uncertainty'. pp. 2057-2063.

Elledge, A., Thornton, C. 2012. The Brigalow Catchment Study: Comparison of soil fertility, forage quality and beef production from buffel grass vs. leucaena-buffel grass pastures. In: L.L. BURKITT and L.A. SPARROW, eds. Proceedings of the 5th Joint Australian and New Zealand Soil Science Conference: Soil solutions for diverse landscapes, 2-7 December 2012, Australian Society of Soil Science Inc, pp. 181-184.

Elledge, A., Thornton, C. 2012. The Brigalow Catchment Study: Nitrogen runoff generation rates from pasture legumes and changes since land development, S. WESTA, ed. In: Proceedings of the 34th Hydrology and Water Resources Symposium, 19-22 November 2012, pp. 1000-1007.

Silburn, D.M., Wilkinson, S.N., Whish, G., Stokes, C.J., Thornton, C., O'Reagain, P., Hawdon, A.A., Henderson, A.E., Dougall, C. 2012. Paddock to Reef Synthesis of Management Practice Effectiveness in Grazing (GBR-wide) knowledge to date. (In press).

Thornton, C., Elledge, A. 2012. The Brigalow Catchment Study: Increases in runoff associated with land development can still be detected in flood events at a small catchment scale, S. WESTRA, ed. In: Proceedings of the 34th Hydrology and Water Resources Symposium, 19-22 November 2012, pp. 1566-1570.

Thornton, C., Cowie, B., Silburn, M. 2012. The Brigalow Catchment Study: forty-five years of paired catchment monitoring in the Brigalow Belt of Australia. In: Revisiting experimental catchment studies in forest hydrology, IAHS Publication 353 (eds. A. Webb, M. Bonell, L. Bren, P. Lane, D. McGuire, D. Neary, J. Nettles, D. Scott, J. Stednick and Y. Wang), 26-32. Proceedings of a workshop held during the XXV IUGG General Assembly in Melbourne, Australia, June-July 2011.

Thornton, C., Yu, B. 2012. The Brigalow Catchment Study: Effects of land development on peak runoff rate and its prediction in central Queensland, Australia, S. WESTRA, ed. In: Proceedings of the 34th Hydrology and Water Resources Symposium, 19-22 November 2012, pp. 362-369.

Thornton, C., Cowie, B., Davison, L., Tang, W., Elledge, A. 2013. Appendix 14: Nitrogen generation rates from grass pastures over-sown with butterfly pea or leucaena in the Burnett-Mary and lower Burdekin catchment. In: Final report: Paddock to Reef: Paddock Scale Monitoring and Modelling - Rainfall Simulation Program 2010 – 2013. pp. 59-61.

Thornton, C.M., Elledge, A.E. 2013. [Runoff Nitrogen, Phosphorus and Sediment Generation Rates from Pasture Legumes: An Enhancement to Reef Catchment Modelling](#). Report to the Reef Rescue Water Quality Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (85 pp.).

Thornton, C.M. and Elledge, A.E. 2014. [Runoff Nitrogen, Phosphorus and Sediment Generation Rates from Pasture Legumes: Addendum to Paddock Scale Water Quality Monitoring for 2013 and 2014 \(Project RRRD009\)](#). Report to the Reef Rescue Water Quality Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (12 pp.).

Sugarcane related research

RRRD004

Bhattarai, S.P. and Midmore, D.J. 2015. Advanced drip and optimised furrow irrigation to minimise sediment, nutrient and pesticide losses to the environment through deep drainage and run-off from sugarcane and banana industries in northern Queensland. Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (41pp.).

Bhattarai, S.P., Midmore, D.J., McShane T, Attard, S., Davis, A. in review. Enhancement of crop water use efficiency, nutrient use efficiency, and opportunity for optimization of sugarcane subsurface drip irrigation to minimize the yield gap for sugarcane production in the Burdekin region of QLD, Australia. *Journal of Agriculture Water Management*.

Bhattarai, S.P., Midmore, D.J. in review. Enhancement of crop water use efficiency, nutrient use efficiency, and opportunity for optimization of drip and mini-sprinkler irrigation to minimize the yield gap and off-farm movement of pollutants with banana production in the Bundaberg region of QLD, Australia. *Journal of Agriculture Water Management*.

RRRD020

No formal publications to date.

RRRD056

Thorburn, P.J., Wilkinson, S.N., Meier, E.A. 2011. Prioritising practice changes in Reef Rescue. CSIRO Water for a Healthy Country National Research Flagship Report series ISSN 1835-095X, CSIRO, Canberra, 56 pp.

Thorburn, P.J., Wilkinson, S.N., Silburn, D.M. 2013. Water quality in agricultural lands draining to the Great Barrier Reef: Causes, management and priorities. *Agriculture Ecosystems and Environment*, 180, 4-20 (<http://dx.doi.org/10.1016/j.agee>).

Thorburn, P.J., Wilkinson, S.N., 2013. Conceptual frameworks for estimating the water quality benefits of improved agricultural management practices in large catchments. *Agriculture Ecosystems and Environment*, 180, 192-209 (doi:10.1016/j.agee.2011.12.021).

Biggs, J.S., Thorburn, P.J., 2013. Assessing the sensitivity of nitrogen losses from cropping systems to different farm management practices. In Piantadosi, J., Anderssen, R.S. and Boland J. (Eds) MODSIM2013 Abstracts, 20th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2013, p 359.

Thorburn, P., Rolfe, J., Wilkinson, S., Silburn, M., Blake, J., Gongora, M., Windle, J., VanderGragt, M., Wegscheid, C., Ronan, M., Carroll, C. 2013. "The water quality and economic benefits of agricultural management practices" in Synthesis of evidence to support the Reef Water Quality Scientific Consensus Statement 2013, Department of the Premier and Cabinet, Queensland Government, Brisbane.

Brodie, J., Waterhouse, J., Schaffelke, B., Johnson, J., Kroon, F., Thorburn, P., Rolfe, J., Lewis, S., Warne, M., Fabricius, K., McKenzie, L., Devlin, M. 2013. Reef Water Quality Scientific Consensus Statement 2013, Department of the Premier and Cabinet, Queensland Government, Brisbane.

Socio economic related research

RRRD010

Akbar, D., Rolfe, J., Greer, L., Smith, P., and Marshall, N. 2013. [Factors affecting adoption of land management practices that have water quality benefits: Evaluation of scenarios for cane farming in GBR catchments](#). Report to the Reef Rescue Research & Development Program. Centre for Environmental Management, CQ University, Rockhampton (53 pp.). ISBN: 978-1-925088-27-4

Greer, L., Hopkinson, S., Akbar, D., Rolfe, J., Kabir, Z. 2012. *Shareholder Preferences for the Future Direction of Mackay Sugar Limited – Final report*, Centre for Environmental Management, CQUniversity (Unpublished report).

RRRD011

Freebairn, D.M. and Cutajar, J.L. 2013. [Capturing paddock scale hydrology and water quality experiences relevant to the Great Barrier Reef \(Project RRRD011\)](#). Report to the Reef Rescue Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (76pp).

Freebairn, D.M., Cutajar, J., Silburn, D.M. 2012. Assessing water quality from farms – how much detail is required for a model to be useful? Joint SSA and NZSSS Soil Science Conference 2-7 December 2012 Wrest Point, Hobart.

Robinson, J.B., Shaw, M., Chamberlain, T., Searle, R., Freebairn, D.M. 2012. A quantitative and functional soil classification for modelling the terrestrial water balance of north-eastern Australia. Joint SSA and NZSSS Soil Science Conference. 2-7 December 2012 Wrest Point, Hobart.

RRRD039

Edwards, B., Beutel, T., Star, M., Rolfe, J. 2013. Understanding sediment reductions at a regional level RRRD39- Component Two: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Gregg, D., Rolfe, J. 2013. Experiments to assess the effect of risk and uncertainty in adoption decisions. Report to the Reef Rescue Water Quality Research and Development Program. CQUniversity, Rockhampton.

Harvey, S., Rolfe, J., Taylor, B., Gregg, D. 2013. Understanding the factors that will drive changes in land management in sugar. Report to the Reef Rescue Water Quality Research and Development Program, CQUniversity, Rockhampton.

Harvey, S., Rolfe, J., Taylor, B. and Whitten, S. 2014. [Regulations versus voluntary mechanisms to improve adoption of best management practices in GBR catchments](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (27pp.).

Star, M., Edwards, B. 2013. Economics of land regeneration RRRD39- Component Two: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Star, M., Rolfe, J., Whish, G., East, M. 2013. Predicting economic costs of improving grazing management in the Herbert, Burdekin and Fitzroy Catchments. . RRRD39- Component Two: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Van Grieken, M.E., Poggio, M., Harvey, S., Rolfe, J., Taylor, B., Boullier, A. 2013. Management practice profiles for water quality improvement. RRRD39- Component Two: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program from CSIRO Water for a Healthy Country Flagship, Cairns.

Van Grieken, M.E., Poggio, M., Taylor, B., Smith, M., Faure, C., Boullier, A., Whitten, S. 2013. Cane management action cost-effectiveness and advice for regions and landholders. RRRD39- Component Two: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program from CSIRO Water for a Healthy Country Flagship, Cairns.

Whitten, S.M., Rolfe, J., Star, M., Van Grieken, M., Taylor, B., Poggio, M., Marinoni, O., Gregg, D., Harvey, S., East, M., Timms, M., Edwards, M., Smith, M. and Goward, R. 2013. Final Report Integrated Assessment of BMP Cost-Effectiveness and Impediments to Adoption. RRRD39- Component One: Integrated assessment of BMP cost-

effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Whitten, S.M., Marinoni, O. and Van Grieken, M. 2013. Integrated assessment of BMP cost-effectiveness and decision advice for regions and landholders. RRRD39- Component One: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Whitten, S.M., Marinoni, O., Van Grieken, M., Star, M. and Rolfe, J. 2013. Costs of management change to reduce agricultural pollutants entering the GBR lagoon. RRRD39- Component One: Integrated assessment of BMP cost-effectiveness and decision tool for regions and landholders. Report to the Reef Rescue Water Quality Research and Development Program, Cairns.

Horticulture related research

RRRD049

Armour, J., Mortimore, C., Pathania, N., Wiltshire, N., Daniells, J., Masters, B. and Reghenzani, J. 2013. [Minimising off-farm movement of nitrogen in the north Queensland banana industry](#). Report to the Reef Rescue Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (32 pp.). ISBN: 978-1-925088-26-7.

Daniells, J.W. 2012. Field event walks the talk on research. *Australian Bananas* 37: 7.

Reghenzani, J., Daniells, J.W., Armour, J., Wiltshire, N., Lindsay, S. 2012. Reef health nitrogen study bears fruit. *Australian Bananas* 36: 26.

Reghenzani J., Pathania, N., Wiltshire, N., Armour, J., Daniells, J.W., Mortimore, C. and Masters, B. (2013) Investigations on minimising off-farm movement of nitrogen in the north Queensland banana industry. Poster at 10th Australian Banana Industry Congress, Coolumb May/June 2013 [Congress program page 19]

RRRD054

Webster, A.J., Hargreaves, J.N.G., Daniells, J.W. and Lindsay, S. 2014. [Simulation of growth, development and nitrogen balance of banana in APSIM. Project RRRD054: Development of a banana modeling capability to enhance reporting of Reef Rescue outcomes](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (26pp.).

RRRD055

Rowlings, D., Koci, J., Nelson, P. and Kowitz, R. 2014. [Validating the cost/benefits of improved fertiliser practices and quantifying nutrient loads and pathways from irrigated dairy pastures in the Wet Tropics and the Burnett-Mary regions](#). Report to the Reef Rescue Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (131pp.). ISBN: 978-1-925088-281.

Pesticide threat, delivery and management

RRRD037 and RRRD038

Botté, E.S., Jerry, D.R., Codi King, S., Smith-Keune, C., Negri, A.P., 2012. Effects of chlorpyrifos on cholinesterase activity and stress markers in the tropical reef fish *Acanthochromis polyacanthus*. Marine Pollution Bulletin online first.

Davis, A.D., Lewis, S.E., O'Brien, D.S., Bainbridge, Z.T., Mueller, J.F., Brodie, J., 2014. Water resource development and high value coastal wetlands on the lower Burdekin floodplain, Australia. *Estuaries 2050 and Beyond*.

Davis, A.M., Thorburn, P.J., Lewis, S.E., Bainbridge, Z.T., Attard, S.J., Milla, R., Brodie, J.E. In press. Herbicide run-off dynamics of furrow irrigated sugarcane farms and associated drainage systems on the Burdekin River Floodplain, north-eastern Australia. *Agriculture, Ecosystems and the Environment*.

Davis, A.M., Lewis, S.E., Bainbridge, Z.T., Brodie, J.E., Glendenning, L., Turner, R. in press. Dynamics of herbicide transport and partitioning under event flow conditions in the lower Burdekin region, Australia. Marine Pollution Bulletin. Online. doi:10.1016/j.marpolbul.2011.08.025

Lewis, S., Brodie, J., Andersen, J., Armour, J., Baillie, C., Davis, A., Eaglesham, G., Elledge, A.E., Fillols, E., Flores, F., Gallen, C., Kookana, R., McHugh, J., Masters, B., Mercurio, P., Mortimore, C., Mueller, J., Negri, A.P., O'Brien, D., Oliver, D., Packett, B., Paxman, C., Rojas-Ponce, S., Shaw, M., Silburn, D.M., Smith, R., Thornton, C.M., Turner, R., Warne, M. 2014. [Pesticide Dynamics in the Great Barrier Reef Catchment and Lagoon: Management practices \(sugar, grazing, bananas\) and risk assessments: Overview report for project number RRRD037 and RRRD038](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (22pp.). ISBN 978-1-925088-24-3.

Lewis, S.E., Schaffelke, B., Shaw, M., Bainbridge, Z.T., Rohde, K.W., Kennedy, K.E., Davis, A.M., Masters, B.L., Devlin, M.J., Mueller, J.F. Brodie, J.E. 2012. Assessing the risks of PS-II herbicide exposure to the Great Barrier Reef. Marine Pollution Bulletin 65, 280-291.

Lewis, S.E., Smith, R., Brodie, J.E., Bainbridge, Z.T., Davis, A.M., Turner, R. 2011. Using monitoring data to model herbicides exported to the Great Barrier Reef, Australia. In Chan, F., Marinova, D. and Anderssen, R.S. (eds) MODSIM2011, 19th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2011, pp. 2051-2056. ISBN: 978-0-9872143-1-7. www.mssanz.org.au/modsim2011/E5/lewis.pdf

O'Brien, D.S, Lewis, S.E., Davis, A., Gallen, C., Paxman, C., Smith, R., Warne, M., Mueller, J., Brodie, J.E., 2013. [Pesticide exposure within the Barratta Creek Catchment](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (58pp.). ISBN 978-1-925088-08-3.

Magnusson, M., Heimann, K., Ridd, M., Negri, A.P., 2012. Chronic herbicide exposures affect the sensitivity and community structure of tropical benthic microalgae. Marine Pollution Bulletin online first.

Negri, A.P., Mercurio, P., Flores, F., Mueller, J.F. 2013. [Pesticide dynamics in the Great Barrier Reef catchment and lagoon: grazing, bananas and grain. Herbicide persistence in the marine environment](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (26pp).

Packett, R. 2014. [Pesticide dynamics in the Great Barrier Reef catchment and lagoon: management practices \(grazing, bananas and grain\) and risk assessments. Dissolved and particulate herbicide transport in central Great Barrier Reef catchments](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (29 pp.). ISBN 978-1-925088-09-0.

Shaw, M., Silburn, D.M., Ponce, S.R., Lewis, S., David, A. 2014. [Herbicide degradation on Queensland cropping soils and crop residues. Half-lives measured in a controlled environment](#). Department of Natural Resources and Mines. Queensland Government.

Thornton, C. M. and Elledge, A.E. 2014. [Pesticide Dynamics in the Great Barrier Reef Catchment and Lagoon: Management Practices \(Grazing, Bananas and Grain Crops\) and Risk Assessments \(Project RRRD038\). Tebuthiuron Management in Grazing Lands \(Subproject 2\)](#). Report to the Reef Rescue Water Quality Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (35 pp.). ISBN: 978-1-925088-07-6.

van Dam, J.W., Negri, A.P., Mueller, J.F., Altenburger, R., Uthicke, S. 2012. Additive pressures of elevated sea surface temperatures and herbicides on symbiont-bearing foraminifera. PLoS ONE 7(3), e33900.

van Dam, J.W., Negri, A.P., Mueller, J.F., Uthicke, S. 2012. Symbiont-specific responses in foraminifera to the herbicide diuron. Marine Pollution Bulletin online first.

RRRD058

Herron, R., Prasad, R., Choy, S., Mitrovic, S., Kefford, B. in press. Determining the sensitivity of benthic diatom communities to herbicides using rapid toxicity testing: a comparison of methods.

Kefford, B.J., Wood, R.J., Mitrovic, S. and von der Ohe, P. 2014. [Biomonitoring effects of pesticides in rivers draining on to the Great Barrier Reef](#). Final report for project number RRRD058: A novel biological method of monitoring herbicides. Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (109pp.). ISBN: 978-1-925088-18-2.

Prasad, R., Choy, S., Mitrovic, S., Kefford, B. in press Assessing the sensitivity of freshwater benthic algae to several common herbicides in North Queensland, Australia.

Tracking change - water quality monitoring techniques and reporting

RRRD030

Bainbridge, Z., Lewis, S., Smithers, S., Kuhnert, P., Henderson, B., Brodie, J. 2014. Fine-suspended sediment and water budgets for a large, seasonally dry tropical catchment: Burdekin River catchment, Queensland, Australia. *Water Resources Research* 50: doi:10.1002/2013WR014386.

Lewis, S., Bainbridge, Z., Kuhnert, P.M., Sherman, B.S., Henderson, B., Dougall, C., Cooper, M. and Brodie, J.E. 2013. Calculating sediment trapping efficiencies for reservoirs in tropical settings: A case study from the Burdekin Falls Dam, NE Australia. *Water Resources Research* 49, 1017–1029, doi:10.1002/wrcr.2011.

Pagendam, D.E., Kuhnert, P.M., Leeds, W.B., Wikle, C.K., Bartley, R. and Peterson, E.E. 2014. Assimilating catchment processes with monitoring data to estimate sediment loads to the Great Barrier Reef. *Environmetrics*, Special Issue 25: 214-229.

Kuhnert, P., Henderson, B., Lewis, S.E., Bainbridge, Z.T., Wilkinson, S., Brodie, J.E., 2012. [Quantifying total suspended sediment export from the Burdekin River catchment using the Loads Regression Estimator Tool](#). *Water Resources Research*, 48: W04533. doi:10.1029/2011WR011080

Kuhnert, P.M., Pagendam, D., Bartley, R., Searle, R., Peterson, E., Leeds, W.B., Wikle, C.K., Ellis, R., Turner, R., Waters, D., Dougall, D., Lewis, S., Bainbridge, Z. and Brodie, J. 2013. [Integrating measurements with models for improved confidence in pollutant loads estimation](#). Project RRRD030 Pollutant Load Estimation for Great Barrier Reef Catchments (GBR): Accounting for Uncertainty. Report to the Reef Rescue Research and Development Program. Reef and Rainforest Research Centre Limited, Cairns (39pp.). ISBN: 978-1-925088-32-8.

RRRD016

Álvarez-Romero, J.G., Devlin, M., Teixeira da Silva, E., Petus, C., Ban, N.C., Pressey, R.L., Kool, J., Roberts, J.J., Cerdeira-Estrada, S., Wenger, A.S., Brodie, J., 2013. A novel approach to model exposure of coastal-marine ecosystems to riverine flood plumes based on remote sensing techniques. *Journal of Environmental Management* 119, 194-207.

Brando, V.E., Devlin, M.J., Dobbie, M., MacNeil, A., Schaffelke, B. and Schroeder, T. 2014. [Developing integrated assessment metrics for reporting of water quality in the Great Barrier Reef lagoon](#). Report to the Reef Rescue Water Quality Research & Development Program. Reef and Rainforest Research Centre Limited, Cairns (53pp.).

Schroeder, T., Devlin, M.J. Brando, V.E. Dekker, A.G. Brodie, J.E. Clementson, L.A. and McKinna, L. 2012. Inter-annual variability of wet season freshwater plume extent into the Great Barrier Reef lagoon based on satellite coastal ocean colour observations. *Marine Pollution Bulletin* 65(4–9): 210-223.

Appendix 3: Summary of Reef Rescue R&D communication

As part of the Communication Strategy, a number of statistics were identified for tracking program communications. A summary of the activities documented for the program is provided below, derived from reporting provided by each project. A detailed list of the communication activities undertaken to date for each of the projects and the Science Coordination Team are provided below.

Project Teams

Product	Total
Number of presentations given (conferences, workshops):	~100
Number of field days or industry forums ¹	~65
Number of articles in relevant newsletters (industry, other research programs, Reef Plan):	15
Number of scientific publications (journal articles):	21
Publications In press:	10
Number of Reef Rescue R&D technical reports:	21
In review:	14
Number of other technical reports:	7
Number of conference papers:	21
Meetings/workshops attended to formally represent the project:	~50

¹Note that the Reef Rescue Regional Science Forums are already counted in the presentations above.

Science Coordination Team

Product	Total
Number of presentations given (conferences, workshops, etc):	25
Meetings/workshops attended representing the program:	~70

Formal events

- Reef Rescue R&D Inception Workshop June 2011, Brisbane
- Reef Rescue Forum August 2012, Brisbane
- Reef Rescue R&D and NERP Tropical Ecosystems Hub joint conference May 2013, Cairns
- Reef Rescue R&D Regional Science Forum – Mackay Whitsunday, 9 & 10 September 2013
- Reef Rescue R&D Regional Science Forum – Fitzroy, 16 & 17 September 2013
- Reef Rescue R&D Regional Science Forum – Wet Tropics and Cape York, 8 & 9 October 2013
- Reef Rescue R&D Regional Science Forum – Burnett Mary, 16 & 17 October 2013
- Reef Rescue R&D Regional Science Forum – Burdekin, 22 & 23 October 2013

Other Meetings

The Science Coordination Team has regular contact with all of the Reef Rescue R&D Project Leaders. Other specific external meetings with the Reef Rescue/Reef Programme team, end users and collaborators are listed below.

May 2011

- Meeting 5 May: Water Quality R&D Coordination meeting organised by RRRC as part of the planning for NERP to bring leaders of water quality R&D Programs to discuss synergies and potential overlap. Involved representatives from Reef Plan broadly, Reef Plan Paddock to Reef, Reef Protection Package Science Program, Reef Rescue R&D, eReefs and NERP).

July 2011

- *Phone link 8 July:* Science Coordination Team and Reef Rescue team regarding research linkages, contracting and program communications.

August 2011

- *Meeting 9 August:* Jane Waterhouse met with John Bennett and Chris Carroll from DERM regarding links between *Reef Rescue R&D*, the Paddock to Reef Program and the Reef Protection Package Science Program.
- *Meeting 23 August:* Jane Waterhouse and David Souter presented an overview of the NERP including *Reef Rescue R&D* linkages to DEEDI staff in Townsville (including Peter Mellors, June Powell, Adam West and Anne Clarke).
- *Meeting 25 August:* Jane Waterhouse met with Ian Dight, NQDT, regarding process for engaging Reef Rescue R&D projects in their activities. Also discussed specific issues regarding collaboration with RRRD024 regarding selection of study sites and provision of landholder information on D condition land.
- *Phone link 25 August:* Science Coordination Team and Reef Rescue team regarding general update of progress.
- *Meeting 31 August:* Jane Waterhouse and Michelle Devlin met with Jean Erbacher, Gay Crowley and John Bennett (DERM) regarding project linkages between the proposed Reef Protection Package Science Program projects and *Reef Rescue R&D*.

September 2011

- *Meeting 5 September:* Jane Waterhouse met with Sarah Strutt from AgForce Queensland working in the Burdekin region to provide an overview of Reef Rescue R&D and to make linkages with specific grazing projects in the region.
- *Meeting 12 September:* Jane Waterhouse met with Marie Vitelli, Sarah Strutt and Natalie Schick from AgForce Queensland to provide an overview of Reef Rescue R&D and discuss approaches to communication and engagement.
- *Phone link 13 September:* Jane Waterhouse and Chris Chinn regarding program update and coordination with relevant initiatives.
- *Meeting 20 September:* Michelle Devlin met with Nick Heath from WWF to provide an overview of *Reef Rescue R&D* projects and discuss approaches to communication and engagement.
- *Meeting 21 September:* Michelle Devlin met with Bianca Cairns and Ben Baldwin from SRDC to provide an overview of *Reef Rescue R&D* projects, discuss approaches to communication and engagement and linkages to SRDC research.
- *Meeting 22 September:* Colin Creighton met with Bianca Cairns and Ben Baldwin from SRDC regarding mechanisms for direct linkages between *Reef Rescue R&D* and SRDC research, and potential joint communication events such as a Practice Forum in November.
- *Meeting 22 September:* Colin Creighton met with Claire Anderson and Anita Leahy from the Reef Plan Secretariat regarding coordination of *Reef Rescue R&D* within the broader range of initiatives supporting Reef Plan, future directions and potential joint communication events.

October 2011

- *Meeting 14 October:* Jane Waterhouse attended the P2R Program Coordination and Advisory Group meeting (CAG) in Brisbane and provided a status update on *Reef Rescue R&D*.
- *Phone link 21 October:* Science Coordination Team and Reef Rescue team regarding general update of progress.
- *Meeting 25 October:* Jane Waterhouse attended the Reef water quality research coordination group meeting and presented a number of proposals to facilitate improved coordination and integration between the related research programs.

November 2011

- *Workshop 3-4 November:* Jane Waterhouse attended the DERM Grazing Education and Extension Showcase in Townsville and presented an overview of on *Reef Rescue R&D*.
- *Phone link 17 November:* Jane Waterhouse linked into the Reef Rescue Operatives meeting to describe *Reef Rescue R&D*.
- *Workshop 22-23 November:* Jane Waterhouse attended the DERM Cane Education and Extension Showcase in Mackay and presented an overview of on *Reef Rescue R&D*.

December 2011

- *Meeting 1 December:* Jane Waterhouse met with Gay Crowley (DERM) and Mark Poggio (DEEDI) regarding links between RRRD039 and proposed economic Reef Protection Package science projects.

- *Workshop 7-8 December:* Jane Waterhouse attended the DERM Cane Education and Extension Showcase in Ayr and presented an overview of on *Reef Rescue R&D*.
- *Meeting 8 December:* Jane Waterhouse met with Val Sapin, Adam Knapp, Jean Erbacher and Milena Gongora to discuss opportunities for collaboration between Reef Rescue, Reef Protection Package and P2R Program communication events.
- *Meeting 13 December:* Jane Waterhouse attended the project meeting for RRRD004 in Townsville.
- *Workshop 15 Dec:* Jane Waterhouse attended the Mackay P2R Program management practice synthesis workshop.

January 2012

- *Meeting 30 January:* Jane Waterhouse attended part of the project team meeting for RRRD032 led by Scott Wilkinson.
- *Meeting 31 January:* Jane Waterhouse presented an overview of *Reef Rescue R&D* at the NERP Water Quality Implementation Group meeting (coordinated by Michelle Devlin).

February 2012

- *Meeting 15 February:* Jane Waterhouse presented an overview of *Reef Rescue R&D* at the Reef Rescue Operatives meeting, Brisbane.
- *Meeting 15 February:* Jane Waterhouse met with Jean Erbacher and Gay Crowley from the Reef Protection Package Science Program to discuss joint program communications, Brisbane.
- *Workshop 16 February:* Jane Waterhouse presented an overview of *Reef Rescue R&D* at Mackay Cane Trial Information Day coordinated by BSES, Mackay.
- *Workshop 17 February:* Jane Waterhouse attended the Mackay P2R program cane management practice synthesis workshop for herbicide management.
- *Workshop 20 February:* Jane Waterhouse facilitated the Burdekin P2R program cane management practice synthesis workshop, Townsville.
- *Site visit 21 February:* Jane Waterhouse participated in the Wet Tropics P2R program monitoring sites field trip, including a visit to the monitoring sites for RRRD049 banana project.
- *Workshop 22 February:* Jane Waterhouse facilitated the Wet Tropics P2R program cane management practice synthesis workshop, Innisfail.
- *Workshop 28 February:* Michelle Devlin attended the DERM Cane Education and Extension Showcase in Ingham and presented an overview of *Reef Rescue R&D*.

March 2012

- *Workshop 13 March:* Jane Waterhouse facilitated the P2R program internal grazing management practice synthesis workshop, Brisbane.
- *Meeting 16 March:* Jane Waterhouse participated in the P2R program Coordination and Advisory Group meeting (CAG) regarding the P2R Management practice synthesis workshops.
- *Workshop 20 March:* Jane Waterhouse facilitated the Burnett Mary P2R program cane management practice synthesis workshop, Bundaberg.
- *Meeting 21 March:* Juliana Doupe and Jane Waterhouse met with the Reef Rescue team and communication staff to discuss the *Reef Rescue R&D* website proposal.
- *Phone link 29 March:* Jane Waterhouse participated in a project meeting for the Cape York sediment tracing project.

April 2012

- *Meeting 17 April:* Juliana Doupe met with the Reef Rescue team and communication staff to discuss *Reef Rescue R&D* website development and communications generally.
- *Phone link 17 April:* Jane Waterhouse participated in a project meeting for the Cape York sediment tracing project with the P2R catchment modelling team.
- *Phone link 19 April:* Jane Waterhouse participated in a discussion regarding planning for the Reef Rescue event in August 2012.

May 2012

- *Workshop 30 May:* Jane Waterhouse attended the Wet Tropics Terrain NRM Reef Rescue Cane Working Group meeting and presented an overview of the Reef Rescue R&D projects, Innisfail.

June 2012

- *Meeting 19, 20 June:* Jane Waterhouse attended the P2R CAG meeting, Brisbane.

July 2012

- *Project Workshop 3 July:* Jane Waterhouse attended the RRRD030 stakeholder workshop, Brisbane.

August 2012

- *Meeting 8 August:* Michelle Devlin attended / convened the NERP Water Quality Implementation Group meeting.
- *Phone link 14 August:* Jane Waterhouse attended the first Reef Rescue Evaluation Technical Committee meeting.
- *Workshop 20 August:* Jane Waterhouse attended the MMP Integration Workshop, Townsville.
- *Meeting 22 August:* Jane Waterhouse attended the P2R CAG meeting, Townsville.
- *Workshop 28-30 August:* Science Coordination team attended the Reef Rescue Forum.

September 2012

- *Workshop 12 September:* Michelle Devlin convened the first Pesticide Working Group meeting, Townsville.

October 2012

- *Meeting 24 October:* Michelle Devlin met with the communications staff from SRDC to discuss future opportunities for working together on sharing project outcomes.
- *Meeting 24 October:* Jane Waterhouse attended the Reef Rescue Operatives group meeting, Brisbane.
- *Meeting 25 October:* Jane Waterhouse attended the P2R CAG meeting – Program assessment and prioritization, Brisbane
- *Meeting 25 October:* Jane Waterhouse Chaired the Reef Plan R&D Coordination Group meeting, Brisbane.
- *Meeting 26 October:* Johanna Johnson and Jane Waterhouse attended a focus meeting for the socio economic projects, Brisbane.
- *Meeting 29 October:* Col Creighton and Jane Waterhouse attended the Reef Rescue 2 Investment Prioritisation Working Group meeting, Brisbane.
- *Workshop 30 October:* Jane Waterhouse and Michelle Devlin attended the eReefs Dashboard User Workshop, Townsville.

November 2012

Meeting 22 November: Jane Waterhouse attended the Steering Committee meeting for RRRD027, Townsville.

December 2012

No specific meetings were held.

January 2013

- *Ph link 31 January:* Jane Waterhouse attended the P2R CAG meeting – Program assessment and prioritization

February 2013

- *Workshop 26 February:* Jane Waterhouse presented an overview of Reef Rescue R&D at the Project Catalyst Forum, Cairns.

March 2013

- *Meeting 12 March:* Jane Waterhouse attended the P2R nested monitoring workshop as part of the CAG role, Townsville.
- *Meeting 25 and 26 March:* Jane Waterhouse attended the P2R CAG meeting, Brisbane.

April 2013

- *Ph link 24 April:* Jo Johnson participated in the Reef Plan R&D Coordination Group meeting.

May 2013

- *Conference 7 to 10 May:* Reef Rescue R&D and NERP joint conference.

June 2013

- *Ph link 11 June:* Jane Waterhouse attended the P2R CAG meeting.
- *Meeting 18 June:* Jane Waterhouse participated in the Reef Rescue 2 Water Quality Grants and Partnerships Technical Panel.

July 2013

- No specific meetings were held.

August 2013

- *Meeting 7 and 8 August:* Jane Waterhouse participated in the NERP Water Quality Implementation Group meeting, Townsville.
- *Meeting 9 August:* Jane Waterhouse attended the Project Steering Committee meeting for RRRD027, Townsville.
- *Meeting 9 August:* Jane Waterhouse provided an update of Reef Rescue R&D to the Reef Operatives meeting, Townsville.
- *Symposium 27 August:* Project RRRD039 convened an international symposium to disseminate socio-economic results on practice adoption and barriers.

September 2013

- *Various meetings:* Jane Waterhouse coordinated the Reef Rescue Regional Science Forums for the Mackay Whitsunday and Fitzroy regions.
- *Phone link 25 September:* Jane Waterhouse participated in the Reef Plan R&D Coordination Group meeting.

October 2013

- *Various meetings:* Jane Waterhouse and Michelle Devlin coordinated the Reef Rescue Regional Science Forums for the Wet Tropics, Cape York, Burnett Mary and Burdekin regions.
- *Meeting 14 and 15 October:* Jane Waterhouse attended to the P2R CAG meeting in Brisbane as part of the review of the P2R Program.
- *Meeting 25 October:* Jane Waterhouse attended the MCASS Investment Prioritisation Working Group meeting, Brisbane.

November 2013

- *Phone link 20 November:* Jane Waterhouse participated in the Reef Plan R&D Coordination Group meeting to establish the Reef Plan RD&I Strategy.

December 2013 to September 2014

- *Meeting 30 January 2014:* Jane Waterhouse and Michelle Devlin participated in the NERP WQ Implementation Group meeting to share project updates.
- *Meeting 12 February 2014:* Jane Waterhouse attended the Canegrowers N management forum in Townsville.
- *Meeting 5 March 2014:* Jane Waterhouse attended the Reef Operatives meeting in Brisbane to share project updates.
- *Meeting 1 April 2014:* Jane Waterhouse attended to the P2R CAG/ISP meeting in Brisbane as part of the review of the P2R Program and Report Card review.
- *Meeting 29 July 2014:* Jane Waterhouse participated in the Reef Plan R&D Coordination Group meeting.
- *Meeting 31 July and 1 August 2014:* Jane Waterhouse attended to the P2R CAG/ISP meeting in Brisbane as part of the review of the P2R Program.
- *Meeting 6 August 2014:* Jane Waterhouse and Michelle Devlin participated in the NERP WQ Implementation Group meeting to share project updates.

Individual Project Leaders also made considerable efforts throughout the program to engage end users as part of project planning, data collection and result dissemination. These are outlined below.

Project specific communications

Grazing

RRRD024: Trevor Hall

- Several meetings with NQDT and FBA staff regarding site selection and history of activities of rehabilitation of D class land.

Workshop Representation

- Paddock to Reef grazing synthesis workshop (Townsville May 2012); NQDT Science project RP69G 'Grazing management systems report for the Burdekin Dry Tropics' workshop (May 2012)
- Reef Protection Program Grazing Science Project Update (Townsville, March 2012)
- RPP R&D Grazing Management Working Group workshop (Oonoonba, March 2012)

Presentations

- Trevor Hall (April 2011): "Reef Rescue Rehabilitation Project RRRD.024; preliminary concept and proposal", GCI Forum (Brisbane, 2011). (PowerPoint presentation).
- Trevor Hall (October 2011): "Reef Rescue Project RRRD.024, Reef Rehabilitation Field Trial "Spyglass". Primary Industries Minister and DAFF Executive field day handout.
- Reef Rescue forum, Brisbane (August 2012): <http://www.reefrescueresearch.com.au/events/reef-rescue-forum/2-uncategorised/61-rrrd024-rehabilitating-degraded-grazing-lands.html>
- An on-site field day and presentation to NABRC, 40 producers and DAFF staff at Spyglass, 11 October 2012.
- Trevor Hall (2013): "Quantifying the impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement". NERP Conference, Cairns (May 2013).
- Reef Rescue Regional Science Forum (Mackay, September 2013) – overview of RRRD024 project results.

Articles

- Project summary article prepared for Catchment organisations and DAFF (previously DEEDI) staff.
- The satellite camera web site (<http://live.usee.com/sites>) and access codes have been provided to DAFF researchers and advised at the Reef Forum in Brisbane in August.
- The satellite weather station web site and access codes have been provided to DAFF researchers and advised at the Reef forum in Brisbane in August.

Camera: Log-on: <http://live.usee.com/sites> to open the uSee website and open with **username** "spyglass" and **password** "spyglass".

Weather Station: Log on: <http://bontech.agmon.com.au/?menu=6> with username "TrevorH" and password "HallT"; Click "List of items" and Agmon23: Select the graphs and data ranges required.

- Spyglass Beef Research Facility Web site: Project summary: Rehabilitating degraded grazing lands – Reef Rescue Project (RRRD.024) - "Quantifying the impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement".
- Hall, T.J. (October 2012): "Quantifying the impacts of rehabilitating degraded lands on soil health, pastures, runoff, erosion, nutrient and sediment movement" NABRC field day handout.
- Reef Rescue Research web site: <http://www.reefrescueresearch.com.au/research/all-projects/34-rrrd024-quantifying-the-impacts-of-rehabilitating-degraded-lands-on-soil-health-pastures-runoff-erosion-nutrient-and-sediment-movement.html>

Extension activities, field days and industry forums:

- Burdekin field trial site (Primary Industries Minister; DAFF Executive; NABRC; AgForce; landholders; catchment staff; R&E staff).

RRRD027: Terry Beutel

- Team meeting was conducted in Townsville on 22/6/11 to clarify and planned project activities and contributions. Project Steering Committee established.
- The team has integrated the project into relevant professional and technical networks. These include involvement from FBA and NQDT in the steering committee, technical contributions to a number of *Reef Rescue R&D* projects, participation in a number state level reef projects including Reef Protection Program officer training, steering committee participation for Reef Protection research projects and consultation with Delbessie team members.
- VegMachine training for 12 new DEEDI, FBA and NQDT staff and data updates (2010) for staff in both regions. VegMachine training booked for 28 additional agency staff including 24 Reef Protection staff in February and March 2012.

- 2 meetings with stakeholders in FORAGE and Paddock GRASP redevelopment in 2012 (link also to role in Burdekin Extension work).
- VegMachine Training Day for DERM technical staff (RPP, RSC, Delbessie, QCCCE) – 7 officers (8 March 2012).
- Two VegMachine Training days for (28 and 29 Feb 2012) for FBA and DEEDI extension staff who work across the Burdekin and Fitzroy.
- Team meeting in Brisbane 18 July 12 to formalise fractional cover data requirements for VegMachine.
- Conducted/attended the Ground Cover Reporting and Information Requirements Workshop (19 July 12) in Brisbane to outline and agree on formats/ protocols around new fractional imagery.
- Attendance and presentation at the DAFF Burdekin Extension project meeting Charters Towers (6th August 2012) to plan ongoing extension activities in the Burdekin and integrate this project's outputs into extension activities.
- Team meeting in Townsville 15th August 2012 to clarify changing role of CSIRO in project following departure of Brett Abbott due to illness.
- Conducted advanced VegMachine training day (16th August 2012) for four NQDT staff in Townsville.
- Conducted advanced VegMachine training day (17th August 2012) for five NQDT staff in Townsville. Training targets better production of VegMachine reports.
- Attendance by two project partners at the Enhancing FORAGE (RP68G) and Paddock GRASP re-development (RP67G) meeting in Brisbane (27th August 2012).
- Attendance at the annual Reef Rescue Forum in Brisbane (28-30 August 2012), and presentation of the project results to over 100 participants including other researchers, government agencies, industry and regional NRM groups.
- Interview with ABC North Queensland (10th October 2012) regarding fractional ground cover data and its relevance to the pastoral industry.
- Contribution and review of content for the project page on the new Reef Rescue R&D website.
- Reef protection grazing projects working group meeting (Townsville 21st November 2012).
- Second project steering group meeting (Townsville 22nd November 2012).

[RRRD032: Scott Wilkinson](#)

Project Fact Sheets

Wilkinson, S. and McKellar, K. (2013). [RRRD032: Land condition outcomes from grazing land management](#). Project Fact Sheet for the Reef Rescue Water Quality Research and Development Program.

Workshop representation

- Intensive 3-day GRASP modelling working group (QDERM, QDAFF and CSIRO) in Toowoomba (March 2012)
- Scott Wilkinson presented a seminar including the project activities on 18 August 2012 at the Australian Tropical Sciences and Innovation Precinct, JCU Townsville, which was attended by ~50 people including representatives from AgForce, NQ Dry Tropics, DERM, DEEDI, AIMS, GBRMPA, Dept of Defence, CSIRO, and JCU.
- NQ Dry Tropics revision of the Management Practice Framework for improving Water Quality in Grazing (May 2013)
- FBA Grazing prioritisation workshop (Nov 2013 – by phone)
- NQ Dry Tropics Grazing ABCD Framework prioritization workshop (Nov 2013 – by phone)
- NQ Dry Tropics Grazing spatial prioritisation workshop (Jan 2014, Brisbane)

Presentations

- CESE 2010 (Sep 2010) (prior to contract but in project scope)
- RRRD conference (Jun 2011)
- Project seminar at ATSIP, JCU (Aug 2011)
- Catchment Science 2011 (Dublin; Sep 2011)
- International Rangelands Congress (Argentina, Apr 2011)
- P2R workshop Practice Effectiveness in Grazing (May 2012)
- Reef Rescue Forum – Grazing synthesis and Project presentations (Aug 2012)
- International Coral Reef Symposium (Sep 2012)
- NERP / Reef Rescue conference (May 2013)
- Fitzroy regional RRRD forum (Sep 2013)
- Burdekin regional RRRD forum (Oct 2013)

[RRRD009: Craig Thornton](#)

Project Fact Sheets

- Elledge, A.M. and Thornton, C.M. (2014). Pasture type effect on runoff nitrogen, phosphorus and sediment generation rates: a comparison of grass, butterfly pea and leucaena pastures to the virgin brigalow landscape. Project Fact Sheet for the Reef Rescue Water Quality Research and Development Program.
- Elledge, A.M. and Thornton, C.M. (2014). Land use effect on runoff nitrogen, phosphorus and sediment generation rates: a comparison of cropping and grazing to the pre-European landscape. Project Fact Sheet for the Reef Rescue Water Quality Research and Development Program.
- Elledge, A.M. and Thornton, C.M. (2014). Seasonal trends in soil and plant nutrient concentrations from grass pastures with and without legumes and risk to runoff water quality. Project Fact Sheet for the Reef Rescue Water Quality Research and Development Program.

Workshop presentations

- Field study site tour undertaken on 5/12/11 to provide linkages between this project, RRRD038 and a number of P2R Program components in the Fitzroy, Mackay Whitsunday and Wet Tropics.
- Project update presented at Taroom “Accelerated adoption of Leucaena” State wide Information day.
- Project update provided to CQ Beef Research Committee in Nov 11.
- Craig Thornton and Amanda Elledge (2012) RRRD009: Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. In “Reef Rescue Forum 2012”, Brisbane, 28-30 August 2012. Available at <http://www.reefrescueresearch.com.au/events/reef-rescue-forum.html> [accessed February 2013].
- Elledge, A. and Thornton, C. (2012) RRRD009: Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. In “Pesticides and the Great Barrier Reef Working Group”, James Cook University, Townsville, 12 September 2012.
- Thornton, C. and Elledge, A. (2012) RRRD009: Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. In “Reef Rescue Forum 2012”, Brisbane, 28-30 August 2012. Available at <http://www.reefrescueresearch.com.au/events/reef-rescue-forum.html> [accessed February 2013].
- Thornton, C. and Elledge, A. (2013) Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. In “NERP Tropical Ecosystems Hub and Reef Rescue R&D Conference 2013”, Cairns, 7-10 May 2013. Available at <http://www.reefrescueresearch.com.au/events/reef-rescue-conference-2013.html> [accessed June 2013].
- Thornton, C. and Elledge, A. (2013) RRRD009: Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. In “Pesticides and the Great Barrier Reef Working Group”, James Cook University, Townsville, 24 April 2013.
- Thornton, C. and Elledge, A. (2013) RRRD009: Runoff nitrogen generation rates from pasture legumes – an enhancement to reef catchment modelling. Presented at the following Reef Rescue Regional Science Forums: Reef Catchments (Mackay) Sep 2013; Fitzroy Basin Association (Rockhampton) Sep 2013; North Queensland Dry Tropics (Townsville) Oct 2013; Burnett-Mary Regional Group (Bundaberg) Oct 2013.

3 oral presentations given to the 2012 Hydrology and Water Resources Symposium

- Amanda Elledge and Craig Thornton (2012) *The Brigalow Catchment Study: Nitrogen runoff generation rates from pasture legumes and changes since land development*. In “Proceedings of the 34th Hydrology and Water Resources Symposium”, 19-22 November 2012, Sydney, Australia.
- Craig Thornton and Amanda Elledge (2012) *The Brigalow Catchment Study: Increases in runoff associated with land development can still be detected in flood events at a small catchment scale*. In “Proceedings of the 34th Hydrology and Water Resources Symposium”, 19-22 November 2012, Sydney, Australia.
- Craig Thornton and Bofu Yu (2012) *The Brigalow Catchment Study: Effects of land development on peak runoff rate and its prediction in central Queensland, Australia*. In “Proceedings of the 34th Hydrology and Water Resources Symposium”, 19-22 November 2012, Sydney, Australia.

1 poster presentation given to the 2012 Soil Science Conference

- Amanda Elledge and Craig Thornton (2012) *The Brigalow Catchment Study: Comparison of soil fertility, forage quality and beef production from buffel grass vs. leucaena-buffel grass pastures*. In “Proceedings of the Joint SSA and NZSSS Soil Science Conference, Soil solutions for diverse landscapes”, 2-7 December 2012, Hobart, Australia.
- Article published in CQ Crop Sequencing (DEEDI).

Fifty (50) field days and industry forums have also been listed for the project.

Sugar

RRRD056: Peter Thorburn

- Project meetings: Project staff had regular meetings with the internal project team members, i.e. BBIFMAC (field site contractors), Farmacist (Project Catalyst site managers), and the collaborating farmers to coordinate.

Presentations

- Reef Rescue Forum Aug 2012 (Brisbane), “Evaluating and improving A-Class management practices in the sugarcane industry”. Presented at the annual Reef Rescue Forum in Brisbane, August 2012.
- Presented at Reef Rescue R&D and NERP Conference in Cairns, May 2013.
- Reef Rescue Regional Science Forums; Reef Catchments (Mackay) Sep 2013, Terrain (Cairns) Oct 2013, NQDT (Townsville) Oct 2013.
- MODSIM 2013, Adelaide Dec 2013.
- Reef Catchments workshop on “Enhanced Nitrogen Use Efficiency in Sugar Cane Production in GBR Catchments”, Townsville 9/12/2013
- Project Catalyst Mackay Whitsunday Regional Grower Event held at Scott Simpson’s Farm at Bloomsbury on 8/12/11. Included 28 growers, 3 DEEDI staff and 3 Reef Catchments staff.
- E&E strategy held in Mackay on 22-23/11/11 with a range of industry extension staff and DEEDI/DERM employees.
- Reef Rescue Regional Cane Industry Working Group on 13/12/11 with Reef Catchments, Canegrowers, Mackay Sugar, BSES, MAPS and PCPSL.

Articles

- Articles in relevant newsletters (industry, other research programs, Reef Plan): Steve Attard was interviewed (3/10 and 17/10) by Ogilvy Impact, media managers for Project Catalyst, about the partnership between our RRR&D project and Project Catalyst. Promotional material is being developed from those interviews for Project Catalyst. The material will be reported when it is published.

Field days or industry forums

- Project Catalyst Annual Forums; May 2011 (Mackay), Feb 2012 (Townsville) and Feb 2013 (Cairns).
- Project Catalyst Annual Forum field trip to the Burdekin Feb 2012 (Research site visited).

RRRD004: David Midmore / Surya Bhattarai

- Discussion with irrigation businesses in the Burdekin region regarding the drip and subsurface drip irrigation for sugarcane particularly with Green Irrigations (Aaron Moore), and Netafim Australia (Sam Birrell, and Peter Durand). Similar discussion with the irrigation business and industries in the Bundaberg region.

Workshop representation

- Initial meeting of all project operators (28/2/11) for discussion of ongoing project activities. Field visits to Ayr, Innisfail, Bundaberg for meetings with potential co-operators involved in the field and data collection levels. Site visit to Emerald to investigate the movement of DERM equipment to NQ and CQ.
- Surya Bhattarai participated and presented in the Denitrification meeting held in QDAFF Townsville on 21 August 2012 to discuss on Components of the N budget in cane presented by Dr Philip Moody, Principal Scientist (Soil Processes), Environment and Resource Sciences, Department of Science, Information Technology, Innovation and the Arts. This is aimed at developing synergies between the project for measurement and monitoring of nitrogen mass balance in sugarcane with different irrigation management. The meeting and the collaborators in this project team decided to get involved in this proposed activities on NOx monitoring, and it will be carried out in the two sugarcane sites, Home Hill and Clare.
- A meeting with sugar industry partners in Burdekin conducted on 22 August 2012 for a new project EOI that has been submitted to SRDC with the title “A carbon-smart nutrient source from cane trash biochar and mill-mud (Smart BIOCHARMM)” that involves most of the collaborators from the current project and Pioneer sugar mills in Burdekin.
- Irrigation Australia conference organised by Irrigation Australia limited, 2012 and 2014

Presentations

- In-house presentation in the CQUniversity seminar series.

- Surya Bhattarai attended the Reef Rescue Annual Forum in Brisbane conducted on 28-31 August 2012 where the up to date data from both research sites (Bundaberg and Burdekin) were presented and discussed in the details.
- Presented at Reef Rescue R&D and NERP Conference in Cairns, May 2013.
- Reef Rescue R&D Regional Science Forum: Burdekin, 23 October 2013, Attended by Surya P Bhattarai and David J Midmore, presented a talk of Irrigation management of sugarcane.
- Upgrading underway for the CQUniversity link to reef rescue research website: <http://www.cqu.edu.au/research/research-organisations/institutes/resource-industries-and-sustainability/centres2/centre-for-plant-and-water-science/research-oxygation,-stevia,-waste-water,-phytoremediation-and-non-invasive-assessment/reef-rescue-research>.

RRRD020: Bernard Schroeder

- Discussions / meetings held in June 2011 to determine strategies to enable current trials to be continued in the Herbert, Mackay and Bundaberg districts.
- Meeting between BSES AND Queensland DSITIA are ongoing throughout this project. These have continued.
- Meetings (Schroeder (BSES) and Moody (DSITIA) were held to discuss plans for the second pot experiment, supporting laboratory activities and the incubation studies (7 Aug 2012 and 30 Oct 2012).
- Several meetings / telephone calls that involved members of the project team were held to ensure that the trials in the Herbert, Mackay and Bundaberg districts were progressing according to plan.
- Contribution and review of content for the project page on the new Reef Rescue R&D website

Presentations

- Abstract submitted to the Australian Society of Sugar Cane Technologists for possible presentation at the conference in May 2013.
- Bernard Schroeder and Phil Moody attended the annual Reef Rescue Forum in Brisbane 28 August 2012. The project results (to date) were presented to over 100 participants that included researchers, government agencies, industry and regional NRM groups.

Horticulture & dairy

RRRD049: John Reghenzani / John Armour

- First project team meeting to plan project design and framework in Atherton June 2011, linking with RRRD054.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference
- 9-10 Oct 2013 in Cairns - Reef Rescue Science Forum- Wet Tropics and Cape York Regions
- 16-17 Oct 2013 in Bundaberg- Reef Rescue Science Forum to Burnett Mary Region
- 29 May – 01 June 2013 at Coolool - 10th Australian Banana Industry Congress with an update on project progress displayed on a poster.

Articles

- 2 articles in the Australian Banana Magazine (Volume 36).

Field days or industry forums

- 29 November 2011 at South Johnstone - Field walk for 20 banana growers and 10 fertiliser company representatives to inform attendees of the scope of the work in progress.
- 9 November 2012 at South Johnstone - More than 40 banana growers attended a field walk. A written progress report on RRRD049, including results from the plant crop, was given to attendees. Growers showed considerable interest in the controlled release fertilisers on trial.
- Hosted a film crew and field walk at the study site (August 2012).
- Controlled release product suppliers have visited the trial site on five occasions. Two groups of international visitors have also toured the trial site and were presented with informal talks on objectives of the trial.

- Field walk for banana growers and fertiliser company representatives held in November at South Johnstone trial site to communicate knowledge of the scope of the work in progress.

RRRD054: Tony Webster

- Regular informal meetings between projects RRRD054 and RRRD049 occur around management of the trial work at South Johnstone Research Station.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference
- 9-10 Oct 2013 in Cairns - Reef Rescue Science Forum- Wet Tropics and Cape York Regions

RRRD055: Ruth Chalk

- Regular meetings/teleconferences of the Queensland Dairy Reef-wide Steering Committee and Research Advisory Committee.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference
- 9-10 Oct 2013 in Cairns - Reef Rescue Science Forum- Wet Tropics and Cape York Regions

Articles

- Four articles published about the project in the Northern Dairyfarmer magazine (Aug/Sep 2012 and Dec 2012), the Dairying for Tomorrow Newsletter (Dec 2012) and Incitec Pivot Agronomy News (Sept 2012).

Field days or industry forums

- Two field days at their study sites in Ravenshoe and Gympie in September 2012.
- A fact sheet was prepared and distributed to attendees of the field days to demonstrate what the project entails, what is being monitored and what the results are showing so far

Socio economic

RRRD010: Delwar Akbar

- Presentation and participation at workshop on socio-economic projects in the GBR catchment (October 2012).
- Drafted media release of project objectives.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference

RRRD011: David Freebairn

- Reference Group consultation May-June 2011. Scientists (data and modellers) contacted as part of establishing a reference group of key stakeholders, and consulted regarding the project approach. Draft database has been circulated to the reference group.
- Regular informal meetings/discussions with Ken Rhode, Megan Menner, Mark Silburn and Brett Robinson regarding the Howleaky field studies database and modelling exercises (DNRM, DSITIA).
- Media release: Website gathers runoff research March 2013

Presentations

- Paper presented at the 2012 Australian Soil Science Conference. *Assessing water quality from farms – how much detail is required for a model to be useful?*
- Presentation at the National Environmental Research Program (NERP) Conference in Cairns (2013). *Capturing paddock scale hydrology and water quality experience relevant to Great Barrier Reef.*
- Presenting at the Soil Science Australia mini-conference, Brisbane, October 2013. *Ready access to water quality studies relevant to the Great Barrier Reef.*
- Launch and presentation of field studies database website at Reef Rescue Forum, August 2012 *RRRD011: Capturing paddock scale hydrology and water quality experience relevant to GBR.*

RRRD039: Stuart Whitten

- First bi-annual project team meeting in Townsville June 2011.
- Presentation and participation at workshop on socio-economic projects in the GBR catchment (October 2012).
- Monthly project meetings, plus regular meetings with DEEDI researchers.
- Team members have attended a number of regional meetings where they formally and informally presented on aspects of the project.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference
- 9-10 Oct 2013 in Cairns - Reef Rescue Science Forum- Wet Tropics and Cape York Regions

Pesticides

RRRD038 and RRRD037: Jon Brodie

- May-June 2011 - Convened a number of meetings to organise sub contracts, engage project teams and plan execution of the projects. Undertook general discussions to coordinate the projects with Paddock to Reef, and specifically in the Herbert River catchment 'Herbert project'. Convened meetings with the Queensland Government to attract funding from the Reef Protection Program and seeking investment to complement the RRRD037 and 038. Commenced discussions with Canegrowers (Matt Kealley), Nick Heath (WWF), Project Catalyst. Facilitated documentation of the pesticide cluster with NERP and further discussions (specifically with Andrew Negri, AIMS) to coordinate this project with NERP pesticide projects which were under assessment.

Presentations

- Consensus statement meeting (2nd July 2012) to properly obtain pesticide information into statement drawing on Reef Rescue projects (Jon Brodie)
- ICRS conference (9-13th July 2012) – Management of pesticides in the GBR (Jon Brodie)
- NERP working group on pesticides (12th September 2012) – presentation of Reef Rescue outputs (Jon Brodie, Stephen Lewis)
- Coast to Coast Meeting Brisbane (17-21st September) – presentation on GBR water quality including pesticides (Jon Brodie)
- Paddock to Reef Monitoring Workshop (4-5th December 2012) - presentation on Reef Rescue outputs (Stephen Lewis, Aaron Davis, Mark Silburn)
- Rocky muster (17-18th October 2012) – presentation on the effect of Queensland floods (Jon Brodie)
- Herbert Water Quality Monitoring Workshop (3rd December) – presentation of pesticide data from Reef Rescue (Jon Brodie)
- Reef Plan Risk Project & Reef Rescue II prioritisation workshop (19-20th November 2012) – use of pesticide data produced in Reef Rescue into the GBR risk assessment and pesticide gaps to be addressed (Jon Brodie)
- Earth Outlook Conference II National Academy of Sciences (26-27 November 2012) – presentation on Great Barrier Reef water quality including pesticide work from Reef Rescue (Jon Brodie)
- Canegrowers shed meeting (9th November 2012) – presentation of water quality data and pesticide project outcomes (Aaron Davis)

- Reef Rescue R&D and NERP Conference (10th May 2013) – presentation on runoff and deep drainage of glyphosate and glufosinate (acid) in banana cropping (Bronwyn Masters)

RRRD058: Ben Kefford

- While in Townsville, Kefford separately met with Jon Brodie and Steven Lewis. We discussed our current projects. We also discussed and prospects for future collaboration on issues of pesticides in the Reef and its catchments.
- Kefford also attended and presented at the pesticides and the Great Barrier Reef working group in September in Townsville. The title of the presentation in Townsville was: Biomonitoring pesticides in GBR rivers - new techniques.

Presentations

- Kefford attended at the annual Reef Rescue Forum in Brisbane 28-30 August 2012, and made a presentation of the project results to over 100 participants including other researchers, government agencies, industry and regional NRM groups. The title of the presentation in Brisbane was: Biological pesticide monitoring techniques.
- A conference presentation at the Society for Environmental Toxicology and Chemistry (SETAC) Australasian annual meeting was given in Brisbane in July 2012, this meeting was attended by Kefford and Herron and many informal communications were conducted. The title of the presentation at SETAC was: *A novel biological method of monitoring herbicides*.
- Conference presentation: *The development of a novel method to monitor herbicide toxicity in rivers via changes in diatom community*. Australian Society for Limnology annual meeting, NSW 2013.

Monitoring and reporting

RRRD030: Petra Kuhnert

- May-June 2011 - Collaboration with US researchers in the area of data assimilation and Bayesian Hierarchical Modelling. Meetings with the project team (including DERM and ACTFR) commenced.
- Project Workshop held on 3-4 July 2012 with stakeholders and was well attended by DERM, DPC, NRM, CSIRO and ATCFR.
- Chris Wikle visited CSIRO in July and participated in the July Workshop with stakeholders to discuss the methodology and refine the outputs required from the Source Catchments model.

Presentations

- Petra Kuhnert and Chris Wikle presented the data assimilation methodology for loads at the 12th International Coral Reef Symposium, Cairns on July 9-13, 2012.
- Petra Kuhnert presented the data assimilation methodology for the Weany Creek case study at the Joint Statistical Meetings (JSM) in San Diego, CA, USA on the 28 July – 2 August, 2012.

RRRD016: Vittorio Brando

- May-June 2011 - General discussions have commenced to coordinate / align the project with existing activities in the Marine Monitoring Program and Paddock to Reef Program.
- A stakeholder workshop was held in Townsville on 21/11/12. The attendees were Hugh Yorkston, Katherine Martin and Carol Honchin (GBRMPA) and Kevin Gale (Reef Rescue R&D). Chris Chinn and Milena Gongora (Paddock to Reef) were unable to attend due to travel restrictions.

Presentations

- 16-17 June 2011 in Brisbane - Project Leader (John Reghenzani), John Armour and Jeff Daniells attended the Reef Rescue Inception Workshop, where the objectives, methods and deliverables of the project were presented to other project leaders and a range of stakeholders.
- 28-30 August 2012 in Brisbane - Project presentation at the Reef Rescue Forum.
- 07-10 May 2013 in Cairns - Project presentation at the NERP TE Hub and Reef Rescue Conference.