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AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Summary report: the cost-effectiveness protocol used to assist in the prioritisation of the second phase of Reef Trust investment

Final Report to the Department of the Environment

Prue Addison and Terry Walshe

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AIMS: Australia's tropical marine research agency

Executive summary

This report has been prepared by the Australian Institute of Marine Science (AIMS) for the Department of the Environment. It outlines the cost-effectiveness estimation process developed by AIMS that has informed the prioritisation of management interventions for investment under the second phase of Reef Trust. The Reef Trust is a Commonwealth Government programme designed to strategically deliver funding in the Great Barrier Reef and catchments, focusing on known critical areas for investment – improving water quality and coastal habitat along the Reef, controlling outbreaks of crown-of-thorns starfish, and protecting threatened and migratory species, particularly dugong and turtles.

This report provides: (1) an overview of the cost-effectiveness estimation process; (2) a summary of the cost-effectiveness estimates of the nine proposed management interventions under the second phase of Reef Trust; (3) an interpretation of the cost-effectiveness estimates, including a prioritised list of proposed management interventions, ranked in order of cost-effectiveness, to assist the Environment Minister in making decisions on investment through the Reef Trust; and (4) advice on opportunities for improvement in any future application of the cost-effectiveness estimation process.

The cost-effectiveness estimation process follows a series of steps to assist in the prioritisation of management interventions in a transparent and scientifically rigorous way, within the constraints of the resources and time available for decision-making. The cost-effectiveness of each proposed management intervention is estimated by drawing on costings of the management interventions, expert judgement about the environmental benefit of the interventions, and value judgements about the relative importance of Reef Trust natural values. Environmental benefits of management interventions were characterised via four objectives (Reef Trust natural values): seagrass, inshore coral reefs, mid-shelf coral reefs and wetlands.

Experts attended a workshop in December 2014 to estimate the environmental benefits of the nine proposed management interventions. These participants held a cross-section of expertise in the Reef Trust natural values, water quality, and the effectiveness of land or sea-based management interventions in the Great Barrier Reef World Heritage Area (GBRWHA) and in neighbouring catchments. The estimates of cost-effectiveness for the proposed Reef Trust management interventions in the GBRWHA are shown in Figure ES1 and detailed in Section 3 of this report.

A sensitivity analysis of the cost-effectiveness estimates revealed a coarse delineation of proposed interventions, with five interventions consistently achieving higher rankings than the remaining four. Based on the order of most likely cost-effectiveness estimates (blue bars of the cost-effectiveness graph shown in Figure ES1; also verified by the sensitivity analysis in Appendix 8), the top-five ranking proposed interventions are: the rehabilitation of coastal ecosystems (intervention 8), erosion control in priority grazing landscapes (intervention 5), Smartcane best management practice accreditation (intervention 1), farmer led innovative cane management practices (intervention 4), and the expansion of holistic grazing pilot project (intervention 2).

The cost-effectiveness protocol is restricted to an assessment of the estimated return on investment for specified environmental outcomes under the administration of Reef Trust. There is a range of other social and economic factors that will need to be considered when selecting investments under the Reef Trust, alongside consideration of synergies and complementarities with other programs contributing to environmental outcomes for the Great Barrier Reef World Heritage Area. Thus, the results of the cost-effectiveness analysis are intended to be just one line of evidence that the

Department of the Environment will use when considering potential investments under the Reef Trust.

Environmental monitoring and assessment will be important for the Department to transparently demonstrate that the selected management interventions are addressing the Reef Trust outcomes: the long term improvement in water quality and coastal habitats in the reef catchments, and protecting species within the GBRWHA. The necessity to use expert judgment in this process means that the estimated environmental benefits of interventions are to some extent speculative. Quantitative monitoring of environmental outcomes will help evaluate the actual benefit of the interventions on the Reef Trust outcomes. Monitoring is the key to adaptive management, whereby re-investment in underperforming interventions can be avoided and greater resources can be allocated to those that exceed expectations. Monitoring data could also be used in predictive models, which could compliment expert judgement to predict the environmental benefits of future management interventions, thus assist future planning and investment decisions in the GBRWHA.

Five key recommendations are made for the future application of the cost-effectiveness process to the Reef Trust: (1) Clarify the description of management interventions (e.g., spatial extent, and anticipated level of adoption of agricultural interventions); (2) Clarify whether maintenance funding will be provided to maintain environmental benefits of interventions in the long term; (3) Consider management interventions at different scales of investment, to explore how varying the scale of investment influences the environmental benefit and thus the cost-effectiveness of the intervention; (4) Decouple local and regional scale benefits to explore whether interventions offer substantial positive benefit at local scales (i.e., within a region); and (5) Allow more time for the experts to understand the decision context and provide consequence estimates.

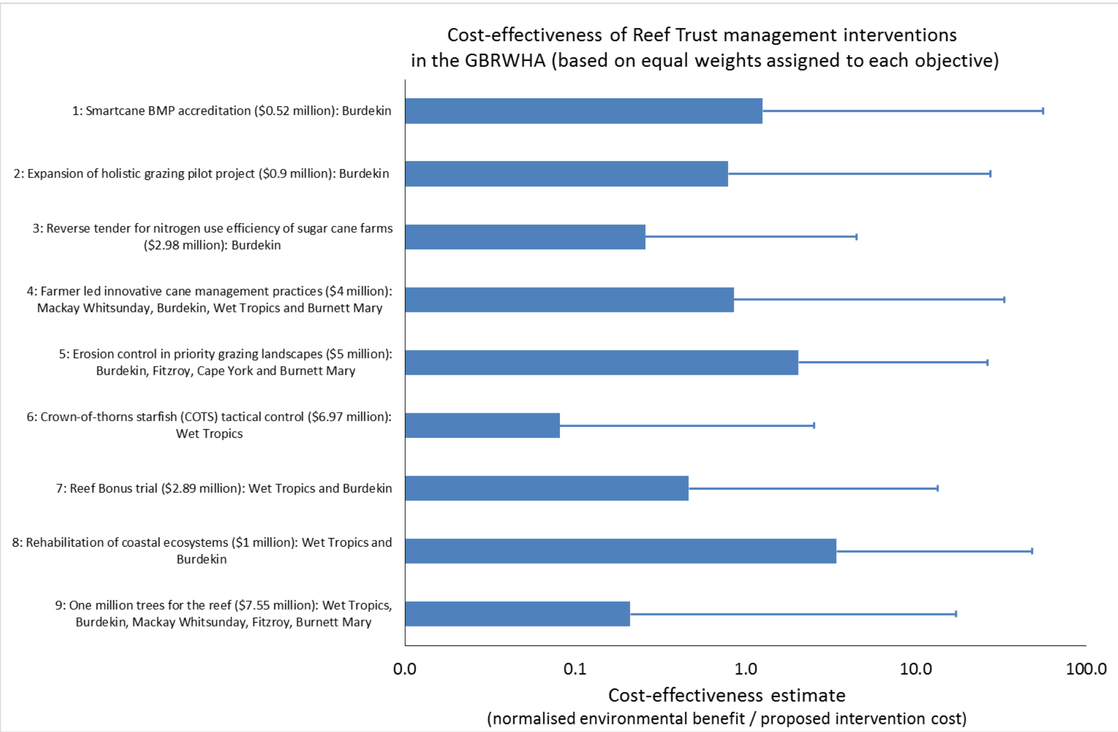

Figure ES1. The cost-effectiveness estimates for the nine proposed interventions, based on equal preference weights assigned to each objective. The most likely cost-effectiveness estimates for each intervention (the solid blue bars) and the best case cost-effectiveness estimates for each intervention (positive error bars) are shown. Note that cost-effectiveness is shown on a log scale.

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Glossary of terms

Attributes **–** the water quality parameters (nutrients, sediment and pesticides) and natural values (wetland condition and mid-shelf coral cover) for which experts directly estimated environmental benefits under each of the proposed interventions at the Reef Trust workshop and follow-up meetings.

Attribute benefit **–** represents the difference between the outcome of the intervention at 2030 (if delivered over the next 3 – 3.5 years), and the most likely outcome of no action at 2030 in a given region for a given attribute (these two estimates were provided by experts at the Reef Trust workshop and follow-up meetings).

Cost-effectiveness estimate – the ratio of the summed objective benefits (i.e., the sum of the benefits on the four objectives) divided by the costs of implementation of each intervention.

Objectives **–** the Reef Trust natural values (seagrass, inshore coral reefs, mid-shelf coral reefs, and wetlands).

Objective benefit **–** calculated using an index derived from the five attribute benefits (following equation 3), to represent the difference between the outcome of the intervention at 2030 (if delivered over the next 3 – 3.5 years), and the most likely outcome of no action at 2030 in a given region for a given objective.

Predictive weight –the predicted relative importance of the attributes on the four objectives (Reef Trust natural values).

Preference weight – used in the final cost-effectiveness calculation to reflect the relative importance (value judgement) of the four objectives (Reef Trust natural values).

1 Introduction

Given the diverse and wide-ranging threats to the Great Barrier Reef World Heritage Area (GBRWHA), strategic prioritisation of management interventions is vital to ensure that threats to the reef are addressed in an effective, efficient and appropriate manner. The Reef Trust was established in 2014 as a funding mechanism for the Department of the Environment (the Department) to invest in management interventions that address the highest priority threats, values and regions of the GBRWHA (as identified within the scope of the Reef Trust; Department of the Environment, 2014a). Under the second phase of Reef Trust, the Department sought to prioritise proposed management interventions based on their cost-effectiveness in a transparent and scientifically rigorous way, within the constraints of the resources and time available for decision-making.

To achieve targeted results from investment and to ensure existing investment is not spread too thinly across the GBRWHA, a process to identify the key threats being faced by the GBRWHA and the priority natural values for protection, improvement and conservation was undertaken in 2014. This process used existing work undertaken for the Great Barrier Reef, drawing heavily on the risk ratings and condition status given to threats and values in the Outlook Report 2014 (GBRMPA, 2014a) and the Great Barrier Reef strategic assessments (GBRMPA, 2014b).

The following criteria were used to determine the threats and values considered as 'within the scope of the Reef Trust': natural values needed to align with the three Reef Trust outcomes (water quality, coastal habitats and species protection; as identified in the Reef 2050 Long Term Sustainability Plan; Department of the Environment, 2014b); natural values needed to be listed as either being in Poor or Very Poor condition or Good but deteriorated condition; and the threats to these natural values needed to have a rating of either High or Very High. The resulting list of Reef Trust natural values covered species and habitats such as dugongs, seasnakes, coral reefs, and seagrass habitats (Appendix 1).

The Department prepared an investment framework to provide assistance for developing proposed management interventions for investment under the second phase of Reef Trust. The framework used a 3-tier approach to determining potential Reef Trust investments. The first tier applied an early filtering process based on simple criteria that reflected the essence of the Reef Trust to target investment towards known high priorities within the confines of the defined scope. The second tier assessment was more detailed and aimed to draw out information about the proposed intervention to identify alignment with the Reef Trust principles. This included consideration of previous and current investment, and how the proposed intervention would complement and build on efforts already undertaken. The proposed interventions that addressed tiers 1 and 2 were considered suitable investment prospects for the Reef Trust. The third tier of the investment framework was to assess the cost-effectiveness of the proposed interventions (as presented in this report).

Nine proposed management interventions were put forward for assessment of their cost-effectiveness to inform investment decisions for the second phase of Reef Trust (Table 1). These proposed management interventions were evaluated using estimates of their cost-effectiveness.

The Australian Institute of Marine Science (AIMS) developed a process to assist the Department assess the cost-effectiveness of proposed management interventions and inform investment decisions in the GBRWHA. The cost-effectiveness estimation process follows the steps of structured decision-making (Gregory *et al.*, 2012). Structured decision-making can draw on a broad suite of decision-analysis techniques to aid rigorous, transparent and logical decision-making (Addison *et al.*, 2013), and is increasingly being used to support conservation decision-making around the world (e.g., Runge, 2011; Gregory *et al.*, 2013; Walshe *et al.*, 2013).

This cost-effectiveness estimation process draws on: (1) expert judgement about the environmental benefit of the interventions, (2) value judgements about the relative importance of Reef Trust natural values, and (3) the costings of management interventions. The allocation of Reef Trust resources using cost-effectiveness as a decision criterion can result in optimal or near-optimal outcomes. That is, for a finite budget the greatest cumulative benefit over multiple actions is achieved through selecting the most cost-efficient actions until the budget is exhausted (Weitzman, 1998; Bottrill *et al.*, 2008).

Empirical evidence (e.g., scientific data) is an ideal source of information to predict the environmental benefits of proposed management interventions. However, when empirical evidence about the effectiveness of specific types of management interventions is lacking, carefully elicited expert judgement is a valid alternative (Speirs-Bridge *et al.*, 2010). When using expert judgement to estimate the expected consequences of management interventions, best-practice suggests that better judgments can be expected from multiple experts rather than a single expert (Martin *et al.*, 2012). The Department and AIMS enlisted eleven experts to provide their expert judgement about the environmental benefits of the proposed management interventions considered for investment under the second phase of Reef Trust. These experts were a diverse group of researchers, natural resource managers and planners, who provided a cross-section of expertise in the Reef Trust natural values, water quality, and the effectiveness of land or sea-based management interventions in the GBRWHA and in neighbouring catchments.

Ten experts attended a workshop in Townsville in December 2014 (hereafter the *Reef Trust workshop*) to estimate the environmental benefits of the nine proposed management interventions. During the workshop, experts discussed the comprehensive list of Reef Trust natural values (Appendix 1) and helped reduce this list to cover key habitats that reflected the Reef Trust natural values and those that were influenced by the proposed management interventions. The final list of environmental objectives included seagrass, inshore coral reefs, mid-shelf coral reefs and wetlands (Table 2). As the majority of the proposed management interventions occurred on land and focussed on improving water quality, the experts agreed that it was necessary to first estimate the effect of the proposed management interventions on water quality attributes such as nutrients, sediment and pesticides (attributes 1 – 3, Table 3).

Experts worked in three groups at the Reef Trust workshop to provide their expert judgment regarding the effect of eight of the interventions (occurring on land and in wetlands) on water quality attributes. Timing constraints meant that the experts were unable to complete the elicitation process for estimating the environmental benefits for the Reef Trust natural values during the workshop.

Following the workshop, experts were invited to comment on whether they considered it necessary to provide estimates of the effectiveness of the proposed interventions on the objectives (seagrass, inshore coral reefs, mid-shelf coral reefs, or wetlands). Eight of the ten experts responded, and all considered that the estimates provided for the water quality attributes made at the workshop would adequately reflect the influence of the eight land-based interventions on two of the environmental objectives: seagrass and inshore coral reefs (Table 2). They considered that it would be worthwhile to provide estimates for two additional attributes (wetland condition and mid-shelf coral cover; Table 3) to contribute to a more comprehensive assessment of the effectiveness of the proposed interventions on the two remaining objectives: wetlands and mid-shelf coral reefs.

In January 2015, two experts provided estimates of the effect of eight of the land-based proposed interventions on wetland condition (all land-based interventions; Table 1), and three experts provided estimates of the effect of crown-of-thorns starfish (COTS) tactical control (intervention # 6; Table 1) on mid-shelf coral cover (as the proposed intervention occurs in the mid-shelf of the GBRWHA).

Experts provided their judgement about the environmental benefits of proposed management interventions, which took the form of quantitative consequence estimates that reflect their conceptual understanding, supported by empirical evidence when available, of cause-and-effect relationships of the management interventions on the attributes.

Following the Reef Trust workshop and subsequent meetings, the experts' estimates of the environmental benefits of proposed management interventions were pooled and used to estimate the cost-effectiveness of each of the proposed management interventions.

This report provides: (1) an overview of the cost-effectiveness estimation process; (2) a summary of the cost-effectiveness estimates of the nine proposed management interventions under the second phase of Reef Trust; (3) an interpretation of the cost-effectiveness estimates, including a prioritised list of proposed management interventions, ranked in order of cost-effectiveness, to assist the Environment Minister in making decisions for investment through the Reef Trust; and (4) advice on opportunities for improvement in any future application of the cost-effectiveness estimation process.

Table 1. Summary of the nine proposed management interventions considered for investment under the second phase of Reef Trust.

Intervention	Summary	Duration	Cost (AUD) to Reef Trust GST exclusive
1: Smartcane best management practice (BMP) accreditation: Burdekin	• Grants for farmers to undertake best management practice (BMP), to be accredited at industry or above industry standard. • This targeted assistance will assist accreditation against the reef water quality related Smartcane BMP modules (e.g., irrigation, soils, nutrients and pesticide management). • Annual funding for three years would ensure annual review of practices by farmers, helping to maintain compliance with the BMP standards and track management improvement over time. • Lower cost option compared to grants for infrastructure/equipment and targeting of highest priority practice changes through completion of irrigation, soils, nutrients and pesticide management modules.	3 years	$517,500
2: Expansion of holistic grazing pilot project: Burdekin	• Extension of 'holistic grazing' management approaches across the Burdekin region, linked with grazing best management practice. • Delivered via direct grant to partner organisation who would engage the landholders, therefore increasing the amount of land managed under a holistic approach. • There are a variety of assumed benefits of the holistic approach, most notably it is predicted that there will be improved water quality through the reduction of sediment loads leaving the properties.	3.5 years	$900,000
3: Reverse tender for nitrogen use efficiency of sugar cane farms: Burdekin	• Delivered via a competitive tender, positive financial incentives would be provided to sugar cane farmers in the highest priority sub-catchments of the Burdekin region to improve nitrogen use efficiency and farm sustainability. • Participating sugar cane farmers can determine their own nitrogen and water use efficiency targets and cost-effective means of achieving those targets.	3.5 years	$2,982,500
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary	• The basis of this project would be farmer based innovation and development of improved nutrient and pesticide management to suit specific land types and landscapes. • Efficient, cost effective and profitable innovations will then be promoted for wider adoption within the regions (based on appropriate land type and place in the landscape). • This investment would be managed by one or more regional organisations based on a common formula and would build upon "game changing" work undertaken by Reef Catchments in collaboration with NRM and industry partners.	3 years	$4,000,000
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary	• Through funding guidelines, the Reef Trust partners would seek applications from organisations who wish to undertake the role of delivery partners. The successful applicants will then work with landholders in the regions to pilot low cost, effective techniques guided by the latest available scientific information to address high risk gully hotspots. • Active gully remediation is possibly research/innovation/A-class (unproven) at this time. Passive gully remediation is B class. Could approach as on-ground trials/demo farms project remediation associated with an extension component, to ensure dissemination of water quality and productivity outcomes and, with water quality and improved BMP development.	3.5 years	$5,000,000
6: Crown-of-thorns starfish (COTS) tactical control: Cape York, Wet Tropics, Burdekin, Mackay Whitsunday	• The intervention proposes funds from July 2015 for one vessel to continue to undertake tactical control of COTS on high value tourist reefs and development of an Integrated Pest Management approach for management of COTS to reduce predation on coral reefs into the longer-term. • This COTS control intervention would be delivered by a nominated service provider who would engage a delivery agent for the control.	3.1 years	$6,970,000

Table 1 cont'd. Summary of the nine proposed management interventions considered for investment under the second phase of Reef Trust.

Intervention	Summary	Duration	Cost (AUD) GST exclusive
7: Reef Bonus trial: Wet Tropics and Burdekin	• Provision of a financial bonus to sugar cane farmers in the lower Burdekin for reducing fertiliser application rates. • A flexible approach could be used based on growers identifying lower yielding portions of their farms. • The bonus would be paid retrospectively to farmers. Farmers would be required to maintain fertiliser use records, provide evidence and share their fertiliser use data.	3.5 years	$2,890,000
8: Rehabilitation of coastal ecosystems: Wet Tropics and Burdekin	• Through a service provider(s), undertake a systems approach to rehabilitating coastal ecosystems to improve connectivity and ecosystem services to the Great Barrier Reef. • Focus would be on three demonstration creek systems in intensive agricultural production landscapes in the Wet Tropics and Burdekin. • Different types of intervention such as revegetation, fish passage restoration and weed control will be undertaken in different parts of the system to address connectivity.	4 years	$1,000,000
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary	• Planting of one million trees across the largest area possible across all the catchments of the Great Barrier Reef.	3 years	$7,550,000

Table 2. The objectives used to assess the environmental benefits of the proposed management interventions. Note outer coral reefs were not included because the impact of proposed interventions on outer reefs was considered negligible due to distance from river mouths.

Objective	Description
1) Seagrass	Seagrass beds provide nursery habitat for several species, contribute to trapping and stabilising large amounts of sediment and nutrient cycling in the GBRWHA. Seagrass habitats occur in estuaries, shallow coastal waters, and in the GBR lagoon – sometimes in association with coral reefs. Seagrass is the main food source for dugongs and some marine turtles.
2) Inshore coral reef	Coral reefs provided habitat for hard coral, soft corals, sea fans, sea pens, fish, invertebrates and algae, and contribute strongly to the outstanding universal value of the GBRWHA. Inshore coral reefs occur within approximately 20 kilometres of the coast.
3) Mid-shelf coral reef	Coral reefs provided habitat for hard coral, soft corals, sea fans, sea pens, fish, invertebrates and algae, and contribute strongly to the outstanding universal value of the GBRWHA. Mid-shelf coral reefs occur between inshore areas and the outer barrier reefs.
4) Wetlands	Natural wetlands are recognised as important coastal habitats that protect the GBRWHA. They slow the overland flow of water, capture and recycle nutrients/sediments that would otherwise enter the GBRWHA. Wetlands also provide important habitats for many animals and plants are integral to some species for key parts of their life cycle.

Table 3. Environmental attributes used to estimate the benefits of the proposed management interventions and no action.

Attribute	Performance measure
1) Nutrients	Total load of dissolved inorganic nitrogen (DIN); tonnes/year
2) Sediment	Load of total suspended solids, millions tonnes/year. Representing suspended sediment and particulate nutrients.
3) Pesticides	Load of total pesticides; kg/year
4) Mid-shelf coral	% cover of mid-shelf hard coral
5) Wetland condition	Estuarine and freshwater wetland functions and components (index from 1 - 5)

2 Methodology

The cost-effectiveness estimation process is based on the steps of structured decision-making. These steps promote critical thinking about decisions, providing an organised approach to identifying and evaluating creative alternatives and making defensible choices for complex decisions in the face of uncertainty. Structured decision-making is designed to engage decision-makers, stakeholders and scientists in the decision-making process. The steps of structured decision-making can be supported by a variety of modelling techniques, to incorporate both scientific facts and values, acknowledging that decision-making is rarely a value-free process (Failing *et al.*, 2007; Addison *et al.*, 2013).

The steps of structured decision-making are outlined here with specific reference to the methods used to estimate the cost-effectiveness of the nine proposed management interventions under the second phase of Reef Trust.

2.1 The cost-effectiveness estimation process

There are six iterative steps in structured decision-making (Figure 1; Gregory *et al.*, 2012). The first five steps are directly relevant to estimating the cost-effectiveness of proposed management interventions, and are outlined below. The final step of structured decision-making (implement and monitor) is described in the Discussion, as this step is beyond the remit of AIMS' consultation to the Department.

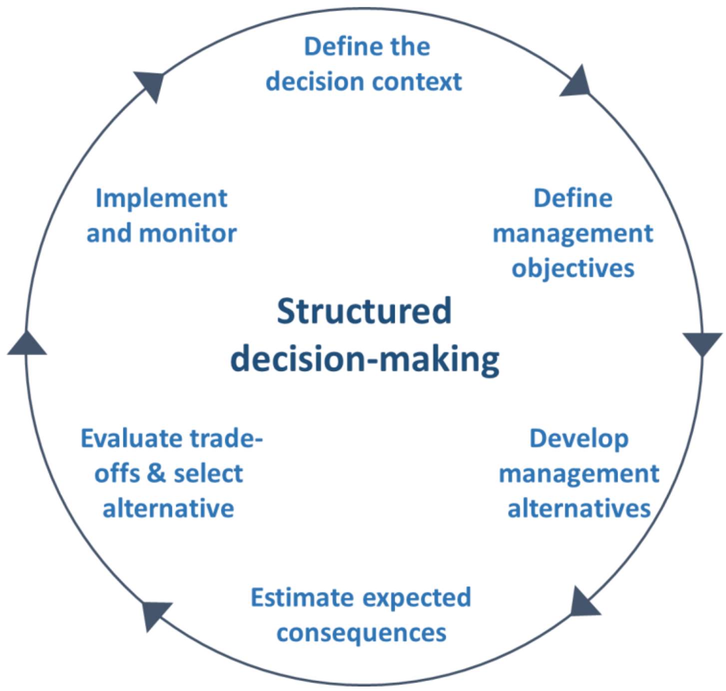


Figure 1**.** The six iterative steps of structure decision-making, adapted from Gregory *et al.* (2012).

Step 1 Define the decision context

The decision context was defined by the Department: to prioritise management interventions based on their estimated cost-effectiveness. This prioritised list would then be used to inform investment in a selection of management interventions under the second phase of Reef Trust.

Step 2 Define management objectives

Defining objectives can be surprisingly difficult. Objectives should appeal to decision-makers' or stakeholders' fundamental values (Runge & Walshe, 2014). A common mistake is to confuse 'means' objectives with 'fundamental' or 'ends' objectives. Means objectives are intermediate goals that serve as stepping-stones towards the things that are of fundamental concern. For example, the improvement of water quality is a means to the fundamental (end) objective of conserving biodiversity in the GBRWHA. Inclusion of both means and ends leads to double counting, which is an improper approach to assessing cost-effectiveness.

Experts at the Reef Trust workshop helped narrow the list of Reef Trust natural values (Appendix 1) to a shortened list of environmental objectives that reflected key habitats that were directly influenced by the proposed management interventions. The agreed list of objectives were: seagrass, inshore coral reefs, mid-shelf coral reefs and wetlands (Table 2). As the majority of the proposed management interventions occurred on land and focussed on improving water quality, the experts agreed that it was necessary to first estimate the effect of the proposed management interventions on water quality attributes such as nutrients, sediment and pesticides (attributes 1 – 3, Table 3; n.b., these are considered 'means' objectives). Experts also agreed on the unit of measurement that would be used to estimate the benefits of the interventions on these attributes, which are referred to as performance measures (Table 3). As the water quality attributes represent 'means objectives', these were combined as an index to estimate the effects of the management interventions on the 'fundamental objectives' (referred to as objectives here).

Following the Reef Trust workshop, experts agreed that the water quality attributes (means objectives) would adequately reflect the influence of the eight interventions on two of the environmental objectives: seagrass and inshore coral reefs. However, they thought it was also necessary to provide estimates for two additional attributes (wetland condition and mid-shelf coral cover; Table 3) to contribute to a more comprehensive assessment of the effectiveness of the proposed interventions on the two remaining objectives: wetlands and mid-shelf coral reefs.

Step 3 Develop management alternatives

Management alternatives should represent discrete management interventions to benefit the environmental objectives identified in step 2 (Runge & Walshe, 2014). In this case, management alternatives are the proposed interventions that were considered for funding under the second phase of Reef Trust.

Nine proposed management interventions were put forward for consideration by the Reef Trust under phase two of its investment (Table 1). A template (Appendix 2) was prepared to help gather standardised background information about proposed management interventions. The template required details such as a description of the intended goal of the interventions (e.g., to reduce sediment loads entering the GBRWHA), the intervention spatial and temporal scale, and the cost of the intervention. It also required information about the anticipated level of adoption for agricultural practice change interventions, and whether maintenance funding would be required to maintain the environmental benefits beyond the life of the intervention.

It was important that the proposed management interventions were clearly described, as experts were asked to estimate the environmental benefits of these interventions in step 4. The clarity of description of the nine interventions varied substantially, with some proposed management interventions requiring further detail about important aspects such as the anticipated spatial extent and location of the management interventions, and the anticipated level of adoption (for the agricultural practice change interventions).

Step 4 Estimate expected consequences

Estimating the expected consequences of management alternatives on objectives is the traditional domain of predictive science, where data and expert judgment are interrogated and synthesized to provide plausible forecasts (Gregory *et al.*, 2012). When empirical evidence (e.g., scientific data) about the effectiveness of specific types of management intervention is lacking, carefully elicited expert judgement is a valid alternative (Speirs-Bridge *et al.*, 2010).

Experts were asked at the Reef Trust workshop and subsequent meetings to estimate the expected consequences of the nine management interventions and ‘no action’ on attributes defined in step 2 (Table 3). The ‘no action’ management alternative involved the existing level of management in the GBRWHA and catchments, which was assumed to be maintained in the absence of the Reef Trust management interventions until 2030 (i.e., there would be no management interventions funded by Reef Trust management over the next 15 years).

Experts were asked to provide their expert judgement about the environmental benefits of proposed management interventions (which were 3 – 3.5 years in duration; Table 1) over the specified time horizon of 15 years (at 2030). The 15 year time horizon was selected to allow enough time for the environmental attributes to respond to the potential benefits of the proposed management interventions (i.e., taking into account the turnover rate of some of these ecosystems).

Experts were provided with information on the current levels of the environmental attributes, summarised from documented sources (Appendix 3) to assist their estimates of the environmental benefits of the expected consequences of the nine management interventions and 'no action' on the five environmental attributes.

The judgements provided by experts were in the form of quantitative consequence estimates that reflected their conceptual understanding of cause-and-effect relationships of the management interventions on the relevant attributes (Table 4). To capture the uncertainty in participants' judgments and to insulate against overconfidence, the 4-point elicitation technique (Speirs-Bridge *et al.*, 2010) was used. Participants were asked to estimate the following four quantities relating to the environmental benefits of proposed management interventions by 2030 on the attribute performance measures:

a. *Plausible **best case** estimate*
b. *Plausible **worst case** estimate*
c. ***Most likely** estimate (which should lie between the best and worst case estimates)*
d. ***Confidence** estimate that the truth will lie between the nominated lower and upper bounds (as a percentage ≥50%)*

Experts were asked to make their consequence estimates in each reef catchment where the management interventions are proposed (Table 5): Cape York, Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, and Burnett Mary.

Experts worked in three groups (of 3 – 4 people) at the Reef Trust workshop to provide their combined judgment on the effect of eight of the interventions (occurring on land and in wetlands) on water quality attributes. In subsequent meetings, two experts provided their individual estimates of the effect of eight of the land-based proposed interventions on wetland condition (all land-based interventions), and three experts provided estimates of the effect of crown-of-thorns starfish (COTS) tactical control (intervention # 6; Table 1) on mid-shelf coral cover (as the proposed intervention occurs in the mid-shelf region).

This difficult prediction task was made more onerous by considerable ambiguity in the description of several of the proposed interventions. In part, the uncertainty in environmental benefits estimated by the experts stemmed from their variable interpretation of the details of how the interventions would be implemented. In addition, the experts' uncertainty reflected their views on the technical and social feasibility of implementing the management intervention, the prospects for a run of good (or bad) years (e.g., storms), and uncertainty in the ecological response to the management interventions.

Group and single expert judgements were first standardised to represent 80% confidence bounds. This was done by adjusting the best case and worst case estimates accordingly if these were reflecting experts' confidence that was lower or higher than 80% (e.g., if an expert provided estimates reflecting 60% confidence, then their best case and worst case estimates were widened to represent 80% confidence estimates). Following standardisation to 80% confidence estimates, the equally weighted group and single expert judgements were then combined to provide an average group estimate of the effectiveness of each management intervention on the relevant attributes. The environmental attribute benefits were then used to estimate the environmental benefit of the management interventions on the objectives (described in detail in section 2.2), and then cost-effectiveness of each management intervention (in step 5).

Table 4. Summary of the combination of management intervention and attribute consequence estimates provided by experts (● = estimate required, - = no estimate required).

Proposed management interventions	**Attributes**				
	Nutrients	**Sediment**	**Pesticides**	**Corals mid-shelf**	**Natural wetlands**
1: Smartcane best management practice (BMP) accreditation	●	●	●	-	●
2: Expansion of holistic grazing pilot project	-	●	-	-	●
3: Reverse tender for nitrogen use efficiency of sugar cane farms	●	-	-	-	●
4: Farmer led innovative cane management practices (game changer)	●	●	●	-	●
5: Erosion control in priority grazing landscapes (gully restoration)	-	●	-	-	●
6: Crown-of-thorns starfish (COTS) tactical control	-	-	-	●	-
7: Reef Bonus trial	●	-	-	-	●
8: Rehabilitation of coastal ecosystems	●	●	-	-	●
9: One million trees for the reef	●	●	-	-	●

Table 5. Summary of the GBR regions where each of the proposed management interventions occur (● = intervention occurs in the region, - = intervention does not occur in the region).

Proposed management interventions	GBR region					
	Cape York	Wet Tropics	Burdekin	Mackay Whitsunday	Fitzroy	Burnett Mary
1: Smartcane best management practice (BMP) accreditation	-	-	●	-	-	-
2: Expansion of holistic grazing pilot project	-	-	●	-	-	-
3: Reverse tender for nitrogen use efficiency of sugar cane farms	-	-	●	-	-	-
4: Farmer led innovative cane management practices (game changer)	-	●	●	●	-	●
5: Erosion control in priority grazing landscapes (gully restoration)	●	-	●	-	●	●
6: Crown-of-thorns starfish (COTS) tactical control	-	●	-	-	-	-
7: Reef Bonus trial	-	●	●	-	-	-
8: Rehabilitation of coastal ecosystems	-	●	●	-	-	-
9: One million trees for the reef	-	●	●	●	●	●

Step 5 Evaluate trade-offs and select an alternative

When multiple objectives are encountered in decision-making, a formal trade-off step is required, whereby decision-makers specify the extent to which a gain in one objective is compensated by loss on another objective. We avoided these difficult judgments in this exercise. Instead, we assigned equal weight to each of the four objectives, and subsequently performed a sensitivity analysis to explore the influence of setting a range of weights on each objective.

Once consequence estimates were elicited from the experts, preference weights assigned, and costing of the management interventions were known, the cost-effectiveness of each management intervention could then be estimated (see section 2.2 for full details).

2.2 Calculating cost-effectiveness of management interventions

All judgements provided by experts were entered into the cost-effectiveness spreadsheet (“reeftrust_costeffectiveness_final.xlsx”), where the cost-effectiveness of the nine proposed management interventions was calculated. Appendix 4 provides a full description of the inputs, calculations and outputs of each worksheet contained within the cost-effectiveness spreadsheet (making reference to equations 1 – 5 presented in this section of the Summary Report).

The cost-effectiveness of each intervention is the ratio of the weighted summed objective benefits (i.e., the sum of the benefits on the four environmental objectives (Table 2); hereafter referred to as ***objectives***), divided by the costs of implementation of each intervention. As the experts provided their judgements about the benefit of the management interventions on the ***attributes*** (Table 3), there are several steps involved in estimating the cost-effectiveness of each intervention. First, the approach used to calculate cost-effectiveness is explained (equation 1), followed by an explanation of the approach used to calculate ***objective*** benefits (which feed into the cost-effectiveness calculation; equations 2 & 3), which were calculated using the experts' ***attribute*** consequence estimates of no action and the proposed management interventions in the different GBR regions (equations 4 & 5).

The additive model of multi-attribute value theory was used to aggregate the environmental benefits of the ***objectives*** (von Winterfeldt & Edwards, 1986). A common simplification prior to aggregation is to normalise each objective using a linear value function, with the poorest performance on any single objective *i* assigned a value of 0 and the best performance assigned a value of 1 across all alternatives. The assumption of linearity avoids the tedious demands of formal elicitation and is reasonable over the local range of consequences associated with most problems (Durbach & Stewart, 2009).

More formally the cost effectiveness, *CE* of each intervention *i* is the summation of the normalised benefits of each objective *j* in each of *k* GBRWHA regions (*normalised objective benefit*$_{ijk}$) multiplied by the preference weight assigned to each objective (*preference weight*$_j$), and then divided by the cost of the intervention (*cost*$_i$):

$$CE_i = \frac{100 \times (\sum normalised\ objective\ benefit_{ijk} \times preference\ weight_j)}{cost_i} \quad (1)$$

The preference weights used in the cost-effectiveness calculation were the value judgements that reflect the relative importance of the four objectives (determined in step 5 of structured decision-making; section 2.1). The Department were interested in calculating the cost-effectiveness of the proposed interventions by assigning **equal preference weights to the four objectives** (i.e., a weight of 0.25 was assigned to each objective in equation 1).

The normalised benefit of each intervention on each ***objective*** in each region (*normalised objective benefit*$_{ijk}$) was based on the benefit of each intervention on each objective in each region (*objective benefit*$_{ijk}$), divided by the range bounded by the best and worst case benefits for a given objective within a given region (*best case objective benefit*$_{ijk}$ – *worst case objective benefit*$_{ijk}$):

$$normalised\ objective\ benefit_{ijk} = \frac{objective\ benefit_{ijk}}{best\ case\ objective\ benefit_{jk} - worst\ case\ objective\ benefit_{jk}} \quad (2)$$

The best case benefit (*best case objective benefit*$_{jk}$) was the maximum benefit of a given objective within a given region across all interventions. The worst case benefit (*worst case objective benefit*$_{jk}$) was the minimum benefit of a given objective within a given region across all interventions.

The benefit of each intervention on each ***objective*** in each region (*objective benefit*$_{ijk}$) was calculated using an index derived from the five ***attributes*** that were estimated by experts (Table 6).

The benefit of each ***objective*** was calculated using a weighted linear composite model:

$$objective\ benefit_{ijk} = \sum \beta_l \times normalised\ attribute\ benefit_{ikl} \tag{3}$$

The benefit of each intervention on each objective in each region (*objective benefit*$_{ijk}$) was the weighted sum of normalised ***attribute*** benefits (*normalised attribute benefit*$_{ijk}$) and the predictive weights (β_l, reflecting the predicted relative importance of the attributes, *l*, on the four objectives; Table 7).

The benefit of each intervention on the seagrass and inner reef coral ***objectives*** in each region was based on an index derived from the three water quality ***attributes*** (Table 6 and Table 7; see equation 4). The benefit of each intervention on the mid-shelf coral reef and wetlands objectives was based on one attribute each: mid-shelf coral and wetland condition respectively (Table 6 and Table 7; see equation 5).

Note that the predictive weights for each of the three water quality ***attributes*** were provided by experts at the Reef Trust workshop on the basis of a 25% reduction in each water quality attribute (Table 7). This implies, for example, that for the response of seagrass to a reduction of 25% in water quality parameters, sediment is a four-fold more important determinant of the extent and condition of seagrass than pesticides; and, sediment is approximately three-fold more important than nutrients (Table 7).

The ***attributes***, mid-shelf coral cover and wetland condition, were each assigned a predictive weight of 1, when calculating the normalised benefit for the mid-shelf coral reef and wetlands objectives, as only one attribute was contributing to each objective (Table 7).

The normalised ***attribute*** benefits (*normalised attribute benefit*$_{ikl}$) were calculated as follows:

Water quality ***attributes*** (nutrients, sediment and pesticides) - the *normalised attribute benefit*$_{ikl}$ represents the difference between the outcome of the intervention and the most likely outcome of no action in a given region for a given attribute, divided by a 25% reduction in the most likely outcome of no action for each attribute within each region:

$$normalised\ attribute\ benefit_{ikl} = \frac{outcome\ of\ intervention_{ikl} - \ most\ likely\ outcome\ of\ no\ action_{kl}}{(0.75 \times most\ likely\ outcome\ of\ no\ action_{kl}) - \ most\ likely\ outcome\ of\ no\ action_{kl}} \tag{4}$$

The normalised attribute benefit was first calculated for each of the three expert groups using their standardised 80% confidence intervals (from the Reef Trust workshop), and then averaged across the three groups to provide a final estimate of the *normalised attribute benefit*$_{ikl}$.

The normalised attribute benefit was calculated for the most likely, best case and worst case benefit (i.e., using most likely, best case and worst case outcomes of the interventions).

Natural value ***attributes*** (mid-shelf coral and wetland condition) - the *normalised attribute benefit*$_{ikl}$ represent the difference between the outcome of an intervention and the most likely outcome of no action in a given region for a given attribute, divided by the range of the best to worst case outcomes for a given attribute within a given region (*best case outcome*$_{kl}$ - *worst case outcome*$_{kl}$):

$$normalised\ attribute\ benefit_{ikl=} = \frac{outcome\ of\ intervention_{ikl} - outcome\ of\ no\ action_{kl}}{best\ case\ outcome_{kl} -\ worst\ case\ outcome_{kl}} \quad (5)$$

The *best case benefit*$_{jk}$ was the maximum outcome estimated by each expert for a given attribute within a given region across all interventions. The *worst case benefit*$_{jk}$ was the minimum outcome estimated for a given objective within a given region across all interventions.

The normalised attribute benefit was first calculated for each expert using their standardised 80% confidence intervals, and then averaged across the experts to provide a final estimate of the *normalised attribute benefit*$_{ikl}$.

The *normalised attribute benefit*$_{ikl}$ was calculated for the most likely, best case and worst case benefit estimates provided by the experts (i.e., using most likely, best case and worst case outcomes of the interventions).

Table 6. The objectives (Reef Trust natural values) and the attributes used to estimate each objective.

Objective	Attributes used to estimate each objective
1) Seagrass	Index based on: nutrients, sediment, pesticides (attributes 1 – 3 of Table 3)
2) Inshore coral reef	Index based on: nutrients, sediment, pesticides (attributes 1 – 3 of Table 3)
3) Mid-shelf coral reef	Direct measure: mid-shelf coral cover (attribute 4 of Table 3)
4) Wetlands	Index: wetland condition (attribute 5 of Table 3)

Table 7. Predictive weights used in the linear composite model (equation 3).

Attribute name	Predictive weights used to calculate the benefits for each objective			
	Seagrass	Inner coral reef	Mid-shelf coral reef	Wetlands
1) Nutrients	0.3	0.5	-	-
2) Sediment	1	1	-	-
3) Pesticides	0.25	0.2	-	-
4) Mid-shelf coral	-	-	1	-
5) Wetland condition	-	-	-	1

3 Results

In order to estimate the cost-effectiveness of each of the nine proposed management interventions, the following steps were taken: **(1)** calculating normalised ***attribute*** benefits of each management intervention using the pooled expert estimates elicited at the Reef Trust workshop and follow-up meetings (using equations 4 & 5, section 2.2); **(2)** calculating the normalised ***objective*** benefits of each management intervention using the normalised attribute benefit estimates calculated in step 1 (using equations 2 & 3); and **(3)** combining the normalised ***objective*** benefits (from step 2), preference weights and management intervention costs to finally calculate the cost-effectiveness of each management intervention (using equation 1). This results section of the report walks readers through each of these steps in the process of calculating the cost-effectiveness of each of the nine proposed management interventions under the second phase of Reef Trust.

3.1 Summary of the benefits of interventions on *attributes*

The original consequence estimates provided by the experts at the Reef Trust workshop and follow-up meetings are presented in Appendix 5 (water quality benefits), Appendix 6 (wetlands benefits) and Appendix 7 (mid-shelf coral reef benefits). All estimates provided by the experts were informed by the current levels of the attributes from documented sources (see Appendix 3). Anonymity is an important element of unbiased expert judgment. The experts are intentionally not named in this report or any supporting appendices to maintain their anonymity.

The average normalised attribute benefits of each proposed management intervention on the five attributes (nutrients, sediment, pesticides, mid-shelf coral and wetlands) are shown in Figures 2 – 4 (calculated following equations 4 or 5; section 2.2). Note that Figures 2 – 4 show the **normalised attribute benefits**. To see the original estimates of the benefits of the proposed interventions on each attribute provided by experts, see Appendix 5 – 7.

Figures 2 – 4 highlight that the normalised "most likely" benefits of the interventions (blue bars) on each attribute are most often less than 0.1. This means that the difference between the most likely outcome of the intervention and the most likely outcome of no action is 10% of the range from best to worst outcomes of the attribute documented across all interventions in the region (see section 2.2 for a description of what the worst outcomes represented for each attribute). The magnitude of these modest benefits estimated by the experts was shaped by:

- The limited spatial scale of the interventions relative to the size of the GBRWHA or region. (i.e., the area of land/reef/wetlands targeted within a region, the number of farmers targeted for agricultural practice change).
- An assumption that funding for implementation and maintenance beyond 3.5 years would be unavailable. Should funding be extended, the benefits of the proposed interventions at 2030 would generally be more substantial.
- A lack of clarity around the likely level of uptake and adoption of the agricultural interventions (interventions 1–5 & 7), within the (assumed) funded intervention period (up to 3.5 years) and post intervention until 2030. The experts found this very challenging, and for some interventions they estimated that the level of uptake/adoption might be low.

The modest benefits documented here emphasise the importance of co-investment in other programs alongside Reef Trust and/or increased investment in a subset of Reef Trust interventions that promise higher returns if scaled up (see the Discussion of pay-off curves in section 4.2 for more on this point).

The best case benefits (positive error bars in Figures 2 – 4) estimated by experts highlight the much larger potential benefit of the interventions when comparing the difference between the ***best case outcome of the intervention*** and the ***most likely outcome of no action***. In many cases the best case benefits represented 80–100% of the total range (best – worst case) of the attribute documented across all interventions in the region.

The negative error bars are not shown in Figures 2 – 4, as all “worst case” benefits are less than zero (reflecting the possibility of high natural variation and extreme weather).

Assessing the most likely, best case and worst case benefits in Figures 2 – 4, highlights that experts typically considered that the most likely benefits would be small (<0.1), and there is a large amount of uncertainty surrounding their judgements about the best case and worst case outcomes of the interventions and no action as at 2030.

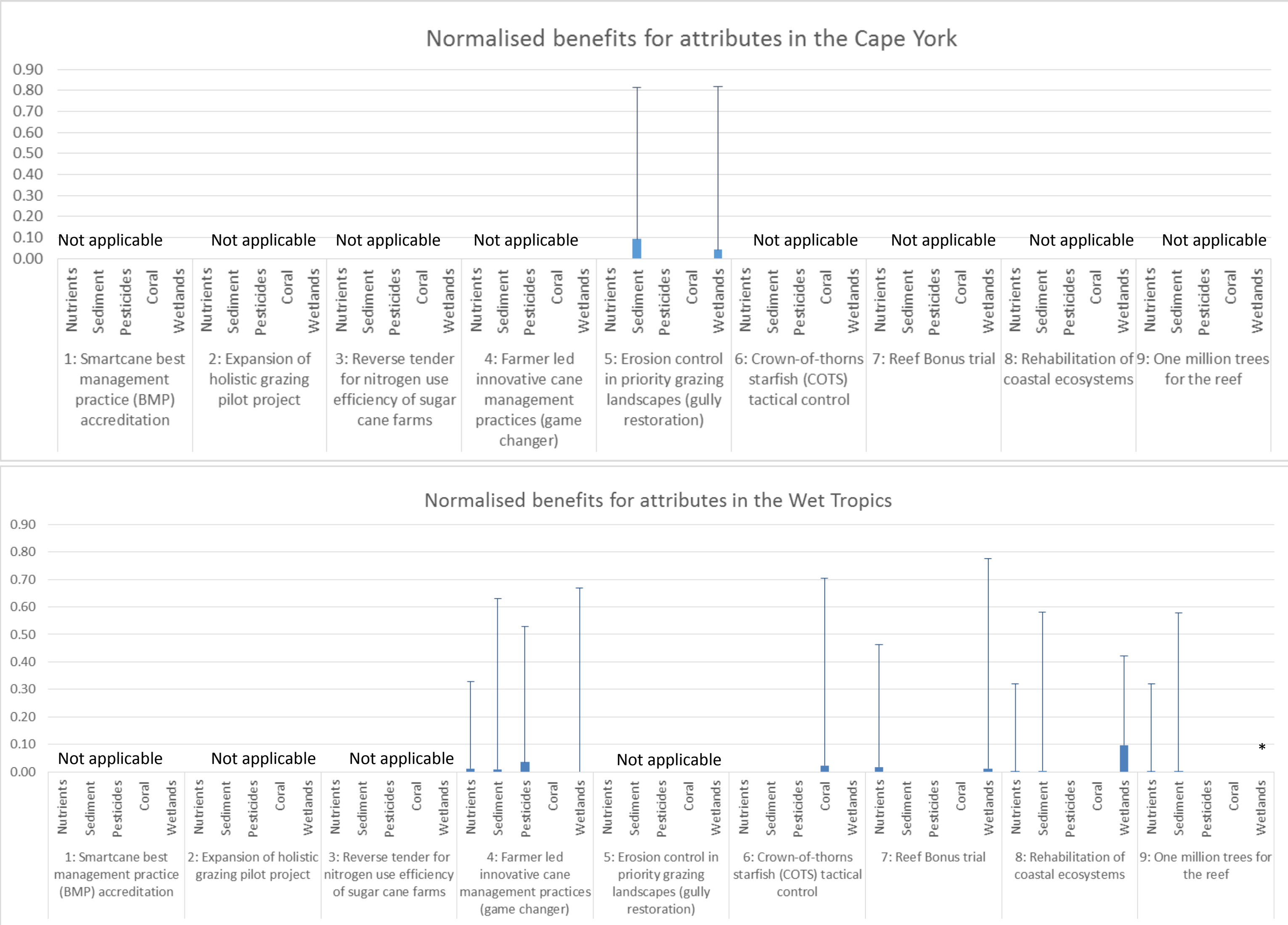
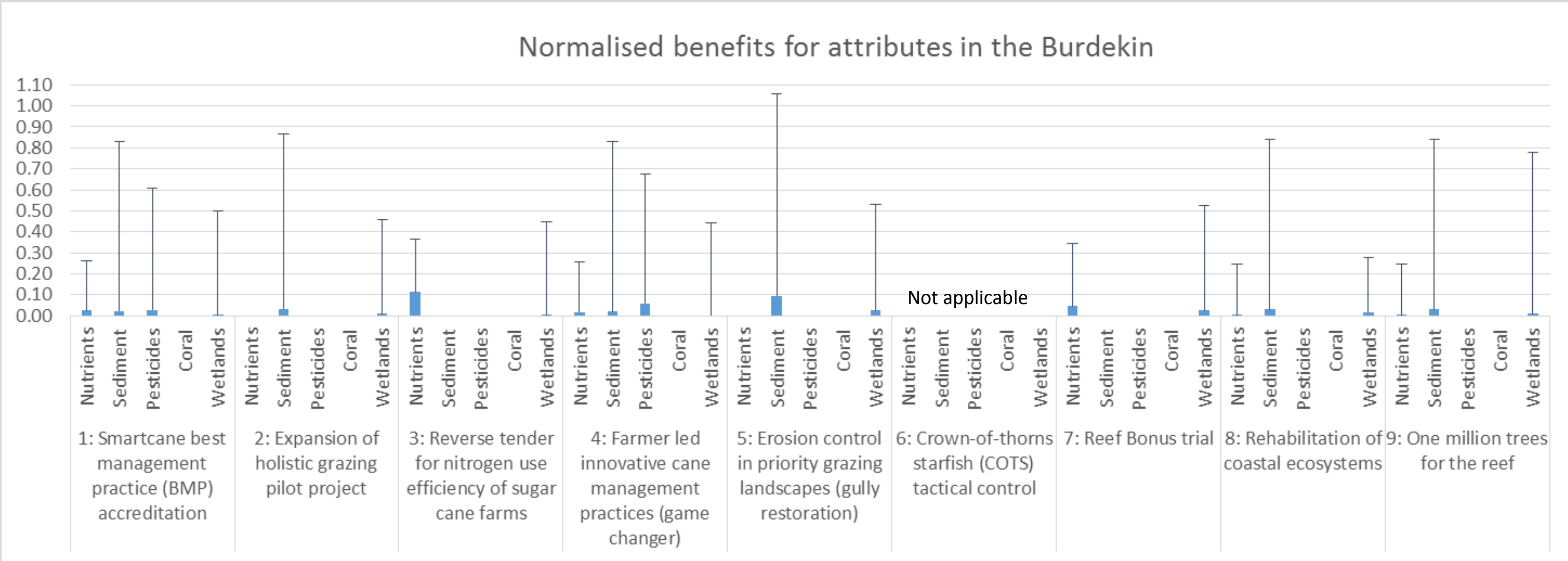


Figure 2. The normalised ***attribute*** benefits in the Cape York and Wet Tropics regions. The blue bars show the "most likely" benefit, and the positive error bars show the "best case" benefit (best case benefit from the intervention minus most likely benefit from no action). The negative error bars are not shown as all "worst case" benefits = 0. * No estimate provided for wetlands by experts, as they suggested that this intervention focus on the priority regions (based on highest sediment threats) in the first instance (Burdekin, Fitzroy, Burnett Mary) – see Appendix 6 for further details.



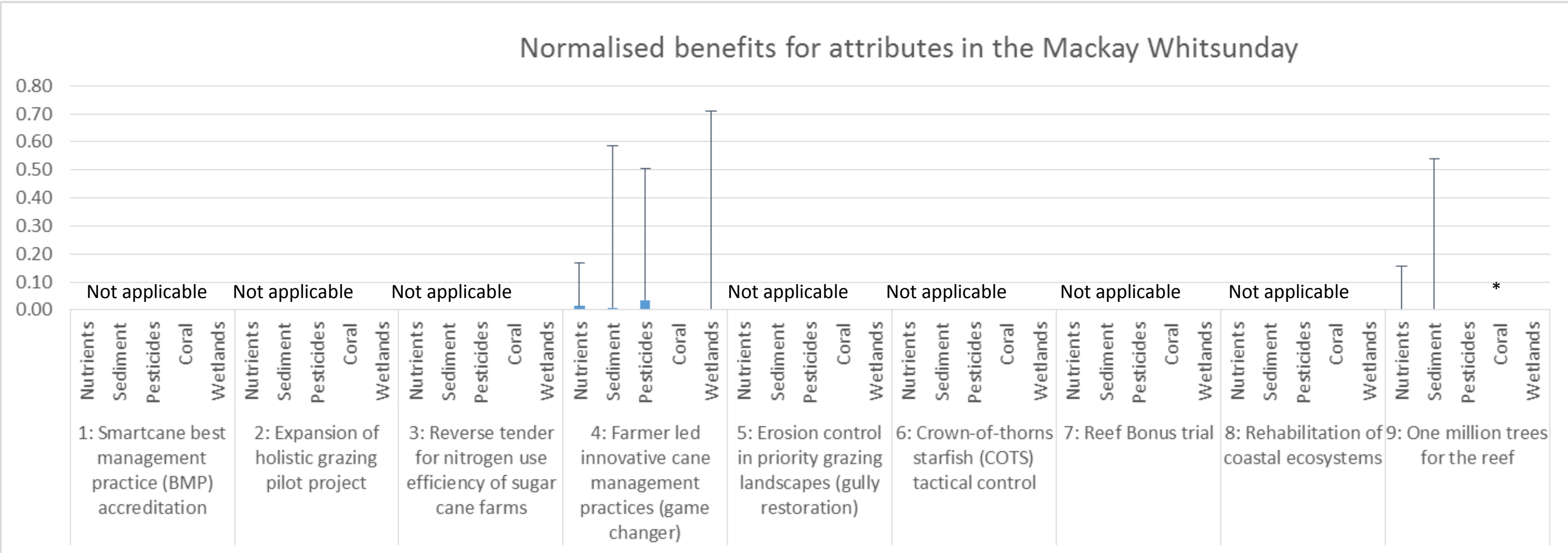


Figure 3. The normalised ***attribute*** benefits in the Burdekin and Mackay Whitsunday regions. The blue bars show the "most likely" benefit, and the positive error bars show the "best case" benefit. * No estimate provided for wetlands by experts, as they suggested that this intervention focus on the priority regions (based on highest sediment threats) in the first instance (Burdekin, Fitzroy, Burnett Mary) – see Appendix 6 for further details.

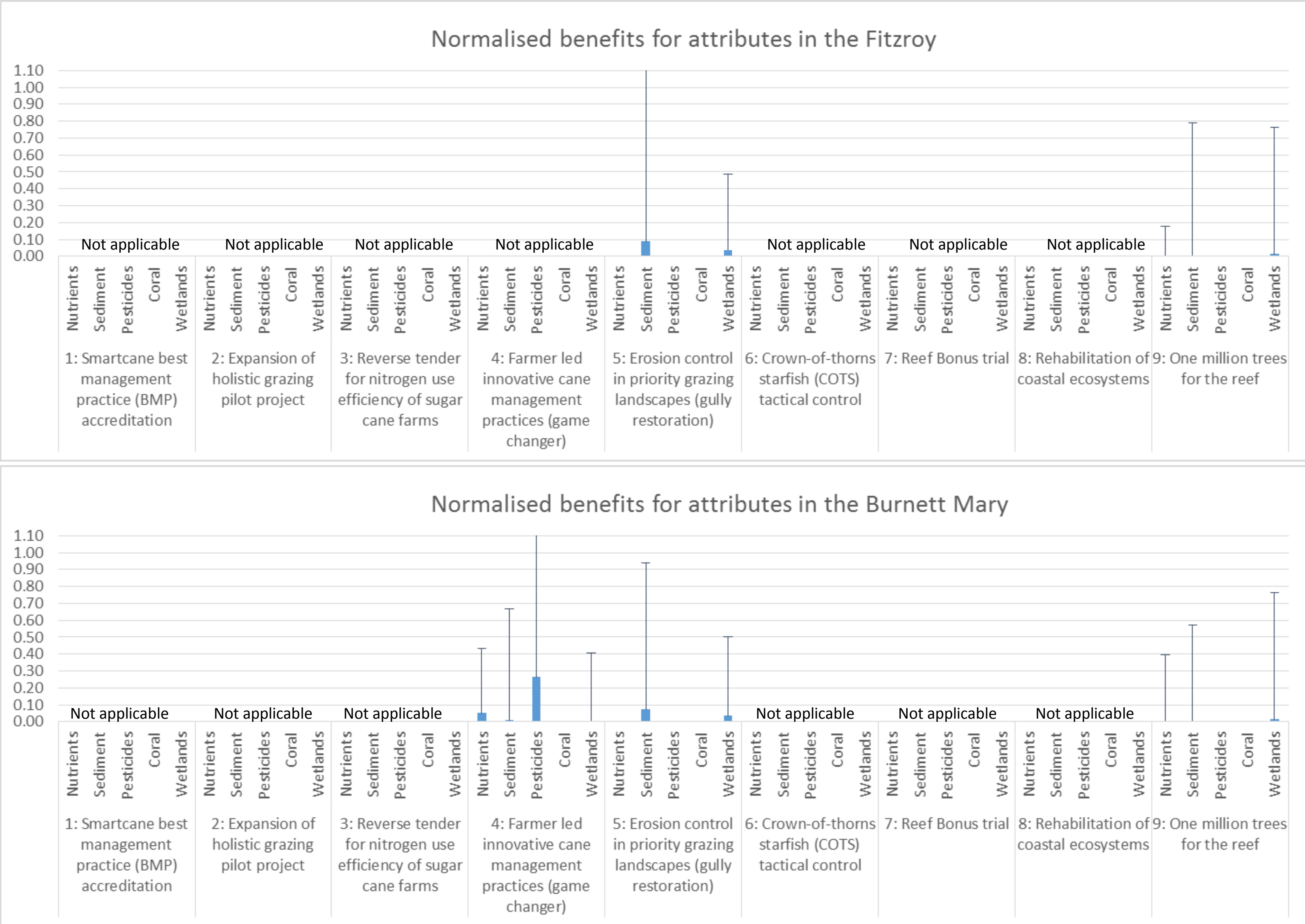


Figure 4. The normalised ***attribute*** benefits in the Fitzroy and Burnett Mary regions. The blue bars show the “most likely” benefit, and the positive error bars show the “best case” benefit.

3.2 Summary of the benefits of interventions on *objectives*

The ***objective*** benefits of each intervention were constructed using the linear composite model based on the five attributes (following equation 3, section 2.2). Figures 5 – 7 show the normalised ***objective*** benefits, which were calculated using equation 2 in section 2.2.

The normalised objective benefits of the interventions (Figures 5 – 7) reflect a similar pattern as the normalised attribute benefits (Figures 2 – 4). Once again the normalised “most likely” objective benefits of the proposed interventions (blue bars) are small (<0.1). This means that the difference between the most likely outcome of the intervention and the most likely outcome of no action on the objectives is only 10% of the total range (best – worst case) of the objective documented across all interventions in the region.

The best case benefits (positive error bars in Figures 5 – 7) estimated by experts highlight the much larger potential benefit of the interventions when comparing the difference between the best case outcome of the intervention and the most likely outcome of no action. The best case benefits represented up to 80% of the total range (best – worst case) of the attribute documented across all interventions in the region.

The negative error bars are not shown in Figures 5 – 7, as all “worst case” benefits are less than zero.

Assessing the most likely, best case and worst case benefits in Figures 5 – 7, again highlights that the predicted benefits of the intervention on the Reef Trust objectives would be modest (<0.1), and there is a large amount of uncertainty surrounding the predicted best case and worst case outcomes of the interventions and no action as at 2030.

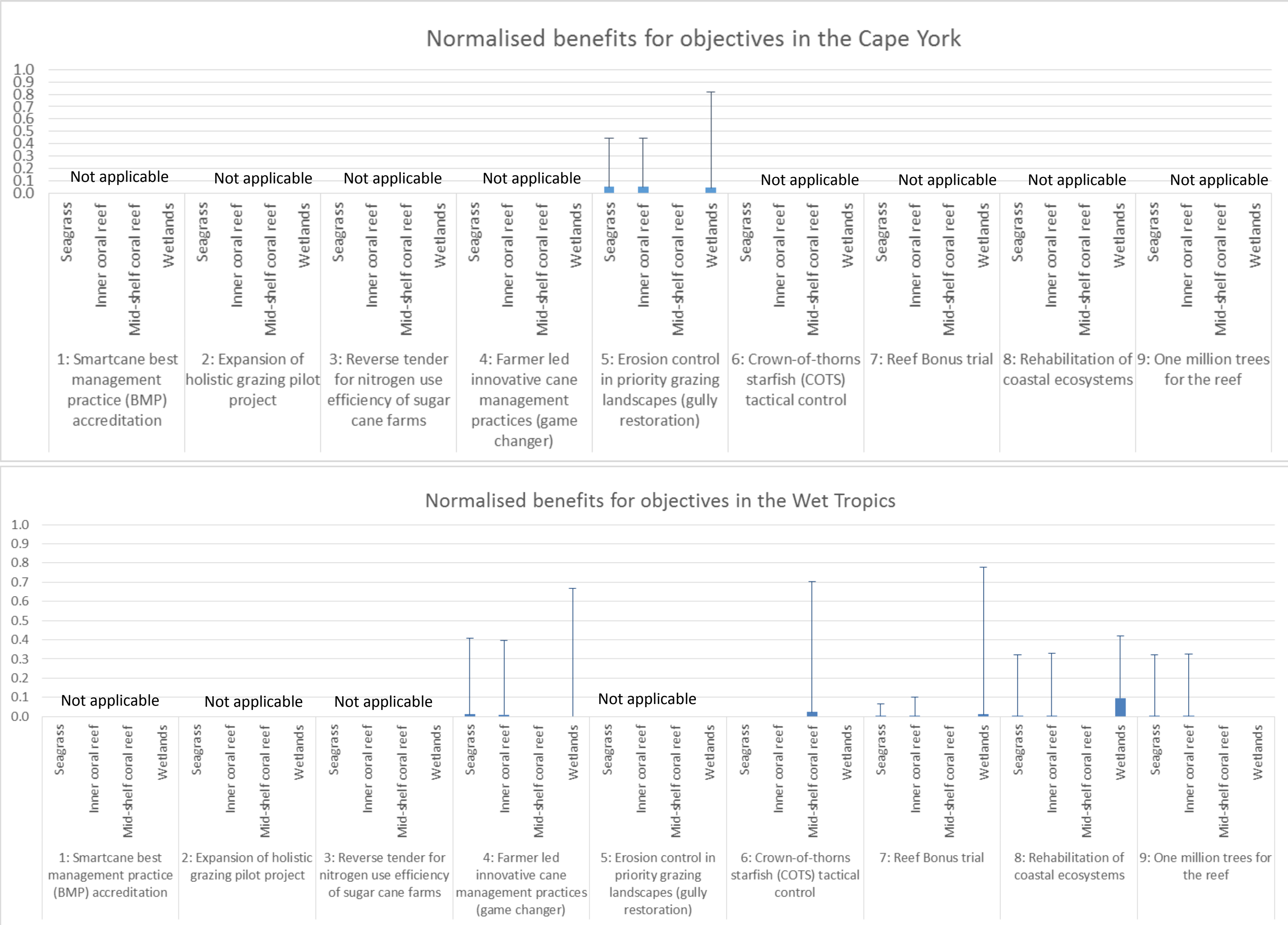
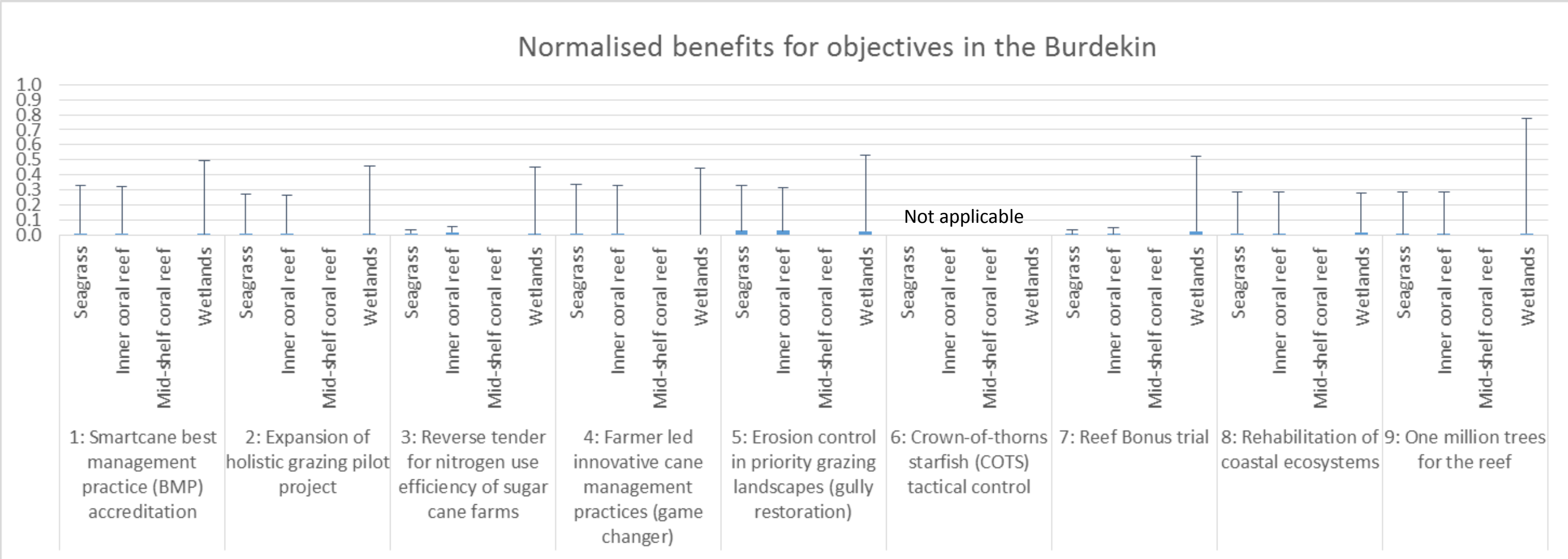


Figure 5. The normalised ***objective*** benefits in the Cape York and Wet Tropics regions. The blue bars show the “most likely” benefit, and the positive error bars show the “best case” benefit.



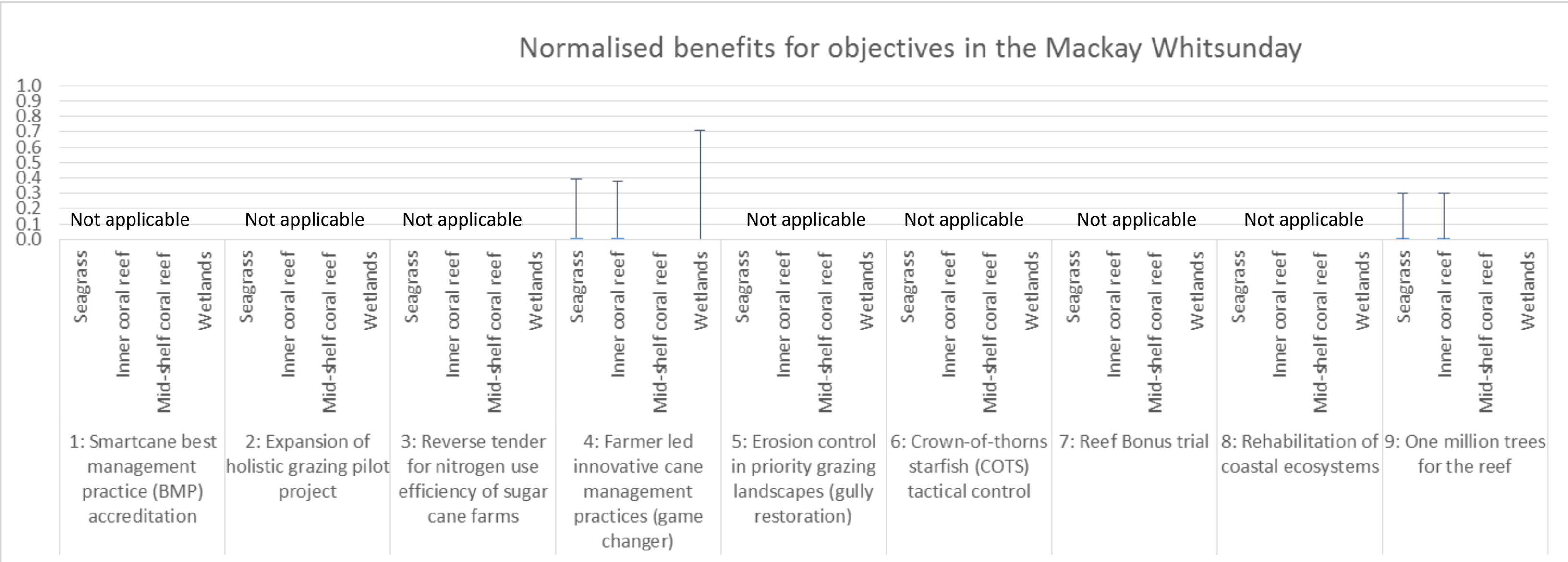
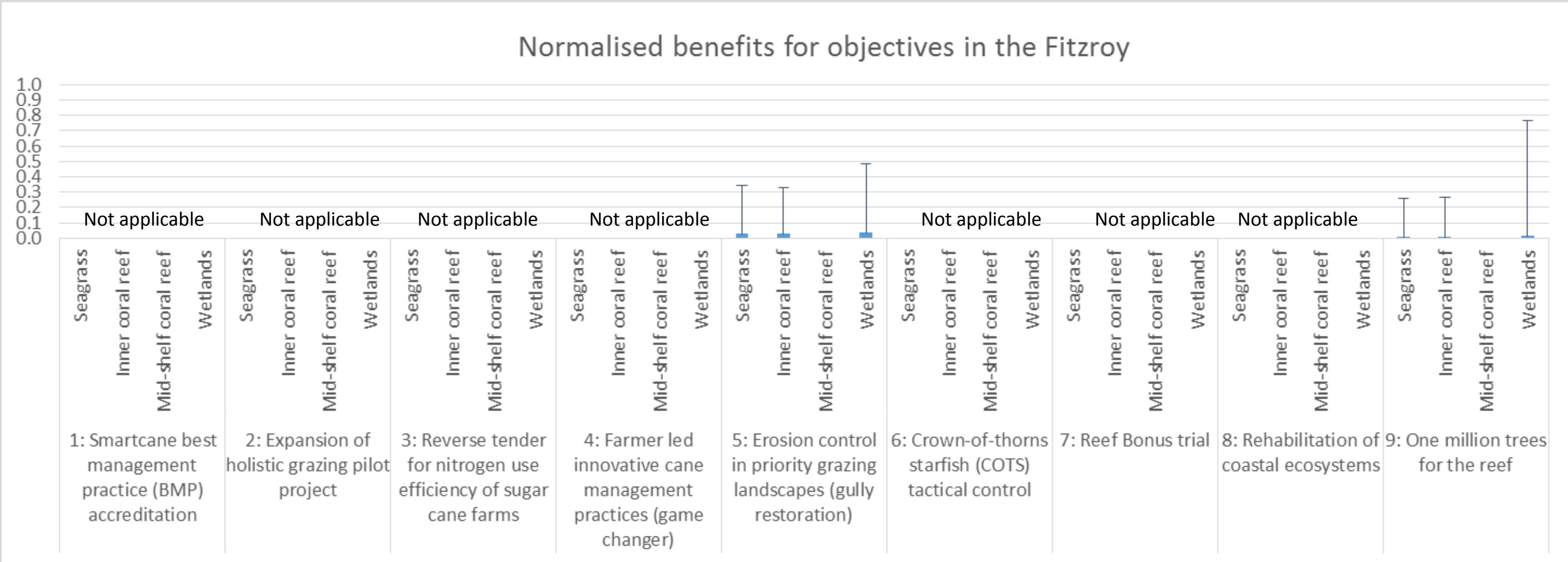


Figure 6. The normalised ***objective*** benefits in the Burdekin and Mackay Whitsunday regions. The blue bars show the "most likely" benefit, and the positive error bars show the "best case" benefit.



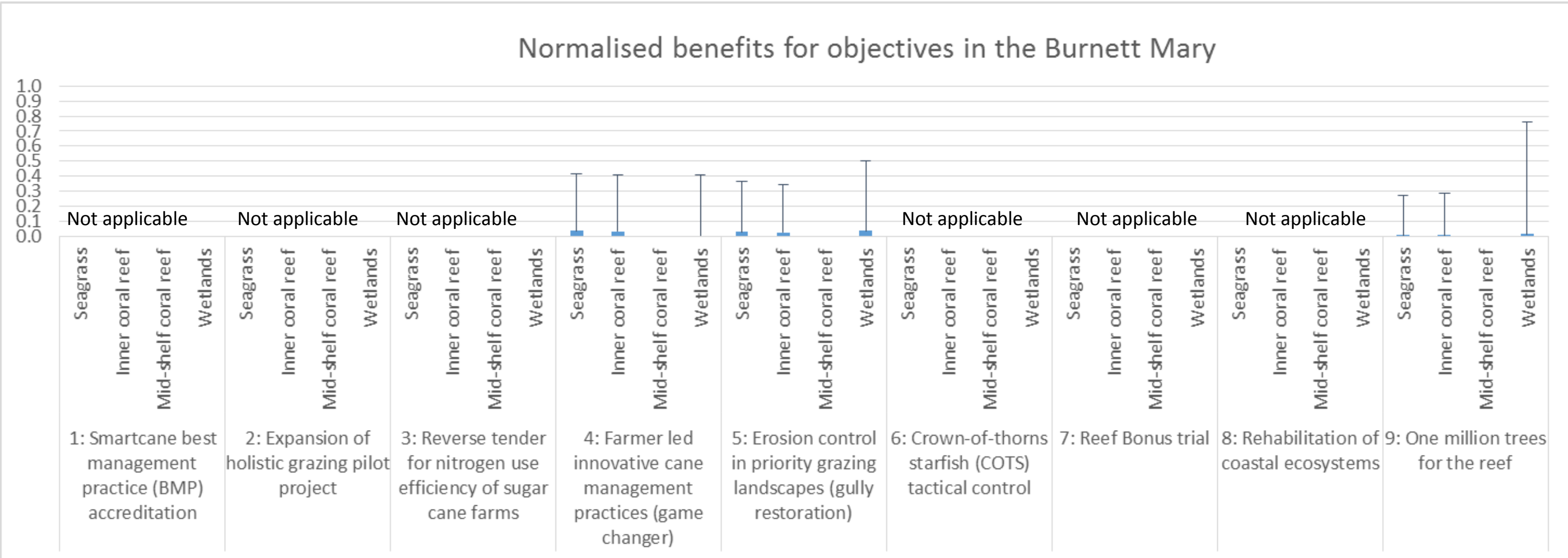


Figure 7. The normalised ***objective*** benefits in the Fitzroy and Burnett Mary regions. The blue bars show the “most likely” benefit, and the positive error bars show the “best case” benefit.

3.3 The cost-effectiveness of the proposed management interventions

The cost-effectiveness of each intervention was calculated using the summation of the normalised benefits of each objective (shown in Figures 5 – 7) in each of *k* GBRWHA regions, multiplied by a preference weight of 0.25 for each objective (following the Department assigning equal preference weights (0.25) to the four objectives), and then divided by the cost of the intervention (as outlined in equation 1, section 2.2).

The normalised ***objective*** benefits summed across all regions of the GBRWHA are shown in Figure 8 (showing the sum of the regional benefits displayed in Figures 5 – 7). This figure simply shows (a) the most likely and (b) the best case ***objective*** benefits of each intervention, which contribute to the numerator of the cost-effectiveness calculation (equation 1).

The final cost-effectiveness estimates for each intervention are shown in Figure 9, which highlights the most likely cost-effectiveness estimates for each intervention (the solid blue bars) and the best case cost-effectiveness estimates for each intervention (positive error bars). These estimates were derived from the most likely and best case benefits on the objectives under each intervention. Note that the negative error bars are not shown in Figure 9, as **all "worst case" cost-effectiveness estimates are assigned a value of zero**. This is an upside biased treatment of the experts' worst case estimates, where they believed it possible (mainly due to natural variation and extreme weather) for all of the interventions to have a negative outcome compared to the most likely outcome of no action on the attributes in each GBR region by 2030 (this can be seen in the original estimates provided in Appendices 5 – 7).

There are several ways to interpret the cost-effectiveness estimates (Figure 9) to discern better investments from lesser investments. Under uncertainty, decision-makers can interpret the cost-effectiveness estimates for the proposed interventions in three ways (following Chankong & Yacov, 1983):

1) The best-estimate rule: Select the highest performing interventions based on the largest most likely estimates of cost-effectiveness (the solid bars for each intervention). This ignores the uncertainty surrounding the most likely estimates of cost-effectiveness.
2) The optimistic rule: Select the highest performing interventions based on the largest best case estimates of cost-effectiveness (the positive error bars for each intervention). This rule maximises exposure to windfall outcomes.
3) The pessimistic rule: Select the highest performing interventions based on the largest worst case estimates of cost-effectiveness. This rule minimises exposure to downside surprise. In the context of the large uncertainties encountered in this analysis, the pessimistic rule is an unhelpful decision criterion. It does not distinguish the merit of the proposed interventions because all interventions were assigned a lower (worst case) bound of zero.

In Table 8, the proposed interventions are ranked based on the order of their most likely and best case cost-effectiveness (i.e., following the best guess and optimistic rules for decision making under uncertainty). A sensitivity analysis of the cost-effectiveness estimates (based on 1,000 randomisations of the preference weights assigned to the four objectives; Appendix 8) revealed a coarse delineation of proposed interventions, with five interventions consistently achieving the highest ranking out of the nine interventions (highlighted in Table 8). Following the best-estimate rule (i.e., using the blue bars of the cost-effectiveness graph (Figure 9) and the results of the sensitivity analysis (Appendix 8)), the top-five ranking proposed interventions are: the rehabilitation of coastal ecosystems (intervention 8), erosion control in priority grazing landscapes (intervention 5), Smartcane best management practice accreditation (intervention 1), farmer led innovative cane management practices (intervention 4), and the expansion of holistic grazing pilot project (intervention 2).

The four proposed interventions that rarely attained top-five status using random preference weights in the sensitivity analysis (Appendix 8) were: the reef bonus trial (intervention 7), reverse tender for nitrogen use efficiency of sugar cane farms (intervention 3), one million trees for the reef (intervention 9), and the crown-of-thorns starfish tactical control (intervention 6).

It is important to note that experts were only asked to consider each intervention with a fixed level of investment. If the scale of investment in an intervention is varied, this will influence the likely environmental benefit and thus the cost-effectiveness of the intervention. Please refer to the Discussion of pay-off curves in section 4.2, which addresses the likely non-linear relationship between investment and cost-effectiveness of the interventions.

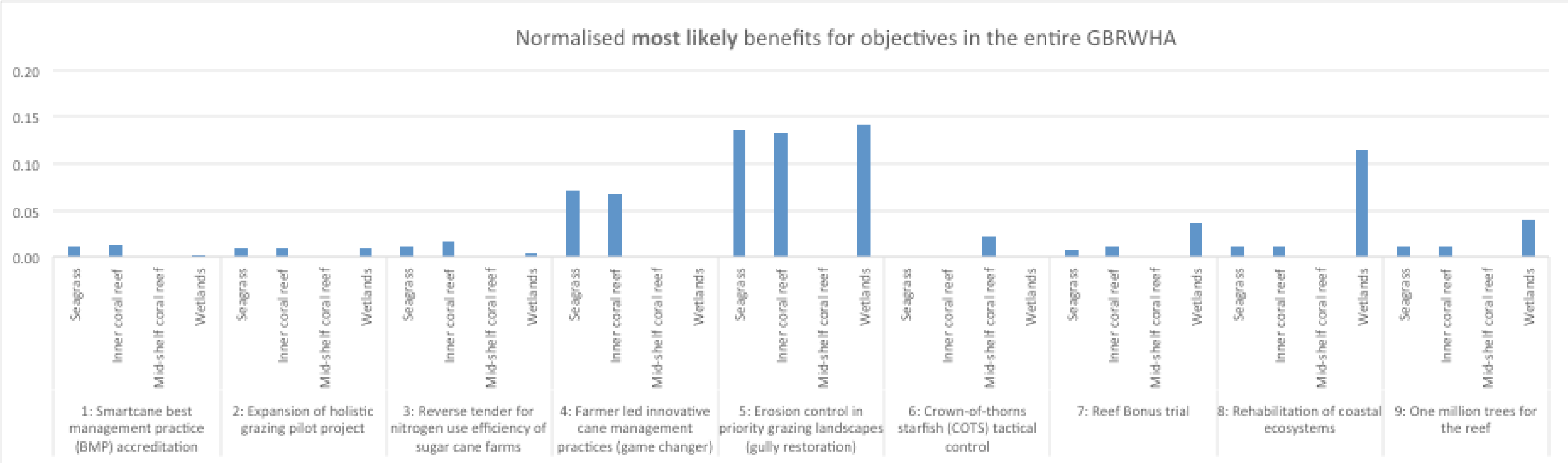


Figure 8a. The normalised **most likely** benefits for objectives for the entire GBRWHA.

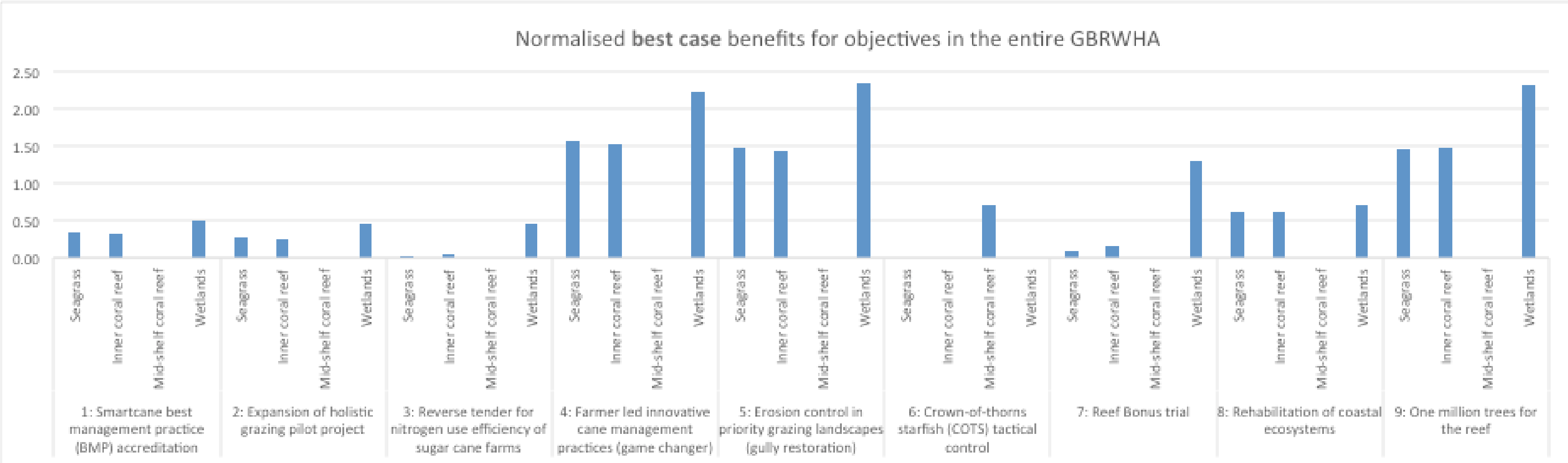


Figure 8b. The normalised **best case** benefits for objectives for the entire GBRWHA.

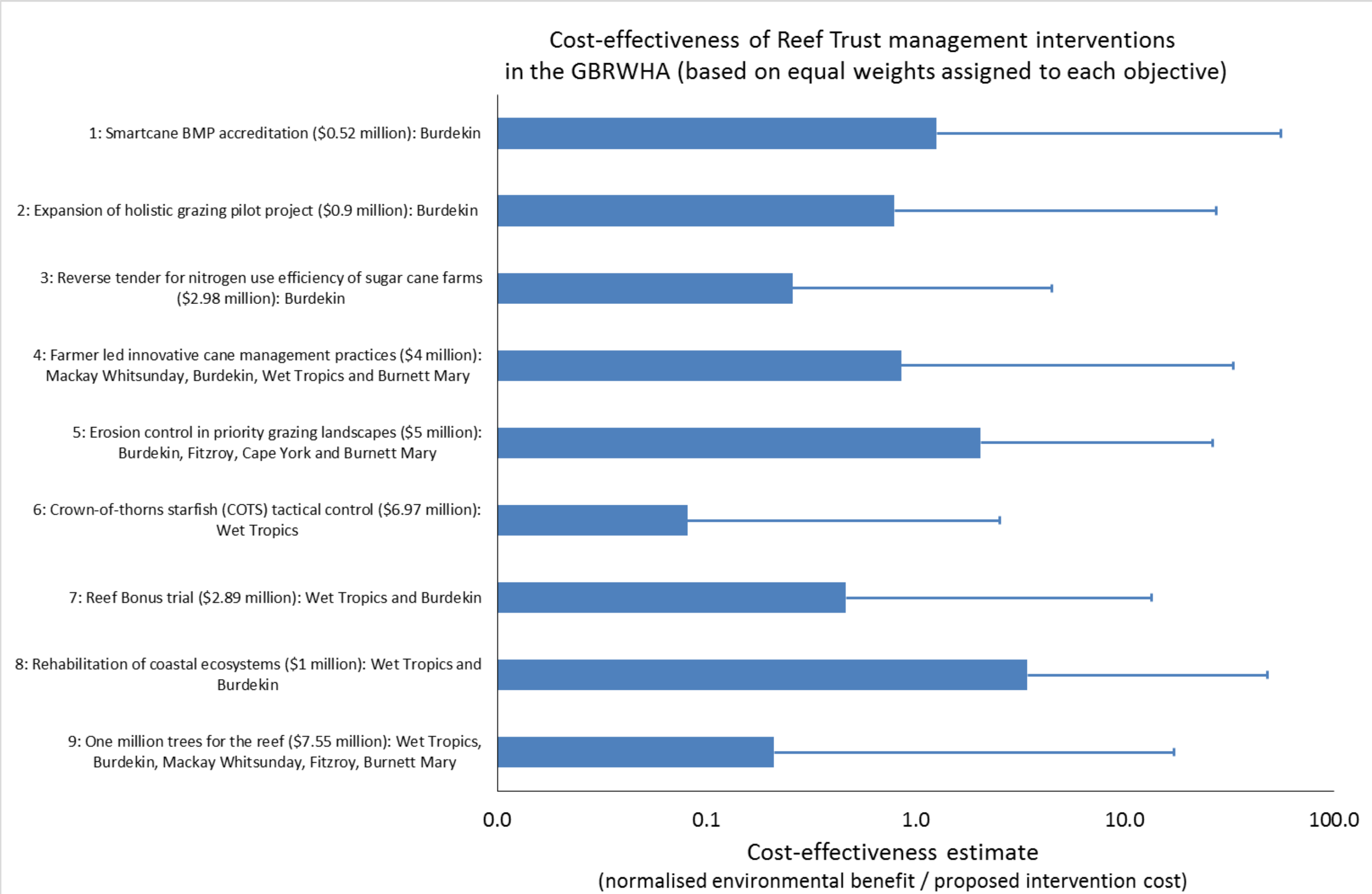


Figure 9. Cost-effectiveness estimates for the nine proposed interventions, based on equal preference weights assigned to each objective, displayed on a log scale to promote clarity in the rank order of the interventions. The most likely cost-effectiveness estimates for each intervention (the solid blue bars) and the best case cost-effectiveness estimates for each intervention (positive error bars) are shown. Cost-effectiveness estimates are calculated following equation 1.

Table 8. Summary of the ranking of proposed interventions based on the most likely and best case cost-effectiveness estimates (1 is assigned to the most cost-effective intervention, and 9 is assigned to the least cost-effective intervention).

Intervention	Rank based on most likely cost-effectiveness estimate	Rank based on best case cost-effectiveness estimate
1: Smartcane BMP accreditation ($0.52 million): Burdekin	3	1
2: Expansion of holistic grazing pilot project ($0.9 million): Burdekin	5	4
3: Reverse tender for nitrogen use efficiency of sugar cane farms ($2.98 million): Burdekin	7	8
4: Farmer led innovative cane management practices ($4 million): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary	4	3
5: Erosion control in priority grazing landscapes ($5 million): Burdekin, Fitzroy, Cape York and Burnett Mary	2	5
6: Crown-of-thorns starfish (COTS) tactical control ($6.97 million): Wet Tropics	9	9
7: Reef Bonus trial ($2.89 million): Wet Tropics and Burdekin	6	7
8: Rehabilitation of coastal ecosystems ($1 million): Wet Tropics and Burdekin	1	2
9: One million trees for the reef ($7.55 million): Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary	8	6

4 Discussion

4.1 Interpretation of cost-effectiveness estimates for the nine interventions considered under the second phase of Reef Trust

This cost-effectiveness assessment has focused on assessing environmental objectives (from experts directly estimating attribute benefits). There are a raft of other considerations (e.g., social and economic objectives) that will need to be considered when selecting interventions to invest in through the Reef Trust. Thus, the results of the cost-effectiveness analysis are intended to be just one line of evidence that the Department of the Environment will use when considering investments under the Reef Trust.

As the cost-effectiveness of each intervention is the environmental benefit divided by the cost of the intervention, a small intervention cost can substantially increase the cost-effectiveness estimate for an intervention. This is particularly apparent when looking at intervention 1 (Smartcane BMP), which has comparably low benefits on the objectives (Figure 8), but because this is one of the lowest cost interventions ($0.52 million) the cost-effectiveness of this intervention comes out as the third highest estimate out of the nine interventions (following the best-estimate rule).

The attribute benefits of each intervention in each region estimated by experts (Figures 2 – 4) are important estimates to refer back to when considering what interventions to invest in through the Reef Trust. Equally, the objective benefits that were estimated based on the attribute benefits (following equation 3; section 2.2) are also important to refer back to (Figures 5 – 7), including the summation of the objective benefits across all of the GBRWHA regions (Figure 8). The summation of the benefits of the interventions on seagrass, inshore coral reefs, mid-shelf coral reefs, and wetlands are modest, reflecting the modest levels of investment in the interventions relative to the scale of the GBRWHA and the intensity of its threats (Figure 8).

The analysis clearly indicates there is potential for some interventions to provide greater benefits than others. The cost-effectiveness results (Figure 9; Table 8) and the sensitivity analysis of the model outputs (Appendix 8) can be used to help differentiate between better versus poorer performing management interventions.

Following the selection of the management interventions for investment under the second phase of Reef Trust, the Department can consider the final step of structured decision-making: to implement and monitor the management interventions (Figure 1). It is important during this stage to differentiate between different types of monitoring that can be conducted. Some monitoring programs focus on assessing whether interventions were implemented in the way that was planned. These programs can be referred to as process or output monitoring (Hockings *et al.*, 2006), and can include monitoring things like the number of farmers who were approached to be involved in an agricultural practice change program, or the length of gullies remediated. Whilst important aspects of an intervention to monitor, these programs do not measure the ultimate environmental benefit of the interventions (referred to as outcomes).

Outcome monitoring and assessment should focus on measuring the environmental benefits of the Reef Trust management interventions in the GBRWHA. Outcomes monitoring should include monitoring quantitative environmental outcomes at the site(s) where interventions are in place (e.g., impact site) and control sites to assess what outcomes would have looked like in the absence of the intervention (i.e., impact evaluation; Ferraro, 2009). For example, a monitoring program associated with the COTS control intervention could include measuring the effects of COTS removal on the percentage cover or condition of hard corals in the mid-shelf reefs. Monitoring programs associated with the agricultural practice change interventions should not only focus on monitoring the changes in water quality entering the GBRWHA but also the resulting impact of these changes on wetlands, seagrass and coral habitats. Outcome monitoring and evaluation will be key elements for the Department to transparently demonstrate that the management interventions invested in through the Reef Trust are addressing the Reef Trust outcomes: the long term improvement in water quality and coastal habitats in the reef catchments, and protecting species within the GBRWHA; Department of the Environment, 2014b).

If outcome monitoring reveals that the management interventions surprise on the downside (or upside) relative to what the experts estimated (through their attribute estimates in step 4), the Department will have a sound evidence base upon which it can reconsider its allocations and investments as part of an adaptive approach to management.

The environmental data collected from such monitoring programs could also be used to inform future planning and investment in new interventions in the GBRWHA. Such data could be used in predictive models, which could compliment expert judgement to predict the environmental benefits of future management interventions in the GBRWHA.

4.2 Recommendations for future application of the cost-effectiveness process for Reef Trust management interventions

This summary report has outlined the process to estimating cost-effectiveness and refers to the spreadsheet ("reeftrust_costeffectiveness_final.xlsx"; with supporting explanation in Appendix 4), which can be used as a template should the Department wish to assess the cost-effectiveness of management interventions under future phases of investment under the Reef Trust.

The final section of this report raises five key recommendations for consideration by the Department should they wish to repeat this cost-effectiveness process in the future.

1) Clarify the description of management interventions

A template (Appendix 2) was prepared to help gather standardised background information about each of the proposed management interventions. This template was modelled off other well developed project development processes, such as the Investment Framework for Environmental Resources (INFFER) framework (Pannell *et al.*, 2013). The Reef Trust intervention template required details such as a description of the intended goal of the interventions (e.g., the reduction of sediment loads entering the GBRWHA), the intervention spatial and temporal scale, and the cost of the intervention. It also required information about the anticipated level of adoption for agricultural practice change interventions, and specification of the level of maintenance funding that would be provided to maintain the environmental benefits into the future.

With more time available, improvements could be made to the level of detail and consistency of information about the proposed management interventions. Efforts were made to obtain complete descriptions of the proposed management interventions, however time was a constraint in the development process.

The consequences of the insufficiently defined management interventions were apparent at the Reef Trust workshop. Many experts commented that there was not enough detail provided for them to confidently estimate the environmental benefits of the interventions. The uncertainty associated with some experts' consequence estimates reflects in part the lack of clarity around the description of what each intervention would exactly entail. For some interventions it was not clear what the intended spatial extent of management would be (e.g., the area of land or number of farms targeted within a region), and little to no description was provided about the anticipated level of uptake and wider adoption of the agricultural interventions (see discussion of adoption below). Where insufficient information was available, experts made their own assumptions about various aspects of these proposals. In some cases experts did not believe that the proposed agricultural interventions were well designed and as a result assumed that the resulting level of uptake/adoption might be low. Whilst some details could be easily provided with more planning time (e.g., area within a region that would be targeted for a specific intervention), others like the level of adoption will remain a challenging aspect of proposed interventions.

There are a range of factors that can influence the adoption of new approaches by farmers, such as social, cultural and economic factors, and many characteristics about the innovation itself (Pannell *et al.*, 2006). Predicting the likely level of adoption of new approaches can be a challenging task, but fortunately tools have been developed to assist project proponents in this task. One such tool is ADOPT (Adoption and Diffusion Outcome Prediction Tool), which is a user-friendly spreadsheet that walks proponents through a number of questions to consider factors that may affect adoption of a proposed intervention (Kuehne *et al.*, 2011).

For future phases of the Reef Trust, it is recommended that up to two months be made available to fully develop and describe proposed management interventions. Up to one month should also be allowed for consultation between the Department and intervention proponents to help ensure detailed and standard information about interventions is collated. The Department should also consider using a tool such as ADOPT (Kuehne *et al.*, 2011), to help with predicting the likely level of adoption of agricultural interventions.

2) *Clarify whether maintenance funding will be provided to maintain environmental benefits of interventions*

The interventions considered under the second phase of Reef Trust were proposed for a duration of 3.5 years or less, and in most cases did not include provisions for maintenance – where funding is committed to maintain the environmental benefits over decadal scales. The turn-over rates of marine systems means that some species can take many decades to show recovery and the benefits of management interventions.

The lack of maintenance funding for the proposed management interventions considered under the second phase of Reef Trust is an issue for achieving the Reef Trust goals: the long term improvement in water quality and coastal habitats in the reef catchments, and protecting species within the GBRWHA (Department of the Environment, 2014b). Such short term projects are unlikely to significantly contribute to achieving targets on their own. Should funding be extended for some of the proposed interventions it is possible that the environmental benefits of the interventions at 2030 would be more substantial.

Future intervention proposals should include provision for the environmental benefits of the interventions to be maintained in the long term, or built on with new and improved interventions.

3) *Consider management interventions at different scales of investment*

Each of the nine management interventions proposed under the second phase of Reef Trust had a fixed level of proposed investment. Some experts expressed the belief that if the investment in some of these interventions was scaled up or down, then their environmental benefit could be very different. This in turn could result in a substantially different estimate of the cost-effectiveness of an intervention. This intuition is entirely reasonable, and is illustrated in hypothetical pay-off curves in Figure 10. Changing the scale of an intervention may include increasing the spatial extent (e.g., expand an intervention across multiple regions), intensity (e.g., number of farmers targeted), or duration (e.g., the number of years an intervention is undertaken).

By estimating the likely environmental benefit of an intervention at varying levels of investment, a pay-off curve can be constructed. Pay-off curves are an effective means of exploring the non-linear relationship between investment and environmental response (Figure 10). Pay-off curves can be particularly illuminating for decision-makers who may wish to explore the implications of a greater (or lesser) budget for allocation across projects.

As an example, a decision-maker with a small budget may look at Figure 10 and decide that Intervention C is only worth investing in at a low level of investment (1). Even with a more substantial budget, increasing investment in Intervention C will provide little additional return on investment. With a larger budget, a decision-maker may look at Figure 10 and decide to only invest in intervention A, at a much higher level of investment (3), to achieve the greatest return on investment out of all three proposed interventions.

The scope of this project did not include eliciting additional estimates from experts under varying levels of investment of each intervention, however this is recommended for any future application of cost-effectiveness analysis. The imperative for credible characterisation of pay-off curves increases with the level of funding administered under Reef Trust. Future assessments of the cost-effectiveness of management interventions could involve detailed model development, model interrogation and expert judgement about the likely environmental benefit of an intervention at varying levels of investment.

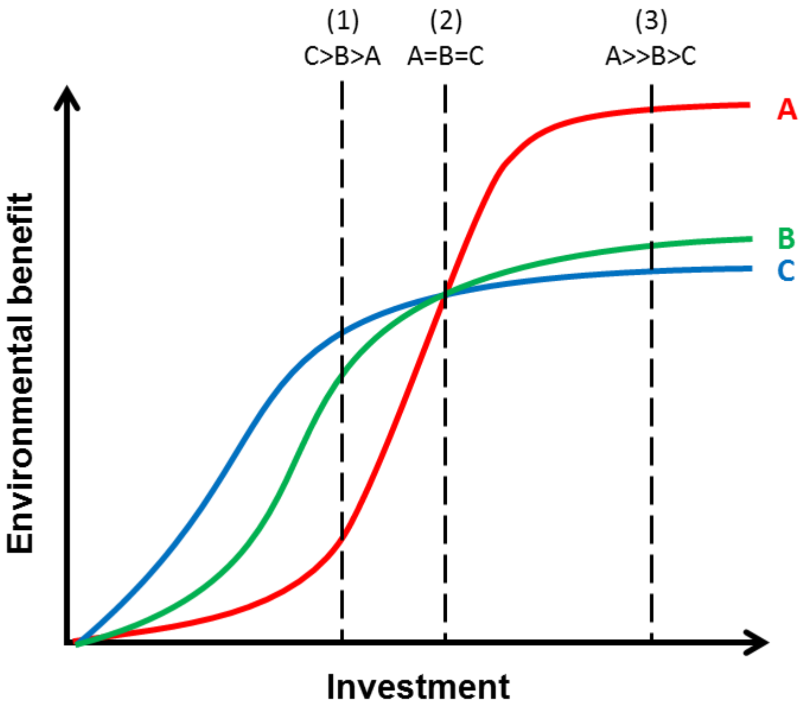


Figure 10. Pay-off curves for three hypothetical management interventions (A, B, and C), illustrating how varying the level of investment in each intervention can influence the environmental benefit, and thus return on investment. The cost-effectiveness of each intervention is the gradient of the curve at any point.

4) Decouple local and regional scale benefits

Some interventions have the potential to contribute to a substantial positive benefit on the Reef Trust natural values at a local scale (i.e., within a region) either on their own or in combination with the broad suite of actions underway across reef catchments through a range of initiatives led by governments, industry and the community. The scale of the assessment undertaken here is too coarse for capturing localised benefits.

If local benefits are of material consequence, then those responsible for administering Reef Trust should consider trading these local scale pay-offs against the broader-scale pay-offs documented in this report, alongside other concerns beyond the scope of this analysis. Alternatively the interventions invested through the Reef Trust could be treated as pilot studies to illustrate the potential of application at a larger (e.g., catchment-wide or multi-region) scale in the future.

5) Allow more time for the experts to understand the decision context and provide consequence estimates

The Reef Trust workshop held in December 2014 involved two full days to work through the estimation of the environmental benefits of the nine proposed interventions. This workshop timing and duration was constrained by the project start date with AIMS, and the Department's operational requirements with regard to Reef Trust timelines.

In hindsight, two full days were not enough time for experts to understand the decision context and to estimate the environmental benefits of the nine proposed interventions, for multiple attributes and objectives, and across up to six regions of the GBRWHA. Whilst a pre-workshop package of information was provided to experts one week prior to the workshop (e.g., containing the agenda, and explanation of the workshop process and intended outputs, and the full descriptions of all interventions), the first half day was still spent discussing the management interventions to help clarify any confusion, and narrowing the scope of the Reef Trust in terms of the four environmental objectives.

To overcome the issues faced at the Reef Trust workshop, the following recommendations are proposed:

- Provide proposed intervention descriptions to experts one month prior to the main elicitation workshop, and hold a teleconference meeting with experts at least two weeks prior to the main elicitation workshop. This should provide ample opportunity for the experts to understand the decision context, the intervention details and ask questions to clarify their understanding of the interventions.
- Allow for more time at the main elicitation workshop – acknowledging that two full days is already a large time commitment given by experts. It may be that smaller workshops (e.g., single day) could be run over a month.
- Access and query relevant models available within government organisations and research institutions. These models may assist experts' structure and refine their judgments.

5 Conclusion

The cost-effectiveness estimation process developed by AIMS has now been used to inform investment of interventions under the second phase of Reef Trust. This report has provided an overview of the cost-effectiveness estimation process, a summary of the cost-effectiveness results, and an interpretation of these results to assist the Environment Minister in making decisions on investment through the Reef Trust. As this was the first trial of the cost-effectiveness estimation process with the Department there are likely to be many lessons from this process.

The cost-effectiveness estimation process entails a series of logical steps to assist in the prioritisation of management interventions in a transparent and scientifically rigorous way, within the constraints of the resources and time available for decision-making. There is a range of other social and economic factors that will need to be considered when selecting investments under the Reef Trust, alongside consideration of synergies and complementarities with other programs contributing to environmental outcomes for the Great Barrier Reef World Heritage Area. Thus, the results of the cost-effectiveness analysis are intended to be just one line of evidence that the Department of the Environment will use when considering investments under the Reef Trust.

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7 List of supporting appendices

Appendix 1: Outline of the Reef Trust natural values

Appendix 2: Reef Trust - proposed intervention template

Appendix 3: The current levels of attributes in the GBRWHA regions

Appendix 4: cost-effectiveness spreadsheet notes

Appendix 5. Summary of effectiveness of interventions on water quality attributes

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Appendix 7: Summary of effectiveness of the crown-of-thorns starfish (COTS) tactical control on mid-shelf coral reefs

Appendix 8: Sensitivity analysis of the cost-effectiveness model outputs

Appendix 1: Outline of the Reef Trust natural values

Information and results from the Outlook Report 2014 and the Great Barrier Reef Strategic Assessments were used to incorporate the prior and existing work to identify the priority Reef Trust natural values for protection, improvement and conservation. The Reef Trust natural values selected included those that have been identified as in “poor” or “good, but deteriorated” condition:

Reef Trust natural values
Bony fish - include species of bony fish listed under the EPBC Act
Corals - includes coral reefs generally, as well as hard coral, soft corals, sea fans and sea pens in the GBR. Coral diversity contributes strongly to the outstanding universal value of the Great Barrier Reef World Heritage Area
Dugongs - including dugongs, their breeding and feeding habitats
Grass and sedge lands - typically composed of perennial native grasses with no canopy of trees. Used for feeding and roosting by migratory birds; helps slow the overland flow of water; and captures nutrients and sediments
Indo-Pacific humpback and snubfin dolphins - considered a priority for management because of their small, localised populations, exposure to high levels of human activity, and suspected population declines
Marine turtles - including GBR specific species and breeding colonies.
Natural wetlands - slow the overland flow of water, capture and recycle nutrients/sediments that would otherwise enter the GBR. Also used by some species for key parts of their life cycle
Saltmarshes - important, highly productive, interface between marine and terrestrial environments in the upper intertidal area along the length of the GBR coast.
Seabirds and shorebirds - includes listed and migratory species of seabirds and shorebirds, as well as the associated breeding and feeding habitats.
Seagrasses - typically the main food source for dugongs and some marine turtles; provides nursery habitat for several GBR species, contribute to trapping and stabilising large amounts of sediment and nutrient cycling. Grows in estuaries, shallow coastal waters, and in the GBR lagoon — sometimes in association with coral reefs.
Seasnakes - includes species endemic to the GBR and breeding populations.
Shark and rays - includes listed migratory species and listed threatened species within the GBR.

Appendix 2: Reef Trust intervention template

Introduction to Reef Trust

Given the diverse and wide-ranging threats to the Great Barrier Reef, strategic prioritisation of Reef Trust investment remains key to ensure that threats to the reef are addressed in an effective, efficient and appropriate manner. An investment strategy is being developed to inform future Reef Trust investment. The scope of the Reef Trust has been defined to focus investment on the highest priority threats, values and regions in which intervention is most required (refer to **Attachment A** for the defined Reef Trust scope). The purpose of this template is to identify and develop potential interventions that fit within the defined scope and can be considered for their cost-effectiveness through a process of prioritisation.

The information requested will provide decision-makers and technical assessors with an understanding of the spatial and temporal scale of the proposed intervention, the costs involved in delivery and the alignment of the intervention with the defined scope and the Reef Trust principles for investment (these can be found on page 10 of the interim Investment Strategy at: http://www.environment.gov.au/reef-trust).

Preferred interventions will need to be strongly aligned to each of the principles of investments. This includes interventions having an on-ground[1] delivery focus, clearly defined outcomes and targets, and well-planned activities. Interventions with a strong degree of innovation, whether this be in the methods, technologies or delivery mechanisms, are encouraged and supported to capitalise on the flexible and opportunistic nature of the Reef Trust and the desire to explore new means that make positive changes to the system beyond tried and tested techniques.

At this point in time, the duration of proposed interventions should be no longer than three or four years. As the Reef Trust evolves, and new investment avenues such as the pooling of offset funds or private donations are realised, there may be opportunity to extend the duration of proposed interventions in line with the likely size and appropriate timeframes of available funds in the Reef Trust and co-investment opportunities.

[1] On-ground activities are those of a practical nature whereby action is undertaken to facilitate a direct change. In the context of the Reef Trust, this is intended to also include activities carried out on-water, and activities that create social change, such as behavioural changes to improve management practice.

Your contact details

1. Organisation name: Click here to enter text.
2. Contact person: Click here to enter text.
3. Email: Click here to enter text.
4. Address: Click here to enter text.
5. Phone number Click here to enter text.

Intervention overview

6. Provide a short description of the proposed on-ground intervention(s):

7. How would the intervention be delivered (e.g. use of a market based instrument, open grant process, negotiated delivery etc.)?

   Click here to enter text.

8. Please describe any innovative techniques, methods or technologies that will be used to deliver the project:
   Click here to enter text.

9. Does the proposed intervention build on existing/previous activities (e.g. an extension)?
   ☐ Yes ☐ No
   If yes, please describe how the project is an extension of existing/previous activities, does not replace other available funding, and does not support business as usual activities:
   Click here to enter text.

10. Describe the types of organisations who could undertake the intervention. If the intervention is best managed via a partnership, please also describe the nature of such a partnership (e.g. educating farm owners about environmentally friendly land management practices):
    Click here to enter text.

Intended outcomes

11. Which of the three Reef Trust outcomes, and specific values of the GBR does this intervention aim to address (please select at least one outcome and value):

☐ **Outcome 1** Improve the quality of water entering the Great Barrier Reef from broad-scale land use to increase the health and resilience of the Great Barrier Reef	☐ **Outcome 2** Improve the health and resilience of coastal habitats	☐ **Outcome 3** Improve and protect marine biodiversity, including the reduction of crown-of-thorns starfish and protection of listed threatened and migratory species, such as dugongs and turtles
☐ Ecological connectivity	☐ Beaches and coastlines	☐ Sharks and rays
☐ Light availability	☐ Grass and sedge lands	☐ Seasnakes
☐ Natural wetlands	☐ River deltas	☐ Marine turtles
☐ Island ecosystems	☐ Corals	☐ Indo-Pacific humpback and snubfin dolphins
☐ Saltmarshes	☐ Seabirds and shorebirds	☐ Dugongs
☐ Seagrasses	☐ Bony fish	

12. Please indicate which of the threats to the GBR this intervention will target (please select at least one threat):

Outcome 1 threats	**Outcome 2 threats**	**Outcome 3 threats**
☐ Nutrient run-off	☐ Clearing or modifying coastal habitats	☐ Outbreak of crown-of thorns
☐ Sediment run-off	☐ Increased freshwater inflow	☐ Outbreak of disease
☐ Pesticide run-off	☐ Artificial barriers to flow	☐ Human related impacts on marine animals
		☐ Marine debris

Specify the intervention goal(s). Goals should be specific, measurable and time-bound, and include information about how the project will target the threat(s), the anticipated effects on the selected value(s) and how the anticipated effects can be measured (refer to Appendix A for guidance). For example: A proposal to lethally inject crown-of-thorns starfish may have the following goal – to reduce the impact of crown-of-thorns starfish on high value tourist reefs (*the threat*), with

an expected maintenance or improvement in coral of up to 30% cover within reefs (*the value and measure*) by 2030 (*the timeframe*).
Click here to enter text.

13. Is there any supporting material that suggests the proposed intervention will be effective in meeting its goal(s)? If yes, briefly describe any of the following types of supporting material, e.g. published results of previous studies (provide details), expert opinion (name), local knowledge from scientists, stakeholders or management organisation staff (name)):
Click here to enter text.

Intervention location

14. Please indicate the region of the Great Barrier Reef World Heritage Area or adjacent catchment where the intervention would be undertaken:
☐ Cape York
☐ Wet Tropics
☐ Burdekin
☐ Mackay Whitsunday
☐ Fitzroy
☐ Burnett Mary
☐ Far Northern Management Area
☐ Cairns / Cooktown Management Area
☐ Townsville / Whitsunday Management Area
☐ Mackay / Capricorn Management Area

15. Please nominate, where possible, the sub-catchment or marine region in which the intervention would be delivered, and provide justification as to why that area is being proposed:

Click here to enter text.

16. Where will this intervention take place:

On land
☐ Private land (i.e., farmland)
☐ Public land (i.e., protected area)

Inland waterways
☐ Streams
☐ Gullies
☐ Rivers
☐ Estuaries

Marine waters
☐ Inshore marine waters (within 20 km of the coast)
☐ Off-shore marine waters (areas along the edge of the continental shelf)

☐ Mid-shelf marine waters (areas between inshore areas and the off-shore barrier reefs)

17. If known, please describe the exact location of the intervention (e.g. provide location name and latitude and longitude), the spatial units (e.g. size of farms/sites/reefs) and replication (e.g. the number of farms/sites/reefs) where the intervention will be undertaken:
Click here to enter text.

Intervention duration

18. What is the duration of the proposed intervention (in years):

Project phase	Number of years
Setup (e.g. planning)	
Operating (e.g. undertaking the on-ground action)	

19. Please define the timing (e.g. month / season) that the operational phase of the intervention will be undertaken:
Click here to enter text.

Intervention cost estimates

20. PERSONNEL DAYS: Provide an estimate of the total number of person days required for the setup and operational phases of the intervention over the next four years (NB: only fill in cells for the total number of years of the proposed intervention specified in question 18). Also indicate the proportion of personnel time that will be offered as in-kind support:

	Total personnel time (person days)			
	2014-15	2015-16	2016-17	2017-18
Setup phase				
Operational phase				
% of personnel time provided as in-kind support				

21. COSTS OTHER THAN PERSONNEL: Provide cost estimates for the setup and operating phase of the intervention, broken down by cost item (e.g., materials required for on-ground actions, infrastructure, travel, workshops, and Reef Trust reporting requirements) and cost type (e.g., cash being sought from Reef Trust, cash already committed from other sources, and in-kind contributions).

Items for consideration in preparing the budget include:

Salaries
Extension officers/field officers
Project leadership/coordination
Administration/support
Technical support/research
Other

Operating costs
Payments to land/water managers
On-ground works (funded directly, not via payment to land/water managers)
Workshops/meetings
Travel
Monitoring and evaluation
Other

Item description	**Estimated costs Total for each year of the intervention**			
	Cash (being sought for this project)($)	**Cash (committed from other sources) ($)**	**In-kind input[2] ($)**	**Total ($)**
2014-15				
2015-16				
2016-17				
2017-18				
Total ($)				

[2] In-kind contributions do not include contributions by private landholders (which are considered to be part of the private net benefits). Rather, they refer to contributions by the organisation administering the project (and potentially other partner organisations).

In-kind contributions should not include allowance for organisational overheads. They should be strictly costs that are directly attributable to the project, such as a proportion of salary and on-costs for staff members involved in the project.

Maintenance cost estimates

The following two questions relate to a maintenance phase of the intervention that may be thought necessary to maintain the benefits generated by the intervention. This is not about Reef Trust providing maintenance funding, rather trying to assess whether the benefits of the intervention will be seen in 2050 with or without maintenance funding. It's also to ascertain whether there is any potential for other funding sources to support the maintenance of a Reef Trust investment after its completion.

22. Will maintenance funding be required at the completion of the operational phase of the intervention to ensure that the benefits generated by the intervention are maintained until 2050?

☐ Yes ☐ No

If yes, what amount of maintenance funding will be required per year to maintain the benefits generated by this intervention? Specify the types and amount ($/year) of these ongoing costs:

Item description	Funding ($/year)

23. What are the prospects for the required long-term funding being obtained?

☐ Very Likely. The long-term plans and institutions are in place and funding committed. (Probability 0.9)

☐ Likely. The long-term plans and institutions are in place but funding is yet to be committed. (Probability 0.7)

☐ Possible. There is no firm long-term plan and institutions are in place but funding is yet to be committed (Probability 0.5)

☐ Unlikely. There is no firm long-term plan, institutional manager or funding in place, but there are reasonable prospects of this occurring. (Probability 0.3)

☐ Very Unlikely. There is no firm long-term plan, institutional manager or funding in place, and the prospects of this occurring appear poor. (Probability 0.1)

☐ Long-term funding not required. (Probability 1)

Enter custom value for probability of long-term funding: Click here to enter text.

Appendix A

Guidance for setting intervention goals

“Specific” means that the goal is described in a precise and unambiguous way.

“Measurable” means that the goal definition is based on a variable which is able to be monitored and recorded reliably and without going to unreasonable expense to do so.

“Time-bound” means that a particular date is provided by which time the goal will have been achieved. The time frame for the goal can be of any relevant duration.

The goals specified should focus as much as possible on achievement of outcomes for the value, not just activities or outputs. Goals should be specified over a time frame of 35 years (i.e. from now to 2050).

Appendix 3: The current levels of attributes in the GBRWHA regions

Attribute	Performance measure	Cape York	Wet Tropics	Burdekin	Mackay Whitsunday	Fitzroy	Burnett Mary	Source
Nutrients	Load of dissolved inorganic nitrogen (DIN; tonnes / yr)	492	4437	2647	1129	1272	554	Waters *et al.*, 2014
Sediment	Load of total suspended solids (tonnes / yr) discharged to the GBR	2.4 million tonnes	1.4 million tonnes	4.7 million tonnes	1.5 million tonnes	4.1 million tonnes	3.1 million tonnes	Great Barrier Reef Marine Park Authority, 2012
Pesticides	Load of total pesticides (kg / yr) discharged to the GBR	no data	10,000 kg	4,900 kg	10,000 kg	2,300 kg	1,000 kg	Great Barrier Reef Marine Park Authority, 2012
Mid-shelf coral reef	Hard coral cover (average % cover per region from LTRMP)	approx 24% at 2010 (95% CI = 20,30) for northern region	approx 14.1% at 2010 (95% CI = 5,17) for central region	approx 14.1% at 2010 (95% CI = 5,17) for central region	approx 8.2% at 2010 (95% CI = 7,12) for southern region	approx 8.2% at 2010 (95% CI = 7,12) for southern region	approx 8.2% at 2010 (95% CI = 7,12) for southern region	De'ath *et al.*, 2012
Wetlands	Wetland condition (1= very low functions and components to support values; 5 = very high functions and components to support values)[1]	4	4	3	2	2.5	2.5	Estimates based on wetlands experts judgement and the draft Wetland GBR Hazard Assessment (Department of Science Information Technology Innovation and the Arts, 2014)

[1] The performance measure used to reflect Wetlands is wetland condition (as a reflection of the components (soils, water, flora, fauna etc. and processes (hydrologic, nutrient processes etc) and how they support wetland values. For more details see: Department of Environment and Heritage Protection, 2014

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Appendix 4. Cost-effectiveness spreadsheet notes

Executive summary

This report provides guidance for use of the cost-effectiveness spreadsheet ("reeftrust_costeffectiveness_final.xlsx"), which has been provided to the Department of the Environment. The spreadsheet was used to calculate the cost-effectiveness of nine proposed management interventions in the Great Barrier Reef World Heritage Area (GBRWHA) for consideration through Phase 2 of Reef Trust investment.

This report is an Appendix to the Summary Report, which provides a summary of the estimated cost-effectiveness of the proposed management interventions calculated using the spreadsheet after capture of expert judgments.

Outline of the cost-effectiveness spreadsheet

This report describes use of the worksheets contained within the cost-effectiveness spreadsheet ("reeftrust_costeffectiveness_final.xlsx"). Note that the data contained within the spreadsheet is the final data (i.e., expert estimates of environmental benefits and costs of proposed interventions) that was used to estimate the cost-effectiveness of the nine proposed management interventions in the Great Barrier Reef World Heritage Area (GBRWHA) for consideration through Phase 2 of Reef Trust investment. For a summary and interpretation of the cost-effectiveness results, see the Summary Report: "Summary report: the cost-effectiveness protocol used to assist in the prioritisation of Phase 2 Reef Trust investment".

Throughout the spreadsheet orange cells represent inputs, and green cells are calculated automatically based on the inputs provided.

Attributes worksheet

Lists the environmental attributes, their performance measure (unit of measure) and preference (more is better / less is better), used to estimate the environmental benefits of the proposed management interventions. The attributes are described in Table 3 of the Summary report.

Intervention worksheet

Lists the nine proposed management interventions for consideration through Phase 2 of Reef Trust investment. Also indicates the GBRWHA regions where the interventions are planned. This worksheet also includes a strategy table, which outlines the environmental attributes that experts believed would be affected by each intervention (rows 13 – 22). A full description of the proposed management interventions can be found in Table 1 of the Summary Report.

Cost worksheet

Outlines the costs associated with each of the nine proposed management interventions. This includes the cost of the intervention (personnel and cash resources) over the intervention horizon (typically 3 – 3.5 years), in-kind support (cash amount, and who will provide the cash support), and whether maintenance funding is provided following the intervention.

No action worksheet

The "NO ACTION" worksheet contains experts' estimates of the effect of no action on attributes across the six GBR regions over a time horizon of 15 years (i.e., estimates of outcomes under a scenario of no intervention by the Reef Trust on attributes at 2030). Note that no action assumes business as usual over the next 15 years of management conducted by agencies/organsiations outside of the Department of the Environment's Reef Trust (e.g., the Great Barrier Reef Marine Park Authority, Queensland Government, catchment management groups, and other NGO and private landholder initiatives).

To insulate against overconfidence, each judgment involves estimation of four quantities:

a. *Plausible **best case** estimation*
b. *Plausible **worst case** estimation*
c. ***Most likely** estimate (which should lie between the best and worst case estimates)*
d. ***Confidence** estimate that the truth will lie between the nominated lower and upper bounds (as a percentage ≥50%)*

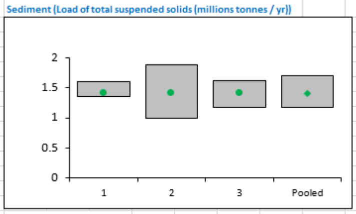
Experts are referred to as assessors in the worksheet, and are numbered from 1 – 4 to protect their anonymity. Experts worked in three groups to provide their expert judgment regarding the effect of no action (and the interventions) on the water quality attributes. Two experts provided estimates of the effect of no action (and the interventions) on the wetland attribute, and three experts provided estimates of the effect of crown-of-thorns starfish (COTS) tactical control on the mid-shelf coral attribute.

As experts provided estimates with different levels of confidence (orange cells), their estimates were standardised to present best case, worst case and most likely estimates of no action for the attributes with 80% confidence (calculated in the green cells). These standardised estimates are plotted throughout the worksheet showing estimates by each assessor and a pooled (average) assessor estimate, e.g.:

Sediment Load of total suspended solids (millions tonnes / yr)	1	2	3
best case scenario	1.3580	0.9000	1.2000
worst case scenario	1.6100	2.0000	1.6000
most likely estimate (this should lie between worst and best case scenarios)	1.4000	1.4000	1.4000
how confident are you the truth will lie between your nominated worst case and best ca	80	99	70

1	2	3	Pooled
1.358	0.996	1.171	1.18
1.610	1.885	1.629	1.71
1.400	1.400	1.400	1.40

No Action, Wet Tropics
Sediment (Load of total suspended solids (millions tonnes / yr))



Payoffs worksheets

There are nine payoff worksheets – one for each of the proposed interventions (e.g., "Payoff_Intv 1"). Similar to the NO ACTION worksheet, these nine payoff worksheets include assessor estimates of the benefits of the interventions on the five attributes (whichever were specified as being affected in the strategy table in the "Interventions worksheet").

As experts provided estimates with different levels of confidence (orange cells), their estimates were standardised to present best case, worst case and most likely estimates of no action for the attributes with 80% confidence (calculated in the green cells). These standardised estimates are plotted throughout the payoffs worksheet showing estimates by each assessor and a pooled (average) assessor estimate. In addition, the payoff of each intervention is calculated for each assessor, which is based on the difference between the benefit of the intervention – no action estimates by each assessor (in the grey cells with orange text), e.g.:

Nutrients Load of total DIN (tonnes / yr)	1	2	3
best case scenario	2589.10	2093.00	2571.00
worst case scenario	2911.70	2893.00	2900.00
most likely estimate (this should lie between worst and best case scenarios)	2618.10	2393.00	2685.00
how confident are you the truth will lie between your nominated worst case an	80	80	80

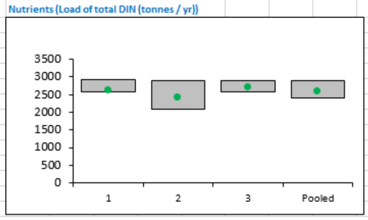
Adjusted for uniform confidence level =

	1	2	3	Pooled
best	2589.10	2093.00	2571.00	2417.70
worst	2911.70	2893.00	2900.00	2901.57
most likely	2618.10	2393.00	2685.00	2565.37

PAYOFF (Intervention – no action (most likely est))

	1	2	3	Average payoff
Optimistic	-57.900	-307.000	-129.000	-164.63
Pessimistic	264.700	493.000	200.000	319.23
Most likely	-28.900	-7.000	-15.000	-16.97

Strategy 1, Burdekin
Nutrients (Load of total DIN (tonnes / yr))



Groups best – worst worksheet

There is no input required on this sheet. This worksheet calls upon the “no action” and intervention “payoff” worksheets to determine the best and worst case levels of each attribute across all interventions within each GBR region estimated by the three assessors. For the water quality attributes the best case is a 25% reduction in the most likely outcome of no action for each attribute within each region, and the worst case is the most likely outcome of no action (see Section 2.2 of the Summary Report for further explanation of this). For the coral and wetland attributes, the best case is the highest level of the attribute and the worst case is the lowest level of the attribute. The range of best – worst case for each attribute in each region is then calculated as the difference, e.g.:

Each Groups Min and Max values							
Assessor 1							
		Cape York	Wet Tropics	Burdekin	Mackay Whitsunday	Fitzroy	Burnett Mary
Nutrients	Best	369.00	3327.75	1985.25	846.75	954.00	415.50
	Worst	492.00	4437.00	2647.00	1129.00	1272.00	554.00
	Difference	-123.00	-1109.25	-661.75	-282.25	-318.00	-138.50
Sediment	Best	1.80	1.05	3.58	1.13	3.08	2.33
	Worst	2.40	1.40	4.77	1.50	4.10	3.10
	Difference	-0.60	-0.35	-1.19	-0.38	-1.03	-0.78
Pesticides	Best		7500.00	3675.00	7500.00		750.00
	Worst		10000.00	4900.00	10000.00		1000.00
	Difference		-2500.00	-1225.00	-2500.00		-250.00
Corals midshelf	Best		31.85				
	Worst		5.61				
	Difference		26.25				
Natural wetlands	Best	4.68	4.73	4.56	2.34	3.60	3.44
	Worst	3.03	2.57	1.66	1.55	1.46	1.32
	Difference	1.65	2.16	2.90	0.78	2.14	2.12

The “difference” values form the denominator for the calculation of the normalised attribute benefits of each proposed management intervention on each attribute in equations 4 and 5 of the Summary Report (section 2.2).

Predictive weights worksheet

This worksheet contains the ***predictive weights*** (β_l used in equation 3 of the Summary Report) for each attribute that were used in the weighted linear composite model to calculate the benefit of the interventions on each objective (seagrass, inshore coral reef, mid-shelf coral reef and wetlands). See section 2.2 of the Summary Report for more background on the predictive weights and the weighted linear composite model.

Regional benefit worksheets

There is no input required on these sheets. There are six regional benefit worksheets for the GBR regions: Cape York (CY benefit), Wet Tropics (WT benefit), Burdekin (Burd benefit), Mackay Whitsunday (MW benefit), Fitzroy (Fitz benefit), and Burnett Mary (BM benefit).

In these worksheets, the ***normalised attribute benefits*** of each proposed management intervention are calculated (following equations 4 and 5 in Summary Report; rows 79 – 95). These worksheets divide the assessors’ estimates of the payoffs from each intervention (standardised to 80% confidence; from the nine payoff worksheets) by the difference between the best – worst case for each attribute in each region (from the “Groups best-worst” worksheet). The average of the normalised attribute benefits estimated by the three assessors is then taken, e.g. “Burd benefit” rows 79 – 95:

1	**Normalised attribute benefit (following eqn 4&5)**	•								
2		**Burdekin**								
3		•	•	•	•	•	-	•	•	•
4		1: Smartcane	2: Expansion	3: Reverse te	4: Farmer le	5: Erosion co	6: Crown-of-	7: Reef Bonu	8: Rehabilita	9: One million trees
77										
78	**Most Likely (normalised) - Assessor Averages**									
79	Outcome 1 - nutrients	0.03	0.00	0.11	0.02	0.00	0.00	0.05	0.00	0.00
80	Outcome 1 - sediment	0.02	0.03	0.00	0.02	0.09	0.00	0.00	0.03	0.03
81	Outcome 1 - pesticides	0.03	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
82	Outcome 3 - Corals midshelf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	Outcome 2 - Natural wetlands	0.00	0.01	0.00	0.00	0.03	0.00	0.02	0.02	0.01
84	**Best case (normalised) - Assessor Averages**									
85	Outcome 1 - nutrients	0.26	0.00	0.36	0.25	0.00	0.00	0.34	0.25	0.25
86	Outcome 1 - sediment	0.83	0.87	0.00	0.83	1.06	0.00	0.00	0.84	0.84
87	Outcome 1 - pesticides	0.61	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00
88	Outcome 3 - Corals midshelf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	Outcome 2 - Natural wetlands	0.50	0.46	0.45	0.44	0.53	0.00	0.53	0.28	0.78
90	**Worst case (normalised) - Assessor Averages**									
91	Outcome 1 - nutrients	-0.51	0.00	-0.51	-0.53	0.00	0.00	-0.57	-0.61	-0.61
92	Outcome 1 - sediment	-1.52	-1.53	0.00	-1.52	-1.51	0.00	0.00	-1.92	-1.92
93	Outcome 1 - pesticides	-0.69	0.00	0.00	-0.71	0.00	0.00	0.00	0.00	0.00
94	Outcome 3 - Corals midshelf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	Outcome 2 - Natural wetlands	-0.18	-0.17	-0.18	-0.18	-0.19	0.00	-0.19	-0.13	-0.22
96										

The ***objective benefits*** for each intervention are then calculated (following equation 3 in the Summary Report (Section 2.2); rows 100 - 115), using the average of the normalised attribute benefits calculated in rows 78 – 95 and the predictive weights (in the Predictive weights worksheet), e.g. “Burd benefit” rows 100 - 115:

1	**Normalised attribute benefit (following eqn 4&5)**	•								
2		**Burdekin**								
3		•	•	•	•	•	-	•	•	•
4		1: Smartcane	2: Expansion	3: Reverse te	4: Farmer le	5: Erosion co	6: Crown-of-	7: Reef Bonu	8: Rehabilita	9: One million trees f
98	**Objectives benefits (per region) following eqn 3**									
99	**Most Likely**									
100	Seagrass	0.04	0.03	0.03	0.04	0.09	0.00	0.01	0.03	0.03
101	Inner-coral reef	0.04	0.03	0.06	0.04	0.09	0.00	0.02	0.03	0.03
102	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
103	Wetlands	0.00	0.01	0.00	0.00	0.03	0.00	0.02	0.02	0.01
104										
105	**Best case**									
106	Seagrass	1.06	0.87	0.11	1.07	1.06	0.00	0.10	0.91	0.91
107	Inner-coral reef	1.08	0.87	0.18	1.09	1.06	0.00	0.17	0.96	0.96
108	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
109	Wetlands	0.50	0.46	0.45	0.44	0.53	0.00	0.53	0.28	0.78
110										
111	**Worst case**									
112	Seagrass	-1.85	-1.53	-0.15	-1.85	-1.51	0.00	-0.17	-2.11	-2.11
113	Inner-coral reef	-1.91	-1.53	-0.25	-1.92	-1.51	0.00	-0.28	-2.23	-2.23
114	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	Wetlands	-0.18	-0.17	-0.18	-0.18	-0.19	0.00	-0.19	-0.13	-0.22
116										

The ***normalised objective benefits*** for each intervention are then calculated (rows 126 – 141) using the objective benefits for each intervention (rows 100 – 115) divided by the range bounded by the best and worst case benefits for a given objective within a given region (*best case objective benefit – worst case objective benefit*; rows 118 - 121). This calculation follows equation 2 in the Summary Report (Section 2.2). e.g., “Burd benefit” rows 118 - 141:

116										
117		Best	Worst	difference						
118	**Seagrass**	1.07	-2.11	3.18						
119	**Inner-coral reef**	1.09	-2.23	3.32						
120	**Mid-shelf coral reef**	0.00	0.00	0.00						
121	**Wetlands**	0.78	-0.22	1.00						
122										
123										
124	**Objectives NORMALISED benefits (per region) following eqn 2**									
125	**Most Likely**	1: Smartcane	2: Expansion	3: Reverse te	4: Farmer led	5: Erosion co	6: Crown-of-	7: Reef Bonu	8: Rehabilita	9: One million trees
126	Seagrass	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01
127	Inner-coral reef	0.01	0.01	0.02	0.01	0.03	0.00	0.01	0.01	0.01
128	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129	Wetlands	0.00	0.01	0.00	0.00	0.03	0.00	0.02	0.02	0.01
130										
131	**Best case**									
132	Seagrass	0.33	0.27	0.03	0.34	0.33	0.00	0.03	0.29	0.29
133	Inner-coral reef	0.33	0.26	0.05	0.33	0.32	0.00	0.05	0.29	0.29
134	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135	Wetlands	0.50	0.46	0.45	0.44	0.53	0.00	0.53	0.28	0.78
136										
137	**Worst case**									
138	Seagrass	-0.58	-0.48	-0.05	-0.58	-0.48	0.00	-0.05	-0.66	-0.66
139	Inner-coral reef	-0.58	-0.46	-0.08	-0.58	-0.46	0.00	-0.09	-0.67	-0.67
140	Mid-shelf coral reef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
141	Wetlands	-0.18	-0.17	-0.18	-0.18	-0.19	0.00	-0.19	-0.13	-0.22
142										

These worksheet also include graph data and graphs of the normalised most likely and best case attribute and objectives benefits for each region (Figures 2 – 7 in the Summary Report).

GBR objectives benefit worksheet

There is no input required on this sheet. This worksheet calculates the ***summation of the normalised objective benefits*** (from the previous regional benefit worksheets) in each of GBRWHA regions (following the numerator of equation 1 in the Summary Report), e.g.:

	A	B	C	D	E	F	G	H	I	J	K
1	**SUM of objectives NORMALISED benefits across regions (start of eqn3)**	1: Smartcane best management practice (BMP) accreditation	2: Expansion of holistic grazing pilot project	3: Reverse tender for nitrogen use efficiency of sugar cane farms	4: Farmer led innovative cane management practices (game changer)	5: Erosion control in priority grazing landscapes (gully restoration)	6: Crown-of-thorns starfish (COTS) tactical control	7: Reef Bonus trial	8: Rehabilitation of coastal ecosystems	9: One million trees for the reef	
2	**Most Likely**										
3	Seagrass	0.011428088	0.010189983	0.01054323	0.070291788	0.136223843	0	0.006807472	0.011598205	0.01183306	
4	Inner-coral reef	0.012093202	0.009760684	0.016831749	0.066397519	0.132636761	0	0.010745253	0.011254306	0.011704238	
5	Mid-shelf coral reef	0	0	0	0	0	0.022605605	0	0	0	
6	Wetlands	0.002584425	0.008614748	0.003445899	0	0.141369242	0	0.036362616	0.11428344	0.040110416	
7											
8	**Best case**										
9	Seagrass	0.332634586	0.272918214	0.03439948	1.561885057	1.484405138	0	0.098272402	0.609330792	1.44289523	
10	Inner-coral reef	0.325350461	0.261420307	0.054917079	1.510953904	1.440681844	0	0.153693842	0.617584855	1.464943463	
11	Mid-shelf coral reef	0	0	0	0	0	0.705168792	0	0	0	
12	Wetlands	0.498506777	0.457686123	0.448850483	2.228612682	2.339291557	0	1.303465621	0.699714168	2.306041206	
13											
14	**Worst case**										
15	Seagrass	-0.579764963	-0.48121275	-0.04794534	-2.342763109	-1.950016582	0	-0.15913197	-1.246923961	-3.091646945	
16	Inner-coral reef	-0.575371667	-0.460939498	-0.076542379	-2.326211145	-1.892896656	0	-0.248932261	-1.272072102	-3.157833859	
17	Mid-shelf coral reef	0	0	0	0	0	-0.294831208	0	0	0	
18	Wetlands	-0.182345509	-0.172339147	-0.175387443	-0.871339789	-0.770415704	0	-0.40983555	-0.265164567	-0.693958794	
19											

This worksheet also includes graph data and graphs of the normalised most likely and best case objectives benefits for the entire GBRWHA (Figures 8a&b in the Summary Report).

CE calc worksheet

This sheet requires value judgments (expressed as preference weights) on the relative importance of each objective in the context of the range of outcomes specified in worksheet #6 “Groups best-worst”. The default is equal weighting (0.25 assigned to each objective).This worksheet calculates ***the cost-effectiveness of each intervention*** following equation 1 of the Summary Report: the summation of the normalised objective benefits across all regions (calculated in GBR objectives benefit worksheet) multiplied by the preference weight assigned to each objective (columns B – E), and then divided by the cost of the intervention (specified in row 3, columns G – O):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1							Most Likely								
2							1: Smartcane	2: Expansion	3: Reverse ter	4: Farmer led	5: Erosion cor	6: Crown-of-t	7: Reef Bonus	8: Rehabilitati	9: One million
3		Seagrass	Inner-cor	Mid-shelf	Wetlands	cost	0.5175	0.9	2.9825	4	5	6.97	2.89	1	7.55
4	Preference weight	0.250	0.250	0.250	0.250	Cost-effectiveness	1.26114563	0.79348378	0.25834768	0.85430817	2.05114923	0.0810818	0.46639568	3.42839877	0.21075402
5						Rank	3	5	7	4	2	9	6	1	8
6															

CE graph data worksheet

There is no input required on this sheet. This worksheet simply transposes the cost-effectiveness estimates in the CE calc worksheet in a format suitable for graphing.

CE chart_normal scale worksheet

This is a figure illustrating the cost-effectiveness estimates for the nine management interventions (presented on a normal scale).

CE chart_log scale worksheet

This is a figure illustrating the cost-effectiveness estimates for the nine management interventions (presented on a log scale).This is Figure ES1 and Figure 9 of the Summary Report.

Ranks worksheet

There is no input required on this sheet. This is the ***rank order of the interventions***, calculated in the CE calc worksheet (row 5), and is shown in Table 8 of the Summary Report.

Random preference weights worksheet

There is no input required on this sheet. This is where ***1000 sets of random preference weights*** were generated for the sensitivity analysis (described in Appendix 8 of the Summary Report).

Sensitivity analysis worksheet

There is no input required on this sheet. This is the ***sensitivity analysis*** conducted to explore the influence of changing the preference weights of the objectives on the ranking of the proposed management interventions derived from the cost-effectiveness model outputs. The final graphs that summarise the sensitivity analysis results are in columns AI – AX, rows 1030 – 1115 (these are Figures 1 – 9 presented in Appendix 8 of the Summary Report).

Appendix 5. Summary of effectiveness of interventions on water quality attributes

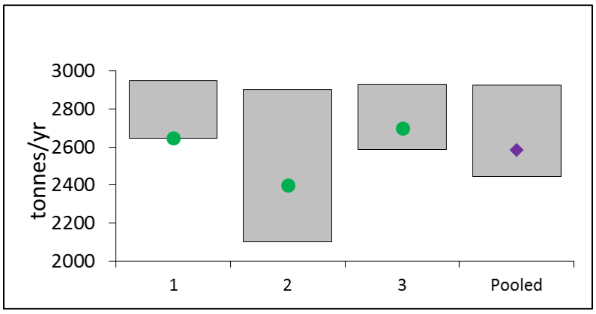
This document summarises Groups 1, 2, and 3's estimates of the effectiveness of each management intervention and "no action" on the three intermediate objectives at 2030:

Nutrients	Load of total dissolved inorganic nitrogen (DIN; tonnes / yr)
Sediment	Load of total suspended solids (millions tonnes / yr). Representing suspended sediment and particulate nutrients
Pesticides	Load of total pesticides (kg / yr)

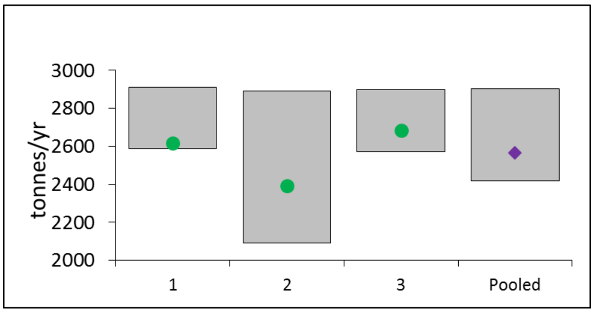
We use the following format to summarise the workshop results:

1) We show a graph of the group estimates (green dots = most likely estimate, upper grey bar = best case estimate, lower grey bar = worst case estimate) and the pooled group estimates (purple diamonds with grey bar) for no action vs each management interventions (for all relevant regions and the water quality attributes), standardised to 80% confidence, e.g.:

No Action (Burdekin) – standardised 80% C.I.s



Intervention 1 (Burdekin) – standardised 80% C.I.s



2) We summarise the change in attributes based on the groups estimates of the intervention – no action, and summarise the average environmental change estimated by the three groups (NB a negative change represents a reduction in the water quality attributes). e.g.:

Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN[1]	-57.90	-307.00	-129.00	-164.63
Pessimistic change in DIN[2]	264.70	493.00	200.00	319.23
Most likely change in DIN[3]	-28.90	-7.00	-15.00	-16.97

3) We also document the original estimates provided by each group. e.g.,:

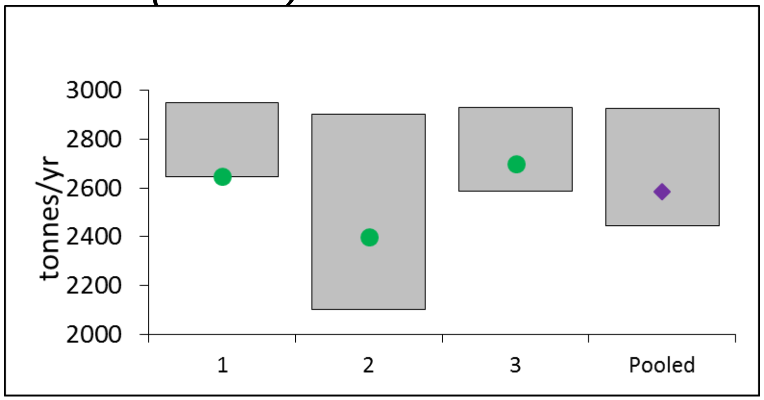
	No Action			**Intervention 1**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2589.1	2093.0	2571.0
Worst case scenario	2911.7	2900.0	2900.0	2911.7	2893.0	2900.0
Most likely estimate	2647.0	2400.0	2700.0	2618.1	2393.0	2685.0
Confidence	70.0	80.0	70.0	80	80	80

[1] Optimistic change = intervention best case – no action most likely estimate
[2] Pessimistic change = intervention worst case– no action most likely estimate
[3] Most likely change = intervention most likely estimate – no action most likely estimate

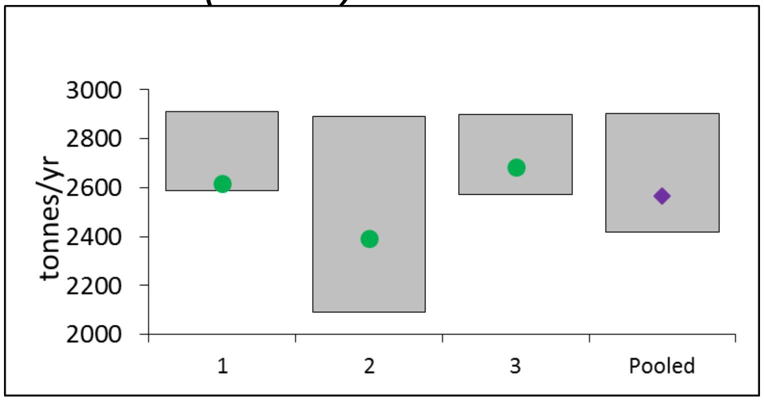
Intervention 1: Smartcane best management practice (BMP) accreditation: Burdekin

1. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 1 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Group estimates (tonnes/yr)			Average (tonnes/yr)
	1	2	3	
Optimistic change in DIN[4]	-57.90	-307.00	-129.00	-164.63
Pessimistic change in DIN[5]	264.70	493.00	200.00	319.23
Most likely change in DIN[6]	-28.90	-7.00	-15.00	-16.97

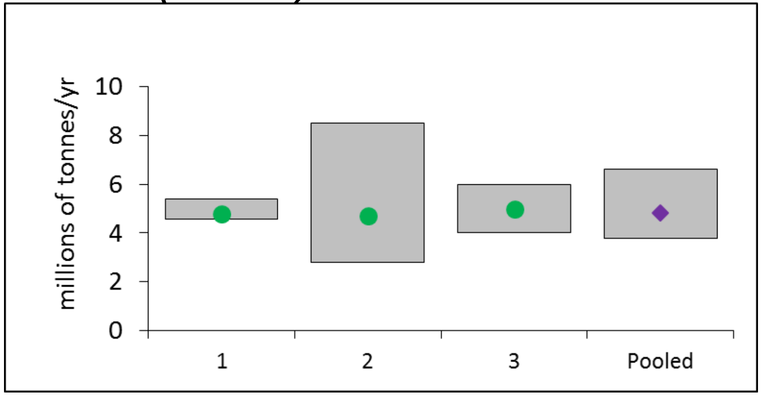
Original estimates provided

	No Action			Intervention 1		
	1	2	3	1	2	3
Best case scenario	2647.0	2100.0	2600.0	2589.1	2093.0	2571.0
Worst case scenario	2911.7	2900.0	2900.0	2911.7	2893.0	2900.0
Most likely estimate	2647.0	2400.0	2700.0	2618.1	2393.0	2685.0
Confidence	70.0	80.0	70.0	80	80	80

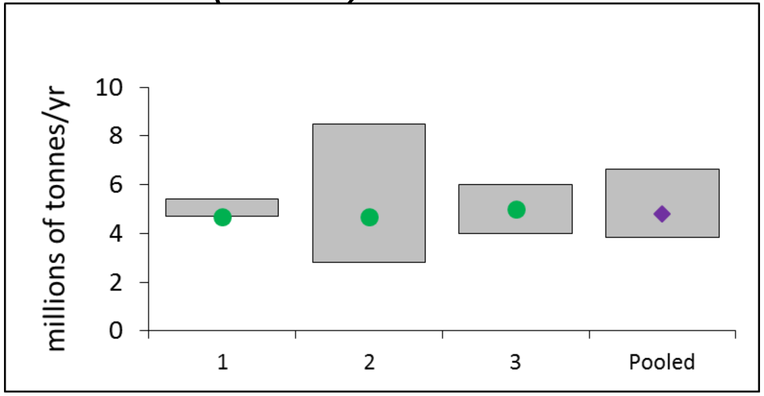
[4] Optimistic change = intervention best case – no action most likely estimate
[5] Pessimistic change = intervention worst case– no action most likely estimate
[6] Most likely change = intervention most likely estimate – no action most likely estimate

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 1 (Burdekin) – standardised 80% C.I.s



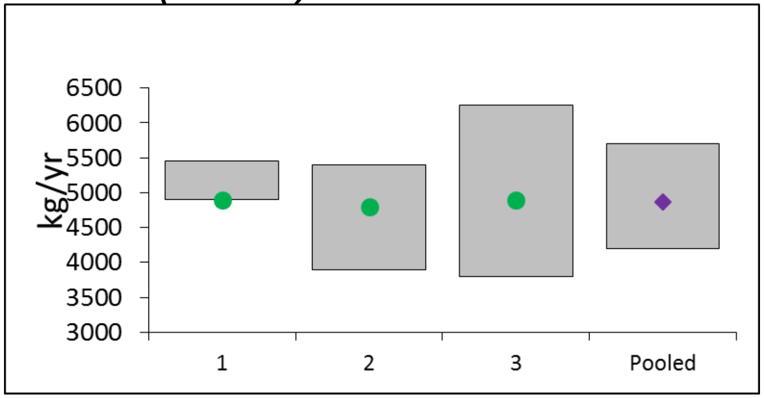
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.076	-1.904	-1.000	-0.993
Pessimistic change in TSS	0.635	3.793	1.000	1.809
Most likely change in TSS	-0.073	-0.005	0.000	-0.026

Original estimates provided

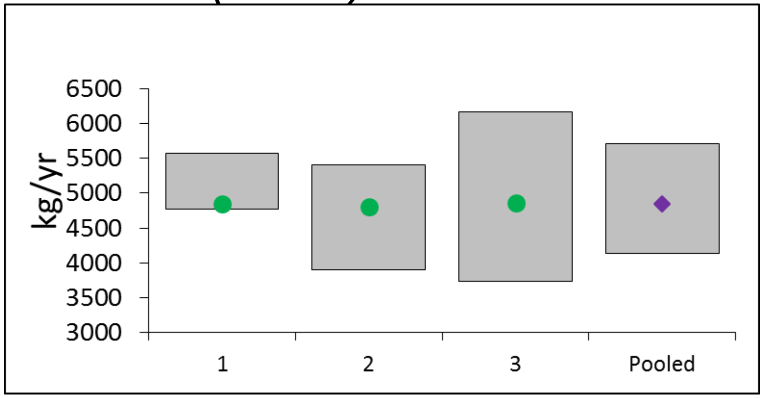
	No Action			**Intervention 1**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4.559	2.350	4.000	4.6942	2.3450	4.0000
Worst case scenario	5.405	9.400	6.000	5.4050	9.3950	6.0000
Most likely estimate	4.770	4.700	5.000	4.6971	4.6950	5.0000
Confidence	80	99	80	80	99	80

3. Pesticides (Load of total pesticides, kg/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 1 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (kg/yr)**			**Average (kg/yr)**
	1	**2**	**3**	
Optimistic change in Pesticides	-136.67	-902.00	-1171.43	-736.70
Pessimistic change in Pesticides	672.67	598.00	1262.86	844.51
Most likely change in Pesticides	-58.00	-2.00	-40.00	-33.33

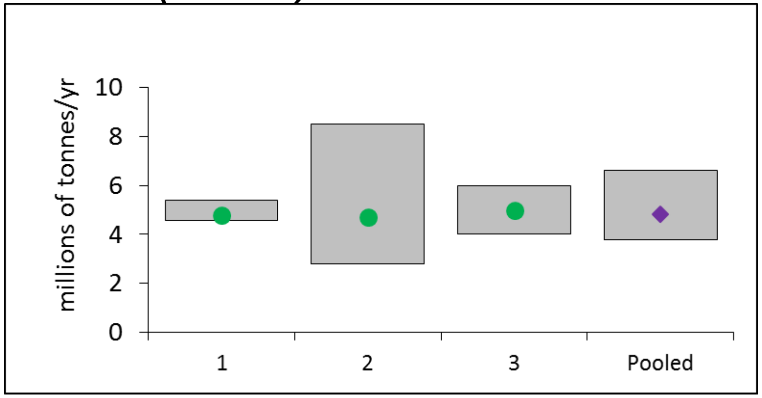
Original estimates provided

	No Action			**Intervention 1**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4900	3900	4000	4783	3898	3870
Worst case scenario	5390	5400	6000	5390	5398	6000
Most likely estimate	4900	4800	4900	4842	4798	4860
Confidence	70	80	65	60	80	70

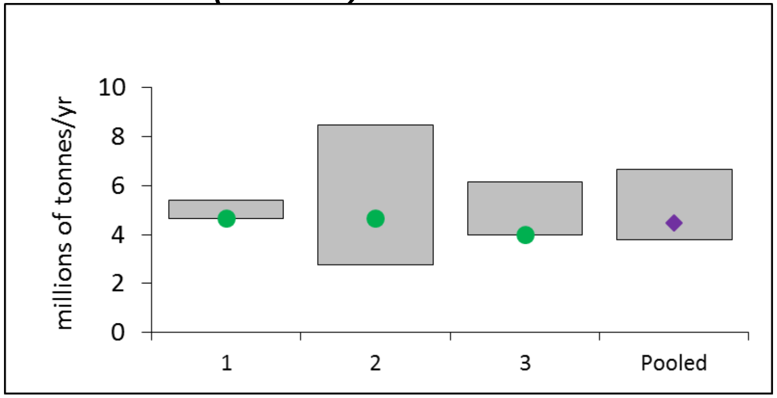
2: Expansion of holistic grazing pilot project: Burdekin

1. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 2 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.11	-1.93	-1.03	-1.02
Pessimistic change in TSS	0.64	3.77	1.13	1.85
Most likely change in TSS	-0.09	-0.02	-1.01	-0.37

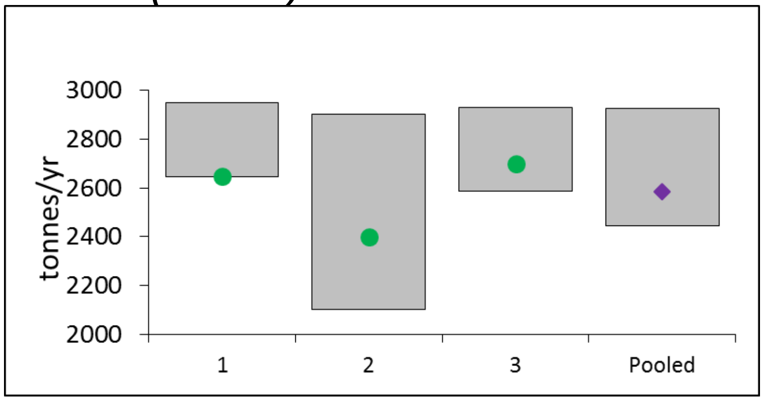
Original estimates provided

	No Action			**Intervention 2**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4.559	2.35	4.00	4.660	2.320	3.976
Worst case scenario	5.405	9.4	6.00	5.405	9.370	6.000
Most likely estimate	4.77	4.7	5.00	4.680	4.680	4.994
Confidence	80	99	80	80	99	75

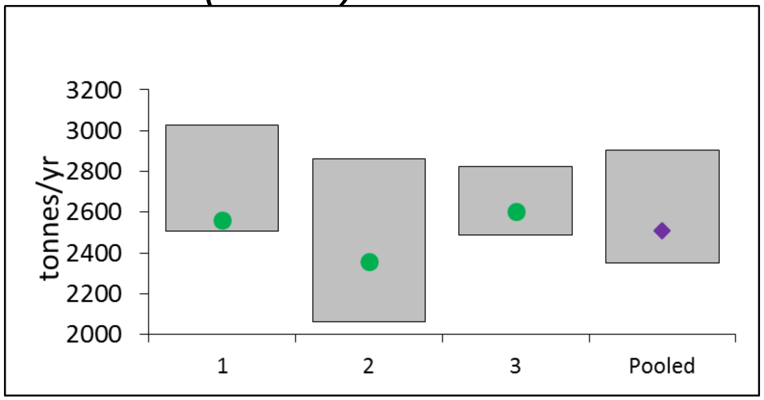
3: Reverse tender for nitrogen use efficiency of sugar cane farms: Burdekin

1. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 3 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-141.33	-340.00	-212.33	-231.22
Pessimistic change in DIN	381.20	460.00	123.67	321.62
Most likely change in DIN	-84.80	-40.00	-95.00	-73.27

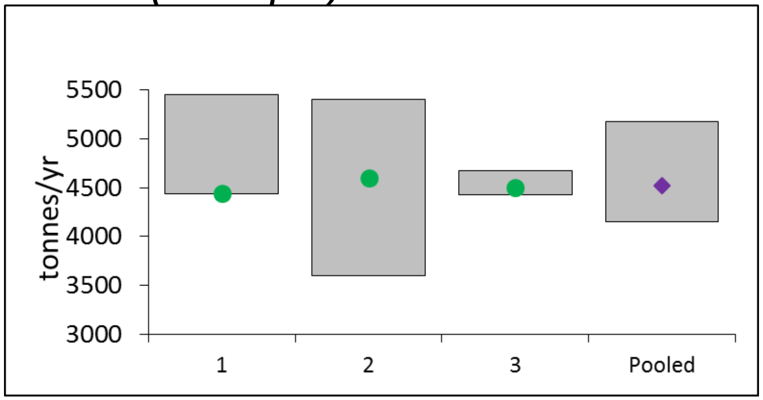
Original estimates provided

	No Action			**Intervention 3**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2519.80	2060.00	2495.00
Worst case scenario	2911.7	2900.0	2900.0	2911.70	2860.00	2810.00
Most likely estimate	2647.0	2400.0	2700.0	2562.20	2360.00	2605.00
Confidence	70	80	70	60	80	75

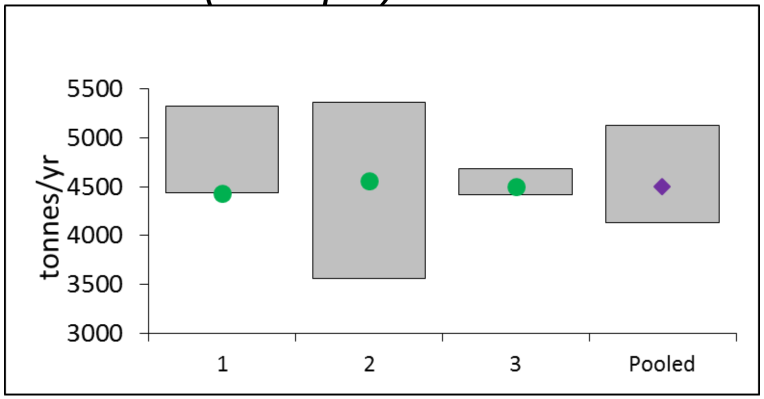
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

1. Nutrients (DIN tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 4 (Wet Tropics) – standardised 80% C.I.s



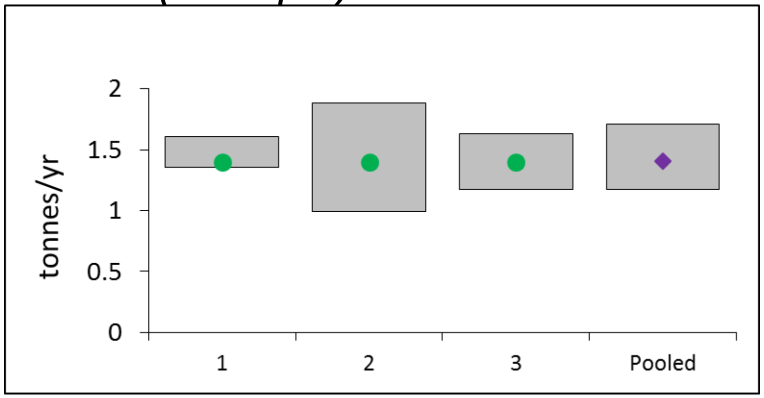
Estimated changes (based on standardised 80% C.I.s)	Group estimates (tonnes/yr)			Average (tonnes/yr)
	1	2	3	
Optimistic change in DIN	-4.80	-1040.00	-87.00	-377.27
Pessimistic change in DIN	887.40	760.00	186.33	611.24
Most likely change in DIN	-2.40	-40.00	-1.00	-14.47

Original estimates provided

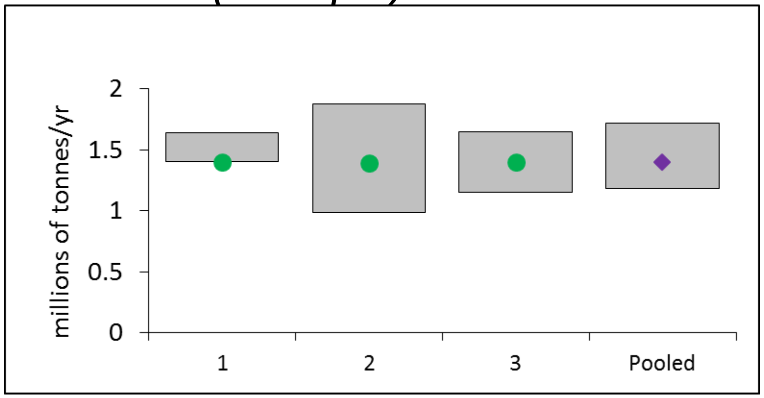
	No Action			Intervention 4		
	1	2	3	1	2	3
Best case scenario	4437.0	3600.0	4437.0	4432.2	3560.0	4434.5
Worst case scenario	5324.4	5400.0	4640.0	5324.4	5360.0	4639.5
Most likely estimate	4437.0	4600.0	4500.0	4434.6	4560.0	4499.0
Confidence	70	80	65	80	80	60

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 4 (Wet Tropics) – standardised 80% C.I.s



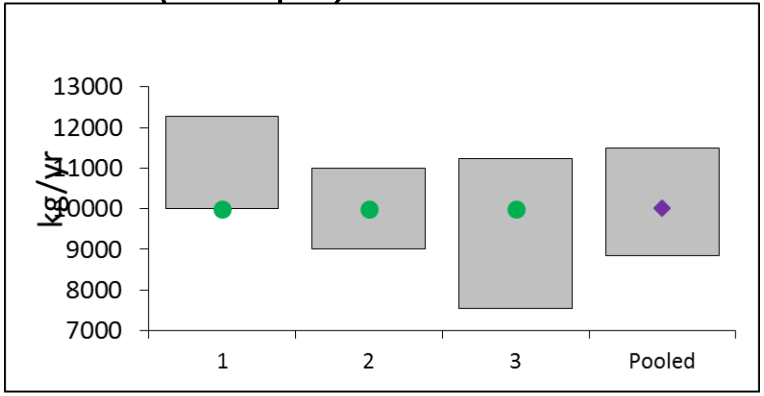
Estimated changes (based on standardised 80% C.I.s)	Group estimates (mill tonnes/yr)			Average (mill tonnes/yr)
	1	**2**	**3**	
Optimistic change in TSS	-0.0008	-0.4140	-0.2463	-0.2204
Pessimistic change in TSS	0.2401	0.4748	0.2462	0.3204
Most likely change in TSS	-0.0004	-0.0100	0.0000	-0.0035

Original estimates provided

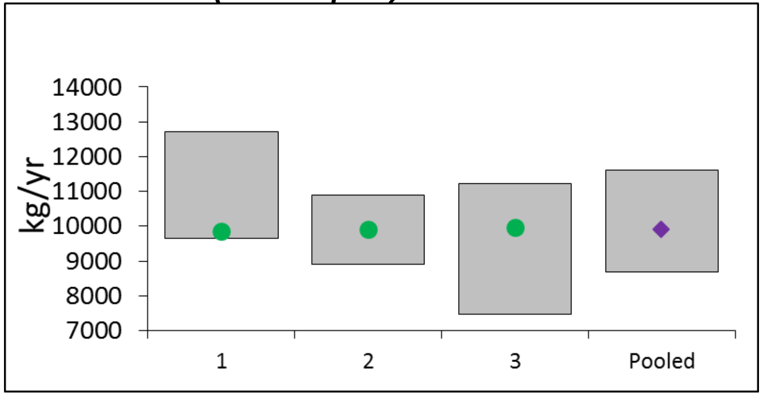
	No Action			Intervention 4		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.358	0.900	1.200	1.399250	0.890000	1.199900
Worst case scenario	1.610	2.000	1.600	1.610000	1.990000	1.600000
Most likely estimate	1.400	1.400	1.400	1.399625	1.390000	1.399970
Confidence	80	99	70	70	99	65

3. Pesticides (Load of total pesticides, kg/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 4 (Wet Tropics) – standardised 80% C.I.s



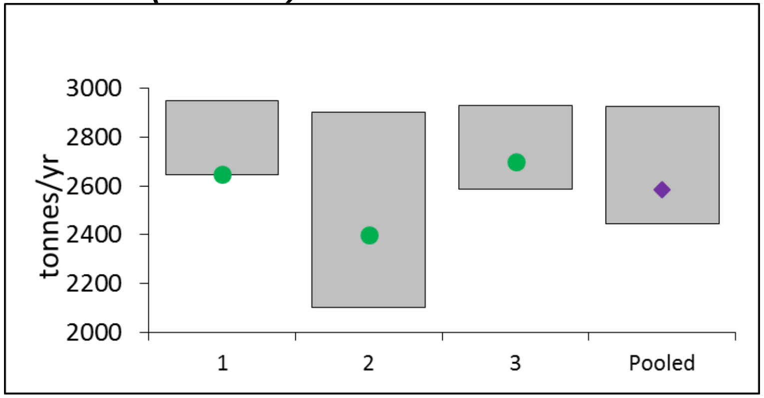
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (kg/yr)**			**Average (kg/yr)**
	1	**2**	**3**	
Optimistic change in Pesticides	-350.00	-1100.00	-2518.46	-1322.82
Pessimistic change in Pesticides	2716.67	900.00	1223.08	1613.25
Most likely change in Pesticides	-150.00	-100.00	-20.00	-90.00

Original estimates provided

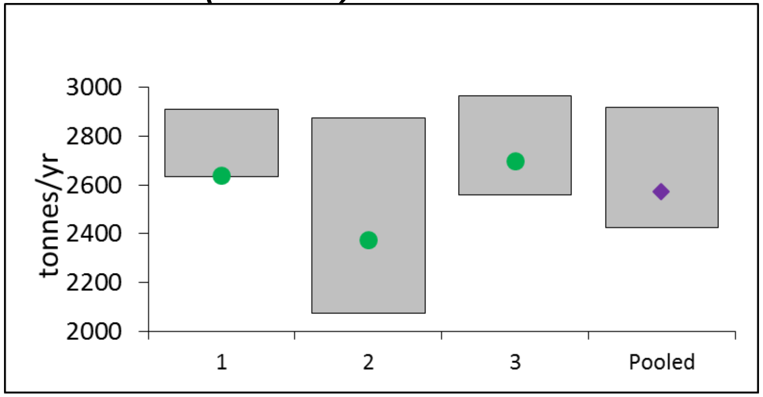
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	10000	9000	8000	9700	8900	7950
Worst case scenario	12000	11000	11000	12000	10900	10990
Most likely estimate	10000	10000	10000	9850	9900	9980
Confidence	70	80	65	60	80	65

1. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 4 (Burdekin) – standardised 80% C.I.s



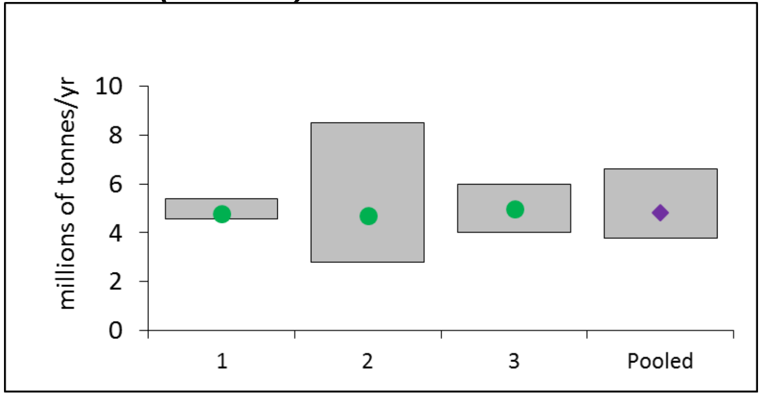
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-11.50	-324.00	-139.93	-158.48
Pessimistic change in DIN	264.70	476.00	265.80	335.50
Most likely change in DIN	-5.80	-24.00	-2.20	-10.67

Original estimates provided

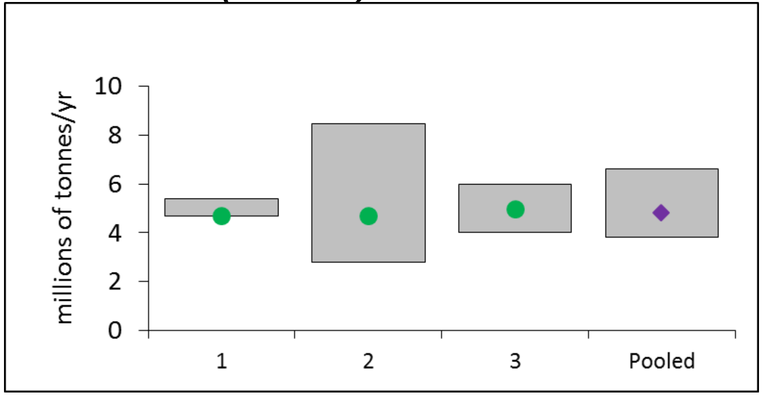
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2635.50	2076.00	2594.50
Worst case scenario	2911.7	2900.0	2900.0	2911.70	2876.00	2898.80
Most likely estimate	2647.0	2400.0	2700.0	2641.20	2376.00	2697.80
Confidence	70	80	70	80	80	60

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 4 (Burdekin) – standardised 80% C.I.s



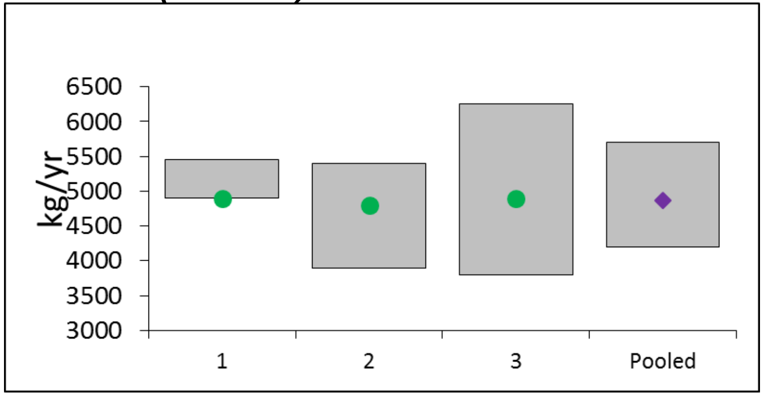
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.0707500	-1.9151515	- 1.0000000	-0.9953005
Pessimistic change in TSS	0.6350000	3.7818182	1.0000000	1.8056061
Most likely change in TSS	-0.0703750	0.0000000	0.0000000	-0.0234583

Original estimates provided

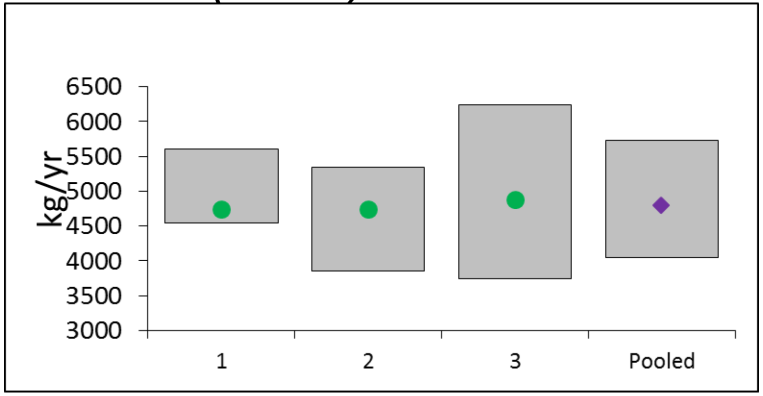
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4.559	2.35	4.00	4.699250	2.330000	4.000000
Worst case scenario	5.405	9.4	6.00	5.405000	9.380000	6.000000
Most likely estimate	4.77	4.7	5.00	4.699625	4.700000	5.000000
Confidence	80	99	80	80	99	80

3. Pesticides (Load of total pesticides, kg/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 4 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (kg/yr)**			**Average (kg/yr)**
	1	**2**	**3**	
Optimistic change in Pesticides	-350.00	-950.00	-1153.23	-817.74
Pessimistic change in Pesticides	703.33	550.00	1347.69	867.01
Most likely change in Pesticides	-150.00	-50.00	-16.00	-72.00

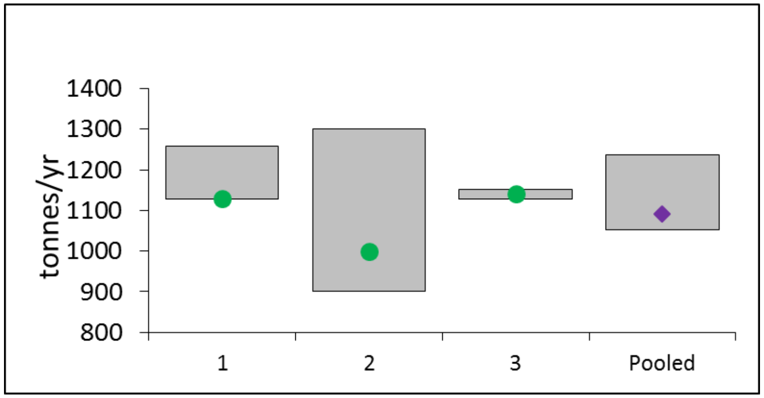
Original estimates provided

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4900	3900	4000	4600	3850	3960
Worst case scenario	5390	5400	6000	5390	5350	5992
Most likely estimate	4900	4800	4900	4750	4750	4884
Confidence	70	80	65	60	80	65

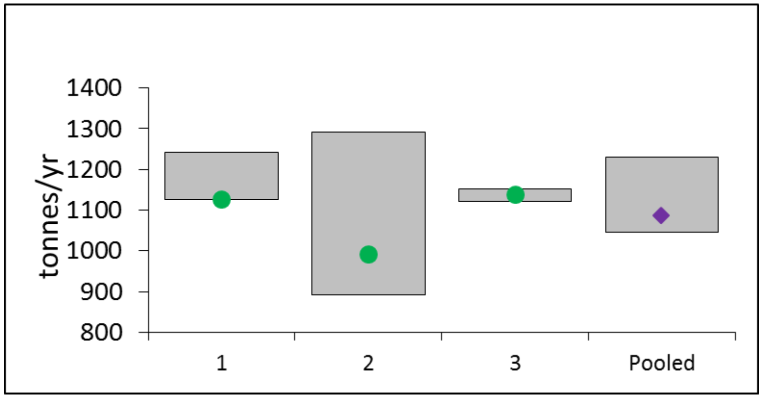
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

1. Nutrients (DIN tonnes/year)

No Action (Mackay Whitsunday) – standardised 80% C.I.s



Intervention 4 (Mackay Whitsunday) – standardised 80% C.I.s



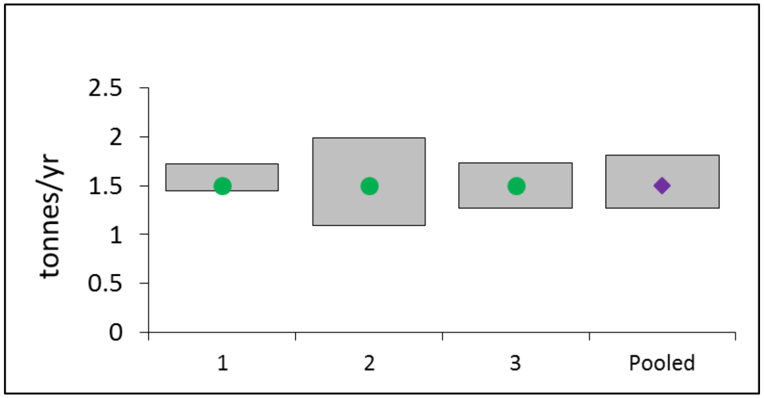
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-4.00	-108.00	-17.67	-43.22
Pessimistic change in DIN	112.90	292.00	13.00	139.30
Most likely change in DIN	-2.50	-8.00	-1.00	-3.83

Original estimates provided

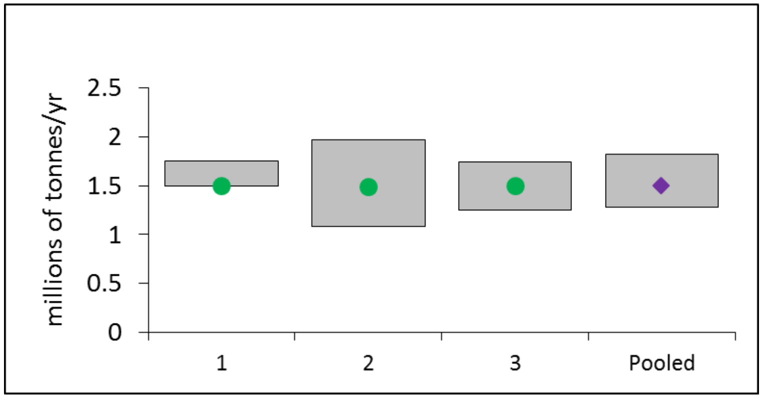
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1129.0	900.0	1129.0	1125.0	892.0	1126.5
Worst case scenario	1241.9	1300.0	1150.0	1241.9	1292.0	1149.5
Most likely estimate	1129.0	1000.0	1140.0	1126.5	992.0	1139.0
Confidence	70	80	70	80	80	60

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Mackay Whitsunday) – standardised 80% C.I.s



Intervention 4 (Mackay Whitsunday) – standardised 80% C.I.s



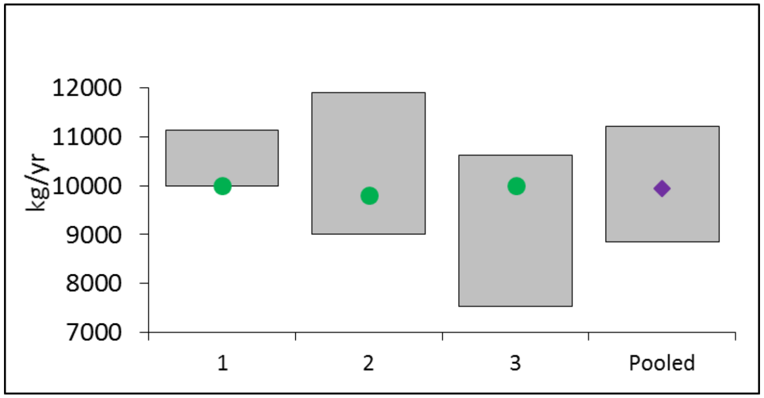
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.00080	-0.41404	-0.24627	-0.22037
Pessimistic change in TSS	0.25720	0.47485	0.24616	0.32607
Most likely change in TSS	-0.00038	-0.01000	-0.00003	-0.00347

Original estimates provided

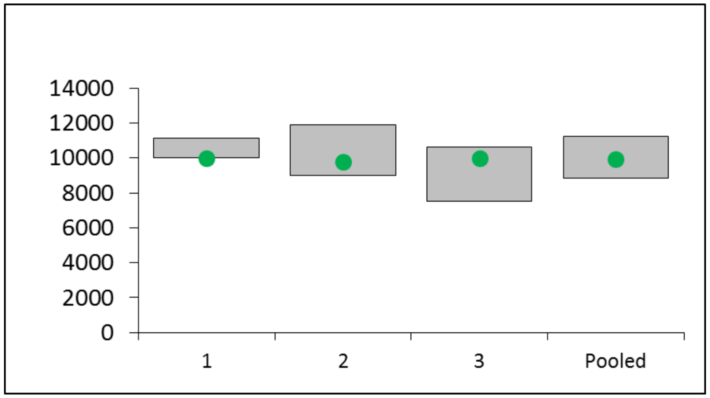
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.445	1.000	1.300	1.499250	0.990000	1.299900
Worst case scenario	1.725	2.100	1.700	1.725000	2.090000	1.700000
Most likely estimate	1.500	1.500	1.500	1.499625	1.490000	1.499970
Confidence	80	99	70	70	99	65

3. Pesticides (Load of total pesticides, kg/year)

No Action (Mackay Whitsunday) – standardised 80% C.I.s



Intervention 4 (Mackay Whitsunday) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (kg/yr)**			**Average (kg/yr)**
	1	**2**	**3**	
Optimistic change in Pesticides	-350.00	-900.00	-2518.46	-1256.15
Pessimistic change in Pesticides	1383.33	2000	607.69	1330.34
Most likely change in Pesticides	-150.00	-100	-20.00	-90.00

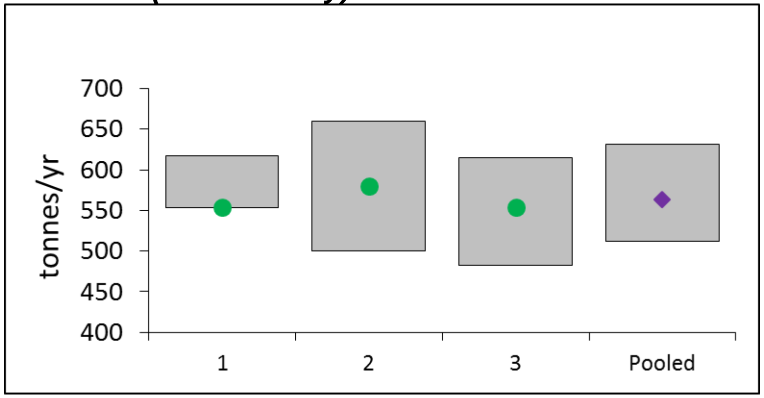
Original estimates provided

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	10000	9000	8000	9700	8900	7950
Worst case scenario	11000	11900	10500	11000	11800	10490
Most likely estimate	10000	9800	10000	9850	9700	9980
Confidence	70	80	65	60	80	65

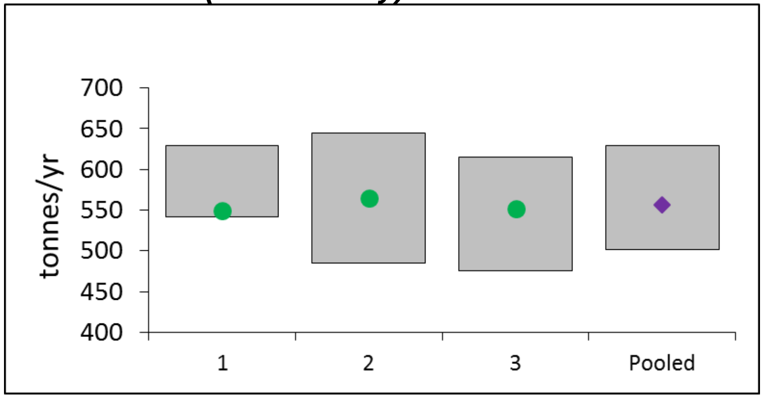
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

1. Nutrients (DIN tonnes/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 4 (Burnett Mary) – standardised 80% C.I.s



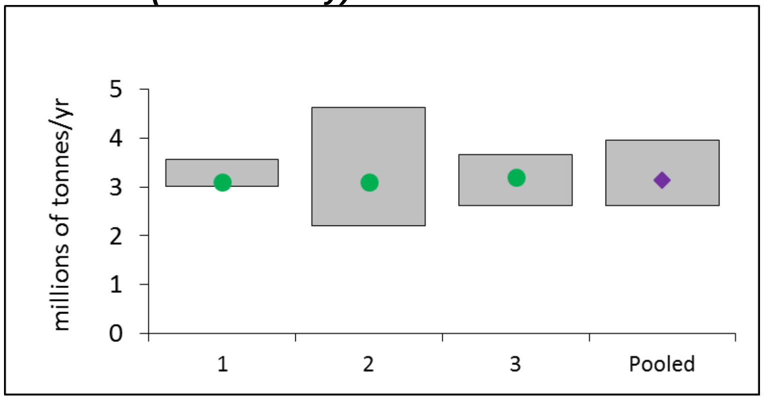
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-11.90	-95.00	-78.00	-61.63
Pessimistic change in DIN	75.57	65.00	60.67	67.08
Most likely change in DIN	-5.10	-15.00	-2.00	-7.37

Original estimates provided

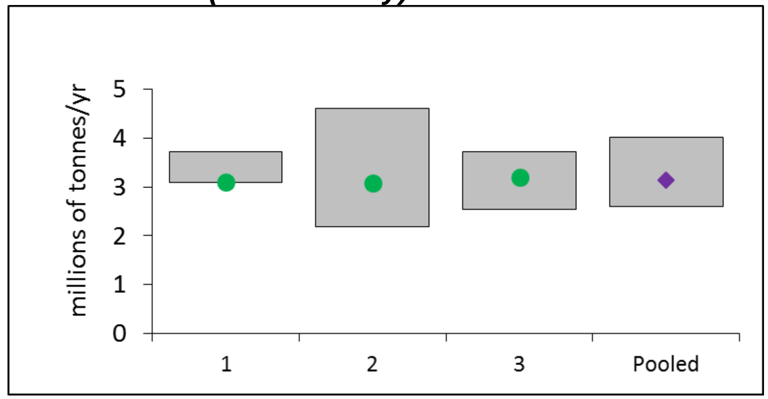
	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	554.0	500.0	500.0	543.80	485.00	495.00
Worst case scenario	609.4	660.0	600.0	609.40	645.00	599.00
Most likely estimate	554.0	580.0	554.0	548.90	565.00	552.00
Confidence	70	80	60	60	80	60

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 4 (Burnett Mary) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Group estimates (mill tonnes/yr)			Average (mill tonnes/yr)
	1	**2**	**3**	
Optimistic change in TSS	-0.00088	-0.90889	-0.66679	-0.52552
Pessimistic change in TSS	0.62013	1.51535	0.53334	0.88961
Most likely change in TSS	-0.00038	-0.02000	-0.00003	-0.00680

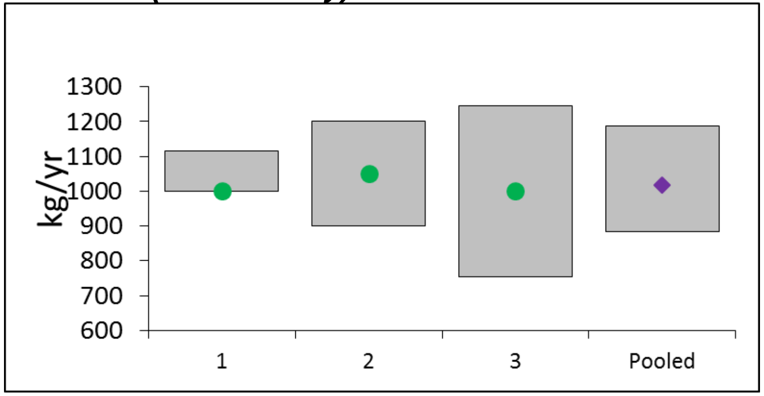
Original estimates provided

	No Action			Intervention 4		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.0070	2.0000	2.7000	3.099250	1.980000	2.699900
Worst case scenario	3.5650	5.0000	3.6000	3.565000	4.980000	3.600000
Most likely estimate	3.1000	3.1000	3.2000	3.099625	3.080000	3.199970
Confidence	80	99	70	60	99	60

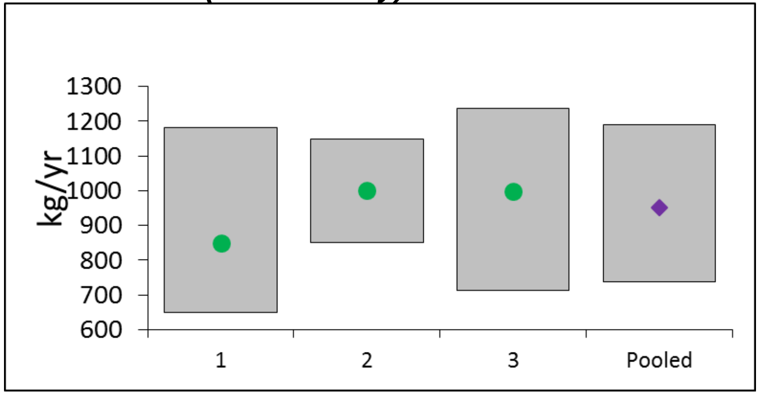
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

3. Pesticides (Load of total pesticides, kg/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 4 (Burnett Mary) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (kg/yr)**			**Average (kg/yr)**
	1	**2**	**3**	
Optimistic change in Pesticides	-350.00	-200	-286.47	-278.82
Pessimistic change in Pesticides	183.33	100	238.45	173.93
Most likely change in Pesticides	-150.00	-50	-1.30	-67.1

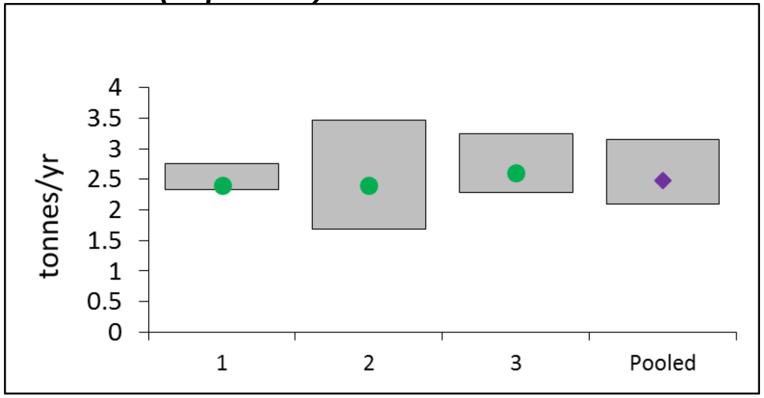
Original estimates provided

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1000	900	800	700	850	767
Worst case scenario	1100	1200	1200	1100	1150	1193.5
Most likely estimate	1000	1050	1000	850	1000	998.7
Confidence	70	80	65	60	80	65

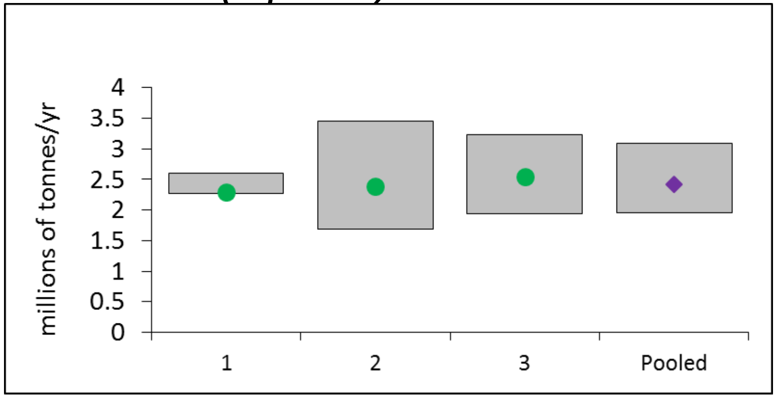
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary

1. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Cape York) – standardised 80% C.I.s



Intervention 5 (Cape York) – standardised 80% C.I.s



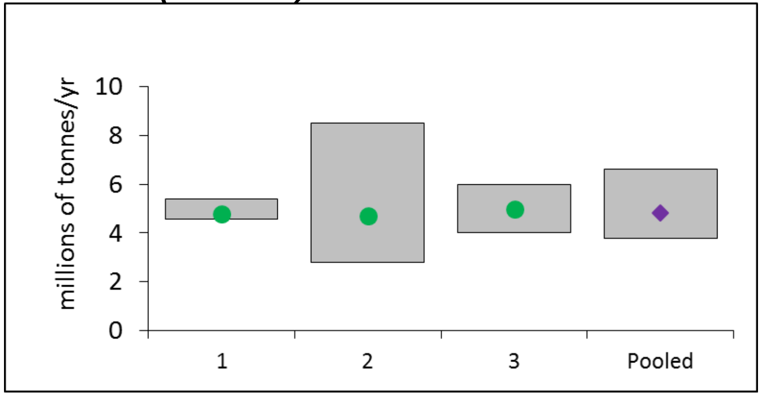
Estimated changes (based on standardised 80% C.I.s)	Group estimates (mill tonnes/yr)			Average (mill tonnes/yr)
	1	**2**	**3**	
Optimistic change in TSS	-0.13	-0.72	-0.67	-0.50
Pessimistic change in TSS	0.19	1.06	0.63	0.63
Most likely change in TSS	-0.10	-0.01	-0.06	-0.06

Original estimates provided

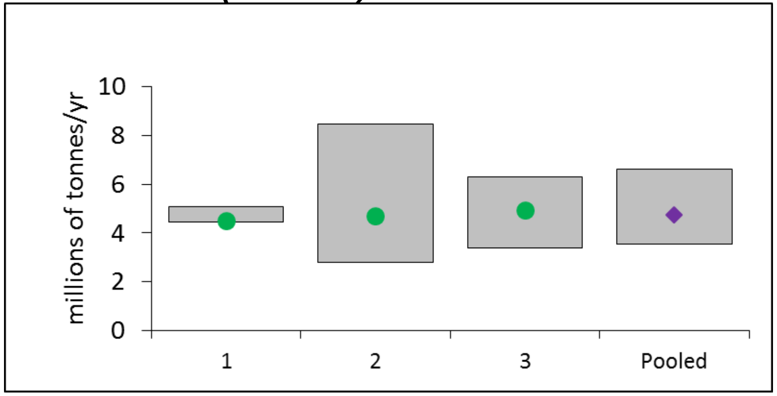
	No Action			Intervention 5		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.328	1.600	2.400	2.2800	1.5900	2.1600
Worst case scenario	2.760	3.600	3.000	2.5200	3.5900	2.9700
Most likely estimate	2.400	2.400	2.600	2.3000	2.3900	2.5380
Confidence	80	90	50	60	90	50

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 5 (Burdekin) – standardised 80% C.I.s



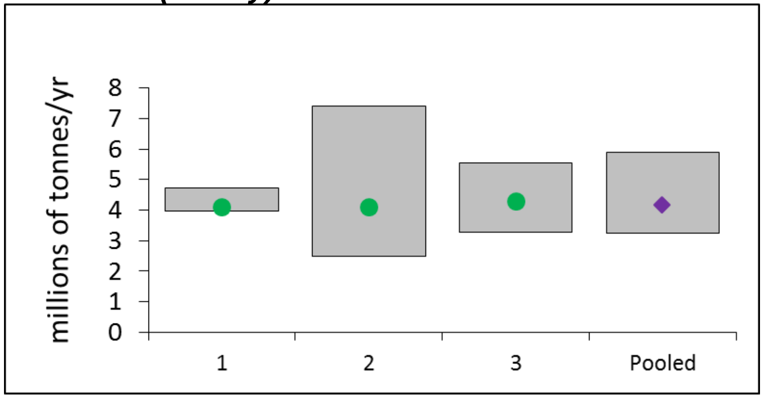
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.32	-1.91	-1.61	-1.28
Pessimistic change in TSS	0.31	3.79	1.32	1.80
Most likely change in TSS	-0.27	-0.01	-0.06	-0.11

Original estimates provided

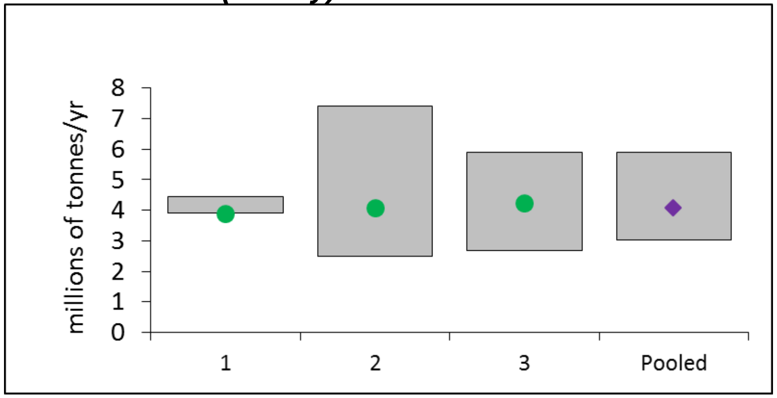
	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4.559	2.35	4.00	4.4650	2.3400	3.7800
Worst case scenario	5.405	9.4	6.00	4.9350	9.3900	5.9720
Most likely estimate	4.77	4.7	5.00	4.5000	4.6900	4.9380
Confidence	80	99	80	60	99	60

3. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Fitzroy) – standardised 80% C.I.s



Intervention 5 (Fitzroy) – standardised 80% C.I.s



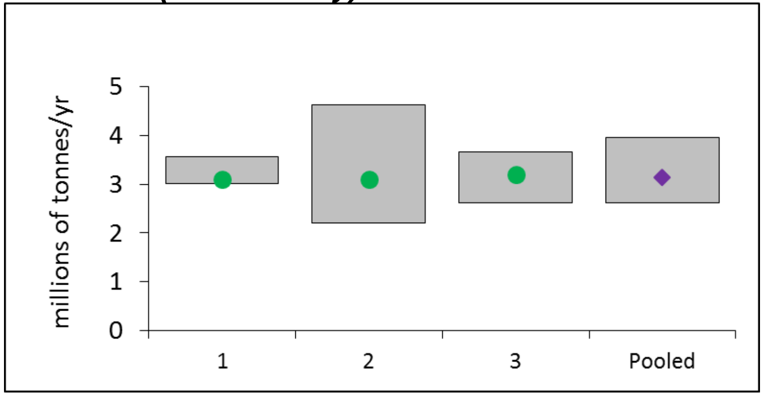
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.21	-1.63	-1.63	-1.15
Pessimistic change in TSS	0.34	3.30	1.59	1.74
Most likely change in TSS	-0.20	-0.01	-0.06	-0.09

Original estimates provided

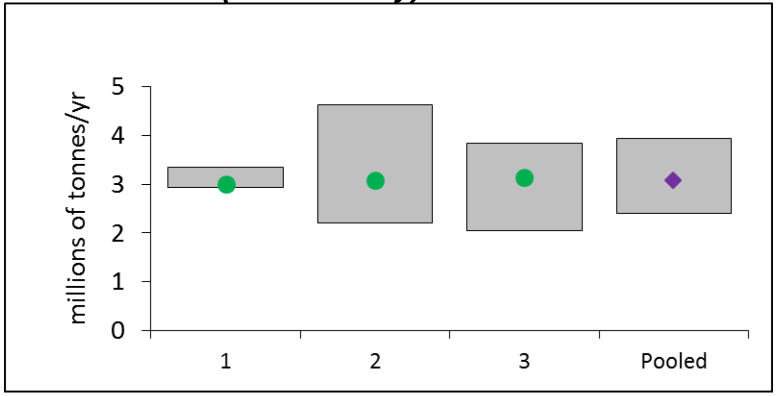
	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.977	2.100	3.400	3.8950	2.0900	3.1600
Worst case scenario	4.715	8.200	5.400	4.3050	8.1900	5.3720
Most likely estimate	4.100	4.100	4.300	3.9000	4.0900	4.2380
Confidence	80	99	70	60	99	55

4. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 5 (Burnett Mary) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.17	-0.90	-1.15	-0.74
Pessimistic change in TSS	0.24	1.53	0.63	0.80
Most likely change in TSS	-0.10	-0.01	-0.06	-0.06

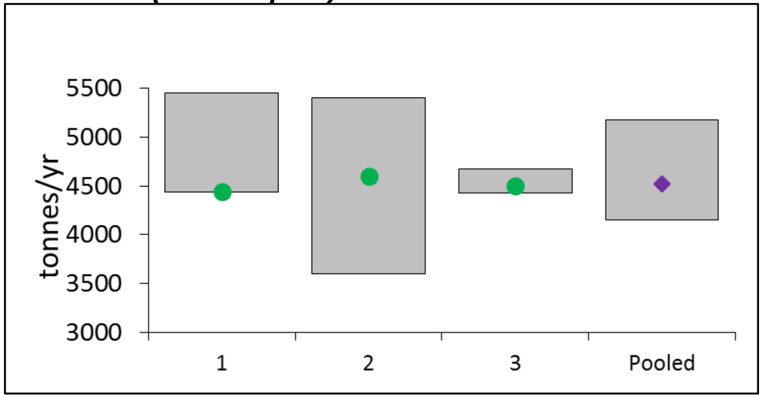
Original estimates provided

	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.0070	2.0000	2.7000	2.9450	1.9900	2.4600
Worst case scenario	3.5650	5.0000	3.6000	3.2550	4.9900	3.5720
Most likely estimate	3.1000	3.1000	3.2000	3.0000	3.0900	3.1380
Confidence	80	99	70	60	99	50

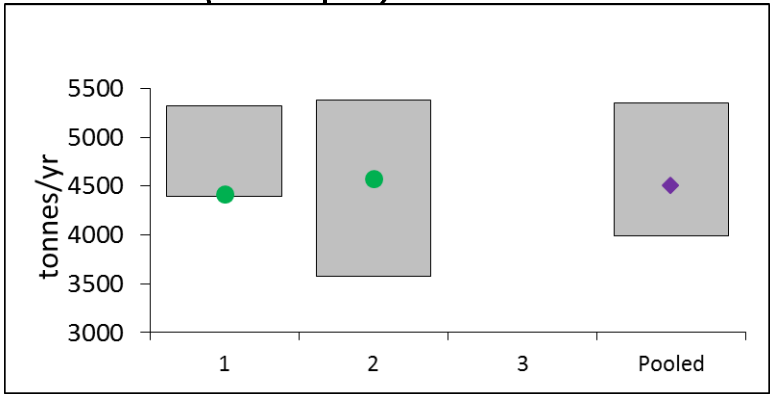
7: Reef Bonus trial: Wet Tropics and Burdekin

1. Nutrients (DIN tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 7 (Wet Tropics) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-40.00	-1020.00		-530.00
Pessimistic change in DIN	887.40	780.00		833.70
Most likely change in DIN	-20.00	-20.00		-20.00

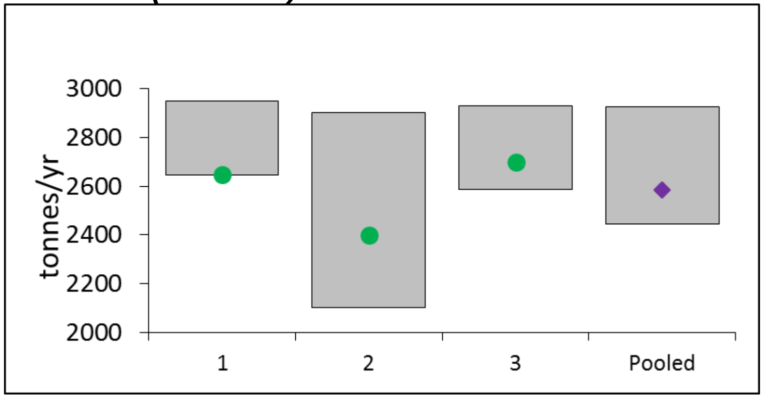
Group 3 did not provide estimates for DIN levels in Wet Tropics. Comment provided: “chosen not to provide as no info plus goal refers only to Burdekin”

Original estimates provided

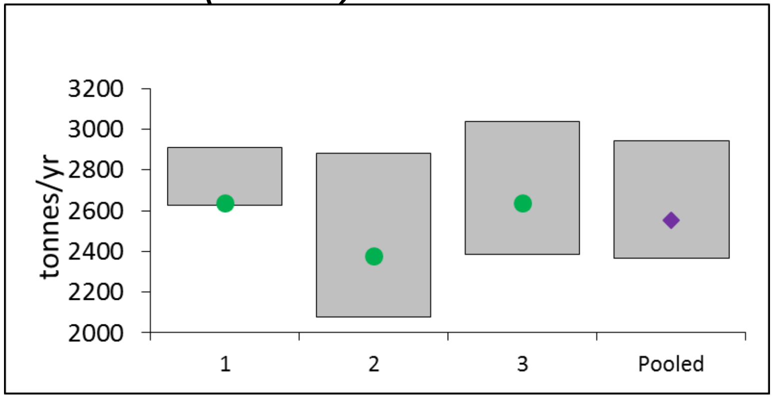
	No Action			**Intervention 7**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4437.0	3600.0	4437.0	4397	3580	
Worst case scenario	5324.4	5400.0	4640.0	5324	5380	
Most likely estimate	4437.0	4600.0	4500.0	4417	4580	
Confidence	70	80	65	80	80	

2. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 7 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-18.30	-320.00	-316.00	-218.10
Pessimistic change in DIN	264.70	480.00	340.00	361.57
Most likely change in DIN	-9.20	-20.00	-60.00	-29.73

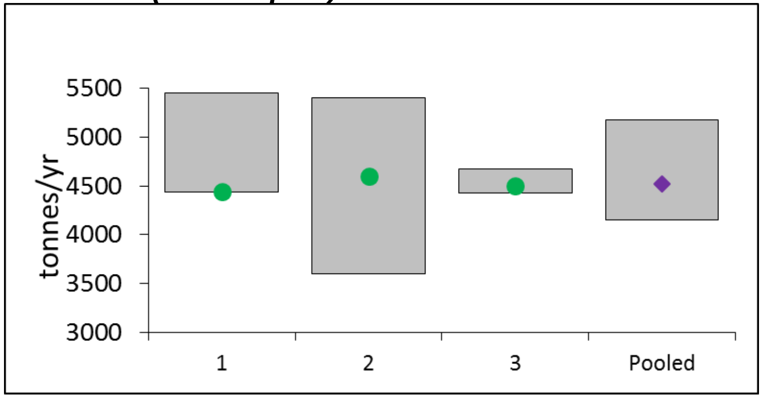
Original estimates provided

	No Action			**Intervention 7**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2628.7	2080.0	2480.0
Worst case scenario	2911.7	2900.0	2900.0	2911.7	2880.0	2890.0
Most likely estimate	2647.0	2400.0	2700.0	2637.8	2380.0	2640.0
Confidence	70	80	70	80	80	50

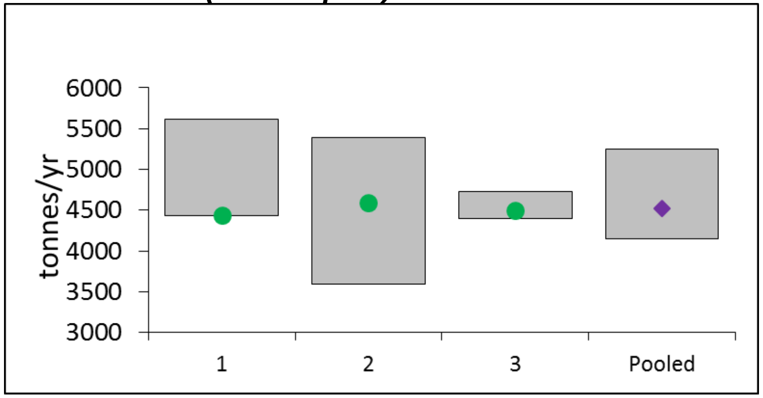
8: Rehabilitation of coastal ecosystems: Wet Tropics and Burdekin

1. Nutrients (DIN tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 4 (Wet Tropics) – standardised 80% C.I.s



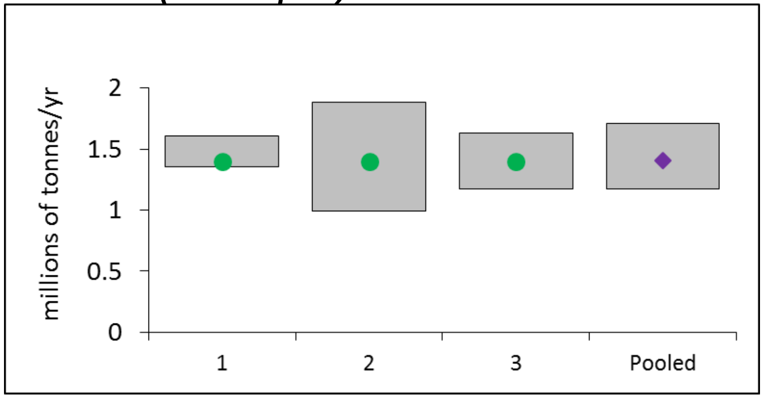
Estimated changes (based on standardised 80% C.I.s) (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.23	-1005.00	-100.96	-368.73
Pessimistic change in DIN	1183.23	795.00	225.60	734.61
Most likely change in DIN	-0.10	-5.00	0.00	-1.70

Original estimates provided

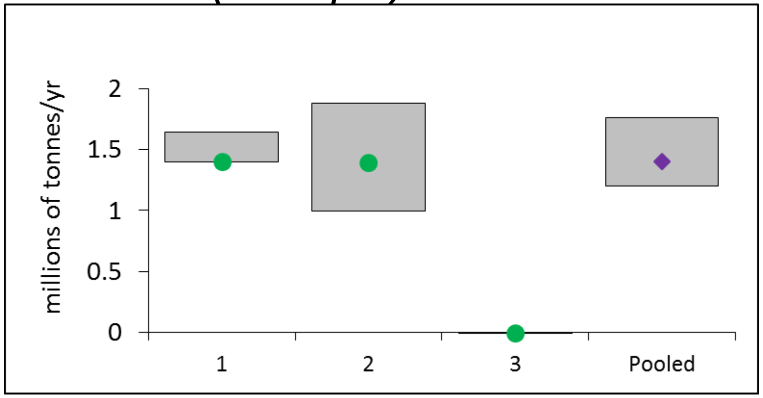
	No Action			**Intervention 8**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4437.0	3600.0	4437.0	4436.80	3595.00	4436.90
Worst case scenario	5324.4	5400.0	4640.0	5324.40	5395.00	4641.00
Most likely estimate	4437.0	4600.0	4500.0	4436.90	4595.00	4500.00
Confidence	70	80	65	60	80	50

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 8 (Wet Tropics) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Group estimates (mill tonnes/yr)			Average (mill tonnes/yr)
	1	2	3	
Optimistic change in TSS	-0.00011	-0.40654		-0.20333
Pessimistic change in TSS	0.24000	0.48235		0.36118
Most likely change in TSS	-0.00002	-0.00250		-0.00126

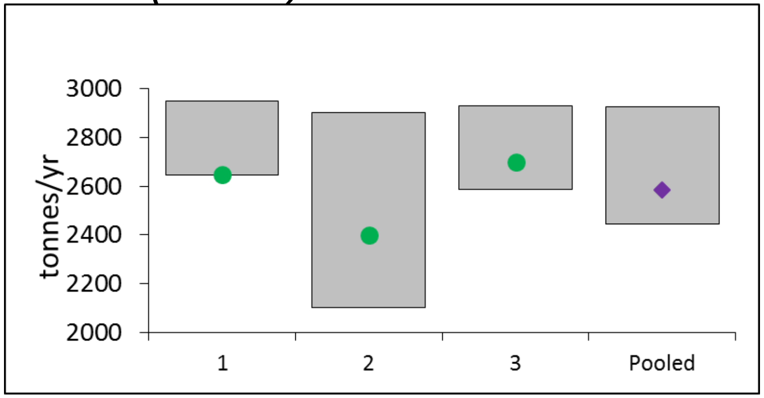
Group 3 did not provide estimates for TSS levels in any region. Comment provided: “insufficient information to quantify estimates”

Original estimates provided

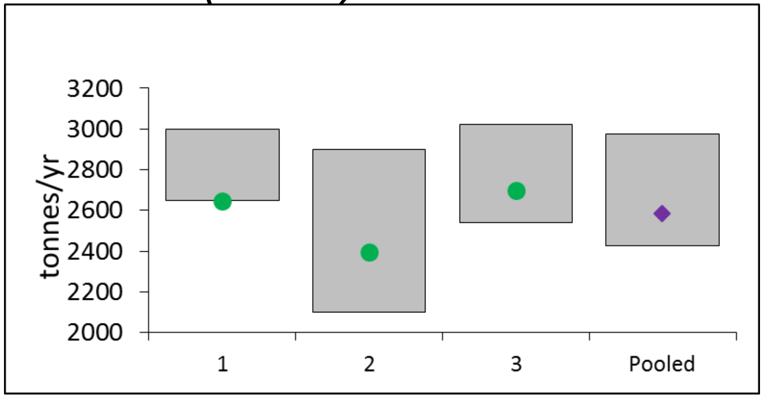
	No Action			Intervention 8		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.3580	0.9000	1.2000	1.399900	0.897500	
Worst case scenario	1.6100	2.0000	1.6000	1.610000	1.997500	
Most likely estimate	1.4000	1.4000	1.4000	1.399975	1.397500	
Confidence	80	99	70	70	99	

3. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 8 (Burdekin) – standardised 80% C.I.s



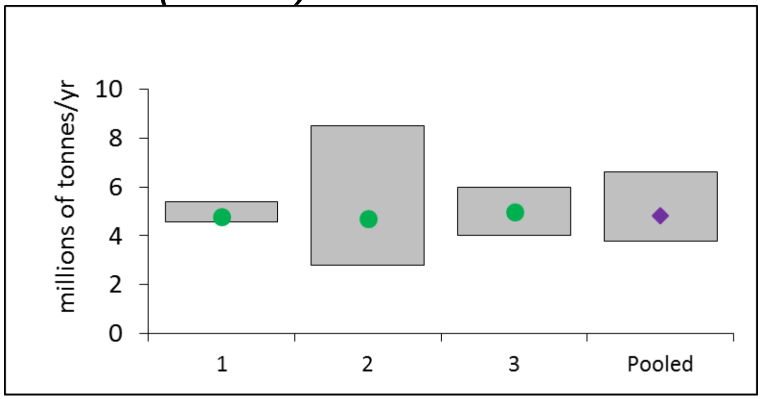
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.23	-302.00	-160.40	-154.21
Pessimistic change in DIN	352.97	498.00	321.60	390.86
Most likely change in DIN	-0.10	-2.00	0.00	-0.70

Original estimates provided

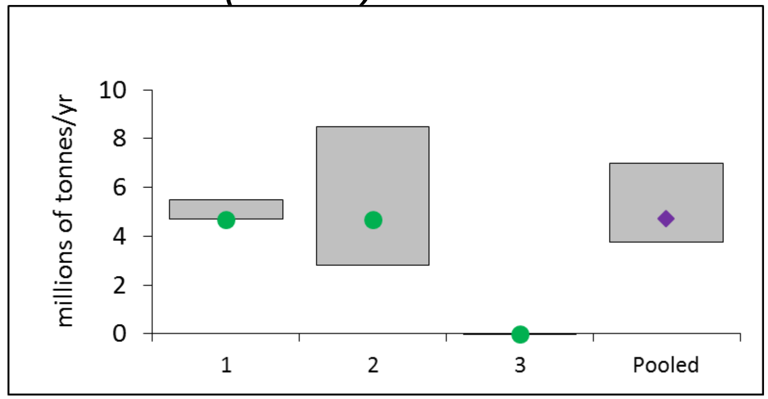
	No Action			**Intervention 8**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2646.80	2098.00	2599.75
Worst case scenario	2911.7	2900.0	2900.0	2911.70	2898.00	2901.00
Most likely estimate	2647.0	2400.0	2700.0	2646.90	2398.00	2700.00
Confidence	70	80	70	60	80	50

4. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 8 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.0701	-1.9015		-0.9858
Pessimistic change in TSS	0.7357	3.7955		2.2656
Most likely change in TSS	-0.0700	-0.0025		-0.0363

Group 3 did not provide estimates for TSS levels in any region. Comment provided: “insufficient information to quantify estimates”

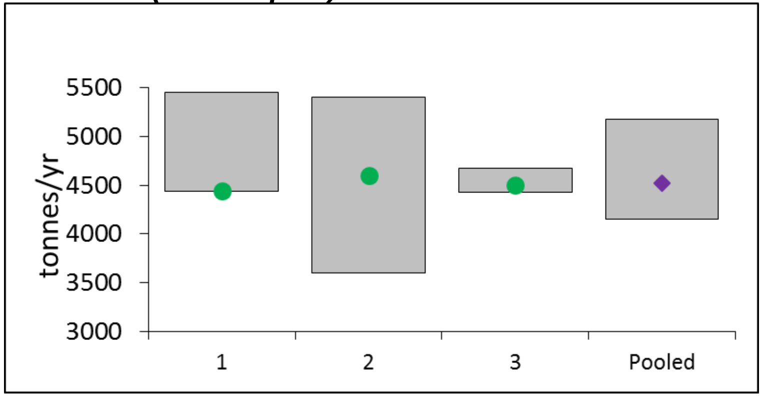
Original estimates provided

	No Action			**Intervention 8**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4.559	2.35	4.00	4.699900	2.347500	
Worst case scenario	5.405	9.4	6.00	5.405000	9.397500	
Most likely estimate	4.77	4.7	5.00	4.699975	4.697500	
Confidence	80	99	80	70	99	

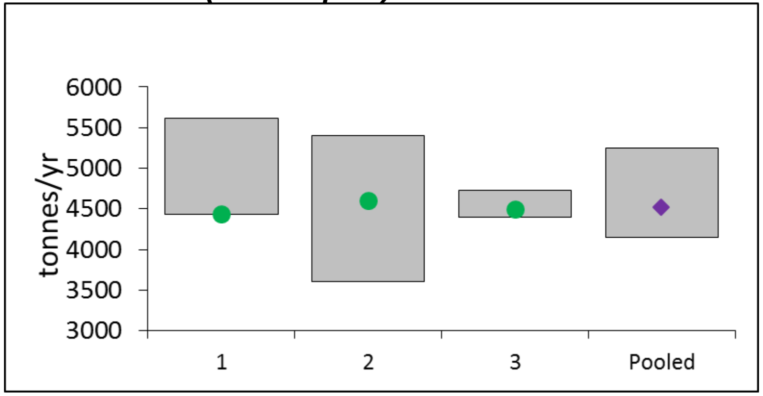
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

1. Nutrients (DIN tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 9 (Wet Tropics) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.14	-1001.00	-101.54	-367.56
Pessimistic change in DIN	1183.77	799.00	224.06	735.61
Most likely change in DIN	-0.10	-1.00	-0.10	-0.40

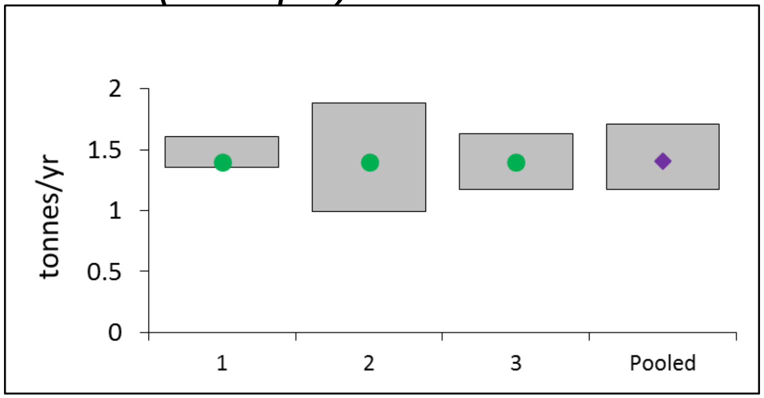
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	4437.0	3600.0	4437.0	4436.870	3599.000	4436.500
Worst case scenario	5324.4	5400.0	4640.0	5324.800	5399.000	4640.000
Most likely estimate	4437.0	4600.0	4500.0	4436.900	4599.000	4499.900
Confidence	70	80	65	60	80	50

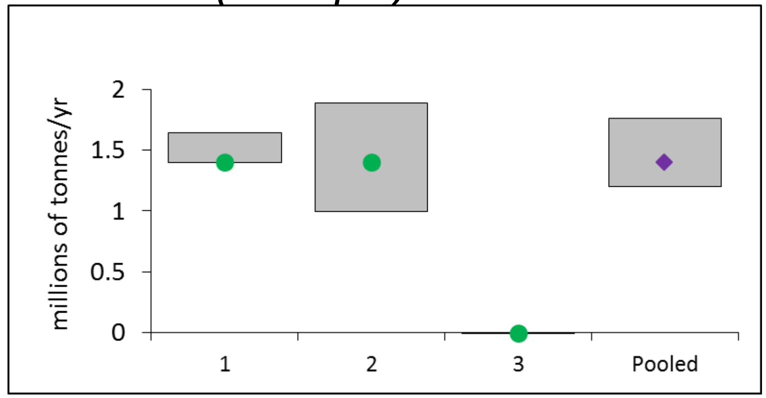
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

2. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Wet Tropics) – standardised 80% C.I.s



Intervention 9 (Wet Tropics) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.0001	-0.4050		-0.2026
Pessimistic change in TSS	0.2400	0.4838		0.3619
Most likely change in TSS	0.0000	-0.0010		-0.0005

Group 3 did not provide estimates for TSS levels in any region. Comment provided: “assessment of effectiveness need to be at right scale. Insufficient info to make quantified estimates.”

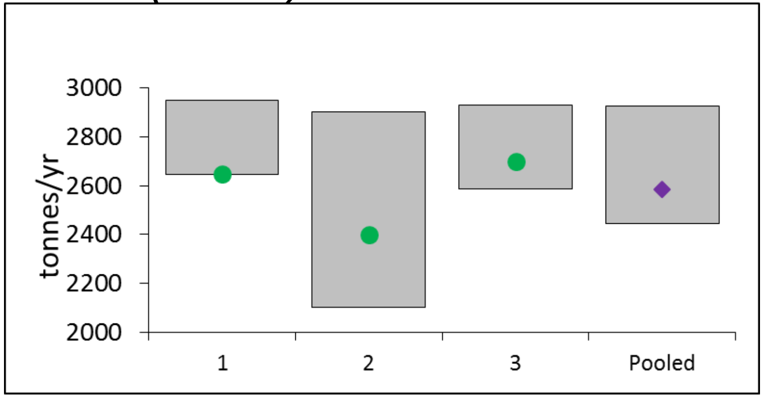
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.3580	0.9000	1.2000	1.399900	0.899000	
Worst case scenario	1.6100	2.0000	1.6000	1.610000	1.999000	
Most likely estimate	1.4000	1.4000	1.4000	1.399975	1.399000	
Confidence	80	99	70	70	99	

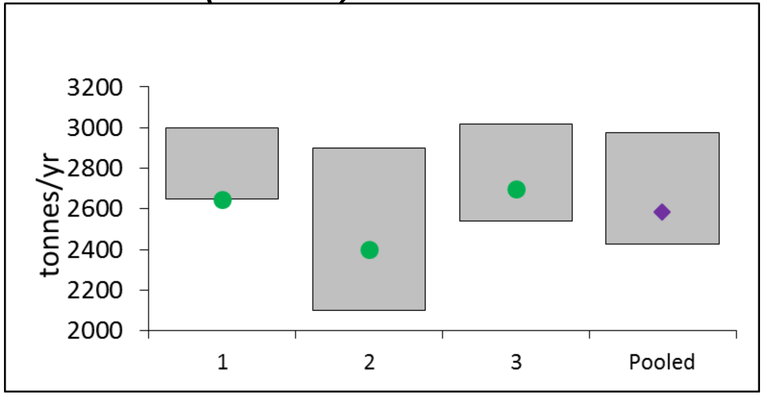
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

3. Nutrients (DIN tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 9 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.14	-301.00	-160.37	-153.84
Pessimistic change in DIN	353.33	499.00	320.03	390.79
Most likely change in DIN	-0.10	-1.00	-0.05	-0.38

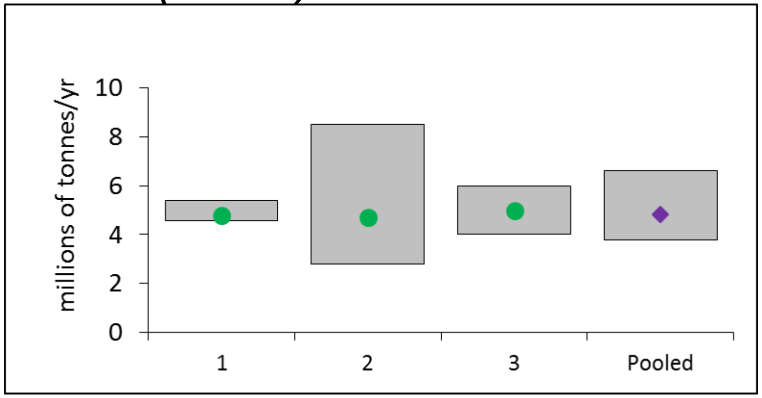
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2647.0	2100.0	2600.0	2646.870	2099.000	2599.750
Worst case scenario	2911.7	2900.0	2900.0	2911.970	2899.000	2900.000
Most likely estimate	2647.0	2400.0	2700.0	2646.900	2399.000	2699.950
Confidence	70	80	70	60	80	50

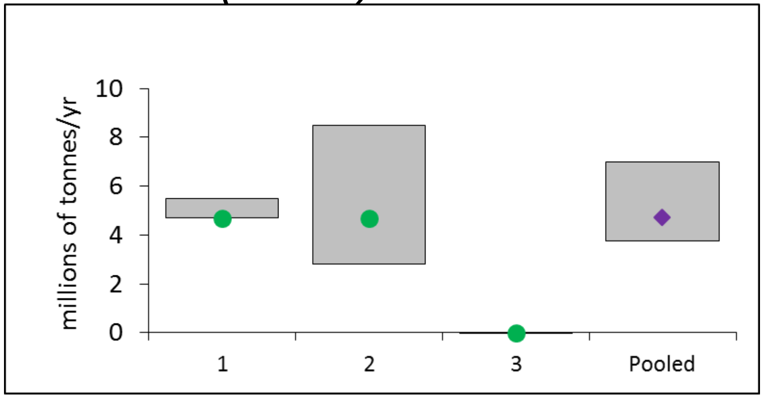
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

4. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burdekin) – standardised 80% C.I.s



Intervention 9 (Burdekin) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Group estimates (mill tonnes/yr)			Average (mill tonnes/yr)
	1	2	3	
Optimistic change in TSS	-0.0701	-1.9000		-0.9851
Pessimistic change in TSS	0.7357	3.7970		2.2663
Most likely change in TSS	-0.0700	-0.0010		-0.0355

Group 3 did not provide estimates for TSS levels in any region. Comment provided: “assessment of effectiveness need to be at right scale. Insufficient info to make quantified estimates.”

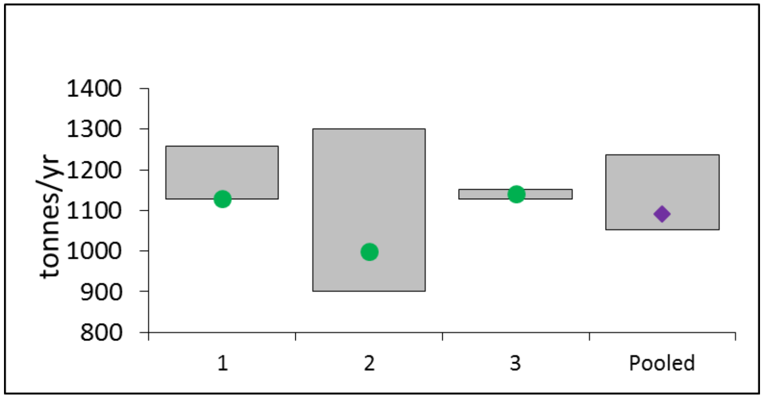
Original estimates provided

	No Action			Intervention 9		
	1	2	3	1	2	3
Best case scenario	4.559	2.35	4.00	4.699900	2.349000	
Worst case scenario	5.405	9.4	6.00	5.405000	9.399000	
Most likely estimate	4.77	4.7	5.00	4.699975	4.699000	
Confidence	80	99	80	70	99	

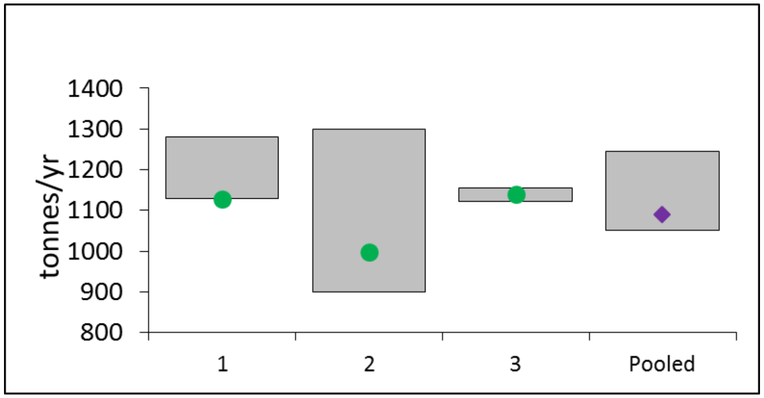
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

5. Nutrients (DIN tonnes/year)

No Action (Mackay Whitsunday) – standardised 80% C.I.s



Intervention 9 (Mackay Whitsunday) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.14	-101.00	-17.75	-39.63
Pessimistic change in DIN	150.71	299.00	16.01	155.24
Most likely change in DIN	-0.10	-1.00	-0.02	-0.37

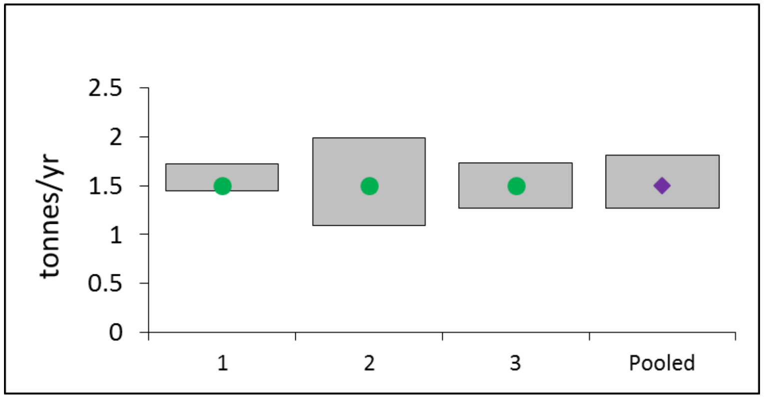
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1129.0	900.0	1129.0	1128.87	899.00	1128.90
Worst case scenario	1241.9	1300.0	1150.0	1242.01	1299.00	1150.00
Most likely estimate	1129.0	1000.0	1140.0	1128.90	999.00	1139.98
Confidence	70	80	70	60	80	50

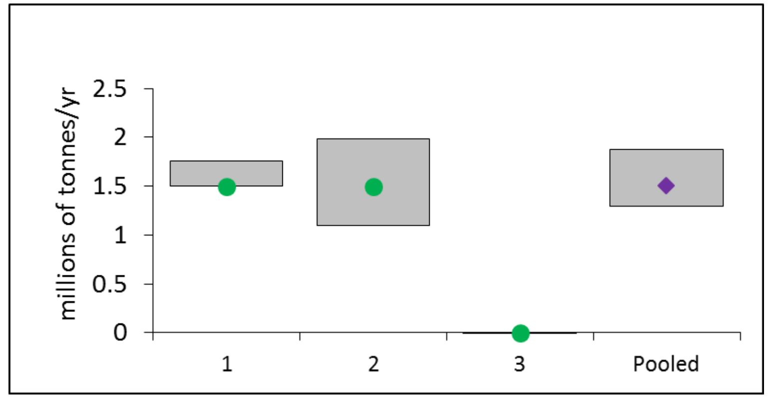
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

6. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Mackay Whitsunday) – standardised 80% C.I.s



Intervention 9 (Mackay Whitsunday) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.00011	-0.40504		-0.20258
Pessimistic change in TSS	0.25715	0.48385		0.37050
Most likely change in TSS	-0.00002	-0.00100		-0.00051

Group 3 did not provide estimates for TSS levels in any region. Comment provided: “assessment of effectiveness need to be at right scale. Insufficient info to make quantified estimates.”

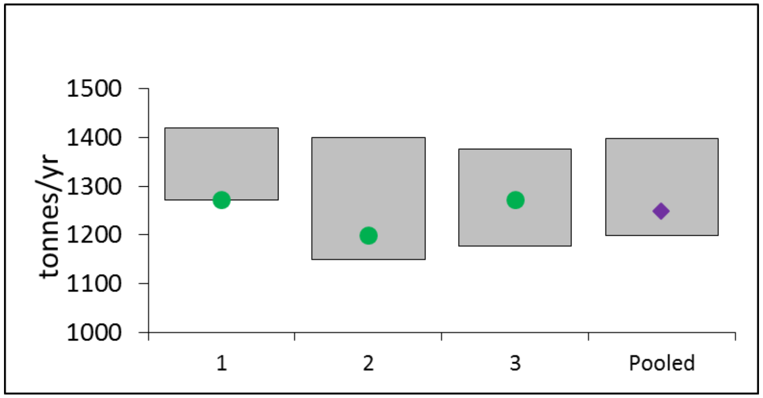
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.445	1.000	1.300	1.4999	0.999	
Worst case scenario	1.725	2.100	1.700	1.725	2.099	
Most likely estimate	1.500	1.500	1.500	1.499975	1.499	
Confidence	80	99	70	70	99	

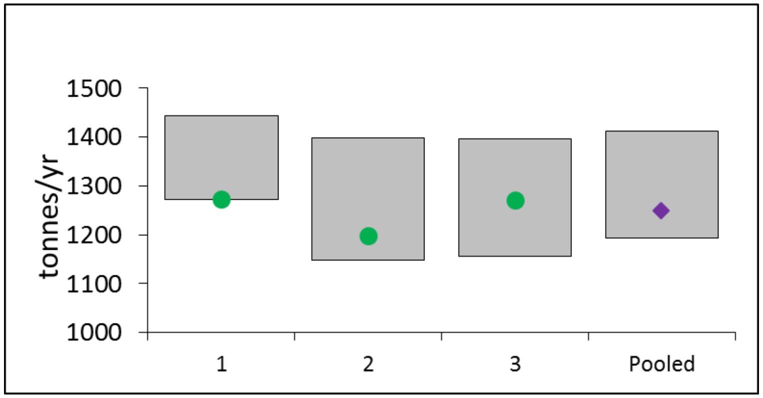
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

7. Nutrients (DIN tonnes/year)

No Action (Fitzroy) – standardised 80% C.I.s



Intervention 9 (Fitzroy) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	0.86	-51.00	-115.34	-55.16
Pessimistic change in DIN	170.94	199.00	124.82	164.92
Most likely change in DIN	0.90	-1.00	-0.03	-0.04

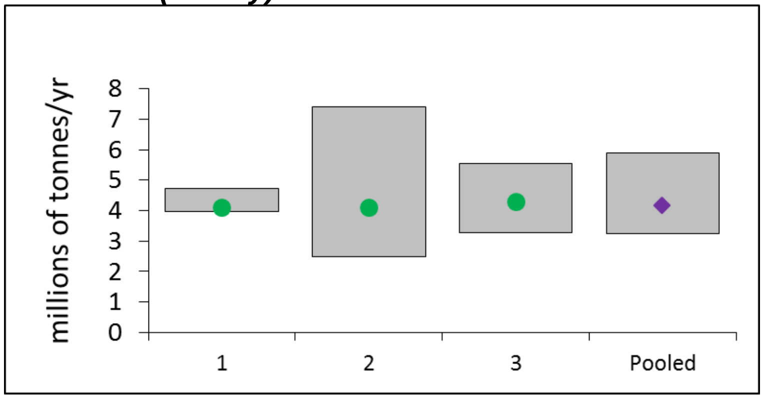
Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1272.00	1150.00	1200.00	1272.870	1149.000	1199.900
Worst case scenario	1400.30	1400.00	1350.00	1400.430	1399.000	1350.000
Most likely estimate	1272.00	1200.00	1272.00	1272.900	1199.000	1271.970
Confidence	70	80	60	60	80	50

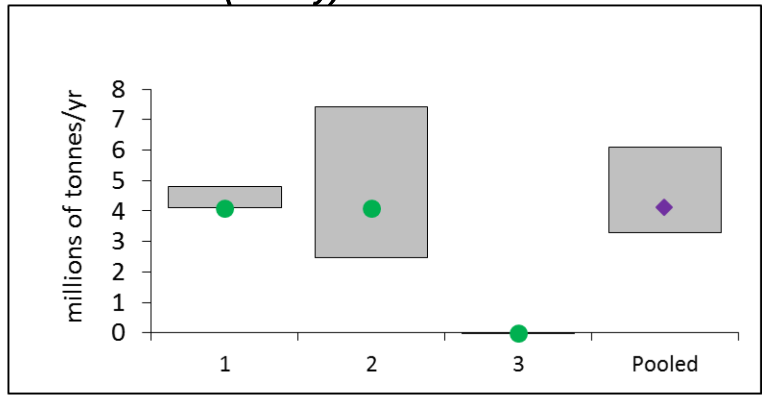
9: One million trees for the reef: Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy, Burnett Mary

5. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Fitzroy) – standardised 80% C.I.s



Intervention 9 (Fitzroy) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.000111	-1.617162		-0.808636
Pessimistic change in TSS	0.702861	3.312131		2.007496
Most likely change in TSS	-0.000025	-0.001000		-0.000512

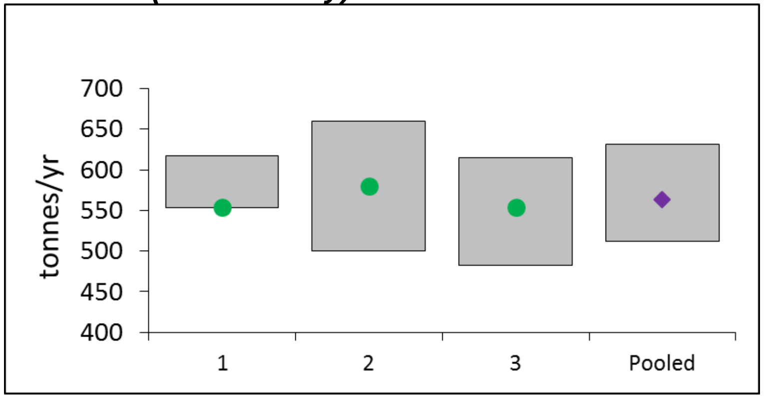
Group 3 did not provide estimates for TSS levels in any region. Comment provided: “assessment of effectiveness need to be at right scale. Insufficient info to make quantified estimates.”

Original estimates provided

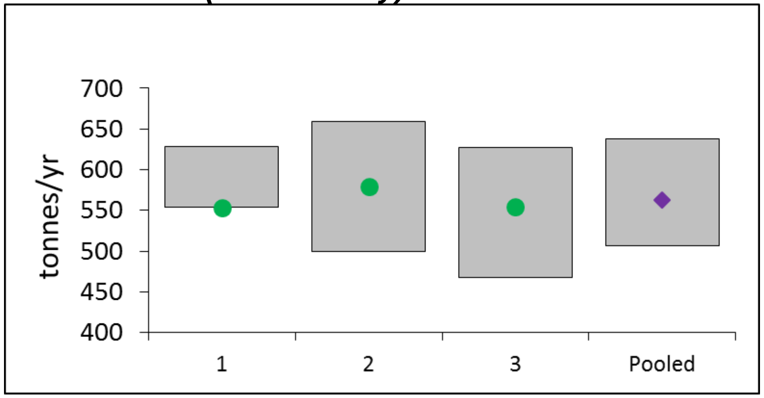
	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.977	2.100	3.400	4.0999	2.099	
Worst case scenario	4.715	8.200	5.400	4.715	8.199	
Most likely estimate	4.100	4.100	4.300	4.099975	4.099	
Confidence	80	99	70	70	99	

8. Nutrients (DIN tonnes/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 9 (Burnett Mary) – standardised 80% C.I.s



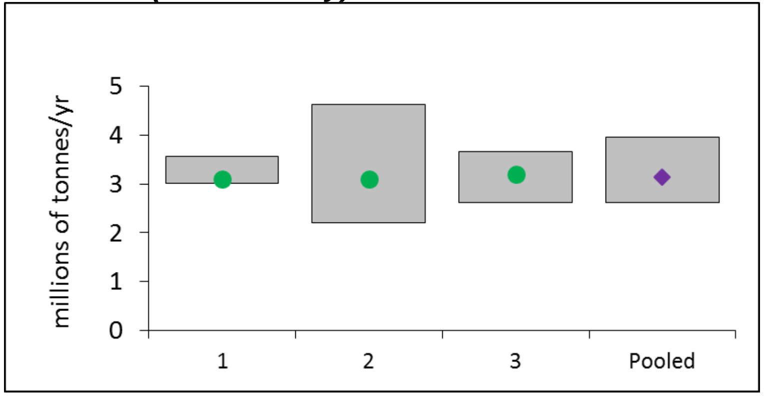
Estimated changes (based on standardised 80% C.I.s)	**Group estimates (tonnes/yr)**			**Average (tonnes/yr)**
	1	**2**	**3**	
Optimistic change in DIN	-0.14	-81.00	-86.47	-55.87
Pessimistic change in DIN	73.98	79.00	73.61	75.53
Most likely change in DIN	-0.10	-1.00	-0.01	-0.37

Original estimates provided

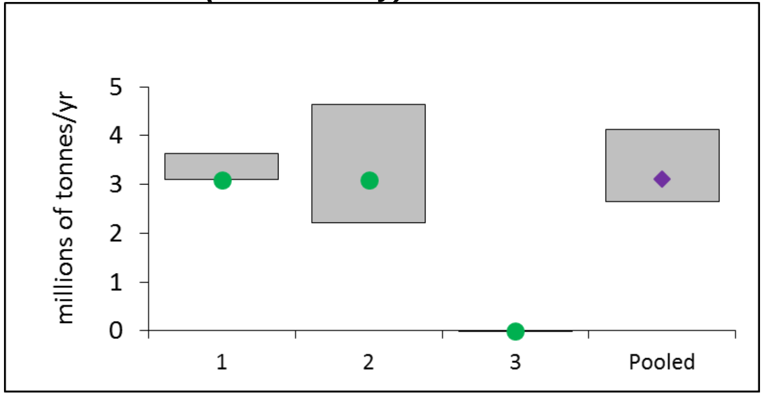
	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	554.00	500.00	500.00	553.870	499.000	499.950
Worst case scenario	609.40	660.00	600.00	609.460	659.000	600.000
Most likely estimate	554.00	580.00	554.00	553.900	579.000	553.990
Confidence	70	80	60	60	80	50

9. Sediment (load of total suspended solids, millions of tonnes/year)

No Action (Burnett Mary) – standardised 80% C.I.s



Intervention 9 (Burnett Mary) – standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Group estimates (mill tonnes/yr)**			**Average (mill tonnes/yr)**
	1	**2**	**3**	
Optimistic change in TSS	-0.0001	-0.8899		-0.4450
Pessimistic change in TSS	0.5314	1.5344		1.0329
Most likely change in TSS	0.0000	-0.0010		-0.0005

Group 3 did not provide estimates for TSS levels in any region. Comment provided: "assessment of effectiveness need to be at right scale. Insufficient info to make quantified estimates."

Original estimates provided

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.0070	2.0000	2.7000	3.09990	1.99900	
Worst case scenario	3.5650	5.0000	3.6000	3.56500	4.99900	
Most likely estimate	3.1000	3.1000	3.2000	3.09998	3.09900	
Confidence	80	99	70	70	99	

Appendix 6: Summary of effectiveness of interventions on wetland condition

This document summarises the estimates of the effectiveness of each management intervention and “no action” on wetlands at 2030, provided by two wetlands experts at a follow-up meeting in January in Brisbane.

The performance measure used to reflect Wetlands is wetland condition (as a reflection of the components (soils, water, flora, fauna etc. and processes (hydrologic, nutrient processes etc) and how they support wetland values).

Wetland condition is scored between 1 (very low functions and components to support values) and 5 (very high functions and components to support values). This index has been used consistently in other Queensland wetlands projects, such as Wetland GBR Hazard Assessment (draft – unpublished), AquaBAMM and the Wetlands Field Assessment Tool.

The performance measure reflects the following natural values of wetlands (source Wetland values, Wetland*Info*, Department of Environment and Heritage Protection, Queensland, http://wetlandinfo.ehp.qld.gov.au/wetlands/management/wetland-values/):

- Provide habitat vital for the survival of a range of plants and animals
- Provide an important nursery for varieties of fish and crustaceans
- Help maintain or improve water quality by transforming and retaining nutrients and sediment from run-off which would otherwise go into creeks and rivers that flow to the ocean
- Provide a buffer against coastal erosion, storm surges and flooding which helps build resilience to flood and cyclone events
- Deliver a range of products such as medicine, food and water vital for people, livestock, agriculture and industry.

As a first step the two experts identified the current condition of wetlands using a number of performance measures:

	Cape York	**Terrain (Wet Tropics)**	**NQ Dry Tropics (Burdekin)**	**Reef Catchments (Mackay Whitsunday)**	**Fitzroy**	**Burnett Mary**
Wetaland area (km^2; source: WetlandInfo)	1023	1262	4673	743.6	4133	1680
Total area of each region (km^2; source: WetlandInfo)	38024	22230	141000	9335	156762	55768
Extent change (% of pre-clear wetlands remaining; source: WetlandInfo)	≈99%	69%	89.9%	84.9%	81.2%	70.7%
Landuse and infrastructure hazard assessment (scale: 1 (v low) to 10 (v high); source: p64 Wetland GBR Hazard Assessment (draft - unpublished)	2	2	4	6	5	5
Wetland condition (experts combined assessment, based on the Landuse and infrastructure hazard assessment)	4	4	3	2	2.5	2.5

The experts then estimated the influence of each intervention on the threats to wetlands (identified in the draft Wetlands GBR Hazard Assessment) and on the natural values of the wetlands. This assessment did not take into account the scale of the intervention, just the potential influence of the intervention on wetland threats and natural values. In the following step (estimating benefits on wetland condition), experts took into account the actual scale of the interventions.

	1: Smartcane best management practice (BMP) accreditation	2: Expansion of holistic grazing pilot project	3: Reverse tender for nitrogen use efficiency of sugar cane farms	4: Farmer led innovative cane management practices (game	5: Erosion control in priority grazing landscapes (gully restoration)	7: Reef Bonus trial	8: Rehabilitation of coastal ecosystems	9: One million trees for the reef
Wetlands threats								
Inputs	●	●	●	●	●	●	●	●
Hydrology*	-	●	-	-	●	-	●	●
Weeds/ferals	-	●	-	-	-	-	●	●
Physical disturbance*	-	●	-	-	-	-	●	●
Harvesting*	-	-	-	-	-	-	-	-
Wetland natural values								
Habitat for species	L	M	L	L	M	L	H	M
Nursery for fish and crustaceans	L	M	L	L	M	L	H	L
Sequestration of nitrogen, phosphorus and sediment	L	L	L	L	M	L	L	M
Buffer against erosion and flooding		M			M		M	M
Productivity		L			M		M	L

L: Low influence on improving wetland value; M: Medium influence on improving wetland value; H: High influence on improving wetland value.

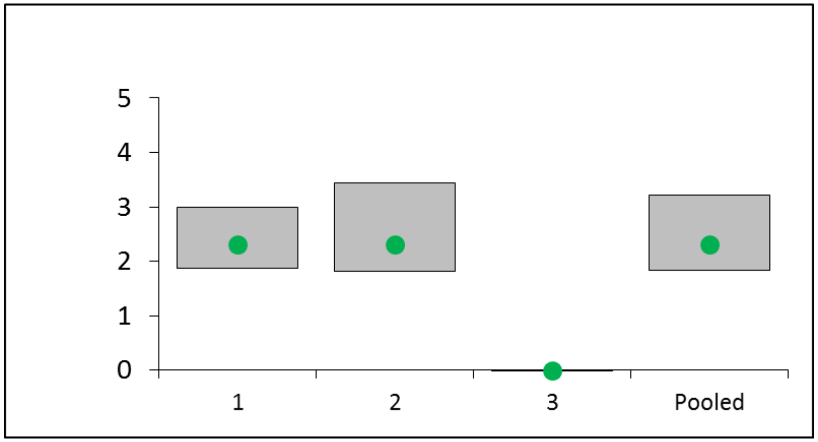
*These threats (changes to hydrology; physical disturbance to wetlands; and, harvesting) are not being addressed in any substantial way by the Reef Trust.

Intervention 1: Smartcane best management practice (BMP) accreditation: Burdekin

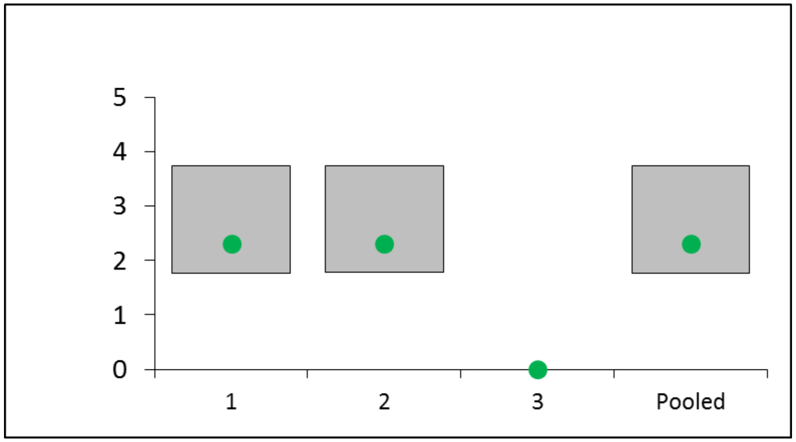
Estimated influence of the intervention on wetlands in the region: 1.05% of the wetlands in the Burdekin (= 1063 km^2 / 2 = 500 km^2 = 0.35% of Burdekin x 3 (wetland multiplier) = 1.05%)

Natural wetlands (Estuarine and freshwater wetlands functions and components (index from 1 - 5)):

No Action (Burdekin) – standardised 80% C.I.s



Intervention 1 (Burdekin) – standardised 80% C.I.s



These graphs show the two experts estimates (green dots = most likely estimate, upper grey bar = best case estimate, lower grey bar = worst case estimate) and the pooled group estimates for no action vs each management interventions, standardised to 80% confidence

Estimated changes (based on standardised 80% C.I.s)	Experts estimated payoff (wetland condition)			Average
	1	2	3	
Optimistic change in wetlands[1]	1.447	1.447		1.45
Pessimistic change in wetlands[2]	-0.535	-0.523		-0.53
Most likely change in wetlands[3]	0.005	0.010		0.01

Original estimates provided:

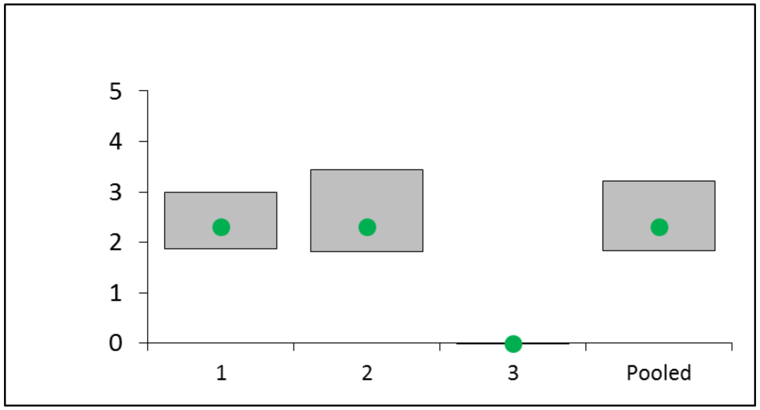
	No Action			**Intervention 1**		
	1	2	3	1	2	3
Best case scenario	2.8	2.8		2.81	2.81	
Worst case scenario	1.9	1.9		1.9	1.91	
Most likely estimate	2.3	2.3		2.305	2.31	
Confidence	75	65		60	60	

[1] Optimistic change = intervention best case – no action most likely estimate
[2] Pessimistic change = intervention worst case– no action most likely estimate
[3] Most likely change = intervention most likely estimate – no action most likely estimate

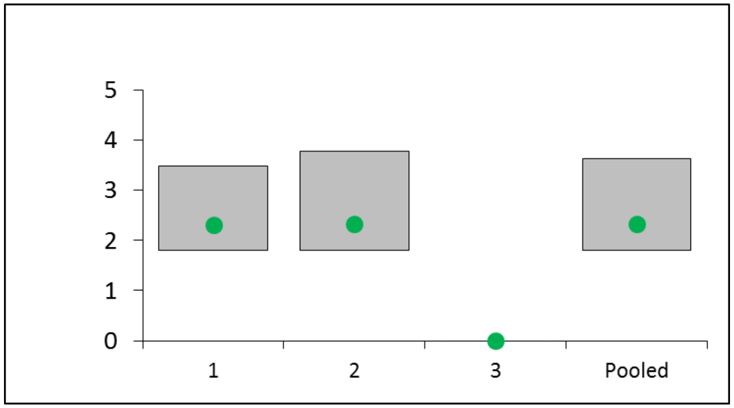
2: Expansion of holistic grazing pilot project: Burdekin

Estimated influence of the intervention on wetlands in the region: 2.1% of the wetlands in the Burdekin (1000 km^2 / 141,000 km^2 = 0.007 = 0.7% (from intervention description) x 3 (multiplier for potential wetland impact))

No Action, Burdekin - standardised 80% C.I.s



Intervention 2, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.183	1.473		1.33
Pessimistic change in wetlands	-0.497	-0.503		-0.50
Most likely change in wetlands	0.020	0.030		0.03

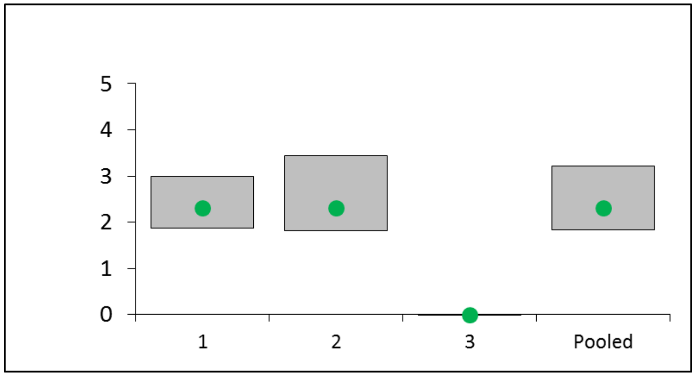
Original estimates provided:

	No Action			**Intervention 2**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.8	2.8		2.83	2.83	
Worst case scenario	1.9	1.9		1.9	1.93	
Most likely estimate	2.3	2.3		2.32	2.33	
Confidence	75	65		65	60	

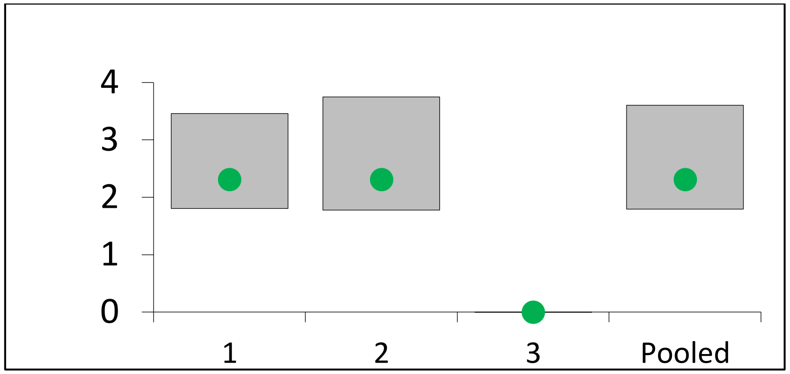
3: Reverse tender for nitrogen use efficiency of sugar cane farms: Burdekin

Estimated influence of the intervention on wetlands in the region: 0.34% of the wetlands in the Burdekin (($160\ km^2/141{,}000 km^2$) x 3 = 0.34%)

No Action, Burdekin - standardised 80% C.I.s



Intervention 3, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Experts estimated payoff (wetland condition)			Average
	1	2	3	
Optimistic change in wetlands	1.158	1.447		1.30
Pessimistic change in wetlands	-0.495	-0.523		-0.51
Most likely change in wetlands	0.010	0.010		0.01

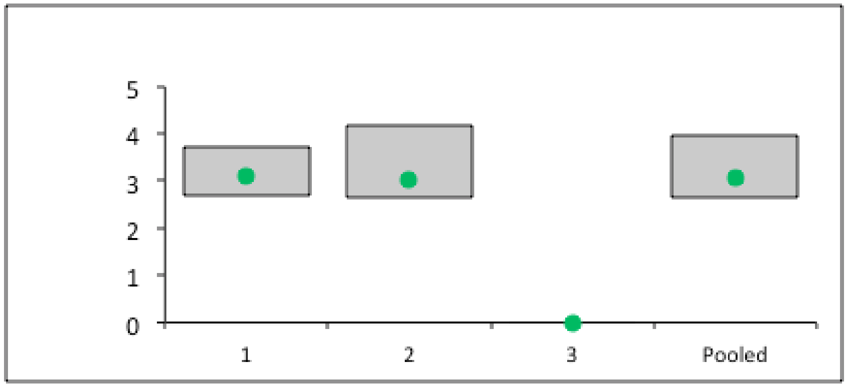
Original estimates provided:

	No Action			Intervention 3		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.8	2.8		2.81	2.81	
Worst case scenario	1.9	1.9		1.9	1.91	
Most likely estimate	2.3	2.3		2.31	2.31	
Confidence	75	65		65	60	

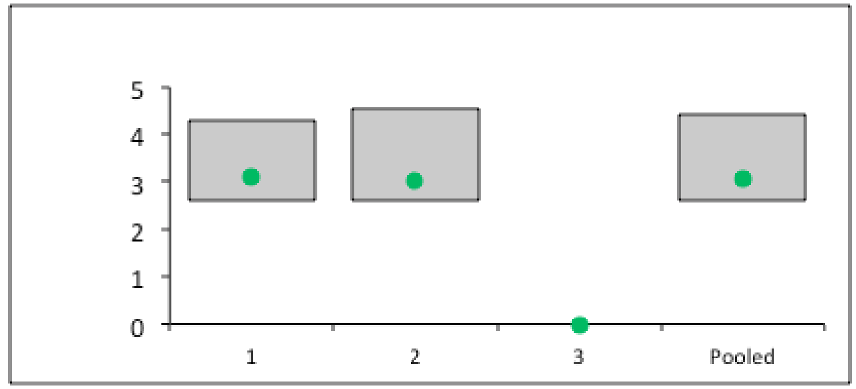
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: 0.02% of the wetlands in the Wet Tropics (($1.5\ km^2/22{,}230\ km^2$) x 3 = 0.02%)

No Action, Wet Tropics - standardised 80% C.I.s



Intervention 4, Wet Tropics- standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.208	1.533		1.37
Pessimistic change in wetlands	-0.492	-0.400		-0.45
Most likely change in wetlands	0.000	0.000		0.00

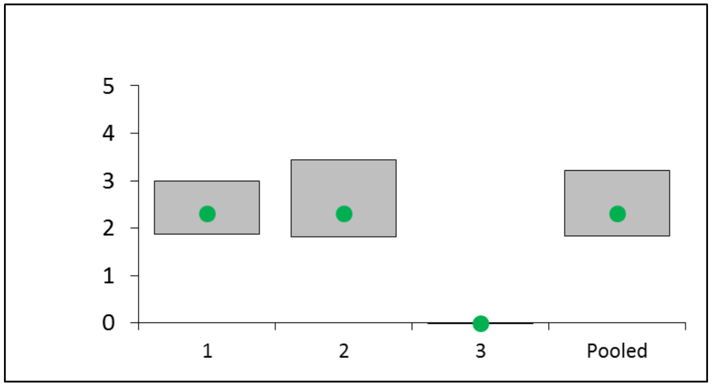
Original estimates provided:

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.5	3.4		3.5	3.4	
Worst case scenario	2.7	2.7		2.7	2.7	
Most likely estimate	3.1	3		3.1	3	
Confidence	75	65		65	60	

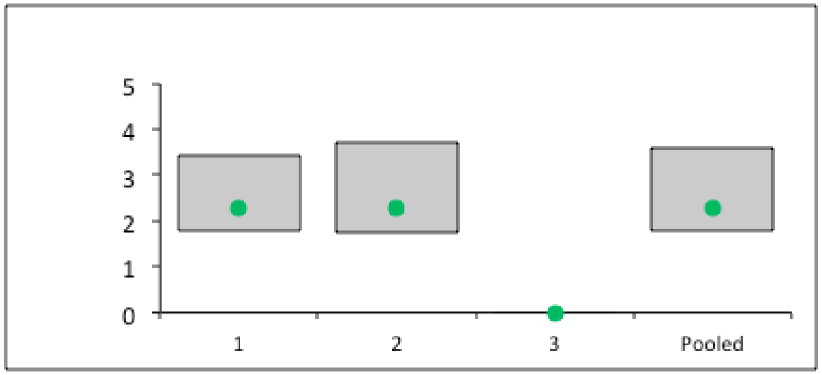
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: 0.003% of the wetlands in the Burdekin (($1.5\ km^2/141{,}000\ km^2$) x 3 = 0.003%)

No Action, Burdekin - standardised 80% C.I.s



Intervention 4, Burdekin- standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.146	1.433		1.29
Pessimistic change in wetlands	-0.492	-0.533		-0.51
Most likely change in wetlands	0.000	0.000		0.00

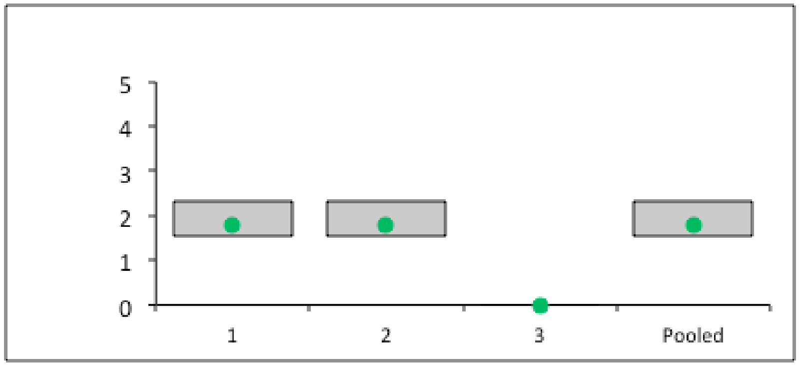
Original estimates provided:

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.8	2.8		2.8	2.8	
Worst case scenario	1.9	1.9		1.9	1.9	
Most likely estimate	2.3	2.3		2.3	2.3	
Confidence	75	65		65	60	

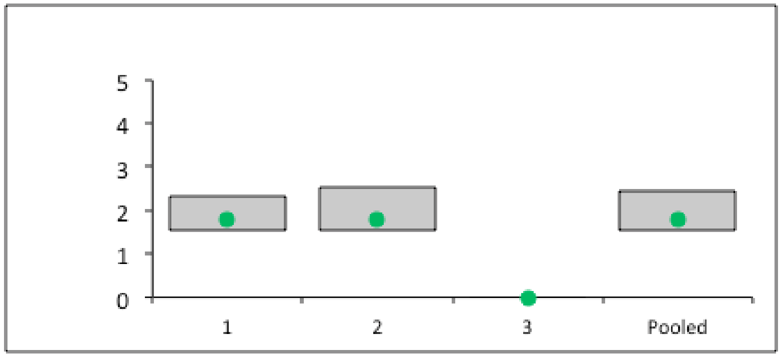
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: 0.0048% of the wetlands in the Mackay Whitsunday (($1.5\ km^2/9{,}335\ km^2$) x 3 = 0.0048%)

No Action, Mackay Whitsunday - standardised 80% C.I.s



Intervention 4, Mackay Whitsunday - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	0.538	0.733		0.64
Pessimistic change in wetlands	-0.246	-0.267		-0.26
Most likely change in wetlands	0.000	0.000		0.00

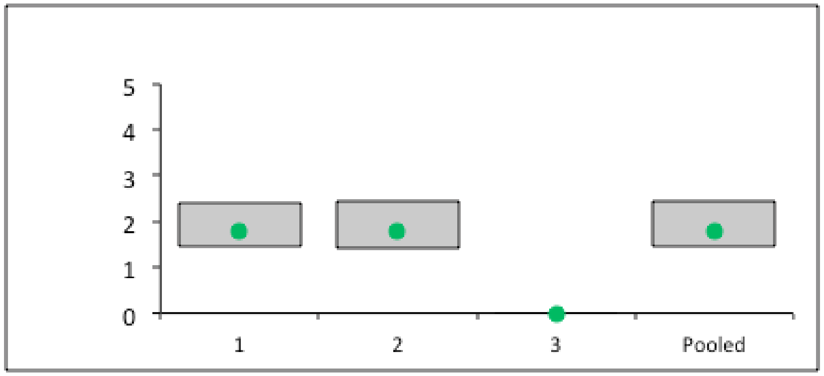
Original estimates provided:

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	1.9	1.9		1.9	1.9	
Worst case scenario	1.6	1.6		1.6	1.6	
Most likely estimate	1.8	1.8		1.8	1.8	
Confidence	65	65		65	60	

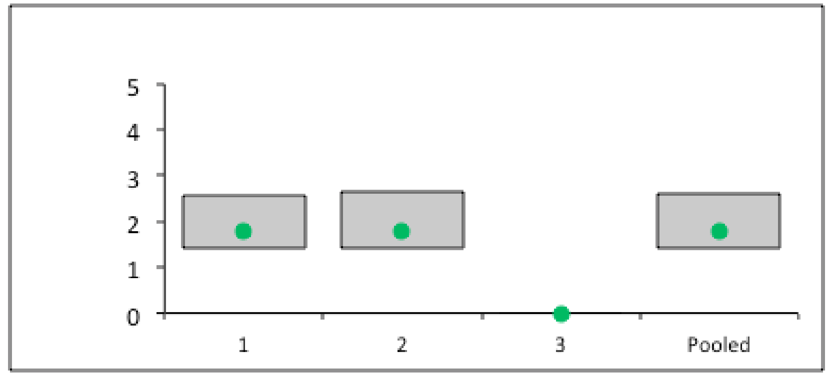
4: Farmer led innovative cane management practices (game changer): Mackay Whitsunday, Burdekin, Wet Tropics and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: 0.008% of the wetlands in the Burnett Mary (($1.5\ km^2/55{,}768\ km^2$) x 3 = 0.008%)

No Action, Burnett Mary - standardised 80% C.I.s



Intervention 4, Burnett Mary - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	0.785	0.867		0.83
Pessimistic change in wetlands	-0.369	-0.400		-0.38
Most likely change in wetlands	0.000	0.000		0.00

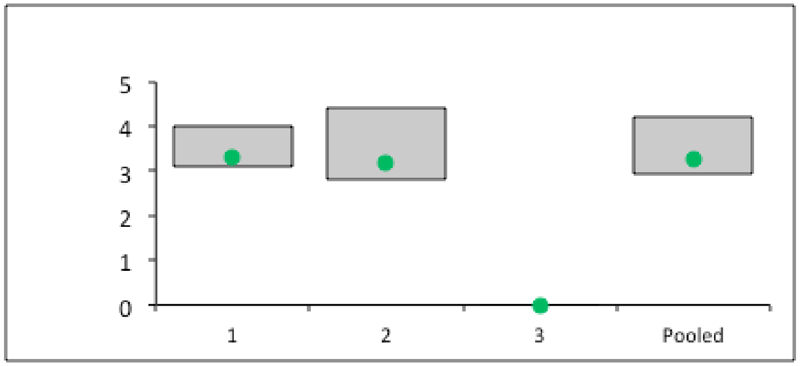
Original estimates provided:

	No Action			**Intervention 4**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.1	2		2.1	2	
Worst case scenario	1.5	1.5		1.5	1.5	
Most likely estimate	1.8	1.8		1.8	1.8	
Confidence	70	65		65	60	

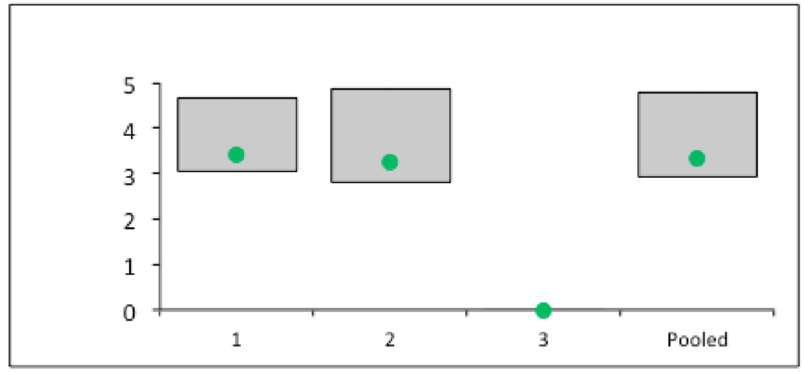
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated an average reduction of -0.06 million tonnes of TSS

No Action, Cape York - standardised 80% C.I.s



Intervention 5, Cape York - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.377	1.667		1.52
Pessimistic change in wetlands	-0.269	-0.403		-0.34
Most likely change in wetlands	0.100	0.050		0.08

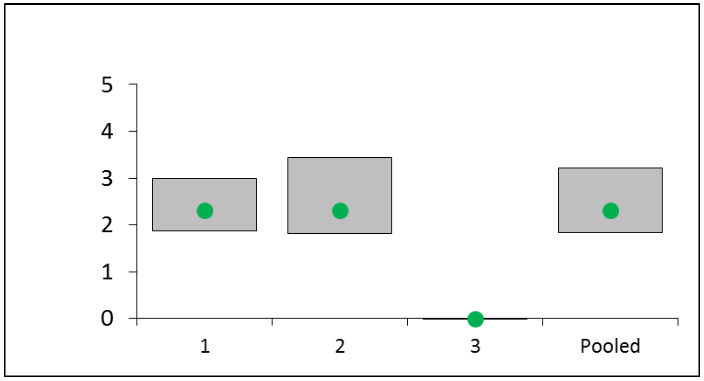
Original estimates provided:

	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.75	3.6		3.8	3.65	
Worst case scenario	3.1	2.9		3.1	2.91	
Most likely estimate	3.3	3.2		3.4	3.25	
Confidence	75	65		65	60	

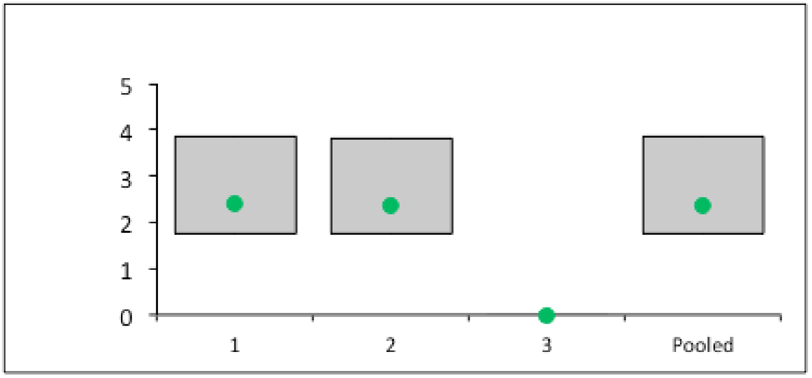
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated an average reduction of -0.11 million tonnes of TSS

No Action, Burdekin - standardised 80% C.I.s



Intervention 5, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.567	1.500		1.53
Pessimistic change in wetlands	-0.553	-0.537		-0.55
Most likely change in wetlands	0.100	0.050		0.08

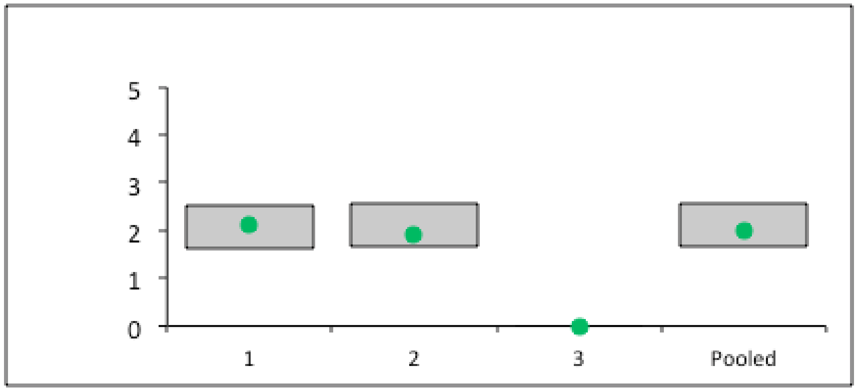
Original estimates provided:

	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	
Best case scenario	2.8	2.8		2.9	2.85	
Worst case scenario	1.9	1.9		1.91	1.91	
Most likely estimate	2.3	2.3		2.4	2.35	
Confidence	75	65		60	60	

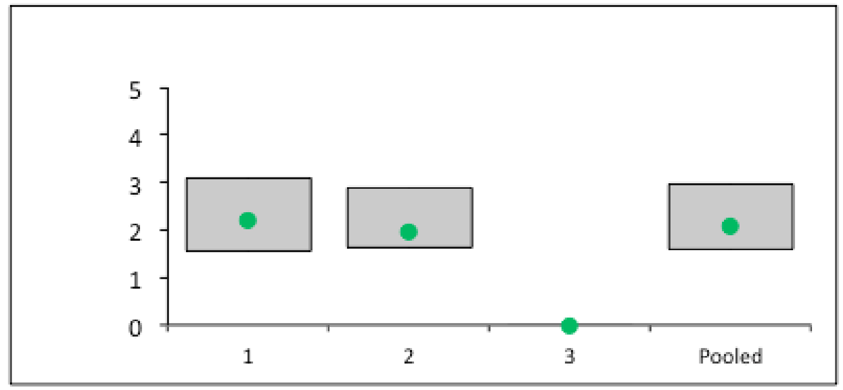
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated an average reduction of -0.09 million tonnes of TSS

No Action, Fitzroy - standardised 80% C.I.s



Intervention 5, Fitzroy - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	0.967	0.967		0.97
Pessimistic change in wetlands	-0.553	-0.270		-0.41
Most likely change in wetlands	0.100	0.050		0.08

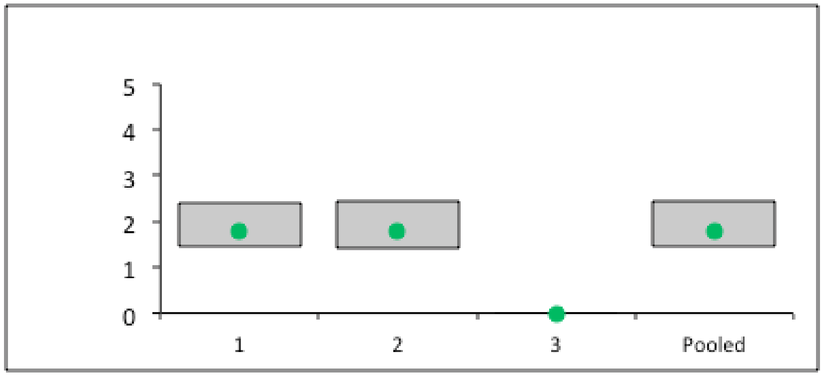
Original estimates provided:

	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.2	2.1		2.3	2.15	
Worst case scenario	1.7	1.7		1.71	1.71	
Most likely estimate	2.1	1.9		2.2	1.95	
Confidence	70	65		60	60	

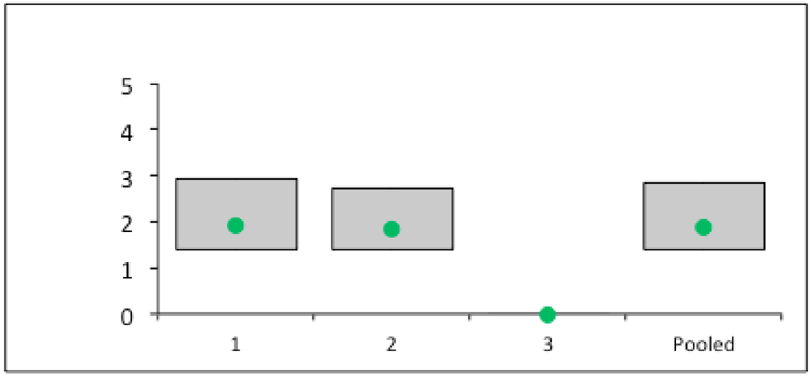
5: Erosion control in priority grazing landscapes (gully restoration): Burdekin, Fitzroy, Cape York and Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated an average reduction of -0.06 million tonnes of TSS

No Action, Burnett Mary - standardised 80% C.I.s



Intervention 5, Burnett Mary - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.133	0.933		1.03
Pessimistic change in wetlands	-0.420	-0.403		-0.41
Most likely change in wetlands	0.100	0.050		0.08

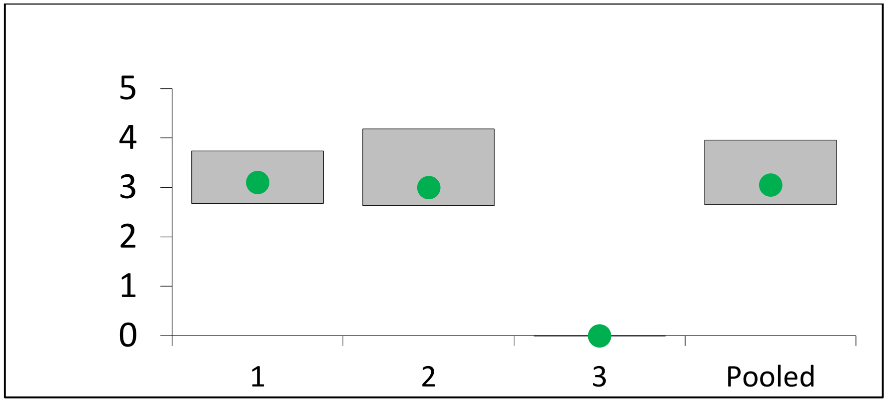
Original estimates provided:

	No Action			**Intervention 5**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.1	2		2.2	2.05	
Worst case scenario	1.5	1.5		1.51	1.51	
Most likely estimate	1.8	1.8		1.9	1.85	
Confidence	70	65		60	60	

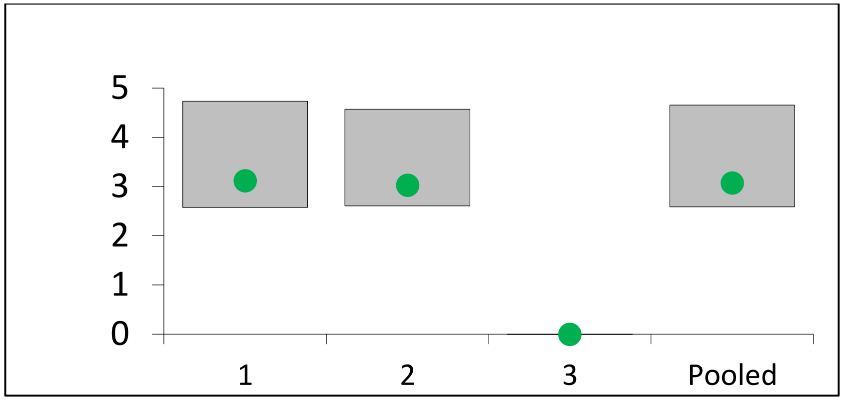
7: Reef Bonus trial: Wet Tropics and Burdekin

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 5% area of wetlands will be affected (no cane farm estimates)

No Action, Wet Tropics - standardised 80% C.I.s



Intervention 7, Wet Tropics - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.633	1.573		1.60
Pessimistic change in wetlands	-0.527	-0.397		-0.46
Most likely change in wetlands	0.020	0.030		0.02

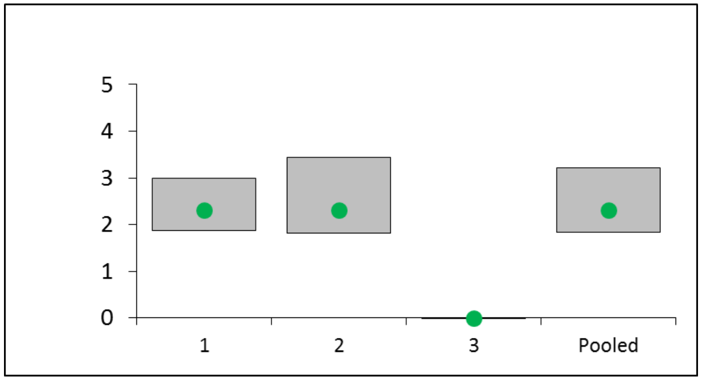
Original estimates provided:

	No Action			**Intervention 7**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.5	3.4		3.55	3.43	
Worst case scenario	2.7	2.7		2.71	2.71	
Most likely estimate	3.1	3		3.12	3.03	
Confidence	75	65		60	60	

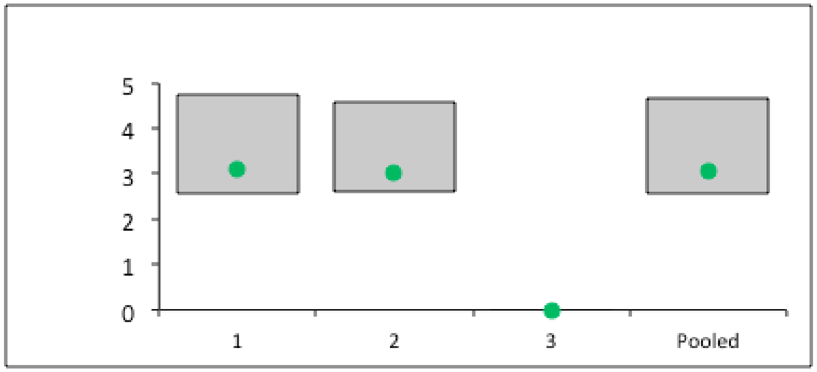
7: Reef Bonus trial: Wet Tropics and Burdekin

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 1.05% area of wetlands will be affected (based on estimates for intervention 1)

No Action, Burdekin - standardised 80% C.I.s



Intervention 7, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	Experts estimated payoff (wetland condition)			Average
	1	2	3	
Optimistic change in wetlands	1.593	1.460		1.53
Pessimistic change in wetlands	-0.560	-0.527		-0.54
Most likely change in wetlands	0.120	0.020		0.07

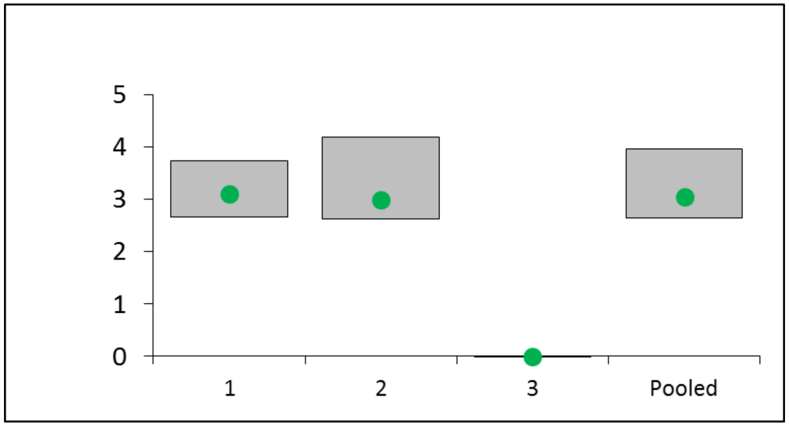
Original estimates provided:

	No Action			Intervention 7		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.5	3.4		3.55	3.43	
Worst case scenario	2.7	2.7		2.71	2.71	
Most likely estimate	3.1	3		3.12	3.03	
Confidence	75	65		60	60	

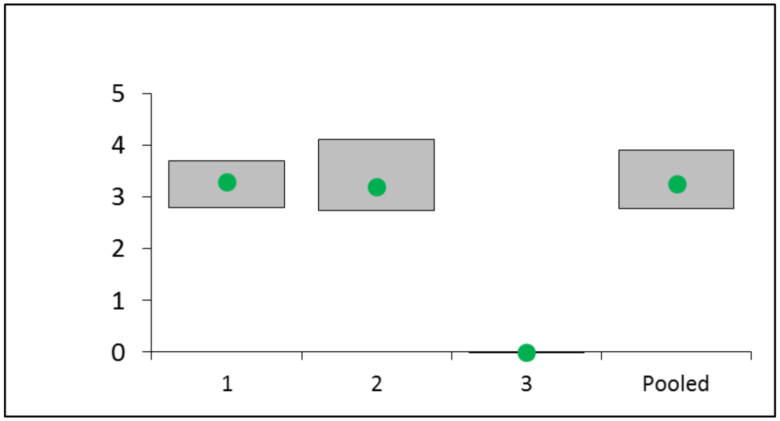
8: Rehabilitation of coastal ecosystems: Wet Tropics and Burdekin

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 0.5% of wetlands will be affected

No Action, Wet Tropics - standardised 80% C.I.s



Intervention 8, Wet Tropics - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	0.600	1.114		0.86
Pessimistic change in wetlands	-0.300	-0.257		-0.28
Most likely change in wetlands	0.200	0.200		0.20

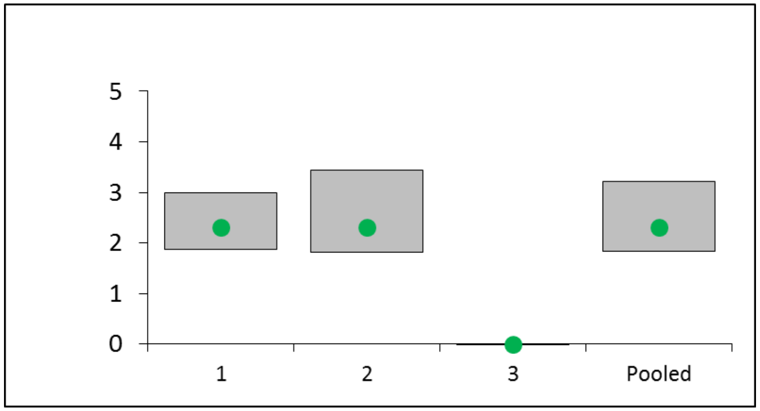
Original estimates provided:

	No Action			**Intervention 8**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	3.5	3.4		3.7	3.6	
Worst case scenario	2.7	2.7		2.8	2.8	
Most likely estimate	3.1	3		3.3	3.2	
Confidence	75	65		80	70	

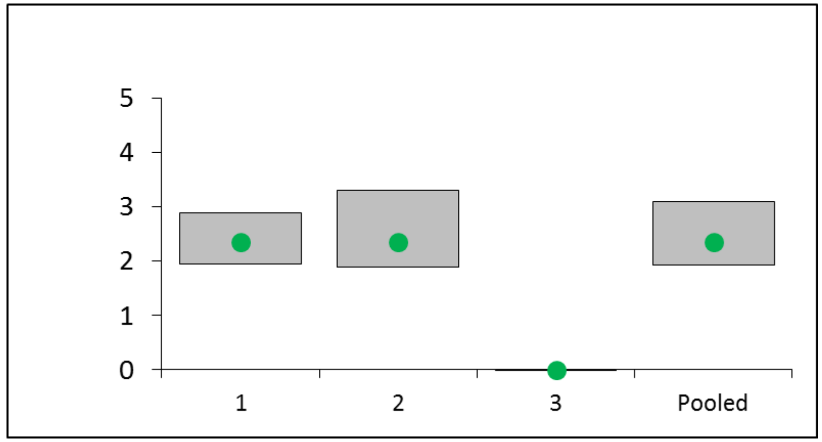
8: Rehabilitation of coastal ecosystems: Wet Tropics and Burdekin

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 0.1% of wetlands will be affected

No Action, Burdekin - standardised 80% C.I.s



Intervention 8, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	0.600	1.014		0.81
Pessimistic change in wetlands	-0.350	-0.407		-0.38
Most likely change in wetlands	0.050	0.050		0.05

Original estimates provided:

	No Action			**Intervention 8**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.8	2.8		2.9	2.9	
Worst case scenario	1.9	1.9		1.95	1.95	
Most likely estimate	2.3	2.3		2.35	2.35	
Confidence	75	65		80	70	

9: One million trees for the reef: ~~Wet Tropics,~~ Burdekin, ~~Mackay Whitsunday,~~ Fitzroy, Burnett Mary

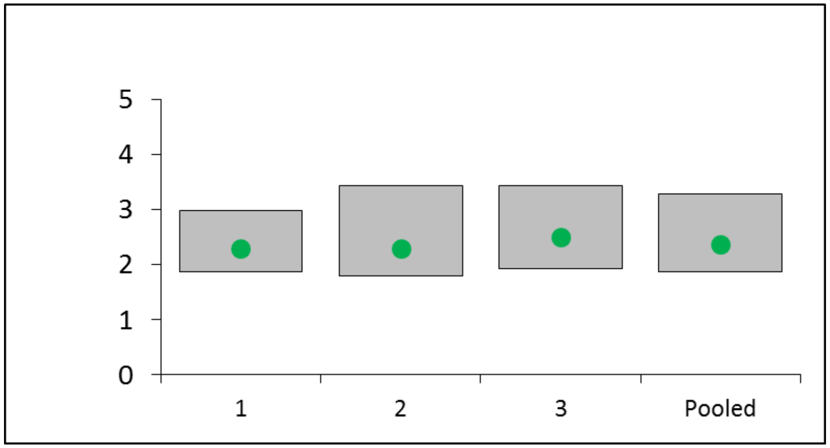
The experts did not believe that the 1 million trees program should occur in Wet Tropics or Mackay Whitsunday regions. Instead they suggested that this intervention focus on the priority regions (based on highest sediment threats) in the first instance: Burdekin, Fitzroy, Burnett Mary. Thus, they only made assessments for these three areas.

Note experts had much lower confidence (i.e. 50% confidence) in the estimates for intervention 9. This is because they were unsure whether the trees would be strategically planted. They commented that they assumed that all one million trees would be placed in a strategic way as to benefit wetland health / productivity – for example rehabilitation of riparian areas and enhancement / protection of lacustrine wetlands. But as this was not described in the intervention summary, they weren't so confident that this strategic planting would occur. They highlighted that there are a number of tools already developed (e.g. Blue Maps, Queensland Wetlands Mapping as well as the NRM & Climate Change Adaption Plans under development by the Regional NRM bodies) that could be used to focus investment.

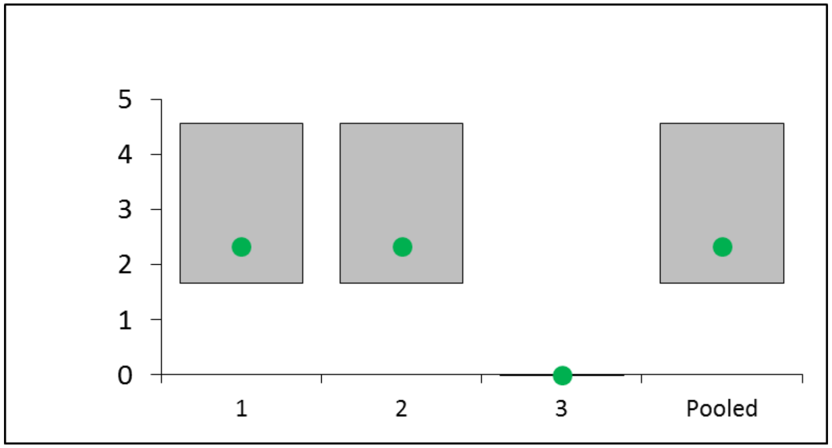
9: One million trees for the reef: Burdekin, Fitzroy, Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 0.1% of wetlands will be affected

No Action, Burdekin - standardised 80% C.I.s



Intervention 9, Burdekin - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	2.260	2.260		2.26
Pessimistic change in wetlands	-0.642	-0.642		-0.64
Most likely change in wetlands	0.030	0.030		0.03

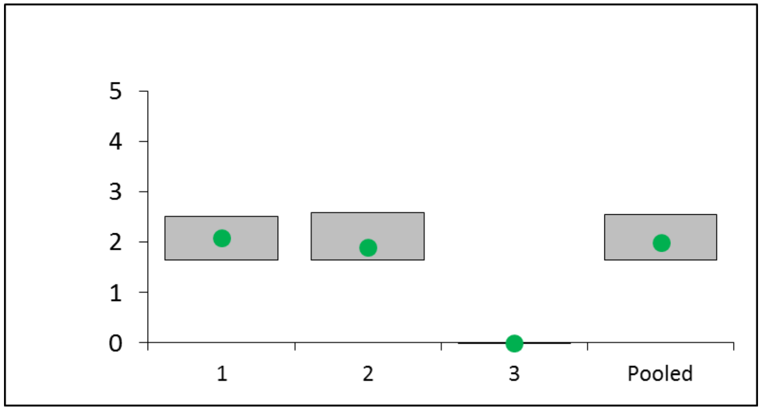
Original estimates provided:

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.8	2.8	3	2.85	2.85	
Worst case scenario	1.9	1.9	2	1.91	1.91	
Most likely estimate	2.3	2.3	2.5	2.33	2.33	
Confidence	75	65	70	50	50	

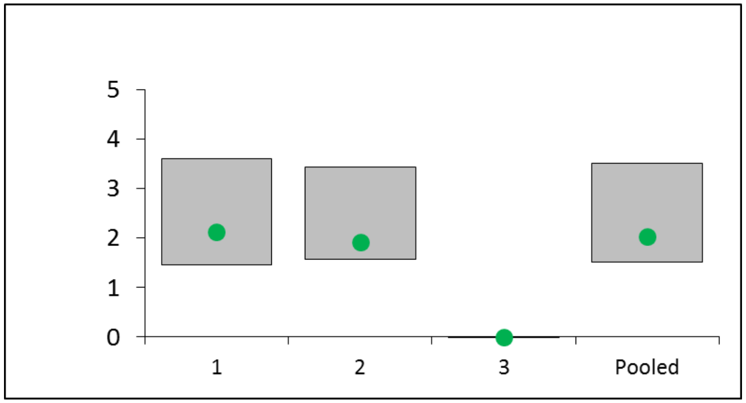
9: One million trees for the reef: Burdekin, Fitzroy, Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 0.1% of wetlands will be affected

No Action, Fitzroy - standardised 80% C.I.s



Intervention 9, Fitzroy - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.500	1.540		1.52
Pessimistic change in wetlands	-0.642	-0.322		-0.48
Most likely change in wetlands	0.030	0.030		0.03

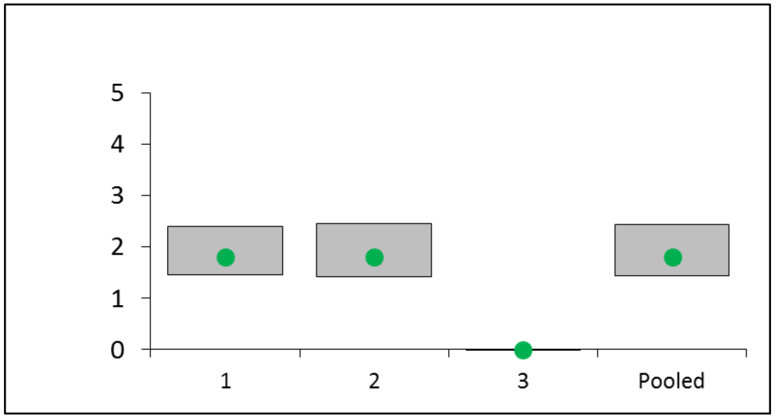
Original estimates provided:

	No Action			**Intervention 9**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.2	2.1		2.25	2.15	
Worst case scenario	1.7	1.7		1.71	1.71	
Most likely estimate	2.1	1.9		2.13	1.93	
Confidence	70	65		50	50	

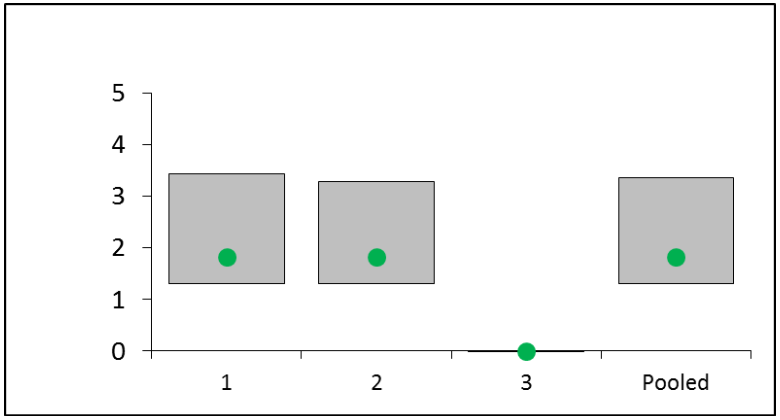
9: One million trees for the reef: Burdekin, Fitzroy, Burnett Mary

Estimated to influence of the intervention on wetlands in the region: experts estimated approx 0.1% of wetlands will be affected

No Action, Burnett Mary - standardised 80% C.I.s



Intervention 9, Burnett Mary - standardised 80% C.I.s



Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (wetland condition)**			**Average**
	1	2	3	
Optimistic change in wetlands	1.640	1.480		1.56
Pessimistic change in wetlands	-0.482	-0.482		-0.48
Most likely change in wetlands	0.030	0.030		0.03

Original estimates provided:

	No Action			**Intervention 7**		
	1	**2**	**3**	**1**	**2**	**3**
Best case scenario	2.1	2		2.15	2.05	
Worst case scenario	1.5	1.5		1.51	1.51	
Most likely estimate	1.8	1.8		1.83	1.83	
Confidence	70	65		50	50	

Appendix 7: Summary of effectiveness of the crown-of-thorns starfish (COTS) tactical control on mid-shelf coral cover

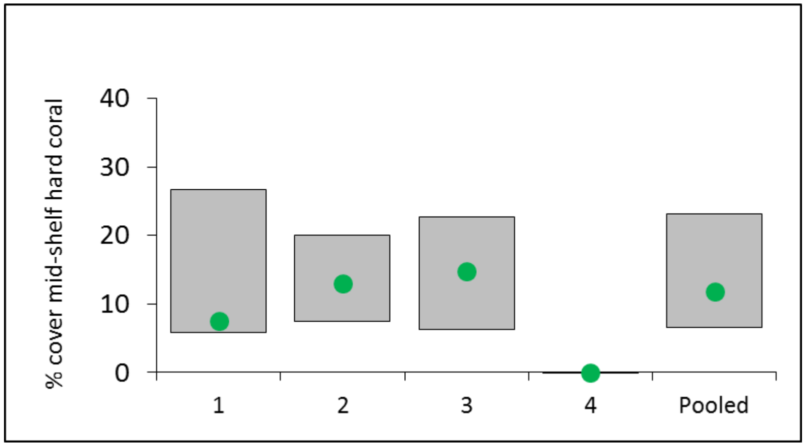
This document summarises discussions about the COTS tactical control intervention in the Wet Tropics, by four coral reef experts over the course of two teleconferences in January 2015. We also summarise the estimates of the effectiveness of the intervention and “no action” on mid-shelf coral reefs in the Wet Tropics at 2030 provided by three of the experts.

Experts concluded that the description of this intervention was unclear. Their discussions helped clarify the following:

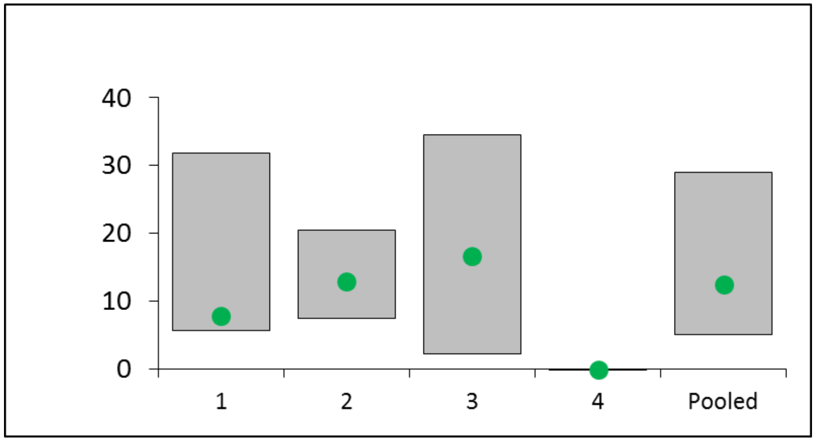
- All of the 21 reefs where the COTS tactical control is proposed occur in the Wet Tropics (Table 1), making up approximately 60% of the habitat available in this region.
- The experts concluded that one boat for COTS control is inadequate for this number of reefs, and if the boat was to visit all 21 reefs then this would allow for effort equivalent to only one visit per year (one visit = 4 days in port, 10 operational).
- Based on recent cull rates, the projected cull achievable from the proposed intervention would be approximately 85,000 COTS per year (estimated by experts)
- Based on the estimated level of visitation, the proposed COTS control intervention could realistically protect less than 10% of the perimeter of the 21 coral reefs.
- Experts recommend that if this intervention were to target fewer of the 21 proposed reefs, then the sites selected should be based on: a) tourism sites, and b) sites with good coral patches on mid-shelf reefs to ensure there are both social (tourism industry) and ecological (protecting coral reef) benefits.

The experts used the current level of mid-shelf hard coral cover outlined in De’ath et al. (2012), which was $\bar{x} =$ 14.1% at 2010 (95% CI = 5,17; central region). They made the following estimates of the effectiveness of no action and the COTS control intervention on mid-shelf hard coral cover in the Wet Tropics:

No Action, Wet Tropics - standardised 80% C.I.s



COTS control intervention, Wet Tropics - standardised 80% C.I.s



These graphs show the three experts estimates (green dots = most likely estimate, upper grey bar = best case estimate, lower grey bar = worst case estimate) and the pooled group estimates for no action vs each management interventions, standardised to 80% confidence.

Estimated changes (based on standardised 80% C.I.s)	**Experts estimated payoff (mid-shelf hard coral cover)**				**Average**
	1	**2**	**3**	**4**	
Optimistic change in hard coral cover[1]	24.355	7.500	19.760		17.20
Pessimistic change in hard coral cover[2]	-1.891	-5.500	-12.600		-6.66
Most likely change in hard coral cover[3]	0.320	0.000	1.800		0.71

NB: Expert number 4 was unable to provide estimates by the required deadline.

[1] Optimistic change = intervention best case – no action most likely estimate
[2] Pessimistic change = intervention worst case– no action most likely estimate
[3] Most likely change = intervention most likely estimate – no action most likely estimate

Original estimates provided:

	No Action				COTS Intervention			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Best case scenario	20	20	19.8		21.9	20.5	21.6	
Worst case scenario	6.3	7.5	7.4		6.3	7.5	7.6	
Most likely estimate	7.5	13	14.8		7.82	13	16.6	
Confidence	60	80	70		55	80	50	

NB: Expert number 4 was unable to provide estimates by the required deadline.

Table 1. Proposed 21 reefs in the Wet Tropics (source: Peter Doherty)

	Reef Name (ID)	Characteristics	Perimeter (km)
6	Tongue Reef (16-026)	Tourism, Super spreader	83.8
14	Arlington Reef (16-064)	Super spreader	54.5
7	Batt Reef (16-029)	Super spreader	46
2	Undine Reef (16-020)	Super spreader	35.2
3	Rudder Reef (16-023)	Super spreader	31.9
21	Elford Reef (16-073)	Super spreader	27
18	Moore Reef (16-071)	Tourism	23.2
13	Green Island Reef (16-049)	Tourism, Super spreader	16.8
4	Chinaman Reef (16-024)	Super spreader	9.9
12	Michaelmas Reef (16-060)	Tourism, Super spreader	25.4
5	Opal Reef (16-025)	Tourism	22.1
11	Hastings (16-057)	Tourism, Super spreader	14
17	Thetford Reef (16-068)	Tourism, Super spreader	11.5
20	Fitzroy Island Reefs (16-054)	Tourism	8.2
8	Low Isles (16-028)	Tourism	6.5
19	Briggs Reef (16-074)	Tourism	4.1
1	St Crispin Reef (16-019)	Tourism	23
9	Norman Reef (16-030)	Tourism	8.3
16	Milln Reef (16-060)	Tourism	6.9
10	Saxon (16-032)	Tourism	6.5
15	Flynn (16-065)	Tourism	5.3
		Total perimeter of 21 reefs	470.1
		Proportion of Wet Tropics total	56.14%

Literature cited

De'ath, G., Fabricius, K.E., Sweatman, H. & Puotinen, M. (2012) The 27-year decline of coral cover on the Great Barrier Reef and its causes. *Proceedings of the National Academy of Sciences of the United States of America*, **109**, 17995–17999.

Appendix 8: Sensitivity analysis of the cost-effectiveness model outputs

A sensitivity analysis is useful to explore the influence of changing the preference weights of the objectives on the ranking of the proposed management interventions derived from the cost-effectiveness model outputs. Random preference weights were assigned to the four objectives 1000 times. The frequency of ranking (between 1 and 9) based on the cost-effectiveness estimates is plotted in histograms below for each of the proposed management interventions. These histograms show the ranking based on most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars). A star denotes the ranking given using the equal weight on all four objectives (0.25), which is shown in Table 7 of the Summary Report).

This sensitivity analysis of the cost-effectiveness estimates has revealed a course delineation of proposed interventions, with five interventions consistently achieving the highest ranking out of the nine interventions. Using the most likely cost-effectiveness estimate the top-five ranking proposed interventions are: the rehabilitation of coastal ecosystems (intervention 8), erosion control in priority grazing landscapes (intervention 5), Smartcane best management practice accreditation (intervention 1), farmer led innovative cane management practices (intervention 4), and the expansion of holistic grazing pilot project (intervention 2). The four proposed interventions that rarely attained top-five status using random preference weights were: the reef Bonus trial (intervention 7), reverse tender for nitrogen use efficiency of sugar cane farms (intervention 3), one million trees for the reef (intervention 9), and the crown-of-thorns starfish tactical control (intervention 6).

The sensitivity analysis histograms (Figures 1 – 9) illustrate further how the ranking of the proposed interventions can fluctuate with 1,000 randomisations of the preference weights assigned to the four objectives. The rankings given to each proposed intervention (based on the equal weighting) are relatively insensitive to changes in the weights assigned to the four objectives. That is most of the intervention rankings achieved with equal preference weights, are maintained approximately 80% of the time despite changes in the preference weights assigned to the objectives.

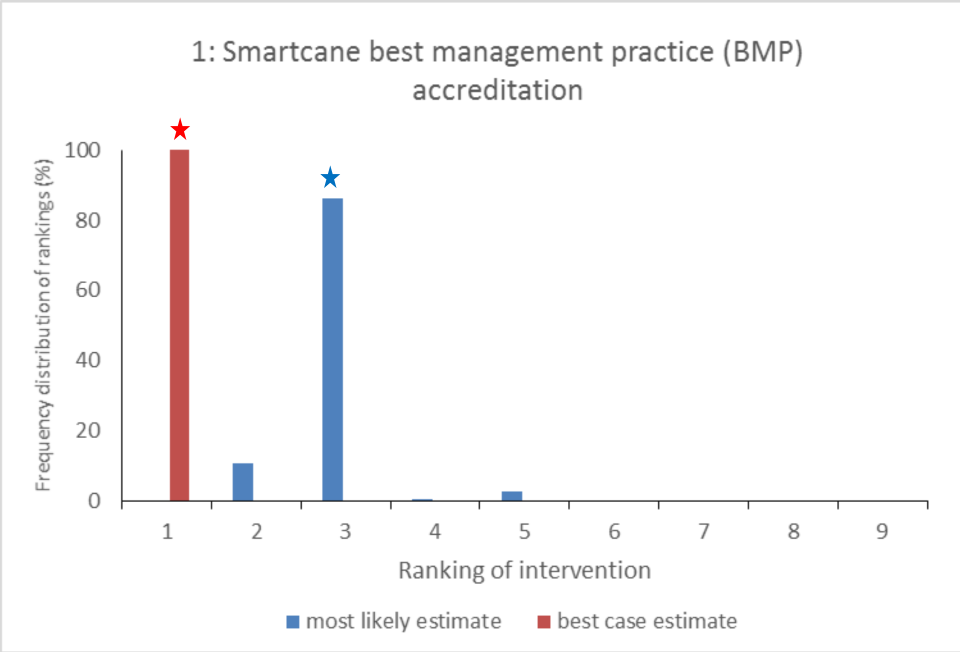


Figure 1. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 1 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

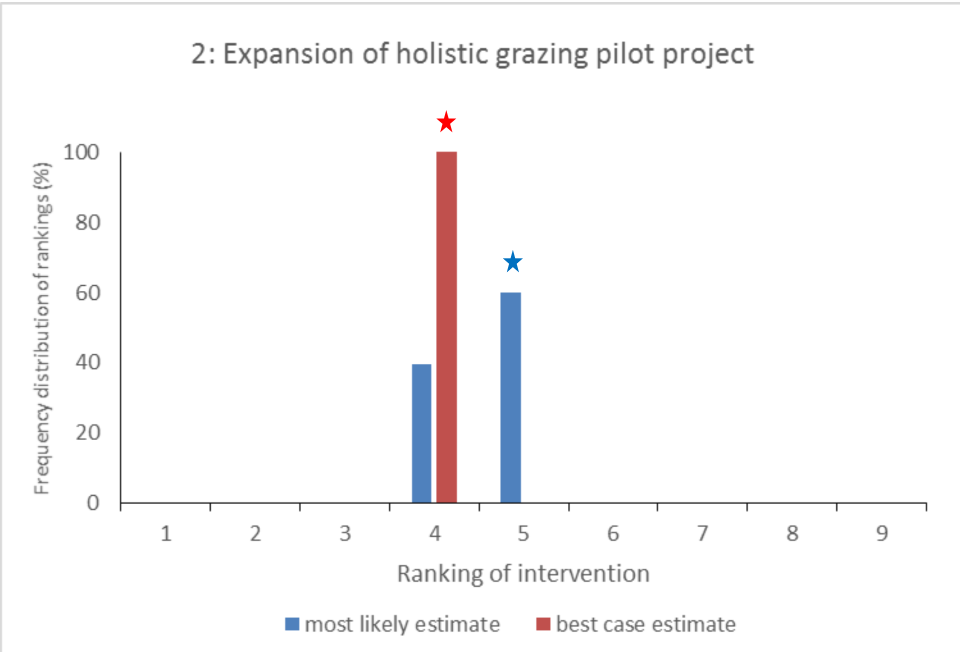


Figure 2. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 2 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

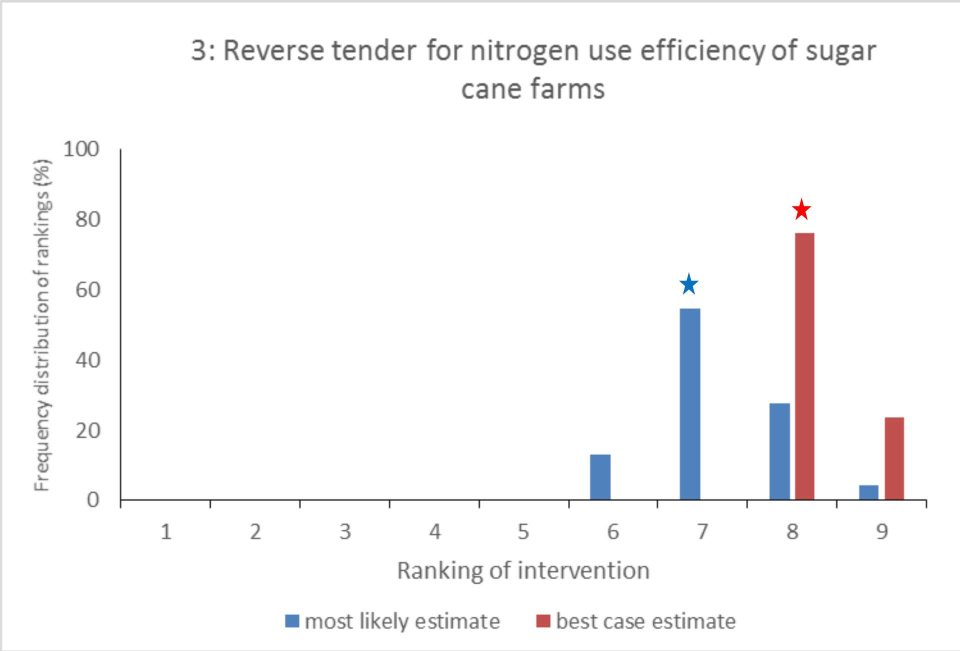


Figure 3. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 3 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

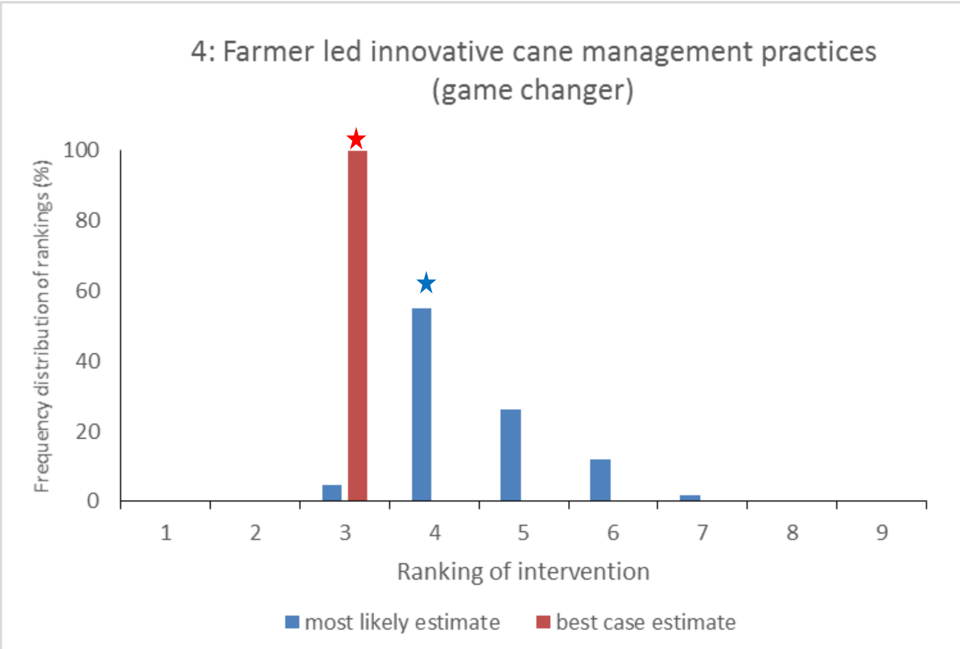


Figure 4. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 4 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

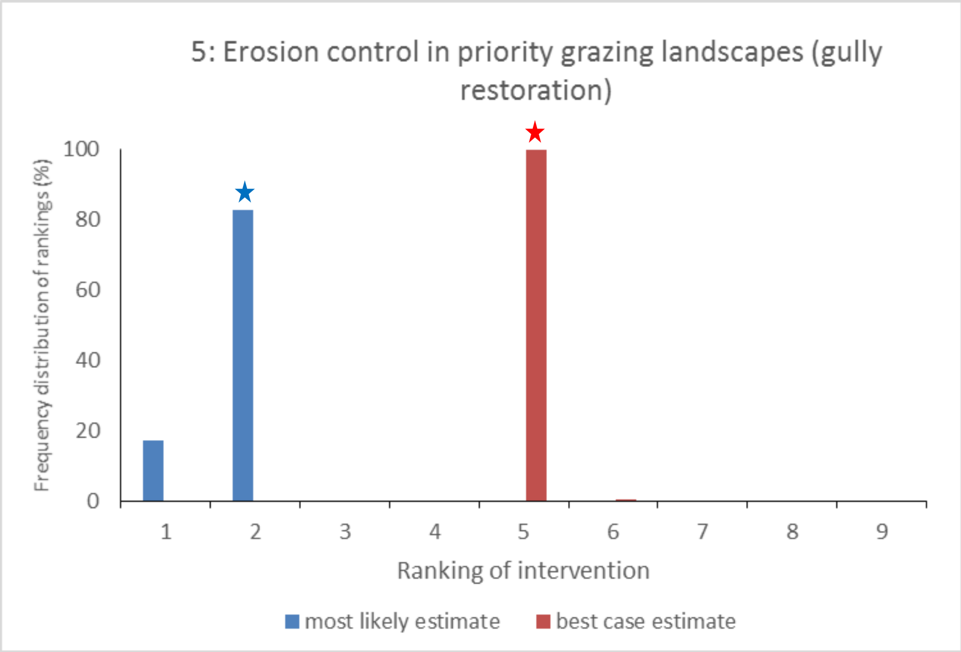


Figure 5. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 5 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

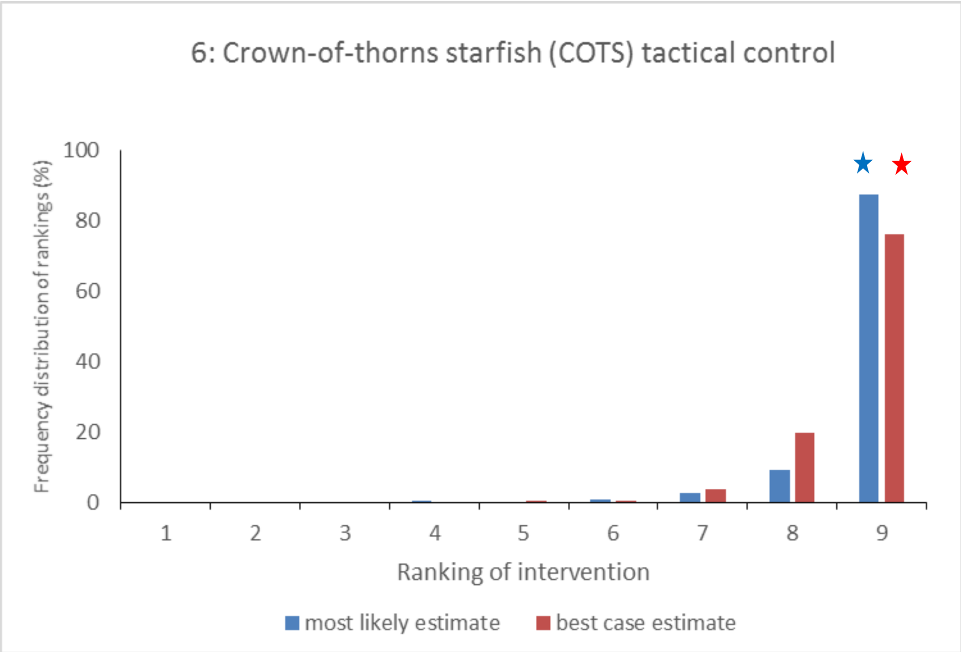


Figure 6. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 6 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

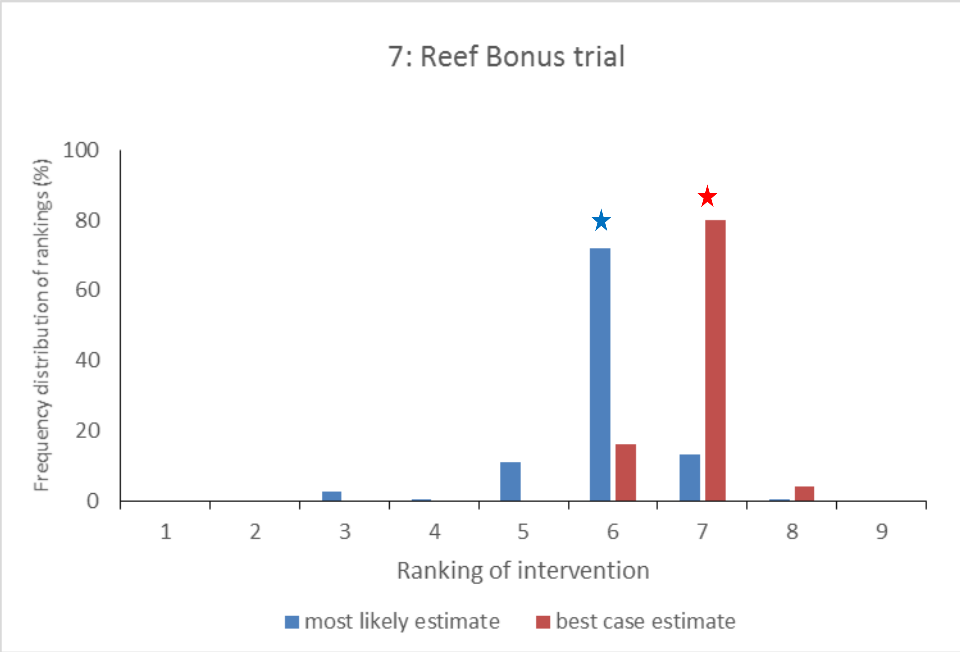


Figure 7. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 7 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

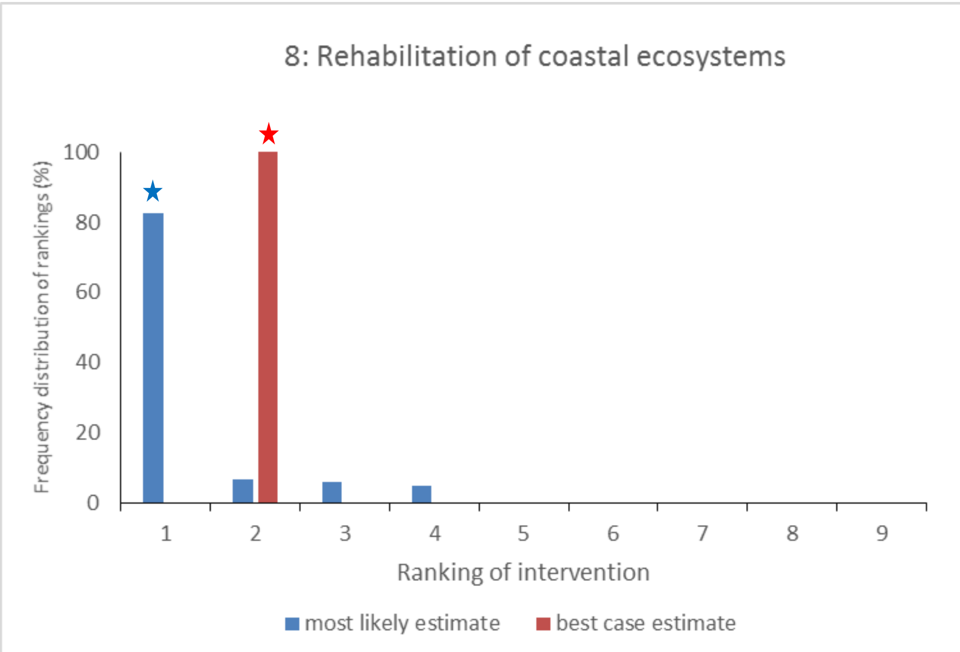


Figure 8. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 8 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).

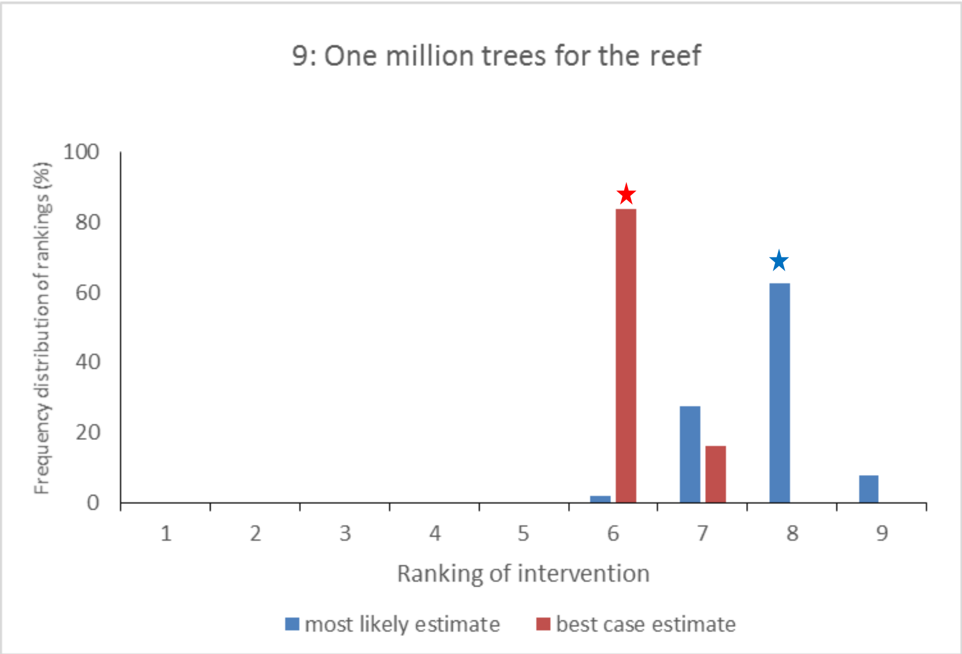


Figure 9. Sensitivity analysis histogram showing slight fluctuations in the ranking of intervention 9 with 1,000 randomisations of the preference weights assigned to the four objectives. The most likely cost-effectiveness estimates (blue bars) and best case cost-effectiveness estimates (red bars) are shown. A star denotes the ranking given using the equal weight on all four objectives (0.25).