Great Barrier Reef Foundation

Crown of Thorns Starfish Control Innovation Program: Feasibility and Design Phase

Application of Structured Decision Making to Guide Investment Prioritisation and Program Design

Summary Report

29 June 2021

Prepared by Adaptus for the Great Barrier Reef Foundation

Great Barrier Reef Foundation

adaptus

About Us

Adaptus is a boutique management consulting firm that partners with leaders in business & society to understand & respond to the risks & opportunities of climate change.

We use approaches from the risk & decision sciences to help clients solve complex ESG & climate resilience challenges, make robust decisions that protect & create value in the face of climate change uncertainty, and achieve a commitment to action with partners, investors & stakeholders.

Established in 2020, our team has a combined 30 years' experience helping clients across a diverse range of public & private sectors successfully prioritise investment in sustainability & climate action, leveraging our multi-disciplinary expertise in environmental engineering, water resources management, anthropology, sustainability, economics, investment finance, risk management & program delivery.

Acknowledgement of Country

The author acknowledges the Gurambilburra Wulgurukaba, Bindal, Nywaigi, Gugu Badhun, Turrbal, Gimuy-walubarra yidi, Wurundjeri and Noongar peoples as the Traditional Owners of the land and sea where this work took place. We pay our respects to their Elders past, present and emerging, and we acknowledge their continuing spiritual connection to their land and sea.

Report Details

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1. Introduction

1.1. Program Overview

Outbreaks of coral-eating crown-of-thorns starfish (COTS) are a major cause of coral decline on the Great Barrier Reef and future COTS outbreaks are almost certain. Managing these damaging outbreaks is a critical priority to improve the health of the Great Barrier Reef World Heritage Area. Effective COTS outbreak management is also a necessary complement to research and innovation that helps the Great Barrier Reef resist, adapt to, and recover from the impacts of climate change.

The Great Barrier Reef Foundation (GBRF) has convened a consortium of partners to deliver the Crown of Thorns Starfish Control Innovation Program (CCIP), tasked with exploring enhanced and potential new interventions for COTS surveillance and control. The program is being delivered as a multidisciplinary collaboration between GBRF, the Australian Institute of Marine Science (AIMS), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), James Cook University (JCU) and the University of Queensland (UQ), with cross-institutional teams focused on designing (phase 1, 2020-2021) and delivering (phase 2, 2021-2024) a research and development (R&D) program. Additional experts from beyond the core partner institutions have also been engaged through an open Expression of Interest process. In total, 43 technical experts from across partner institutions and third parties have been engaged in designing the program.

The CCIP is an important initiative under the Reef Trust Partnership (RTP), from which the program has received $9.8m in investment as part of the COTS Component of the RTP. The RTP's COTS Component has stated **near-term goals** to:

1) trial and / or implement innovative control and surveillance methods,
2) develop and test early warning systems, and
3) better predict and detect primary outbreaks;

stated **medium-term goals** to:

1) reduce coral mortality from COTS outbreaks at key reefs, and
2) identify new methods to manage COTS at scale;

and stated **long-term goals** to:

1) improve coral cover across the GBR, and
2) suppress primary outbreaks.

Within this context, the CCIP had a stated goal at its initiation to **'create a step change and accelerate the development of innovative control and surveillance methods while continuing to improve the efficacy and efficiency of current methods'**.

1.2. Feasibility and Design Phase

The CCIP's Feasibility and Design phase (phase 1) is focused on reviewing the current state of the art, identifying knowledge and capability gaps, identifying and assessing the feasibility (technical, social and regulatory), cost and benefit (impact) at scale of a broad range of possible improvements and interventions

in COTS surveillance and control, and prioritising opportunities to inform an ultimate integrated R&D program (phase 2) to deliver on the overarching goal of the CCIP.

1.3. Study Approach

Prior to undertaking the design phase study, six Program Areas were identified that represented key research themes for achieving CCIP goals:

- COTS biology and ecology,
- proximal causes of outbreaks,
- population control methods,
- decision support and modelling,
- monitoring and surveillance, and
- traditional owners, social acceptance and regulation.

Cross-institutional teams were assembled for each Program Area, and Figure 1 depicts the overarching approach for how these Program Area teams worked together to deliver the CCIP Feasibility and Design study. Detailed descriptions of each Program Area, including team membership, are presented in Appendix A.

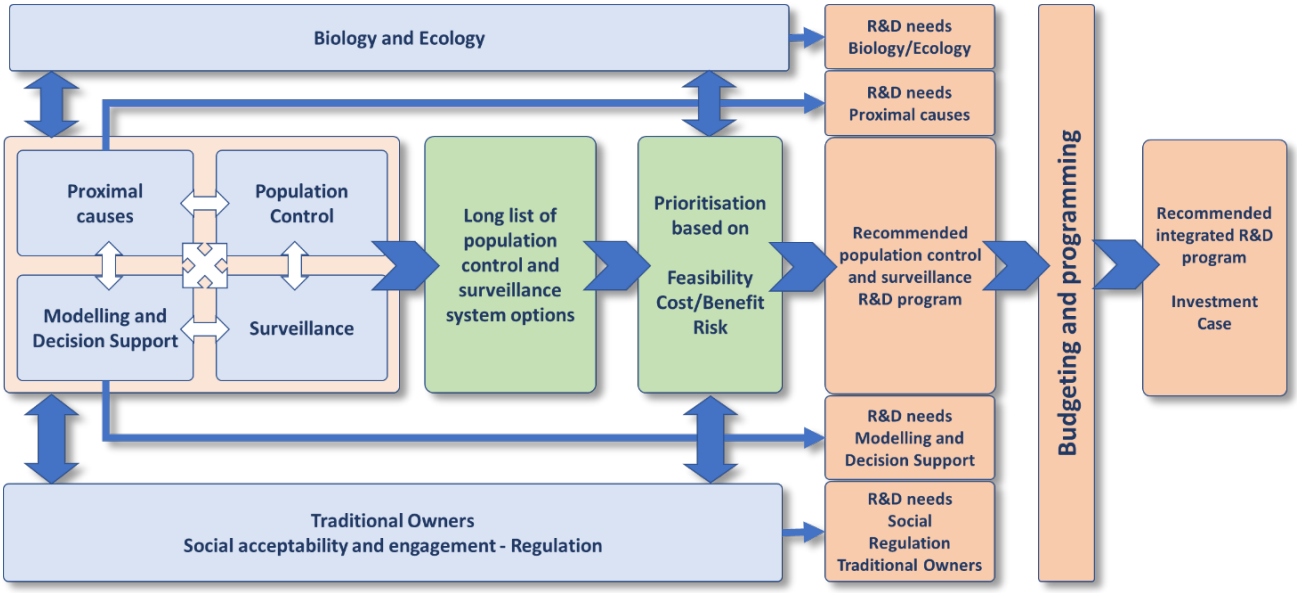


Figure 1. CCIP Feasibility and Design Phase Approach Framework

Achieving the objective of the CCIP requires targeted research that drives progress while also managing cost and risk. The challenge is that there are a wide range of research opportunities that could potentially contribute to delivering CCIP's goal. Moreover, the feasibility and benefits of many potential research opportunities in delivering innovative COTS management outcomes are not well understood. Consequently, the program is faced with a complex problem in deciding which research opportunities warrant investment.

Given this complexity, the program planned to adopt structured decision-making principles to inform major program assessments and decisions, including research opportunity assessment and prioritisation in order to design the subsequent R&D program. Structured decision-making is an organised, inclusive and

transparent approach to understanding complex problems and evaluating alternative options to address them (Keeney 1982[1], Gregory et al. 2012 [2]). It is based on the concept that quality decisions are those which are based on values (i.e. understanding what's important) and consequences (i.e. understanding what's likely to happen). It is useful when different disciplines need to work together on complex problems to develop solutions that are rigorous, inclusive, defensible and transparent. This is discussed in more detail in Section 3.

The study was divided into 6 distinct steps:

1) Program-Wide: Kick-Off
2) By Program Area: Gap analysis of knowledge and capability
3) By Program Area: Opportunity Identification and Assessment
4) Program-Wide: Portfolio Assessment and Opportunity Prioritisation
5) By Program Area: Scope Rationalisation and Budgeting for Prioritised Opportunities
6) Program-Wide: Final Program Design

This report primarily focuses on detailing the process and outcomes involved in step 4, the Program-Wide Portfolio Assessment and Opportunity Prioritisation, as this was the key step in which Adaptus contributed to the CCIP Feasibility and Design phase study. Two companion reports, the ***CCIP Feasibility and Design Phase Technical Report*** and the ***CCIP R&D Program Design Recommendations*** report, detail the process and outcomes of the remaining steps.

1.3.1. Program-Wide Kick-Off

The Feasibility and Design study commenced in November 2020 with a kick-off meeting facilitated by the CCIP Program Director and attended by the leads of each Program Area. Adaptus was not involved during this stage. Notably, the program agreed:

- the opportunity statement, i.e. that the objective of the study was to **"identify which combination of research opportunities should be invested in during the R&D phase to best achieve the goals of the CCIP"**,
- not to apply any boundaries or constraints to the scope of research opportunities developed for consideration, except that research would need to focus on the GBR,
- a preliminary long list of potential values that are likely to be important in informing the identification, conceptual development, assessment (through evaluation criteria), and prioritisation (through prioritisation criteria) of research opportunities, and
- the need for a vision statement for COTS control in 2025 and 2040 to inform finalisation of evaluation criteria.

[1] Keeney RL. Decision Analysis: An Overview. Operations Research. 1982; 30(5):803–38.

[2] Gregory R, Failing L, Harstone M, Long G, McDaniels T, Ohlson D. Structured Decision Making: A Practical Guide to Environmental Management Choices. Chichester: John Wiley & Sons; 20

1.3.2. Program Area Gap Analysis

Each Program Area then reviewed the current state of the art within their thematic area of focus, and subsequently established research, knowledge and capability gaps to inform the development of potential Research Opportunities within their work stream. A detailed description of activities and outcomes from the Gap Analyses can be found in the ***CCIP Feasibility and Design Phase Technical Report***. Adaptus was not involved during this stage.

1.3.3. Program Area Opportunity Identification and Assessment

Following the Gap Analysis, Research Opportunities were identified and scoped by each Program Area, and subsequently assessed using a structured evaluation framework that was developed and led by the Decision Support and Modelling Program Area Lead. In total, 52 research opportunities were identified and assessed across the Program Areas. Adaptus was not involved in these early activities during this phase. A summary of the Program Area Opportunity Identification and Assessment Process is presented in Appendix C, while the results from the Program Area Opportunity Assessments, including descriptions of opportunities developed in each Program Area, are presented in Appendix D. A detailed description of the activities and outcomes related to the identification and assessment of Research Opportunities within each Program Area is provided in the ***CCIP Feasibility and Design Phase Technical Report***.

2. Adaptus Scope

Adaptus was engaged by the GBRF on behalf of the CCIP during the opportunity identification and assessment phase, to:

1) provide independent expertise and advice to the CCIP Program Director and broader CCIP program on the application of structured decision-making principles,
2) provide independent expertise and advice to the CCIP Program Director and Decision-Support and Modelling Program Area lead on the design of the research opportunity assessment process, and
3) provide independent expertise, advice and support to the CCIP Program Director in the design and facilitation of the program-wide process for prioritising opportunities through a portfolio assessment.

Figure 2 depicts the primary focus of the Adaptus scope in the context of the entirety of the CCIP Feasibility and Design Phase Study workplan.

ADAPTUS' Scope

	Within Program Areas			Across Program	
	Gap Analysis / Literature Review	Scope Research Opportunities	Assess Research Opportunities	Develop Research Portfolio Options	Prioritise Portfolio for Investment
Why	To systematically identify gaps in knowledge within each CCIP Program Area (PA)	To collect information on benefits, costs, risk, feasibility of potential research opportunities	To assess and score proposed research opportunities using Evaluation Criteria	To consider research opportunities across PAs and develop integrated portfolios that combine to achieve alternative strategic outcomes	To systematically consider the feasibility and benefit of different strategic research portfolio investment options
How	Workshop, followed by desktop analysis / literature review	Desktop work using Research Opportunity template provided, workshop if required for brainstorming and / or coordination across team	Pre-workshop scoring by members of each PA team using a survey tool, followed by half-day workshop within each PA team to discuss outcomes and refine scores (if necessary), facilitated by DS&M team members	Desktop analysis using outcomes of PA assessment workshops, building of multiple portfolio options for assessment	Pre-scoring of portfolios using survey tool, followed by full day workshop in Cairns with whole CCIP team to discuss and refine outcomes, facilitated by consultant
Who	PA leads + teams	PA leads + teams	PA leads + teams	PD and Consultant In consultation with PA leads, Steering Committee and external assessors	PD and Consultant In consultation with PA leads, Steering Committee and external assessors
Outcome	Review document (or table) that can be used to inform development of the list of Research Opportunities within PA	'Long list' of research opportunities (with completed templates for each) within each PA that can be assessed/scored	Group discussion on the feasibility and benefit of research opportunities, resulting in an assessed list of research opportunities within PAs	Development of multiple research portfolio strategies to be considered for CCIP investment	Group discussion across CCIP and agreement on recommended portfolio of research for CCIP investment case
Indicative Timing	Nov / Dec 2020	Due 30 January - list of opportunity titles for each PA Due 10 February – fully completed opportunity reports for each PA	Pre-scoring research opportunities week of 15th February Workshop week of 22nd February	Portfolio framing workshop 2nd week March	Pre-scoring portfolios week of 15th March Workshop Wednesday 31st March in Cairns

Figure 2. The Adaptus scope in the context of the CCIP Feasibility and Design Study.

3. Structured Decision Making

Structured decision-making (SDM) is a general term to describe approaches used to help individuals and groups navigate through tough multi-dimensional choices characterised by uncertain science, disparate information, diverse stakeholders and difficult trade-offs. Structured decision-making is derived from the science of decision analysis, the foundations of which are summarised in *Decision Analysis: An Overview* (Keeney, 1982[3]). It is also from here that the popular alternative definition of structured decision-making as "a formalisation of common sense for decision problems that are complex for informal use of common sense" emanates.

The primary purpose of structured decision-making is to aid and inform decision-makers, rather than to prescribe a preferred solution. It is based on the concept that quality decisions are those which are based on values (understanding what's important) and consequences (understanding what's likely to happen). It is aimed at providing consistency, transparency and defensibility to decisions.

At the core of structured decision-making are six key elements that should underpin any decision process to ensure a quality decision outcome. These elements are:

- Establish a relevant decision frame – What are the objectives of the CCIP feasibility and design phase? How do they relate to the broader objectives of CCIP and the COTS component of the RTP? How will we know if we have been successful in achieving these objectives? Are all stakeholders aligned on the objectives of the project?
- Generate creative, doable alternatives – What are the different research activities we can invest in to resolve knowledge and capability gaps? Are the activities feasible and achievable? Are they relevant to the objectives they are mean to serve?
- Source relevant, reliable information – Is there relevant and reliable information to support the alternatives? Is the information endorsed by expert opinion?
- Understand consequences and trade-offs – Do we know what is important to the decision makers and stakeholders when assessing alternatives? Do we know what the trade-offs are between different values? Do we know what the consequences will be of trading-off different values? Are these consequences acceptable to decision makers and stakeholders?
- Use robust logical analysis – Have we used robust analytical methods that are underpinned by sound scientific study? Have we consulted subject matter experts in the analysis process?
- Facilitate a commitment to action – Have we used the results of the analysis to help facilitate a commitment to action? Has the process enabled the identification of robust and defensible research investment priorities?

The process for assessing and selecting research investment priorities to improve COTS surveillance and control has been underpinned by the principles of structured decision making and detailed throughout this report.

[3] Keeney RL. Decision Analysis: An Overview. Operations Research. 1982; 30(5):803–38.

4. Opportunity Prioritisation: Portfolio Assessment

4.1. Approach and Intent

A portfolio approach was proposed by the CCIP Program Director and Steering Committee in order to establish high-priority opportunities and engender alignment on their relative priority across program decision makers (i.e., Program Director and Steering Committee). The objectives of the process were:

1) to identify and characterise aspirational strategic approaches to program design,
2) to elicit and understand Steering Committee perspectives on the relative differences between program design aspirations and the ability of identified opportunities to deliver those aspirations,
3) to establish agreed aspiration for program design and inform resultant program design strategy, and
4) to identify areas of necessary Program Area and opportunity rationalisation to inform final program design.

Specifically, the process steps entailed:

1) A framing workshop to establish the frame for the prioritisation process, including refresh of the program opportunity statement, confirmation of key success factors, identification of potential strategic R&D portfolio themes, and evaluation criteria;
2) Construction of alternative strategic R&D portfolios using opportunities generated by the experts across Program Areas;
3) Assessment of alternative strategic R&D portfolios against agreed evaluation criteria;
4) Identification of individual opportunities that strongly perform across the best performing portfolio; and
5) Generation of insights to inform opportunity rationalisation and final design of an ultimate R&D portfolio.

The intent of the process was to ascertain a directional view on desired aspirations for CCIP based on the work done to date, to inform final program area development, opportunity rationalisation and selection, and ultimate program design.

4.2. Framing Workshop

A framing workshop was held in March 2021, attended by the CCIP Program Director, CCIP Program Area leads, CCIP Steering Committee and four external assessors invited by the CCIP Steering Committee to contribute to the process. The convened group:

- Agreed to update the CCIP opportunity statement to **"to create a step change and accelerate the development and uptake of innovative methods that improve the efficacy and efficiency of COTS control and surveillance"**,
- Established a list of key success factors for CCIP;
- Established a long list of potential strategic R&D portfolio themes; and
- Established a long list of potential evaluation criteria.

Workshop outputs are presented in Appendix E.

4.3. Portfolio Construction

Together with the CCIP Program Director, the long list of potential strategic R&D portfolio themes was reviewed and consolidated into a final list of 7 proposed themes, as described in Table 1, collapsing overlapping concepts discussed at the framing workshop.

Table 1. Final Portfolio Themes and Descriptions

Theme	Focus
Emphasis on Managing the Current Outbreak	This portfolio comprises R&D opportunities focussed on improving manual control by 2025 • It is focused on R&D that aims to improve the monitoring, modelling and decision support used to inform the current manual control program • It is not focussed on R&D that seeks to improve understanding and efficacy of other forms of control, including water quality and zoning, or develop new control methods
Emphasis on Suppressing the 2025 Outbreak	This portfolio comprises R&D opportunities focussed on improving control methods used in 2025 - 2035 (including manual control, predation, zoning and water quality) • It is focussed on R&D that could suppress the intensity or frequency of outbreaks at individual reefs within the GBR, but not prevent the spread of a primary outbreak entirely • It includes greater emphasis on R&D that seeks to improve understanding and efficacy of predation, zoning and water quality as means of control
Emphasis on Preventing Future Primary Outbreaks (Long-Term)	This portfolio comprises R&D opportunities focused on prevention of a future primary outbreak (in the long-term) • It is focused on increasing understanding of mitigating factors that lead to primary outbreak initiation • It includes development of GBR-scale control approaches for COTS prevention and suppression
Emphasis on Improving System Understanding	This portfolio comprises R&D opportunities focused on improving knowledge and understanding of the entire COTS management system, including biological and social components and their interaction, in order to generate GBR-scale outcomes It is not focussed on R&D that seeks to develop new control methods
Emphasis on Creating New Control Approaches	This portfolio comprises R&D opportunities focused on development of new control approaches (i.e., not manual control, zoning or water quality) • It includes biological R&D required to develop those approaches • It includes social R&D required to achieve social license and regulatory approvals to enable implementation of those approaches
Emphasis on Informing Strategy	This portfolio comprises R&D opportunities focused on informing long-term strategy and strategic decisions

Theme	Focus
	• It is focussed on R&D that informs high-value / high-cost / high-uncertainty decisions pertaining to where, when and how to optimally deploy finite management resources on COTS prevention and suppression • It includes enabling research to optimise strategy development and decision-making
Emphasis on Synergies within CCIP & across GBR Programs	This portfolio comprises R&D opportunities that are likely to make beneficial contributions to other parts of CCIP & other GBR programs • It is focussed on R&D that is most highly synergistic with other opportunities within CCIP and potentially across other GBR programs

In order to construct alternative portfolio options, the broad approach taken was to:

- define the intent of each portfolio theme (i.e., what are we specifically trying to achieve through this portfolio),
- review the opportunities within each Program Area and assess the extent to which it would align to the intent of each portfolio theme,
- select those opportunities across each Program Area that most strongly meet the intent of the portfolio theme, until a total budget envelope of ~$14m was reached, and
- tweak the final list of opportunities in each portfolio to ensure all Program Areas are represented in each portfolio, and, with very few exceptions, ensure all opportunities are represented in at least one portfolio.

As part of the construction process, each of the 52 research opportunities was assessed for its alignment to the intent of each portfolio theme. Opportunities were assessed on a scale of 0 (not aligned) to 4 (highly aligned), and the most highly aligned opportunities (i.e., highest scoring) were selected for inclusion in each portfolio. Descriptions of each opportunity are presented in Appendix D, while Appendix F contains more detail on the scoring and selection of opportunities for portfolios.

Program Area leads were invited to review and provide feedback on the portfolio themes and their definitions, and the opportunities included in each portfolio. Final portfolio construction incorporated this feedback prior to finalisation.

It is important to note that these 7 alternative portfolios were not intended to represent the final design options for the program. Rather, they were lenses by which to explore different R&D investment strategies, to provide directional insight on what investment strategy should be pursued in the final design of the program. As such, the intent of the portfolio construction process was to select a list of opportunities that broadly align to the theme being considered such that the steering committee and external assessors could discern between the different portfolios.

4.4. Portfolio Evaluation Criteria

Together with the CCIP Program Director, the long list of potential portfolio evaluation criteria was reviewed and consolidated into a final list of 6 criteria, as described in Table 2. The portfolio evaluation criteria started with the list of evaluation criteria used for the opportunity assessments and refined based on what would effectively discriminate among portfolios, and what would align to the concepts captured in our opportunity statement and key success factors. Further, the opportunity assessments were leveraged

for knowledge on which criteria did not contribute much to opportunity score, nor were particularly discriminating between opportunities, to justify their consolidation or exclusion.

Detailed descriptions and scoring scales are presented in Appendix G.

Table 2. Final Portfolio Evaluation Criteria

Evaluation Criteria	Evaluation Criteria Question	Key Success Factors
1. Extent of Impact on Coral	How significantly does this Portfolio improve our impact on coral through prevention and/or suppression of COTS outbreaks across spatial and temporal scales?	The portfolio improves our ability to have a beneficial impact on coral at scale, meaning that: • It enables prevention of future COTS outbreaks • It enables less frequent COTS outbreaks • It enables less severe COTS outbreaks • It enables us to have impact on coral at scale (i.e., spatially) • It enables us to have sustained impact on coral (i.e., over time)
2. Directness of Impact on Coral	How direct is the path from this Portfolio to improvement in our impact on coral from prevention and / or suppression of COTS outbreaks?	The portfolio has a direct path to improving our ability to have a beneficial impact on coral at scale, meaning that: • There is a transparent link between CCIP and COTS outbreak prevention and suppression activities • Outcomes of research can be directly implemented to COTS management • Its ability to impact is not reliant on additional subsequent R&D activities • Its ability to impact is not subject to outcomes from activities outside CCIP or COTS management
3. Immediacy of Impact on Coral	To what extent can this Portfolio improve our ability to impact on coral in the short-term through prevention and / suppression of COTS outbreaks?	The portfolio enables us to immediately improve our ability to have a beneficial impact on coral at scale, meaning that: • It enables reduction in the severity of the current COTS outbreak • It improves our readiness to manage the 2025 outbreak • It enables reduction in the severity of the 2025 COTS outbreak
4. Potential for Step-Change in COTS Management	To what extent does this Portfolio enable a step-change in COTS outbreak surveillance and control capability?	The portfolio enables us to achieve a step-change in COTS outbreak surveillance and control at scale, meaning that: • It enables transformation in surveillance and / or control capability • It enables a significant improvement in resource efficiency for COTS management • It enables a significant improvement in at-scale efficacy of COTS management
5. Co-Benefits: Traditional Owner and Community	To what extent does this Portfolio provide positive outcomes for Traditional Owners and communities?	The portfolio delivers positive benefits for Traditional Owners and communities, meaning that: • It enables avenues for cultural knowledge to inform / benefit COTS management and enhance integration • It enables participation and capability development opportunities for Traditional Owners and the Community • It enables increased economic opportunities for Traditional Owners and Community
6. Risk: Uncertainty in	To what extent is there certainty in realising the	The portfolio is not subject to uncertainty in terms of its ability to deliver impact on coral at scale, meaning that: • Success outcomes from R&D are clear

Evaluation Criteria	Evaluation Criteria Question	Key Success Factors
Delivering Impact on Coral	desired outcomes from R&D?	• There are no material uncertainties that impact success of R&D • There are no material uncertainties that impact the translation of R&D to outcomes • There are no material regulatory hurdles that impact conducting and / or implementing R&D

4.5. Portfolio Assessment Survey

In order to assess the portfolios, CCIP Steering Committee members, Program Area leads and external assessors were invited to complete:

1) a pairwise assessment via survey to help establish the relative importance of each evaluation criteria, and
2) an assessment via survey of each portfolio against each evaluation criteria.

4.5.1. Pairwise Assessment of Evaluation Criteria

Participants were asked to make judgements of the relative importance of each evaluation criteria, to inform the relative weights to be ascribed to each evaluation criteria when comparing portfolio themes. This was completed by means of a pairwise comparison, where respondents were asked how much more important each criterion was compared to each other criteria.

Example survey questions are presented in Appendix H.

4.5.2. Assessment of Portfolios against Evaluation Criteria

Participants were asked to assess the performance of each portfolio on a scale of 0 to 10 against each of the 6 identified evaluation criteria. An example criteria definition and scale is presented in Table 3. Given the subjective nature of the exercise, participants were able to respond with a range encompassing their best estimate given uncertainty. Given that individual responses were then accumulated across the number of respondents, this reduced the sensitivity of the process to the precise value of any one assessment.

Table 3. Evaluation Criteria Scale – Extent of Impact on Coral

EC Question: How significantly does this Portfolio improve our impact on coral through prevention and/or suppression of COTS outbreaks across spatial and temporal scales?										
Key Success Measures: In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio improves our ability to have a beneficial impact on coral at scale, meaning that: - It enables prevention of future COTS outbreaks - It enables less frequent COTS outbreaks - It enables less severe COTS outbreaks - It enables us to have impact on coral at scale (i.e., spatially) - It enables us to have sustained impact on coral (i.e., over time)										
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No change in impact from COTS outbreak prevention and surveillance i.e., • Outbreak frequency ~15-17 years • Outbreak extent limited to 10-15% of individual reefs • Peak COTS densities ~15 – 1000 COTS / ha	Low (~15%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Low reduction in outbreak frequency • Low reduction in impacted reefs • Low reduction in COTS densities			Moderate (~30%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Moderate reduction in outbreak frequency • Moderate reduction in impacted reefs • Moderate reduction in COTS densities			Significant (~50%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Significant reduction in outbreak frequency • Significant reduction in impacted reefs • Significant reduction in COTS densities			Highly significant improvement in impact from COTS outbreak prevention and / or surveillance i.e., • No COTS outbreaks on the GBR

Example survey questions are presented in Appendix H.

4.6. Results

4.6.1. Pairwise Assessment of Evaluation Criteria

Figure 3 depicts the mean (coloured bars) and low and high (error bars) outcomes from the pairwise assessment of evaluation criteria, split by respondent group (CCIP Steering Committee (SC), CCIP Program Area leads (PAL), and external assessors (EA)). The relative rank of each evaluation criteria is displayed also.

Extent of impact was ranked either 1 or 2 across all groups, with *step-change potential* assessed to be the most important criteria by the Steering Committee and *immediacy of impact* assessed to be the most important criteria by the external assessors (though notably it ranked in the bottom two for the Steering Committee and Program Area leads). *Traditional owner and community co-benefits* was consistently in the 3 least important criteria across groups relative to other evaluation criteria in assessing the performance of portfolios in achieving their strategic intent. *Uncertainty of impact* was considered important by the Program Area leads, but less important by the Steering Committee or external assessors.

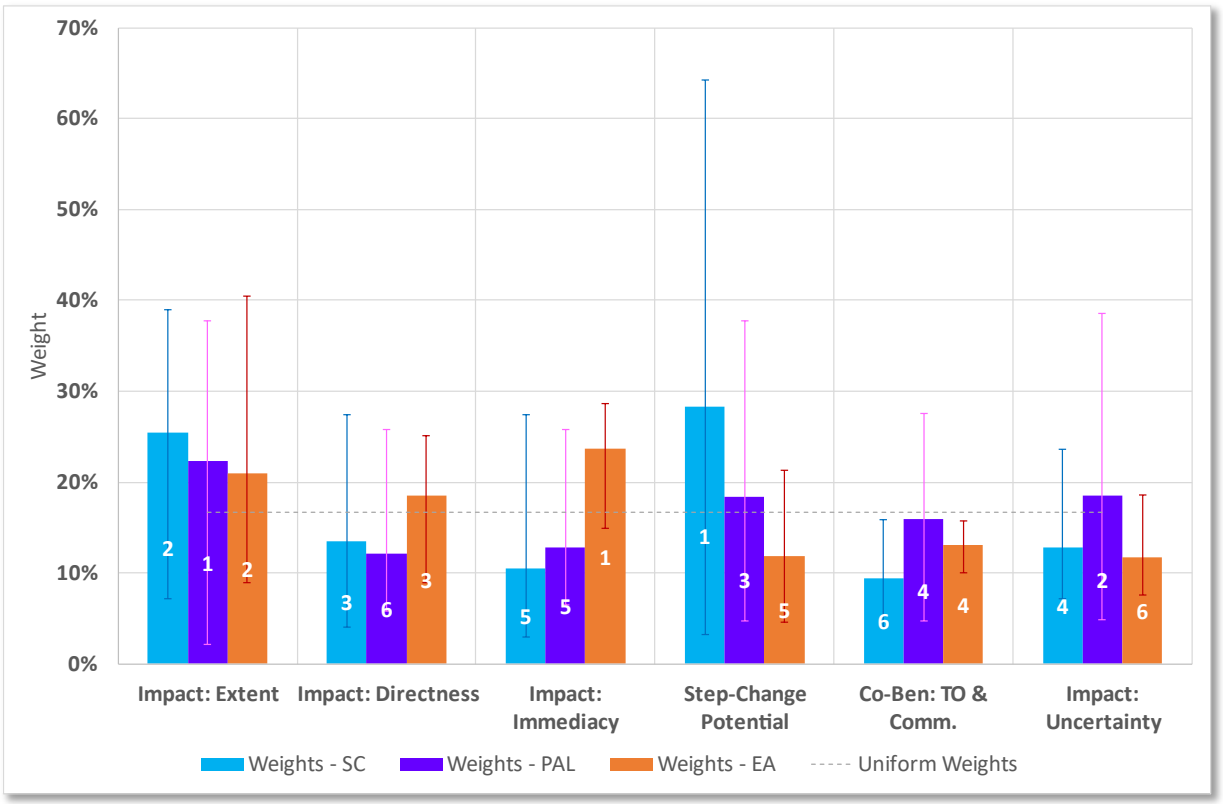


Figure 3. Results from pairwise assessment of evaluation criteria – means, low, high and ranks by assessing group

Figure 4 depicts the weighted mean results across all groups (in green), with individual group means presented as blue (Steering Committee, SC), purple (Program Area leads, PAL) and yellow (external assessors, EA) symbols. *Extent of impact* and *step-change potential* are assessed to be the two most important criteria in evaluating the performance of portfolios. *Directness of impact, immediacy of impact*, and *uncertainty in impact* are assessed to be relatively equally important, with *traditional owner and community co-benefits* slightly less important.

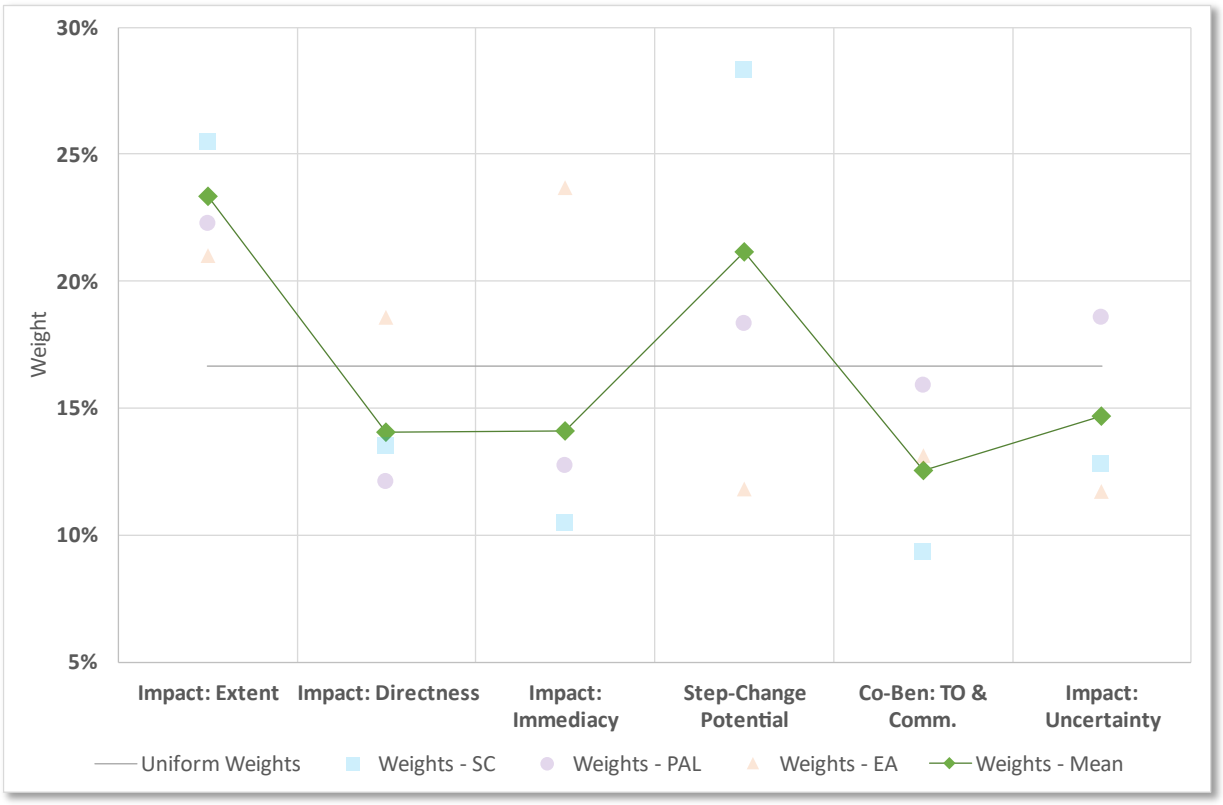


Figure 4. Results from pairwise assessment of evaluation criteria – population mean weights

Figure 5 depicts the count of instances where, based on each individual respondent's assessments, an evaluation criterion was ranked 1 through to 6. Fourteen (14) of the 19 respondents (>70%) assessed *extent of impact* to be either the most important or 2nd most important criteria, while 10 of 19 (>50%) assessed *step change potential* to be either the most important or 2nd most important criteria.

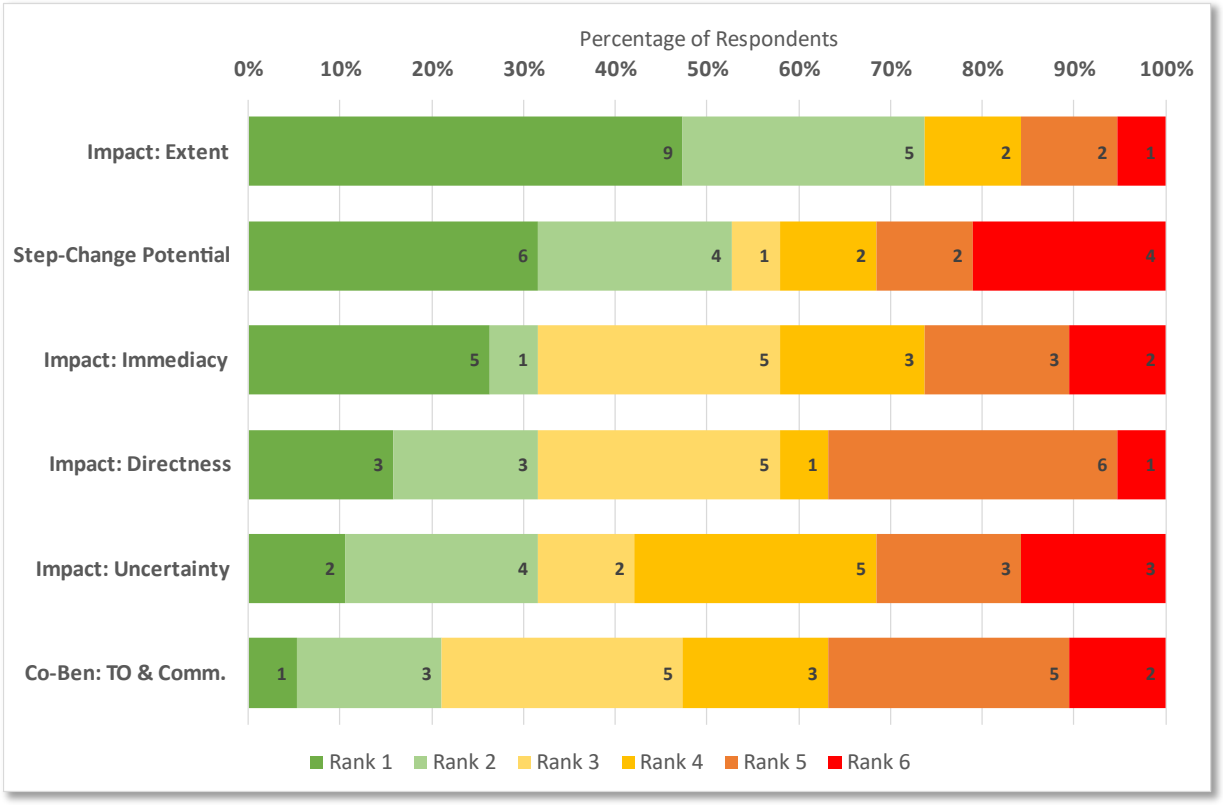


Figure 5. Results from pairwise assessment of evaluation criteria – individual response rankings

4.6.2. Assessment of Portfolios against Evaluation Criteria

Figure 3 depicts the mean (coloured bars) and low and high (error bars) outcomes from the assessment of portfolio performance against evaluation criteria, split by respondent group. These results use the mean weights from the pairwise evaluation criteria assessment results.

The Steering Committee and Program Area leads assessed *suppressing the 2025 outbreak* and *preventing future outbreaks* as among their top 3 portfolios. The Steering Committee and external assessors assessed *managing the current outbreak* as among their top 2 portfolios. These 3 portfolios were consistently stronger performing than the remaining 4 portfolios (it should be noted that the opportunities contained within the *managing current outbreak* portfolio are all contained in the *suppress 2025 outbreak* portfolio). *Improving system understanding* was consistently among the least favoured portfolios.

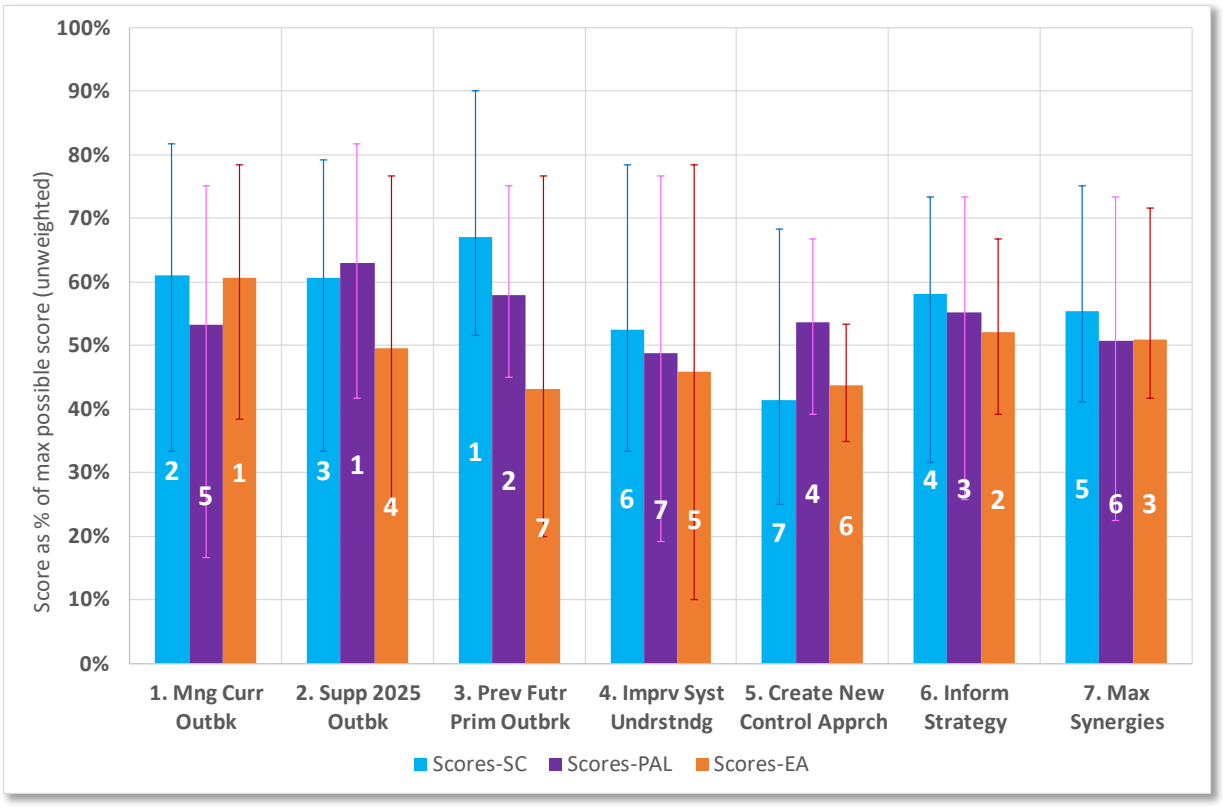


Figure 6. Results from portfolio assessment – means and ranks by assessing group (unweighted)

Figure 7 depicts the portfolio assessment results across all respondents, with the left-hand side chart showing mean portfolio assessment scores only (i.e., no weighting of evaluation criteria) and the right-hand side chart including application of mean weights from the pairwise assessment. *Preventing future primary outbreaks* and *suppressing the 2025 outbreak* are the top two portfolios, with *managing the current outbreak* closely behind. Again, it should be noted that the opportunities in this portfolio are all included in the *suppressing the 2025 outbreak* portfolio. Application of weights makes no difference to the relative performance order of portfolios, though does slightly increase the discretisation of the top three portfolios. *Improving system understanding* and *creating new control approaches* are the worst performing portfolios.

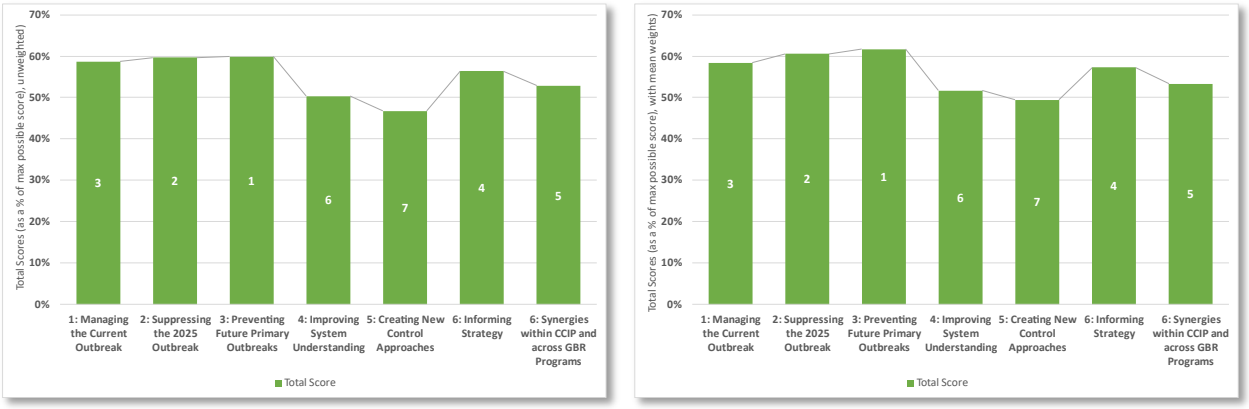


Figure 7. Results from portfolio assessment – unweighted (left) and weighted (right) population means and ranks

Figure 8 depicts the contribution of scores for each evaluation criteria to the total scores of each portfolio, with the left-hand side chart showing mean portfolio assessment scores only (i.e., no weighting of evaluation criteria) and the right-hand side chart including application of mean weights from the pairwise

assessment. *Suppressing the 2025 outbreak* is consistently the best performing or 2nd best performing portfolio across all criteria except step-change potential (where it is ranked 5). *Preventing future primary outbreaks* is the best performing portfolio for *extent of impact*, *step-change potential* and *traditional owner and community co-benefits*. The former two were deemed to be the 2 most important and highest weighted criteria from the pairwise assessment of evaluation criteria, which is why this portfolio is more clearly the best performing portfolio when evaluation criteria weightings are considered (right hand side image). *Managing the current outbreak* was ranked highest for *directness of impact* and *immediacy of impact*. The opportunities in this portfolio are all included in the *suppressing the 2025 outbreak* portfolio (which ranked 2nd for these two criteria). *Improving system understanding* and *creating new control approaches* performed in the bottom two for four of the 6 criteria, with the exception being *step-change potential* where they ranked 3rd and 2nd respectively.

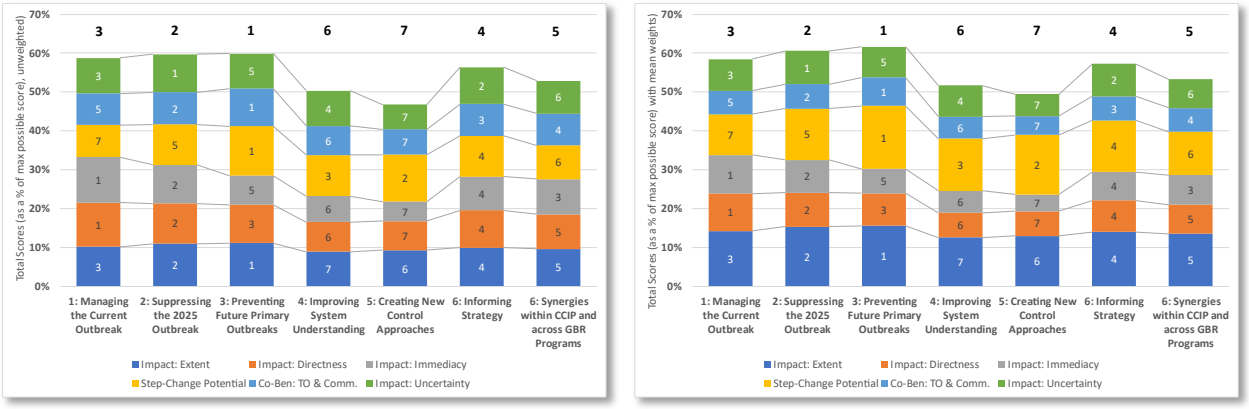


Figure 8. Results from portfolio assessment – unweighted (left) and weighted (right) ranks by portfolio and evaluation criteria

Figure 9 depicts the results from a Monte-Carlo analysis of the portfolio assessment and pairwise assessment results. A model was created to assess the probabilistic performance of portfolios given the range of scores and weights results across respondents. In 46% of all possible combination of individual weights and scores, *suppressing the 2025 outbreak* and *preventing future primary outbreaks* are ranked 1st or 2nd. *Improving system understanding* and *creating new control approaches* are ranked 7th or 6th (i.e. last or second to last) in 50% of all possible combinations of individual weights and scores.

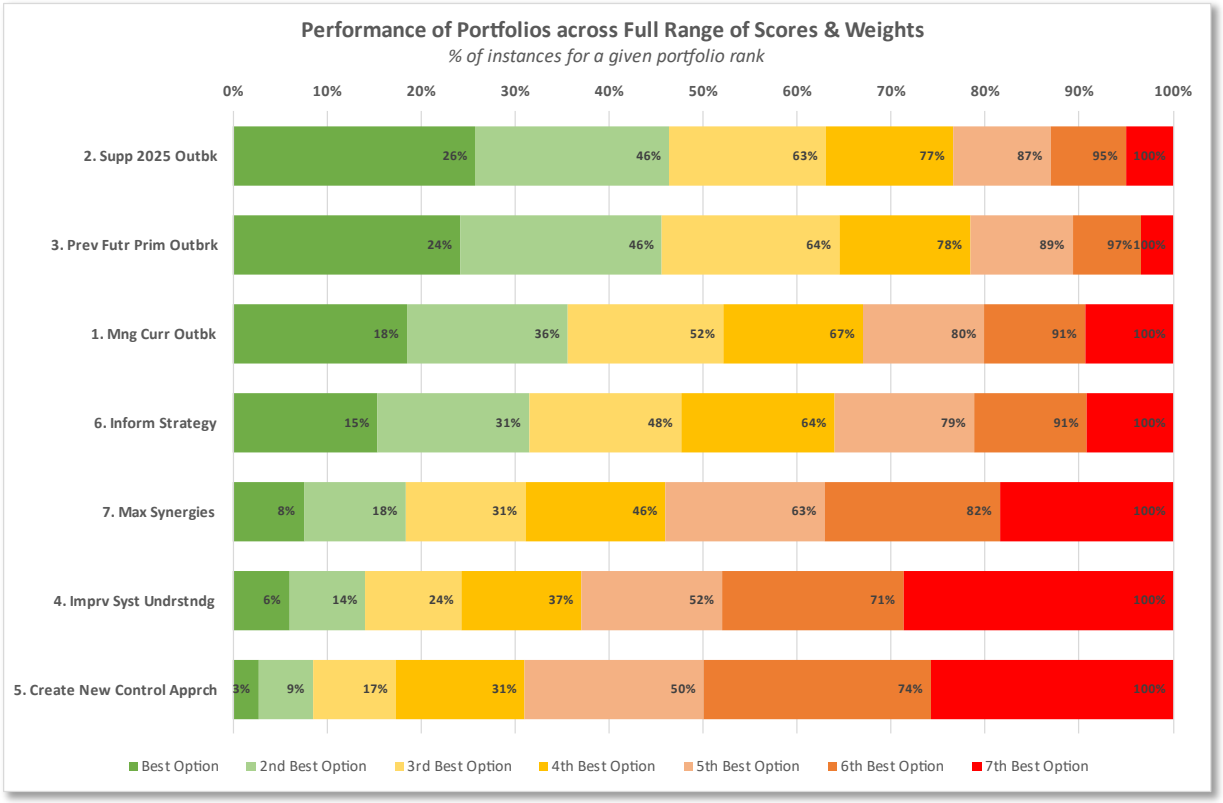


Figure 9. Results from portfolio assessment – unweighted (left) and weighted (right) ranks by portfolio and evaluation criteria

Full results are presented in Appendix I.

4.7. Outcomes and Insights from the Portfolio Assessment and Opportunity Prioritisation Process

The portfolio assessment process revealed some important findings for program decision makers:

- A program design that delivers 1) *improvement in the ability to impact coral across spatial and temporal scales* and 2) *the potential to create a step-change in COTS management*, is preferred by program stakeholders, above other identified measures of program value and impact.

- A program design that is focussed on both 1) *suppressing the 2025 outbreak* and 2) *preventing future primary outbreaks*, is strongly preferred by program stakeholders, above other potential strategic R&D portfolio themes for program design.

- A program design that is focussed on *creating new control approaches* is the least preferred R&D portfolio strategy by program stakeholders.

- Eight research Opportunities were identified that strongly aligned to delivering innovations across both the 1) *suppressing the 2025 outbreak* and 2) *preventing future primary outbreaks* portfolios: :

    1) **BE-4**: **Understanding initiation zone demography** – research that delivers new knowledge of inter-annual changes in density, distribution and demography for pre-outbreak COTS populations across the outbreak initiation region to provide an early-warning of impending primary outbreaks.

2) **MS-1**: **Sampling design** – research that delivers a plan for a monitoring program that delivers information on COTS and coral at spatial and temporal scales relevant to COTS outbreak management decision-making, including recommendations on the use of various sampling tools and how the monitoring would be integrated into other related programs.

3) **MS-6 / MS-8: TUVs** – research that develops an image-based monitoring tool, such as a Towed Underwater Vehicle (TUV), to deliver information on COTS density and distribution, and coral cover, across broader spatial and temporal scales than is currently possible through diver-based surveys.

4) **MS-7: TUV image processing** – research that develops informatics system, workflows, and machine learning models to process high-volume imagery collected by an image-based monitoring tool and deliver that data for use in relevant COTS modelling and decision support systems.

5) **DSM-1/9: Information infrastructure with risk and uncertainty** – research that develops an information infrastructure to underpin and accelerate innovation in COTS management by enabling the efficient sharing and distribution of field, derived, and modelled data amongst scientific collaborators and management stakeholders, including transparent reporting of uncertainty and clear data provenance.

6) **DSM-5: Reef-scale modelling –** research that develops dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds for COTS control, evaluating the performance of different COTS management strategies, and guiding the spatial distribution of effort.

7) **DSM-6: Regional modelling –** research that develops regional modelling capability across two ecosystem models (CoCoNet and ReefMod) in order to deliver insights into the relative benefits of different COTS control and surveillance strategies on coral reef health and resilience.

8) **DSM-12: Connectivity modelling** – research that uses an ensemble model approach, incorporating a range of hydrodynamic and biophysical assumptions, in order to improve robustness and quantify uncertainty in predictions of COTS larval dispersal for use in regional modelling and decision support systems.

- These eight research Opportunities should form the base of the portfolio that is funded under the R&D phase of CCIP.
- Additional research Opportunities can be added to build on this base portfolio until the available funding envelope has been reached. Potential options for building on this base portfolio include:

    1) Selecting Opportunities that are highly aligned to the *suppressing the 2025 outbreak* investment strategy;

    2) Selecting Opportunities that are highly aligned to the *preventing future primary outbreaks* investment strategy*;*

3) Selecting a mix of Opportunities that are aligned to both the *suppressing the 2025 outbreak* and *preventing future primary outbreaks* investment strategies.

CCIP decision-makers should consider these outcomes and insights as they select and refine the Opportunities included in the final program design. Overall, the application of structured decision making has been successful in providing clarity and transparency on potential program design approaches and value drivers, alignment amongst a broad range of 40+ contributors, stakeholders and decision makers on those program design approaches and drivers that best meet desired success measures for the program, and direction for decision makers on opportunity areas to prioritise in finalising program design.

Appendix A – Program Area Descriptions

COTS Biology & Ecology

The objective of this cross-cutting program area will be to undertake a systematic identification of gaps in our knowledge of COTS biology & ecology which affect our ability to understand, predict, detect, control & mitigate the impact of COTS outbreaks. This program area will aim to develop recommendations on research priorities that need to be addressed as part of an integrated R&D program to enable the design, implementation or ongoing improvement of long-term COTS management strategies.

The technical team assembled to deliver this work plan is comprised of 10 experts in COTS biology & ecology, including two experts from third party institutions. This team is led by Prof. Morgan Pratchett of JCU.

Table. Biology/Ecology program area team.

Program Area	Resource name	Institution
COTS Biology & Ecology	Morgan Pratchett	JCU
	Ciemon Caballes	JCU
	Bethan Lang	JCU
	Cherrie Motti	AIMS
	Sven Uthicke	AIMS
	Laura Crous	CSIRO
	Kenny Wolfe	UQ
	Amy Desbiens	UQ
	Symon Dwornjanyn	SCU
	Maria Byrne	USyd
	RA (tbd)	JCU

Proximal Causes

This program area will conduct an in-depth analysis of the conditions, processes & mechanisms that directly influence the likelihood & timing of a COTS outbreak as well as its scale & subsequent propagation. This program area will aim to identify knowledge gaps & develop recommendations on an R&D program to address such gaps, and guide the prioritisation, design & implementation of innovations identified under the population control & monitoring & surveillance program areas. For clarity, this program area does not deal with the ultimate causes of COTS outbreaks which, while they can be informed by this program, are not considered within scope.

The technical team assembled to deliver this work plan is comprised of 8 experts in COTS outbreak development & spread, including one expert from a third-party institution. This team is led by Dr. Sven Uthicke of AIMS.

Table. Proximal Causes program area team.

Program Area	Resource name	Institution
Proximal Causes	Sven Uthicke	AIMS
	Morgan Pratchett	JCU
	Ciemon Caballes	JCU
	Laura Crous	CSIRO
	Cynthia Riginos	UQ
	Karlo Hock	UQ
	Peter Mumby	UQ
	Maria Byrne	USyd
	RA (Maria Cabrera)	AIMS

Population Control

This program area will conduct a comprehensive review of innovation in the control of COTS population outbreaks, as part of an integrated pest management strategy to protect live hard coral on the GBR. Specifically, this program area will consider & prioritise potential innovations in the current (i) CoTS Control Program & (ii) water quality improvement programs, as well as the broad range of possible biologically based control technologies for COTS reviewed in Hoj et al. (2020), namely (iii) Predators & coral-symbiotic fauna, (iv) Microbial agents, (v) Semio-chemicals, and (v) Genetic biocontrol. The review will include an in-depth assessment of the mode of action, level of maturity, technical feasibility & risk, deployment strategies & cost. The Program Area needs to ensure that all options, irrespective of their readiness, have been considered & prioritised. Linking with other Program Areas, these options will be subjected to a further qualitative 'cost-benefit' analysis & prioritised for further investigation in the subsequent R&D program.

The technical team assembled to deliver this work plan is comprised of 8 experts in molecular biology, COTS biology & pest management, including one expert from a third-party institution. This team is led by Dr. Frederieke Kroon of AIMS.

Table. Population Control program area team.

Program Area	Resource name	Institution
Population Control	Frederieke Kroon	AIMS
	Lone Hoj	AIMS
	Cherie Motti	AIMS
	David Westcott	CSIRO
	Owain Edwards	CSIRO
	Sharon Hook	CSIRO
	Bernie Degnan	UQ
	Scott Cummins	USC
	RA (Maria Cabrera)	AIMS

Monitoring & Surveillance

This program area will undertake a systematic assessment of COTS monitoring & surveillance needs & a comprehensive review of existing & upcoming technologies/systems that could address these needs. This will include an in-depth assessment of the level of maturity, technical feasibility & risk, deployment strategies & cost of these technologies/systems in order to prioritise investment & recommend an integrated R&D program.

The technical team assembled to deliver this work plan is comprised of 12 experts in COTS monitoring, technological engineering, eDNA techniques, and modelling, including two experts from third-party institutions. This team is led by Dr. David Westcott of CSIRO.

Table. Monitoring & Surveillance program area team.

Program Area	Resource name	Institution
Monitoring & Surveillance	David Westcott	CSIRO
	Cameron Fletcher	CSIRO
	Emma Lawrence	CSIRO
	Brano Kusy	CSIRO
	Scott Foster	CSIRO
	Sven Uthicke	AIMS
	Jason Doyle	AIMS
	Geoff Page	AIMS
	Juan Carlos Ortiz	AIMS
	Morgan Pratchett	JCU
	Brett Kettle	Babel-sbf
	Richard Stump	Marenray
	RA (Stewart MacDonald)	CSIRO

Decision Support & Modelling

This program area has two roles in the CCIP Feasibility & Design Phase. One role involves assessing the modelling & decision support needs to enable the prediction, detection, and control of COTS outbreaks & to mitigate their impact. To achieve this, the program area will comprehensively review the current state of modelling & decision support relevant to COTS surveillance & control & provide recommendations on investment as part of an integrated R&D program. In addition, this program area will also be responsible for driving the cost-benefit assessment of research opportunities identified across all program areas & developing the decision framework that will be used to deliver recommendations for an integrated R&D program.

The technical team assembled to deliver this work plan is comprised of 10 experts in decision science, cost-benefit analysis, and modelling (e.g. ecological, hydrodynamic, and systems models), including one expert from a third-party institution. This team is led by Dr. Cameron Fletcher of CSIRO.

Table. Decision Support & Modelling program area team.

Program Area	Resource name	Institution
Decision Support & Modelling	Cameron Fletcher	CSIRO
	Eva Plaganyi-Lloyd	CSIRO
	Gabriela Scheufele	CSIRO
	Scott Condie	CSIRO
	Karlo Hock	UQ
	Pete Mumby	UQ
	Sam Matthews	JCU
	Carla Ewels	JCU
	Severine Choukroun	JCU
	Michael Bode	QUT

Social Science

The cross-cutting social science program area will conduct preliminary desktop & qualitative enquiries to identify & prioritise research areas for social acceptability & implementation of COTS control methods with key stakeholders, with exploration of economic institutional & regulatory matters. This will include identifying gaps in stakeholder & community understandings of COTS control & the potential direct & indirect costs & benefits of proposed innovations in the wider economy. This program area will also scope the policy & regulatory implications of proposed COTS control methods & describe the related social, institutional & regulatory environment surrounding their implementation. This will culminate in informed recommendations for further social science research as part of an integrated R&D program.

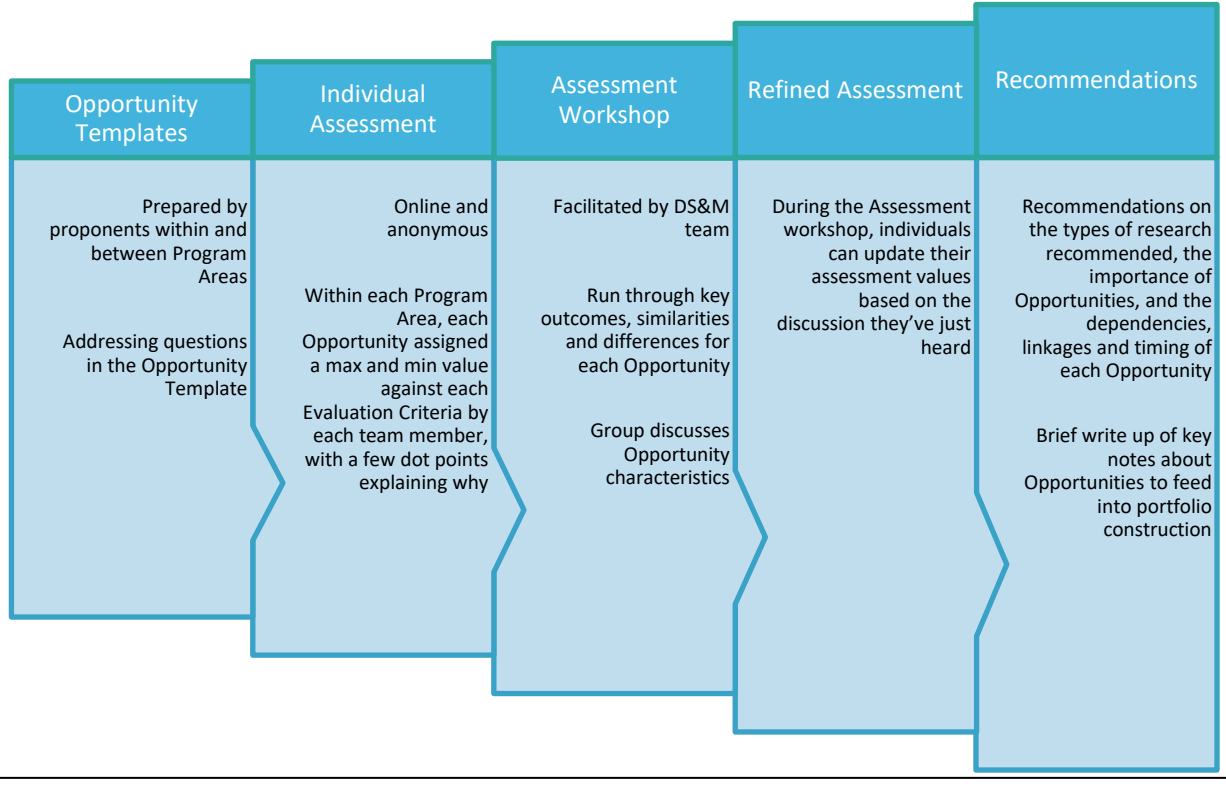
The technical team assembled to deliver this work plan is comprised of 6 inter-disciplinary experts in environmental social sciences, including policy, economics & behaviour change. This team is led by Dr. Aditi Mankad of CSIRO.

Table. Social Science program area team.

Program Area	Resource name	Institution
Social acceptability, regulatory & institutional arrangements	Aditi Mankad	CSIRO
	Lucy Carter	CSIRO
	Matt Curnock	CSIRO
	Gabriela Scheufele	CSIRO
	Pedro Fidelman	UQ
	Stewart Lockie	JCU

Appendix B – Opportunity Identification & Assessment Process

CCIP – Opportunity Assessment Process



Appendix C – Opportunity Descriptions & Assessment Results

Great Barrier Reef Foundation

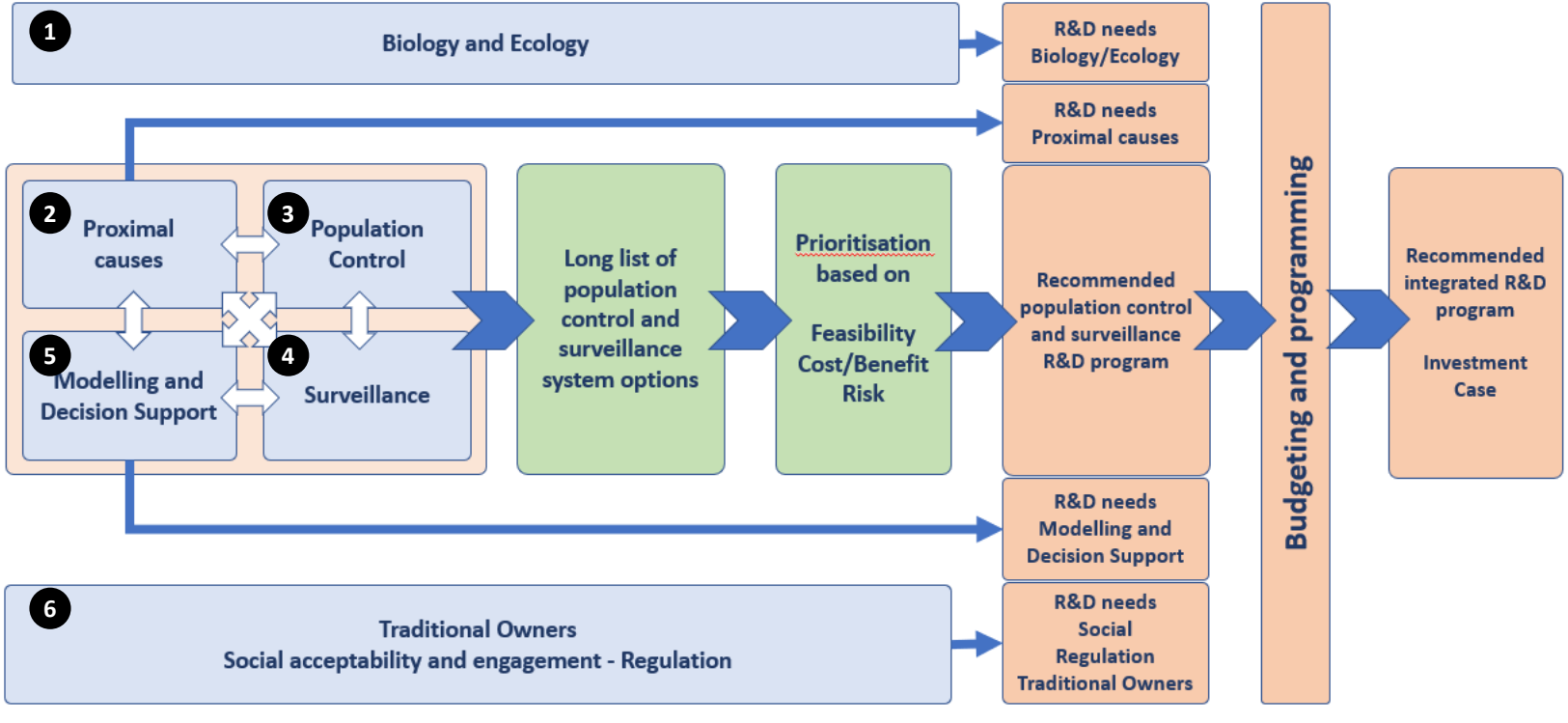
CCIP Design Phase

Prioritisation Process – Opportunity Assessment Summaries

March 2021

Australian Government | Reef Trust | Great Barrier Reef Foundation | Australian Government | Australian Institute of Marine Science | CSIRO | James Cook University Australia | The University of Queensland Australia

Program Overview



Opportunity Assessment: Evaluation Criteria

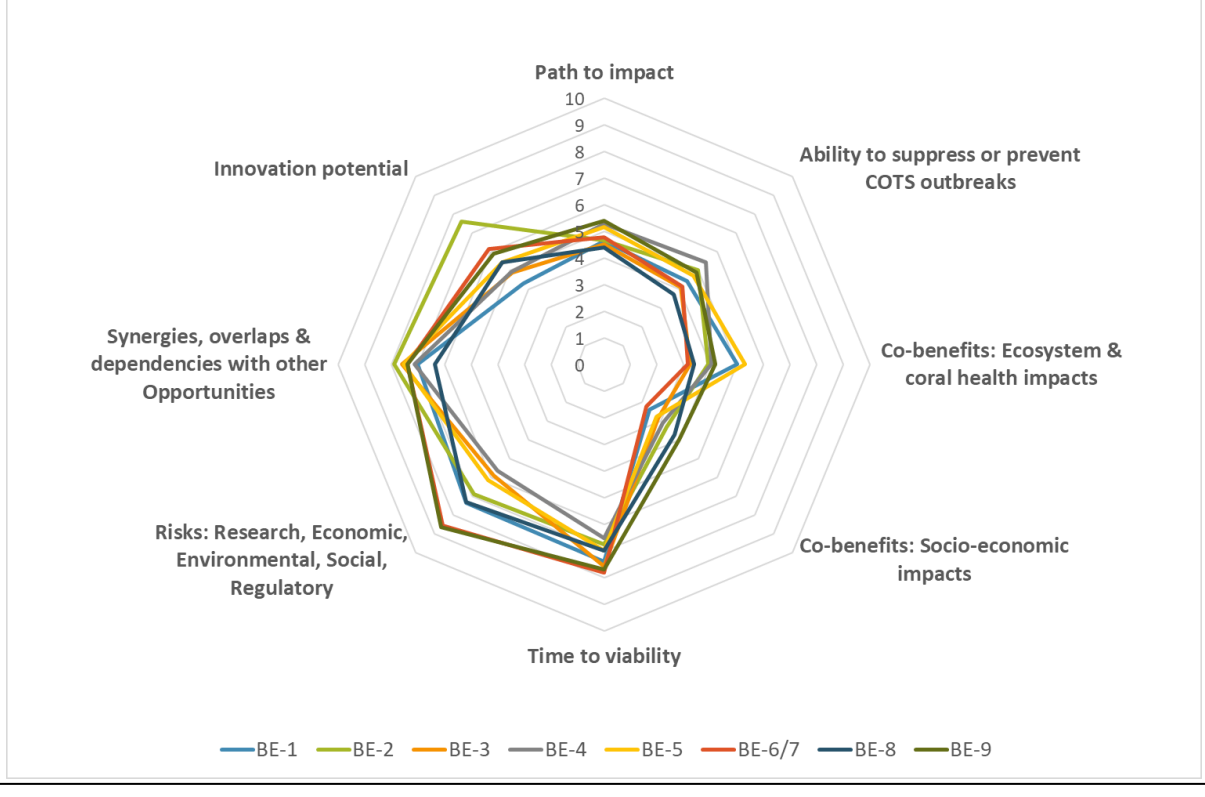
Evaluation Criteria	CCIP Value	Evaluation Criteria Question	Evaluation Criteria Objective
1. Path to impact	- Maximises the potential for future prevention of COTS outbreaks on the Great Barrier Reef	Does this Research Opportunity provide a pathway to deliver innovative COTS control outcomes, in alignment with CCIP vision and values, and how direct is the pathway to impact?	Ensure that research funded under CCIP has a path to impact
2. Ability to suppress or prevent COTS outbreaks	- Maximises the potential for future prevention of COTS outbreaks on the Great Barrier Reef - Maximises the capacity for early warning and effective suppression of the next outbreak	How significantly would realising this Opportunity improve our ability to prevent or suppress COTS outbreaks?	To assess the extent to which the research could contribute to suppression or prevention of future outbreaks, meaning that it could lead to less severe and / or less frequent outbreaks.
3. Co-benefits: Ecosystem & coral health impacts	- Maximises the benefit to coral (i.e. minimises loss and/or enhances resilience)	Would this research deliver positive coral health impacts on the Great Barrier Reef above and beyond those provided by more effective reduction of COTS impact, and how significant would those benefits be?	To assess the extent to which the research would benefit coral health, meaning that it could lead to protection or improvement in coral cover, and/or enhanced resilience of coral communities
4. Co-benefits: Socio-economic impacts	- Provides socio-economic benefits to communities and/or Reef-based industries	Would this research provide positive socio-economic outcomes for Traditional Owners, communities, and/or Reef-based industries beyond that generated by suppressing or preventing COTS outbreaks, and how significant would it be?	To assess the potential for the research to deliver socio-economic benefits, meaning that it creates economic opportunities for Traditional Owners and/or community, and is co-beneficial to the tourism and/or fishing industries.
5. Time to viability	- Maximises the capacity for early warning and effective suppression of the next outbreak;	What is an approximate time estimate for this research to generate on-water impact reducing the impacts of COTS on the GBR?	To assess the timeframe required for a research opportunity to achieve an applied outcome, meaning that it delivers knowledge, tools or technologies that can be trialled and implemented in COTS management (assuming no regulatory barriers).
6. Research cost	- Delivers value for money when considering the costs of research, development and deployment.	What are the approximate (± 25%) quantitative dollar estimates of all costs involved in conducting the research (e.g. personnel, facilities, fieldwork, consumables, travel)?	To assess the cost effectiveness of the research investment, in terms of research development.
7. Implementation cost	- Delivers value for money when considering the costs of research, development and deployment.	What are the approximate (± 50%) quantitative dollar estimates of all costs involved in implementing the outcome of this research to generate the real-world impact outlined in section 1, at the scale most relevant to the Opportunity (e.g. per reef, over the entire GBR, per year)?	To assess the cost effectiveness of the research investment, in terms of implementation (if applicable).
8. Risks – Research, Economic, Environmental, Social, Regulatory	- Able to be safely deployed in the Marine Park with risks minimised and/or manageable	How significant are the research risks associated with this Opportunity, including economic, environmental, social and regulatory risks?	To clarify whether there are additional risks of the innovation that could affect its success or acceptability not captured elsewhere
9. Synergies, overlaps & dependencies with other Opps.	- Maximises complementarity across research opportunities, capitalising on synergies	How does the proposed Opportunity interact with other potential research in CCIP? Is it primarily dependent on other research, does it overlap with other research, or does it enable other research?	To clarify whether the knowledge gap to be filled by the opportunity could be filled by other opportunities, or whether two opportunities together could generate more benefit than either on their own
10. Innovation potential	Overall	Overall, what is the potential for this Research Opportunity to deliver innovation in COTS surveillance and/or control on the Great Barrier Reef?	To assess the potential for research funded under CCIP to transform COTS surveillance and/or control on the GBR

Biology & Ecology

Biology & Ecology: Opportunity Descriptions

Opportunity Title	Opportunity Description	Cost Estimate
BE-1: In situ feeding rates of crown-of-thorns starfish and fate of prey corals	Aim: To quantify feeding rates of CoTS in the field, to better resolve ecological impacts of CoTS on coral assemblages relative to the size and abundance of CoTS as well as changes in prey availability (coral cover and composition) and seasonal variation in seawater temp.	**$527,000**
BE-2: Beyond eDNA: New genetic tools for CoTS management and monitoring	Aim: To develop two further techniques (beyond eDNA monitoring technology) critical for understanding outbreak dynamics and improving monitoring, focussing on 1) estimating age of individual CoTS (especially juveniles) and 2) measuring eRNA to provide increased information on structure of CoTS populations, adding to quantitative estimates of individual abundance from eDNA sampling.	**$197,000**
BE-3: Supply-side ecology for CoTS: the link between larval supply, settlement rates and adult densities	Aim: To simultaneously assess 1) local densities of adults, 2) levels of larval supply and 3) rates of settlement for COTS across a range of reefs along the length of the Great Barrier Reef. This research, along with improved understanding of larval dispersal, settlement patterns, and post-settlement movement, will inform how CoTS spread within and among reefs.	**$730,040**
BE-4: Inter-annual changes in density, distribution and demography for pre-outbreak populations of CoTS on Australia's Great Barrier Reef	Aim: To establish when and where population irruptions of CoTS originate in the northern or far northern sectors of the Great Barrier Reef. We will use intensive annual surveys to test for changes in density, distribution and population replenishment of CoTS populations at select reefs (n ≥ 18 reefs).	**$645,000**
BE-5: Inter-reef differences in the incidence of population irruptions of CoTS: testing the role of larval supply versus settlement substrates	Aim: To assess the mechanistic basis of striking and consistent differences in the incidence of population irruptions of CoTS among reefs on the Great Barrier Reef. This project will quantify patterns of larval supply and settlement rates for CoTS along cross-shelf gradients, while also considering changes in 1) abundance of adult CoTS, 2) cover and composition of corals (adult prey), 3) cover and composition of coralline algae (juvenile prey), and 4) quality and quantity of settlement habitat.	**$519,820**
BE-6: Tagging and mark recapture of adults to determine a method to age CoTS, case study with stable low density population at One Tree Reef	Aim: Through a mark-recapture study, 1) verify the spine pigment bands as a tool to age CoTS and as an aging method that can be used in the field and 2) characterise stable low density CoTS populations and how their traits differ from those in outbreaking populations.	**$275,380**
BE-8: Recruitment of juvenile CoTS to coral on modern reefs; how seaweed, coral cover, warming & predation inhibit and promote first coral feeding on CoTS	Aim: To examine how recruitment of CoTS onto coral is inhibited and promoted by factors that are prevalent on modern coral reefs.	**$317,640**
BE-9: Specialised traits of CoTS larvae: resilience or starvation in tropical waters: maternal provisioning, larval energetics, when do they need to feed, microbiome facilitation, DOM & influence of cloning	Aim: To construct a comprehensive understanding of the nutritive energetics and feeding ecology of COTS larvae in nature and the specialised traits that facilitate their success.	**$207,300**

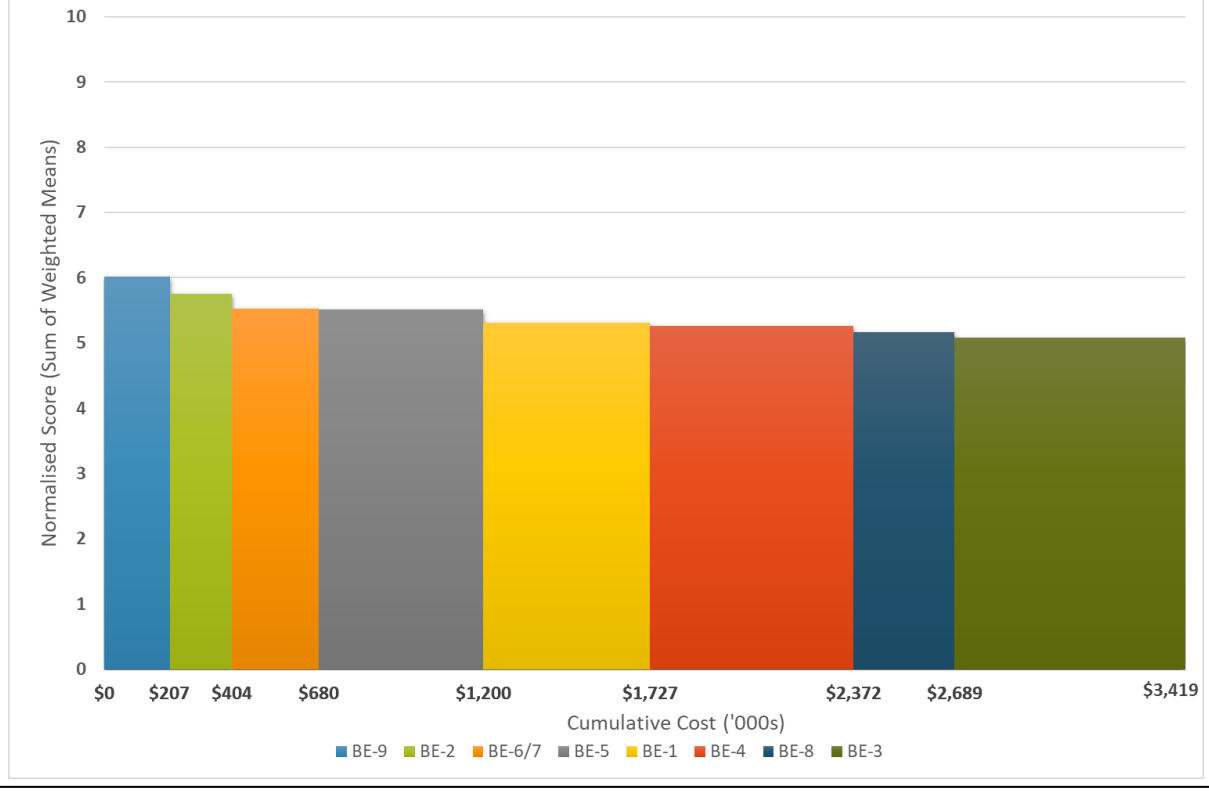
Biology & Ecology: Results (by criteria & opp., based on Weighted Means)



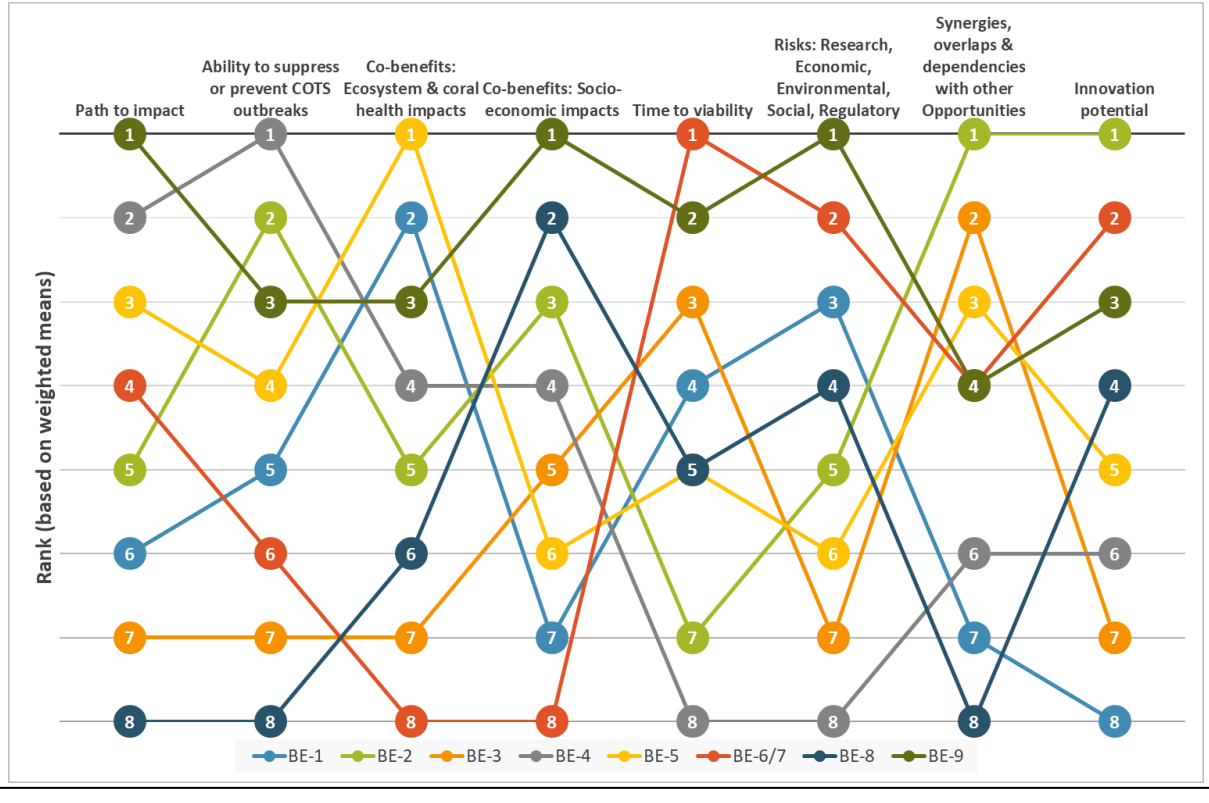
**Note regarding Risk Criteria: A high score (e.g., 10) indicates the opportunity is less risky than an opportunity with a lower score (e.g., 5)*

Biology & Ecology: Results (Score based on Weighted Means)

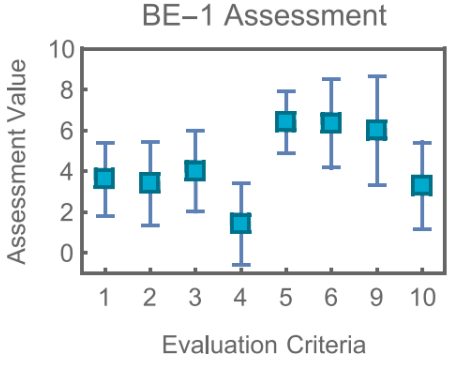
**Note regarding normalized scores: this represents the sum of weighted means of the scores for each criteria*

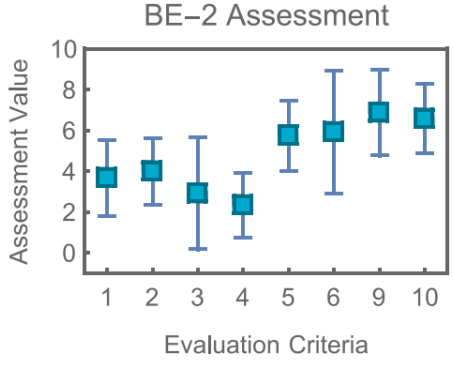


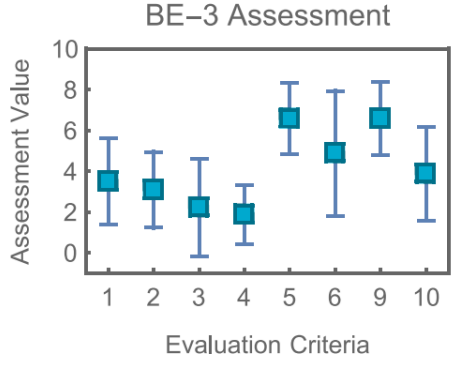
Biology & Ecology: Results (Ranking based on Weighted Means)

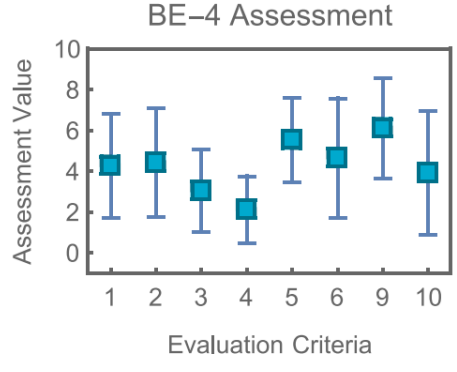


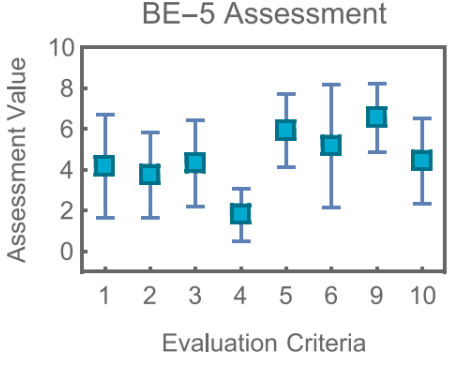
Biology & Ecology: Range of Responses & Weighted Means (by opp)

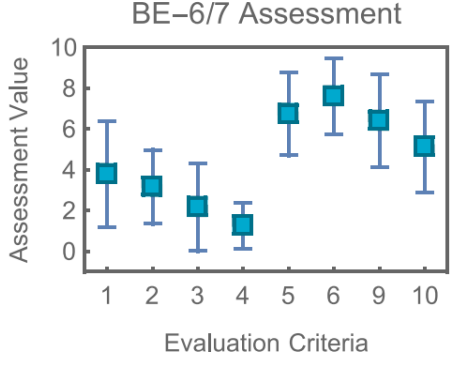


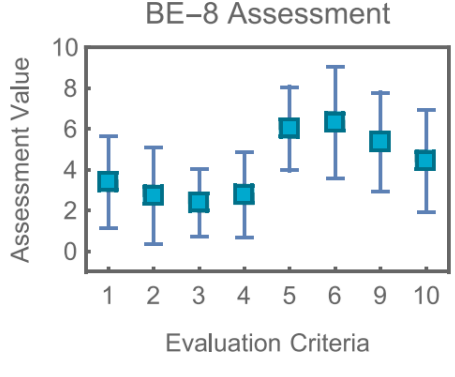


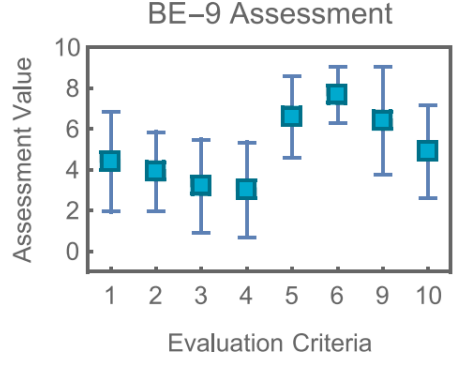




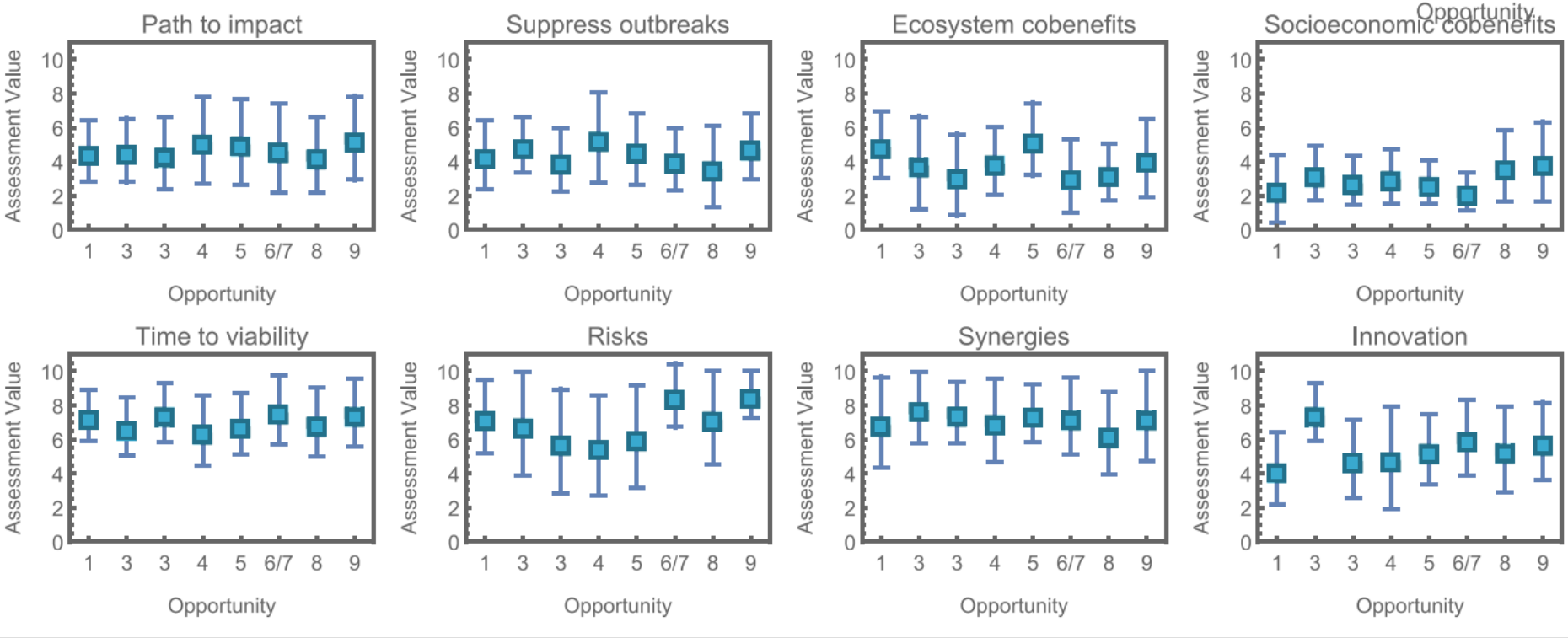








Biology & Ecology: Range of Responses & Weighted Means (by criteria)



Proximal Causes

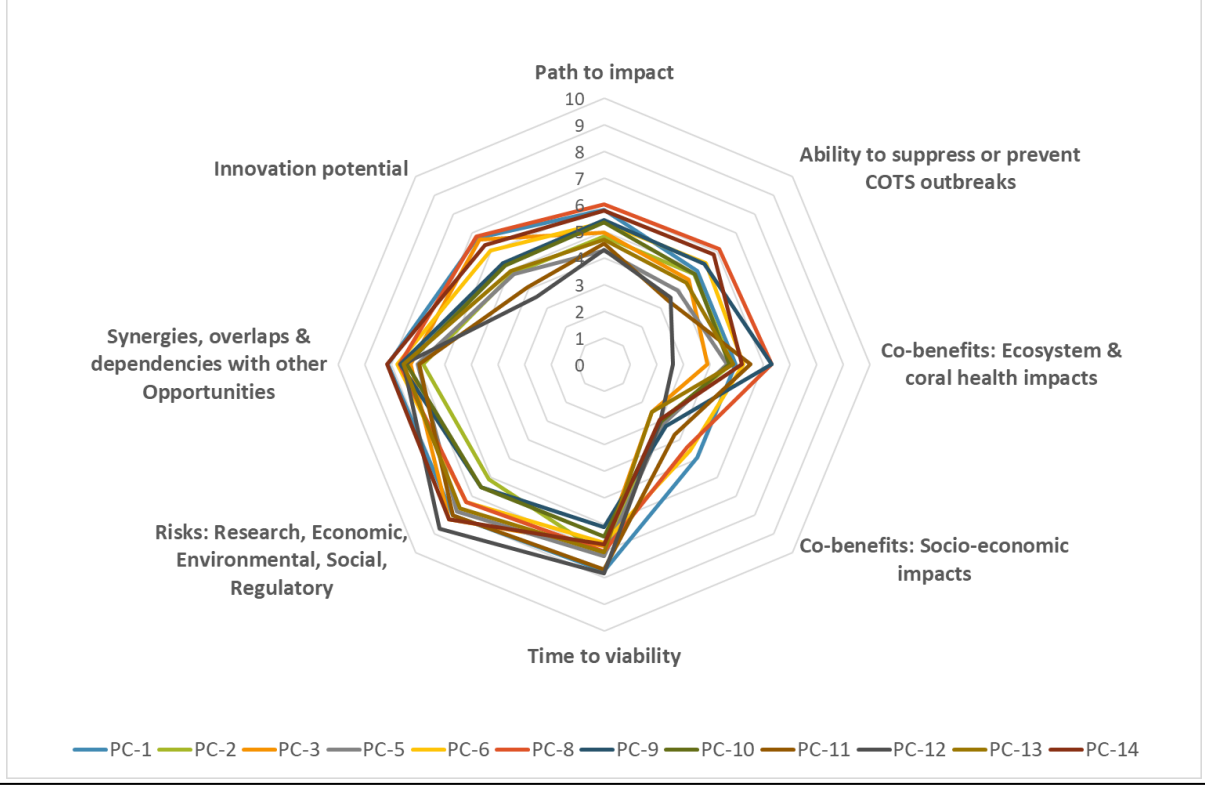
Proximal Causes (1)

Opportunity Title	Opportunity Description	Cost Estimate
PC-01: Using genomics to improve knowledge of larval connectivity	Aim: To answer fundamental questions about COTS larval dispersal to provide insights regarding spreading dynamics and sources of outbreaks. E.g., are select reefs key sources for COTS outbreaks, with initiation and subsequent spread occurring in a stepping-stone manner? Or, is COTS spread diffuse, with many source reefs at any time and mixing of larvae during dispersal?	**$276,837**
PC-02: Effects of prey limitation on the boom and bust of CoTS populations	Aims: 1) To relate reef level coral cover and community structure with CoTS density (based on field surveys and culling data) and with reproductive traits (i.e., egg size, gonadosomatic index), and 2) to examine the role of prey availability on the demise of outbreaks, in particular, whether abrupt declines in the abundance of CoTS at the end of outbreaks can be attributed to local depletion of prey resources resulting in subsequent starvation and reduced immunity against opportunistic pathogens.	**$332,950**
PC-03: Juvenile resilience hypothesis - the potential that reserve populations of herbivorous COTS may seed outbreaks and juvenile-coral and juvenile-adult interactions – assessing the potential for semiochemical communication	Aim: To characterise growth-age phenotypic plasticity of juvenile COTS and their behavioural responses to assess the contribution of this life stage as a proximate contributor of outbreaks, potentially years after settlement.	**$188,500**
PC-05: COTS larvae in low salinity plumes – impacts of multiple water quality stressors on larval success	Aim: to determine the impact of low salinity - high nutrient water on the larvae of COTS as they might encounter a riverine plume in nature and with consideration of potential contaminants.	**$111,500**
PC-06: Understanding the nutrient hypothesis: Spatio-temporal abundance of CoTS larvae in relation to water quality and nutrient sources, nutrient transformation and larval food demand	Aim: To analyse oceanographic and biochemical modelling data to gain further insight regarding nutrient sources and the role of catchment-derived nutrients in driving phytoplankton productivity in initiation zone (for primary outbreaks) and generally to mid-shelf reefs (for secondary outbreaks).	**$985,898**
PC-08: The other 90% - resolving the impact of benthic and cryptic predation on CoTS	Aims: 1) To characterise which benthic predators have the strongest influence on mortality rates of CoTS during their rubble-based life phases, 2) determine the distribution of cryptic predators, such as crabs, across the GBR for use as bioindicators of CoTS outbreaks, and 3) use eDNA and metabarcoding analyses to characterise cryptic predators and food webs involving CoTS, as done recently for fishes (Kroon et al 2020).	**$571,960**

Proximal Causes (2)

Opportunity Title	Opportunity Description	Cost Estimate
PC-09: Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones and corresponding differences in abundance of putative predators	Aim: To explicit quantify rates of predation on CoTS at reefs within contrasting Great Barrier Reef Marine Park (GBRMP) management zones. More specifically, we will quantify predation and mortality rates for adult CoTS, as well as differences in the abundance and composition of potential predators, between reefs where fishing is permitted (Marine National Park or Green zones), restricted (Conservation Park or Yellow zones) or effectively prohibited (Habitat Protection or Blue zones) as per current Great Barrie Reef Marine Park (GBRMP) zoning.	**$432,850**
PC-10: Models to test the efficacy of top-down predator control on CoTS	Aim: Using ecological models (e.g. MICE), test the efficacy of top-down predator control on CoTS using models to better understand whether predators may play a role in supressing CoTS outbreaks and management implications thereof	**$244,500**
PC-11: Effect of elevated temperature and coral bleaching on distribution, feeding behaviour and physiological condition of crown-of-thorns starfish	Aim: To assess potential effects of elevated temperature and coral bleaching on the distribution, feeding behaviour and population viability of CoTS.	**$251,100**
PC-12: Effects of ocean warming and marine heatwaves on settlement success and population replenishment of crown-of-thorns starfish	Aim: To assess potential effects of ocean warming, and in particular marine heatwaves (MHW) on settlement success and population replenishment for CoTS.	**$95,350**
PC-13: Modelling the potential effect of substate change and coral health on CoTS dynamics and future CoTS outbreaks	Aim: Assess how changes to corals reefs (primarily due to climate change) such as coral bleaching, coral decline, rubble bed extent and distribution, changes in the reef algal complex, increased temperature and/or ocean acidification may impact CoTS population dynamics and future outbreaks.	**$202,500**
PC-14: Data-driven dynamic models to interrogate multiple CoTS outbreak hypotheses	Aim: To evaluate the evidence for causality of multiple outbreak hypotheses, both in isolation and combination, with the use of dedicated modelling tools in order to inform practical management action.	**$200,000**

Proximal Causes: Results (by criteria & opp., based on Weighted Means)



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Proximal Causes: Results (Score based on Weighted Means)

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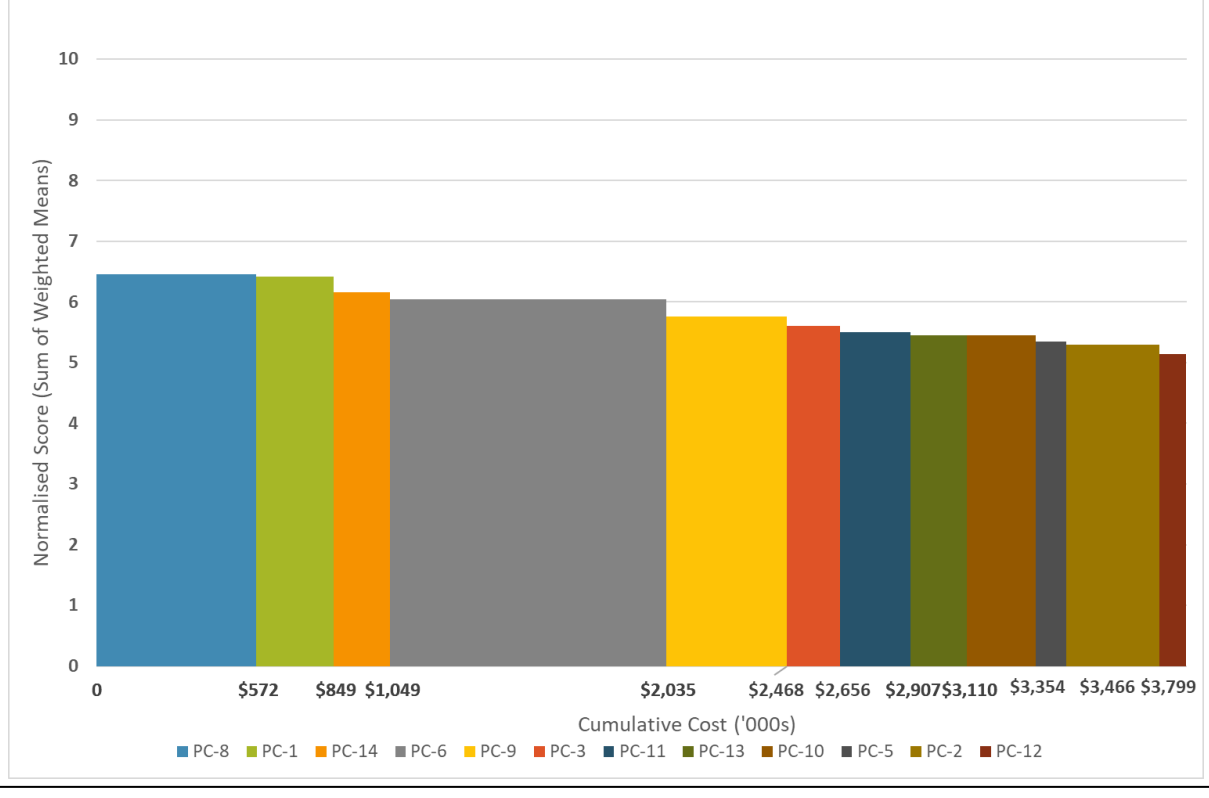
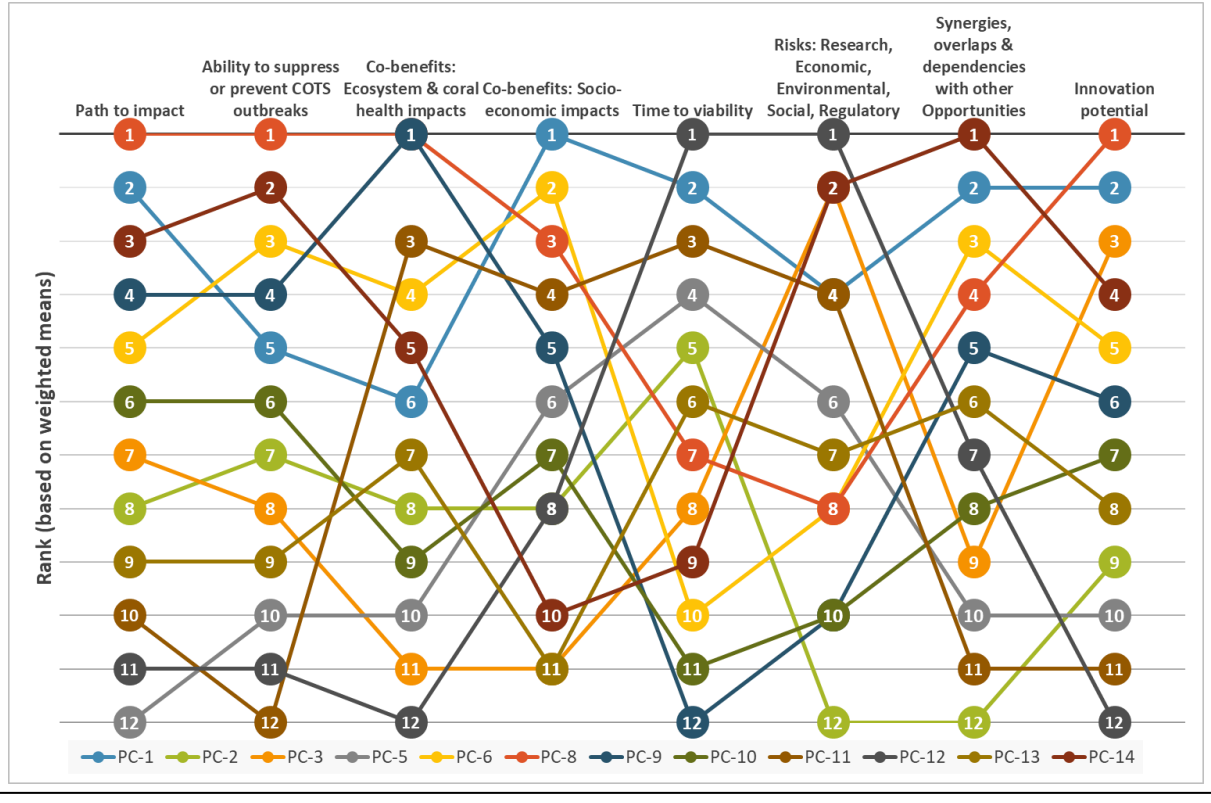
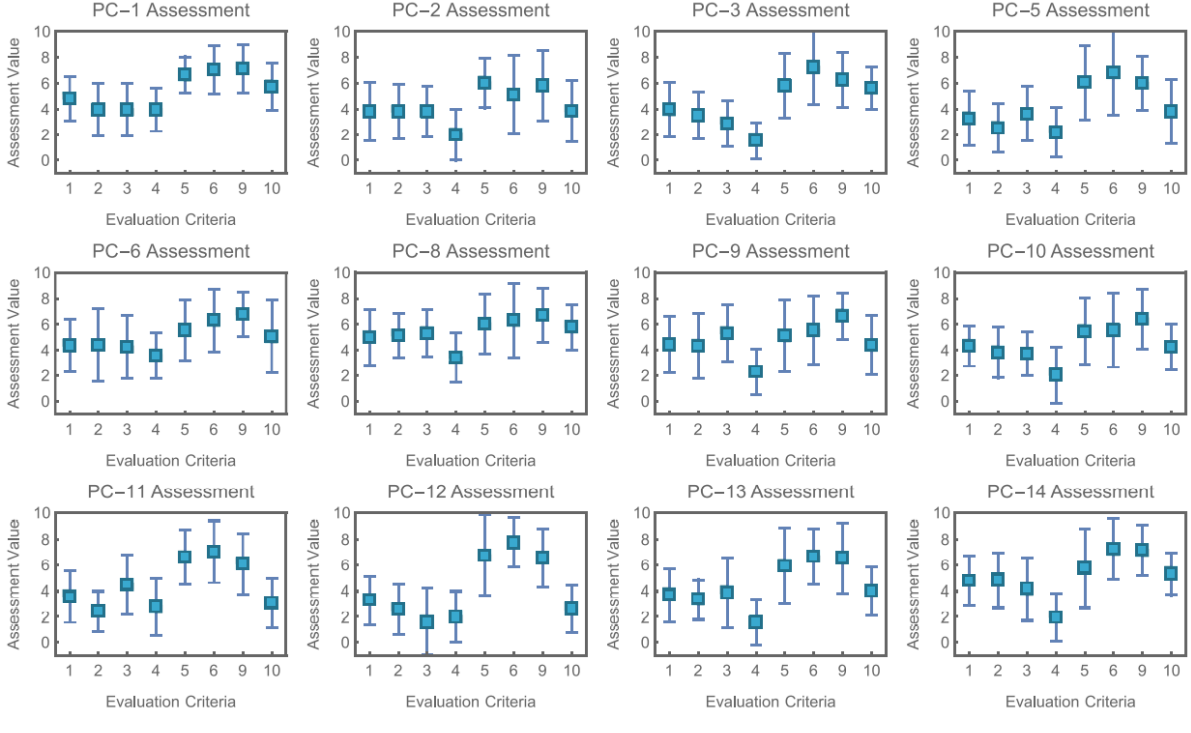


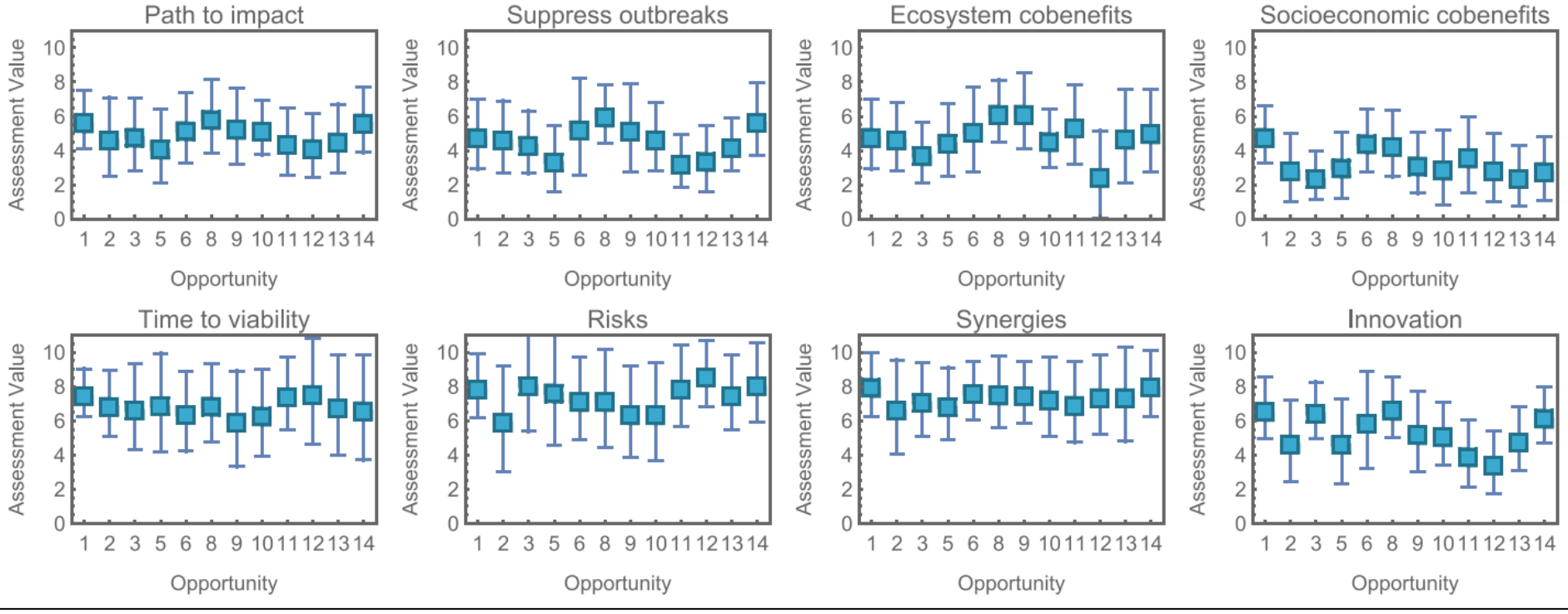
Proximal Causes: Results (Ranking based on Weighted Means)



Proximal Causes: Range of Responses & Weighted Means (by opp)



Proximal Causes: Range of Responses & Weighted Means (by criteria)

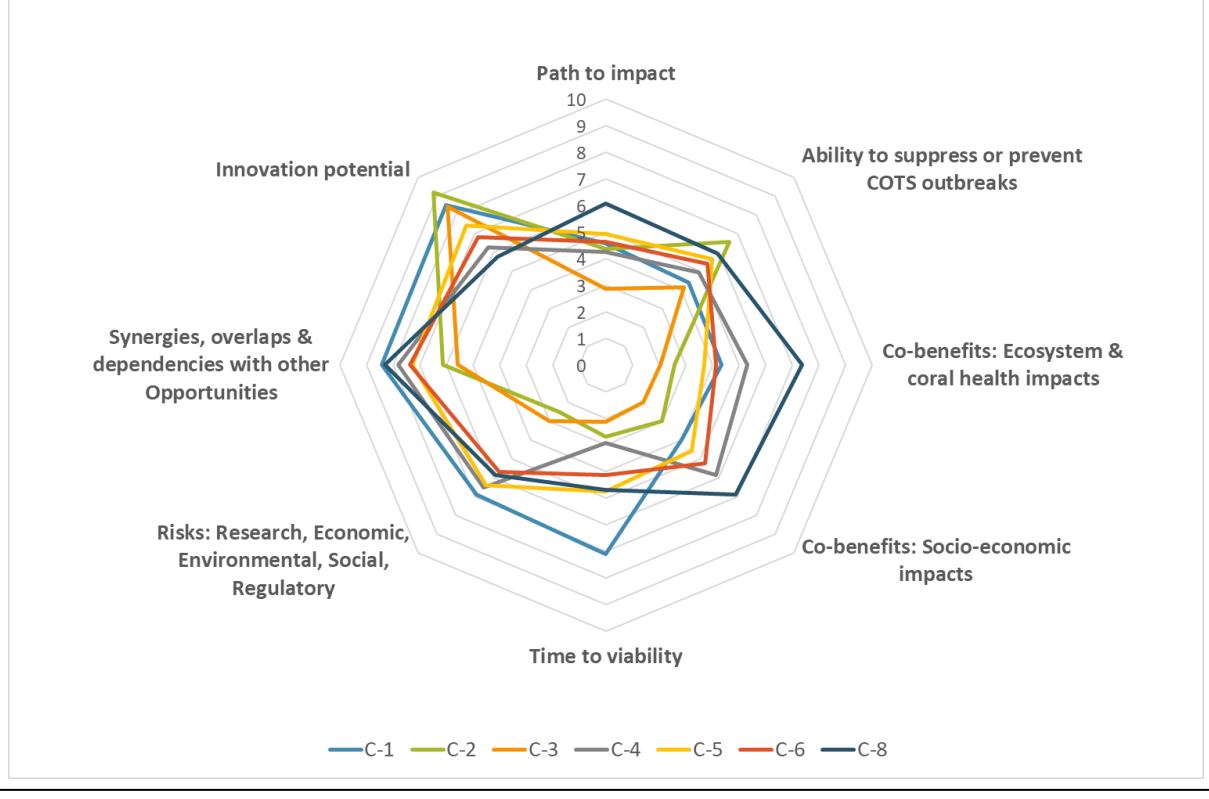


Population Control

Population Control

Opportunity Title	Opportunity Description	Cost Estimate
C-1: Further development and delivery of COTS genomics resources	Aim: To substantially improve existing CoTS genomic resources by 1) improving the genome assembly, 2) identifying the function of more genes, 3) understanding within-species genetic variation, and 4) understanding between-species genetic variation.	**$242,750**
C-2: Genetic approaches to COTS control	Aim: To develop components of an area-wide management strategy for COTS using 1) sterile male technology and 2) mating disruption, using cutting edge genetic and synthetic biology approaches to expedite the development of these technologies, drawing inspiration from the field of integrated insect pest management.	**$828,000**
C-3: Spiroplasma-related symbionts: potential agents for targeted delivery of genetic COTS control?	Aim: To develop culture methods and genetic information for a bacterial symbiont (Spiroplasma) present in gonads and the digestive system of CoTS, which has potential use as a targeted genetic vector for CoTS control.	**$187,000**
C-4: The Giant Triton: does it have what it takes to be a biocontrol agent of the Crown-of-Thorns starfish?	Aim: To improve understanding of the biological attributes of Giant triton as an indigenous conservation biocontrol agent against CoTS, specifically 1) effectiveness of release at local scales and 2) impacts on unintended non-target species. Ultimately, findings will guide management decisions regarding restocking of tritons on the GBR for the long-term sustainable control of CoTS.	**$528,500**
C-5: The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	Aim: To identify CoTS pheromone attractants that modify conspecific behaviour. This will facilitate the development of a potentially revolutionary control method to complement individual lethal injection. If proven effective, technology based on pheromone attractants has the potential to 1) significantly improve culling efficiency, 2) reduce reliance on or replace manual control and 3) enhance monitoring and surveillance efforts.	**$1,403,850**
C-6: Revealing the nature of the Giant triton's 'landscape of fear'	Aim: To identify kairomone deterrents capable of disrupting normal CoTS behaviours, facilitating development of alternate methods to complement individual lethal injection. If prove effective, technology based on kairomones will potentially 1) deter CoTS populations at a local scale, 2) depending on application beeffective in 'flushing out' cryptic CoTS not culled in the first pass and 3) suppress CoTS reproductive processes long term.	**$813,200**
C-7: Controlling outbreaks of CoTS through identifying highly connected reefs for spatial management plans	Aim: To examine the effects of alternative spatio-temporal zoning arrangements on CoTS population outbreaks in the GBR Marine Park.	**$170,000**

Population Control: Results (by criteria & opp., based on Weighted Means)



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Population Control: Results (Score based on Weighted Means)

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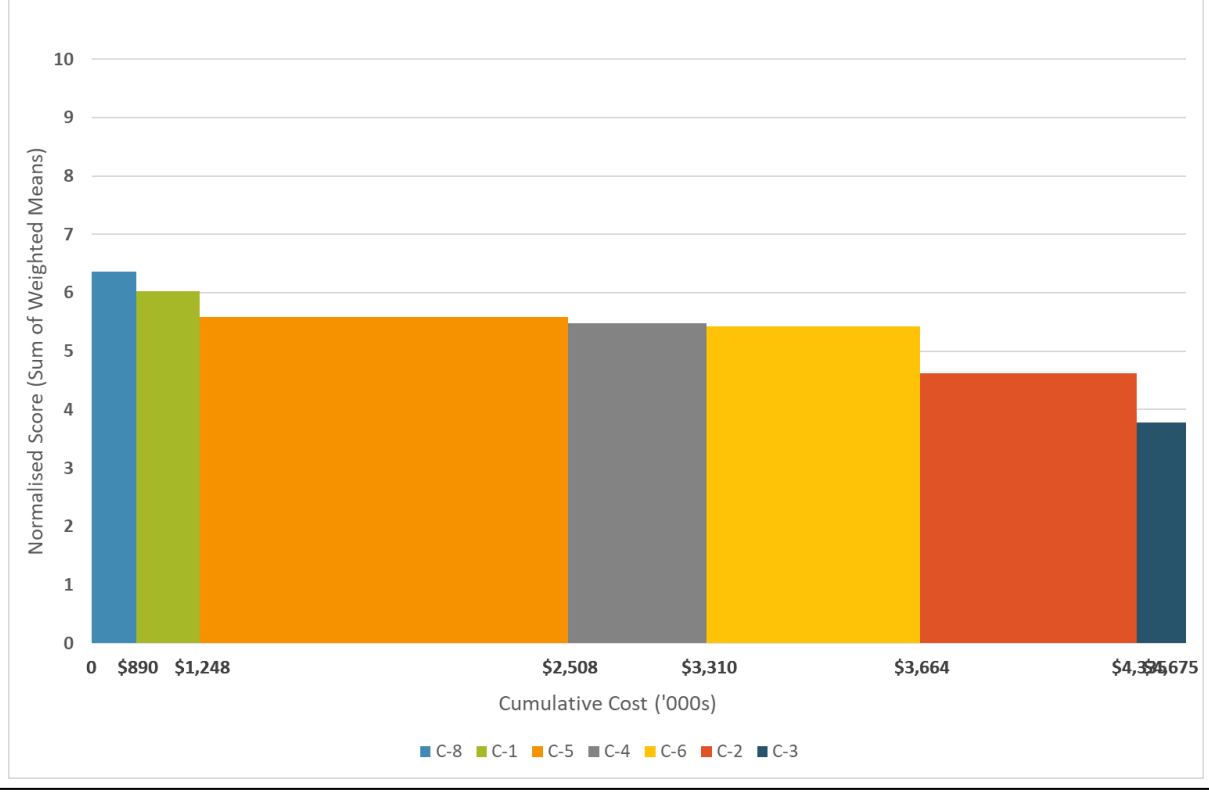
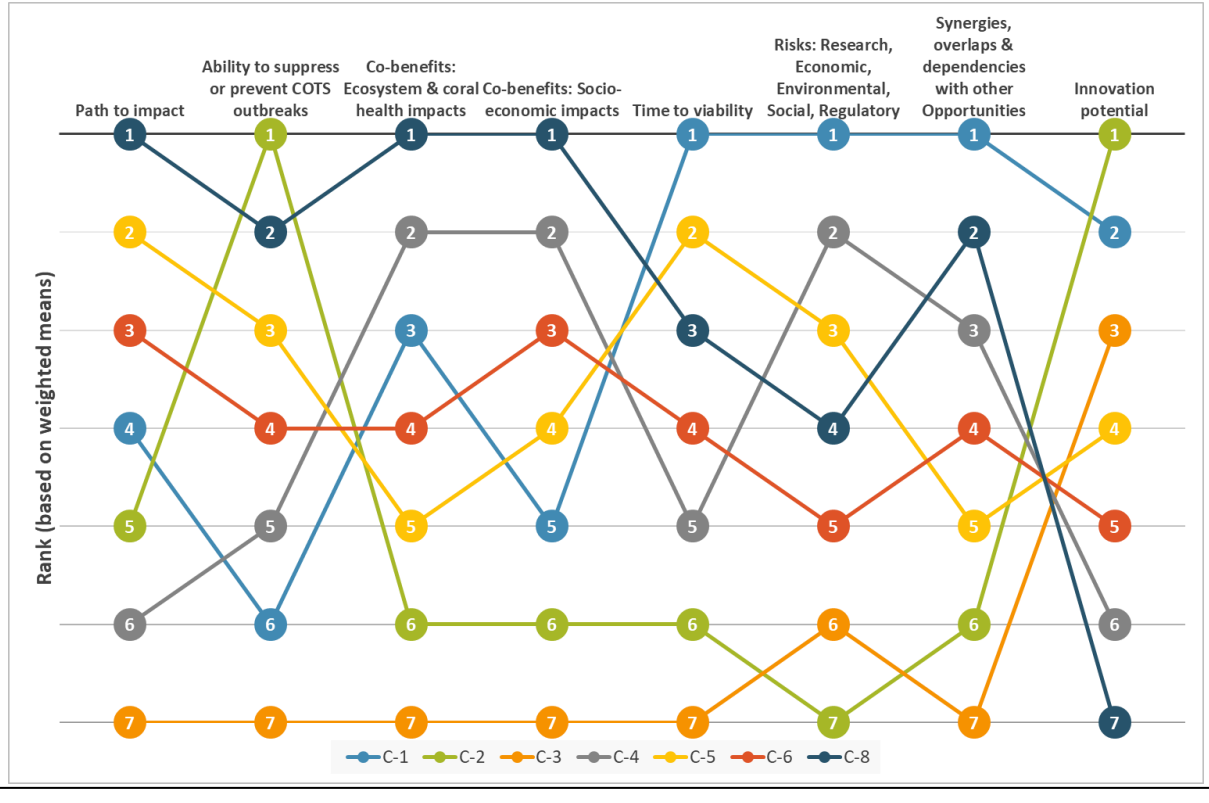
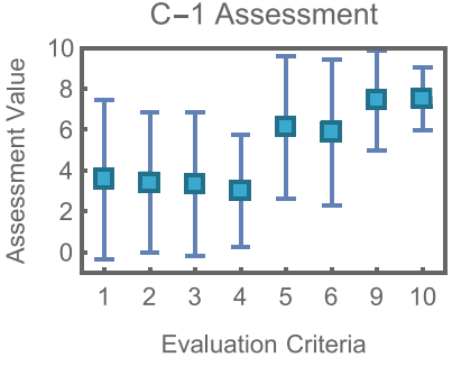
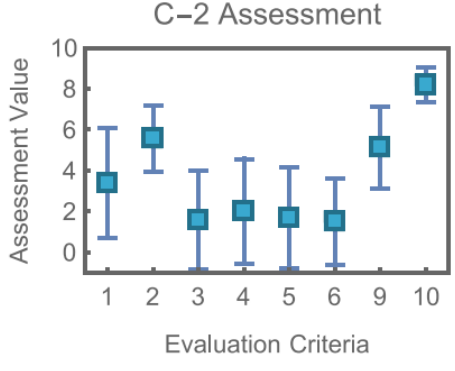


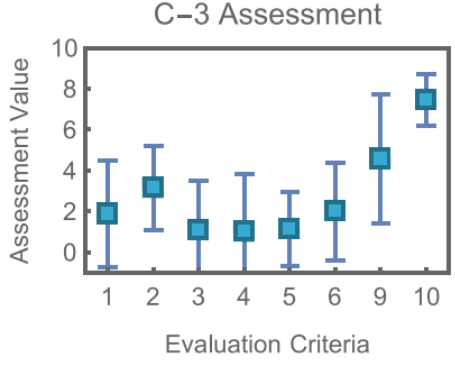
Population Control: Results (Ranking based on Weighted Means)

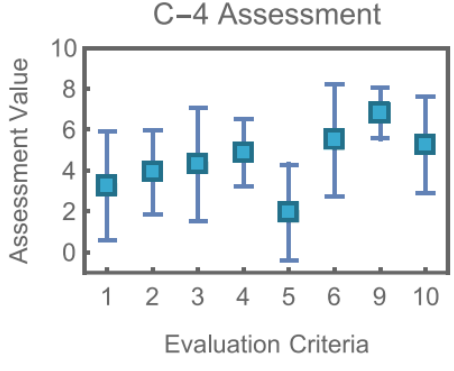


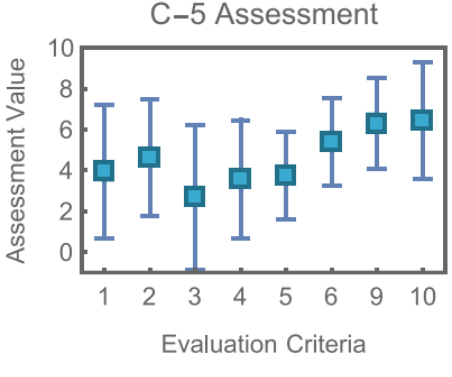
Population Control: Range of Responses & Weighted Means (by opp)

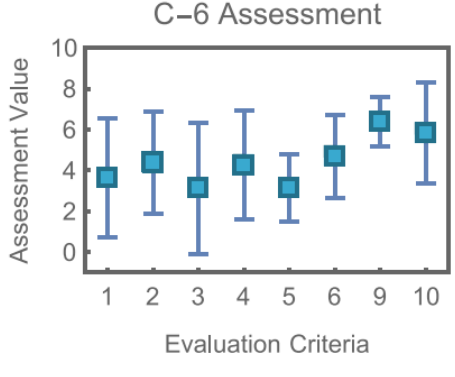


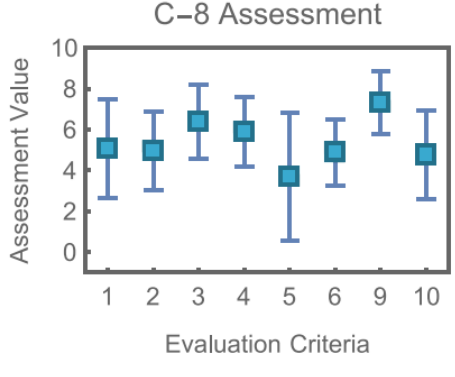




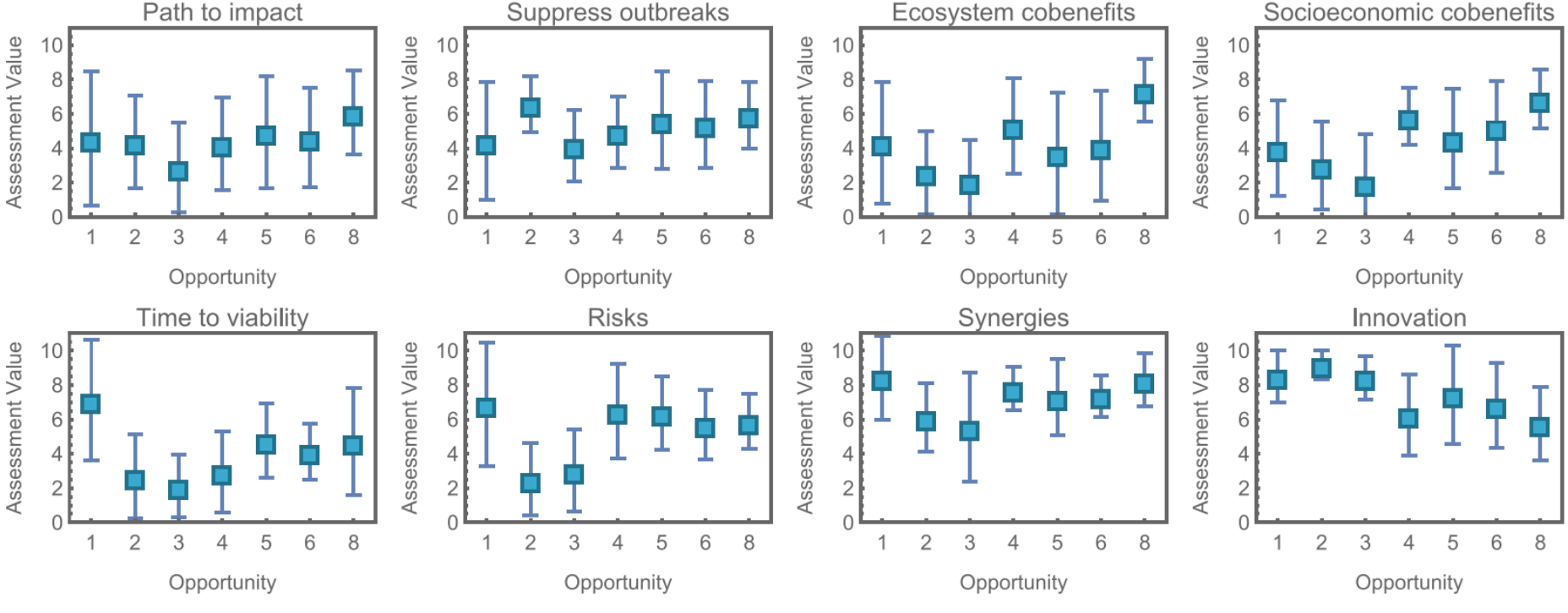








Population Control: Range of Responses & Weighted Means (by criteria)



Monitoring & Surveillance

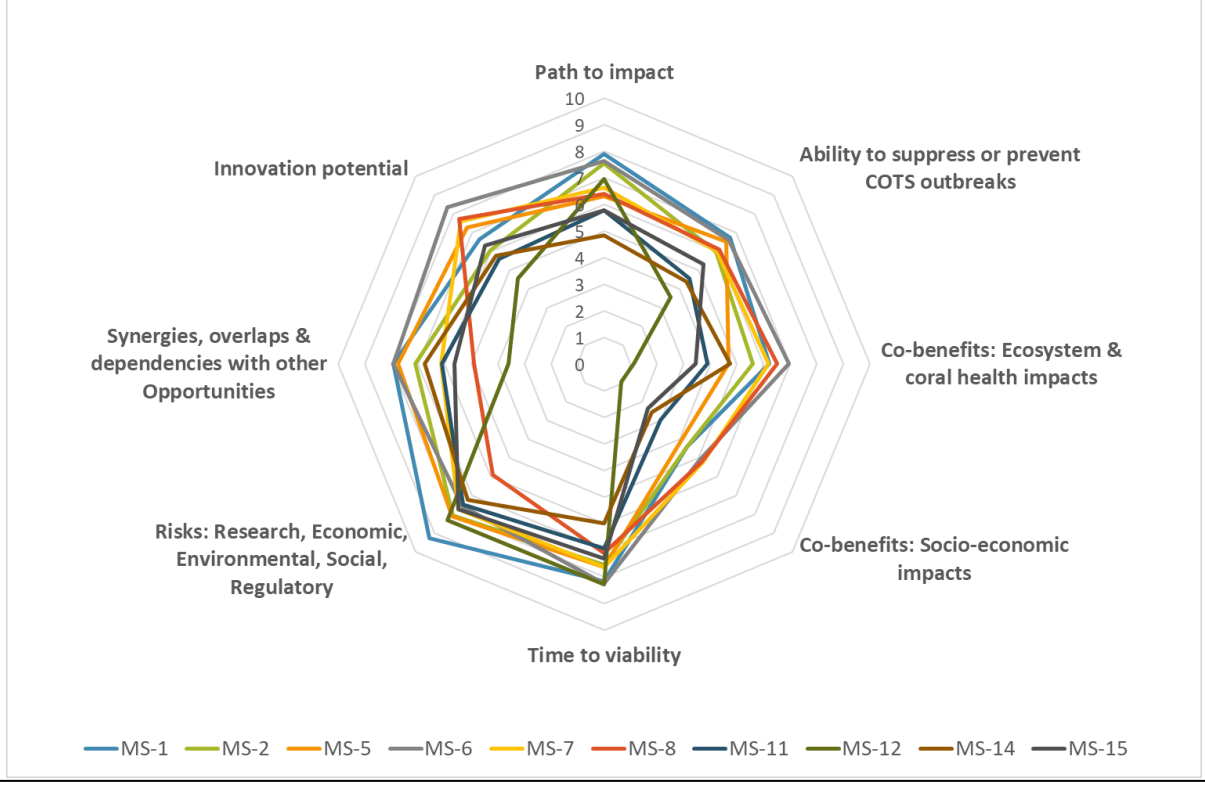
Monitoring and Surveillance (1)

Opportunity Title	Opportunity Description	Cost Estimate
MS-1: COTS Monitoring Design: from error estimation and sampling design to inference in management and research	Aims: 1) clearly articulate the objectives of the CoTS monitoring program, in consultation with key stakeholders, 2) specify the plan for the monitoring program to guide decision making in the CoTS Control Program, 3) develop decision rules for trading-off investment in monitoring and control activities that are cognizant of, and responsive to, the outbreak phase and the urgency of control needs, 4) assess all sampling tools currently used or proposed for deployment in the short term, and 5) integrate these components into a monitoring program and work with managers and control operators to ensure its successful implementation in the control program.	**$358,000**
MS-2: Estimating and accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	Aim: To provide two relevant and related pieces of information from existing data and from a dedicated survey 1) an understanding of the errors associated with each sampling tool under a variety of conditions, and 2) a calibration of the different sampling tools that will allow collation of multiple sources of information. This will then allow historical COTS monitoring data and data from other monitoring programs and surveys to be amalgamated to produce meaningful management decisions.	**$354,000**
MS-5: Operationalising and Implementing CoTS eDNA monitoring on the GBR	Aim: To test and implement at scale a next-generation COTS monitoring program based on eDNA that will significantly increase the responsiveness of control programs.	**$802,346**
MS-6: Accelerating the development, deployment, and support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	Aim: To complete a small amount of research and then to operationalise the Vertigo3 glider for near-term deployment in CoTS management in the GBR under CCIP.	**$890,000**
MS-7: Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	Aim: To build an integrated CCIP Computer Vision Cloud Informatics Platform (CVCIP) that consists of 1) a hardware-agnostic underwater survey data management system that is able to ingest large imagery datasets, 2) machine learning models / workflows to understand marine ecosystems at reef to GBR scale (e.g., COTS population density and size structure, coral coverage, and reef/asset condition) and 3) visualisation and analytics tools allowing non-expert and experienced teams to rapidly review analytics results.	**$1,260,000**

Monitoring and Surveillance (2)

Opportunity Title	Opportunity Description	Cost Estimate
MS-8: ReefScan-Transom – a visual survey system for CoTS detection	Aim: Implementation of one configuration of AIMS' end-to-end monitoring system ReefScan, called ReefScan-Transom, targeted at CoTS detection.	**$670,300**
MS-11: Wearable tech for in-water data collection	Aim: To deliver a functional in-water proof of concept for in-water data collection wearable technology within 6 months of commencement, where each dive is videoed and data on each cull event is logged as time, location, depth and a tagged image corresponding to the moment of injection.	**$437,000**
MS-12: Underwater human-machine interface for logging CoTS cull events	Aim: To build a waterproof, depth rated handheld device for divers to record CoTS cull events.	**$121,147**
MS-14: Environmental DNA survey of interspecies interactions to determine the drivers of CoTS outbreaks	Aim: To reveal the dynamics of interspecies interactions with CoTS by establishing whether 1) predators can prevent CoTS outbreaks by influencing spawning aggregations; limiting fertilisation success; and/or reducing the abundance of pelagic larvae and settled juveniles and adults; and 2) plankton can drive CoTS larval condition, survival and abundance, and ultimately successful recruitment into the settled population	**$1,163,787**
MS-15: Larval advection probability models and V3 surveys	Aim: To develop a probability mapping tool for locating CoTS populations using Vertigo3 glider surveys integrated with scaled larval advection modelling that will identify settlement (forecast) and spawning (hindcast) locations to inform operations in the CoTS control program on the GBR	**$340,000**

Monitoring & Surveillance: Results (by criteria & opp., based on Weighted Means)



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Monitoring & Surveillance: Results (Score based on Weighted Means)

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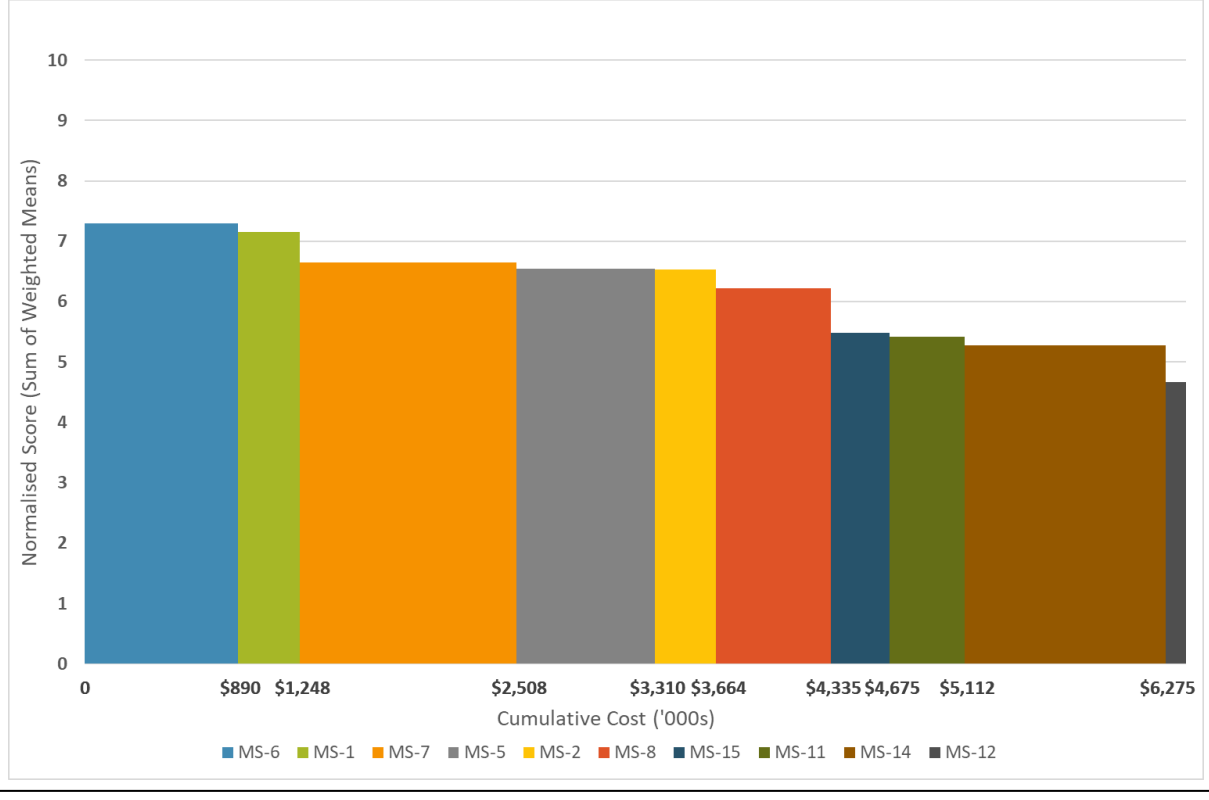
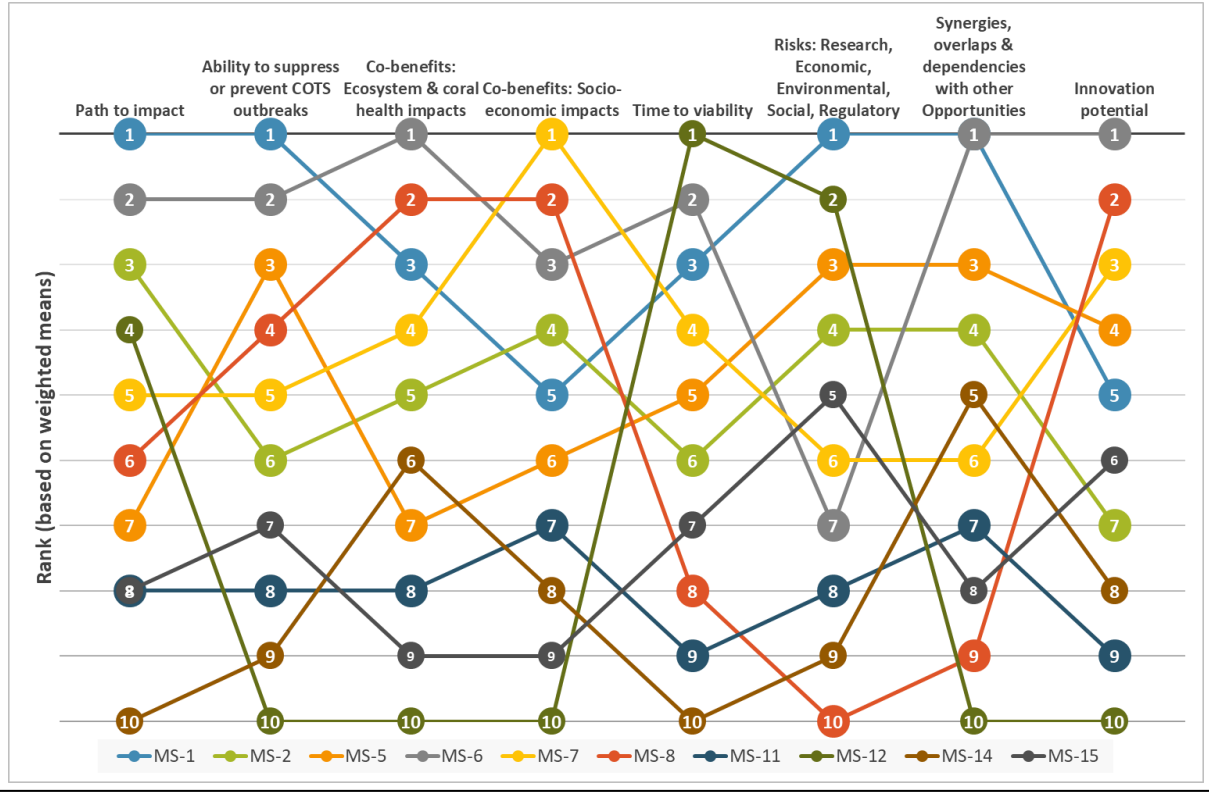
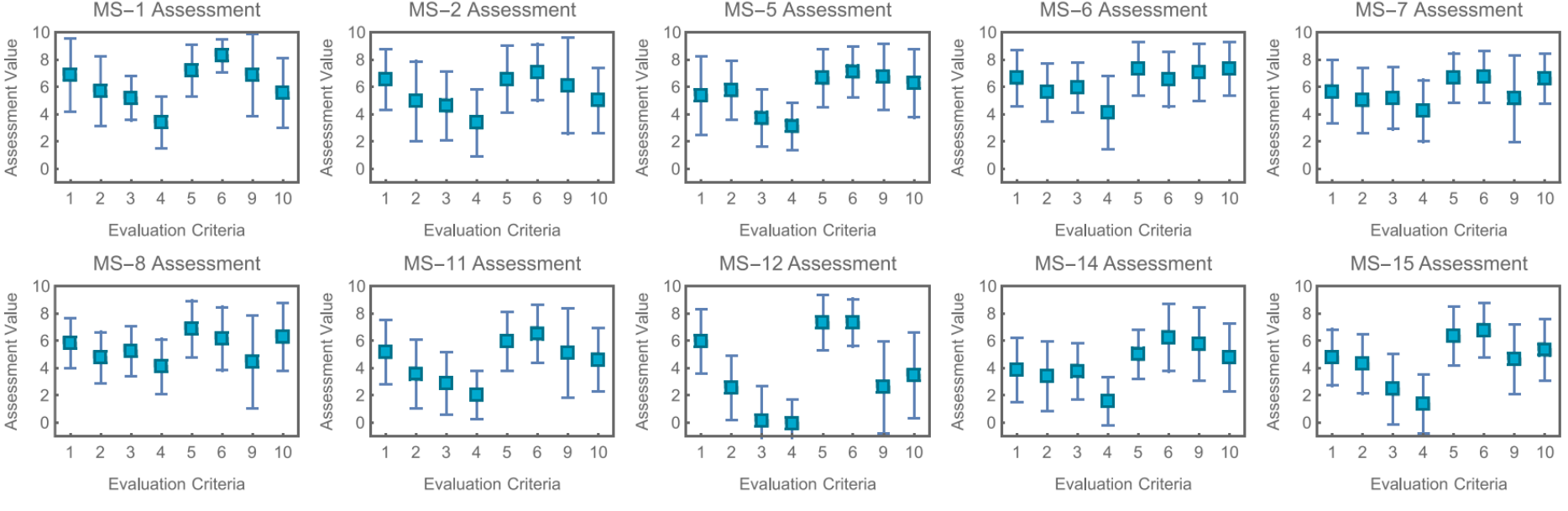


Monitoring & Surveillance: Results (Ranking based on Weighted Means)



Monitoring & Surveillance: Range of Responses & Weighted Means (by opp)



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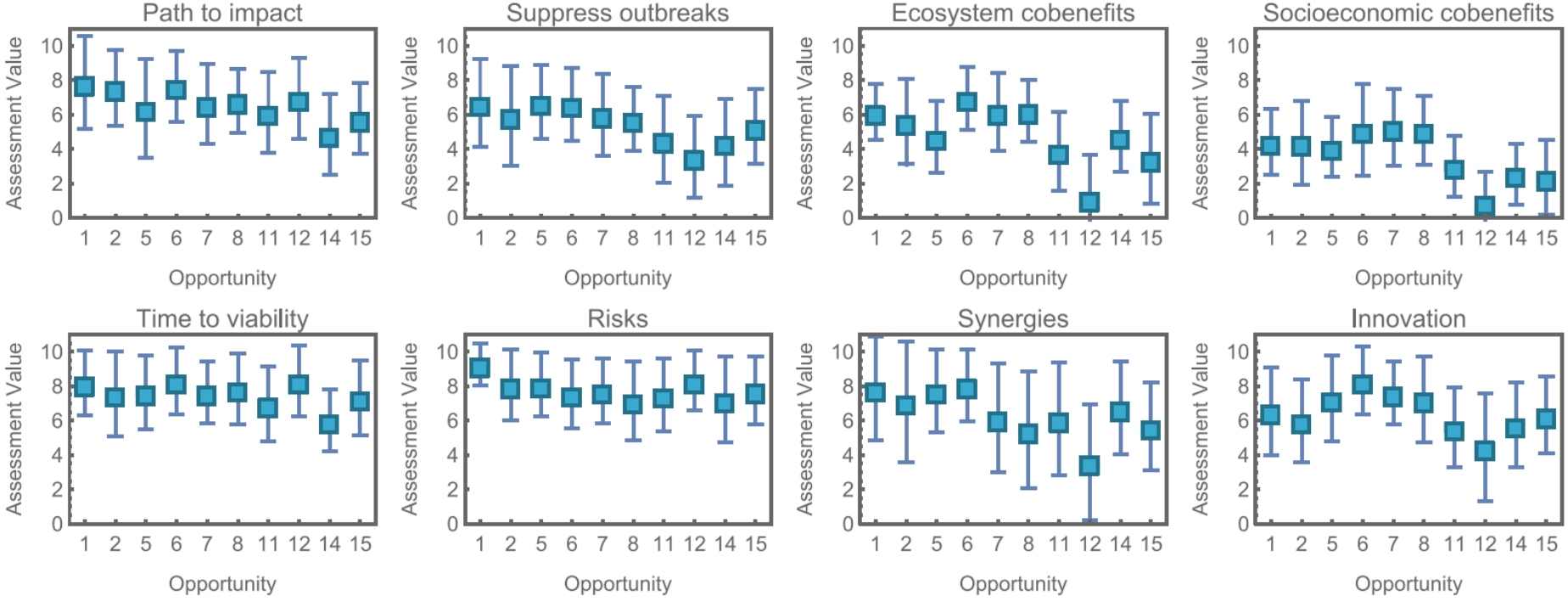


Decision Support & Modelling

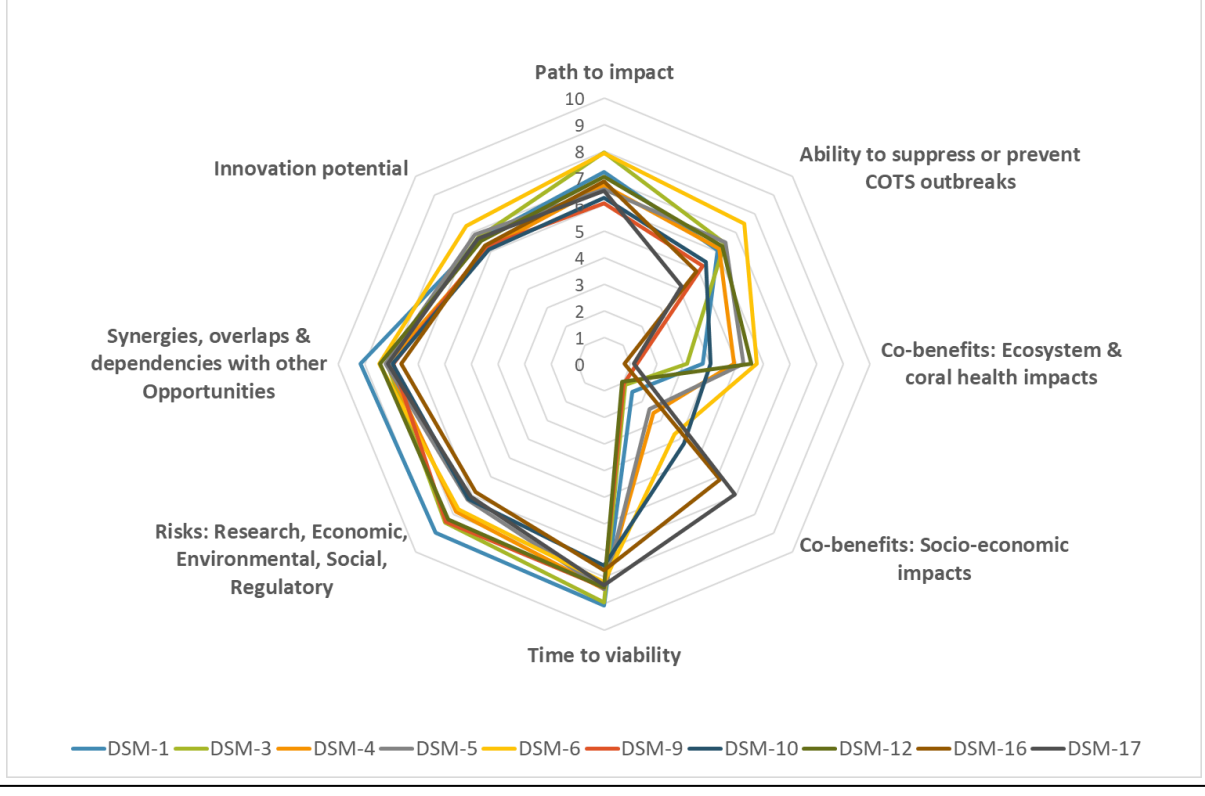
Decision Support & Modelling (1)

Opportunity Title	Opportunity Description	Cost Estimate
DSM-1: Information Infrastructure to Underpin and Accelerate Innovation in COTS Control	Aims: To create an Information Infrastructure to underpin the sharing and distribution of field, derived and model data between the control program, researchers across CCIP, and on-water operators, as well as a digital delivery mechanism to provide research recommendations back to decision makers quickly and efficiently	**$338,000**
DSM-3: Increasing the efficiency and effectiveness of the COTS Control Program through improvements to end-user Decision Support	Aim: To refine existing decision support tools, the COTS Control Centre and the GBRMPA Dashboards, to provide better and more efficient decisions and increase the impact of current COTS control efforts.	**$351,000**
DSM-4: Empirical analysis of control program and monitoring data for delivery to other modelling enterprises and developing an empirical based early warning system for primary outbreaks	Aims: To provide 1) better understanding of the short- and long-term trends in COTS populations in Australian's GBR through empirical analyses of data collated from multiple sources, and particularly, to deliver high quality data to other modelling enterprises in timely manner through digital infrastructure, reducing the likelihood of data handling error and noise; and 2) implementation of an early warning system for primary outbreaks using data from different aspects of the COTS management system.	**$194,000**
DSM-5: Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds and guiding the spatial distribution of effort	Aims: 1) To evaluate relative performance of different intervention strategies (including surveillance) for management control of CoTS populations at the scale of management sites; 2) characterise the conditions under which alternative and/or suites of management interventions are most efficacious in limiting CoTS impacts at management sites; and 3) refine ecological thresholds for management control of CoTS by incorporating local factors that impact CoTS-coral dynamics.	**$468,000**
DSM-6: Design and optimisation of regional models and decision support strategies for CoTS control and ecosystem resilience	Aims: 1) refine and calibrate existing reef meta-community models of coral and CoTS against current and future field data; 2) design strategies for regional deployment of control resources, test the sensitivity of CoTS outbreaks to proposed regional control strategies and distribution of effort (e.g. number of vessels, decisions of vessel crews), and identify strategies that engender optimal ecosystem outcomes; and 3) translate optimised control strategies into practical guidelines for use in on-water operations (e.g. regional prioritisation and route planning)	**$831,000**

Decision Support & Modelling (2)

Opportunity Title	Opportunity Description	Cost Estimate
DSM-9: Risk and uncertainty analysis of COTS control strategies and innovations	Aims: 1) To measure uncertainty in a) the empirical measurements that underpin our understanding of the current state and dynamics of CoTS outbreaks; and b) the hydrodynamic, biological, and ecological models that are used to forecast CoTS abundance and distribution, and 2) to develop a comprehensive risk analysis framework for choosing priority CoTS control locations in the face of this uncertainty.	**$190,000**
DSM-10: Ensemble of ensembles: A unified COTS management modelling capability for application and exploration	Aim: To provide access to and interpretation of the suite of CoTS-related models developed under CCIP to answer pressing questions of importance to managers, researchers from other CCIP Program Areas, and DS&M modellers themselves.	**$295,000**
DSM-12: Using ensembles of biophysical larval dispersal models to improve robustness and quantify uncertainty in connectivity predictions.	Aims: 1) Harmonise multiple diverse hydrodynamic models of the GBR lagoon and surroundings, to ensure that they make comparable predictions about currents, across the same spatiotemporal window, on the basis of input data of comparable quality (e.g., habitat maps & bathymetry, low frequency forcing, tides, wind), 2) contrast the predictions of this model ensemble with spatiotemporal empirical validation data on observed COTS densities on sampled and controlled reefs, and 3) support the integration of the modelling ensemble with decision-making processes.	**$481,000**
DSM-16: Platform for understanding the relative effectiveness, cost-effectiveness, and economic efficiency of combinations of COTS control methods	Aim: To assess relative effectiveness, cost-effectiveness, and economic efficiency of COTS control methods.	**$225,000**
DSM-17: Multi-criteria decision-making framework for balancing management priorities under resource constraints.	Aim: Through a combination of surveys, workshops, and computational decision-support tools, (1) elicit and understand the range of stakeholder values; (2) use the best available ecological science and multi-criteria decision analysis methods to determine how a range of alternative COTS control strategies will affect these values, and 3) present these results in an interactive forum to examine the resultant trade-offs, and to allow stakeholders and Traditional Owners to express their judgements about the methods and control strategies.	**$325,000**

Decision Support & Modelling: Results (by criteria & opp., based on Weighted Means)



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Decision Support & Modelling: Results (Score based on Weighted Means)

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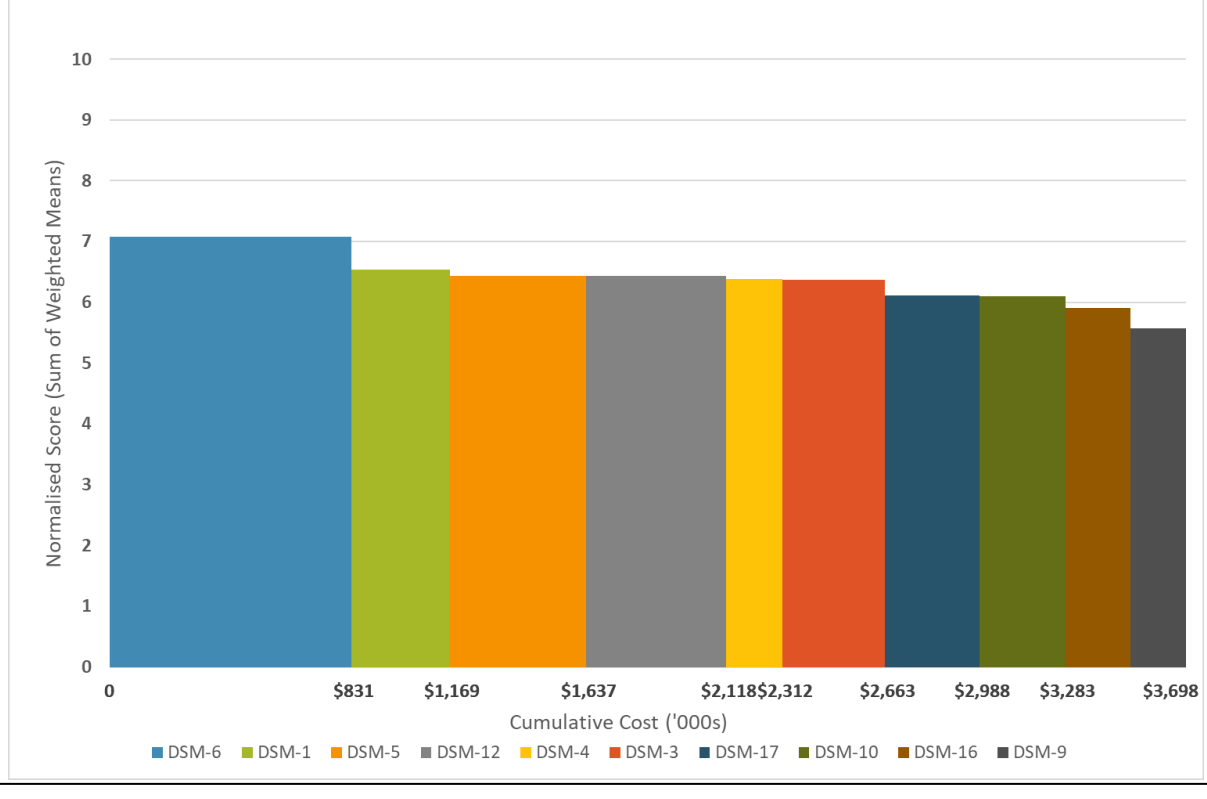
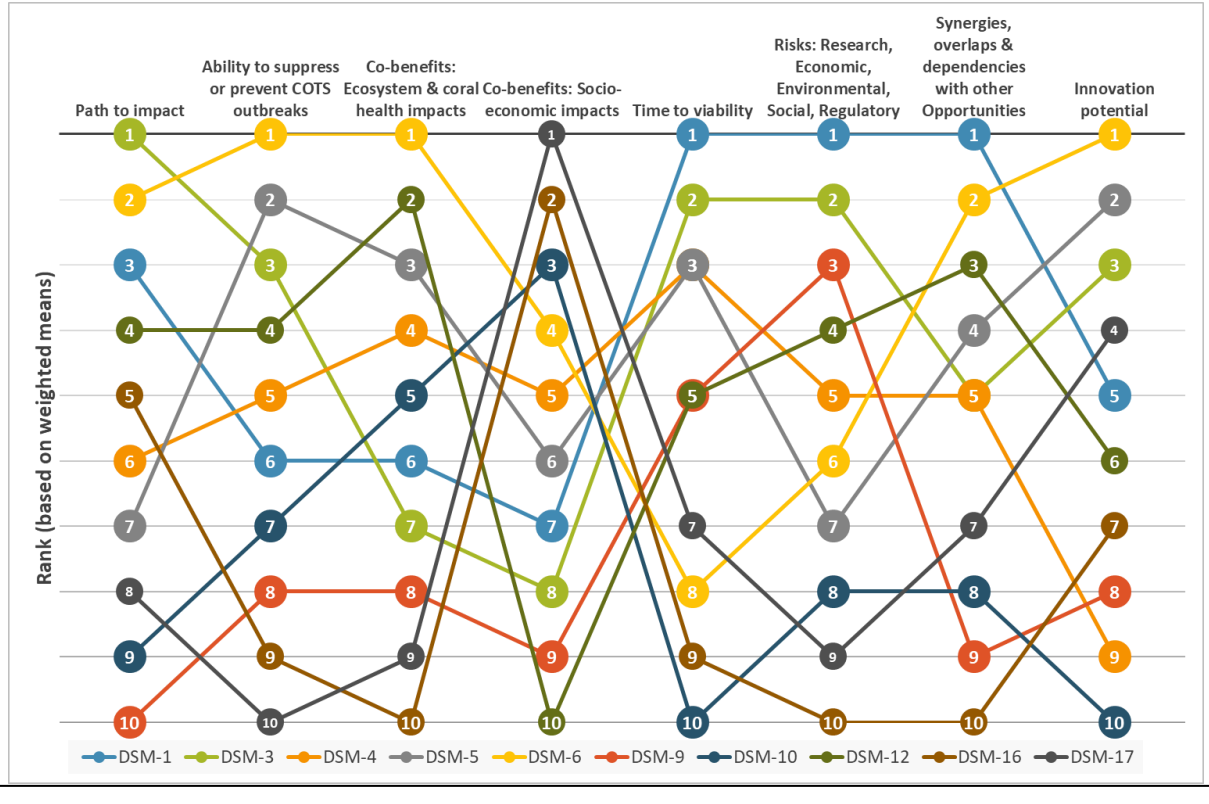
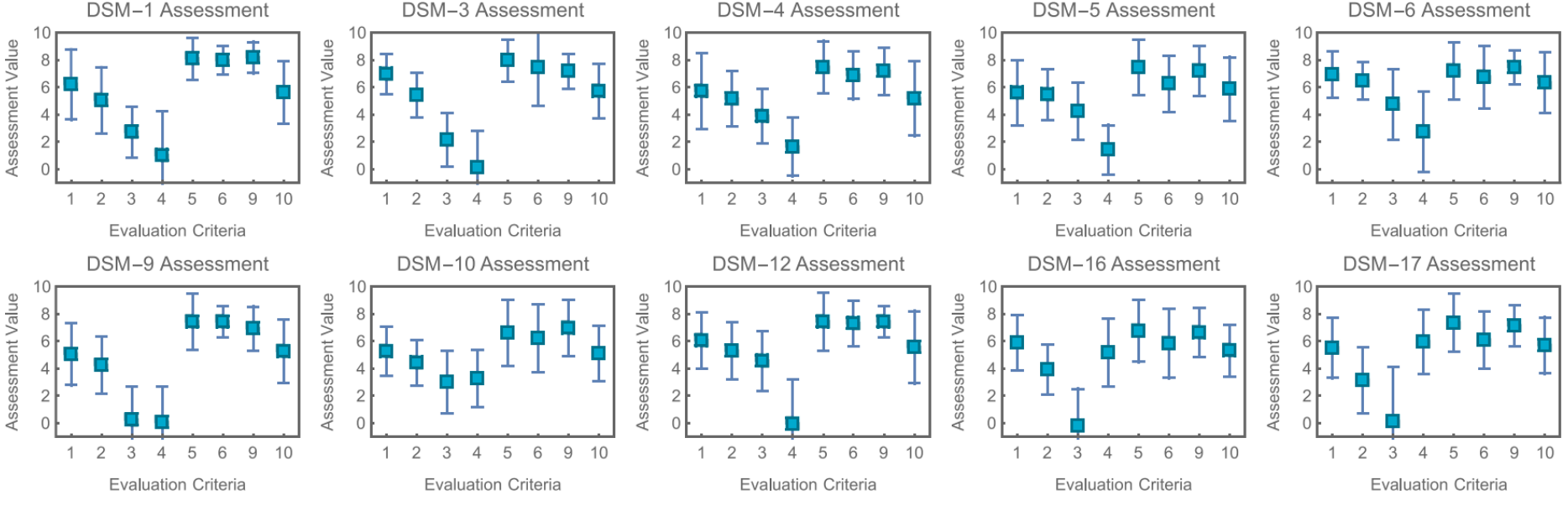


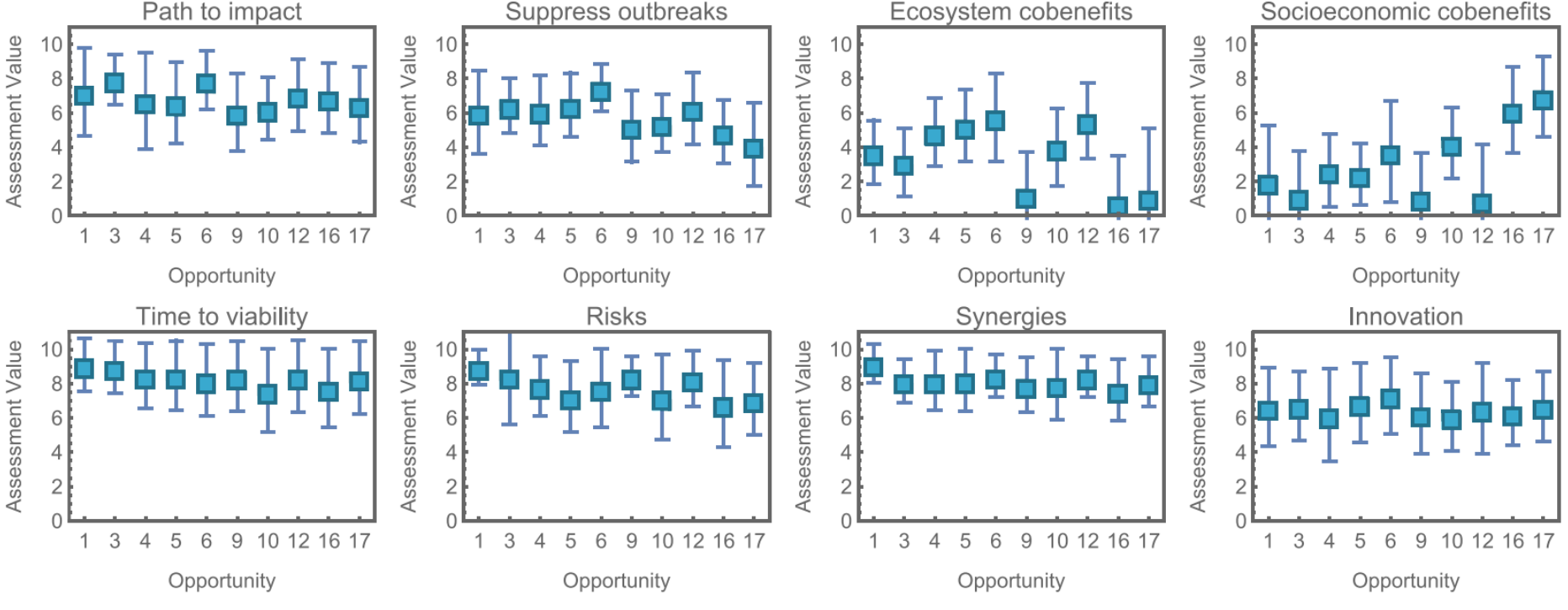
Decision Support & Modelling: Results (Ranking based on Weighted Means)



Decision Support & Modelling: Range of Responses & Weighted Means (by opp)



Decision Support & Modelling: Range of Responses & Weighted Means (by criteria)

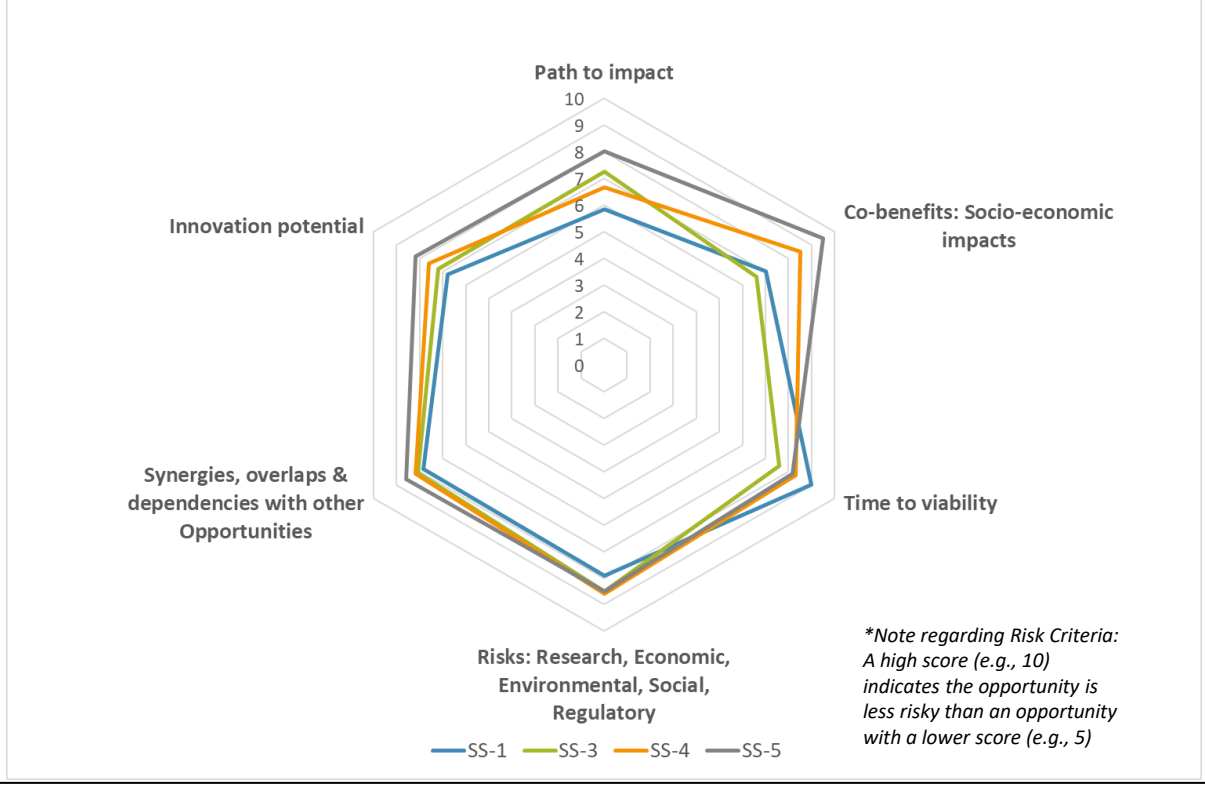


Social Acceptability, Regulatory & Institutional Arrangements

Social Acceptability, Regulatory & Institutional Arrangements

Opportunity Title	Opportunity Description	Cost Estimate
SS-1: Understanding the preferences of and non-use benefits to the Australian public associated with CoTS control methods.	Aim: Through a discrete choice experiment, 1) assess public preferences towards alternative control methods and the associated trade-offs, 2) assess preference heterogeneity, 3) identify socio-economic indicators for longer-term monitoring, and 4) estimate economic value of non-use benefits generated by COTS control.	**$95,000**
SS-2: Understanding the costs of alternative (other than manual) CoTS control methods.	Aim: To estimate the economic cost of implementing (combinations of) alternative COTS control methods that can be used as inputs in cost-effectiveness and efficiency assessments.	**$180,000**
SS-3: Policy and regulatory environment for COTS R&D	Aims: 1) Investigate the capacity of the existing regulatory and policy frameworks to address R&D and deployment of innovative COTS control methods, 2) scope which methods are permitted and under what conditions (e.g., scale, location and timing) with the aim to inform relevant CCIP program areas, and 3) help enhance the capacity of the regulatory system to assess the range of risks and impacts associated with R&D and deployment of innovative COTS control methods.	**$293,000**
SS-4: Public and stakeholder perceptions of COTS, COTS management and novel control techniques	Aim: To support the development and deployment of COTS management options that are perceived by the public and stakeholders as socially responsible and acceptable. It will achieve this through a combination of qualitative and quantitative research methods. Specifically, this project will identify and monitor public and stakeholder perceptions of COTS, COTS management and novel control techniques with a particular focus on attitudes and risk perceptions.	**$1,225,000**
SS-5: Biocultural values and governance assessment	Aim: To inform the development and deployment of COTS management options that reflect Reef Traditional Owner values and which support aspirations for collaboration with research institutions and meaningful involvement in program co-design and delivery. In part, this will be achieved by adapting research activities designed to monitor public and stakeholder perceptions of COTS, COTS management and novel control techniques to suit the preferences of Traditional Owners.	**$465,000**

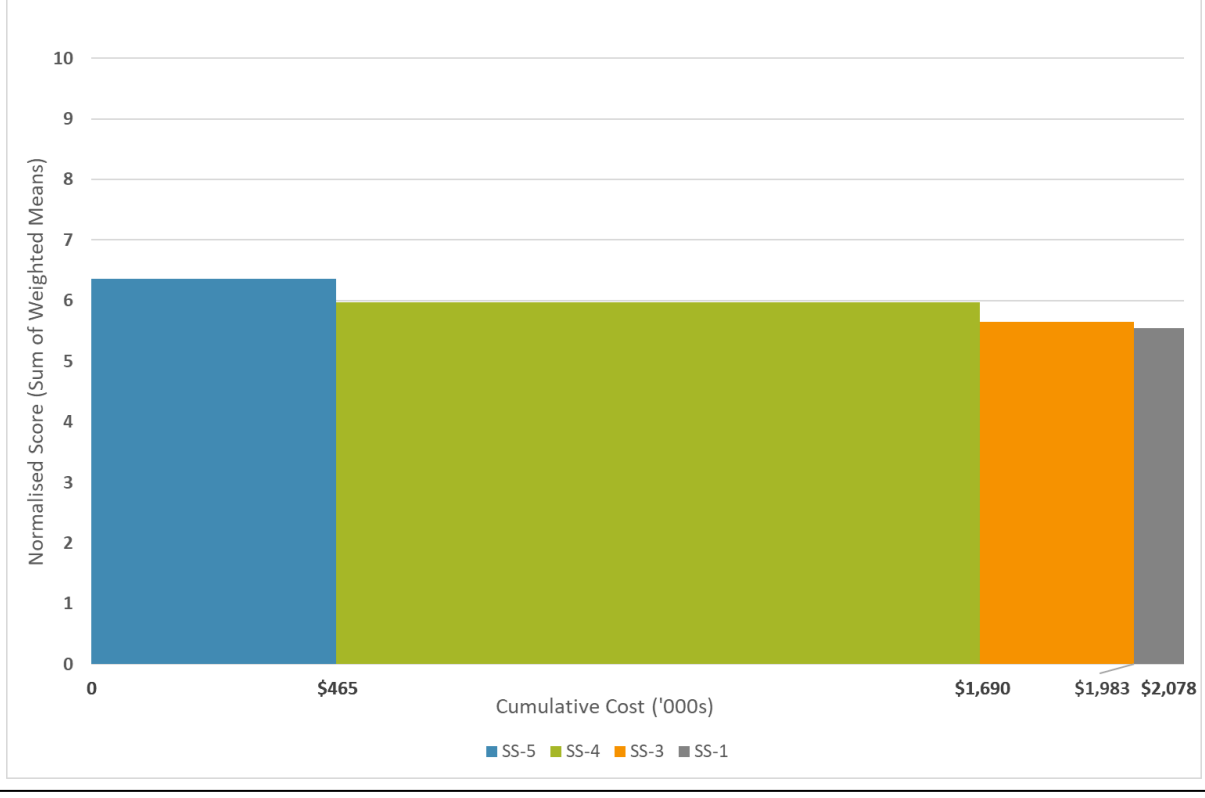
Social Sciences: Results (by criteria & opp., based on Weighted Means)



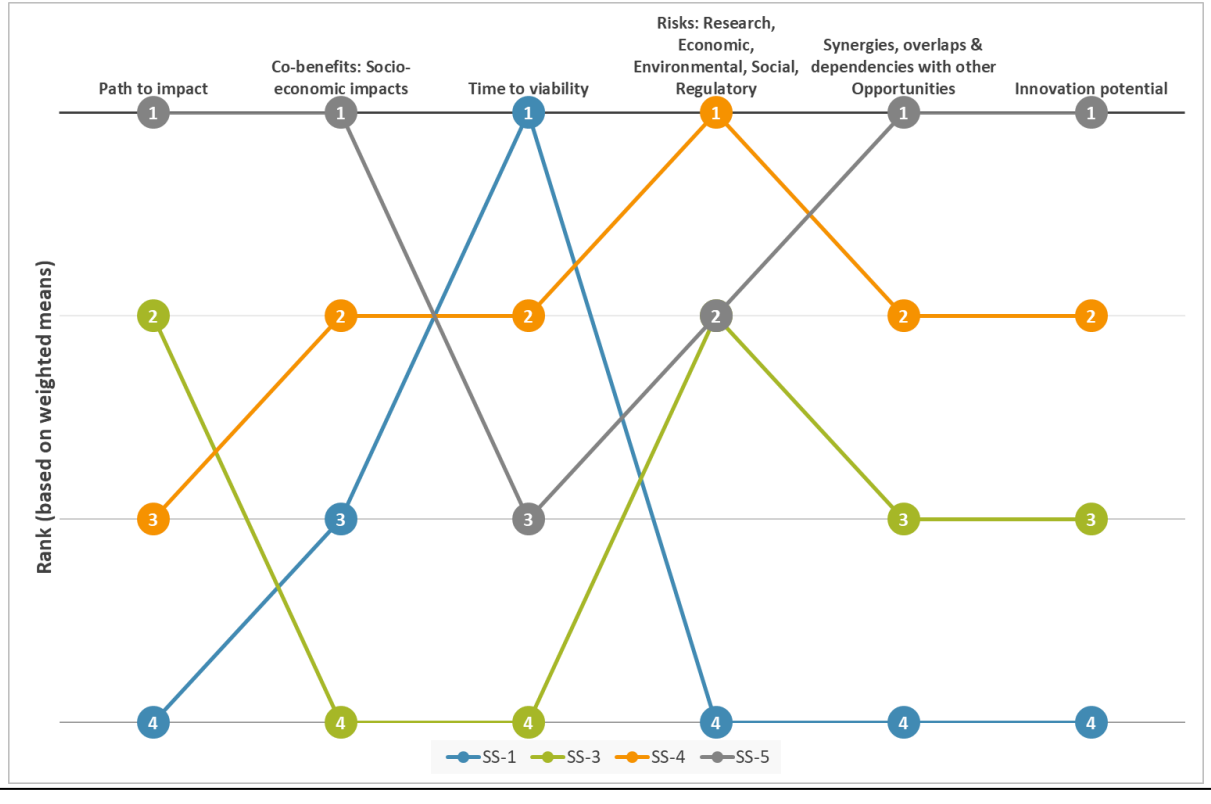
**Note regarding Risk Criteria: A high score (e.g., 10) indicates the opportunity is less risky than an opportunity with a lower score (e.g., 5)*

Social Sciences: Results (Score based on Weighted Means)

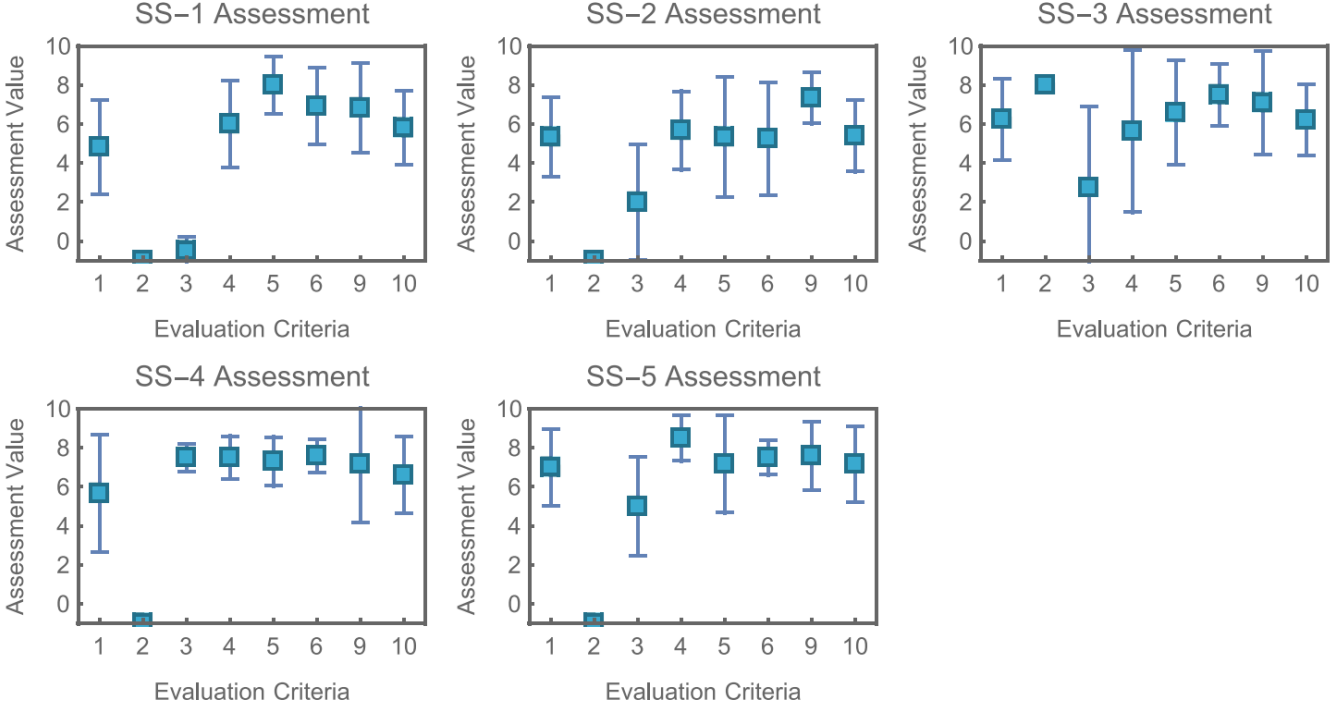
**Note regarding normalized scores: this represents the sum of weighted means of the scores for each criteria*



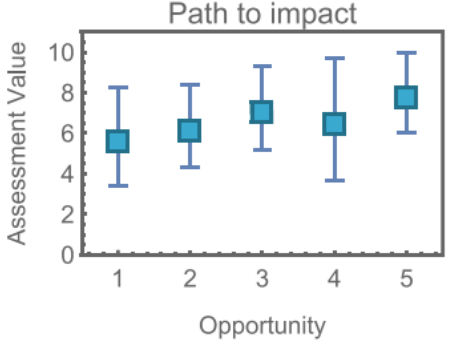
Social Sciences: Results (Ranking based on Weighted Means)



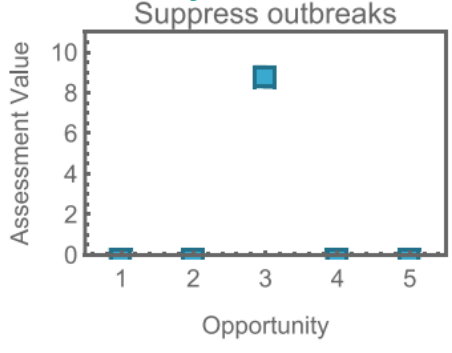
Social Sciences: Range of Responses & Weighted Means (by opp)



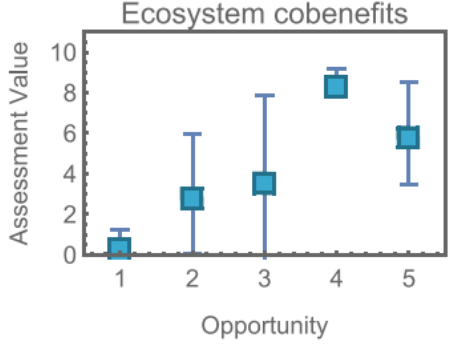
Social Sciences: Range of Responses & Weighted Means (by criteria)

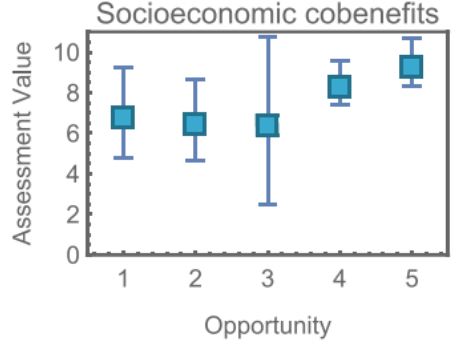


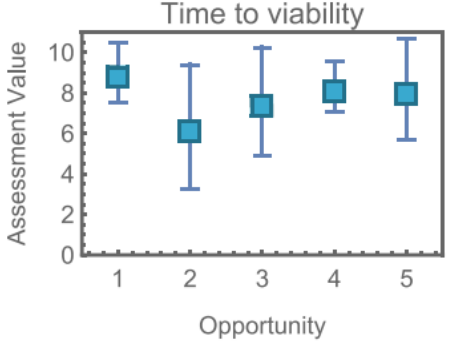
** Most respondents did not evaluate against this criteria*

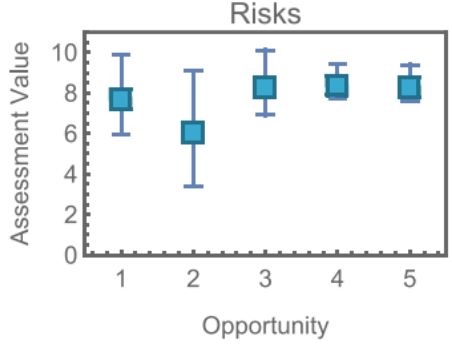


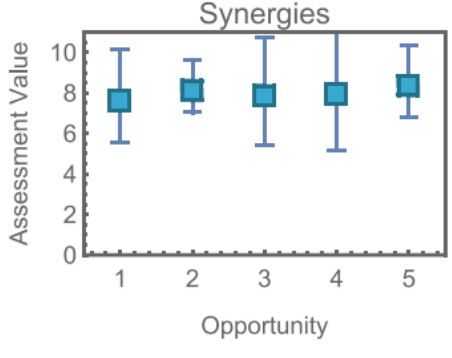
** Most respondents did not evaluate against this criteria*

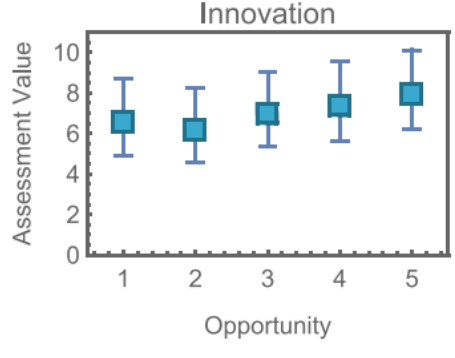


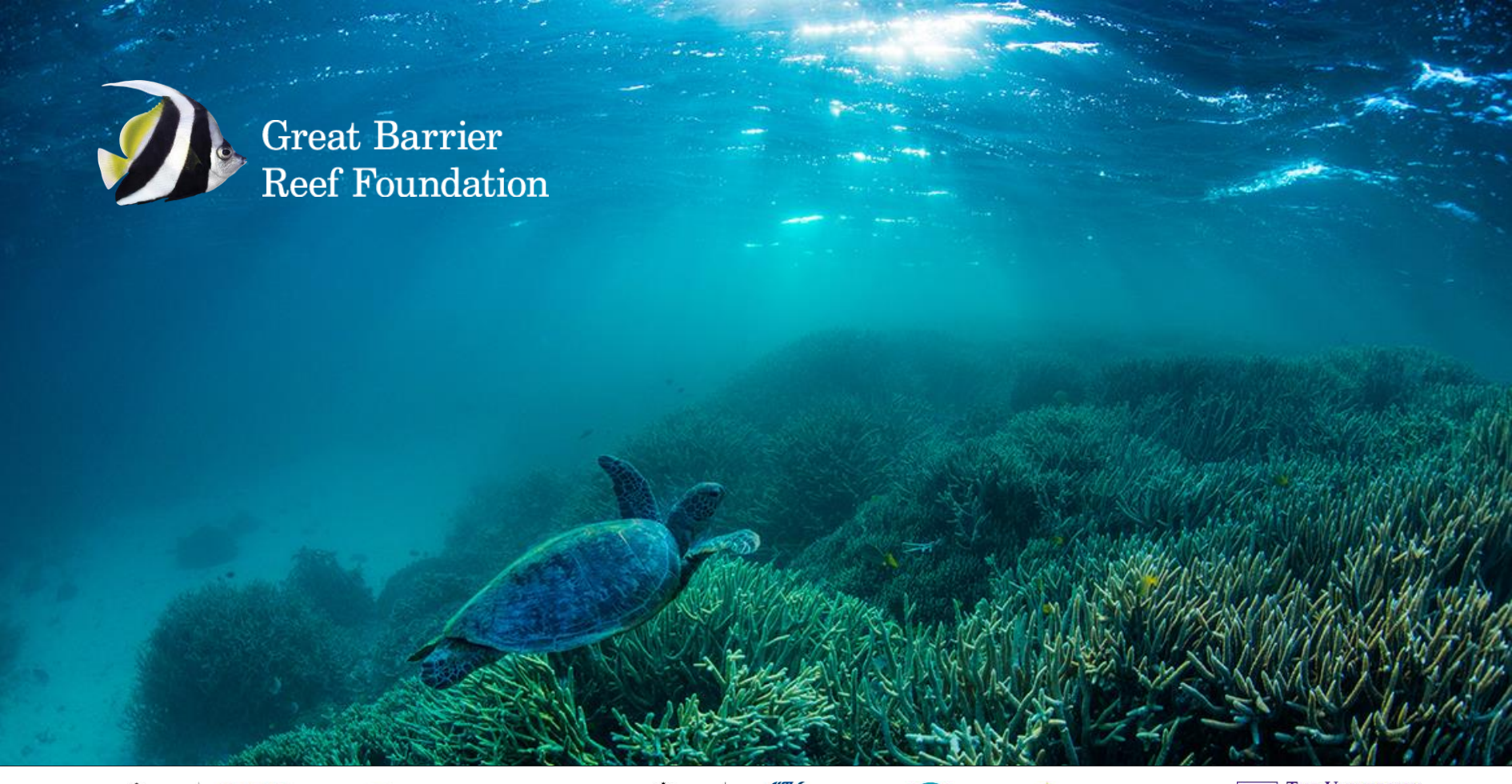












Australian Government | Reef Trust | Great Barrier Reef Foundation | Australian Government | Australian Institute of Marine Science | CSIRO | James Cook University Australia | The University Of Queensland Australia

Appendix D – Portfolio Framing Workshop Canvas

Framing Canvas

Team Name: CCIP **Date:** 10/03/2021

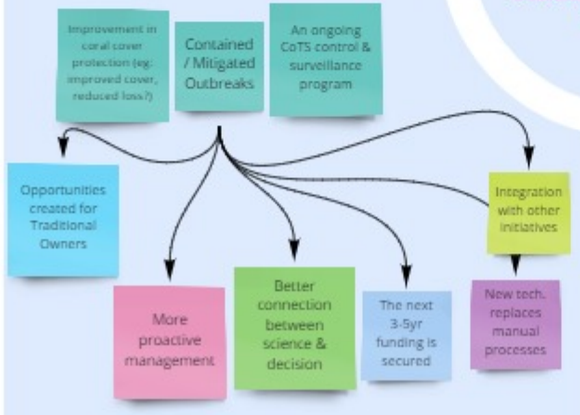
Workshop Objectives

Fundamental Objective:
- To establish and agree the frame for the prioritisation of opportunities for the R&D phase of CCIP

- Reconfirm Opportunity Statement
- Agree Key Success Factors
- Establish portfolio themes
- Agree evaluation criteria
- Agree steps for outstanding alignment

Key success factors

- Through more proactive management, we've minimised the impact of the next primary outbreak.
- A more efficient, seamless connection between the science and the decisions and the actions on the ground (integration of early warning -> feedback information to information systems -> update of the science, -> insights to decision makers -> actions)
- After 3 years, program is so compelling it extracts the next 3 or 5 year funding (from govt or other)
- New technologies being brought to bear to replace manual processes (innovation lens)
- There is ongoing COTS control and surveillance program that is the most important thing that could happen
- This list needs to be organised into an agreed hierarchy and a sequence of success factors.
- Opportunities created for Traditional Owners (leveraging and creating opportunities)
- We have improved coral cover as a result of COTS control
- Integrated with other initiatives to maximise Reef health (e.g., RRAP)
- E.g., social / legal, monitoring, decision support
- Also integrate with water quality improvement, zoning/fisheries management
- We are asking and answering the key questions that enable the most cost effective and efficient deployment of finite resources (portfolio design consideration).



Opportunity Statement

To create a step change and accelerate the development and uptake of innovative methods that improve the efficacy and efficiency of COTS control and surveillance.

Portfolio Themes

What proportion towards measurable change? What proportion towards innovation? What proportion towards long-term step-change? Where are / should we put risk (in the context of COTS innovation) in the portfolio?

1. Emphasis on realising ST vision
2. Emphasis on realising LT vision (204)
3. Emphasis on directness of path to impact
4. Emphasis on immediacy of path to impact
5. Prevention emphasis
6. Suppression emphasis
7. Emphasis on improving scientific knowledge
8. Higher risk emphasis
9. Lower risk emphasis
10. IPM as a framework for prioritisation
11. Emphasis on high readiness for management use
12. Emphasis on ability to test/ validate on exiting outbreaks
13. Emphasis on opportunities without preconditions (same as 3?)
14. Emphasis on opportunities that inform strategic decision
15. Emphasis on opportunities that inform tactical and operational decisions / actions
16. Emphasis on synergistic and enabling opportunities
17. Emphasis on maximising community and Traditional Owner involvement
18. Emphasis on aiding current control approaches
19. Emphasis on creating new control approaches
0. Do nothing (counter-factual)
20. Emphasis on ST use availability (benefit to current outbreak)
21. Emphasis on MT availability (2025 outbreak)
22. Emphasis on LT availability (future outbreaks)
23. Emphasis on a mix of S,M,L availability
24. Emphasis on level of integration with other programs
25. Emphasis on amplification of other program and management activities (merge w 24?)
26. Emphasis on building capacity for adaptive management

Values / Criteria

Ability to suppress or prevent COTS outbreaks
Path to impact
Time to viability
Impact
Current: Directness of impact to the current control program.
Currently a mix between the physical impact and the pathway to impact.
Co-Benefits: ecosystem and coral health impacts
Co-benefits: Socio-economic impact and Traditional Owner outcomes
OT: For me, the ecological co-benefit is more important than the socio-economic benefits for this initiative so would weight higher.
Level of Risk of Opportunity Being Successful (Research)
Risks - Economic, Env., Social, Regulatory
Innovation potential
Synergies, overlaps and dependencies with other opportunities
Benefits to / from other programs (+ avoidance of duplication) e.g. JFMP, LTMP, RRAP, RIMReP

Appendix E – Portfolio Construction

CCIP R&D Design Phase Prioritisation

Portfolio Assessment

March 2021

Portfolio Descriptions

Theme	Focus
Emphasis on Managing the Current Outbreak	This portfolio comprises R&D opportunities focussed on improving manual control by 2025 • It is focused on R&D that aims to improve the monitoring, modelling & decision support used to inform the current manual control program • It is not focussed on R&D that seeks to improve understanding & efficacy of other forms of control, including water quality & zoning, or develop new control methods
Emphasis on Suppressing the 2025 Outbreak	This portfolio comprises R&D opportunities focussed on improving control methods used in 2025 - 2035 (including manual control, predation, zoning & water quality) • It is focussed on R&D that could suppress the intensity or frequency of outbreaks at individual reefs within the GBR, but not prevent the spread of a primary outbreak entirely • It includes greater emphasis on R&D that seeks to improve understanding & efficacy of predation, zoning & water quality as means of control
Emphasis on Preventing Future Primary Outbreaks (Long-Term)	This portfolio comprises R&D opportunities focused on prevention of a future primary outbreak (in the long-term) • It is focused on increasing understanding of mitigating factors that lead to primary outbreak initiation • It includes development of GBR-scale control approaches for COTS prevention & suppression
Emphasis on Improving System Understanding	This portfolio comprises R&D opportunities focused on improving knowledge & understanding of the entire COTS management system, including biological & social components & their interaction, in order to generate GBR-scale outcomes • It is not focussed on R&D that seeks to develop new control methods
Emphasis on Creating New Control Approaches	This portfolio comprises R&D opportunities focused on development of new control approaches (i.e., not manual control, zoning or water quality) • It includes biological R&D required to develop those approaches • It includes social R&D required to achieve social license & regulatory approvals to enable implementation of those approaches
Emphasis on Informing Strategy	This portfolio comprises R&D opportunities focused on informing long-term strategy & strategic decisions • It is focussed on R&D that informs high-value / high-cost / high-uncertainty decisions pertaining to where, when & how to optimally deploy finite management resources on COTS prevention & suppression • It includes enabling research to optimise strategy development & decision-making
Emphasis on Synergies within CCIP & across GBR Programs	This portfolio comprises R&D opportunities that are likely to make beneficial contributions to other parts of CCIP & other GBR programs • It is focussed on R&D that is most highly synergistic with other opportunities within CCIP & potentially across other GBR programs

Portfolio: 1 – Emphasis on Managing the Current Outbreak

This portfolio comprises R&D opportunities focussed on improving manual control by 2025

- It is focused on R&D that aims to improve the monitoring, modelling & decision support used to inform the current manual control program
- It is not focussed on R&D that seeks to improve understanding & efficacy of other forms of control, including water quality & zoning, or develop new control methods

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-1: In situ feeding rates of crown-of-thorns starfish & fate of prey corals	**527**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-8:** Controlling outbreaks of COTS through identifying highly connected reefs for spatial management plans	**170**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1**: Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-02:** Effects of prey limitation on the boom & bust of COTS populations	**333**			**MS-2:** Estimating & accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	**354**	**DSM-3:** Increasing the efficiency & effectiveness of the COTS Control Program through improvements to end-user Decision Support	**351**	**SS-5:** Biocultural values & governance assessment	**465**
		PC-09: Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones & corresponding differences in abundance of putative predators	**433**			**MS-5:** Operationalising & Implementing COTS eDNA monitoring on the GBR	**802**	**DSM-4:** Empirical analysis of control program & monitoring data for delivery to other modelling enterprises & developing an empirical based early warning system for primary outbreaks	**194**		
						MS-6: Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-5:** Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**		
						MS-7: Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**		
						MS-8: ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-9:** Risk & uncertainty analysis of COTS control strategies & innovations	**190**		
						MS-12: Underwater human-machine interface for logging COTS cull events	**121**	**DSM-12:** Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
								DSM-17: Multi-criteria decision-making framework for balancing management priorities under resource constraints.	**325**		

Portfolio: 2 – Emphasis on Suppressing the 2025 Outbreak

This portfolio comprises R&D opportunities focussed on improving control methods used in 2025 - 2035 (including manual control, predation, zoning & water quality)

- It is focussed on R&D that could suppress the intensity or frequency of outbreaks at individual reefs within the GBR, but not prevent the spread of a primary outbreak entirely
- It includes greater emphasis on R&D that seeks to improve understanding & efficacy of predation, zoning & water quality as means of control

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-1: In situ feeding rates of crown-of-thorns starfish & fate of prey corals	**527**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-8:** Controlling outbreaks of COTS through identifying highly connected reefs for spatial management plans	**170**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1:** Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-1:** Understanding the preferences of & non-use benefits to the Australian public associated with COTS control methods.	**95**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-02:** Effects of prey limitation on the boom & bust of COTS populations	**333**			**MS-2:** Estimating & accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	**354**	**DSM-3:** Increasing the efficiency & effectiveness of the COTS Control Program through improvements to end-user Decision Support	**351**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
BE-5: Inter-reef differences in the incidence of population irruptions of COTS: testing the role of larval supply versus settlement substrates	**520**	**PC-03:** Juvenile resilience hypothesis - the potential that reserve populations of herbivorous COTS may seed outbreaks & juvenile-coral & juvenile-adult interactions – assessing the potential for semiochemical communication	**188**			**MS-5:** Operationalising & Implementing COTS eDNA monitoring on the GBR	**802**	**DSM-4:** Empirical analysis of control program & monitoring data for delivery to other modelling enterprises & developing an empirical based early warning system for primary outbreaks	**194**	**SS-5:** Biocultural values & governance assessment	**465**
		PC-06: Understanding the nutrient hypothesis: Spatio-temporal abundance of CoTS larvae in relation to water quality and nutrient sources, nutrient transformation and larval food demand	**986**			**MS-6:** Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-5:** Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**		
		PC-08: The other 90% - resolving the impact of benthic & cryptic predation on COTS	**572**			**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**		
		PC-09: Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones & corresponding differences in abundance of putative predators	**433**			**MS-8:** ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-9:** Risk & uncertainty analysis of COTS control strategies & innovations	**190**		
						MS-12: Underwater human-machine interface for logging COTS cull events	**121**	**DSM-10:** Ensemble of ensembles: A unified COTS management modelling capability for application & exploration	**295**		
								DSM-12: Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
								DSM-16: Platform for understanding the relative effectiveness, cost-effectiveness, & economic efficiency of combinations of COTS control methods	**225**		
								DSM-17: Multi-criteria decision-making framework for balancing management priorities under resource constraints.	**325**		

Portfolio: 3 – Emphasis on Preventing Future Primary Outbreaks (long-term)

This portfolio comprises R&D opportunities focused on prevention of a future primary outbreak (in the long-term)

- It is focused on increasing understanding of mitigating factors that lead to primary outbreak initiation
- It includes development of GBR-scale control approaches for COTS prevention & suppression

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-3: Supply-side ecology for COTS: the link between larval supply, settlement rates & adult densities	**730**	**PC-06:** Understanding the nutrient hypothesis: Spatio-temporal abundance of COTS larvae in relation to water quality & nutrient sources, nutrient transformation & larval food demand	**986**	**C-1:** Further development & delivery of COTS genomics resources	**243**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1**: Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-3:** Policy & regulatory environment for COTS R&D	**293**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-08:** The other 90% - resolving the impact of benthic & cryptic predation on COTS	**572**	**C-2:** Genetic approaches to COTS control	**828**	**MS-6:** Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-5**: Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
BE-5: Inter-reef differences in the incidence of population irruptions of COTS: testing the role of larval supply versus settlement substrates	**520**	**PC-09:** Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones & corresponding differences in abundance of putative predators	**433**	**C-3:** Spiroplasma-related symbionts: potential agents for targeted delivery of genetic COTS control?	**187**	**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-6**: Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**	**SS-5:** Biocultural values & governance assessment	**465**
BE-9: Specialised traits of COTS larvae: resilience or starvation in tropical waters: maternal provisioning, larval energetics, when do they need to feed, microbiome facilitation, DOM & influence of cloning	**207**	**PC-10:** Models to test the efficacy of top-down predator control on COTS	**244**	**C-5:** The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	**1404**	**MS-8:** ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-12:** Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
		PC-13: Modelling the potential effect of substate change & coral health on COTS dynamics & future COTS outbreaks	**202**								
		PC-14: Data-driven dynamic models to interrogate multiple COTS outbreak hypotheses	**200**								

Portfolio: 4 – Emphasis on Improved System Understanding

This portfolio comprises R&D opportunities focused on improving knowledge & understanding of the entire COTS management system, including biological & social components & their interaction, in order to generate GBR-scale outcomes

- It is not focussed on R&D that seeks to develop new control methods

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-2: Beyond eDNA: New genetic tools for COTS management & monitoring	**197**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-1:** Further development & delivery of COTS genomics resources	**243**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1**: Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-3:** Policy & regulatory environment for COTS R&D	**293**
BE-3: Supply-side ecology for COTS: the link between larval supply, settlement rates & adult densities	**730**	**PC-03:** Juvenile resilience hypothesis - the potential that reserve populations of herbivorous COTS may seed outbreaks & juvenile-coral & juvenile-adult interactions – assessing the potential for semiochemical communication	**188**	**C-8:** Controlling outbreaks of COTS through identifying highly connected reefs for spatial management plans	**170**	**MS-5:** Operationalising & Implementing COTS eDNA monitoring on the GBR	**802**	**DSM-5:** Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**	**SS-4**: Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-06:** Understanding the nutrient hypothesis: Spatio-temporal abundance of COTS larvae in relation to water quality & nutrient sources, nutrient transformation & larval food demand	**986**			**MS-6**: Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**	**SS-5:** Biocultural values & governance assessment	**465**
BE-5: Inter-reef differences in the incidence of population irruptions of COTS: testing the role of larval supply versus settlement substrates	**520**	**PC-08:** The other 90% - resolving the impact of benthic & cryptic predation on COTS	**572**			**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-10:** Ensemble of ensembles: A unified COTS management modelling capability for application & exploration	**295**		
BE-6: Tagging & mark recapture of adults to determine a method to age COTS, case study with stable low density population at One Tree Reef	**275**	**PC-09:** Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones & corresponding differences in abundance of putative predators	**433**			**MS-8:** ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-12:** Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
BE-8: Recruitment of juvenile COTS to coral on modern reefs; how seaweed, coral cover, warming & predation inhibit & promote first coral feeding on COTS	**318**	**PC-11:** Effect of elevated temperature & coral bleaching on distribution, feeding behaviour & physiological condition of crown-of-thorns starfish	**251**								
BE-9: Specialised traits of COTS larvae: resilience or starvation in tropical waters: maternal provisioning, larval energetics, when do they need to feed, microbiome facilitation, DOM & influence of cloning	**207**	**PC-12:** Effects of ocean warming & marine heatwaves on settlement success & population replenishment of crown-of-thorns starfish	**95**								
		PC-14: Data-driven dynamic models to interrogate multiple COTS outbreak hypotheses	**200**								

Portfolio: 5 – Emphasis on Creating New Control Approaches

This portfolio comprises R&D opportunities focused on development of new control approaches (i.e., not manual control, zoning or water quality)

- It includes biological R&D required to develop those approaches
- It includes social R&D required to achieve social license & regulatory approvals to enable implementation of those approaches

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-1:** Further development & delivery of COTS genomics resources	**243**	**MS-1**: COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1:** Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-1**: Understanding the preferences of & non-use benefits to the Australian public associated with COTS control methods.	**95**
BE-5: Inter-reef differences in the incidence of population irruptions of COTS: testing the role of larval supply versus settlement substrates	**520**	**PC-03:** Juvenile resilience hypothesis - the potential that reserve populations of herbivorous COTS may seed outbreaks & juvenile-coral & juvenile-adult interactions – assessing the potential for semiochemical communication	**188**	**C-2:** Genetic approaches to COTS control	**828**	**MS-2:** Estimating & accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	**354**	**DSM-5**: Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**	**SS-3**: Policy & regulatory environment for COTS R&D	**293**
		PC-08: The other 90% - resolving the impact of benthic & cryptic predation on COTS	**572**	**C-3**: Spiroplasma-related symbionts: potential agents for targeted delivery of genetic COTS control?	**187**	**MS-6:** Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
				C-4: The Giant Triton: does it have what it takes to be a biocontrol agent of the Crown-of-Thorns starfish?	**528**	**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-9**: Risk & uncertainty analysis of COTS control strategies & innovations	**190**	**SS-5:** Biocultural values & governance assessment	**465**
				C-5: The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	**1404**	**MS-8:** ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-12:** Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
				C-6: Revealing the nature of the Giant triton's 'landscape of fear'	**813**			**DSM-16:** Platform for understanding the relative effectiveness, cost-effectiveness, & economic efficiency of combinations of COTS control methods	**225**		

Portfolio: 6 – Emphasis on Opportunities that Inform Strategy

This portfolio comprises R&D opportunities focused on informing long-term strategy & high-value / high-risk decisions

- It is focussed on R&D that informs strategic high-value / high-cost / high-uncertainty decisions pertaining to where, when & how to optimally deploy finite management resources on COTS prevention & suppression
- It includes enabling research to optimise strategy development & decision-making

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-3: Supply-side ecology for COTS: the link between larval supply, settlement rates & adult densities	**730**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-5:** The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	**1404**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1:** Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-1:** Understanding the preferences of & non-use benefits to the Australian public associated with COTS control methods.	**95**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-02:** Effects of prey limitation on the boom & bust of COTS populations	**333**	**C-8:** Controlling outbreaks of COTS through identifying highly connected reefs for spatial management plans	**170**	**MS-2:** Estimating & accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	**354**	**DSM-4:** Empirical analysis of control program & monitoring data for delivery to other modelling enterprises & developing an empirical based early warning system for primary outbreaks	**194**	**SS-3:** Policy & regulatory environment for COTS R&D	**293**
		PC-11: Effect of elevated temperature & coral bleaching on distribution, feeding behaviour & physiological condition of crown-of-thorns starfish	**251**			**MS-5:** Operationalising & Implementing COTS eDNA monitoring on the GBR	**802**	**DSM-5:** Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
		PC-12: Effects of ocean warming & marine heatwaves on settlement success & population replenishment of crown-of-thorns starfish	**95**			**MS-6:** Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**	**SS-5:** Biocultural values & governance assessment	**465**
		PC-14: Data-driven dynamic models to interrogate multiple COTS outbreak hypotheses	**200**			**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-9:** Risk & uncertainty analysis of COTS control strategies & innovations	**190**		
						MS-8: ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-10:** Ensemble of ensembles: A unified COTS management modelling capability for application & exploration	**295**		
								DSM-12: Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
								DSM-16: Platform for understanding the relative effectiveness, cost-effectiveness, & economic efficiency of combinations of COTS control methods	**225**		
								DSM-17: Multi-criteria decision-making framework for balancing management priorities under resource constraints.	**325**		

Portfolio: 7 – Emphasis on Synergies within CCIP & across GBR programs

This portfolio comprises R&D opportunities that are likely to make beneficial contributions to other parts of CCIP & other GBR program

- It is focussed on R&D that is most highly synergistic with other opportunities within CCIP & potentially across other GBR programs

Biology & Ecology	Cost ($'000s)	Proximal Causes	Cost ($'000s)	Population Control	Cost ($'000s)	Monitoring & Surveillance	Cost ($'000s)	Decision Support & Modelling	Cost ($'000s)	Social Sciences & Traditional Owners	Cost ($'000s)
BE-1: In situ feeding rates of crown-of-thorns starfish & fate of prey corals	**527**	**PC-01:** Using genomics to improve knowledge of larval connectivity	**277**	**C-5:** The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	**1404**	**MS-1:** COTS Monitoring Design: from error estimation & sampling design to inference in management & research	**358**	**DSM-1:** Information Infrastructure to Underpin & Accelerate Innovation in COTS Control	**338**	**SS-1:** Understanding the preferences of & non-use benefits to the Australian public associated with COTS control methods.	**95**
BE-4: Inter-annual changes in density, distribution & demography for pre-outbreak populations of COTS on Australia's GBR	**645**	**PC-06:** Understanding the nutrient hypothesis: Spatio-temporal abundance of COTS larvae in relation to water quality & nutrient sources, nutrient transformation & larval food demand	**986**	**C-8:** Controlling outbreaks of COTS through identifying highly connected reefs for spatial management plans	**170**	**MS-2:** Estimating & accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	**354**	**DSM-4:** Empirical analysis of control program & monitoring data for delivery to other modelling enterprises & developing an empirical based early warning system for primary outbreaks	**194**	**SS-3:** Policy & regulatory environment for COTS R&D	**293**
BE-9: Specialised traits of COTS larvae: resilience or starvation in tropical waters: maternal provisioning, larval energetics, when do they need to feed, microbiome facilitation, DOM & influence of cloning	**207**	**PC-08:** The other 90% - resolving the impact of benthic & cryptic predation on COTS	**572**			**MS-6:** Accelerating the development, deployment, & support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	**890**	**DSM-5:** Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds & guiding the spatial distribution of effort	**468**	**SS-4:** Public & stakeholder perceptions of COTS, COTS management & novel control techniques	**1225**
		PC-14: Data-driven dynamic models to interrogate multiple COTS outbreak hypotheses	**200**			**MS-7:** Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	**1260**	**DSM-6:** Design & optimisation of regional models & decision support strategies for COTS control & ecosystem resilience	**831**	**SS-5:** Biocultural values & governance assessment	**465**
						MS-8: ReefScan-Transom – a visual survey system for COTS detection	**670**	**DSM-10:** Ensemble of ensembles: A unified COTS management modelling capability for application & exploration	**295**		
						MS-14: Environmental DNA survey of interspecies interactions to determine the drivers of COTS outbreaks	**1164**	**DSM-12:** Using ensembles of biophysical larval dispersal models to improve robustness & quantify uncertainty in connectivity predictions.	**481**		
								DSM-16: Platform for understanding the relative effectiveness, cost-effectiveness, & economic efficiency of combinations of COTS control methods	**225**		

CCIP R&D Design Phase Prioritisation
Portfolio Assessment
Portfolios - Alignment of Opportunities to Portfolio Emphases

Dark green denotes aligned to portfolio emphasis and included in portfolio.
Light green denotes aligned to portfolio emphasis but not included in portfolio due to budget constraints.
Bar width indicates extent of alignment.

	Opportunity	Cost	Emphasis on Managing Current Outbreak (BAU)	Emphasis on Suppressing the 2025 Outbreak	Emphasis on Preventing Future Primary (Long-Term) Outbreaks	Emphasis on Improved System Understanding	Emphasis on Creating New Control Approaches	Emphasis on Opportunities that Inform Strategy	Emphasis on Synergies within CCIP & across GBR Programs
Biology and Ecology	BE-1: In situ feeding rates of crown-of-thorns starfish and fate of prey corals	$527,000							
	BE-2: Beyond eDNA: New genetic tools for CoTS management and monitoring	$197,000							
	BE-3: Supply-side ecology for CoTS: the link between larval supply, settlement rates and adult densities	$730,040							
	BE-4: Inter-annual changes in density, distribution and demography for pre-outbreak populations of CoTS on Australia's GBR	$645,000							
	BE-5: Inter-reef differences in the incidence of population irruptions of CoTS: testing the role of larval supply versus settlement substrates	$519,820							
	BE-6: Tagging and mark recapture of adults to determine a method to age CoTS, case study with stable low density population at One Tree Reef	$275,380							
	BE-8: Recruitment of juvenile CoTS to coral on modern reefs; how seaweed, coral cover, warming & predation inhibit and promote first coral feeding on CoTS	$317,640							
	BE-9: Specialised traits of CoTS larvae: resilience or starvation in tropical waters: maternal provisioning, larval energetics, when do they need to feed, microbiome facilitation, DOM & influence of cloning	$207,300							
Proximal Causes	PC-01: Using genomics to improve knowledge of larval connectivity	$276,837							
	PC-02: Effects of prey limitation on the boom and bust of CoTS populations	$332,950							
	PC-03: Juvenile resilience hypothesis - the potential that reserve populations of herbivorous COTS may seed outbreaks and juvenile-coral and juvenile-adult interactions – assessing the potential for semiochemical communication	$188,500							
	PC-05: COTS larvae in low salinity plumes – impacts of multiple water quality stressors on larval success	$111,500							
	PC-06: Understanding the nutrient hypothesis: Spatio-temporal abundance of CoTS larvae in relation to water quality and nutrient sources, nutrient transformation and larval food demand	$985,898							
	PC-08: The other 90% - resolving the impact of benthic and cryptic predation on CoTS	$571,960							
	PC-09: Quantifying predation rates on adult crown-of-thorns starfish relative to fisheries management zones and corresponding differences in abundance of putative predators	$432,850							
	PC-10: Models to test the efficacy of top-down predator control on CoTS	$244,500							
	PC-11: Effect of elevated temperature and coral bleaching on distribution, feeding behaviour and physiological condition of crown-of-thorns starfish	$251,100							
	PC-12: Effects of ocean warming and marine heatwaves on settlement success and population replenishment of crown-of-thorns starfish	$95,350							
	PC-13: Modelling the potential effect of substate change and coral health on CoTS dynamics and future CoTS outbreaks	$202,500							
	PC-14: Data-driven dynamic models to interrogate multiple CoTS outbreak hypotheses	$200,000							
Population Control	C-1: Further development and delivery of COTS genomics resources	$242,750							
	C-2: Genetic approaches to COTS control	$828,000							
	C-3: Spiroplasma-related symbionts: potential agents for targeted delivery of genetic COTS control?	$187,000							
	C-4: The Giant Triton: does it have what it takes to be a biocontrol agent of the Crown-of-Thorns starfish?	$528,500							
	C-5: The search for Crown-of-Thorns starfish pheromones: modifying conspecific behaviour to control outbreaks.	$1,403,850							
	C-6: Revealing the nature of the Giant triton's 'landscape of fear'	$813,200							
	C-8: Controlling outbreaks of CoTS through identifying highly connected reefs for spatial management plans	$170,000							
Monitoring & Surveillance	MS-1: COTS Monitoring Design: from error estimation and sampling design to inference in management and research	$358,000							
	MS-11: Wearable tech for in-water data collection	$437,000							
	MS-12: Underwater human-machine interface for logging CoTS cull events	$121,147							
	MS-14: Environmental DNA survey of interspecies interactions to determine the drivers of CoTS outbreaks	$1,163,787							
	MS-15: Larval advection probability models and V3 surveys	$340,000							
	MS-2: Estimating and accounting for error in COTS Monitoring for improved inference (naturally part of previous but separated to make it clear that it is important)	$354,000							
	MS-5: Operationalising and Implementing CoTS eDNA monitoring on the GBR	$802,346							
	MS-6: Accelerating the development, deployment, and support of the Vertigo3 true-flight TUV (Vertigo3) for near-term, in-field operations in the COTS Control Program	$890,000							
	MS-7: Development of informatics systems for autonomous underwater vehicles in support of the COTS monitoring program	$1,260,000							
	MS-8: ReefScan-Transom – a visual survey system for CoTS detection	$670,300							
Decision Support & Modelling	DSM-1: Information Infrastructure to Underpin and Accelerate Innovation in COTS Control	$338,000							
	DSM-10: Ensemble of ensembles: A unified COTS management modelling capability for application and exploration	$295,000							
	DSM-12: Using ensembles of biophysical larval dispersal models to improve robustness and quantify uncertainty in connectivity predictions.	$481,000							
	DSM-16: Platform for understanding the relative effectiveness, cost-effectiveness, and economic efficiency of combinations of COTS control methods	$225,000							
	DSM-17: Multi-criteria decision-making framework for balancing management priorities under resource constraints.	$325,000							
	DSM-3: Increasing the efficiency and effectiveness of the COTS Control Program through improvements to end-user Decision Support	$351,000							
	DSM-4: Empirical analysis of control program and monitoring data for delivery to other modelling enterprises and developing an empirical based early warning system for primary outbreaks	$194,000							
	DSM-5: Dynamic models to inform COTS intervention strategies at the reef-scale, including refining ecological thresholds and guiding the spatial distribution of effort	$468,000							
	DSM-6: Design and optimisation of regional models and decision support strategies for CoTS control and ecosystem resilience	$831,000							
	DSM-9: Risk and uncertainty analysis of COTS control strategies and innovations	$190,000							
Social Sciences & Traditional Owners	SS-1: Understanding the preferences of and non-use benefits to the Australian public associated with CoTS control methods.	$95,000							
	SS-3: Policy and regulatory environment for COTS R&D	$293,000							
	SS-4: Public and stakeholder perceptions of COTS, COTS management and novel control techniques	$1,225,000							
	SS-5: Biocultural values and governance assessment	$465,000							

Appendix F – Evaluation Criteria

Great Barrier Reef Foundation

CCIP Design Phase

Prioritisation Process – Evaluation Criteria

March 2021

Australian Government | Reef Trust | Great Barrier Reef Foundation | Australian Government | Australian Institute of Marine Science | CSIRO | James Cook University Australia | The University of Queensland Australia

Portfolio Assessment: Evaluation Criteria

Evaluation Criteria	Evaluation Criteria Question	Key Success Factors
1. Extent of Impact on Coral	How significantly does this Portfolio improve our impact on coral through prevention and/or suppression of COTS outbreaks across spatial and temporal scales?	The portfolio improves our ability to have a beneficial impact on coral at scale, meaning that: • It enables prevention of future COTS outbreaks • It enables less frequent COTS outbreaks • It enables less severe COTS outbreaks • It enables us to have impact on coral at scale (i.e., spatially) • It enables us to have sustained impact on coral (i.e., over time)
2. Directness of Impact on Coral	How direct is the path from this Portfolio to improvement in our impact on coral from prevention and / or suppression of COTS outbreaks?	The portfolio has a direct path to improving our ability to have a beneficial impact on coral at scale, meaning that: • There is a transparent link between CCIP and COTS outbreak prevention and suppression activities • Outcomes of research can be directly implemented to COTS management • Its ability to impact is not reliant on additional subsequent R&D activities • Its ability to impact is not subject to outcomes from activities outside CCIP or COTS management
3. Immediacy of Impact on Coral	To what extent can this Portfolio improve our ability to impact on coral in the short-term through prevention and / suppression of COTS outbreaks?	The portfolio enables us to immediately improve our ability to have a beneficial impact on coral at scale, meaning that: • It enables reduction in the severity of the current COTS outbreak • It improves our readiness to manage the 2025 outbreak • It enables reduction in the severity of the 2025 COTS outbreak
4. Potential for Step-Change in COTS Management	To what extent does this Portfolio enable a step-change in COTS outbreak surveillance and control capability?	The portfolio enables us to achieve a step-change in COTS outbreak surveillance and control at scale, meaning that: • It enables transformation in surveillance and / or control capability • It enables a significant improvement in resource efficiency for COTS management • It enables a significant improvement in at-scale efficacy of COTS management
5. Co-Benefits: Traditional Owner & Community	To what extent does this Portfolio provide positive outcomes for Traditional Owners and communities?	The portfolio delivers positive benefits for Traditional Owners and communities, meaning that: • It enables avenues for cultural knowledge to inform / benefit COTS management and enhance integration • It enables participation and capability development opportunities for Traditional Owners and the Community • It enables increased economic opportunities for Traditional Owners and Community
6. Risk: Uncertainty in Delivering Impact on Coral	To what extent is there certainty in realising the desired outcomes from R&D?	The portfolio is not subject to uncertainty in terms of its ability to deliver impact on coral at scale, meaning that: • Success outcomes from R&D are clear • There are no material uncertainties that impact success of R&D • There are no material uncertainties that impact the translation of R&D to outcomes • There are no material regulatory hurdles that impact conducting and / or implementing R&D

Portfolio Assessment: Evaluation Criteria

1. Extent of Impact on Coral

EC Question:
How significantly does this Portfolio improve our impact on coral through prevention and/or suppression of COTS outbreaks across spatial and temporal scales?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio improves our ability to have a beneficial impact on coral at scale, meaning that:

- It enables prevention of future COTS outbreaks
- It enables less frequent COTS outbreaks
- It enables less severe COTS outbreaks
- It enables us to have impact on coral at scale (i.e., spatially)
- It enables us to have sustained impact on coral (i.e., over time)

0	1	2	3	4	5	6	7	8	9	10
No change in impact from COTS outbreak prevention and surveillance i.e., • Outbreak frequency ~15-17 years • Outbreak extent limited to 10-15% of individual reefs • Peak COTS densities ~15 – 1000 COTS / ha	Low (~15%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Low reduction in outbreak frequency • Low reduction in impacted reefs • Low reduction in COTS densities			Moderate (~30%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Moderate reduction in outbreak frequency • Moderate reduction in impacted reefs • Moderate reduction in COTS densities			Significant (~50%) improvement in impact from COTS outbreak prevention and / or surveillance i.e., • Significant reduction in outbreak frequency • Significant reduction in impacted reefs • Significant reduction in COTS densities			Highly significant improvement in impact from COTS outbreak prevention and / or surveillance i.e., • No COTS outbreaks on the GBR

Portfolio Assessment: Evaluation Criteria
2. Directness of Impact on Coral

EC Question:
How direct is the path from this Portfolio to improvement in our impact on coral from prevention and / or suppression of COTS outbreaks?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio has a direct path to improving our ability to have a beneficial impact on coral at scale, meaning that:

- There is a transparent link between CCIP R&D and COTS outbreak prevention and suppression activities
- Outcomes of R&D can be directly implemented to COTS outbreak prevention and suppression activities
- Its ability to impact is not reliant on additional subsequent R&D activities
- Its ability to impact is not subject to outcomes from activities outside CCIP or COTS outbreak prevention and / or suppression

0	1	2	3	4	5	6	7	8	9	10
No direct path to impact i.e., • Once R&D is completed, our ability to have impact on coral is dependent on considerable effort currently unknown to us.	Relatively indirect path to impact i.e., • Once R&D is completed, our ability to have impact on coral would be very reliant upon necessary pre-conditions, and there would need to be considerable effort in order to implement the outcomes of the program into existing COTS outbreak prevention and / or suppression activities			Fairly direct path to impact i.e., • Once R&D is completed, our ability to have impact on coral would be somewhat reliant upon necessary pre-conditions, and there would need to be some effort in order to implement the outcomes of the program into existing COTS outbreak prevention and / or suppression activities			Very direct path to impact i.e., • Once R&D is completed, the outcomes of the program would not be subject to many necessary pre-conditions and would be absorbed relatively seamlessly into existing COTS outbreak prevention and / or suppression activities, and translate to impact on coral			Completely direct path to impact i.e., • Once R&D is completed, the outcomes of the program would be absorbed into existing COTS outbreak prevention and / or suppression activities, and translate to impact on coral

Portfolio Assessment: Evaluation Criteria
3. Immediacy of Impact on Coral

EC Question:
To what extent can this Portfolio improve our impact on coral in the short-term through prevention and / suppression COTS outbreaks?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio enables us to immediately improve our ability to have a beneficial impact on coral at scale, meaning that:

- It enables reduction in the severity of the current COTS outbreak
- It improves our readiness to manage the 2025 outbreak
- It enables reduction in the severity of the 2025 COTS outbreak

0	1	2	3	4	5	6	7	8	9	10
No impact in the short-term i.e., • Will not change the current COTS outbreak prevention and suppression activities	Low impact in the short-term i.e., • Will likely provide some incremental improvement in current COTS outbreak prevention and / or suppression activities, and some incremental improvement in readiness to manage the 2025 outbreak			Moderate impact in short-term i.e., • Will likely provide some moderate improvements in current COTS outbreak prevention and / or suppression activities, and some moderate improvement in readiness to manage the 2025 outbreak			Significant impact in the short-term i.e., • Will likely provide significant improvements in current COTS outbreak prevention and / or suppression activities, and significant improvement in readiness to manage the 2025 outbreak			Highly significant impact in the short term i.e., • Will likely provide highly significant improvements in current COTS outbreak prevention and suppression activities

Portfolio Assessment: Evaluation Criteria
4. Potential for Step-Change in COTS Management

EC Question:
To what extent does this Portfolio enable a step-change in COTS outbreak surveillance and / or control?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio enables us to achieve a step-change in COTS outbreak surveillance and / or control at scale, meaning that:

- It enables transformation in surveillance and / or control capability
- It enables a significant improvement in resource efficiency for COTS outbreak surveillance and / or control
- It enables a significant improvement in at-scale efficacy of COTS management

0	1 2 3	4 5 6	7 8 9	10
No advancement in COTS outbreak surveillance and control capability compared to current approaches i.e., • No change in COTS outbreak surveillance and control capability	Limited advancement in COTS outbreak surveillance and / or control capability compared to current approaches i.e., • Limited improvement in resource efficiency • Limited improvement in at-scale efficacy of COTS outbreak surveillance and / or control	Moderate advancement in COTS outbreak surveillance and / or control capability compared to current approaches i.e., • Moderate improvement in resource efficiency • Moderate improvement in at-scale efficacy of COTS outbreak surveillance and / or control	Significant advancement in COTS outbreak surveillance and / or control capability compared to current approaches i.e., • Significant improvement in resource efficiency • Significant improvement in at-scale efficacy of COTS outbreak surveillance and / or control	Transformative impact on COTS outbreak surveillance and control capability compared to current approaches i.e., • Highly significant improvement in resource efficiency • Highly significant improvement in at-scale efficacy of COTS outbreak surveillance and / or control

Portfolio Assessment: Evaluation Criteria
5. Co-Benefits: Traditional Owner & Community

EC Question:
To what extent does this Portfolio provide or enable beneficial outcomes for Traditional Owners and communities?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio delivers or enables positive benefits to be accrued by Traditional Owners and communities, meaning that:

- It enables avenues for cultural knowledge to inform / benefit COTS management and enhance integration
- It enables participation and capability development opportunities for Traditional Owners and the Community
- It enables increased economic opportunities for Traditional Owners and Community

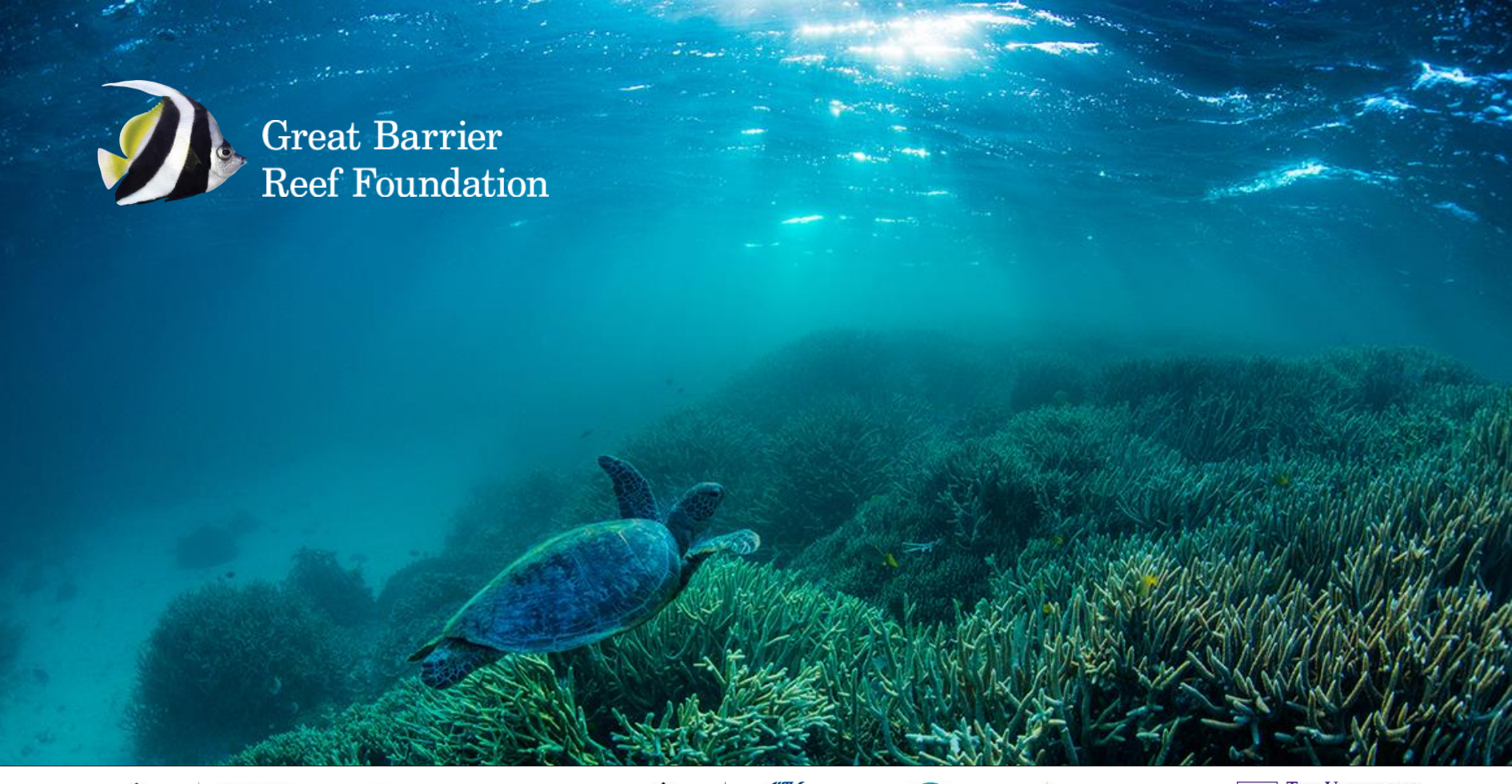
0	1	2	3	4	5	6	7	8	9	10
No co-benefit i.e., • Provides no obvious co-benefit (other than the benefits derived from COTS outbreak prevention and suppression)	Low co-benefits i.e., • Limited potential for participation in or integration to CCIP or COTS management activities • Limited co-benefits accruing from COTS management activities			Moderate co-benefit i.e., • Moderate potential for participation in or integration to CCIP or COTS management activities • Moderate co-benefits accruing from COTS management activities			Significant co-benefit i.e., • Significant and clear opportunities for participation in or integration to CCIP or COTS management activities • Significant co-benefit accruing from COTS management activities			Highly significant co-benefit i.e., • Highly significant and obvious opportunities for participation in or integration to CCIP or COTS management activities • Highly significant co-benefit accruing from COTS management activities

Portfolio Assessment: Evaluation Criteria
6. Risk: Uncertainty in Delivering Impact on Coral

EC Question:
To what extent is there certainty in realising the desired outcomes of R&D?

Key Success Measures:
In considering the performance of a Portfolio against this Evaluation criteria, consider the extent to which the portfolio is not subject to uncertainty in terms of its ability to deliver impact on coral at scale, meaning that:
- Success outcomes from R&D are clear
- There are no material uncertainties that impact success of R&D
- There are no material uncertainties that impact the translation of R&D to outcomes
- There are no material regulatory hurdles that impact conducting and / or implementing R&D

0	1	2	3	4	5	6	7	8	9	10
Significant level of uncertainty in realising desired outcomes from R&D i.e., • there are highly significant uncertainties that impact the success of R&D • there are highly significant uncertainties that impact the translation of R&D to outcomes • there are highly significant regulatory hurdles that impact conducting and / or implementing R&D	High level of uncertainty in realising desired outcomes from R&D i.e., - there are some significant uncertainties that impact success of R&D - there are some significant uncertainties that impact the translation of R&D to outcomes - there are some significant regulatory hurdles that impact conducting and / or implementing R&D			Moderate level of uncertainty in realising desired outcomes from R&D i.e., - there are some moderately significant uncertainties that impact success of R&D - there are some moderately significant uncertainties that impact the translation of R&D to outcomes - there are some moderately significant regulatory hurdles that impact conducting and / or implementing R&D			Low level of uncertainty in realising desired outcomes from R&D i.e., - there are some minor uncertainties that impact success of R&D - there are some minor uncertainties that impact the translation of R&D to outcomes - there are some minor regulatory hurdles that impact conducting and / or implementing R&D			Realising desired outcomes from R&D is certain i.e., - there are no material uncertainties that impact success of R&D - there are no material uncertainties that impact the translation of R&D to outcomes - there are no material regulatory hurdles that impact conducting and / or implementing R&D



Australian Government | Reef Trust | Great Barrier Reef Foundation | Australian Government | Australian Institute of Marine Science | CSIRO | James Cook University Australia | The University Of Queensland Australia

Appendix G - Portfolio Assessment Survey

CCIP Portfolio Assessment

1. Introduction

Welcome to the Portfolio Assessment process for the COTS Control Innovation Program (CCIP).

This survey will:
1) collect your assessment of the relative performance of 7 portfolios of cross-program R&D opportunities that were developed by CCIP Program Areas against a range of 6 Evaluation Criteria, and
2) collect your assessment of the relative importance of each of the 6 Evaluation Criteria compared with one another.

The survey should be completed alongside the following resources sent via email on 17 March 2021:
1) the CCIP Portfolio Assessment Instructions
2) the CCIP Portfolio Descriptions
3) the CCIP Evaluation Criteria Summary
4) the CCIP Opportunity Summaries

You should have received these materials attached to the above mentioned companion email sent on 17 March 2021, which would have arrived around the same time as the email inviting you to complete this survey. If you have not yet received this email, please contact mayuran.sivapalan@adaptus.com.au.

We strongly recommend that you read through the CCIP Portfolio Assessment Instructions and the accompanying documents prior to beginning the assessment process, and that you have copies of the above documents printed out or readily accessible as you assess each Portfolio and Evaluation Criteria.

Further detailed information attached to the above mentioned companion email should be reviewed prior to commencing the survey, and be available for reference and to be used as required:
5) the CCIP Opportunity Assessment Results Summary
6) the CCIP Opportunity Reports
7) the CCIP Program Area Summaries

The survey will automatically save your responses as you progress. You should be able to leave the survey page, return via the link contained in your invitation email, and pick up where you left off. Testing suggested that *if pre-reading had already been completed,* the Portfolio Assessment is likely to take approximately 30 minutes to complete, while the assessment of Evaluation Criteria is likely to take approximately 15 minutes.

The survey will be kept open until 11:59pm Tuesday 23 March 2021 (AEST).

CCIP Portfolio Assessment

2. Respondent Details

* Please enter your name. Individual responses to survey questions will be kept strictly confidential.

Name

CCIP Portfolio Assessment

3. Part 1: Portfolio Assessment against Evaluation Criteria

This section of the survey requires you to assess how each portfolio performs when assessed against each evaluation criteria.

Each page of the survey has an answer matrix which addresses one portfolio.

Each row is an evaluation criteria and the columns represent potential scores from 0 to 10.

Detailed descriptions of the meaning of these evaluation criteria and their associated value scales can be found in the briefing documents provided, and should be referred to when completing this assessment.

Please evaluate each portfolio against each evaluation criteria.

All progress will be saved whenever you change page so you can close the browser and reopen it without losing your responses. You can return to previous pages at any time to change your responses.

CCIP Portfolio Assessment

4. Portfolio One: Emphasis on Managing the Current Outbreak (Short-Term)

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely values of each criteria for this Portfolio.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have requisite expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 1: Managing the Current Outbreak

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

5. Portfolio Two: Emphasis on Suppressing the 2025 Outbreak (Medium-Term)

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 2: Suppressing the 2025 Outbreak

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

6. Portfolio Three: Emphasis on Preventing Future Primary Outbreaks (Long-Term)

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 3: Preventing Future Primary Outbreaks

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

7. Portfolio Four: Emphasis on Improving System Understanding

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 4: Improving System Understanding

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

8. Portfolio Five: Emphasis on Creating New Control Approaches

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 5: Creating New Control Approaches

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

9. Portfolio Six: Emphasis on Informing Strategy

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 6: Informing Strategy

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

10. Portfolio Seven: Emphasis on Synergies within CCIP & across GBR Programs

Please assess the Portfolio against each Evaluation Criteria, by selecting the contiguous range of checkboxes that you feel encompasses the most likely characteristic of this Portfolio for each criteria.

If you are certain of the Criteria, you can select just one checkbox. If you are uncertain, you can select a range. If you feel that a Criteria does not apply to the Portfolio in question, please select "Not Applicable". If you feel that you do not have the expertise to provide any comment, please select "No Idea".

Please consider each Evaluation Criteria independently.

* 6: Synergies within CCIP and across GBR Programs

	0	1	2	3	4	5	6	7	8	9	10	Not Applicable	No Idea
Extent of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Directness of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Immediacy of Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Potential for Step-Change in COTS Control & Surveillance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Co-Benefits: Traditional Owner & Community	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Risks: Uncertainty in Delivering Impact on Coral	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Additional Comments (optional).
Please comment on key characteristics of the Portfolio and / or constituent Opportunities that stood out to you and influenced your assessment.

CCIP Portfolio Assessment

11. Part 2: Pairwise Assessment of Evaluation Criteria

This section of the survey will require you to make judgements of the relative importance of each evaluation criteria. This will be completed by means of a pairwise comparison.

For each square of the matrices, please rate the relative importance of the evaluation criteria in the row compared to the value driver in the column.

For example, on the page entitled 'Extent of Impact on Coral', for the the row labelled 'Directness of Impact on Coral', you are being asked how much more important is 'Directness of Impact on Coral' compared to 'Extent of Impact on Coral'.

A score of 1 means you believe they are equally important. A score of 9 means you believe 'Directness of Impact on Coral' is significantly more important than 'Extent of Impact of Coral'. A score of 1/9 means you believe 'Directness of Impact on Coral' is significantly less important than 'Extent of Impact on Coral'.

Please refer to the CCIP Portfolio Assessment Instructions document for further clarification.

All process will be saved whenever you change page so you can close the browser and reopen it without losing your responses. You can return to previous pages at any time to change responses.

CCIP Portfolio Assessment

12. Evaluation Criteria 1: Extent of Impact of Coral

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Extent of Impact on Coral'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Extent of Impact on Coral
Directness of Impact on Coral	
Immediacy of Impact on Coral	
Potential for Step-Change in COTS Control & Surveillance	
Co-Benefits: Traditional Owner & Community	
Risk: Uncertainty in Delivering Impact on Coral	

CCIP Portfolio Assessment

13. Evaluation Criteria 2: Directness of Impact of Coral

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Directness of Impact on Coral'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Directness of Impact on Coral
Extent of Impact on Coral	
Immediacy of Impact on Coral	
Potential for Step-Change in COTS Control & Surveillance	
Co-Benefits: Traditional Owner & Community	
Risk: Uncertainty in Delivering Impact on Coral	

14. Evaluation Criteria 3: Immediacy of Impact of Coral

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Immediacy of Impact on Coral'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Immediacy of Impact on Coral
Extent of Impact on Coral	
Directness of Impact on Coral	
Potential for Step-Change in COTS Control & Surveillance	
Co-Benefits: Traditional Owner & Community	
Risk: Uncertainty in Delivering Impact on Coral	

CCIP Portfolio Assessment

15. Evaluation Criteria 4: Potential for Step-Change in COTS Control & Surveillance

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Potential for Step-Change in COTS Control & Surveillance'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Potential for Step-Change in COTS Control & Surveillance
Extent of Impact on Coral	
Directness of Impact on Coral	
Immediacy of Impact on Coral	
Co-Benefits: Traditional Owner & Community	
Risk: Uncertainty in Delivering Impact on Coral	

CCIP Portfolio Assessment

16. Evaluation Criteria 5: Co-Benefits: Traditional Owner & Community

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Co-Benefits: Traditional Owner & Community'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Co-Benefits: Traditional Owner & Community
Extent of Impact on Coral	
Directness of Impact on Coral	
Immediacy of Impact on Coral	
Potential for Step-Change in COTS Control & Surveillance	
Risk: Uncertainty in Delivering Impact on Coral	

17. Evaluation Criteria 6: Risk: Uncertainty in Delivering Impact on Coral

For each row of the matrix below, please select a value which reflects how much more important that evaluation criteria is than 'Risk: Uncertainty in Delivering Impact on Coral'.

Scoring Guide:
9 = Extremely More Important
7 = Very Strongly More Important
5 = Strongly More Important
3 = Moderately More Important
1 = Equally Important
1/3 = Moderately Less Important
1/5 = Strongly Less Important
1/7 = Very Strongly Less Important
1/9 = Extremely Less Important

* Please complete the pairwise comparison matrix:

	Risk: Uncertainty in Delivering Impact on Coral
Extent of Impact on Coral	
Directness of Impact on Coral	
Immediacy of Impact on Coral	
Potential for Step-Change in COTS Control & Surveillance	
Co-Benefits: Traditional Owner & Community	

CCIP Portfolio Assessment

18. Summary

Thank you for completing the CCIP Portfolio Assessment process.

You can click back into the survey to review or amend your answers by pressing the Prev button. Soon after clicking the Done button, you should receive an email containing a link to a webpage summarising your responses, which you may copy and paste as a record if desired. You can log back into this survey and amend your responses until it closes at 11:59PM AEST on Tuesday 23 March 2021 by pressing the "Begin Survey" button in the invitation email you originally received.

Your responses will be compiled along with others and will form the basis of discussions during the upcoming Portfolio Prioritisation Workshop on 31 March 2021. The outcomes of that Workshop will inform opportunity selection and finalisation activities for CCIP.

You may click the Done button to complete the survey.

Appendix H – Portfolio Assessment Results

Great Barrier
Reef Foundation

CCIP Design Phase

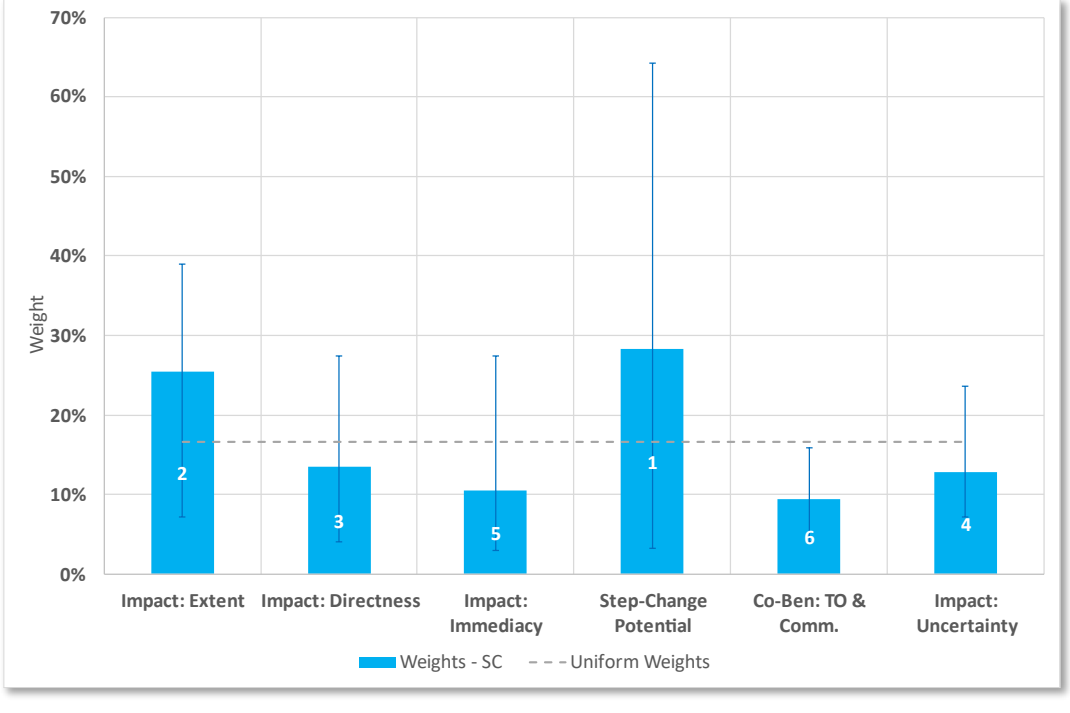
Portfolio Assessment Results

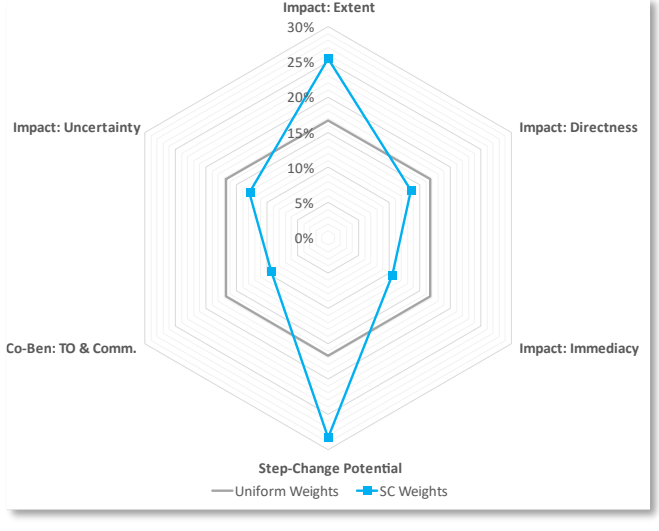
31 March 2021

Australian Government | Reef Trust | Great Barrier Reef Foundation | Australian Government | Australian Institute of Marine Science | CSIRO | James Cook University Australia | The University of Queensland Australia

Evaluation Criteria: Pairwise Assessment Results

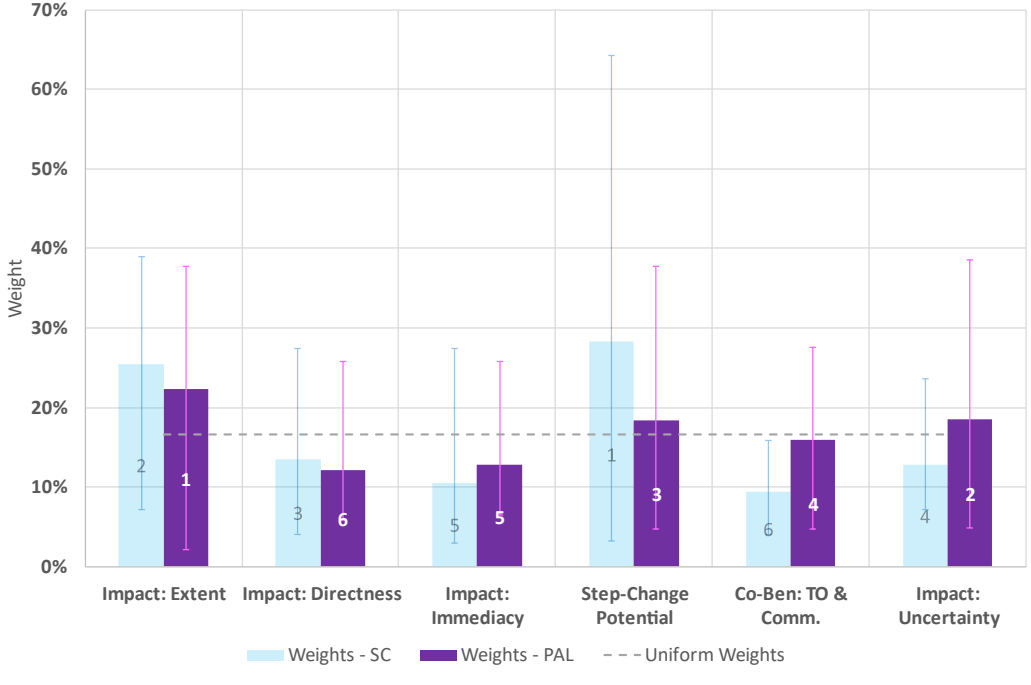
Steering Committee Only

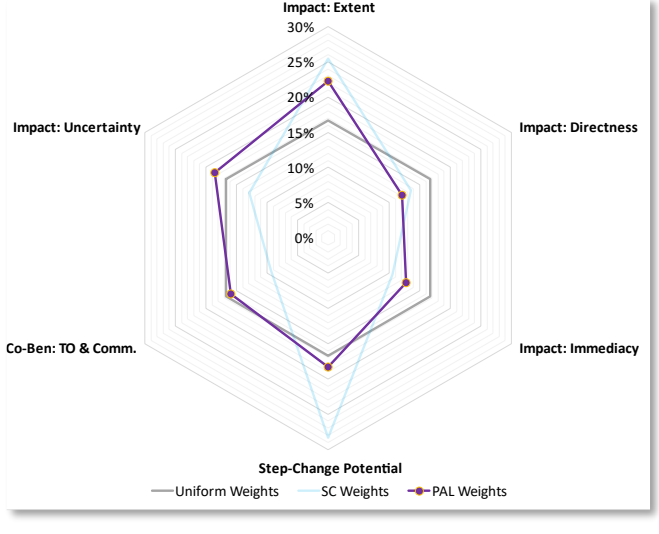




Evaluation Criteria: Pairwise Assessment Results

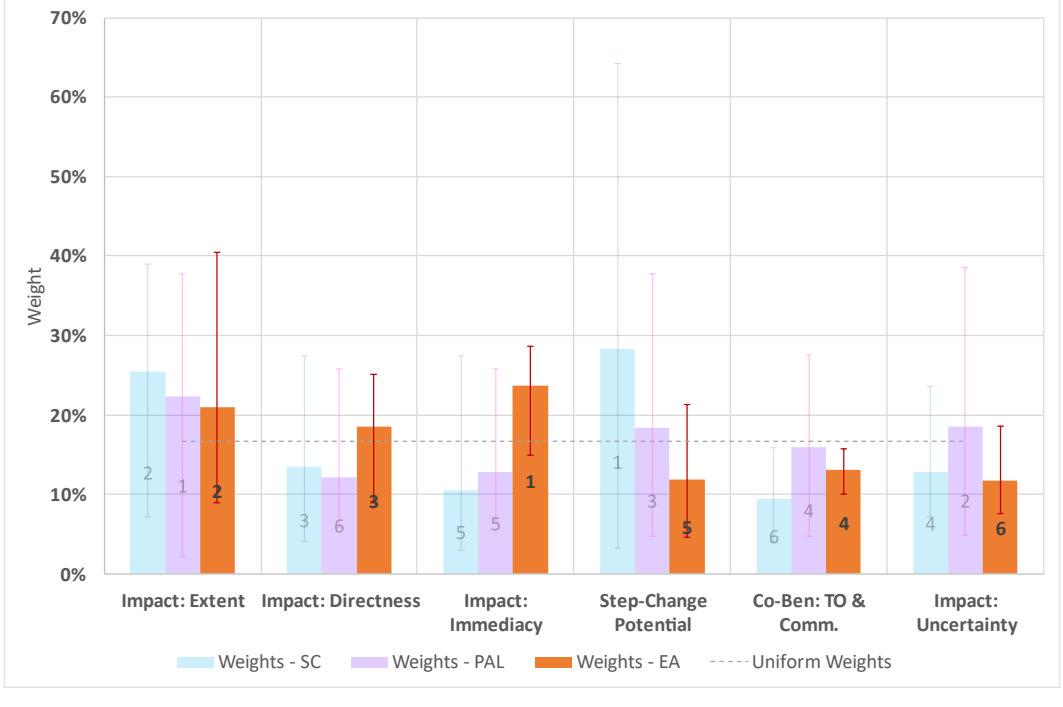
Steering Committee & Program Area Leads

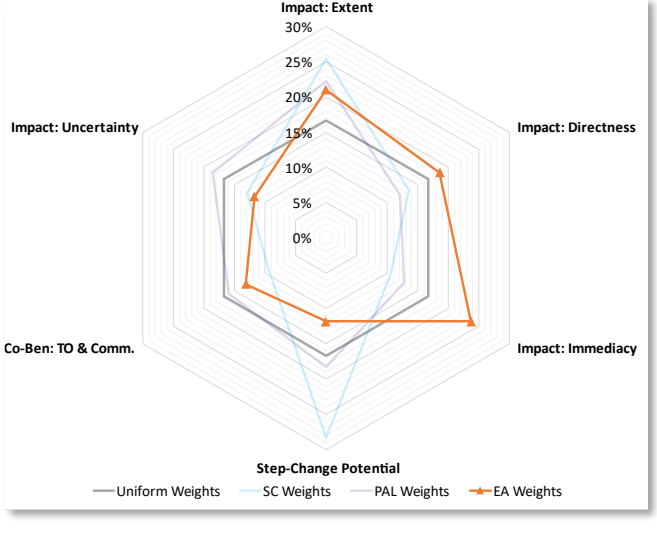




Evaluation Criteria: Pairwise Assessment Results

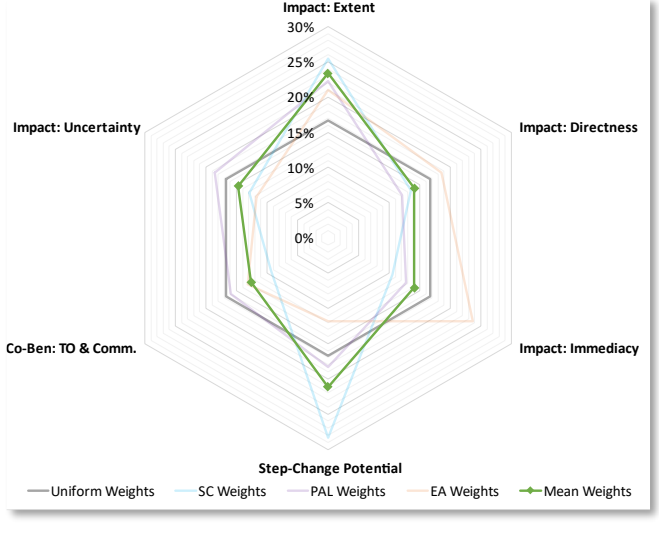
Steering Committee & Program Area Leads





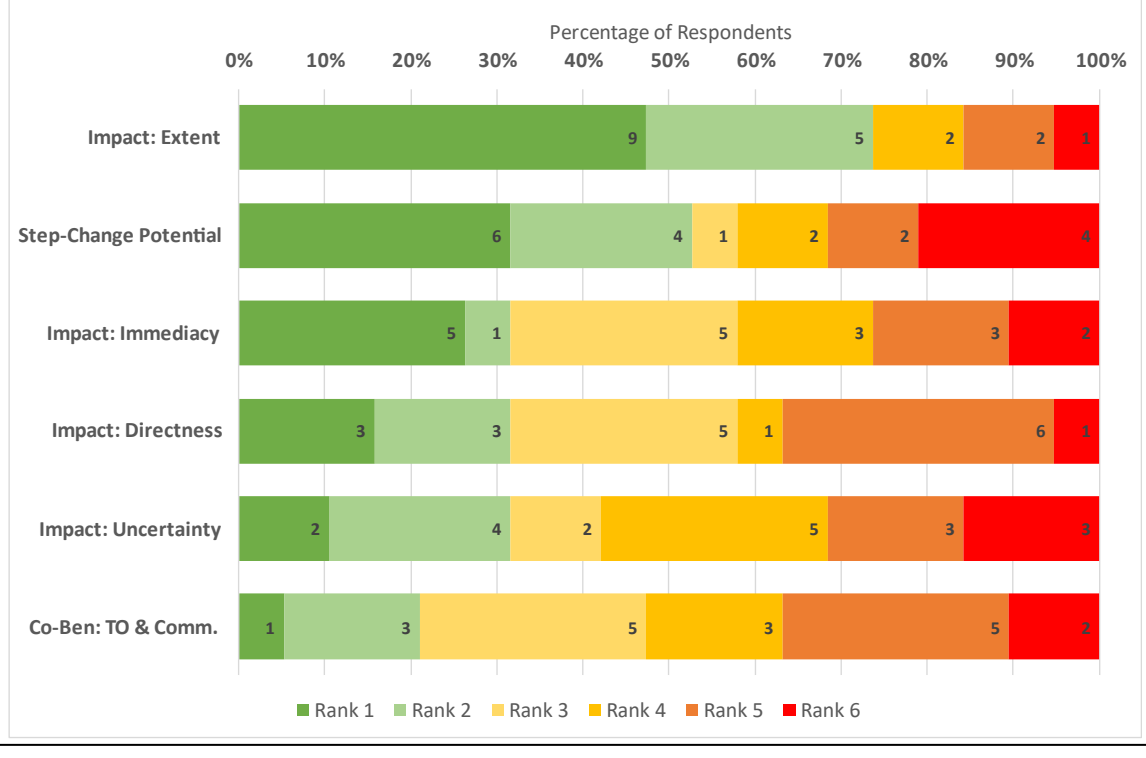
Evaluation Criteria: Pairwise Assessment Results

All Respondents - Summary



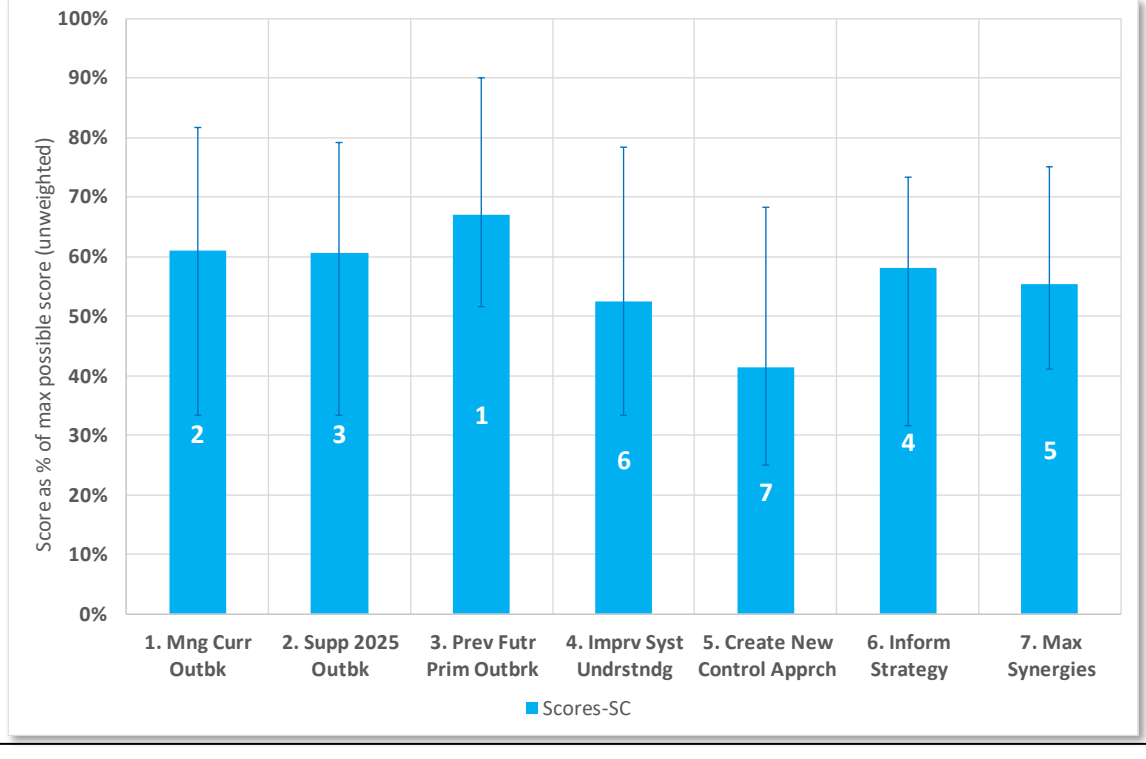
Evaluation Criteria: Pairwise Assessment Results

All Respondents - Summary



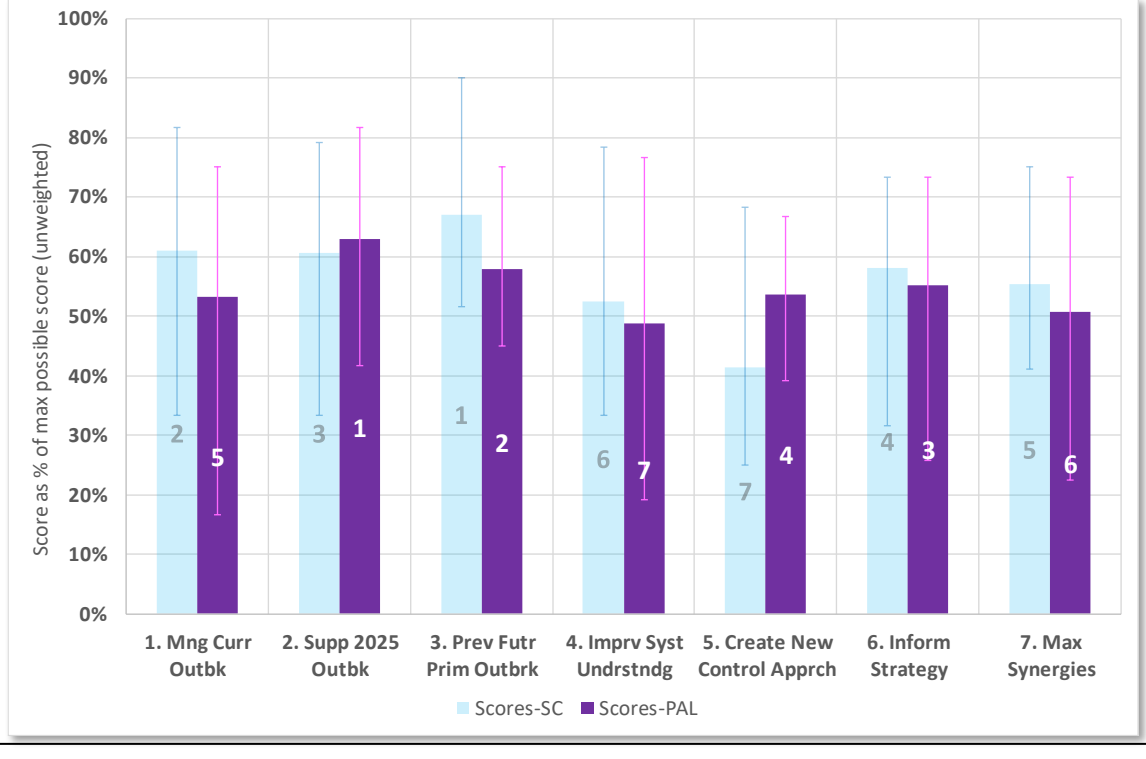
Portfolio Assessment Results (unweighted)

Steering Committee Only



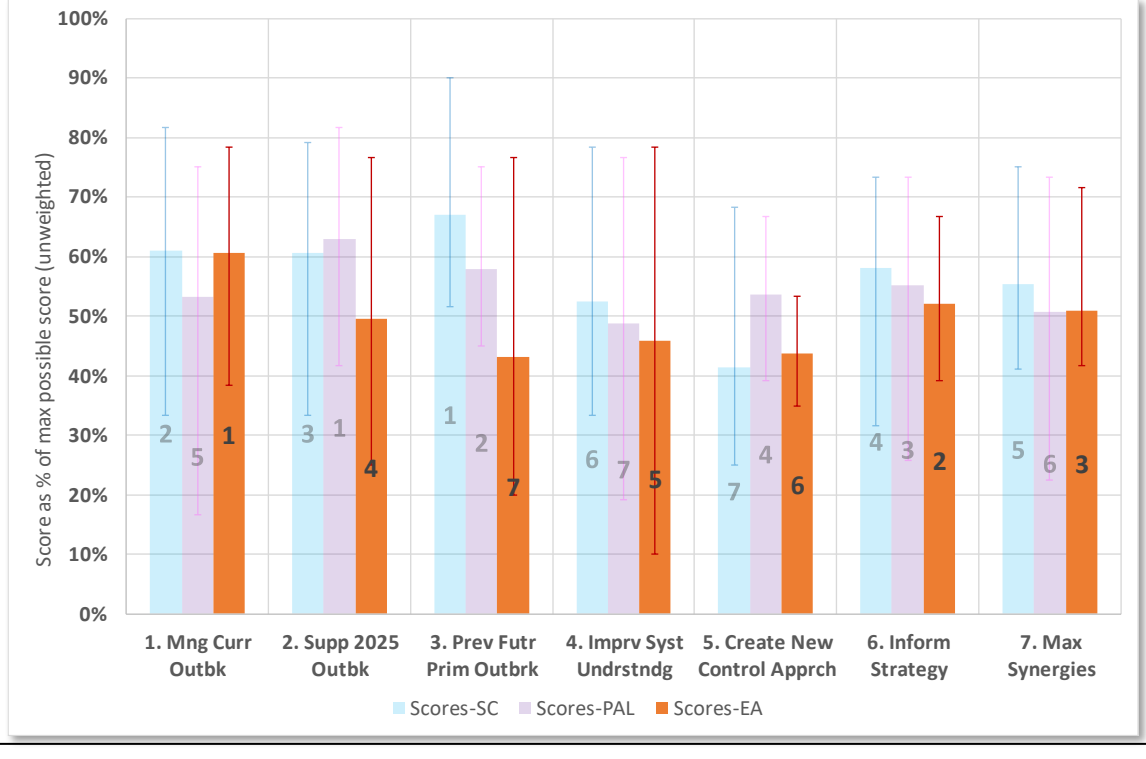
Portfolio Assessment Results (unweighted)

Steering Committee & Program Area Leads



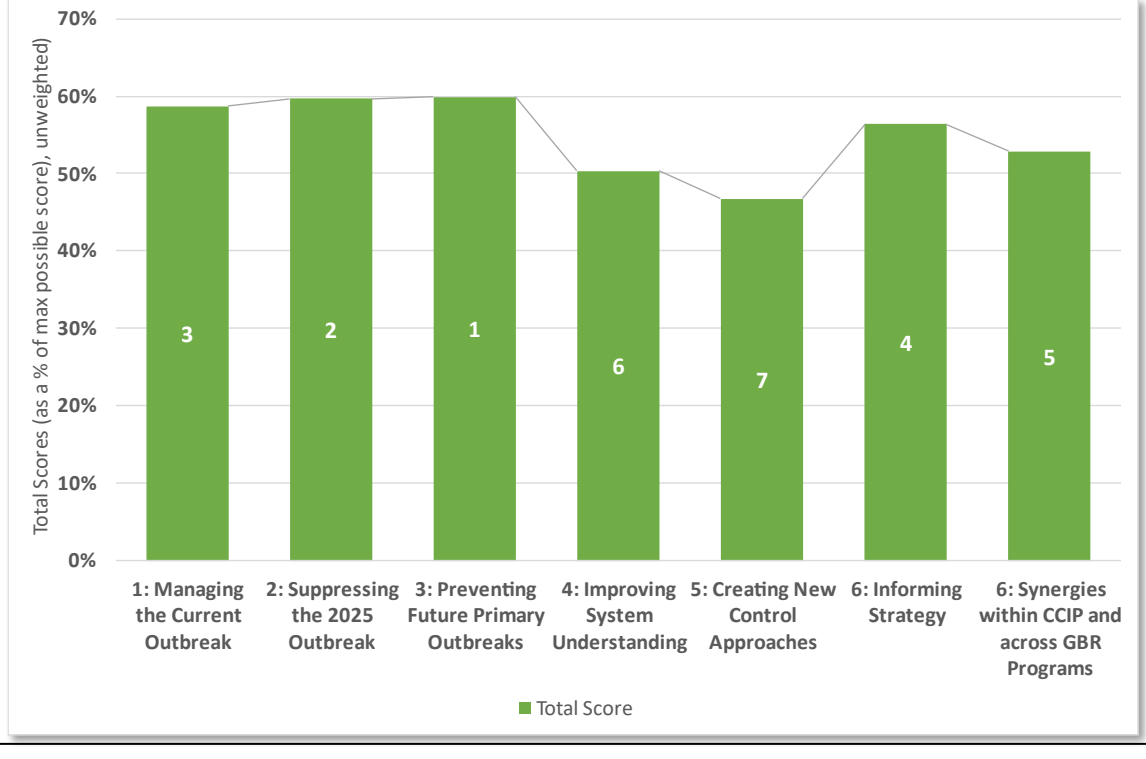
Portfolio Assessment Results (unweighted)

All Respondents



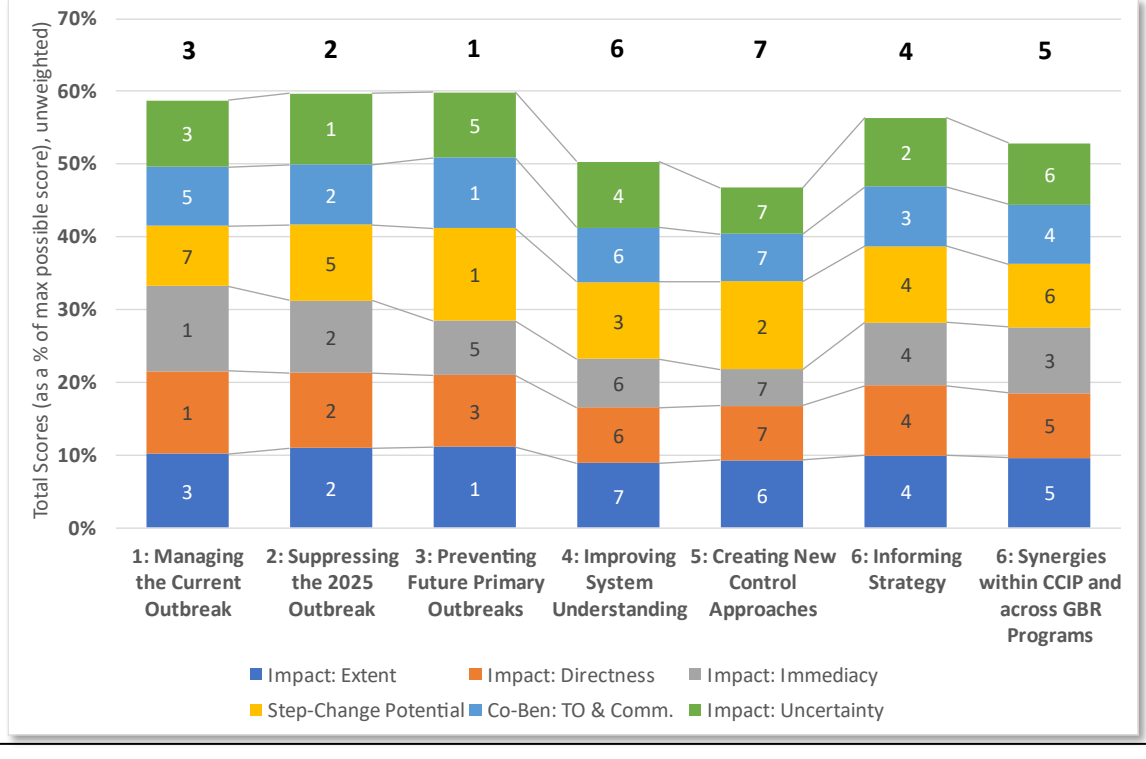
Portfolio Assessment Results (unweighted)

All Respondents



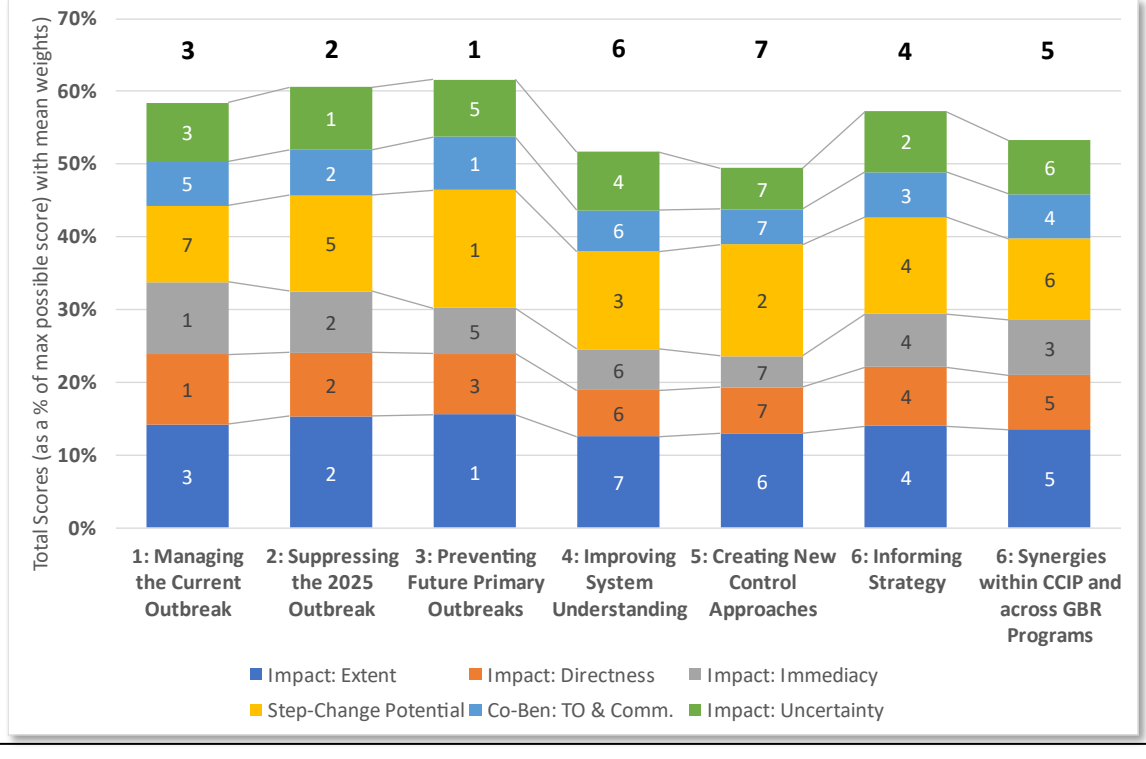
Portfolio Assessment Results (unweighted)

All Respondents



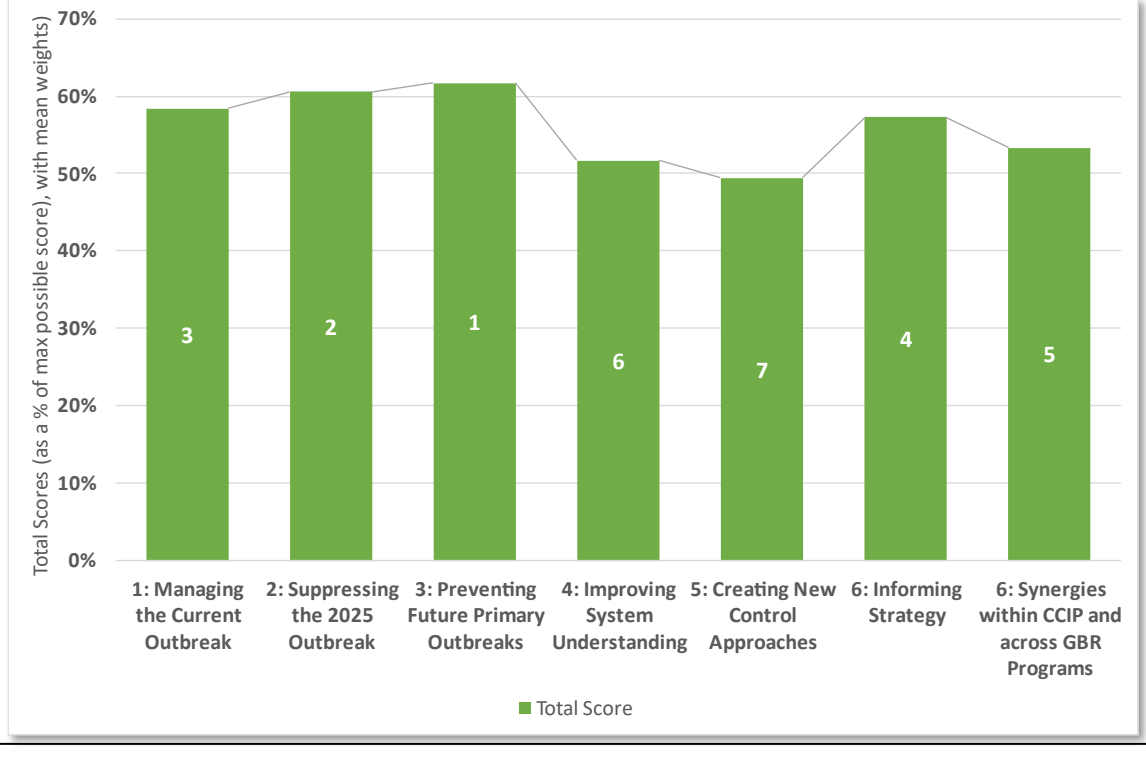
Portfolio Assessment Results (weighted)

All Respondents



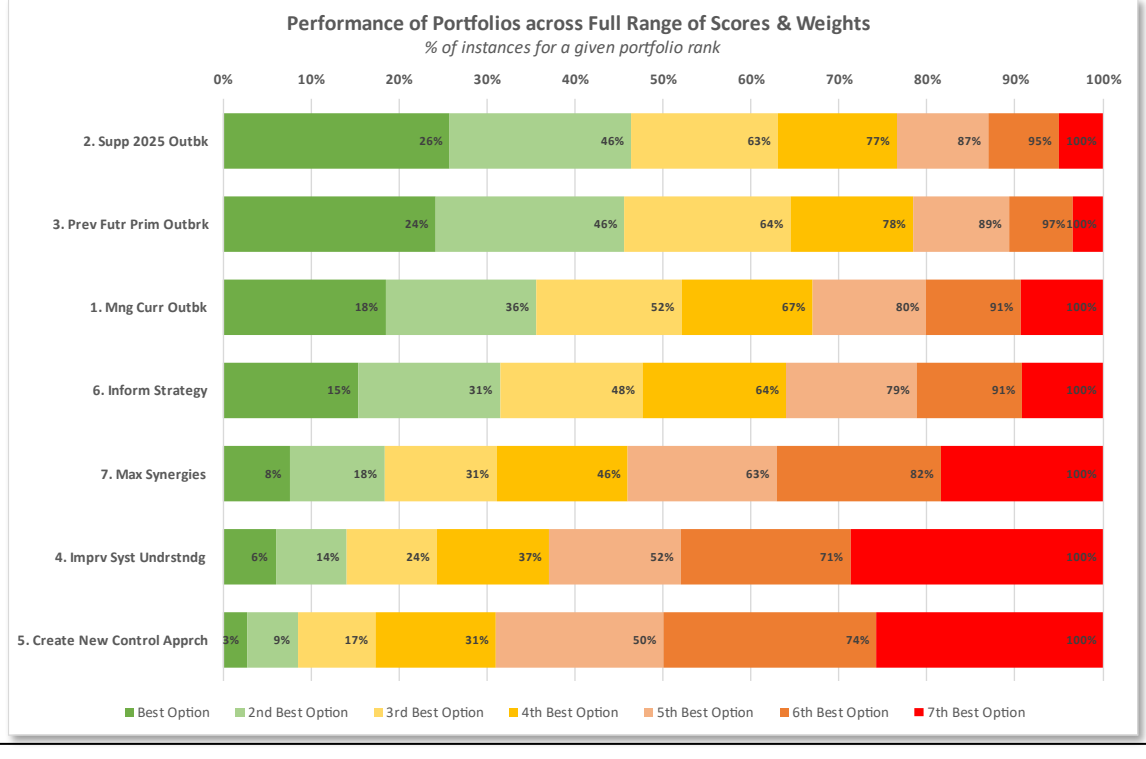
Portfolio Assessment Results (weighted)

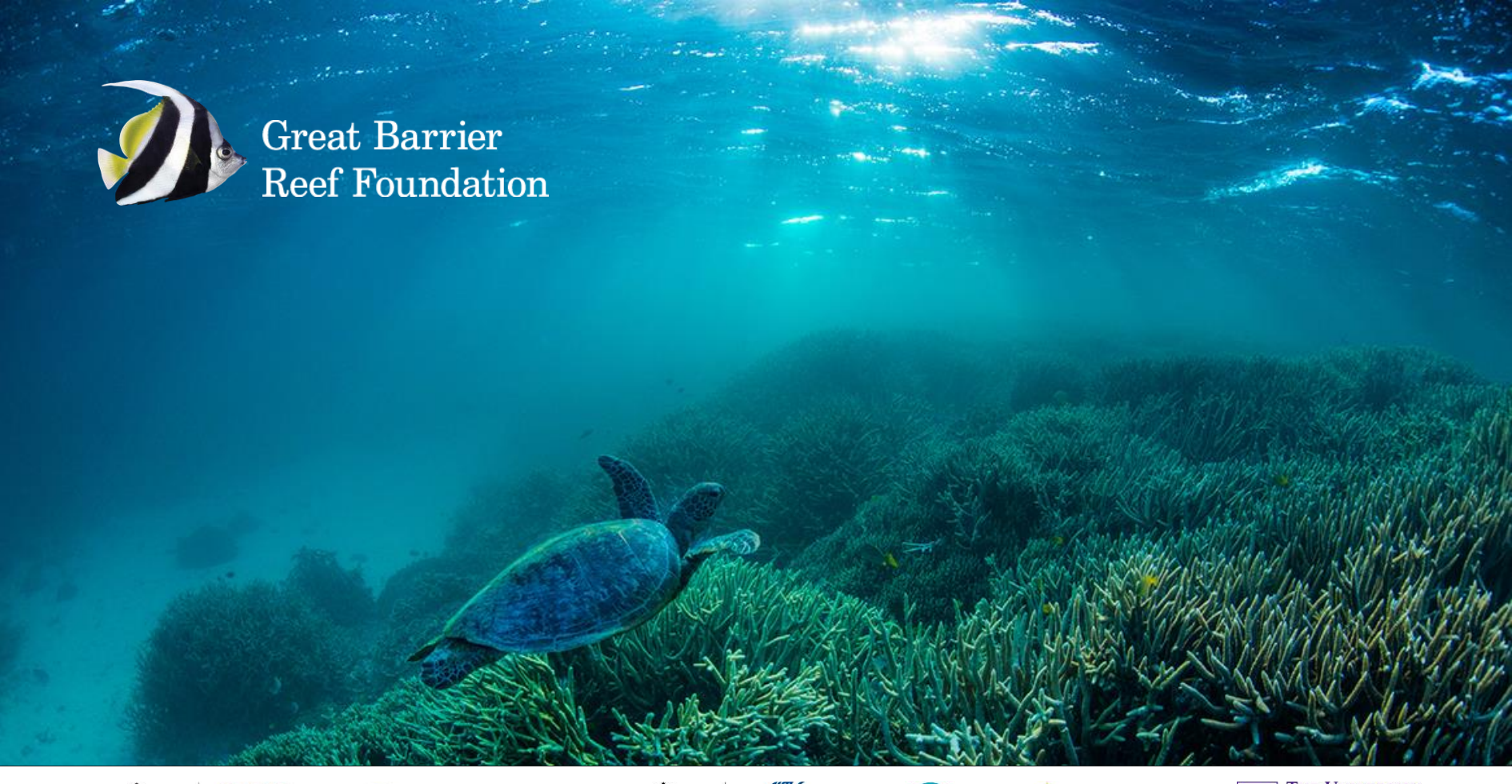
All Respondents



Portfolio Assessment Results (MonteCarlo Analysis)

All Respondents





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