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FINAL REPORT

Project 1.6

A Roadmap for Coordinated Landscape-scale Coastal and Marine Ecosystem Restoration

Megan I. Saunders, Nathan J. Waltham, Toni Cannard, Marian Sheppard, Mibu Fischer, Alice Twomey, Melanie Bishop, Kris Boody, David Callaghan, Beth Fulton, Catherine E. Lovelock, Mariana Mayer Pinto, Ian M. McLeod, Taryn McPherson, Rebecca Morris, Andrew Pomeroy, Mike Ronan, Stephen Swearer, Andy Steven

A roadmap for coordinated landscape-scale coastal and marine ecosystem restoration

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Acronyms

ACRN............ Australian Coastal Restoration Network
AODN .... Australian Ocean Data Network
CITES .... Convention on International Trade in Endangered Species
CNP .... Coral Nurture Program
DELWP .... Vic Department of Environment, Land, Water and Planning
DAWE………. Department of Agriculture, Water and the Environment
DES............... QLD Department of Environment and Science
DOE .... Department of the Environment
DPI................ NSW Department of Primary Industries
DST............... Decision-support Tools
ERF............... Emission Reduction Fund
GBR.............. Great Barrier Reef
GBRF............ Great Barrier Reef Fund
GBRMPA ...... Great Barrier Reef Marine Park Authority
IUCN .... International Union for Conservation of Nature
MaC .... Marine and Coastal Hub
NbS…………. Nature-based Solutions
NESP .... National Environmental Science Program
NGO.............. Non-government organisations
NRM.............. Natural Resource Management
PRISMA .... Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RRRC............ Reef and Rainforest Research Centre Limited
SDM.............. Structured decision-making
SER............... Society for Ecological Restoration
SLR............... Sea-level rise
TCFD .... Taskforce on Climate-related Financial Disclosure
TNC............... The Nature Conservatory
TNFD .... Taskforce on Nature-related Financial Disclosure
UNDRIP .... United Nations Declaration on the Rights of Indigenous People
UWA .... University of Western Australia

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Key Points

- Large scale and coordinated restoration of coastal and marine ecosystems will benefit our natural assets and improve our capability to mitigate and adapt to climate change, while also generating jobs and providing communities with economic and social benefits.
- Scaling up restoration requires a national scale science-based plan adopted at state/territory and local levels, and a new economic model which is blended between government funding as well as investment pipelines from the private sector and philanthropy.
- Coastal and marine restoration projects co-designed with diverse stakeholders (e.g., research, practitioner, community, Aboriginal and Torres Strait Islander Organisations) provide greater value than those designed by single groups; In particular, Traditional Custodians are rights holders and there is a need to work towards improved models of culturally appropriate and meaningful engagement.

Executive Summary

Thriving coastal and marine ecosystems in Australia underpin a healthy economy by supporting fisheries, tourism, and recreation. They provide important ecological functions and services such as processing nutrients and sediments from run-off, protecting shorelines from inundation and erosion, and removing carbon dioxide from the atmosphere. With 80% of Australians living within 100km from the coast, coastal and marine ecosystems form a central feature of our national identity. Intact and functioning coastal and marine ecosystems form one of the most fundamental assets in our portfolio of *Nature-based Solutions* (NbS) to help mitigate and adapt to climate change.

Widespread losses of coastal and marine ecosystems, such as coral reefs, mangroves, saltmarshes, seagrasses, oyster reefs and kelp beds have occurred globally. In Australia, degradation commenced 200 years ago with, for example, harvesting and poor water quality eventually causing destruction of 92% of Sydney rock oyster reefs and the extinction of South Australian oyster reefs. Despite considerable investment into marine protection and other management activities, coastal and marine ecosystems continue to struggle, and this challenge is escalating due to climate change. These impacts are already emerging, with 45% of coastal and marine ecosystems nationally already affected by symptoms of climate change. For example, 95% of Tasmanian giant kelp forests have disappeared due to shifting environmental conditions intersecting with overharvesting of predators of the sea urchins which graze kelp. The recent IPCC report elevated ecological restoration as one of the most important activities we can take to mitigate and adapt to climate change – but we need to keep warming below 1.5 C for these strategies to be effective.

In addition to ongoing efforts to halt the degradation and decline of ecosystems, ecological restoration at large scales is required to recover damage to coastal and marine ecosystems nationally. Momentum is building within the Australian and international communities to support the implementation of restoration and NbS in coastal environments. However, several complex and interdependent challenges spanning environmental, technical, social, economic, and political realms have precluded the widespread implementation and scaling up of ecological restoration in coastal and marine ecosystems globally, including Australia. Consequently, projects have typically been small scale, expensive, and subject to variable rates of success. These challenges, among others, are known to some degree by anyone working in the coastal restoration and NbS space. What is <u>unknown</u> at present is how to address these challenges in a coordinated and meaningful way at a national scale. This project is designed to scope out multiple perspectives and to form the basis of a conversation around how to resolve these issues nationally.

The project consisted of five aims: 1) Engage with end-user groups, including researchers, practitioners and decision makers, to understand the current state, limitations, opportunities, and research needs for scaling up coastal restoration in Australia. This was conducted using a national-scale survey **[Chapter 4**] and focused workshops [**Chapter 6]**. 2) Conduct a targeted approach to Indigenous Engagement to understand the experiences and needs of Traditional Custodians[1] [**Chapter 5**]; 3) Describe case studies of coastal and marine ecological restoration in Australia,

[1] We use the term Traditional Custodian when referring to Aboriginal and Torres Strait Islander Peoples in relation to our engagement activities and survey, which for this report encompasses those who identify with the term Traditional Owner. The term Indigenous is used in the report when referring to activities or management structures that are known as Indigenous i.e., Indigenous Land & Sea Rangers, Indigenous Protected Areas. Elsewhere we will use Aboriginal and Torres Strait Islander peoples or communities.

including information on how barriers were overcome [**Chapter 7**]. 4) Explore data and models that are available across multiple spatial scales in the discipline of coastal engineering that are used to estimate the flood and erosion benefits of coastal and marine ecosystems and which could be used to inform decision science frameworks for NbS to coastal hazards [**Chapter 8**]. 5) Synthesize the findings into a strategic *Roadmap* which outlines the steps required to move from the current state of typically small, uncoordinated and often underfunded efforts to large scale and coordinated ecological restoration in coastal and marine systems [**Chapter 9**].

This report adopted the definition of restoration from the Society of Ecological Restoration - *the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*. It adopts the definition of NbS from the IUCN - *actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits* and focusses on the service of coastal protection to flooding and erosion. In this report the terms NbS and restoration intersect but are not identical – restoration can be conducted for many reasons other than coastal resilience, and NbS includes the activity of restoration but also other approaches such as new habitat creation, or beach nourishment, which employs nature and achieves co-benefits but is not necessarily intended to achieve ecological recovery. The project scope included ecological restoration of the dominant coastal and marine ecosystems in Australia (coral reefs, oyster reefs, kelp forests, mangrove forests, saltmarshes, seagrass meadows, beaches, and dunes).

Our research identified important barriers to scaling up restoration in alignment with previous work. There is a complex regulatory space with an often financially prohibitive permitting process. There is legislative complexity to navigate; for instance, within the Australian Government there are a number of different sections whose interest encompass coastal and marine ecosystems and restoration, however, there is no clear structure to coordinate these intersecting components in the context of restoration and NbS. Such challenges are present among local and state governments as well. There is no consistent approach to mapping and classifying coastal and marine ecosystems and data are inconsistent and not easily located. Engagement processes with Traditional Custodians are not well defined, resourced or executed in many instances. There is no systematic or consistent reporting of restoration activities and outcomes and with the exception of a few groups, very little emphasis on communicating social, economic and cultural outcomes of restoration, impeding knowledge sharing and learning. As for most social-environmental issues, there is insufficient funding to restore many degraded systems, or to attend to maintenance and monitoring, and there is not a clearly defined and agreed framework for the prioritisation of restoration efforts. Restoration is influenced by many actors across a diverse spectrum of organisations, ranging from local communities, State, local and Australian Governments to research organisations, whose priorities and approaches don't necessarily align. Coastal and marine restoration activities now occur within the context of the increasing spectre of climate change.

To begin to overcome these challenges, we drafted a *Roadmap* - a strategic document that defines a desired outcome with major steps required to reach it. To do so, information that was obtained in the project activities were collated and distilled into key headline topics that built a narrative around the current state, desired future, recent relevant NESP research, research gaps and key actions. This document includes 10 headline topics that are central, necessary and summarise the views of the broad responses received during this project (Figure 1). The Roadmap headlines are:

- Co-design is central
- Fit-for-purpose governance
- No-gap funding

- Access to social, economic and biophysical data
- Evidence-based and transparent decision making
- Restoration is coordinated and at scale
- Robust monitoring, maintenance, valuation and reporting
- Clear strategy to adapt to climate change
- Nature-based solutions are implemented
- Knowledge is shared effectively

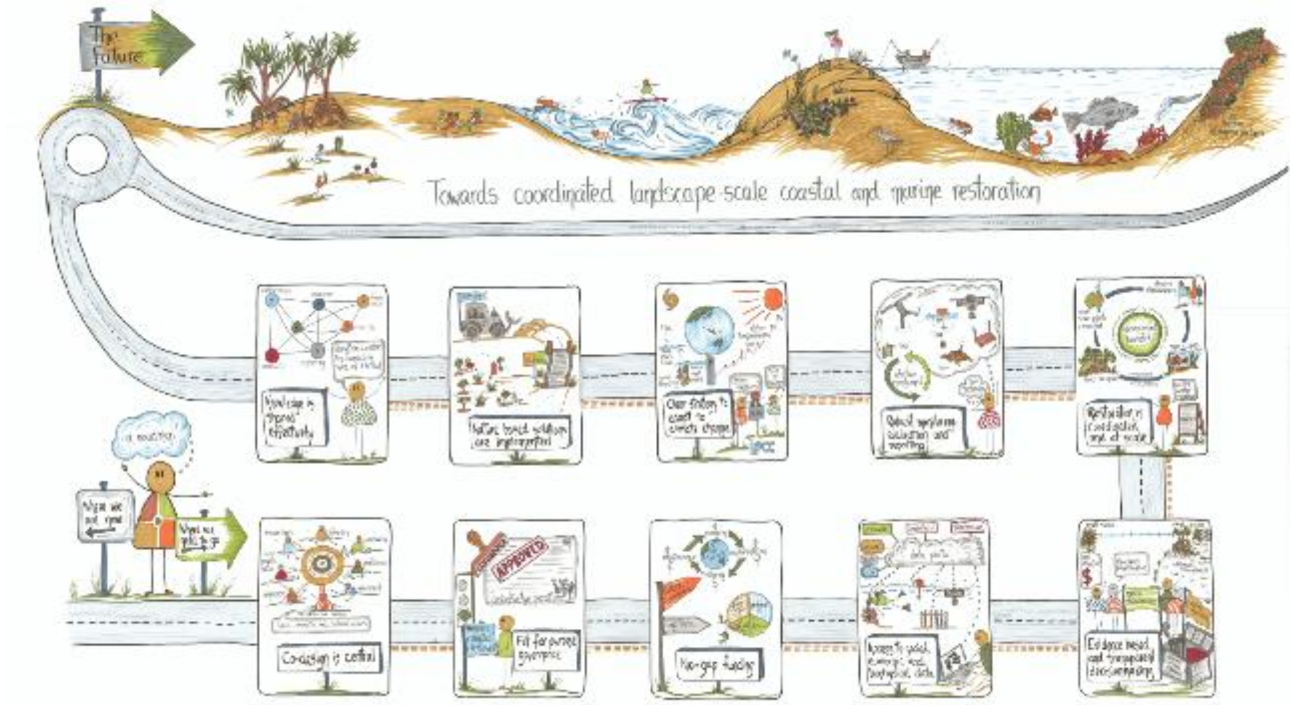


Figure 1: Ten guiding principles towards a roadmap for coordinated landscape scale coastal and marine restoration

The report identifies a number of key actions and research gaps which need to be addressed to scale up restoration and NbS in Australia. Some of these include:

- Develop fit-for-purpose permitting processes for ecological restoration.
- Support integrated mapping and classification of coastal and marine ecosystems.
- Conduct research into the effectiveness and risks of using restoration as Nature-based Solution to coastal hazards.
- Develop a prototype Natural Capital Investment tool which can demonstrate the costs, benefits and viability of integrating Nature-based Solutions in coastal and marine infrastructure.
- Develop guidelines for restoration at national scale which are intended to cascade across state and local levels. In particular, guidelines are required to support decision making with respect to climate change – despite climate uncertainty, managers need to design for and implement restoration projects that can adapt to future climate.
- Develop a process to develop decision-support models to help inform which actions to take and under what circumstances. These will need to communicate uncertainty, risks, trade-offs, and evidence of different outcomes. These models will need to be underpinned by biophysical systems models which are then used to support prioritisation.

- At national or state scale, adapt and implement the Restoration Opportunities Assessment Methodology (ROAM) to commence a systematic approach to prioritisation of restoration.

One of the key learnings was the identification of a large gap between the experiences and perspectives of researchers, practitioners and decision makers compared to Traditional Custodians with respect to Indigenous Engagement, and a need to reconcile this gap moving forward. This is an area which will require further work, however our initial recommendations for researchers and practitioners are:

- Become familiar with Aboriginal and Torres Strait Islander research protocols, using resources such as Our Knowledge, Our Way; Australian Institute of Aboriginal and Torres Strait Islander Studies (*AIATSIS*) Research Protocols and similar documents.
- Shift thinking away from engagement and towards relationship building and genuine partnerships. Aim for continued engagement.
- Do not go into a community with a completely formed idea, but rather with the mindset of seeking to gain knowledge and understanding of the needs and perspectives of the community.
- Be patient, this process is slow.
- Budget adequately – both for personnel within the project to develop the engagement, and for Aboriginal and Torres Strait Islander people's involvement through remuneration for time, knowledge, and access.

The findings of the report, which are synthesised in Chapter 9 as a *Roadmap*, are intended to form the basis of a conversation around transformational change in the implementation of coastal and marine restoration and NbS in Australia. Doing so will ultimately enable Australia to help meet national and international commitments which implicitly or explicitly include coastal and marine restoration, such as the Sustainable Development Goals, the Convention on Biological Diversity Aichi Targets, the Paris Agreement, The United Nations Decade on Ecosystem Restoration, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, and the Ramsar Convention. Following through on the Roadmap has the potential to elevate the state, condition and function of Australia's coastal and marine assets, to substantively increase Australia's capacity to adapt to climate change, and to increase the social, cultural and economic wellbeing of the Australian people. It would position Australia as a world leader with international standing in the restoration of coastal and marine ecosystems, and implementation of coordinated, scaled restoration and Nature-based Solutions.

1 Introduction

Large-scale restoration is required to recover degraded ecosystems and the functions and services which they provide (Duarte et al., 2020; McAfee, Costanza, & Connell, 2021; Saunders et al., 2020). Widespread loss and degradation of coastal marine ecosystems has occurred in Australia (Babcock et al., 2019; Ford & Hamer, 2016; Thurstan et al., 2020). Australia's coastal and marine assets are incredibly valuable: for instance, the Great Southern Reef comprising the temperate reefs of Southern Australia is worth \$10 billion year^{-1} in fishing and tourism revenue (Bennett et al., 2015), and the Great Barrier Reef in Queensland contributes 6.4 billion year^{-} to the economy in direct and indirect uses, and is valued at \$56 billion as an Australian economic, social and iconic asset. The protection of intact habitats and mitigation of stressors are necessary approaches to conservation and have traditionally been the focus of marine environmental management in Australia. However, in many instances these approaches have not succeeded in reversing trajectories of decline – in these instances more interventionist approaches to ecological restoration are required.

This report includes within scope both *ecological restoration* of coastal and marine ecosystems as well as *Nature-based Solutions* for coastal hazards. We adopt the definition of *ecological restoration* provided by the Society for Ecological restoration (SER): *the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed* (Gann et al., 2019). Ecological restoration occurs along a continuum of levels of intervention and objectives: 1 - reducing societal impacts; 2 - improving ecosystem management; 3 - repairing ecosystem function; 4- initiating native recovery; 5 - partially recovering native ecosystems; and 6 - fully recovering native ecosystems (Gann et al., 2019). The scope of this report is broadly in alignment with the more interventionist levels of the continuum (3-6). The term *Nature-based Solutions* (NbS) is defined by (IUCN, 2020) as *actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*. Ecological restoration can be used, but is not the only option available, as NbS. For instance, NbS can also involve the creation of new habitats or use of nature-based approaches to particular challenges which are not necessarily intended to recover an ecosystem which existed previously. For instance, beach nourishment or installation of living shorelines. Newly created, partially recovered, or novel ecosystems can represent intrinsic values and deliver ecosystem services This is particularly important in the Anthropocene, where shifting environmental conditions may make a return to baseline conditions though the process of ecological restoration impossible.

Ecological restoration of coastal and marine ecosystems, such as mangroves, marshes, shellfish reefs, coral reefs, seagrass meadows, kelp forests, dunes and beaches, underpins important NbS to mitigate against coastal hazards such as inundation and erosion (IUCN, 2020; Morris, Bishop, Boon, Browne, Carley, Fest, Fraser, Ghisalberti, Kendrick, Konlechner, et al., 2021; Twomey, O'Brien, Callaghan, & Saunders, 2020). Accordingly, ecological restoration and NbS feature prominently in high level international agreements, declarations and conventions such as The International Panel on Climate Change (*IPCC*), Convention on International Trade in Endangered Species of Wild Fauna and Flora (*CITES*), The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (*IPBES*), Conference of the Parties (*COP*), the UN Sustainable Development Goals (2030), and UN Decade of Ocean Science for Sustainable Development (2020-2031), and the UN Decade on Ecosystem Restoration (2021-2030) (McAfee, Costanza, et al., 2021; Saunders et al., 2020; Waltham et al., 2020).

A number of complex and interdependent challenges currently preclude the widespread implementation and scaling up of ecological restoration in coastal and marine ecosystems globally, including in Australia. Coastal and marine restoration as assessed in the scientific literature has typically been small scale, expensive, and prone to failure (Bayraktarov et al., 2016). A number of systemic barriers spanning environmental, technical, social, economic, and political realms impede restoration (Stewart-Sinclair et al., 2020). For instance, there is no integrated mapping and classification of existing coastal and marine systems, and a complex regulatory space with an often financially prohibitive permitting process (I. M. McLeod et al., 2018). Some groups have identified concern relating to a lack of clear leadership from government with respect to coordinated coastal and marine restoration (I. M. McLeod et al., 2018), which in part stems from diverse groups and interests in the space and a siloed approach to dealing with ecosystems. There is no systematic or consistent reporting of restoration activities and outcomes, and very little emphasis on communicating social, economic and cultural outcomes of restoration, impeding knowledge sharing and learning (Bayraktarov et al., 2020; Bayraktarov et al., 2019; Eger et al., 2022). There is insufficient funding to restore key degraded systems; there are varied and often conflicting motivations for restoration which are important, but can result in trade-offs and conflict, and there is no clearly defined and agreed upon framework for the prioritisation of restoration efforts. There are many actors across a diverse spectrum of organisations, ranging from local communities to the Australian Government. Coastal restoration activities now occur within the context of the increasing spectre of climate change (McAfee, Costanza, et al., 2021; Sheaves et al., 2021).

These challenges, among others, are known to some degree by anyone working in the coastal restoration and NbS space; what is unknown at present is how to address them in a coordinated and meaningful way at a national scale. This project is designed to form the basis of a conversation around how to resolve these issues in Australia.

Interest and funding into marine and coastal ecological restoration in Australia is increasing, hinting that larger scale programs which can achieve societal and environmental objectives are becoming possible. The Commonwealth Government recently invested in a number of substantive programs which include coastal and marine restoration:

- $130 million into research and development on coral restoration on the Great Barrier Reef (GBR) though the Reef Recovery and Adaptation Program;
- $20 million to build shellfish reefs at 13 sites nationally though the Reef Builder program;
- $30 million into The Blue Carbon Conservation, Restoration and Accounting Program;
- a $1 billion package of investment into the GBR which includes restoration within scope of its activities.

Momentum is building within the Australian and international communities to support the implementation of restoration and NbS at scale in coastal environments. Within the Australian National Environmental Science Program (NESP), recent research into restoration included *The role of restoration in conserving matters of national environmental significance in marine and coastal environments* (NESP Biodiversity Hub Project E5) (I. M. McLeod et al., 2018), which articulates the status of important coastal habitats in Australia, how they link to commonwealth policies, and how restoration of those habitats can be accomplished. Significant outcomes of this previous work included the establishment of the Australian Coastal Restoration Network (https://www.acrn.org.au/), as well as the creation of a database of known coastal and marine restoration projects nationally (Figure 2) (https://www.acrn.org.au/database). For coastal NbS, a major outcome of the NESP Earth Systems and Climate Change Hub was *The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards* (Morris, Bishop, Boon, Browne, Carley, Fest, Fraser, Ghisalberti, Kendrick, Konlechner, et al., 2021). This report articulates the need for and approaches to different coastal NbS strategies in Australia. Internationally, the Society for Ecological Restoration *National Standards for ecological restoration* (McDonald, Jonson, & Dixon, 2016) and *International Principles & Standards for the Practice of Ecological Restoration* (Gann et al., 2019) outline ecological principles to follow with restoration, and the *IUCN Global Standard for Nature-based Solutions* (IUCN, 2020) articulates eight standards that are required to underpin NbS.

Figure 2: Locations of coastal and marine restoration projects compiled in the Australian Coastal Restoration Network database. Dark blue (coral); orange (estuaries); red (kelp); green (saltmarsh); light blue (mangroves); yellow (seagrass); purple (shellfish); and pink (wetlands) (ACRN website - https://www.acrn.org.au/database).

A more coordinated approach can help to overcome many of the challenges that currently prelude widespread uptake and implementation of restoration and NbS. Coordination among land holders to agree on shared goals can increase the spatial extent of wetland restoration activities by orders of magnitude. Coordination ensures that trade-offs among multiple objectives are identified and reconciled – such as ensuring that there is a portfolio of projects which achieve diverse objectives including shoreline protection, fisheries enhancement and cultural benefits. Coordination ensures that projects don't adversely impact each other, or collectively achieve adverse impacts; for instance, preventing the installation of a series of projects which ultimately negatively affect transportation or hydrodynamic processes.

We propose that at a high-level some coordination should occur at a national scale in the form of a national strategy to coastal and marine restoration, and this should be co-designed with stakeholders with the intention that it cascade across the state/territory and local government scales where many coastal and marine restoration activities often occur. At the opposite end of the spectrum, increased coordination within jurisdictions will be more feasible but still challenging due to varying priorities and responsibilities among agencies. These activities will need to be explicitly based within (and will not replace) the extensive set of environmental management actions which continue to occur, such as marine protection, pollution control, and fisheries management, and with evidence-based guidance on how to make informed decisions on which action to take. Ultimately the process of increasing coordination of coastal and marine restoration is not a straightforward task due to Australia's large and diverse geographies, heterogeneous environmental impacts, and varied legislations and policies among jurisdictions. Individualised and tailored approaches to restoration acknowledging this variability is essential for project success and for innovation. However, increased coordination, ideally commencing at the national scale, is also necessary moving forward.

Despite many recent major advances, there remains a substantial gap to fill in terms of the articulation of principles required to overcome the hurdles that currently preclude the implementation of restoration and NbS in Australia at scale. As the pressure and momentum to scale up ecological restoration in coastal marine ecosystems increases, a roadmap to inform large-scale, coordinated, climate smart landscape scale restoration is required to ultimately provide measurable, long-term benefits to the environment and society.

2 Project Aims

This project **aims** to develop a prototype roadmap to guide research, investment and action into landscape-scale coastal and marine restoration that embraces NbS for coastal hazards in Australia. Particular focus on the ecosystem service of coastal hazard protection was necessary, given both that the coastal zone will likely see some of the great changes in the landscape under future climate change, and that this focus allowed us to bring in particular expertise on coastal hydrodynamic processes. In formulating a roadmap, it was important to socialise the idea and discuss the full range of benefits, challenges, learning and opportunities, as wide as possible to many beneficiaries. In the timeframes permitted for this project, this was done via surveys, interviews, workshops and focused meetings to capture all these components, in order to develop and conceptualise a roadmap for Australia's coastal and marine ecosystems. Importantly, a goal was to also take a forward-looking perspective where the report identifies research gaps and key actions that are need in order to successfully move forward with a national approach to coastal and marine restoration. To do so it brings together concepts from restoration ecology, coastal engineering and decision science and elicits information from diverse end-users and stakeholders of coastal and marine restoration.

The project addresses 5 objectives:

1. Engage with end-user groups, including restoration researchers, practitioners and decision makers, to understand the current state, limitations, opportunities, and research needs for scaling up coastal restoration in Australia. This was conducted using a national-scale survey **[Chapter 4**] and workshops [**Chapter 6]**.
2. Conduct a targeted approach to Indigenous Engagement to understand the experiences and needs of Traditional Custodians [**Chapter 5**].
3. Describe case studies of coastal and marine ecological restoration in Australia, including information on how barriers were overcome. [**Chapter 7**].
4. Explore data and models that are available across multiple spatial scales in coastal engineering that could be used to inform decision science frameworks for NbS to coastal hazards [**Chapter 8**].
5. Synthesize the findings from **1-3**, and informed by **4**, into a strategic *Roadmap* which outlines the steps required to move from the current state of typically small, uncoordinated and often underfunded efforts to large-scale and coordinated ecological restoration in coastal and marine systems [**Chapter 9**].

The activities under objectives 1-4 underpin the foundation of the research and the outcomes of objective 5 comprises the synthesis of all activities; accordingly, we refer the reader with time constraints to see section 9. The findings are intended to form the basis of a conversation around transformational change in the implementation of coastal and marine restoration and NbS in Australia. Doing so will ultimately enable Australia to help meet national and international commitments which implicitly or explicitly include marine restoration, such as the Sustainable Development Goals, the Convention on Biological Diversity Aichi Targets, the Paris Agreement, and the Ramsar Convention. Following through on the Roadmap has the potential to elevate the state, condition and function of Australia's coastal and marine assets, to substantively increase Australia's capacity to adapt to climate change, and to increase the social, cultural and economic wellbeing of the Australian people. It would also position Australia as a world leader with international standing in the restoration of coastal marine ecosystems and implementation of coordinated, scaled restoration and NbS.

3 Methods

The project consisted of five activities: 1) National-scale survey (Aim 1); 2) Workshops with the project team and stakeholders (Aim 2); 3) Indigenous Engagement program (Aim 3); 4) review of coastal engineering data, models and gaps in knowledge which are available to inform decision making around NbS for coastal hazards (Aim 4); and 4) Synthesis of information gained in 1-4 into a *Roadmap* (Aim 5). Through these activities information was gained on current coastal and marine restoration activities, barriers to restoration and NbS, motivations for restoration, and future research needs from practitioners and decision makers. This report has adopted a broad definition of restoration, inclusive of rehabilitation, repair, partial recovery and habitat addition. It includes concepts of nature-based solutions, which is inclusive of using nature to provide particular services, and not necessarily to return natural ecosystems to baseline or references states.

3.1 National scale end-user survey

A survey of restoration practitioners and decision makers was disseminated nationally in November 2021. The objective of the survey was to understand the perspectives of this group of key research end users as well as to engage nationally. The survey elicited information on the types of restoration activities that are occurring, on how decisions are currently made, what barriers are currently experienced, and how research could help to improve decision making.

3.1.1 Stakeholder survey methodology

The survey was co-designed with internal project stakeholders through an initial workshop. The survey structure and questions were then further refined by a smaller group of projects stakeholders and provided back to the full group of project stakeholders for review and comment.

Two other Marine and Coastal Hub projects (1.7-Towards a consolidated and open-science framework for restoration monitoring and 1.10-A national inventory of implemented nature-based solutions to mitigate coastal hazards) were simultaneously conducting surveys on marine and coastal restoration with some overlap in the target audience. Care was taken to ensure the surveys didn't overlap in content and were complementary.

The survey design and methodology received ethics approval from the CSIRO Social and Interdisciplinary Science and Human Research Ethics Committee (approval number 139/21) in accordance with the National Statement on Ethical Conduct in Human Research 2007 (updated 2018). See Appendix A – End-User Survey.

The survey was distributed through the Australian Coastal Council Association, Australian Coastal Restoration Network (ACRN) and the Australian Shellfish Restoration Network, a CSIRO held database of university researchers involved in marine/ coastal research, as well as publicly listed emails of NRM groups in coastal areas and Traditional Custodians invited to the Indigenous engagement workshops. The project team also distributed the survey to their own networks by email and Twitter, including contacts in local, state and federal government, Traditional Custodians and NGOs. A link to the survey was posted on the Marine and Coastal Hub Facebook page, and cross-posted by the NESP Climate Systems and Resilient Landscapes Hubs.

The survey was distributed 8-10 November 2021 with a reminder email sent out on 23 November 2021. The project team received some questions around whether the survey was to be answered at an organisational level or individual level and some additional text was added to the survey on 11 November 2021 to explain that the organisational information collected was for demographic purposes, but responses should be at an individual level. The survey closed on 29 November 2021.

The survey received 144 responses. Eight respondents did not give consent for their data to be collected, another six participants dropped out at question two, and there was one test response. These fifteen responses were deleted from the dataset, leaving 129 valid responses.

The survey consisted mostly of multiple-choice questions, many with a 5-point Likert scale to rank importance or occurrence. Most questions included an option to provide further information, and the survey elicited good descriptive information from stakeholders elaborating on areas that may not have been on the researchers' radar, for example difference in priorities on barriers – funding opportunities and timeline the highest priority.

3.1.2 Limitations to the survey

The survey had a 64% completion rate and there was a varying number of responses per question. Responses to survey questions were not forced to encourage greater participation. The aim of the survey was to gain a broad overview of coastal restoration in Australia, and in the survey design phase it was agreed that specific data was not as important as ease of response to capture a broad view; this may limit the analysis. The survey questions are listed in the results section (**Section 4**) and in **Appendix 1**.

The survey asked respondents to answer the questions based on a restoration project. Some respondents commented that they were not currently doing a coastal restoration project, and there was a drop in participation from 116 to 82 following question Q8 *Is your organisation undertaking or planning to undertake a coastal or marine ecosystem restoration project?* However, the survey section on motivations (Q13), values (Q14) and barriers (Q15) elicited a consistent number of responses (92-94 responses), as did questions 21-24 on NbS (90-91 responses), providing a reliable data set.

Specific demographic questions were not included in this survey due to privacy considerations in how survey responses are captured in SurveyMonkey. For example, questions that were originally included in the draft survey on respondent's role, and whether the respondent identified as Aboriginal and/or Torres Strait Islander were omitted. Only limited location data was captured because this could, in combination with responses to other questions, potentially result in respondents being identifiable.

Only six organisations identified as Aboriginal and/ or Torres Strait Islander organisations – not a large enough response to be representative or draw conclusions from. Some tentative points have been included which would need validation through more extensive engagement with Traditional Custodians on the motivations and barriers they experience.

3.2 Aboriginal and Torres Strait Islander Peoples Engagement

The **key questions** asked in this section of the study were:

- What are key challenges/barriers facing Aboriginal and Torres Strait Islander communities when it comes to restoration of Sea Country[2]?
- What current co-management or engagement activities are Aboriginal and Torres Strait Islander people participating in?
- What perceptions do Aboriginal and Torres Strait Islander people have of engagement from restoration researchers and practitioners?
- What can be offered to improve participation by Aboriginal and Torres Strait Islander people in Sea Country restoration practices/research?

3.2.1 Online survey of Traditional Custodians

An online survey was designed to illicit understanding to the challenges and barriers faced by Aboriginal and Torres Strait Islander communities and organisations in relation to coastal and marine ecosystem restoration. The survey design and methods were approved by the CSIRO Social and Interdisciplinary Science Human Research Ethics Committee (approval number 139/21). The survey was distributed on 27 January 2022 and closed 6 February 2022, with a reminder email sent on 4 February. Individuals who had previously been contacted by our research team and had shown interest in participating in these activities were contacted. The total number of responses recorded for the survey were eight (8), with three (3) responses only completing 25% of the survey. See Appendix B – Engagement with Traditional Custodians.

3.2.2 Literature review of Aboriginal and Torres Strait Islander people's inclusion in coastal and marine restoration

It continues to be recognised that the inclusion of Aboriginal and Torres Strait Islander people in marine and coastal research is essential to addressing the challenges we face as a nation. How Aboriginal and Torres Strait Islander peoples have been included in practices so far varies and is not well documented in the marine and coastal management space. When looking into restoration frameworks that appropriately include Aboriginal and Torres Strait Islander people and communities there is little available for researchers to follow.

In addition to the online survey mentioned above, a systematic review was conducted to deliver a summary of previous research that involves coastal and marine ecosystem restoration and Aboriginal and Torres Strait Islander people in Australia. The review involved following the PRISMA system for scoping reviews. Databases searched were Web of Science, Scopus, and Google Scholar (n=505) using search terms 'Indigenous' and/or 'Aboriginal' and/or 'Torres Strait Islander', 'Ecosystem Restoration', 'Australia' and 'Coastal' and/or 'Marine'. The records found were reduced through the removal of duplicates in reference software Zotero (n=470). Offline books, factsheets, reports, abstracts, and articles behind paywalls were not included in this review.

2 Country or Sea Country is a term used by Aboriginal and Torres Strait Islander peoples to refer to their traditional lands, seas, waterways and skies.

Of the 470 records found during the literature search, 17 qualified during manual screening using title and abstract against exclusion/inclusion criteria. Of these, 11 papers were identified as being relevant to our area of interest, after reading the full records. The remaining records (n=11) content were analysed in NVivo. From the 11 records several broad themes were predefined including 'Barriers', 'Benefits', 'Best Practice', 'Changes', Engagement', 'Frameworks', 'TK', and 'Timing'. These broad themes were further explored with a total of 27 'child' themes (Figure 3).

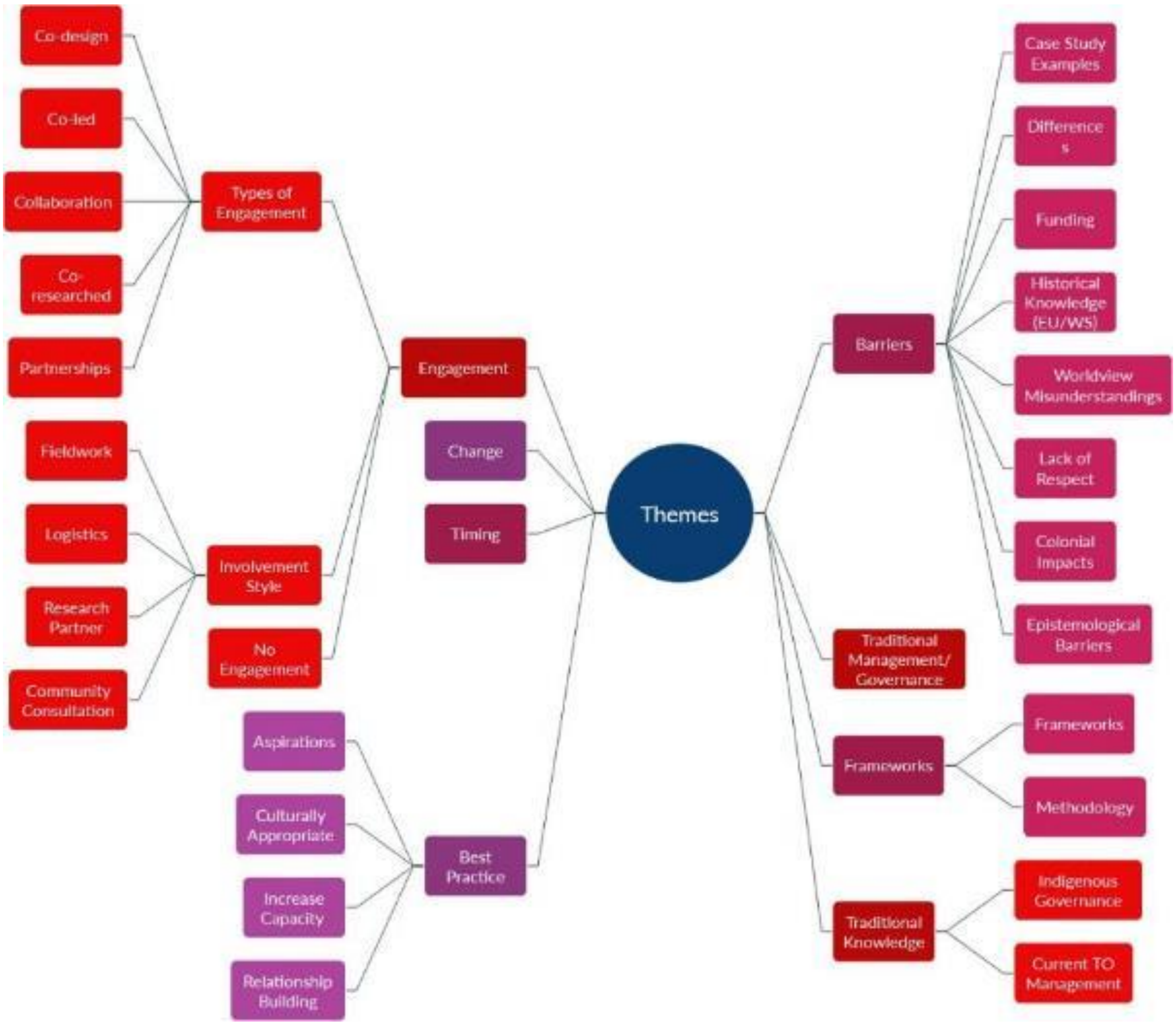


Figure 3: Mapping of Themes for Systematic Review Analysis

3.2.3 Informal discussions

In addition to the review and survey informal discussions were held with individual groups. Conversations were held with groups from southeast Queensland. Individuals from South Australia, Western Australia and North Queensland were also interested in a conversation however a suitable time for all to participate in a workshop was not possible.

3.2.4 Limitations to the Aboriginal and Torres Strait Islander Peoples Engagement activities

The short project timeframe limited the opportunity for appropriate engagement; this was unfortunately exacerbated by unexpected medical leave from within the team. Therefore, our ability to appropriately engage in a larger undertaking of challenges and barriers for all Aboriginal and Torres Strait Islander peoples working or interested in restoration was limited. However, we were able to understand numerous barriers, gaps and challenges in relation to appropriate recognition and inclusion of Indigenous knowledge and science in restoration.

The survey had a small number of responses, with only a total of 8 respondents, of which 3 were incomplete. The responses came from individuals in three states. The survey did not identify between Aboriginal and Torres Strait Islander peoples so we cannot be sure which community voices have been captured.

3.3 Science and Stakeholder workshops

Project team science workshops were held online on 15 November 2021 and 8 February 2022. The aims of the workshops were to; 1) hear the perspectives and experiences of the project co-design end users and researchers, and to discuss the structured decision making (SDM) framework and its applicability to coastal restoration; 2) to refine the content of the Roadmap. A workshop report is provided for the first workshop, and the outcomes of the second workshop are synthesised in the Roadmap chapter.

An end-user workshop was held on 16 November 2021. The workshop was focused primarily on end-users based in or active in QLD; a regional focus was employed to focus the attendee list and to keep the numbers tractable for early engagement. The primary objective of the workshop was to discuss and gain feedback and nuance on some of the key questions in the national scale survey (see below), which the participants had all responded to previously. See Appendix C – End User Workshop Information.

3.3.1 Methods

The workshops employed the “Art of Hosting” technique, which is a participatory practice framework that aims to create conversational structures and principles to foster meaningful conversation and collective intelligence (Quick & Sandfort, 2014; Sandfort & Sarode, 2021; Schwartz, 2016). Rather than conversations just being a dialogue, the conversation is designed to be a mechanism of creativity and of deep democracy, stimulated by well-designed questions to generate genuine communication between all participants, and guided by workshop facilitators to realise focussed conversation around seeking both understanding and solutions (Donnelly, 2020). The deliberations are triggered by spending time investing in developing well-thought-out questions to ask participants. Noting that *a high-quality question focuses on what is meaningful for the participants, triggers our curiosity and invites us to explore further (Magzan, 2011)*. Such questions encourage genuine communication between all participants and the guidance from workshop facilitators keeps the conversation focussed around seeking both understanding and solutions. In essence, the process is that of authentic co-design.

The idea behind Art of Hosting is to align participatory action research using multiple method projects and using dialogue-based processes so groups of people can work together effectively to generate actions based on building communities of practice and knowledge commons. Art of Hosting can enhance social capacities for deliberative policy-making. This approach builds upon earlier participatory approaches. For instance, stakeholder participation in coastal and catchment management, even citizen science, and bringing together a range of stakeholders in order to co-produce a system understanding for large scale issues, such as disaster management (Bonney, Murphy, Hansen, & Baldwin, 2020; Clarke et al., 2013; Lopes & Videira, 2018; Norström et al., 2020; O'Connell et al., 2018; Schwermer, Barz, & Zablotski, 2020).

Workshops are a pragmatic way of bringing together diverse people into a group for participatory conversations. We adopted Art of Hosting practices such as checking expectations at the commencement of the workshop and finding out what each participant was taking away with them at the conclusion. Our workshops aimed to ensure that researchers could consult with and invite feedback from end users. These conversations between science experts, government representatives including policy advisors as well as those responsible for implementing government policies were centred in the aim of determining a roadmap forward.

3.4 A case-study approach to coastal and marine restoration and NbS in Australia

A series of case studies focusing on restoration of a selection of coastal and marine habitats was completed in this study, to present some general learnings, costs, barriers, scale and outcomes. Key members in the broader ACRN were identified by the core project team to invite their contribution. A template was prepared to assist authors to showcase their work and the outcomes. These case studies provide useful insight into the range of projects underway across Australia.

3.5 Review of key concepts: in Coastal Engineering

Following the workshops, we identified a need to examine the availability of data and models which are used in coastal engineering to estimate the impact of waves on shorelines, and the effects of coastal vegetation on flooding and erosion, over multiple spatial scales. Decisions around site placement of restoration projects need to be informed by understanding of coastal processes, and how restoration is likely to affect hydrodynamic processes such as tidal exchange, wave attenuation and long-shore sediment transport. For NbS projects aimed at coastal hazard protection, there is a need for process-based models which simulate the effectivity of the project, for instance, the magnitude of shoreline protection achieved, as well to predict potential adverse effects of the project, such as downstream erosion.

This section:

- synthesizes information on engineering designs for NbS for coastal hazard protection, as well as whole-of-project considerations that go beyond the physical design of the structure.
- discusses the limitations to design of NbS for coastal hazard protection that are driven by considerations beyond the design itself.
- identifies important gaps in the knowledge base required to underpin decision-making.

- highlights a disconnect between coastal engineers and ecologists which must be reconciled moving forward in order to scale NbS for coastal hazard protection.

3.6 Synthesis of information from Survey, Indigenous engagement, Workshops, Case studies, and Key Science into a 'Roadmap'

The final component of the research was to bring the insights and inferences from the surveys, workshops, and Indigenous Engagement activities together into a "Roadmap" to guide coordinated landscape scale restoration in coastal and marine environments. A roadmap is defined as a *strategic plan that defines a goal or desired outcome and includes the major steps required to reach it*.

4 Results of the National Scale End-user survey

Section Leads: Marian Sheppard & Megan Saunders

The purpose of the survey was to engage with end-user groups and to understand the current state, limitations, opportunities and research needs for scaling up coastal restoration in Australia. The survey included some sections that were targeted towards coastal restoration, and others that were targeted towards NbS for coastal hazard protection. The rational for this distinction is that at the outset of the project we anticipated that not all restoration projects would be designed for coastal hazard protection, and conversely, not all NbS projects designed for coastal hazard protection would meet criteria of restoration according to the Society for Ecological Restoration definition. For instance, beach nourishment is considered NbS, but it is not intended as an ecological restoration activity.

4.1 Key findings

Cultural values

- Aboriginal and Torres Strait Islander people are being included in coastal restoration projects, mostly through paid employment and co-design. However, there is variability in how they are involved, with the level and type of involvement depending on the project and the level of maturity of the organisation's process and policies for engagement.

Governance

- Permitting criteria and approval processes were identified as major barriers.

Research gaps

- Habitat suitability modelling and improved methodologies for ecosystem valuation and on-ground works were the most important research needs. Research gaps include:
  - improved understanding of ecosystem function, services and connectivity at varying scales. The ability to estimate ecosystem service delivery allows stakeholders to communicate the business case for restoration to decision makers and funders.
  - improved understanding of the efficacy and risk in applying Nature-based solutions.
  - methodologies for monitoring social and cultural outcomes.

Funding

- Funding opportunities and timescales were the most common barrier to coastal and marine ecosystem restoration.

Access to social, ecological and biophysical data

- A key barrier to scaling up marine and coastal restoration and improving connectivity with adjacent ecosystems is the need for biophysical data at different scales.
- The characterisation of ecosystems with common attributes is beneficial for planning and implementing restoration.
- Access to high resolution data is required by end-users to address site specific challenges (social, cultural, economic and ecological).

Coordination of projects

- Most projects are considering connections among ecosystems in some capacity. However, there are barriers to coordinated multi-ecosystem restoration such as funding, permitting, legislation, and land tenure.

Monitoring & Evaluation

- Most projects consider a monitoring strategy, mostly for ecological outcomes. There is a lack of information on the best approaches for monitoring social and cultural outcomes.

Climate change

- Many practitioners are considering climate change impacts during planning and implementation. The climate change impacts considered are usually at local scale and are not necessarily at landscape/ catchment scale.
- Information on specific adaptation actions and improved knowledge and experience in adaptation were identified as gaps.

Nature-based solutions for coastal hazard protection

- There is significant support for NbS (95% of respondents), and 60% of the respondents' organisations are implementing NbS. There is a recognition that NbS provide a range of benefits and co-benefits, biodiversity being the most highly valued across organisations.

Knowledge sharing

- There is a delineation between the research community and restoration practitioners. The research community is more commonly conducting experimental techniques at smaller scales and are studying emerging methodologies in monitoring and evaluation. Restoration practitioners tend to work on relatively larger scales and with ecosystems with more established restoration methodologies, such as wetlands, compared to those with newer histories of restoration such as kelp and coral.
- Community perception, or understanding, of coastal and marine ecosystems is a barrier.
- Bridging boundaries among engineers, ecologists and practitioners will be important for scaling NbS for coastal hazard protection.

4.2 Overview of responses from Aboriginal and Torres Strait Islander organisations

There was not a large number of responses from identified Aboriginal and/ or Torres Strait Islander organisations. However, we provide a summary of perspectives from Aboriginal and/ or Torres Strait Islander organisations based on six responses compared to the broader survey population. This includes perspectives on motivations, values, objectives and barriers to coastal and marine ecosystem restoration and implementation of Nature-based Solutions (NbS). We refer the reader to Section 5 for more thorough analysis of Aboriginal and Torres Strait Islander peoples' perspectives and requirements.

Aboriginal and/ or Torres Strait Islander organisations:

- Are more likely to be motivated to undertake coastal or marine ecosystem restoration to *restore ecosystems after environmental impacts* or for c*ultural or social benefits.*

- Rank *water filtration and improved water quality, coastal hazard reduction and shoreline protection* as relatively more important objectives.
- Tend to prioritise *social and cultural values.*
- Report that the most significant barriers to coastal and marine restoration include *land use conflict* and *lack of support outside their organisation.* Barriers caused by *legislation* and *funding timelines* were also encountered.
- Most are not implementing NbS but the majority say there's support for implementing NbS in coastal and marine restoration projects within their organisation.
- Perceived benefits and co-benefits are *cultural* (100%) and *improved water quality* followed by *biodiversity, social values* and *fisheries productivity*. *Carbon sequestration* was considered low to moderate benefit.

4.3 Full survey results

4.3.1 Demographic information

Questions 1-5 were intended to understand who the respondents were. They were designed with input from the privacy team at CSIRO to ensure that respondents were not identifiable.

Q1 - I agree to the collection, use and disclosure of my personal information in the ways described above. (144 responses)

Eight respondents (5.56 %) answered no to this question. A 'no' response resulted in automatic exit from the survey and no data was collected.

Q2 - What is the main type of organisation you work for? (129 responses)

The majority of respondents were from universities/research organisations (44) which likely reflects the distribution methods of the survey through the Australian Coastal Restoration Network and through personal connections of the authorship team. There was a substantial number of responses from state government (27) and NRM groups (17). Some federal government departments indicated they usually collate information and submit a consolidated response, so the response rate (9%) may not reflect the extent of the input. No responses were received from native title body or industry association/ peak body segments, and these aren't included in the graph below (Figure 4).

Figure 4: The main categories of organisations represented in the survey

Types of organisations included in the 'other' category:

- regional partnership, incl councils, state govt, business, researchers, NRM groups
- airport
- Aboriginal tour guide
- landscape board
- social enterprise

Q3 - Is your organisation an Aboriginal and/ or Torres Strait Islander organisation? (129 responses)

Six respondents identified as being from an Aboriginal and/ or Torres Strait Islander organisation.

Q4 - Are there any co-management, co-design or Indigenous-led frameworks you know of that you think would work best for coastal restoration projects on your Country? *(5 responses)*

The logic applied to Q3 directed only yes responses to Q4. Only one respondent identified a framework that would facilitate coastal restoration projects, being an Indigenous Protected Area Management Plan.

Q5 - Does your organisation include First Nations people in their coastal restoration activities – how? (123 responses)

The majority of organisations are including First Nations People, through co-design, co-lead, paid employment, volunteer or other mechanisms. Only 20% (25 responses) have not yet engaged First Nations People (Figure 5).

Figure 5: The ways that respondents are including First Nations people in coastal and marine ecosystem restoration

Respondents identified a range of other ways they engage First Nations Peoples, for example through consultation (3%), participation through higher level committees like Ramsar Site Coordinating Committee, protection of cultural heritage or permitting processes. Below are some responses captured to the 'other' category, organised into themes:

Project planning, consultation or collaboration

Some collaborative projects with First Nations people linked to habitat health assessment project partners.

We are a policy focused organisation and do not undertake coastal restoration. We do however seek to include First Nations people in such activities through our influence of projects and planning.

Beginning the journey. Our local registered Aboriginal Party is under-resourced and not yet equipped to assist with co-design or on-ground works, however we do regularly engage with them when developing planning tools/policies etc and aim this relationship and engagement with them is ongoing.

Capability development

Provision of technical support to navigate regulatory frameworks.

Empowerment for them to deliver sea country activities through Traditional Use of Marine Resources Agreements.

Collaboration - support for grant applications.

Responses also indicated variability in how Aboriginal and/ or Torres Strait Islander peoples are involved, types of involvement can depend on the project, the organisation and even different sections within the organisation. Other organisations identified that they are beginning the journey to improving involvement of First Nations people in coastal and marine restoration activities.

In the process of developing an engagement strategy and currently engage on an ad-hoc basis.

Parts of the organisation have co-design. Policy encourages this but our section is yet to implement widely. We have examples of co-design e.g., 'Walking the Landscape' and Catchment Stories (see K'gari).

Engagement in activities, when possible, opportunistically for one project thus far (paid for time) and integrated into another project.

4.3.2 Questions about ecosystem restoration

Respondents were instructed that questions 6-20 were *About coastal or marine ecosystem restoration*. The results from these questions are categorised into sub-sections on

- habitat type, scale, stage and extent of restoration;
- ecosystem connectivity;
- motivations, objectives, values, barriers and monitoring;
- climate change; and
- future research needs.

4.3.2.1 Spatial scale, location, planning stage, habitat type, and spatial extent of projects

Q6 - Are your project/s at a local, state, national or international level? (121 responses)

The majority of projects represented in this survey are local scale, with a decreasing number across the levels (Figure 6).

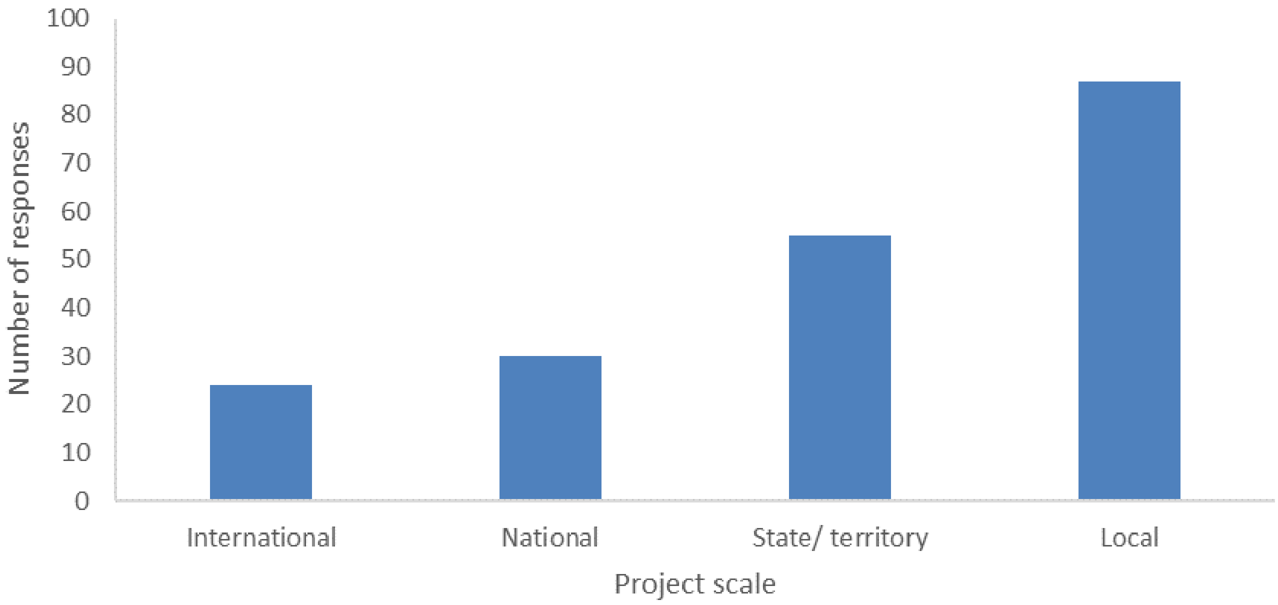


Figure 6: Geographic level of the projects represented in this survey

Q7 - Which state/ territory is the project/s based? (22 responses)

Of the responses to this question (20% of participants) the majority of projects were in Queensland (Figure 7). This likely reflects the overall project methodology, in that we held a Queensland focused online stakeholder workshop where participants were encouraged to complete the survey ahead of time.

Logic applied to Q6 only directed respondents to Q7 if they identified their project was at state level, and not all respondents who identified state level projects in the previous question (55 responses) answered this question (22 responses). Therefore, 80% of respondents did not record their state, and the responses are therefore not an accurate indication of survey participation across the country.

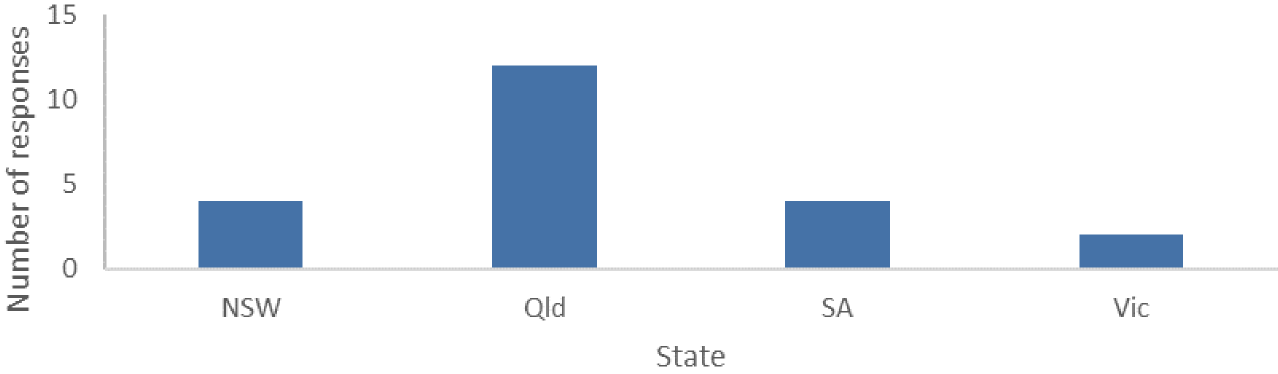


Figure 7: Location of state or territory level projects based on 22 responses

Q8: Is your organisation undertaking or planning to undertake a coastal or marine ecosystem restoration project? (116 responses)

Unsurprisingly, most of the respondents to the survey were in progress of or planning to undertake a coastal or marine restoration project within the next 5 years, see Figure 8. The majority of projects in progress were being undertaken by government or the research community. Only a few respondents, from the NRM and research community, indicated that they are undertaking long term planning (>10 years).

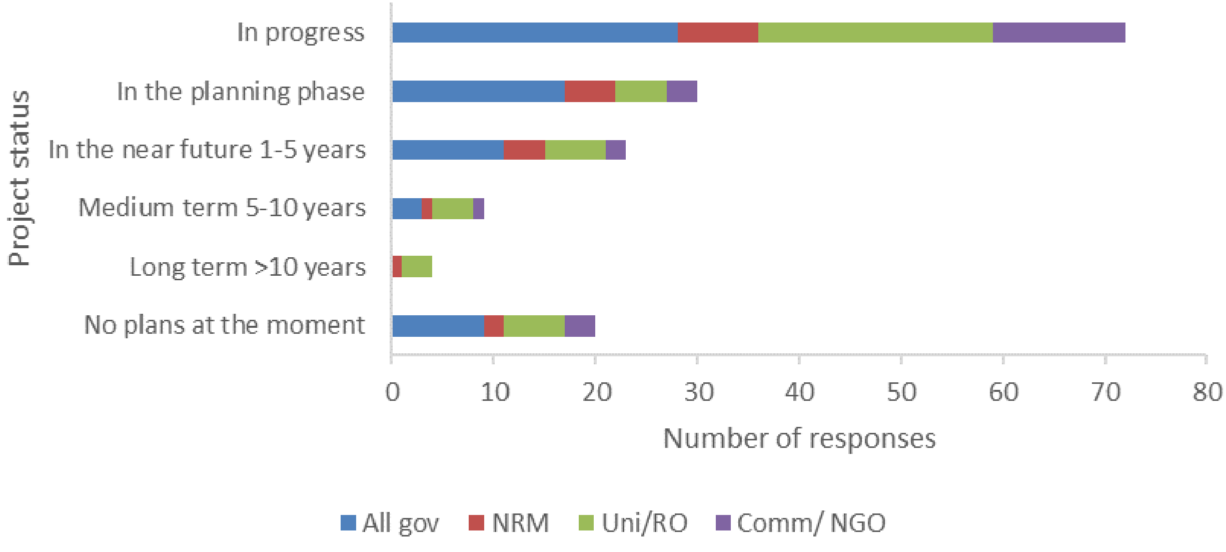


Figure 8: The status of projects being undertaken or planned by organisational types: community groups and NGO, university and research organisation, NRM groups, all levels of government.

Q9 - What types of habitats are represented in this project/s? Select all that apply. (82 responses)

Respondents were asked to select all habitats that apply; on average respondents selected four habitat types. For instance, respondents stated that they worked on both beaches and dunes, or on saltmarsh, mangroves and tidal flood plains. This suggests that individuals either work on projects in multiple habitat types, or that individual projects include multiple habitat types. The habitats identified by respondents in the 'other' category included barrier reef islands, rocky shores, islands/cays, subtidal sediments and mudflats, eco-engineering of built structures, waterways, wetlands, estuaries, and shelf seas. The largest number of respondents were working on seagrass restoration, followed by mangrove and saltmarsh. The fewest number of respondents were working on coral and macroalgae/kelp (Figure 9).

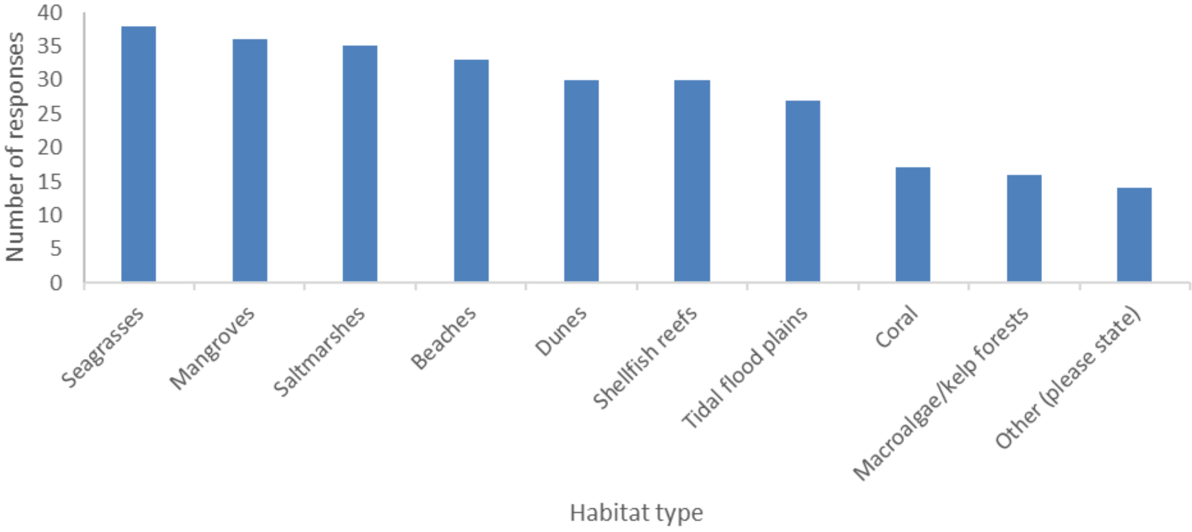


Figure 9: Number of responses to the survey by habitat types

Although the data were not collected using a method that was able to explicitly examine the breakdown of habitat types by organisation type, we were able to interpret some broad trends. Universities and research organisations were more likely to be working on restoration in macroalgae/ kelp and seagrass - where restoration techniques are still relatively new (Bayraktarov et al., 2020)**.** Local councils and NRM groups are working more on restoration in habitats with established restoration methods, for example dunes and beaches, with less involvement in marine habitats. State government respondents worked across habitat types, with the exception of coral and kelp, potentially reflecting their broad jurisdictional responsibilities.

Q10 What spatial scale does this restoration project cover? (79 responses)

The survey results indicate over half (56%) of respondents are completing projects that are greater than 10 hectares (Figure 10). Through interrogation of these responses, we identified that the survey could have been improved with additional categories for larger areas – this information was provided to Marine and Coastal Hub project 1.7 for consideration in their survey (*Towards a consolidated and open-science framework for restoration monitoring to inform their survey design*).

The survey methods did not allow for an analysis of the spatial extent by habitat type, because respondents could report multiple habitat types and multiple spatial extents. However, some broad trends can be inferred. For instance, mangroves, tidal flood plains and saltmarshes were the most commonly reported systems for the greater than 10 ha category. Subtidal habitat types were relatively more commonly conducted at the smallest spatial area (less than 1 hectare), including shellfish reefs, coral, macroalgae/ kelp, and seagrass.

The results align broadly with results from global synthesis studies, which demonstrate the spatial scales of coral and kelp restoration are smaller than that of mangroves and saltmarsh (Bayraktarov et al., 2020; Saunders et al., 2020). Logistical challenges of working in subtidal ecosystems likely influence the relatively small size of restoration in coral, seagrass and kelp restoration. Many coral, kelp and seagrass restoration approaches are still in the proof-of-concept phase and therefore at experimental sizes (Bayraktarov et al., 2020).

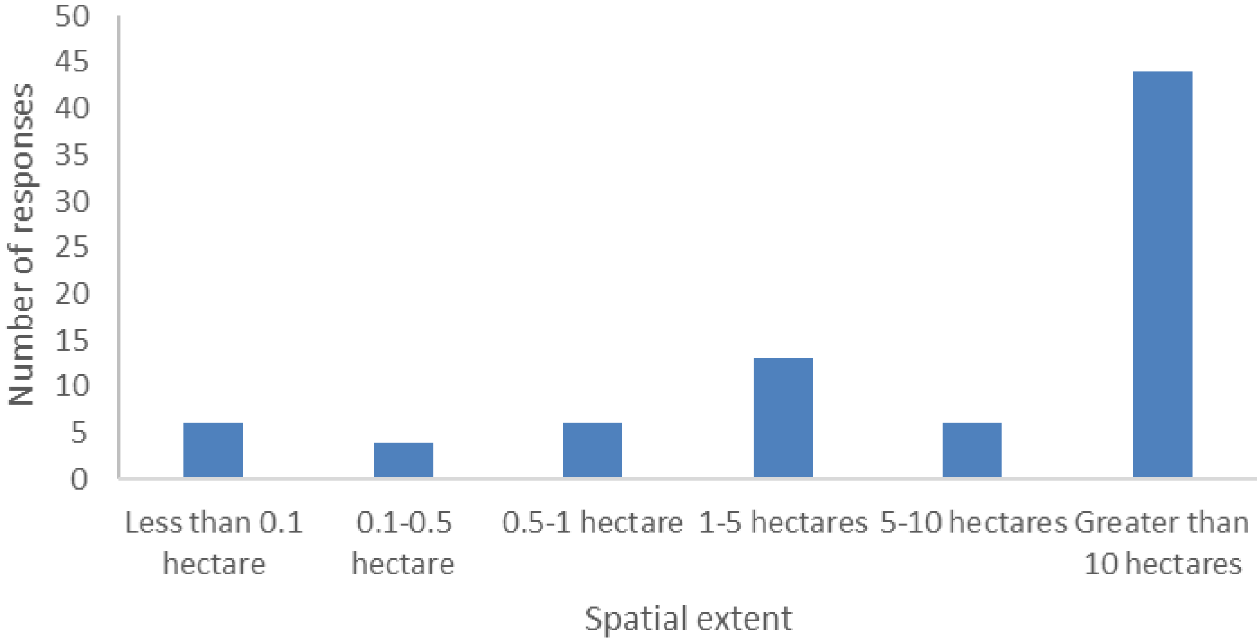
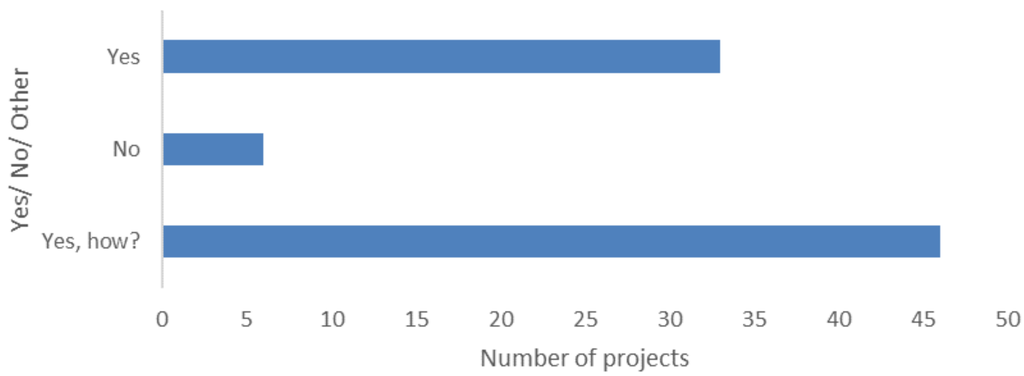


Figure 10: Spatial extent of restoration projects.

4.3.2.2 Ecosystem connectivity

Q 11. Do you consider connectivity between ecosystems in planning restoration projects? If yes, how is ecosystem connectivity considered?

The majority of respondents (93%) are considering ecosystem connectivity in their restoration projects in some form (Figure 11).



(85 responses)
Figure 11: Consideration of connectivity between projects when planning coastal and marine restoration projects

There was a broad range in how connectivity was being considered, and whether this was in a conceptual or explicit way. We examined the responses from the free response section and scored them as ‘enabling’ (e.g. allowing for the consideration of connectivity among habitats) or ‘limiting’ (e.g. leading to challenges for the consideration of connectivity among habitats) (Table 1). We then identified whether the examples of ‘how connectivity is being considered’ fit into one of three categories based on a typology of factors influencing restoration success developed in (Saunders et al., 2020):

- biophysical
- technological
- socio-economic.

The responses assigned to the *technological* category tended to be enabling. For example, the existence of software or modelling tools that would facilitate understanding of connectivity for ecosystem restoration planning and implementation.

The responses in the socio-economic category included both limiting or enabling factors. Although permitting and legislation is noted by respondents in other sections of the survey as being a barrier to ecosystem restoration, the responses to this question indicate that permitting/regulation can also encourage consideration of connectivity with adjacent habitats, i.e., threatened or endangered habitats. Limitations in funding and knowledge of connectivity and monitoring were also noted as limiting the ability to account connectivity among habitats in restoration.

Responses in the biophysical category were scored as enabling rather than limiting. They included concepts such as connectivity being considered for dispersal and reproduction, between physical and biological components, and with respect to landscape/ catchment management.

The full qualitative responses for this question can be found in the corresponding dataset in eAtlas.

Table 1: Examples of how connectivity between ecosystems is being considered in ecosystem restoration

Category	Enabling	Limiting
Technological	purpose built software program system-wide modelling and data collection marine spatial planning framework attribute-based wetlands mapping and ecosystem process understanding spatially map the sites and consider sites with mixed habitats - like patch reef and bare sands	
Socio-economic (sufficient financial investment and commitment to long-term monitoring and maintenance)		single system focus due to funding limitations aquatic connectivity is poorly understood, with limited research and funding monitoring methods are still evolving

Category	Enabling	Limiting
Socio-economic (legal or policy mandates)	permit approval for adjacent endangered or threatened habitats distance between green zones (marine national park zones) design of the land/water interface to integrate recreational use and resource harvesting into the shoreline resilience needs prioritising restoration projects and in conservation planning freshwater interface and the reef are an essential component in both the regulatory and site selection setting targeted research and monitoring needed to better understand the relationship between island and reef and biodiversity	
Biophysical (restoring habitats with sufficient connectivity to source populations)	fish passage and tidal connectivity connectivity from a population point of view (e.g., reproduction, genetics) hydrodynamic connectivity for dispersal connection between physical and biological components	
Biophysical (mitigating multiple stressors using layered interventions)	catchment management actions to improve storm water quality to receiving environment ensuring corridor values are identified and preserved as part of the broader landscape regional management improving riparian vegetation, remediating physical and chemical barriers for fish migration, restoring seasonality in shallow coastal wetlands to improve juvenile fish nurseries and wader bird habitat physical stability, nutrient flows, completion of life-cycles, buffering of negative influences, joint compensatory responses for resilience	

Q12: What are the limitations in considering ecosystem connectivity? (39 responses)

The open answer question format limited the number of responses. Examples of the responses are broken up into biophysical and socio-economic categories used in the analysis of the previous question (Table 2). No responses corresponded to the technological category, reflecting the above interpretations that technology is seen as an enabling factor. A wide range of socio-economic barriers were identified in this question. Permitting and land tenure were the major barriers identified, as were limitations in knowledge and data around biophysical mechanism for connectivity, i.e., dispersal pathways and interactions between biological and physical components of ecosystems.

The full set of responses to this question can be found in the corresponding dataset in eAtlas.

Table 2: Barriers to considering connectivity in restoration

Category	Barriers to considering ecosystem connectivity in restoration
Socio-economic (sufficient financial investment and commitment to long-term monitoring and maintenance)	[in]adequate staff [only a] small number of experts in coastal engineering [lack of] a consolidated and defined approach to monitoring connectivity
Socio-economic (legal or policy mandates)	land ownership (or lack of ownership) and support from landholders/managers scale / tenure of adjacent ecosystems new restoration projects don't have adequate initial planning and objectives/requirements outlined i.e., distance from green zones, impact/location of/ to natural values etc State Government Approvals, the costs associated with submitting applications and restoration activities falling under commercial activities classifications hampering trials and projects restoring multiple ecosystems means multiple applications via separate permit routes, stakeholder engagement processes, time for the application to be approved
Socio-economic (strong local involvement and support from local community)	scale of works, funding limitations competing land uses e.g., commercial fishing concerns about loss of harvest areas, homeowners concerned about views, other coastal projects coastal agricultural zone and the damming of coastal rivers for water supply purposes projects delivered by volunteers limited to areas where volunteers are available
Socio-economic (partnership)	lack of coordinated approach towards restoration and scale lack of coordination among and across organisations involved expanded PhD research pathways can be equally diverse across colleges and even universities
Biophysical (restoring habitats with sufficient connectivity to source populations)	limited local data on the importance of connectivity for fauna and water quality improvement cost of site-specific investigations to understand small scale and site-specific connectivity
Biophysical (adaptive management to provide additional, rapid responses when required)	monitoring different communities on the same scales
Biophysical	limited understanding of dispersal pathways and distances, and how different ecosystems interact both biologically and physically

(context-specific requirements in relation to specific environment and ecology)	ignoring the non-biological - i.e. sediment dynamics understanding the mechanisms of connectivity processes beyond proximity attribute-based classified and mapped intertidal and subtidal ecosystems, with appropriate inventory. Basic info includes bathymetry, morphology, substrate grain size, hydrodynamic energy magnitude, substrate composition, substrate consolidation, and structural macrobiota consideration of genetics in project planning not enough marine field data, e.g., coral cover and maturity on source reefs current knowledge for tropical coastal ecosystems
Biophysical (mitigating multiple stressors using layered interventions)	catchment management actions to improve storm water quality to receiving environment improving riparian vegetation, remediating physical and chemical barriers for fish migration, restoring seasonality in shallow coastal wetlands to improve juvenile fish nurseries and wader bird habitat physical stability, nutrient flows, completion of life-cycles, buffering of negative influences, joint compensatory responses for resilience

4.3.2.3 Motivations, objectives, values, barriers and monitoring

Q13 What do you consider to be the motivations for coastal or marine ecosystem restoration? Score from low importance (1) to high importance (5) **(93 responses)**

Of the responses in the high importance category, the survey responses ranked *to restore biodiversity habitat* (biotic motivation) the most frequently; *to enhance ecosystem services* (pragmatic motivation) second most frequently; and to provide *cultural or social benefits* the third most frequently (Figure 12).

The typology of these motivations was based on (Bayraktarov et al., 2020), who characterised the motivations of the scientific community to engage in the field of marine coastal restoration across five habitat types (seagrass, saltmarsh, oyster reefs, mangroves, corals). That study categorised five broad restoration motivations: biotic, experimental, legislative, pragmatic, and idealistic, earlier defined by Clewell and Aronson (2006). Those categories are largely aligned with the categories used in this survey: biotic aligned to the survey category *to restore biodiversity*, experimental equates to further *ecological knowledge and improve restoration technique*', legislative *to restore ecosystem after environmental impacts, such as for a biodiversity offset*, pragmatic aligns to *enhance ecosystem services*. Idealistic did not have a comparable category in the survey. The survey included an additional category for *cultural or social benefits*.

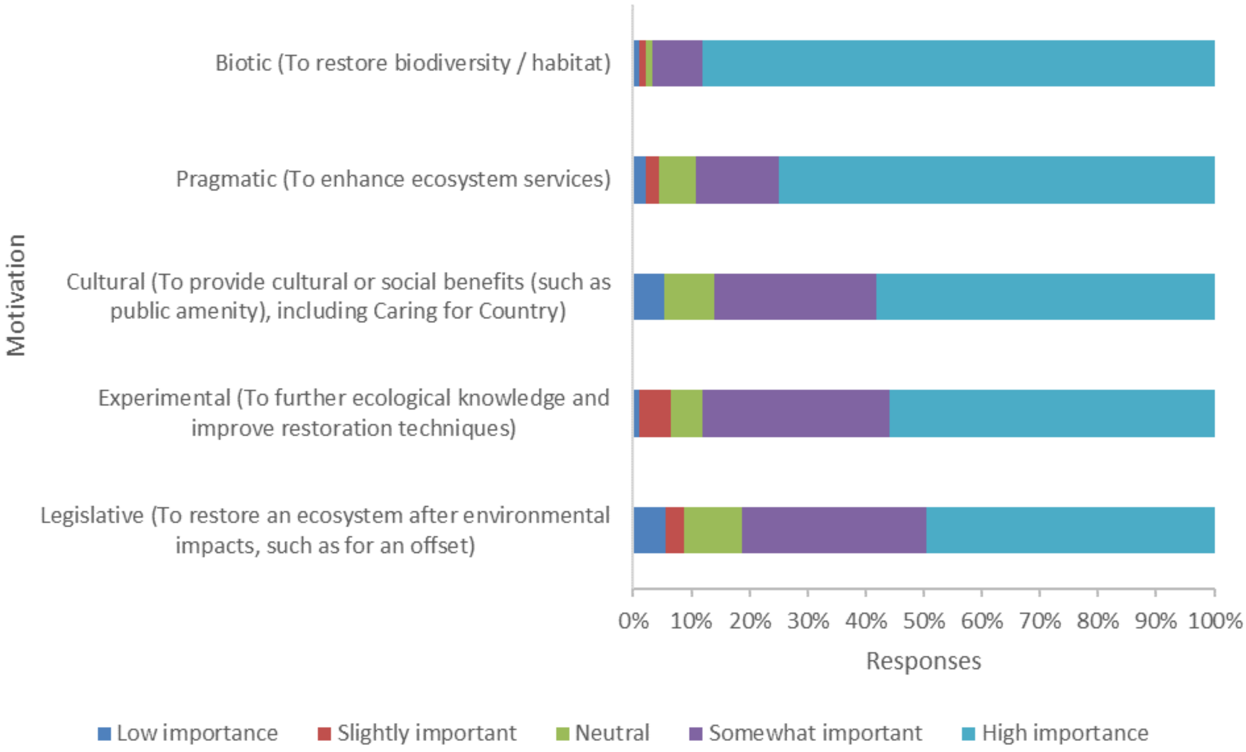


Figure 12: Motivations of survey participants for undertaking coastal and marine ecosystem restoration

Q14 What are the main objectives for the coastal or marine ecosystem restoration project? Please rank from low importance (1) to very important (5) **(93 responses)**

The objectives listed as options represented different types of ecosystem services as well as the improvement of biodiversity. *Biodiversity* (72 responses) followed by *water filtration* and *improved water quality* (57 responses) were considered the most important objectives in restoration, with the highest number of responses in the very important category (Figure 13). Rankings across other objectives were more evenly balanced, around 30-40 respondents ranking these as very important.

Other more specific objectives provided in the comments include:

- genetic diversity
- recovering a functionally extinct habitat
- understanding the functioning of marine ecosystems.

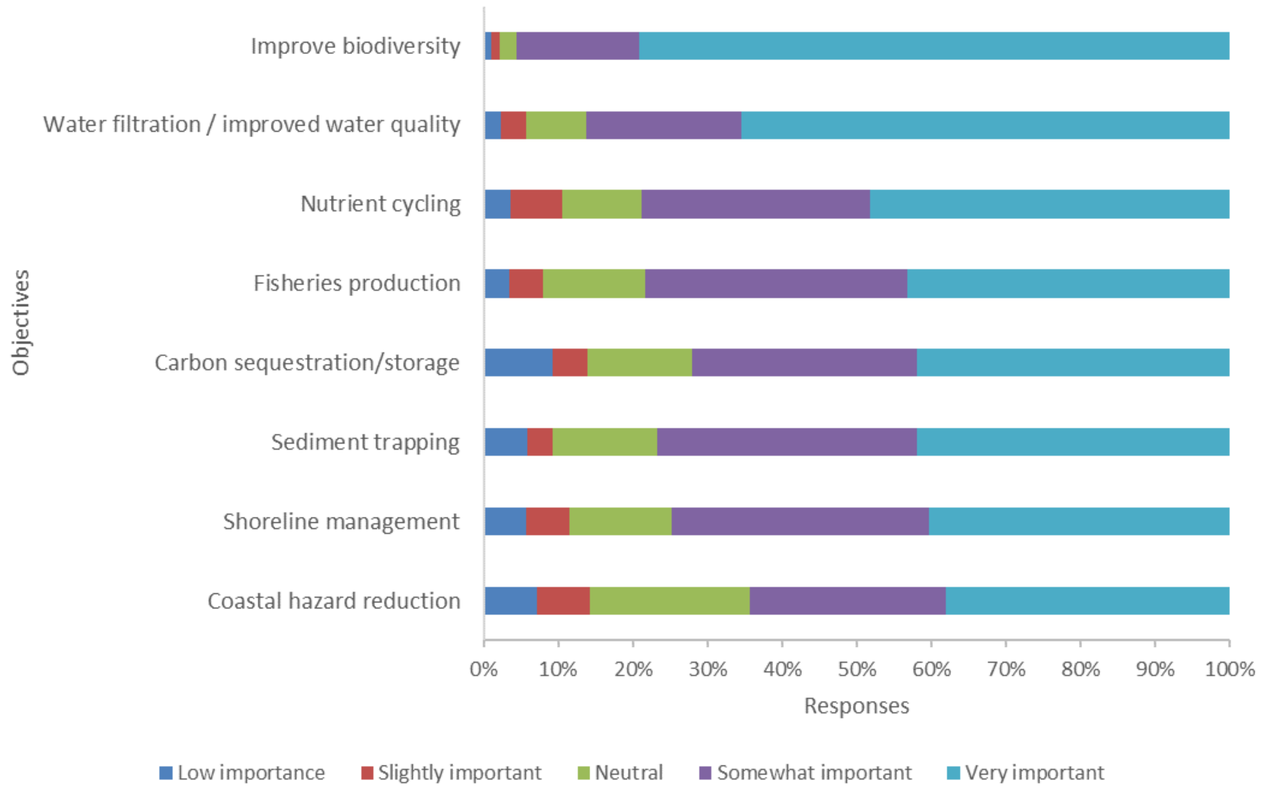


Figure 13: Objectives of survey participants for undertaking coastal and marine ecosystem restoration

Q15 - Which values do you prioritise when considering restoration? Rank from low importance (1) to very important (5) (Responses 94)

Biodiversity values, followed by Delivery of ecosystem services and values were ranked as very important the most often (Figure 14). Cultural and social values were considered somewhat - very important by similar number of respondents. Surprisingly, economic values were least likely to be considered very important.

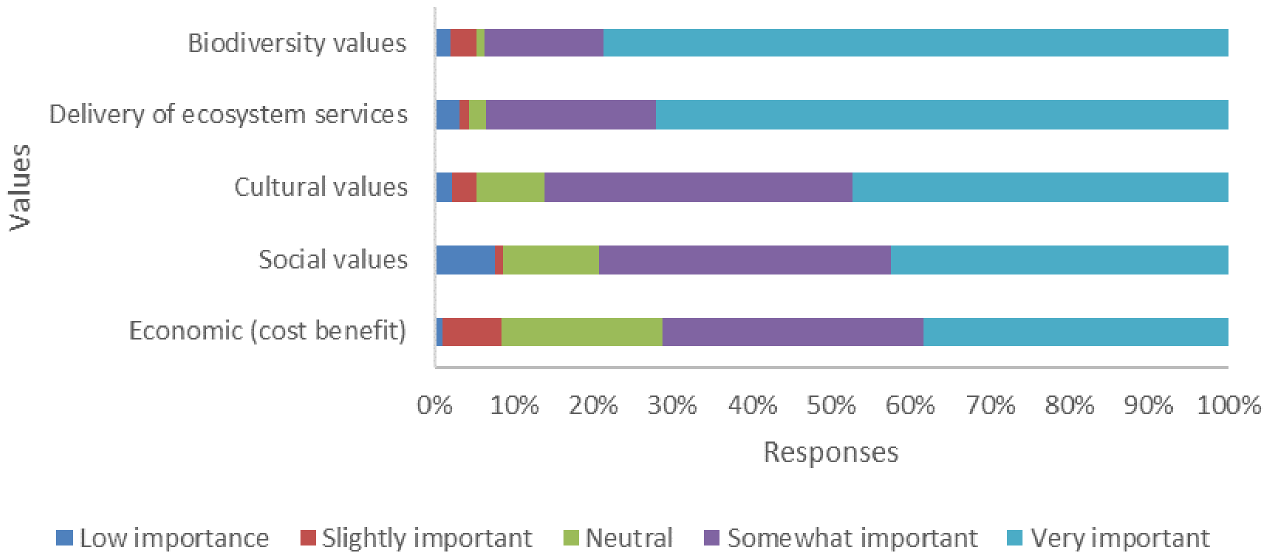


Figure 14: Values prioritised by survey participants when undertaking coastal and marine ecosystem restoration

Q16 - Has your organisation experienced any of the following barriers in planning for or implementing coastal or marine ecosystem restoration? Please rank from never (1) to always (5)
(94 responses)

Funding opportunities and timelines were reported most commonly as *very often* and *always* barriers to coastal and marine ecosystem restoration (Figure 15). The next most common barriers (*very often* or *always*) were legislation, cost-benefit analysis, lack of support by decision makers, and lack of publicly available evidence base. This question included a category for other, where some participants provided more specific details about the barriers issues encountered.

Emphasis placed on Approvals, particularly the cost and time it takes. Approvals and permits criteria often not adequately designed to facilitate restoration activities.

Lack of support by stakeholders outside the organisation and lack of stakeholder support were less commonly encountered.

Net environmental gains from coastal or marine ecosystem restoration are generally cultural and ecosystem positive, which reduces conflict.

Gaps in the evidence base for restoration were reported by ~70% of respondents *sometimes*, *very often* or *always*:

We're interested in the ability of restored shellfish reefs in South Australia to address on-shore coastal erosion issues but there is insufficient evidence at this stage.

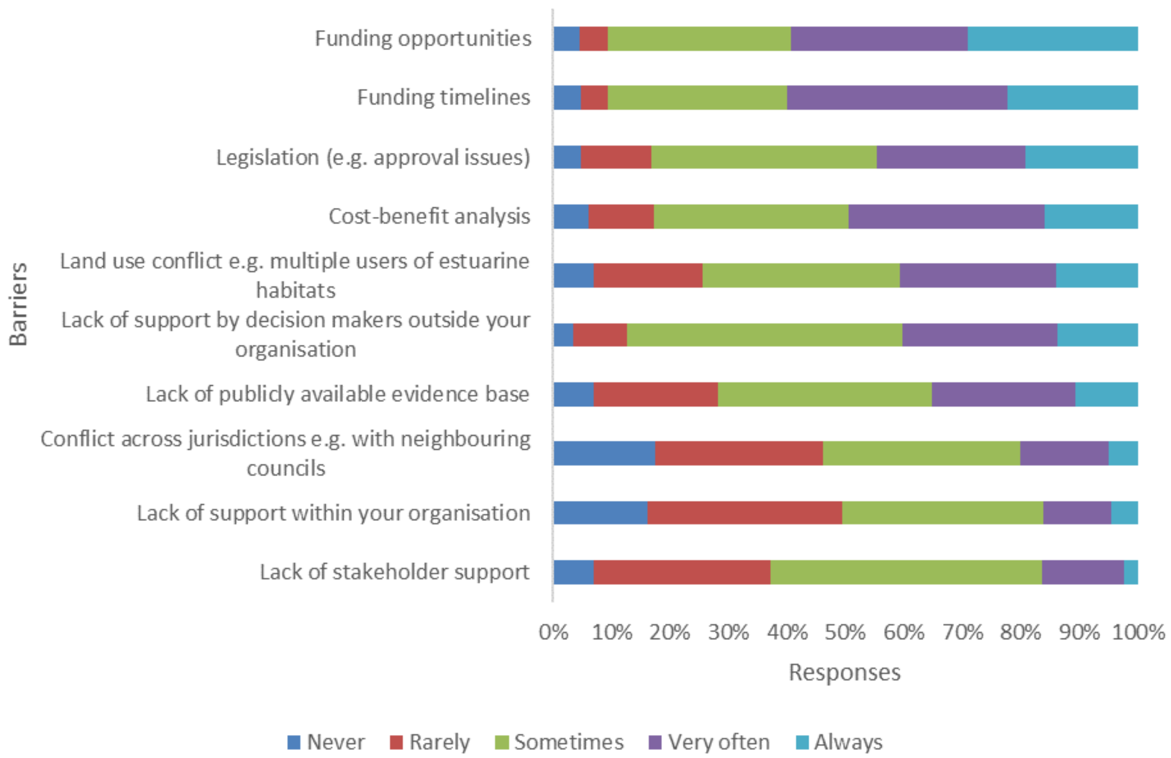


Figure 15: Barriers encountered by survey participants when undertaking coastal and marine restoration

***Q17* - If you are undertaking or planning to undertake a coastal or marine ecosystem restoration project, have you considered a monitoring process in place to measure the following direct or indirect outcomes? Select all that apply.**
(92 responses)

Most respondents are considering a monitoring program (85 out of 92) (Figure 16). *Ecological outcomes* are most commonly monitored, followed by *social*, then *cultural outcomes*. The research community is more likely to be monitoring novel methodologies such as *carbon sequestration* compared to other organisations. Government respondents are monitoring across a range of outcomes, including engineering, ecological, cultural and social. Respondents identified barriers for monitoring such as constrained funding, particular for long-term monitoring, and information on the best approaches for monitoring social/ cultural outcomes as well as carbon sequestration.

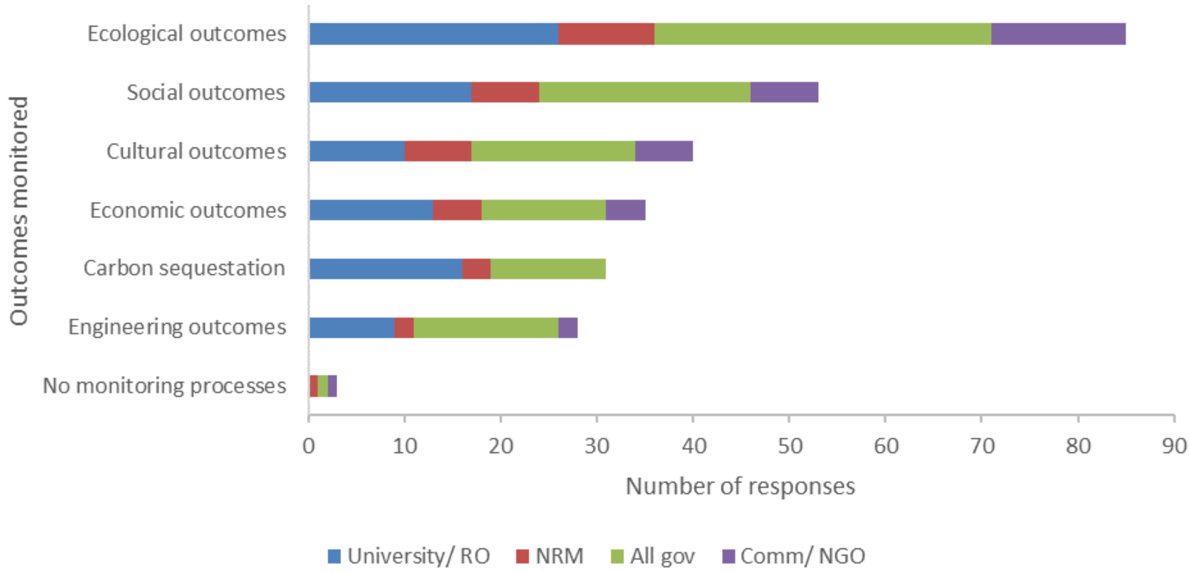


Figure 16: Types of monitoring considered by survey participants to measure direct and indirect benefits of coastal and marine ecosystem restoration by categories; university and research organisation, NRM groups, all governments, community groups and NGOs.

4.3.2.4 Climate Change

Q18 - What climate change stressors should be considered when planning and implementing a coastal or marine ecosystem restoration project? Rank from rarely (1) to always (5)
(93 responses)

Sea-level rise is the climate stressor most frequently considered in coastal and marine restoration; it was considered *very often* or *always* by 77 out of 93 respondents (Figure 17). Increase in extreme weather is the next most commonly considered climate stressor, followed by increased average and extreme temperatures.

Ocean acidification and increase in bushfires were the two least commonly considered climate stressors, with five respondents noting increase in bushfire as not applicable. Research following the 2019/2020 bushfires shows significant increases (up to 200% higher in the first year following fires and 27% in the second year) in sedimentation loads from upstream erosion (Biswas et al., 2021).

Sedimentation can affect light availability for photosynthesising marine vegetation such as seagrass, kelp and macroalgae. Metals and other toxicants stored in upstream vegetation and soil and carried in sediment also have potential to impact on shellfish reefs. There has already a significant increasing trend in the number of dangerous fire weather days, particularly in southern Australia, and that these fires affect saltmarsh and mangroves in NSW (EPA, 2021).

One respondent identified increasing significant wave height and changes in wave direction as a climate stressor, which will impact on and modify coastal processes.

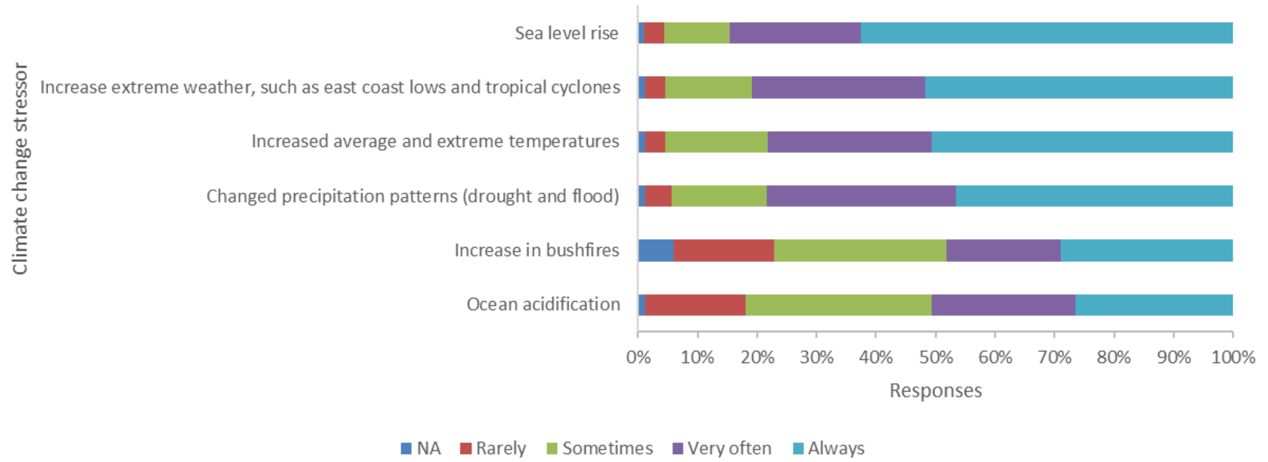


Figure 17: Climate stressors considered by survey participants in coastal and marine restoration

Q 19. How do you explicitly consider and plan for impacts of climate change on the restoration work, for example, selection of heat tolerant species, space to migrate with sea level rise? (62 responses)

This was an open-ended question. In Table 3, we interpret how the climate change impacts are considered by survey respondents within a climate vulnerability assessment and adaptation planning framework. This includes considerations ranging from identifying the climate impact (previous question) to assessing the vulnerability and risk using the climate change information and identifying adaptation measures.

The full set of responses for this question can be found in the corresponding dataset in eAtlas.

Table 3: Climate change impacts considered in restoration projects

Climate change vulnerability/ risk assessment stage	Actions
Assess the vulnerability	climate change vulnerability assessment for Ramsar listed wetlands. We need more information on specific cc adaptation options flood study overlays and predicted flood/storm water levels species requirements e.g., sand particle size, structure height requirements in relation to sea level rise, site drainage impacts, species migration paths/ settlement areas e.g., corals.

Climate change vulnerability/ risk assessment stage	Actions
	considering biophysical attributes and comparing them with the predicted biophysical attributes- and predicted changes in processes for a better understanding of climate change behaviours of ecological systems current and future areal extent of habitats, tidal zones. Future hydrological conditions e.g., riverine flow periods, water permanency in wetlands and riverine systems. Changes to these conditions are factored into restoration works by selecting sites with adequate buffers in water availability, habitat extent etc so that future conditions are less likely to result in critically deleterious conditions restoration work in collaboration with university experts and Traditional Custodians to ensure that the pre-design and scope considers climate and other impacts sea-level-rise investigations to plan for future impacts and using the full range of adaptation options available to us (avoid, protect, retreat) etc. local scale modelling of sea level rise, species selection & tolerance range, options for mitigating upstream effects, input from flooding etc barriers to migrate with sea level rise as often the land directly adjacent is occupied by another use, even if that is largely an abandoned use, coastal land value result in high expectations of landowners
Translate vulnerability to risk	planning processes involve improved elevation data for sea level raise planning attempt to buy back land that will be impacted by sea level rise or by flooding. site choice working well within known tolerances of organisms that are within the bounded climate forecasts modelling of key environmental/ecological parameters across relevant climate change stressors - assessment of appropriate nature-based engineering options - risk analysis and mitigation (environmental, socio-economic and cultural factors) consider space to mitigate sea level rise; geomorphological modelling to determine windows of opportunity
Adaptation planning	restoration activities to support coastal dune stabilisation selection of sites that show higher resilience, selection of heat-tolerant species, selection of sites where restoration efforts can be integrated within other management strategies (e.g., MPAs, watershed management) preventative actions e.g., coastal plantings to reduce erosion, land use planning to prevent development in the coastal zone etc works planning incorporates climate change migration pathways for biodiversity and vegetation species selections based on both current and potential EVC species; project setbacks to allow for migration/coastal squeeze adaptation inland retreat of coastal vegetation communities, expanding the width of riparian vegetation to tolerate potential increased (and less frequent) rainfall events beneficial interactions (e.g., with microorganisms) to enhance resilience to multiple stressors and minimise trade-offs opportunistic land use changes and acquisitions

Climate change vulnerability/ risk assessment stage	Actions
	selection of heat tolerant species (we hope), developing restoration techniques to respond to climate impacts (e.g., cyclones), shading to cool, beach restoration (to respond to impacts of sea-level rise/erosion) identification of genotypes that are tolerant to stressors maintenance of plants is included in project planning, such as additional watering. some work on marine turtle nesting areas has included protection of nests from heat (shading) and additional monitoring. adaptation of major habitat formers that are threatened through population genetics than most programs. creation of thermal refuge targeted pest control to reefs with thermal resilience that are well connected to other reefs, local currents, tides etc for local restoration, selection of thermally resilient stock future proof breeding habitat against heatwaves, predict future foraging areas at sea until 2100 under different scenarios of climate change

4.3.2.5 Future research needs

Q20: How could future research help you in your decision making around where and how to restore coastal and marine ecosystems? Select all that apply.
(89 responses)

Habitat suitability modelling and improved methodologies for ecosystem valuation and on-ground works were the most commonly identified research need, reported by two thirds of respondents (Figure 18). NRM and community/ NGOs had a slightly higher relative need for research on improved methodologies, ecosystem valuation, and on-ground works compared to case studies and habitat suitability modelling.

Improved access to socio-economic data was identified as the least important research need (38% of respondents). Decision support models had been identified by the research team as an important future research direction; however, these were not as widely required by survey respondents as anticipated (45% of respondents). Some of the highly desired research areas, including ecosystem service valuation, habitat mapping, and restoration suitability modelling are all precursors to decision support modelling.

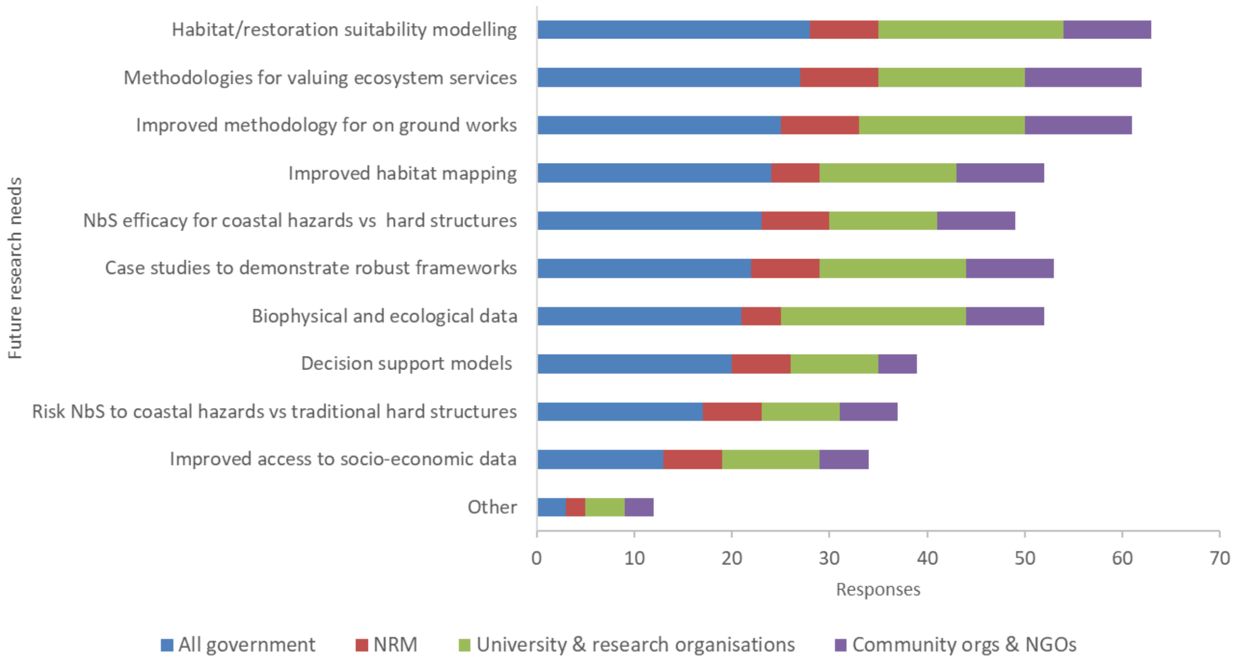


Figure 18: Future research needs of survey participants by organisation type; all government, NRM groups, university and research organisations, and community groups and NGOs.

4.3.3 Questions about nature-based methods for hazard risk reduction

The following questions are specifically focussed on nature-based methods for hazard risk reduction. For instance, through the restoration, creation, or modification of coastal habitats. NbS projects may encompass ecosystem restoration, for instance, restoration of mangroves to provide shoreline stabilisation. They may also include 'building with nature' type approaches such as sand nourishment of beaches, or the installation of new habitats in places where they did not previously occur. The latter use features of nature to achieve coastal hazard protection. They provide ecological co-benefits over hard infrastructure but are not explicitly designed for the end-goal of ecological restoration.

Q21 - Is there support and interest in implementing nature-based solutions in coastal and marine ecosystems for shoreline protection within your organisation? (91 responses)

Ninety-five percent of respondents answered yes. The interest in applying NbS appears to be strong across habitat types (Figure 19), although some caution is recommended in interpreting the values of yes vs no among habitat types as the survey was not specifically designed to interrogate responses by habitat type. Broadly speaking there is support among groups working across all habitat types.

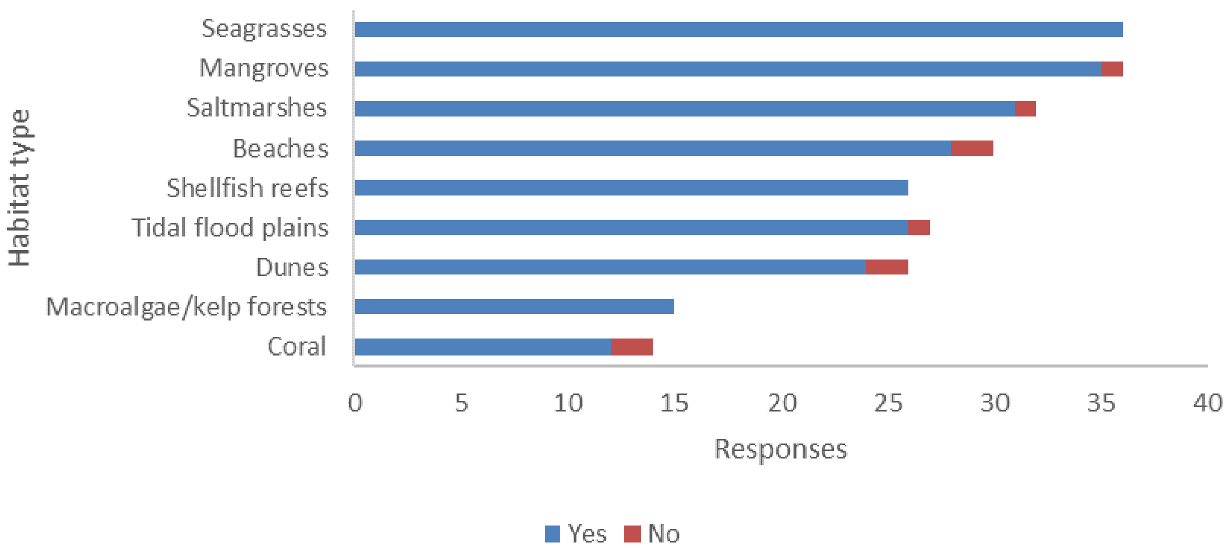


Figure 19: Organisational support for implementing NbS in various habitat types.

Q22 - Is your organisation currently applying nature-based solutions for coastal defence in coastal and marine ecosystems? (90 responses)

Sixty percent of respondents reported that their organisation is currently applying NbS in coastal and marine ecosystems (Figure 20). The majority of NbS projects are being undertaken by government (100% of local, 50% of federal and 61% of state government respondents).

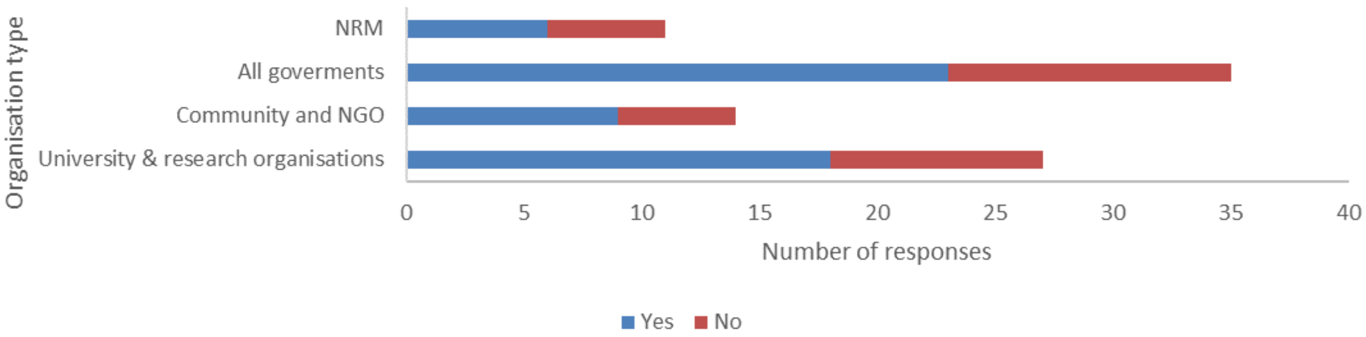


Figure 20: Organisations currently applying NbS for coastal hazard protection

Q23 - What are the perceived benefits and co-benefits of nature-based solutions? Rank from very low (1) to very high (5) (86 responses)

Of the benefits and co-benefits of NbS, biodiversity was rated as *very high* by the largest number of respondents, and *very low* or *low* by the smallest number of respondents (Figure 21).

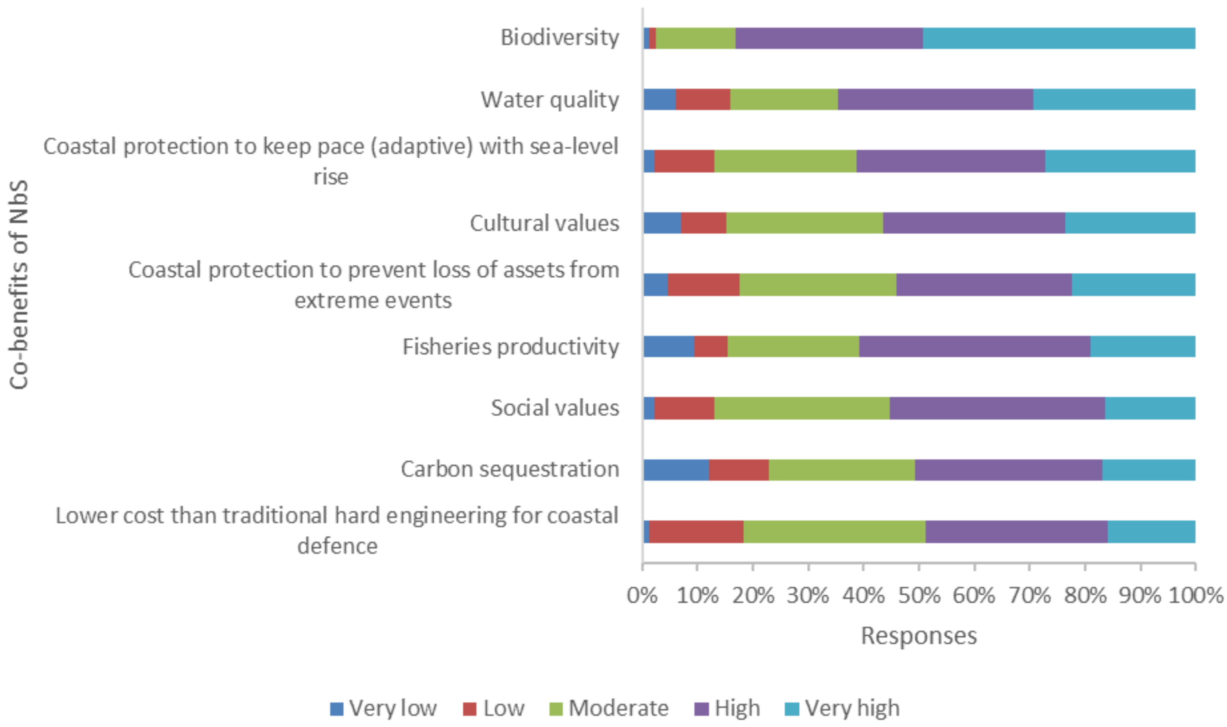


Figure 21: Perceived benefits and co-benefits of Nature-based Solutions.

Q24 - Do different environmental contexts change your perception of risk in applying nature-based solutions for coastal defence? Rank likeliness to implement nature-based solutions for coastal defence in the following shoreline environments from 1) very likely to 5) very unlikely to implement.
(84 responses)

Within each organisation type the environmental setting does not have a strong influence on the likelihood that NbS would be applied, with the exception respondents from research organisations who were relatively less likely to apply NbS in exposed coastal waters compared to other settings (Figure 22).

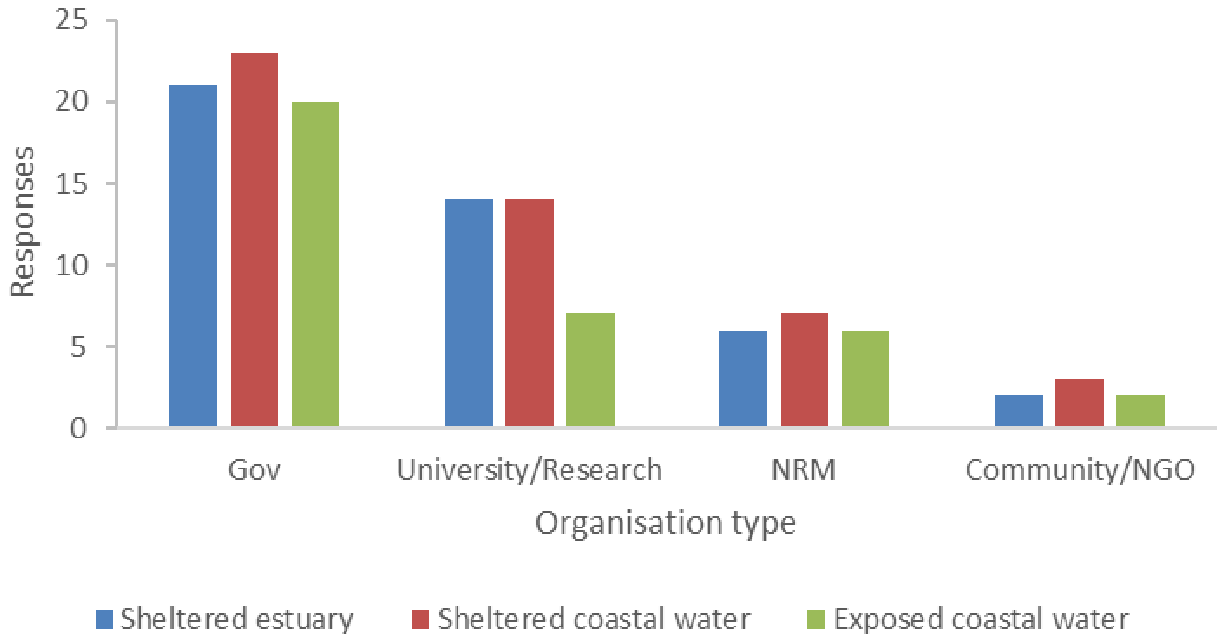


Figure 22: Number of respondents who are likely-very likely to apply Nature-based Solutions for coastal hazard protection in three environmental contexts (sheltered estuary, sheltered coastal water and exposed coastal water) by organisation categories (community groups and NGOs, NRM groups, university and research organisations, all governments).

5 Results of the Aboriginal and Torres Strait Islander Engagement Activities

Section Lead: Mibu Fischer

5.1 Key points

- Aboriginal and Torres Strait Islander people are interested in activities occurring within their Sea Country.
- They also would like to be involved in on country activities conducted by non-Indigenous organizations and governments.
- There is desire for earlier and more meaningful engagement with Aboriginal Torres Strait Islander people in coastal and marine restoration activities, for instance through co-design of projects.

5.2 Background Information

It is becoming widely accepted and known in western science systems that Aboriginal and Torres Strait Islander peoples have intricate understanding of the marine and coastal environments that are embedded within their knowledge systems and protocols, enacted through cultural and lifestyle practices (Fischer et al., 2021). This connection often means they are the first communities to be impacted from changes to climate. The knowledge held by Aboriginal and Torres Strait Islander peoples is seen through their lens which is an alternative worldview than that of western scientific practices (Fischer et al., 2021) (Figure 23). As identified by Tuhiwai Smith (L. T. Smith, 2012), the dominant system of knowledge sharing (written practices) struggles to understand and continually questions the validity of Traditional Knowledge (also referred to as Indigenous Knowledge).

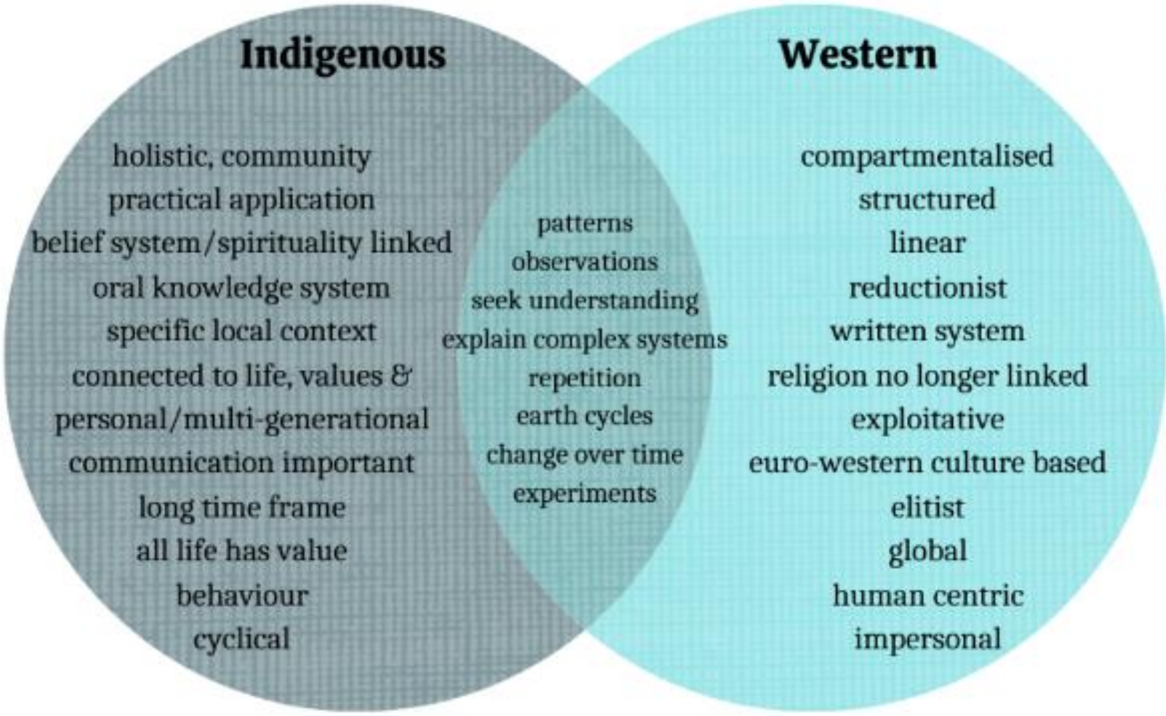


Figure 23: Comparisons of Indigenous and Western Worldviews. Whilst these systems are different, there are many similarities between the different versions of information sharing (Fischer et al. 2021 p.6)

Indigenous People worldwide are considered rights holders, and have the right to self-determination, autonomy, expression of culture and governance processes and have the right to revitalise cultural traditions and protocols. They also have the right to decision-making processes that impact on their other rights. These plus many more rights have been acknowledged and adopted by the United Nations General Assembly on 13th September 2007. They are outlined in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP 2007), which Australia is signatory to. The UN General Assembly has also declared the Decade of Indigenous Languages 2022-2032, with language and ecosystem knowledge intrinsically linked to the importance of supporting Aboriginal and Torres Strait Islander communities to restore Sea Country.

In addition to UNDRIP the following instruments also exist that can assist Indigenous People in having a voice for Country when working with researchers and practitioners:

- Our Knowledge, Our Way Guidelines
- IUCN – Global Indigenous Agenda for the Governance of Indigenous Lands, Territories, Waters, Coastal Seas and Natural Resources
- International Covenant on Economic, Social and Cultural Rights

- Convention on Biological Diversity – Article 8 (j)
- And many more.

With the above in mind, it is a necessity that any framework involving environmental resources include Indigenous voices. Whilst there have been examples amongst practitioners and researchers of engaging with several Aboriginal and Torres Strait Islander communities in restoration activities (see section 7 Case studies), little has been gathered at a national, state, or regional level specifically to understand Indigenous aspirations, barriers, and challenges to participating in coastal and marine restoration. The present section attempted to start scoping these issues in a targeted approach to understanding the status of engagement, or lack thereof, with Aboriginal and Torres Strait Islander peoples with respect to coastal and marine ecosystem restoration activities.

5.3 Results of Online Survey to Traditional Custodians

5.3.1 Location, ecosystem, scale, and motivation for restoration activities

Queensland, Tasmania, and South Australia were the states in which the respondents worked, and the habitats identified as areas of interest for restoration were seagrass, mangroves, saltmarsh, kelp, coral reefs, shellfish reefs, beaches, dunes, and tidal flood plains (Figure 24). The scale of these activities was mostly regional or local. Caring for Country was identified as the most important reason for restoration by all of the respondents.

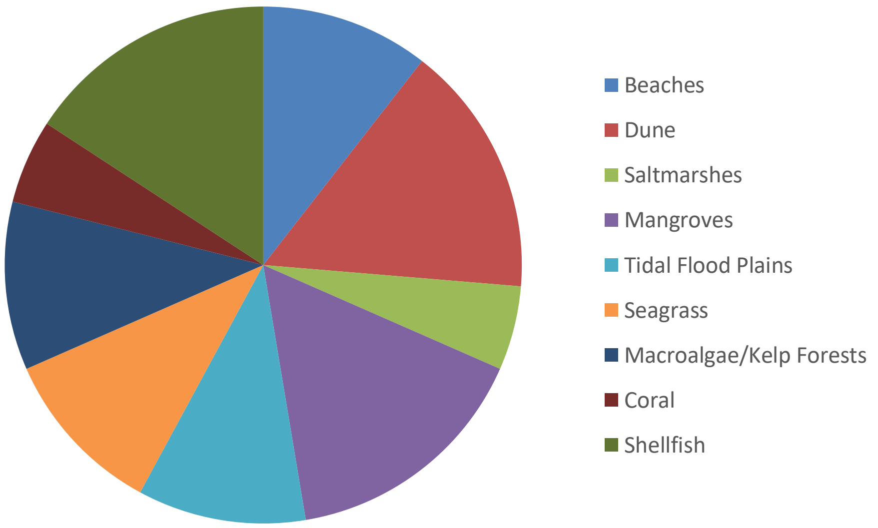


Figure 24: Sea Country habitats of interest to Traditional Custodians respondents for restoration activities

Experiences with researchers and practitioners

When it comes to working with restoration researchers and practitioners and what they can do better, the same sentiment was mentioned by 3 out of 5 complete responses: listen to the needs of Traditional Custodians before starting the project design. The respondents commented in particular:

> My roles have often segregated 'science and restoration' and 'First Nations Engagement' as two separate aspects. This does not allow for complete workflow and holistic system understanding. – Traditional Custodian1 (online survey)
>
> Engage with Traditional Owners and listen to their needs and priorities to care for country. – Traditional Custodian1 (online survey)

> Listen, observe be patient, be involved with the community long term – Traditional Custodian3 (online survey)

5.3.2 Current Engagement

Current engagement with respondents appeared to be in the form of mixed management arrangements, with universities being the most common organisation for respondents to have some type of co-management arrangement.

For Question 14 (*In regard to engagement by coastal and marine ecosystem restoration practitioners and researchers how do you feel about the following*) respondents were asked to grade a number of statements from 1 (not at all) to 8 (in every way) (described in Appendix A, and in Figure 25 below). Of the 5 statements listed, none of the respondents graded any questions above a 3 on the scale, with 'Traditional Custodian engagement feels genuine' the worst graded being perceived as not at all (1) by all respondents, bar one (Figure 25).

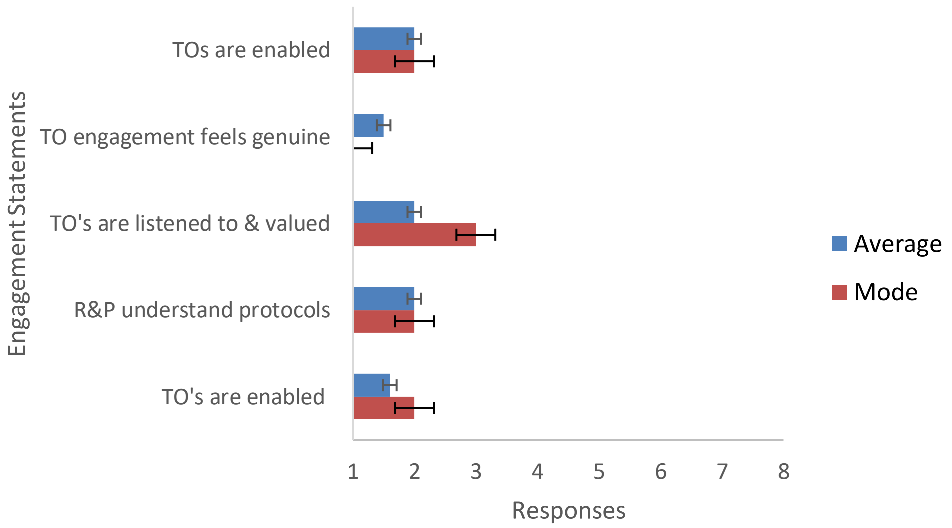


Figure 25: Perceived engagement of Researchers & Practitioners (R&P) by Traditional Custodian (TC) respondents, marked on a scale of 1-8, where 1 is not at all and 8 is in every way (with Standard Deviation bars)

5.3.3 Challenges with engagement – Traditional Custodian Perspectives

The main challenges raised by the survey respondents were a lack of understanding of local protocols and history, lack of discussion throughout the project lifespan, and general lack of engagement. In addition to the challenges identified by respondents, Question 16 asked respondents to rank challenges from most challenging to least (Figure 26).

Figure 26: Challenges to restoration for Traditional Custodians (where 1 is least challenging, and 8 is most challenging)

Formal agreements between researchers/practitioners and First Nations groups are desired, as are identifying mutually beneficial or shared objectives.

> Lack of engagement/discussion throughout research to update industry and TO's of progress. – Traditional Custodian1 (online survey)
>
> They need to enter into agreements with us before the project starts particularly what outcomes are to be achieved by the project – Traditional Custodian3 (online survey)

Respondents identified that limited funding opportunities were seen as a barrier by Traditional Custodians, along with resource difficulties, capability of staff members and existing restoration projects by non-Indigenous groups (Figure 27).

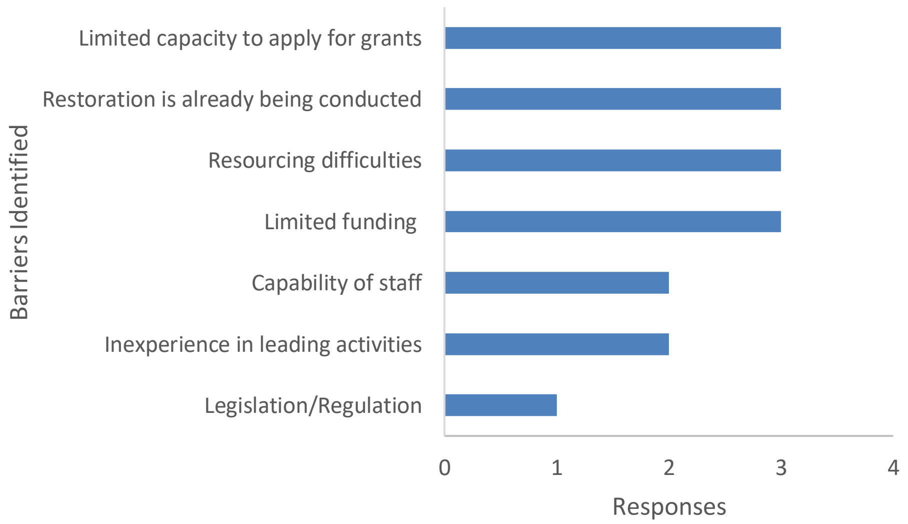


Figure 27: Barriers Identified by Traditional Custodians to Sea Country restoration activities

5.3.4 Capacity, capability, and restoration processes

Reported capacity and capability was highly variable, with responses of 1,4,5, and 8 from the 4 people who answered this question. This suggests a wide variety of capacity in different organisations and communities in relation to restoration activities. Future research could work to identify what the drivers of that variability include, for instance, whether it related to the presence of ‘champions,’ policies, or training programs, for example. This is important, as it would facilitate the implementation of programs aimed at increasing capacity.

Only 1 respondent was aware that restoration practices went through a permitting process, and they expressed the view that Traditional Custodians were not a part of the process.

Respondents were asked how researchers/practitioners could assist in increasing capability of Traditional Custodians, with a range of options presented. The most preferred method identified was for more funding to conduct their own restoration practices. This was followed by training in monitoring, funding to employ more Traditional Custodians to participate and inclusion across multiple project components (Figure 28). The least preferred method was inclusion in reports.

Figure 28: Median preferences ranked, (where 1 is most preferred and 7 is least preferred activity), for capacity/capability building with the help of Researchers & Practitioners.

Finally, respondents were asked what they think should occur to move forward with restoration that involves Traditional Custodians. A general theme emerged that there is a need for structures to coordinate and communicate with communities. For instance:

> Regular reporting back to communities through a designated site as to what is happening in this field – Traditional Custodian2 (online survey)
>
> Create a traditional national body, employing staff to monitor, adapt, create, and deliver programs and projects in a ‘train the trainer’ motif so local communities can be grouped and coordinated and continuously updated and trained in sea country protection, advocacy, and healing – Traditional Custodian3 (online survey)

5.4 Literature Review

The overall synthesis from the literature was that there were limited examples of best practice co-design or collaboration with Aboriginal and/or Torres Strait Islander communities. After an initial search, 11 articles (Table 4) were used to determine status of restoration activities, engagement, frameworks, and methods with Aboriginal and Torres Strait Islander communities in Australia. A word cloud was produced to identify common words across the literature, from this quick breakdown it is seen that whilst the records identify Indigenous and restoration as the most repeated words, the use of co-design, collaboration or co-led are not immediately present (Figure 29).

Table 4: Identifying records used in final literature review thematic analysis

Citation	Type of Article	Habitat	TC involvement	Content Summary
(Austin et al., 2017)	Case Study/Evaluation	Mixed (Land & Sea)	Uunguu Monitoring & Evaluation Committee for Wunambal Gaambera Healthy Country Plan - Authors, collaborators (Kimberley)	Case study on how committee has integrated western and indigenous science at a local level together. Bottom-up approach.
(Dobbs et al., 2016)	Case Study	Wetlands	Kimberley	Collaborative research using both western and Indigenous science and knowledge. Formed base for management plans.
(Ford & Hamer, 2016)	Desktop analysis	Shellfish reefs (Victoria)	None, TC perspectives were included via European historical records	Analysis of decline of shellfish reefs using historical records.
(Gibbs, Gibbs, Newlands, & Ivey, 2021)	Discussion	Coral reefs	Co-author	Ecological imperialism of coral reef restoration in tropics
(I. McLeod, Schmider, Creighton, & Gillies, 2018)	Guest Editorial	Shellfish Reefs	Author & workshop attendees (NZ, Narungga, Mamu, Woppaburra, Yawaalaraay, Bunya Bunya,	Traditional Custodian Shellfish Reef restoration workshop – 7 Pearls of Wisdom, on engagement with

Citation	Type of Article	Habitat	TC involvement	Content Summary
			Quandamooka, Joondoburri & Kabi Kabi)	Traditional Custodians in shellfish reef restoration.
(Murley, Grand, Prince, & Rangers, 2022)	Case Study	Karajarii Protected Area, south-west Kimberley Region, Western Australia	Collaborative partnership – Karajarii Rangers & Bidyadanga community (authors, investigators, interviewers) (Kimberley)	Monitoring and evaluation methodology that appropriately included Traditional Custodians.
(Pyke, 2021)	Case Study	Wetlands	Authors, collaborators (Kimberley)	Multiple Evidence Based approach to TO inclusion in management, monitoring and evaluation. Also, rehabilitation of wetlands by these communities.
(Robinson et al., 2021)	Opinion/Discussion	Land & Sea	None identified	Opinion piece on the need for restoration activities to include Indigenous People and not just extract Traditional Knowledge exacerbating further inequalities.
(Tan et al., 2020)	Review	Seagrass	None identified	Identified gaps in seagrass restoration processes in Australia & New Zealand, with recommendations for Traditional Custodian engagement.
(Thurstan et al., 2020)	Desktop analysis	Oyster Reefs (QLD & NSW)	None, historical records were used for Traditional	Archival records analysed to produce understanding of the decline of

Citation	Type of Article	Habitat	TC involvement	Content Summary
			Custodian information.	oyster reefs in QLD & NSW regions.
(Tran, Ban, & Bhattacharyya, 2020)	Review	Land & Sea	None specified	Review of worldwide literature on Indigenous Protected & Conserved Areas and Indigenous Protected Areas (within Australia)

Figure 29: Word Cloud depicting most frequent words across 11 records used in the literature review

Looking at barriers within the literature there were numerous regarding inclusion, the most common were related to epistemological barriers and misunderstandings around worldviews and Indigenous Knowledge creation and transfer with a total of 46 references to the two themes across the records.

A large barrier of the literature is that 5 articles omitted the inclusion of Aboriginal and/ or Torres Strait Islander peoples however referred to Traditional Custodian practices/knowledge/history and used European historical accounts of Traditional Custodian practices with Sea Country. Whilst many coastal landscapes have changed dramatically in the past 200 years it does not directly mean that there is no current Traditional Knowledge or that Traditional Custodians should not be engaged/included in existing or new restoration projects.

Written case studies have frequently been called for by researchers and practitioners, only 4 of 11 articles were identified as case studies (Austin et al., 2017; Dobbs et al., 2016; Murley et al., 2022; Pyke, 2021). These case studies were all located in the same region, had crossovers with habitat type and communities engaged.

5.5 Synthesis of components

During the informal discussions with several Aboriginal and Torres Strait Islander groups and individuals, it was understood that inclusion in restoration practices is desired. However, being able to shape the narrative and for the restoration to be on terms with local objectives, aspirations, and protocols is highly desired. To understand the process involved in appropriately including and co-designing restoration methods with Aboriginal and Torres Strait Islander peoples more time is needed at the beginning of project timelines to adequately build relationships with communities, to enable feelings of genuine engagement, identified in the online survey as something that is currently lacking.

5.5.1 Challenges

The survey and review both identified several challenges for Aboriginal and Torres Strait Islander peoples when it comes to conducting, co-designing, and working with researchers and practitioners in restoration of coastal and marine ecosystems (Table 5). One overarching challenge is a need for funding to conduct adequate knowledge brokering activities specifically in relation to Aboriginal and Torres Strait Islander peoples' aspirations when it comes to restoration of Sea Country. Survey respondents expressed that national, state, and local government regulations were of little challenge to them when working on Country, this contrasts with the challenges identified in the National Survey and Workshops (see *National Survey and Workshop content*).

Inadequate time to incorporate appropriate engagement was identified in 5 records. Dobbs et al. (2016) identified that due to timing and funding constraints choices were made about where to include Nyul Nyul Traditional Custodians in the project process. The issue of where to focus attention due these limitations is difficult for many researchers and for Aboriginal and Torres Strait Islander peoples, communities and organisations.

In the National Online Survey 4 out of 5 respondents stated that they had Aboriginal and Torres Strait Islander peoples' involvement in their restoration work. However, this is not reflected in our literature search. This leads to challenges identified in several of the records that more case studies where successful co-design and co-research has been conducted need to be co-reported/published so other restoration practitioners, researchers and academics can follow similar project design.

Table 5: Various challenges identified from Traditional Custodian respondents and literature review, with key messages extracted

	TC Online Survey	Literature Review	Key Message
Methods	NA	Approaches to strengthen meaningful and appropriate synergy of both western and Indigenous science is wanted.	There are limited methodologies for inclusion of Indigenous science and communities in coastal and marine restoration.
Resourcing	Capacity to have the resources within communities is limited. Small number of people being asked to contribute to many areas of science/management.	Timing has been a challenge for numerous researchers.	Researcher decisions on where to focus resources for Traditional Custodian engagement has influenced how engagement has previously been conducted. In addition, Traditional Custodians are currently limited by funding, training, and the sheer number of researchers reaching out for engagement.
Respect for TK & TCs	Lack of respect/ understanding of Traditional protocols and knowledge.	Unsure of how to include TCs, so the choice is to not.	There is a general lack of understanding the importance of why Traditional Custodians should be included. There is also a general lack of knowledge by researchers & practitioners on how to engage respectfully via cultural protocols with communities.
Timeframes	Inadequate timeframes for proper inclusion from	Funding timeframes for participation was	Western system timeframes (whether through funders or

	Traditional Custodians was identified as one of the major challenges by respondents.	difficult in examples, but favour for culturally appropriate inclusion found that proper timeframes allowed for better engagement, participation and overall collaboration between researchers and Traditional Custodians.	research bodies) are too narrow for genuine relationship building and inclusion of Traditional Custodians in restoration.

5.5.2 Barriers

There are many barriers identified from the literature and survey, some of these overlap with each, with barriers identified in the literature more prominent than what was identified in the survey (Table 6). A limiting factor that researchers can collaborate with communities to overcome is a lack of case studies available in the literature. With limited examples on how to undertake inclusion, researchers, practitioners and Aboriginal and Torres Strait Islander peoples and communities must seemingly start from scratch each time a restoration/co-management activity is proposed. From the informal conversations similar barriers were discussed, particularly in relation to appropriate funding to pay for the time and services of knowledge holders. Moving forward, funding is needed for inclusion from the start of the project. Aboriginal and Torres Strait Islander peoples would like to be brought on as co-partners during project conception.

Table 6: Various barriers identified from Traditional Custodian online survey and literature review, with key messages extracted

	TC Online Survey	**Literature Review**	**Key Message**
Epistemology	Traditional Custodians feel that western science researchers do not understand their knowledge, practices, and protocols.	Differences in knowledge systems and published restoration and resource principals inhibits support of TCs to participate in on Country activities. Indigenous Ranger Programs also emphasise western science techniques in management.	Epistemological barriers heavily influence the way Traditional Knowledge is included in restoration activities.

	TC Online Survey	Literature Review	Key Message
		Researchers/practitioners unsure how to start engagement with communities. Connections to Country and what that means to communities about activities and governance conducted in various locations.	
Colonial Systems	Respondents felt that colonial systems and ways of thinking were impacting the inclusion of Traditional Custodians in restoration activities.	Colonial system prevents the continued management of Country by Traditional Custodians Some areas may not appear to have any Traditional Custodians when reading European historical accounts/looking at available online information.	As expected, colonisation impacts, in addition to epistemological barriers, influence the ability for meaningful inclusion by Aboriginal and Torres Strait Islander peoples.
Funding	Unsure how to apply for funding or write grants that are successful. Limited funding available for TCs to participate in these activities on Country.	Funding for Traditional Custodians has come from other Traditional Custodian pathways (through ranger funding or IPA programs). It is recognised by several researchers that payment is needed for Traditional Custodians to participate.	Funding is an issue when it comes to participation in restoration by Aboriginal and Torres Strait Islander peoples in the form of funding from research projects to pay participation OR funding directly available to communities to conduct their own restoration.
Methods	NA	Uncertainty of what methods work to appropriately engage TCs. Uncertainty of how to utilise TK in restoration practices	Methods on how to include Traditional Custodians in research are unclear to researchers and practitioners.

	TC Online Survey	Literature Review	Key Message
Frameworks	Indigenous Land Management, Indigenous Protected Areas and	Multiple Evidence Based approach was used in a case study – knowledge negotiation 7 Pearls of Wisdom – how to appropriately engage with Traditional Owners in shellfish reef restoration	A few frameworks have been used/developed to address how to include Traditional Knowledge and Indigenous Science in restoration, however the application has been sparse with limited case studies.

5.5.3 Gaps

Several gaps can be recognised when looking at the challenges and barriers. Case studies, methodologies, and frameworks to guide researchers on how best to include Traditional Knowledge are currently only available in very few habitat and governance types. Examples of how to challenge the current western systems of restoration, along with cultural competency training to increase understanding of Aboriginal and Torres Strait Islander peoples history, protocols and worldviews have not been identified to researchers and practitioners. Understanding of Aboriginal and Torres Strait Islander peoples aspirations is another gap that exists for researchers and practitioners, with different groups at varying stages of readiness to adequately be involved in restoration activities.

To assist in reducing these gaps one of the Indigenous Land & Sea Management Units are taking the idea of restoration with practitioners and researchers to their research committee for further discussions to take place between the wider organisation and the project team, for potential future collaboration across a range of restoration practices in habitats ranging from beaches, seagrass, mangroves, and oyster reefs.

5.6 Recommendations

From the key messages the following recommendations are suggested to further develop and understand how to appropriately include Aboriginal and Torres Strait Islander people, knowledge, culture, and practices in coastal and marine ecosystem restoration.

- Undertake a larger and more in-depth participatory process with Aboriginal and Torres Strait Islander peoples, with an appropriate timeframe, to understand aspirations
- Create a 'hub'/resource that practitioners and researchers can access, as well as Traditional Custodians, when wanting to conduct restoration activities
- Publish of successful case studies with Traditional Custodians, to enable more researchers and practitioners to feel comfortable in engaging and working with alternate knowledge systems

- Cultural competency, awareness and protocol training is needing to be provided by institutions, governments, and universities to staff members to increase their capability to appropriately engage with Aboriginal and Torres Strait Islander peoples and communities, (this also includes increasing Aboriginal and Torres Strait Islander employment statistics)
- Funding bodies need to allocate percentage of grant funding to be used for Aboriginal and Torres Strait Islander engagement, whether through collaboration, participatory development of design methods or through employment as project members.

6 Outcomes of workshops

Section Leads: Megan Saunders & Toni Cannard

6.1 Report: Science Workshop

Attendees: 30 participants from research organisations, local, state and commonwealth government, NRM groups, NGOs and community groups.

6.1.1 Workshop Theme & Background Information

The first science workshop for the project was held on 15 November 2021 in a virtual format. The theme of the Science workshop was "Structured-Decision Making and its application to coastal restoration and NbS for coastal hazard protection." SDM is an approach for careful and organized analysis of natural resource management decisions which is based in decision theory and risk analysis. Key features of SDM include: 1) clearly stated objectives; 2) a fixed budget and timeline; 3) realistic model(s) of the system, and 4) estimates of the costs, benefits, and feasibility of different actions. In marine ecosystems, SDM is often used in the design of marine protected areas, for example, using the conservation planning software Marxan. SDM approaches to prioritising restoration in terrestrial environments are emerging, for instance, to prioritise forest restoration actions in the Atlantic Forest of Brazil and globally (Brancalion et al., 2019; Strassburg et al., 2019). SDM is beginning to gain traction in the field of coastal and marine restoration (Gleason et al., 2021; Possingham, Bode, & Klein, 2015; Saunders et al., 2017). Although its application and uptake in the literature is relatively low to date (Lester, Dubel, Hernán, McHenry, & Rassweiler, 2020), practitioners may be using this general approach but not publishing the results [e.g., though uptake of the Restoration Opportunities Assessment Method (ROAM), (Laestadius et al., 2014)].

6.1.2 Science Workshop - Aims

The workshop aims were to gain insights into 1) how coastal and marine restoration planning decisions are currently made; 2) key challenges or barriers to using structured decision-making for restoration planning; 3) data needs for scaling up restoration from local to regional through to national scales, with emphasis on the ecosystem service of coastal protection.

6.1.3 Science Workshop - Presentations

In the first session, 3-5 min presentations were provided by the research end-users and the scientists. The research end-users were affiliated with Gold Coast City Council, QLD State Government Department of Environmental Science, and Wetlands Section in the Australian Government Department of Agriculture, Water and Environment. The objective of the end-user presentations was to articulate interests, perspectives, and areas of research interest with respect to coastal and marine restoration and NbS. The science presentations then communicated key areas of relevant research and intersecting expertise. Topics included Nature-based Solutions for coastal hazard mitigation, eco-engineering of Living Seawalls, coastal engineering, ecological modelling, and structured-decision making for ecological restoration.

6.1.4 Science Workshop - Discussions

The second and third sessions of the workshop were comprised of Group discussions in both plenary and breakout format. The aim of the discussions was to gain understanding about the applicability and limitations of using the Structured Decision-Making (SDM) framework to inform decision making in coastal and marine restoration. Some of the benefits of SDM that were recognised in the restoration context are: evidence-based, transparent, repeatable, facilitates stakeholder involvement in decision making processes, and lends itself to adaptive management. There were two main challenges to this framework identified. First, it may be difficult to acquire the relevant data and to develop appropriate models during the short timeframes that are often present to decision makers. Second, there is a need to adequately represent and convey risk and uncertainty. The first step in SDM is to develop clear objectives. Outcomes of a brainstorming session for potentially relevant goals and objectives for models of coastal hazard protection are found in Table 7**.**

Table 7: Goals and benefits from restoration for coastal protection, and how these might be quantified.

Goals	Objectives	Quantification
Coastal protection - mangroves provide flood mitigation	Reduce flood severity e.g., for 50 year to 100 year flood events	Assess the flood event frequency, incorporate SLR and sediment accretion. Also need to quantify performance given risk.
Coastal protection - mangroves provide protection from wave activity and storm surge	Protect a particular number of properties and infrastructure along the coast	Accretion of mangroves - reduced flood inundation - beach width expansion, physical expansion, wave run-up
Shoreline protection that minimises flood impacts	A particular number of people are protected from flooding	Estimate the number of people who would be flooded with and without mangroves

The next discussion focused on information needs to guide decision making across different spatial scales. This was intended to be a broad ranging and brain-storming discussion. Each level of government is responsible for allocating funding to restoration activities and due to the different spatial scales of those jurisdictions the information requirements differ – we provide examples next. The Australian Government makes decisions on where to allocate restoration funding at the national scale (e.g. The Blue Carbon Ecosystem Restoration Grants from 2021–22 to 2024–2) and must consider projects across large latitudinal gradients, diverse ecosystem types, and differing socioeconomic contexts. This raises questions such as should they invest in seagrass in one state, or mangroves in another? Should there be multiple ecosystem types funded, or just one? At the state level, for instance, the NSW Environmental Trust Environmental Restoration and Rehabilitation program likely faces similar issues although at a more regional scale. At the local scale, for instance, the City of Gold Coast must make decisions on the particular estuaries in which to invest rehabilitation funds. While there is still a heterogeneous landscape across which to decide on project allocation, the questions are less broad, and the data and models used to inform decision making can be of higher resolution.

6.1.5 Science Workshop – Key Findings

- There are currently no well-defined or clearly communicated ways to prioritise where, when and how restoration in coastal and marine environments takes place.
- Some end-users identified that, from their perspective, Structured Decision Making (or similar evidence-based approaches to resource management decisions) is a required step in guiding decision making or restoration.
- There are multiple spatial scales over which restoration decision making occurs, and the data needs to populate models vary across spatial scales (local, regional, state, national). There are currently challenges in accessing the data required for the development of SDM models. The ROAM (Laestadius et al., 2014) methodology could be modified and applied to guide coastal and marine ecosystem restoration prioritisation at state-national levels.
- Better data on the valuation of ecosystem services is required to guide decision making around restoration. We noted the recent publishing of the Ecosystem Services Valuation Database - Update of global ecosystem services valuation data; however, site and ecosystem specific data for coastal and marine ecosystems are not commonly available. Access to local data (or even regional scale data) on the valuation of ecosystem services would help with the cost-effectiveness and cost-benefit analysis to decide if the project is worth it (to convince funding agencies or organisations). However, some challenges are emerging here still around economists applying discounting factors on future ecosystem services, which could result in the current value of ecosystems being much lower until an evaluation of these services is completed.
- There are clear similarities among SDM and engineering frameworks to guide decision making for coastal defence, although the details and language differ somewhat.
- The development of SDM models must carefully consider and communicate uncertainty.
- There is interest in a spatially explicit mapping tool to help guide decision-making and the application of nature-based solutions for a coastal hazard risk mitigation. The development of this tool would need to be co-designed with multiple stakeholders.
- Despite limitations in data and model availability at the present time, a useful way forward is to use the SDM framework to guide thinking, conversations, and data collection.

6.2 Report: End-User Workshop

6.2.1 End-user Workshop - Information

An external End-user workshop was held on 16 November 2021 in a virtual format. Given that the project had only just commenced, we opted to invite external participants who worked in or who had interests in one jurisdiction (Queensland); however, participants identified that they conducted restoration in Queensland, New South Wales, Victoria and Western Australia (Figure 30). The 30 participants came from a range of different organisations, including Universities, Local, State and Commonwealth Governments, Natural Resource Management Groups, Community Groups, Private Sector, and Non-Governmental Organisations. It was recognised that any future workshops of this type would need to include/be held in all states and territories. The views presented in this workshop report are an interpretation and synthesis made by the project team and do not necessarily reflect the views of all the individuals in attendance.

Figure 30: Map of participants' restoration project locations with very brief description

6.2.2 End-user Workshop – Theme and Background Information

The theme of the workshop was to bring together diverse stakeholders in coastal and marine restoration and NbS to understand varying perspectives on this topic and to gain more detailed nuance on the responses to a subset of the questions of our National Scale survey **(Chapter 4**). Coastal and marine restoration and nature-based solutions are conducted by a diverse set of actors with differing backgrounds, perspectives, motivations and objectives. As restoration is a human endeavour there is a need to understand the motivations and objectives of restoration projects (Bayraktarov et al., 2020; Bayraktarov et al., 2019). Engagement of multiple stakeholders is one of the determinants to restoration success (Saunders et al., 2020; Statton, Dixon, Hovey, & Kendrick, 2012; Tan et al., 2020).

6.2.3 End-user Workshop - Aims

The aims of the workshop were 1) Bring together diverse end-users of research on coastal and marine restoration particularly, but not exclusively, those interested in shoreline protection ecosystem services; 2) Enable discussion of some questions in the nationwide survey (**Chapter 4**) which all participants were asked to respond to; 3) Understand how decisions are currently made on where (how & when) to restore coastal and marine ecosystems; and 4) Support a conversation of what information/data/models would help this decision-making.

6.2.4 End-user Workshop - Presentations

The workshop opened with 3-minute science presentations from the project team. The presentations included information on: Coastal and marine restoration research in the NESP Marine Biodiversity Hub, Nature-based Solutions for coastal hazard mitigation, eco-engineering of Living Seawalls, coastal engineering, and structured-decision making for ecological restoration.

6.2.5 End-user Workshop - Discussion

There were three main discussion sessions. In the first session, which was held in plenary, participants were asked about the ways that they currently make decisions about where and how to restore coastal and marine ecosystems. Notes on the outcomes of this discussion are provided in Table 8. In the second session participants were asked to join one of six breakout groups to discuss one of six questions that were included in the national survey. The questions elicited understanding of whether organisations are using NbS methods for hazard protection, the motivations, objectives, values, benefits/co-benefits, and barriers to restoration and NbS. In the second set of breakout discussions participants were asked to discuss decision support needs over multiple spatial scales (local, regional, state, national).

Table 8: Influences on decision-making for where to conduct coastal and marine restoration

Biophysical	Social and Community	Economic	Legal/Governance
Delivery of multiple ecosystem service benefits	Properties at risk from coastal erosion	Cost - benefit: Low cost, maximum output	Where is it permitted within existing legislation and hierarchies of legislation (e.g., Crown Lands, Fisheries, etc)
Informed by long-term monitoring	Sites where there is political motivation or opportunities to conduct restoration / NbS	Carbon offsets	Opportunities are limited to public lands: Limited opportunities with Private Land tenure: - tidal land grey areas
Locations are suitable based on habitat suitability modelling	Public consultation; avoid areas of conflict. User group and community perspectives are a key	Many restoration actions are too expensive to do without volunteers	Biodiversity offsets and conditions of other development approval developments might specify that the location is local to the development project

Biophysical	Social and Community	Economic	Legal/Governance
The potential to use natural Hydrology and create ecological stability	Influenced by partnerships and local champions. Plus, will the visibility of the site serve as good showcase?	Multiple economic/environ mental services and benefits - what are all the values?	
Trade-offs and competing objectives – e.g., Oyster reef restoration needs to avoid areas of important shorebird habitat	Locations where there is capacity to conduct the works	Cost - The Main barrier for work on isolated offshore islands is the cost of access.	

6.2.6 End-user Workshop – Key Findings

- There are structural barriers preventing the widespread implementation of coastal and marine restoration and NbS in Australia. These include, but are not limited to, challenges with funding and permitting processes. Organisations conducting on ground works would like to see fit-for-purpose permitting processes in place for coastal restoration.
- Once the science has established the legitimacy of projects, it is often political support which results in the project being supported and implemented.
- Overcoming these structural barriers will require action and cooperation among all levels of government, Aboriginal and Torres Strait Islander Organisations, Community groups, Researchers, and Natural Resource Management (NRM) groups.
- Restoration and NbS programs and projects must do better to engage meaningfully with Traditional Custodians. They are rights holders rather than stakeholders, and this needs to be addressed accordingly.
- There is a strong need to assess how restoration should take place in protected areas, and to ensure that unintended consequences and negative outcomes on natural values don't occur.
- A first set of Australia specific National guidelines to NbS have recently been developed under NESP (Morris, Bishop, Boon, Browne, Carley, Fest, Fraser, Ghisalberti, Kendrick, Konlechner, et al., 2021) based on consultation with New South Wales, Victoria, Queensland and South Australia.
- There is a very strong need to assess and communicate the risks and uncertainties of NbS for coastal hazard protection.
- There are temporal aspects to NbS projects which need to be factored into planning & monitoring to ensure long-term efficacy, for instance, ecosystems accrete vertically and laterally, change species composition, and may be affected by extreme events
- There is a need for a national scale strategy (e.g., Guidelines) to coastal restoration and NbS which cascades across scales (to state, regional, local)

- Moving to landscape scale restoration requires consideration about connections among different ecosystems and developing a rational for how to respond to climate change.
- Communication of case-studies of successful restoration and NbS, as well as the challenges that were overcome, would be helpful.

7 Australian Restoration Case Studies

This section presents a range of marine and coastal ecosystem restoration programs underway in Australia and explores some of the key objectives, learnings, barriers to success and scaling up possible, along with the some of the funding models that were accessed and key partnerships that have attributed to the success. The range of ecosystems provided here covers a cross-section of habitat resources of interest in Australia – noting that other restoration programs are underway.

7.1 Reef builder – bringing Australia's shellfish reefs back from the brink of extinction

Authors

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Background

Prior to European settlement, thousands of kilometres of shellfish reefs (oyster reefs and mussel beds) inhabited Australia's coastline. These reef habitats filtered the water, mitigated coastal erosion, provided vital nursery grounds for fish and supported a raft of biodiversity. However, throughout the 19th century and early 20th century, these coastal and estuarine habitats were progressively decimated through overfishing, water pollution, introduced species and disease. Today, Australia's shellfish reefs are considered functionally-extinct, with only 8% remaining.

To reverse this decline, The Nature Conservancy (TNC) has been leading shellfish reef restoration efforts in Australia since 2014 in partnership with the public and private sectors. This effort has built on 25 years of restoration experience in the United States and elsewhere and has been tailored to local ecological conditions. Restoration efforts began in Port Phillip Bay, Victoria, then progressively expanded to other states (SA, WA) on a project-by-project basis. A crucial element of this expansion has been partnership development, consultation and engagement across the community, science, private and government sectors. Following seven years of demonstrating the ecological, social and economic benefits of rebuilding shellfish reefs, this restoration work has now been expanded to a national scale. 'Reef Builder', a partnership between TNC and the Australian Government, is Australia's largest marine restoration program and will rebuild reefs at 13 locations (covering ~50 ha) across southern Australia from Noosa to Perth throughout 2021-2023. This initiative is a significant step towards TNC's broader goal of restoring shellfish reefs at 60 sites around Australia to replace 30% of this lost habitat for the benefit of people and nature (See Figure 31, Figure 32, Figure 33, Figure 34, Figure 35).

Outcome and Learning/Barriers

TNC's shellfish reef restoration work, both in the years preceding Reef Builder and during the first year of this national campaign, has demonstrated clear success against (1) ecological targets (e.g., target densities of restored shellfish populations; increased abundance of fishery species; increased biodiversity); (2) economic targets (e.g., job creation; engagement of local small-to-medium enterprises) and; (3) social targets (e.g., community engagement; volunteer contributions to citizen science or restoration activities).

Developing this restoration program to this scale, however, has required concerted and sustained effort since ~2012. It has involved establishing the case for restoration with scientists, restoration practitioners and decision-makers; synthesising the knowledge base and 'story' of the scale and drivers of shellfish loss; growing awareness across the public and private sectors of the restoration need and benefit; building the business case; developing supportive policy frameworks; growing a collaborative national network of practitioners, scientists and managers; developing skills and expertise in shellfish reef restoration, and; securing significant investment across diverse private and public funding sources.

We have learnt from successes and challenges at all stages of project delivery, including project planning, stakeholder and community engagement; site selection and feasibility; permitting and approvals; procurement of materials and contractors; reef construction and seeding; monitoring and evaluation, and; project handover to relevant local or state partners.

Some key barriers remain, including (1) the complexity and lack of clarity of permitting/approval pathways, which not only differ among local and state jurisdictions and lack an overarching national framework, but are typically designed for grey infrastructure projects and are poorly suited to reef restoration projects; (2) lack of clarity and understanding of the liability and management responsibilities of the reefs following construction, and (3) securing and sustaining the scale of funding required to deliver shellfish reef restoration at impactful scales.

Project Costs and Funding Sources

Shellfish reef restoration requires substantial investment. Delivery of these restoration projects requires dedicated project management expertise; extensive permitting and approvals; the procurement of large quantities of materials (e.g. rock rubble and/or recycled shells for the reef base, shellfish to seed the reefs) and contractors (e.g. earthmovers, engineers, surveyors, maritime construction experts, hatchery managers, scientists, environmental consultants etc); plant and equipment (e.g. barges, tugs, excavators etc), and; monitoring, evaluation and reporting to understand the level of 'success' from environmental and societal perspectives.

Since 2014, funding to support state-by-state shellfish reef restoration projects has been secured from diverse sources across the public and private sectors, including local-state government, industry, philanthropists and community groups. The national-scale Reef Builder initiative supported by the Australian Government has received funding support of $20 million from 2021-23.

Has the project resulted in a step change for managers, landholders, industry or government?

The broader shellfish reef restoration program has supported (1) improved environmental management of our estuaries and coasts by providing long-term and adaptive enhancement of their ecological health and resilience; (2) economic gains for local industries, both during reef building and seeding (e.g. maritime construction, engineering, aquaculture, science) and following reef maturation (e.g. ecotourism, fisheries), with ~8,5 FTE supported per million dollars invested, and (3) other societal benefits such as volunteer engagement and education opportunities in reef restoration, as well as improved recreational benefits (e.g. better fishing).

The program has also delivered a far greater understanding across all sectors of society of the scale of shellfish reef loss and the conservation effort needed to restore it.

Figure 31: Platform barge set up ready for shellfish deployment (photo credit: Streamline Media)

Figure 32: Deploying rocky reef base in Port Phillip Bay, Victoria, November 2021 (Photo credit: Streamline Media).

Figure 33: Deploying rocky reef base at O'Sullivan's Beach, South Australia, November 2021 (Photo credit: Maritime Constructions).

Figure 34: Deploying oysters onto a rocky reef base at Glenelg, South Australia (Photo credit: Adelaide Commercial Diving).

Figure 35: Restored shellfish reef, Port Phillip Bay (Photo credit: Streamline Media).

7.2 Reef build Coral Nurture Program – Rehabilitating Australia's reefs at scale through reef tourism-science partnerships

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Background

Coral propagation and planting was adopted by Great Barrier Reef (GBR) tourism operators in the Cairns Port-Douglas region in 2018, via a globally unique partnership between science and the $6B/year GBR tourism industry. Repeat years of mass bleaching introduced a strong desire amongst tourism operators for new stewardship tools to actively add coral back to the reef, but only if conventional cost-effectiveness (and scale) limitations of coral restoration could be overcome. In its first year with a single tourism operator, new low-cost nurseries (Howlett, Camp, Edmondson, Henderson, & Suggett, 2021; Suggett et al., 2019) and an innovative planting device (Coralclip®; (Suggett, Edmondson, Howlett, & Camp, 2020)), were together integrated into routine tourism operations thereby transforming the cost of in water coral propagation and planting by 1-2 orders of magnitude (See Figure 36, Figure 37, Figure 38, Figure 39).

The next two years (2019-2020) was adoption – and tailoring – of the new approach through multiple operators of different reef tourism business models. The operators planted >20,000 corals across 6 high value tourism sites - and the partnership became the Coral Nurture Program (CNP). As of result of these successes, CNP matured to 'Phase 3' (2021-2024) via blended finance from multiple funders to fully evaluate the longer-term socio-ecological benefits of tourism operators (and stakeholders) with capacity for mass coral propagation and out-planting in the Cairns-Port Douglas region. As of January 2022, CNP has planted >62,000 corals across 27 sites (6 reefs) spanning a footprint of ~2ha, retained a high survivorship of >80% corals planted, and propagated >6,000 corals in nurseries. In 2020 corals in nurseries spawned for the first time, whilst in 2021 the first planted fragments (end 2018) had reached sexual maturity to also spawn for the first time thereby 'closing the loop' of enhancing site regeneration. In January 2022, CNP launched activity with a new pool of operators in the second GBR tourism hub, the Whitsundays. More details on all activities can be found on the Program website: https://www.coralnurtureprogram.org.

Outcome and Learning/Barriers

- Developed a coordinated and collective activity of stakeholders that enables high cost-effectiveness of coral restoration at scale (multiple sites). Importantly, efforts are aimed at both maintaining good reef areas as well as rebuilding more impacted areas.
- Novel workflows have equipped tourism operators with new capacity for local site stewardship, and more sustainable (and resilient) tourism operations.
- Low-cost technologies that can integrate into existing industry operations have resulted in planting at $1-4 per coral (with every $1 invested retaining a minimum of $10 site tourism value).
- Credibility in the outputs (measures of success) rests on scientific validation, which also identifies how to further improve cost-effectiveness. This has resulted in a positive feedback look to enhance operation scale, but also partner and investor confidence.
- Working with operators with different business models revealed how to tailor the approach for broad adoption.
- Coral Nurture Program has developed a model of coral restoration that is now ready to be deployed to other reef regions that are similar reliant on the reef tourism economy.

Project Costs and Funding Sources

- Phase 1 (2018-2019) – Feasibility funded through the Queensland & Australian Government (*Boosting coral abundance challenge*). Establishing methods.
- Phase 2 (2019-2020) – Proof-of-Concept funded through the Queensland & Australian Government (*Boosting coral abundance* challenge). Testing multiparter adoption.
- Phase 3 (2021-2024) – Funded through Reef Trust in partnership with the Great Barrier Reef Foundation (GBRF, Cairns-Port Douglas Restoration Hub). Evaluating ecological and socio-economic outcomes of mass planting by the tourism industry, and developing sustained financing models.
- Additional funding (Feb-Jun 2021) to tourism partners through *Activate Tourism* COVID19 stimulus package, to propagate coral during tourism restrictions.
- First major corporate funder (August 2021-July 2023) – Reeftip Drinks Co. (https://www.reeftip.com.au/en-au) to fund coral planting by operators enabling blended finance for CNP alongside GBRF, resulting in the first demonstration of sustained financing of GBR coral restorations.
- Small research grants have been attracted (e.g., ROLEX, L'Oreal) to target specific research activities within the Program.
- Reef Islands Initiative (also Reef Trust in partnership with GBRF) funds the launch of CNP into the Whitsundays (2022).

Has the project resulted in a step change for managers, landholders, industry or government?

Collective efforts of the tourism industry became recognised as a transformative approach to aid reef site maintenance and rehabilitation at scale, and a completely new form of site stewardship – this was evidenced through COVID19 lockdowns where a Government stimulus grant (*Activate Tourism*) to

CNP operators demonstrate how assets (vessels, skilled staff) could be temporarily repurposed from tourism to propagate coral (and monitor sites). This formed the basis of a new model of operation that leveraged blended financing investment, and importantly providing a new model for industry sustainability (actively rebuilding high value local tourism sites). Reef tourism now sees CNP activity as a primary means to promote World Heritage site values and ensure a more resilient industry.

A major outcome in parallel has been working with GBRMPA throughout to de-risk CNP activity and identify a tangible model that can ultimately provide broader GBR management with new tools and stewardship workflows (and hence advance GBRMPA's Tourism Management Action Strategy 2021). Coraclip® is now considered a tool that can be applied in several core management contexts via GBRAMP activity.

Figure 36: Stocked Low-cost nursery (Opal Reef) Photo: Johnny Gaskill

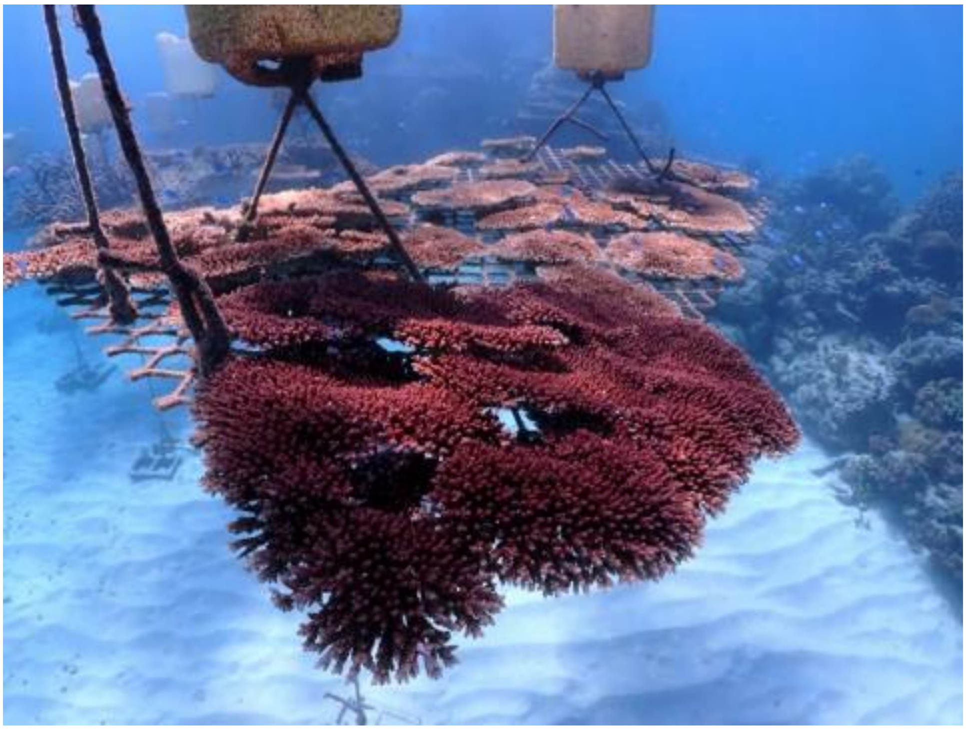

Figure 37: Stocked Low-cost nursery (Opal Reef) Photo: John Edmondson

Figure 38: Outplanted fragment growth at a previous bare reef area (Opal Reef) after 9-12 months. Photo: David Suggett

Figure 39: Attaching coral to bare substrate using Coralclip® (Opal reef) Photo: John Edmondson

7.3 Living Seawalls: scaling up marine eco-engineering

Authors
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Background
The Living Seawalls project addresses the growing, but underappreciated contribution of marine built structures to biodiversity loss in our oceans. Marine built structures protect shorelines from erosion and inundation, support recreation and the blue economy (Dafforn et al., 2015). Collectively they modify an area of seafloor that is greater than the area of the world's mangrove forests and seagrass beds, combined (Bugnot et al., 2021).

The ecological impacts of these structures arise both from their destruction and degradation of natural habitats, but also their flat and often featureless surfaces, which provide little protection from predators and environmental stressors (Bulleri & Chapman, 2010; Dugan, Airoldi, Chapman, & Walker, 2011). The net effect is loss of native biodiversity and spread of pest species (Bulleri & Airoldi, 2005; Chapman, 2003).

Living Seawalls comprise modules, mimicking the habitat features of natural shorelines (e.g. rock pools, crevices, kelp holdfasts) that are fitted in scalable mosaics onto built structures (Figure 40, Figure 41). The complex surfaces increase the habitat area for growth of seaweeds, shellfish and other marine life. They also protect marine life from high temperatures and predators. The habitat modules can be fitted to built structures of varying sizes in a range of configurations, can be planted with native species, and can be fabricated from a variety of upcycled materials. Critically, the habitat modules can be incorporated into new structures, and also retrofitted to the many existing structures that have modified the world's coastline.

The first Living Seawalls modules were panels designed for Sydney Harbour, based on more than 20 years of research. Ten different panel designs are now available. In the three years since installation of the first Living Seawalls, in 2018, under the Sydney Harbour Bridge, more than 1000 habitat panels have been installed at sixteen sites, within Australia and internationally, in Singapore, Gibraltar and Wales with many more opportunities currently being assessed.

Partnerships with local government, industry and community have been instrumental in scaling up Living Seawalls. These partners have provided landowner consent and financing, as well as advocacy and education. For example, North Sydney Council provided interpretive signage at two sites and Volvo Cars Australia and Northern Beaches Council, along with community groups, co-created the Ocean Lovers Festival and Seaweed Forests Festival, respectively, of which Living Seawalls was featured. Stakeholder workshops, involving representatives from government, industry and the research sectors as well as members from the public have identified benefits and risks of Living Seawalls, and enabled us to refine installations to meet stakeholder needs and minimise unintended negative consequences.

Outcome and Learning/Barriers

The Living Seawalls has an accompanying scientific research program that includes before and after monitoring at our installations, control (unmodified built structures) and reference (natural, e.g., rocky reef) sites. This has been crucial to developing an evidence-base and has allowed us to adaptively refine this solution for new objectives and environmental contexts. Results show that overall, Living Seawalls enhance seaweeds, fish and invertebrates, such as crabs, oysters and mussels after as little as one year, with each panel design supporting unique species. Consequently, a mix of panel designs is necessary to maximise biodiversity. At the site scale, benefits vary with tidal elevation (Bishop, Vozzo, Mayer-Pinto, & Dafforn, in press, Jan 2022). In the intertidal zone, native species account for the majority of this biodiversity (and cover) enhancement, with the contribution of non-native species proportionately small (Furchert, 2019).

A key challenge for early Living Seawalls installations was unsupportive policy and management frameworks. We are addressing permitting and planning impediments in New South Wales by working closely with local governments and the NSW Minister for Planning and Public Spaces to reclassify Living Seawalls as restoration works.

Additionally, we developed guiding principles and step-by-step guidelines for planning and constructing eco-friendly foreshore developments. We also developed frameworks for designing marine structures to reduce pest species invasions and increase the resilience of marine ecosystems to climate change.

Our installations have been accompanied by an extensive outreach program, generating public awareness and stewardship of blue space. Since 2018, we have given several seminars, panel discussions, and workshops. Living Seawalls panels have been displayed at the Australian National Maritime Museum, MOD Adelaide and the National Gallery of Victoria, and internationally at the Design Museum London and Cooper Hewitt Design Museum New York. The project has provided

internship opportunities to close to 50 young scientists and designers, and trained six research students from Australia, South Africa and the Philippines. More recently, the invitation to develop partnerships with the Earthshot Global Alliance, which is comprised of a range of internationally renowned organisations spanning the finance, engineering, development and philanthropy sectors, has helped to raise global awareness of the negative impacts of marine built structures
An important outcome to date is the national and international recognition and impact of the Living Seawalls. The project was selected as an inaugural finalist (1 in 3) for the Earthshot Prize in the category Revive our Oceans and winner of the NSW Sustainability Awards in the Biodiversity category as well as a Top Innovator in the Uplink World Economic Forum BiodiverCities Challenge.

Project Costs and Funding Sources

Since 2017, the project has attracted > $2 M in funding from industry, philanthropy and grants funded by local and state governments, e.g., City of Sydney Council, NSW Department of Primary Industries as well as federal government, such as Department of Industry, Innovation and Science (Commonwealth grant).

Project costs vary largely depending on the type of installation and number of panels installed. The full cost of a project includes permit applications (e.g., Review of Environmental Factors and Heritage Impact Statements) completed well before on-the-ground works commence; moulding, fabrication and installation of panels; and ecological monitoring that can span from months to years. To date, most installations have been driven by research and as a result, research funding has paid for most of the associated project costs. Approval, fabrication and installation costs can range from $60,000 for roughly 100 panels covering 50m^2 on an intertidal seawall to ~ $1 M for a customised installation of nearly 400 panels on intertidal and subtidal pilings. Ecological monitoring requires a team of scientists and/or scientific divers to conduct surveys over a series of days and as such, can cost upwards of $25,000 per monitoring survey, depending on the site.

Has the project resulted in a step change for managers, landholders, industry or government?

The frameworks we developed for ecologically enhancing marine infrastructure have been used by Lendlease and the NSW State Government to plan urban renewal projects, such as Barangaroo and the Sydney Fish Markets redevelopment. Our work has also been featured in guidance documents on Fish Friendly Infrastructure and breakwater upgrades, produced by NSW Department of Primary Industries (DPI). Ecologically sensitive construction has been mandated by NSW Department of Primary Industries (DPI) in approvals for several infrastructure upgrades in Aquatic Reserves, and for coastal works receiving government funding. Living Seawalls was showcased in the 2021 Australian State of the Environment Report, in the Conservation Evidence Series Synopsis on Enhancing the Biodiversity of Marine Artificial Structures (2021) (Evans, Moore, Louise, Smith, & Sutherland, 2021) and the High Level Panel for a Sustainable Ocean economy Blue Paper (2020).

Local governments and developers have demonstrated willingness and started initiatives to implement a step change by ecologically engineering coastal structures within their jurisdictions or projects. However, a higher level, government mandated step change, similar to the United Kingdom's 'Biodiversity Net Gain' requirement is still needed. Importantly, Living Seawalls has raised awareness on the growing issue of biodiversity loss due to marine construction and the opportunity to mitigate this impact by designing for humans and nature.

Figure 40: Engineered panel for seawall. Photo: Maria Vozzo

Figure 41: Series of engineered panels attached to seawall increasing habitat complexity. Photo: Alex Goad

7.4 Building coastal resilience using a shellfish reef living shoreline

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Background

Public and private assets are experiencing increased risk of erosion and inundation along the Ramblers Road Foreshore, Bellarine Peninsula, Victoria. The City of Greater Geelong council, the land manager, has trialled several protection methods including sand fencing, minor beach nourishment and raising low lying foreshore areas, but overtopping of waves is still impacting the area. The decision to construct a shellfish reef was made in consultation with relevant stakeholders (Victorian Government's Department of Environment, Land, Water and Planning [DELWP], Parks Victoria and local residents), and was driven, in part, by prohibitive costs associated with the construction of a seawall and the impacts such a structure would have on coastal processes, including marine and coastal communities.

The 130 m long reef was constructed in 2018 of modular steel cages filled with discarded rock from a residential development and recycled shell that would otherwise gone to landfill. The reef was seeded experimentally with mussels (*Mytilus galloprovincialis*) from a local farmer. In collaboration with the National Centre for Coasts and Climate at the University of Melbourne and Port Phillip EcoCentre, baseline surveys and post construction monitoring of the reef has occurred between 2017-2022 and is ongoing. See Figure 42

Outcome and Learning/Barriers

The project is considered successful from an engineering, ecological and social perspective (Climate, 2021).

Engineering outcomes: Digital elevation models created through drone and beach transect monitoring has shown a beach widening of 40 m and sand volume gain of 4,600 m^3 in 3.5 years in the lee of the reef. An average wave attenuation of 49% was observed, and historical analysis is ongoing to determine any potential effect of the reef on other areas of the coastline.

Ecological outcomes: Three separate mussel seeding events have occurred over the project to test the method of seeding, substratum type, and plot size. The greatest survival of mussels occurred on the upper terrace of the reef, with no difference between substratum type (rock versus rock and shell). The assessment of most viable plot size will be completed by mid-2022. Some natural mussel recruitment has also been observed on the reef. Seagrass has established in front of the reef, with ongoing analysis to link this to the presence of the reef. Dune plantings were trialled within and outside of the lee of the reef. Dune plants in the lee of the reef have accumulated more sand than those outside of the reef due to less storm damage and a greater sand supply. This project, therefore has facilitated restoration of a habitat mosaic of shellfish, seagrass meadows and vegetated foredunes.

Social outcomes: The reef design was altered during construction, initially two-tiered to each tier being placed beside each other, the structure was now lower but wider. This was due to the opinion of local residents during construction that the reef detracted from the amenity and was not aesthetically pleasing being exposed during all tidal levels. Due to this adaptive management, the residents were supportive of the as constructed design.

Project Costs and Funding Sources

The project costs included the following amounts:

- Reef design, inclusive of wave modelling = $80,000, funded by DELWP
- Reef construction = $425,000, funded by City of Greater Geelong
- Reef monitoring = $174,548, funded by DELWP through the Port Phillip Bay Fund Grants (2017-2020)

In kind support through equipment and salaries was also contributed for the reef monitoring through the University of Melbourne. In kind support through salary was contributed through City of Greater Geelong for project management, securing permits (Parks Victoria Works Permit and Marine and Coastal Act Consent) and ongoing monitoring as part of the Bellarine Peninsula Monitoring Program. The shellfish reef living shoreline was considerably cheaper than a seawall, which would have had an estimated cost of up to $15,000 per metre.

Has the project resulted in a step change for managers, landholders, industry or government?

This project has led to a step change in the way that the City of Greater Geelong approaches coastal erosion. Due to the success of this project, two new reefs will be installed at another site along the Bellarine Peninsula (Clifton Springs) in 2022. The new living shoreline represents an improvement on the first reef design through the use of units cast using eco-friendly cement and small whole shells as the aggregate. The added habitat complexity of this reef is expected to deliver greater environmental outcomes, is more aesthetically pleasing, and has greater mobility of units (due to the integration of engineered lifting lugs) for adaptive management, if required. There is strong interest from other coastal land mangers on the use of these techniques, which are being increasingly supported by state government.

Figure 42: Nature based solution trial in Port Phillip Bay © Ralph Roob

7.5 Restoring coastal wetland values back into the Great Barrier Reef catchments

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Background

The Great Barrier Reef (GBR) lagoon of north eastern Australia has important tangible linkages with adjacent coastal wetlands and estuaries, which are connected as part of a larger nursery and feeding complex that supports many marine and freshwater species (McCook et al., 2010; Pearson, Connolly, Davis, & Brodie, 2021; Waltham et al., 2019). Many economically important fisheries have a critical estuary lifecycle phase, and rely directly on connectivity between the reef and the shallow tidal and freshwater wetland features (Sheaves, Johnston, & Connolly, 2012). However, many functional characteristics of this habitat complex are under threat owing to on-going expansion of city centres for increasing population, port and industrial expansion and agricultural expansion, with runoff contributing to poor water quality and loss of natural estuarine and freshwater wetlands as nursery habitat (Pearson et al., 2021; Waltham et al., 2019).

The overarching framework for managing the GBR is the Reef 2050 Long-term Sustainability Plan (Reef 2050 Plan hereafter). In the Reef 2050 Plan 'coastal habitat' is recognized as supporting the ecological and biological processes of the Reef, providing habitat for biodiversity, community and economic benefits and increasing resilience to climate change. Reef 2050 Plan has a target for 2020 that 'There is no net loss of the extent, and a net improvement in the condition, of natural wetlands and riparian vegetation that contribute to Reef resilience and ecosystem health'. An important and necessary action has been to implement the Wetlands in the Great Barrier Reef Catchments Management Strategy 2016-2021 that outlines on-ground actions, education and scientific research necessary to improve management and repair of wetlands in the GBR catchment. The Reef 2050 Water Quality Improvement Plan 2017-2022 (Reef WQ Plan) is nested under the water quality theme in the Reef 2050 Plan and is charged with the role to address all land-based sources of water pollution. The Reef WQ Plan identifies the need for targeted catchment repair projects, which is best achieved via a whole-of-system catchment management approach.

A key challenge to achieving these outcomes is that, since European settlement, the GBR catchment has continued to be modified with estimates around 64% of the catchment area cleared of the predominant native vegetation, most occurring south of Cooktown (QLUMP data 2009, Queensland Government), though the rate of clearing has slowed and, in some places, has changed little in the past few decades (Iram et al., 2022; Lewis et al., 2021; Waltham et al., 2019). The remaining undeveloped areas are predominately used for grazing, with around 10% of the catchment area within Protected Areas. The impacts of grazing on remnant natural areas include increased erosion, weed transfer, nutrient enrichment and loss of riparian understory (Lewis et al. 2021). Feral pigs and cattle are also impacting Protected Areas (Doupé, Mitchell, Knott, Davis, & Lymbery, 2009; Waltham & Schaffer, 2018). Noticeably a major limitation in the success of repair efforts is the ongoing competing land uses (e.g., sugar cane production), and so much of the GBR floodplain wetland and connectivity loss is not readily reversible. Investment is needed to understand these complex landscapes, aquatic floodplain connectivity, and how to restore function and achieve solutions that balance the environment with the desires of the community (Waltham et al. 2019). With further investment for implementation, we could then be in a position to scale up efforts in order to work towards achieving the objectives set in the Reef 2050 Plan.

Outcome and Learning/Barriers

Numerous coastal wetland projects have been completed or are underway across the GBR catchments, with the focus on restoring and protecting the natural values and processes at each site (Figure 43, Figure 44). The projects are normally administered through regional Natural Resources Management (NRM), but more recently also through Indigenous Land and Sea Ranger programs, non-government organisations (NGOs), industry, local government, landholders and voluntary groups such as LandCare. This 'grass roots' approach to restoration is important and necessary in ensuring that the desired outcome from the restoration is achieved. Funding these projects is generally delivered through government grant schemes, but there is growing awareness and interest in securing funding via market pipelines – including blue carbon, but also developing markets such as water quality (e.g., Reef Credits) and biodiversity.

The Department of Environment and Science (DES) of the Queensland Government has an active and inclusive network of wetland interest folk, representing government, industry, NGO, scientific, NRM and Aboriginal and Torres Strait Islander groups. This network group meet regularly to share learnings, data, and discuss some of the barriers facing projects across their programs. The GBR Wetlands Network is now more than 40 stakeholders strong, with information and all data shared via a government portal (WetlandInfo). In addition to this network, DES has developed a series of learning modules, summary sheets and conceptual diagrams which are all available on the website. These tools are updated regularly as new scientific data becomes available and is promoted through the network broadly.

Project Costs and Funding Sources

Investment in coastal wetlands and floodplains along the GBR coastline has been delivered through various government funding rounds, but also via landholders, community and industry directly tackling catchment water quality runoff, floodplain aquatic habitat connectivity, and land use practice changes to improve water quality – more projects are on the horizon as interest from private investor groups grows (for example under carbon or water quality markets). Funding and project specifics for many projects have been captured and reported on WetlandInfo. Finer details for each project and following monitoring and reporting is however, not captured in this system, and is held by the program delivery group.

Exciting opportunities to access philanthropic and corporate investment that supports social responsibility toward environmental management and protection are on the horizon, which require careful planning and assessment. Repairing and protecting the GBR coastal wetland ecosystems and connection with offshore coral reef ecosystems is challenging, but the social, environmental, and economic returns for this investment outweighs not doing anything.

Has the project resulted in a step change for managers, landholders, industry or government?

The collective efforts of on-ground work administered through NRM, Indigenous Ranger programs, NGO and industry, and with the data and learnings communicated and shared through the GBR Wetlands network has been transformative in raising the profile of coastal wetland restoration, research and success. Capacity and confidence with respect to restoration is increasing in the region, though the challenge is now large-scale projects that deliver meaningful results and benefit broader GBR reef ecosystem protection and resilience. Advancement in technology will need further development and funding support, and to be then embraced by the network of restoration practitioners. Failures are inevitable, and need to be also shared to ensure broader learning and growth among the network. Most importantly has been the development and recognition of a ‘whole of ecosystem’ approach to restoration, where the link between land-based efforts is viewed as also assisting in improving water quality outcomes for the reef. This approach has been recognised in the Reef 2050 plan, and more recently has been included in the Consensus Scientific Statement for the reef and its ecosystems. More work is also needed in the maintenance of restoration project sites, including the preparation of funding models and ownership of sites to that the capital investment is protected in the future.

Figure 43: Engineered fish ladder designed to reconnect floodplains for successful fish passage

Figure 44: Installation of feral animal exclusion for coastal wetland protection

7.6 Developing Aboriginal partnerships and training for sustained wirriya jalyanu (seagrass) restoration outcomes on Gathaagudu (Shark Bay, Western Australia)

Authors

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Background

Global ecosystems are experiencing a period of unprecedented change, with climate change a major driver of biodiversity loss and species redistribution. High biodiversity marine ecosystems within tropical-temperate zones are showing significant changes as a result of warming – tropicalisation – where temperate species are being impacted by tropical species (Vergés et al., 2014; Wernberg et al., 2016). Approximately 1300km^2 of temperate seagrass meadows were impacted during the 2010/11 marine heat wave on Australia's west coast (Strydom et al., 2020), with some natural recovery of *Posidonia* meadows after six years (Kendrick et al., 2019). Direct impacts have been observed through loss and damage to large temperate, habitat forming seagrasses (*Amphibolis antarctica* and *Posidonia australis*), resulting in subsequent impacts to fauna (reviewed in (Kendrick et al., 2019)), and indirectly through reduced recovery as a result transformations to altered state (sediment resuspension) and increased herbivory. The slow recovery of *Amphibolis* meadows, in particular, led to a discussion with Malgana peoples around how to raise awareness and developing restoration activities that could be used to assist natural recovery of seagrass meadows within Shark Bay.

University of Western Australia (UWA) researchers partnered with the Malgana Aboriginal Corporation on NESP project E6 (Statton, Sinclair, McNeair, Kendrick, & Kendrick, 2021) to train Malgana Rangers in seagrass restoration methods, and develop a plan for ongoing restoration efforts (Figure 45, Figure 46).

Outcome and Learning/Barriers

Six Malgana Land and Sea Rangers (three male and three female; Figure 30) were employed during training and received TAFE certification in Conservation and Land Management. Training in multiple seagrass restoration methods and monitoring was included within the program. Seagrass restoration sites established using adult plants have >95% survival, and will continue to be monitored. The success of a 'seagrass snagger' approach to facilitating natural recruitment of *Amphibolis* (wire weed) seedlings will take longer to assess. A restoration planning framework was adapted from terrestrial systems to simplify restoration planning processes (Table 9 in Statton et al. (2021)).

Local employment. Significant resources were available to appropriately reward time invested, rather than creating a sense of burden through additional work. Six Malgana rangers in training (3 male and 3 female) were employment during training.

Knowledge sharing. Two-way knowledge sharing occurred through informal on Country activities, and was best shared in person.

Creating a shared vision. Discussions around the role of seagrass meadows in shaping the marine environment generated a shared understanding and desire to look after Country and restore seagrass.

Ongoing challenges. We are continuing to partner with the Malgana Aboriginal Corporation, however, there are challenges associated with working with a new organisation as they establish protocols and find and develop expertise that improve communication and turning this into on-ground actions.

Project Costs and Funding Sources

The project was initially funded for two years, with an additional six months through NESP. This enabled financial support for Rangers during training, travel to site (accommodation, vehicle, boat costs), restoration materials (hessian socks), and casual employment of Rangers.

The Malgana Land and Sea Ranger program was also supported by State Government through the Department of Biodiversity, Conservation, and Attractions.

Has the project resulted in a step change for managers, landholders, industry or government?

Contributing a marine restoration activity has led to a broader appreciation for the marine environment by Rangers. Field-based activities enabled interpersonal relationships to develop and create opportunities for two-way knowledge sharing. State Government through the Department of Biodiversity, Conservation, and Attractions have increased their support for the Malgana Land and Sea Ranger program.

Bush Heritage Australia, which now owns and manages Hamelin Station Reserve, a 202, 000 ha property which abuts Hamelin Pool (eastern gulf of Shark Bay), has been employing Malgana Land and Sea Rangers to assist with land management activities. Some of which have a direct benefit to improving marine water quality (through sediment/run-off retention) – recognising that terrestrial and aquatic ecosystems are connected.

The Ranger program is now being run by the Malgana Aboriginal Corporation. A new group of Malgana Rangers (3 females) are beginning training in 2022 – in part inspired by success of those in the initial training program.

Acknowledgement.

We wish to than the Traditional Owners of Gathaagudu for permission to conduct research and restoration activities on Malgana Country.

Figure 45: Photo 1: Nick Pedrocchi, Sean McNeair, Cody Oakley, Alex Dodd, Richard Cross, Nykita McNeair, Maryke Gray, Marika Oakley and Pat Oakley. Credit: Yamatji Marlpa Aboriginal Corporation.

Figure 46: Photo 2: Malgana Ranger Nick Pedrocchi and Dr John Statton (UWA) deploy a 'seagrass snagger' or hessian-filled tube at a restoration site in Shark Bay to assist natural recovery of wire weed, *Amphibolis antarctica*, seedlings. Credit: Gary Kendrick.

7.7 Operation Crayweed: restoring Sydney's missing underwater forests and engaging local communities

Authors
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Background

Crayweed (*Phyllospora comosa*) is a dominant seaweed that forms extensive underwater forests along ~5,100 km of the south-eastern Australian coastline. As a foundation species, crayweed supports a unique ecological community that includes two of Australia's most valuable fisheries: abalone and rock lobster (or crayfish, from where it gets its name) (Marzinelli et al., 2014; Vergés et al., 2020). Crayweed disappeared from 70 km of Sydney's metropolitan coastline in the 1980s, which was linked to major sewage pollution at the time. Although water quality improved dramatically along the city's shoreline following the installation of deep ocean outfalls in the 1990s, crayweed forests did not re-establish in the region (Coleman, Kelaher, Steinberg, & Millar, 2008).

In 2011, an experimental transplant of reproductive crayweed adults onto Sydney's reefs demonstrated that (i) the new environmental conditions were suitable for the survival, reproduction and establishment of crayweed and (ii) recruitment processes were a key limiting factor preventing the natural re-establishment of crayweed onto Sydney's reefs (Campbell, Marzinelli, Vergés, Coleman, & Steinberg, 2014).

Survival and reproduction of crayweed, as well as associated biodiversity, were monitored and compared to crayweed forests outside of Sydney (reference sites) and to non-restored sites in Sydney. Transplanted crayweed showed comparable survival rates to natural populations and reproduced in their new habitats (Campbell et al., 2014). Recruitment rates were higher than in natural populations at one experimental site, while herbivory emerged as an important factor limiting restoration success at the other site (Vergés et al., 2020). Some components of biodiversity such as epifauna started to resemble those found in extant crayweed forests (monitoring continues to date) (Campbell, Marzinelli, Gelber, & Steinberg, 2015; Marzinelli, Leong, Campbell, Steinberg, & Verges, 2016). These initial restoration efforts successfully re-established crayweed at two Sydney and involved scientists from multiple universities, the New South Wales Government and community volunteers.

Genetic studies were subsequently integrated into the scaling-up of crayweed restoration efforts at five new reefs across Sydney. Donor sites were selected following the genotyping of nearby extant populations to replicate regional population genetic diversity and structure. Although donor provenance (from populations north or south of Sydney) influenced survival and condition of crayweed transplants, genotyping of F1 generation recruits confirmed that genetic diversity and structure resembled extant surrounding populations (Wood et al., 2020). Genomics of populations along the entire latitudinal distribution of crayweed is currently being used to identify donor populations/genotypes which may be tolerant of warmer waters, in order to future-proof restored sites (Wood et al., 2021; Wood et al., 2019).

Operation Crayweed has engaged actively with the general public, schools, local councils and state government bodies. Art and storytelling have been powerful tools in communicating the science behind the restoration to wide audiences (Vergés et al., 2020). Community engagement and outreach examples linked to the project include: collaborating on an installation for Sculpture by the Sea, participating in the Live Ocean Revival Experience at the Ocean Lovers Festival Bondi, leading a month-long Seaweed Forests Festival in 2021 and working with school students to produce an original song and a series of artworks. Operation Crayweed researchers also facilitate hands-on experiences for local volunteers at restoration sites and have featured in several short films and media appearances throughout the lifespan of the project. See Figure 47, Figure 48, Figure 49, Figure 50, Figure 51).

Outcome and Learning/Barriers

Crayweed restoration has been attempted in 14 Sydney reefs over a 10-year period (2011-2021; 2 additional sites currently in progress), including sites where scientific experiments tested additional factors such as optimal size of transplant plots, the impact of herbivores, and the importance of genetics. Seven of these 14 sites are now self-sustaining, with crayweed recruiting onto the reefs with expanding distributions and without further interventions from the team. Biodiversity associated with some of these forests is starting to resemble that found in reference locations (Marzinelli et al., 2016). Restoration at one of the other sites was started very recently, so it is too early to assess results. In six of the remaining sites, restoration was initially either fully or partially unsuccessful (few individuals recruited), due mostly to high levels of herbivory and/ or burial by sand.

Lessons learned:

- When, how and where transplants are placed within a reef matters (best results are obtained when plants are physically transplanted in relatively sheltered areas where donor plants are more likely to persist for longer, near other benthic macroalgae to enhance recruitment and there is higher survival/recruitment over colder seasons)
- Some sites may be more vulnerable to herbivores or storms than others and may need more frequent monitoring and multiple plantings before they are successful (Vergés et al., 2020)
- Knowledge of genomics of donor populations allows restoring genetically diverse populations and can be used to inform future-proofing strategies (Coleman et al., 2020; Wood et al., 2021; Wood et al., 2019; Wood et al., 2020)
- Associated biodiversity in restored sites may take time to resemble biodiversity in extant, reference forests (Marzinelli et al., 2016)
- Storytelling/science communication increases engagement, public benefit and funding for restoration (Vergés et al., 2020)
- SCUBA diving and boating for restoration are labour intensive and costly, therefore limiting the frequency of transplanting activities as well as monitoring. The team is now exploring new, cost-effective approaches that aim to reduce these costs.

Project Costs and Funding Sources

We have estimated our crayweed restoration costs at US$46,250 per hectare (2018 year of evaluation; Vergés et al. 2020). This figure includes materials, transport and personnel, and it is based on the self-expansion of crayweed populations over 4,000m^2 in ~6 years from an initial planting of 24m^2 (Vergés et al. 2020). However, this estimation, excludes project management and monitoring, as well as initial and ongoing scientific research done to develop and optimise the restoration methods.

Initial funding was supported from the NSW DPI Recreational Fishing Trust and a science communication and crowdfunding campaign was launched to raise funds to scale-up crayweed restoration efforts. A name ('Operation Crayweed'), logo, website (www.OperationCrayweed.com), short film and associated social media pages were created. The crowdfunding campaign was launched in November 2015 and asked the public to 'give an underwater tree' for Christmas. The project was featured in multiple national TV news bulletins as well as in national and international print and online media. These efforts led to NSW Environmental Trust grants, an Australian Research Council Linkage grant, and significant philanthropic support.

Has the project resulted in a step change for managers, landholders, industry or government?

This project has increased awareness and stewardship for the marine environment and seaweed-dominated reefs to the many thousands of people that we have engaged with. Operation Crayweed is featured as a case study in NESP Marine Biodiversity Hub report on habitat restoration (I. M. McLeod et al., 2019) and related scientific review papers (Eger et al., 2020; Layton et al., 2020; Morris et al., 2020), and was used as an example of restoration in the NSW MEMA. Our project has also recently been used extensively as a case study for educational purposes, including during multiple National Science Week activities, in conferences for the Geography Teachers Association of NSW and ACT Inc. and in online educational materials, e.g. curriculum aligned educational episodes developed by Take 3 and available in Cool Australia Education Resources and in the Australian Broadcasting Corporation "Deep Dive into Australia's Ocean Odyssey" educational set of resources for secondary students.

Figure 47: Transplanted crayweed forest in Cabbage Tree Bay. Photo credit: Harriet Spark

Figure 48: ‘Craybie’ recruit near restored crayweed in North Bondi. Photo credit: John Turnbull

Figure 49: Educational art-meets-science workshop with Balgowlah North Public School. Photo credit: Leah Wood.

Figure 50: Community planting of crayweed at Freshwater Beach. Photo credit: Leah Wood.

Figure 51: The Seaweed Forests Festival included cooking with seaweed workshops, seaweed-themed dishes cooked by Indigenous chef Black Olive, crayweed community restoration, a new musical composition and dance choreography as well as art and science workshops. Photo credit: Leah Wood and Adriana Vergés

8 Key concepts from coastal engineering

Section Lead: Alice Twomey

Knowledge of coastal hydrodynamic processes is required when deciding on restoration and NbS projects in coastal and marine ecosystems for a number of reasons. First, habitat suitability modelling can demonstrate whether the location is suitable for the ecosystem to occur. Second, in some cases hydrodynamic conditions may need to be made suitable for the project to occur – such as tidal reintroduction aimed at creating suitable habitat for coastal wetlands. Third, the project may be designed with the intention to modify hydrodynamic conditions. For example, the installation of an oyster reef intended to provide coastal protection by reducing wave energy and thus stabilising an eroding shoreline. Fourth, the project may inadvertently alter hydrodynamic conditions and result in adverse consequences, such as causing erosion in an adjacent area. In all of these circumstances hydrodynamic models are useful, and in some instances necessary, to inform decision making.

This section builds on existing research to synthesise information across varying spatial scales on data and models used to predict offshore and nearshore coastal hydrodynamics, examine the interaction among hydrodynamics and coastal ecosystems, and predict flood extent and erosion. We define coastal ecosystems within the context of nature-based solutions for coastal protection as those that can provide protection from coastal flooding, erosion, extreme high-water levels and events driven by sea-level rise and high energy waves. Ecosystems located in the upper reaches of estuaries or rivers typically do not provide protection against these specific hazards, instead providing protection against tidal and flood currents. In addition to NbS design considerations, this section elucidates the broader engineering considerations in terms of risk and uncertainty, highlighting implications for decision making when undertaking a NbS project intended to provide protection against coastal hazards.

Key findings:

- Practical implementation of Nature-based Solutions (NbS) as a coastal protection strategy is affected by both epistemic (uncertainty in knowledge) and aleatory (uncertainty due to random effects) uncertainty derived from deficits in guidelines, supporting data and a lack of understanding of physical processes.
- The lack of guidelines and design frameworks for engineering NbS reduces their attractiveness as viable coastal protection solutions.
- Unlike traditional coastal protection strategies that are static in form (e.g., seawalls, levees) or passively evolve (e.g., sand nourishments) that can be 'tuned' to elicit the desired response, many NbS vary due to their dynamic form (height, width, depth, species, roughness) that can evolve over seasonal and decadal temporal scales. Traditional coastal protection strategies have a specified 'design life' or 'immediate level of protection.' The dynamic evolution of marine and coastal ecosystems means that these two project parameters aren’t easily estimated for NbS. Guidance is required to understand how to measure the effectiveness or life span of a NbS project.
- Functional performance of NbS, with respect to project success or failure, is typically measured against the project objectives, which often are not determined by the coastal

engineer. This disconnect can result in a NbS being measured against criteria that are only applicable for a specific spatial or temporal scale.

- Coastal protection strategies aim to reduce or relocate risk. However, there may be trade-offs between mitigating hazards at a specific site or for specific environmental conditions and exacerbating risk for other conditions or indeed shifting hazards elsewhere. For instance, the installation of an oyster reef could in theory provide coastal protection in one location and erosion in another downdrift location.

8.1 Overview: Coastal engineering approach to coastal protection afforded by nature-based solutions

Coastal and marine ecosystems, such as coral reefs, kelp, seagrass, shellfish reefs, tidal flats, mangroves and saltmarsh, have been suggested and in some cases, demonstrated to mitigate coastal hazards and contribute to coastal protection (Narayan et al., 2016). Coastal hazards include flooding, erosion, extreme high-water level events driven by sea-level rise and frequent high energy waves (Muis, Verlaan, Winsemius, Aerts, & Ward, 2016), which threaten coastal communities and their assets. These coastal hazards, if left unmitigated, can result in increased inundation extent and residence time (Sweet, Park, Marra, Zervas, & Gill, 2014), more frequent overtopping (Almar et al., 2021) and the loss of land (Karegar, Dixon, Malservisi, Kusche, & Engelhart, 2017). Fundamentally, coastal protection strategies seek to mitigate these hazards either directly, such as through the attenuation of incident waves (Temmerman et al., 2013), or indirectly such as through the stabilisation and/or accretion of sediment at the shoreline (Duarte, Losada, Hendriks, Mazarrasa, & Marbà, 2013). The magnitude of this direct and indirect protection varies both spatially and temporally (Barbier et al., 2008; Koch et al., 2009). While NbS have been shown to mitigate these hazards in individual studies (Gijsman et al., 2021; Guannel, Arkema, Ruggiero, & Verutes, 2016; Möller et al., 2014; Schoutens et al., 2020; Scyphers, Powers, Heck Jr, & Byron, 2011), little work has been done to locally identify where these coastal hazards occur spatially, how these hazards might overlap with existing ecosystems present and the possible contribution that NbS may contribute to the mitigation of these hazards.

Irrespective of the coastal protection strategy adopted, a key consideration is its functional performance. Usually, such functional performance metrics are defined as specific environmental cases, such as the requirement for the strategy to withstand a 1-in-X annual return interval environmental event. Such metrics of project success or failure may not always be determined by the coastal engineer and may result from a wide range of other (often competing) considerations. However, it is important that these metrics are appropriately defined and clearly articulated whilst being congruent with the design objectives. Defining performance and project success is about managing expectations, especially in terms of the specific conditions or caveats associated with the project performance. For example, a project objective that simply states that the NbS must 'reduce flooding' might omit considerations of the differences between ‘normal’ and extreme conditions when differences in forcings can be the difference between success or failure. Similarly, a seagrass meadow designed to 'attenuate wave energy' over long time periods may form salient or tombolo, which might not be desirable for the project while restoring a degraded ecosystem to its 'original state' may not be possible if the hydrodynamic conditions have changed due to sea-level rise. It is unlikely that a NbS project will meet all objectives over large time scales or forcing conditions, and it is important to remember that ecosystems adapt and change. Therefore, it is critical that project expectations for success and performance are understood, and any caveats and limitations communicated.

For well-studied conventional coastal protection strategies (e.g., seawalls), design guidance has been developed along with a wide range of tools and techniques to quantify functional performance. For these strategies, project risk can be alleviated through design, for example, by increasing the height or width of the structure (Engineers Australia, 2012). This design guidance, along with the tools and techniques that support them, are critical to demonstrate that the protection strategy is expected to satisfy its intended design purpose, which reduces project risk. However, for NbS such guidance and methods are not well established. Over moderate to large spatial scales, differences in ecosystem structure and connectivity, geomorphological composition and form, as well as differences in incident hydrodynamic processes (Koch et al., 2009), all affect the extent and consistency of coastal protection provided by coastal and marine ecosystems. At smaller (site) scales, the geometric arrangement of the NbS, as well as the geometric form of the NbS itself, become important for the quantification of the NbS performance. Noting that for any given project, this performance may differ (e.g., large swell waves vs wind waves with oceanic surges). Furthermore, unlike traditional coastal protection strategies that are static in form (e.g., seawalls) or passively evolve (e.g., sand nourishments) that can be 'tuned' to elicit the desired response, many NbS vary due to their dynamic form that can evolve over seasonal (Coops, Geilen, Verheij, Boeters, & van der Velde, 1996) and decadal (Toimil, Losada, Nicholls, Dalrymple, & Stive, 2020) temporal scales. This has important implications for the design and implementation of these solutions, as well as the perceived risk associated with the solutions. Thus, to design a NbS, there is usually a need to use 'first principal' design methods and to supplement theoretical analysis with field or laboratory experiments.

This report summarises the broader engineering considerations, those in addition to the design itself, that need to be taken into account when undertaking a NbS project. While there is a plethora of academic literature stating that coastal and marine ecosystems can be used as NbS (Baptist et al., 2021; Michael W Beck et al., 2018; Menéndez, Losada, Torres-Ortega, Narayan, & Beck, 2020), and that we should use them as NbS (Morris, Konlechner, Ghisalberti, & Swearer, 2018; Temmerman et al., 2013), there is limited literature providing holistic guidance on how to undertake a NbS project with certainty around engineering performance. Previous reports have provided high-level implementation principles (Morris, Bishop, Boon, Browne, Carley, Fest, Fraser, Ghisalberti, Kendrick, & Konlechner, 2021) or specific instructions for physical design of NbS (see Michale W Beck, Lange, and Accounting (2016)), but these reports do not consider the many other aspects that must be considered as part of the development of a coastal protection solution, whether NbS or otherwise. Building on the work of Michale W Beck et al. (2016) and Morris, Bishop, Boon, Browne, Carley, Fest, Fraser, Ghisalberti, Kendrick, and Konlechner (2021), this report synthesises examples of engineering designs for NbS as well as whole-of-project considerations that go beyond the physical design of the structure. This report discusses the limitations to NbS design that are often driven by considerations beyond the design itself and identifies important gaps in decision-making, highlighting the disconnect between coastal engineers and ecologists.

8.2 Method for predicting coastal protection afforded by coastal and marine ecosystems as nature-based solutions

Fundamentally, coastal protection seeks to reduce or relocate risk. While the aim is usually to achieve risk reduction by mitigating coastal hazards within the project area, in reality, there is a trade-off between mitigating hazards in one area or for one specific condition and exacerbating risk for other conditions or indeed shifting hazards elsewhere (typically downdrift). For example, seagrass may accrete sediment, which may contribute to beach widening in one area, but this new sediment sink may cause or shift erosion downdrift (Twomey et al. submitted). It is therefore important to estimate the existing and residual risk profile that remains after implementation of a NbS both at the project site as well as to connecting landscapes and nearby assets. To quantify the impact of NbS on coastal hazards, and by extension, on risk, it is necessary to quantify physical processes over a cascade of temporal and spatial scales. This typically requires an assessment of (1) the offshore hydrodynamics (section 2.1), (2) the transformation and evolution of these offshore processes to the nearshore (section 2.2), (3) quantification of ecosystem-hydrodynamic interactions (section 2.3), and finally (4) an estimation of the total water level, flood extent or erosion in the area of interest (section 2.4) (Michale W Beck et al., 2016).

8.2.1 Estimating offshore hydrodynamics

Quantification of the offshore hydrodynamic climate is critical to determine the range of incident forcing that may impact the site and can be done using a range of methods (Table 9). Typically, this offshore data is sourced from a range of different data services, including direct offshore measurements (Draper, 1977), global hindcast models (Hersbach et al., 2020) and, in some cases, numerical models developed specifically for the project. These data are analysed to define the wave climate at the specific location as well as to define extreme forcing cases. These offshore forcing hydrodynamic assessments are usually undertaken for depths that are considered 'deep water' and thus for depths beyond where NbS may normally be considered. Although it is worth noting that offshore assessments using numerical models can parameterise the impacts of ecosystems, this is usually through an energy dissipation (bed friction) parameter.

An important outcome of this assessment is a statistical description of the offshore environment, such as wave heights for specific return intervals (e.g., 1 in 100 years). These statistical descriptions are important to define the type of conditions that the NbS will be exposed to and for which the NbS must be effective.

Table 9: Coastal engineering approaches and tools used to estimate offshore hydrodynamics (adapted from Beck et al. 2016) where scales are defined as local (<10 km), regional (10-50 km), and large (>50km)

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem application
Analytical or semi-empirical approximations	Wave generation	All	Hasselmann, Sell, Ross, and Müller (1976)	Arkema et al. (2013)	Coral reefs, mangroves, emergent marsh, seagrass beds, intertidal aquatic vegetation, kelp, oyster reefs, high and low dunes
	Generation of storm surge	Large	Dean (1991)	Reguero, Bresch, Beck, Calil, and Meliane (2014)	Oyster reef and marsh wetland
Numerical modelling	Wave generation	All	WAve Model (WAM)	Kerfoot et al. (2019)	-
			WaveWatch III	Reguero, Méndez, and Losada (2013)	-
				Izaguirre, Méndez, Espejo, Losada, and Reguero (2013)	-
			SWAN	Vatvani et al. (2012)	-
				K. S. D. H. F. Stockdon, Sopkin,	-

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem application
				and Sallenger (2012)	
	Generation of storm surge	Regional to local	DELFT3D	Vatvani et al. (2012)	-
			Coastal and Estuarine Storm Tide (CEST)	K. Zhang et al. (2012)	Mangroves
			Advanced Circulation model (ADCIRC), Sea, Lake, and Overland Surges from Hurricanes (SLOSH)	Kerr, Donahue, et al. (2013)	-
			ADCIRC	Kerr, Martyr, et al. (2013)	-
			Regional Ocean Modelling System (ROMS)	Losada et al. (2013)	-
				Cid, Castanedo, Abascal, Menéndez, and Medina (2014)	-

8.2.2 Estimating nearshore hydrodynamics

Whilst it is critical to understand the incident conditions offshore of the location of interest, the incident conditions at the shoreline where NbS are often implemented are strongly affected by hydrodynamic transformations that occur as waves (and currents) propagate into shallow water. These transformations are predominantly due to changes in the bathymetry, but also the geomorphological context of the site. Quantification of the nearshore hydrodynamics is important to understand for both the design of the NbS and to assess the performance of the proposed solution (see Table 10).

The hydrodynamic transformations that occur from deep to shallow water are generally well understood and are often quantified using numerical models, although analytical methods also exist (see Table 9, Table 10, Table 11). At this temporal and spatial scale, ecosystems are usually encapsulated within these models via changes in the bed bathymetry and the inclusion of an energy dissipation term. Defining the dissipation term is not trivial. In some numerical models, specific dissipation equations for seagrass may be included, while more commonly, a general energy dissipation equation is used that includes a friction factor of sorts that is used as a 'calibration factor'. Whilst such a calibration factor can be used to describe nearshore transformations, where measurements exist to validate the choice of parameter, the choice of this parameter a priori for the design of coastal protection is often problematic, and thus a further analysis stage is usually required to quantify how NbS interact with these nearshore hydrodynamics at a site scale.

Table 10: Coastal engineering approaches and tools used to estimate nearshore hydrodynamics (adapted from Beck et al. 2016) where scales are defined as local (<10 km), regional (10-50 km), and large (>50km)

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem application
Analytical or semi-empirical approximations	Wave propagation	Large	Snell's Law	Mandlier and Kench (2012)	Coral reef
	Storm surge propagation	Large	Dean and Dalrymple (1991)	Anderson, Smith, and McKay (2011)	-
			Nielsen (2009)		
Numerical modelling	Wave propagation	Regional to local	Spectral wave models: SWAN	Camus, Mendez, and Medina (2011)	-
			STeady-state spectral WAVE (STwave)	J. M. Smith and Bryant (2018)	Saltmarsh
			MIKE by DHI	Strauss, Mirferendesk, and Tomlinson (2007)	-
			Coastal Modelling System (CMS)	M. Zhang, Qiao, Xu, Qiao, and Yang (2016)	Vegetated fields
		Local	Mild slope-based models: REFDIF	S.-N. Chen, Sanford, Koch, Shi, and North (2007)	Seagrass
			CGWave	Bosma and Caufield (2004)	-
			OLUCA	Infantes, Terrados, Orfila, Canellas, and Alvarez-Ellacuria (2009)	Seagrass
	Storm surge propagation	All	SLOSH	K. Zhang et al. (2012)	Mangroves
				Vatvani et al. (2012)	-
			ADCIRC	Weaver and Slinn (2005)	-
			DELFT3D	Menendez et al. (2018)	Mangroves
			CEST	Q. Chen et al. (2021)	
			MIKE by DHI	Haigh et al. (2014)	-

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem application
			CMS	Li, Lin, and Burks-Copes (2012)	-

8.2.3 Determining the ecosystem-hydrodynamic interactions

At the site scale, quantification of the interactions between the NbS and the forcing is critical for design and to evaluate performance (Table 11). These interactions describe how incident forcing is dissipated (e.g., by wave breaking or reflection, frictional dissipation or vegetation drag), and in many cases further transformed by the NbS. These interactions are often difficult to quantify and poorly understood. Consequently, a range of different strategies is often used to address this knowledge gap. These strategies include high-resolution computational fluid dynamic studies, laboratory experiments or field experiments. For example, vegetated ecosystems are typically modelled as a 'drag coefficient' (Twomey et al., 2020) or as '2D rigid cylinders' (Burger, 2005; Mancheno et al., 2021; Mancheño, Jansen, Winterwerp, & Uijttewaal, 2021). While both these methods yield important information about how a vegetated ecosystem dissipates energy, the vegetation architecture varies significantly between species within an ecosystem type such that utilising the wrong architecture for rigid cylinders is no longer accurate. The species present and spatial characteristics (density, ecosystem width and length) are site-specific, so variations in ecosystem structure need to be considered. Therefore, much of the research focuses on these interactions, but large gaps remain as well as methods suitable for practical implementation at scale.

Table 11: Coastal engineering approaches and tools used to estimate the interactions between hydrodynamics and the ecosystem (adapted from Beck et al. 2016) where scales are defined as local (<10 km), regional (10-50 km), and large (>50km)

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem applied to
Analytical or semi-empirical approximation	Wave dissipation from vegetation	Large to regional	Dalrymple, Kirby, and Hwang (1984) Mendez and Losada (2004)	Guannel et al. (2015)	Mangroves
				Bradley and Houser (2009)	Seagrass
				Dubi and Torum (1995)	Kelp
				Anderson and Smith (2014)	Saltmarsh
	Storm surge dissipation by vegetation	Large to regional		Krauss et al. (2009) K. Zhang et al. (2012)	Mangroves
				Lovås and Torum (2001)	Kelp
				Möller et al. (2014) X. Zhang, Lin, Gong, Li, and Chen (2020)	Saltmarsh

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem applied to
Numerical Modelling	Wave transmission through the reef	All	Ahrens (1987)	Lugo-Fernández, Roberts, and Suhayda (1998)	Coral reefs
			Van der Meer and Angremond (1992)	Blenkinsopp and Chaplin (2008)	
	Wave dissipation from vegetation	Regional to local	SWAN-Veg	Suzuki, Zijlema, Burger, Meijer, and Narayan (2012)	Mangroves
			IH2VOF	Maza, Lara, and Losada (2013)	
			SWAN-Veg	Zeller et al. (2014)	Seagrass
			STWave	Anderson and Smith (2015)	-
			MIKE by DHI	Narayan et al. (2017)	Wetlands
			XBeach	Figueroa-Alfaro, van Rooijen, Garzon, Evans, and Harris (2022)	Saltmarsh
	Storm surge dissipation by vegetation	Regional to local	ADCIRC	Wamsley, Cialone, Smith, Atkinson, and Rosati (2010)	Mangroves
			CEST	K. Zhang et al. (2012)	
			ADCIRC	Davila, Davila Hernandez, Flores, and Ho (2020)	Seagrass
			SLOSH	Murdukhayeva, August, Bradley, LaBash, and Shaw (2013)	Saltmarsh
	Wave transmission through a reef	Local	FUNWAVE	Buckley, Lowe, and Hansen (2014)	Coral reefs
			COrnell Breaking waves And Structures (COBRAS)	Garcia, Lara, and Losada (2004)	
				Lara, Garcia, and Losada (2006)	
			IH2VOF	Campos Caba (2020)	
			SWASH	Zijlema (2012)	

8.2.4 Assessing the total water level and flood extent

Beyond the NbS, the resultant water level, flood extent or shoreline change is then predicted to estimate the effect of the habitat on the relevant coastal hazard (Table 12). Considerable progress has been made to understand key shoreline processes such as wave runup, flooding and inundation, as well as cross and alongshore morphological change. For many practical applications of NbS, these shoreline impacts can be assessed at a high level simply by using the transformed or 'remaining' incident forcing beyond the NbS as a boundary to the analysis of impacts at the shoreline. However, a more sophisticated approach would recognise that there are multiple interactions between the shoreline impacts and the NbS. These interactions are generally poorly understood (Callaghan, Saint-Cast, Nielsen, & Baldock, 2006). Consequently, a number of other approaches have been developed, such as indexed approaches that assess exposure and vulnerability to assess coastal risk. Examples include the Coastal Vulnerability Module (Arkema et al., 2013) or Drivers-Pressures-State-Impact-Response (Bruno, Saponieri, Molfetta, & Damiani, 2020), amongst others.

Table 12: Coastal engineering approaches and tools used to estimate the total water level and flood extent (adapted from Beck et al. 2016) where scales are defined as local (<10 km), regional (10-50 km), and large (>50km)

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem applied to
Analytical or semi-empirical approximation	Wave runup	All	Beach: H. F. Stockdon, Holman, Howd, and Sallenger Jr (2006)	K. S. D. H. F. Stockdon et al. (2012)	-
			Rubble: Van der Meer and Stam (1992)	Hughes (2004)	-
	Erosion cross-shore evaluation	Large to regional	Dean and Dalrymple (1991)	Dean (1991)	Sandy beaches
			Soulsby (1997)	Le Hir, Monbet, and Orvain (2007)	Seagrass
			Bijker (1971)	Pruszak, Szmytkiewicz, Hung, and Van Ninh (2002)	-
			Engelund and Hansen (1967)	-	Sandy beaches
			Coastal Engineering Research Center (1984)	Shanas and Kumar (2014)	-
Hybrid Models	Shoreline change	Regional to small	Kaergaard and Fredsoe (2013)	Kaergaard et al. (2014)	-
Numerical modelling	Wave runup and inland flooding	Small	SWASH	Ruju, Lara, and Losada (2014) swash	-
				Buckley et al. (2014)	Coral reef
			MIKE by DHI	Anton, Rusu, and Anton (2019)	-

Type of approach	Scope	Scale	Example models	Example application of the approach	Ecosystem applied to
			CMS	Johnson, McFall, Krafft, and Brown (2021)	-
			FUNWAVE	Liu, Shao, Ning, and Zhao (2020)	Coral reef
			IH2VOF	Gainza et al. (2018)	-
			DELFT3D	Menéndez et al. (2020)	Mangroves
			TUFLOW	Palmer, Watson, and Fischer (2019)	Saltmarsh
	Cross-shore evaluation	Regional to small	MOPLA	González et al. (2007)	-
			DELFT3D	Storlazzi, Elias, Field, and Presto (2011)	Coral reef
			XBeach	James et al. (2021), Van Dongeren et al. (2013)	Coral reef, seagrass, mangroves
			MIKE by DHI	Zyserman and Johnson (2002)	-
			CMS	Johnson et al. (2021)	-
	Longshore evaluation of sediment transport	Small	MOPLA	González et al. (2007)	-
			DELFT3D	Van Duin, Wiersma, Walstra, Van Rijn, and Stive (2004)	-
			MIKE by DHI	Zyserman and Johnson (2002)	-
			XBeach	Roelvink et al. (2009)	-
				Jamal, Simmonds, and Magar (2014)	-
			CMS	Wang, Beck, and Roberts (2011)	-
			GENESIS	Eversole and Fletcher (2003)	

8.3 Challenges to the practical implementation of NbS at scale

Practical implementation of NbS at scale as a coastal engineering strategy is affected by both epistemic and aleatory uncertainty. Recalling that the aim of implementing coastal protection is to reduce the risk associated with several coastal hazards, the uncertainty both in terms of design and performance associated with many NbS affects the viability of these solutions for the purpose of coastal protection. And particularly where this protection is required to safeguard communities and protect both public and private assets. For lower-risk environments, these issues are of lesser concern.

This uncertainty typically arises from errors in both the models and real-world observations (Allen, Somerfield, & Gilbert, 2007) due to limitations in data availability affecting model calibration and validation (Xie, Zou, Mignone, & MacRae, 2019), measurement methods (Hare, Eakins, & Amante, 2011) and environmental variability (Romanowicz & Macdonald, 2005). These stacking assumptions and limitations ultimately reinforce the aphorism that "all models are wrong, but some are useful". We explore the uncertainties associated with NbS in the following sections and discuss why they affect practical implementation.

8.3.1 Dataset deficits

The availability of data required to parameterise estimate offshore and nearshore dynamics, to estimate the effect of ecosystems on hydrodynamics, and to estimate flooding and erosion varies across spatial scales (Table 13). These data are commonly used in models for coastal NbS; the specific information required will depend on the context (e.g., type habitat, objective, environmental setting). While process-resolving methods are more precise than index-based approaches, both analytical and numerical modelling approaches have large data requirements that introduce uncertainty where data availability is limited or unavailable. The most integral datasets include nearshore and intertidal bathymetry, and habitat structure and density (Michale W Beck et al., 2016). Yet, these datasets are difficult to obtain, and the assumptions are stacked where data is unavailable. Additionally, empirical datasets are scarce, and thus it is often difficult to validate the model and provide confidence for managers making policy or mitigation decisions (Xie et al., 2019).

While numerous sources provide historical wind and wave data, local bathymetry in the nearshore and intertidal region is difficult to obtain at the resolution required for smaller-scale projects. This is because the nearshore environment is highly spatially heterogeneous, it cannot be sampled in large scale hydrographic operations due to shallow water depths, and conditions changes daily, and so without specific and ongoing measurements, a complete dataset cannot be developed. However, we note that representative bathymetry can often be sufficient. The National Intertidal Extents Model (25 m spatial resolution) (Bishop-Taylor, Sagar, Lymburner, & Beaman, 2019), Global digital elevation model (90 m spatial resolution) (Yamazaki et al., 2017) and Great Barrier Reef bathymetry model (Beaman, 2020) (25 m spatial resolution) provide data at lower resolutions which is acceptable when modelling at national to regional scales. For local scales, data often needs to be at 1 m resolution due to the sensitivity of the nearshore processes, and the relatively low relief of coastal areas. This high-resolution data is typically obtained using LiDAR (although other hydrographic methods also exist), but this is expensive and not achievable for many projects.

Medium-resolution (~30 m) habitat maps for some ecosystems exist on a global and national scale (see Mcowen et al. (2017); Murray et al. (2019); Simard et al. (2019); S. F. UNEP-WCMC (2018); W. C. UNEP-WCMC, WRI, TNC (2018)), but vegetation density is often estimated from other sites, assumed, or not known. Similarly, vegetation species-specific architecture and density are often estimated from aerial imagery or density using allometry relationships, respectively (Duarte, 1991; Komiyama, Ong, & Poungparn, 2008). Vegetation species can significantly affect model results; for example, the mangrove species *Rhizophora* spp. have been shown to attenuate nearshore waves heights by up to 70% (Guannel et al., 2016) in some conditions, whereas species with a much smaller frontal area such as *Avicennia* spp., typically have reduced attenuation (Horstman et al., 2014). National scale data for coastal ecosystems in Australia are not nationally consistent, and contain many geographic and ecological gaps (for instance, deep water (>15 m) seagrass, or a national map for saltmarshes, see Connolly et al. NESP report, Unpublished).

Table 13: Data required for each assessment stage with a measure of data availability at each scale*

Assessment stage	Key data required	Local	Regional	State	National
Estimate offshore hydrodynamics	Historical wave data	green	green	green	green
	Wind and wave measurements	yellow	yellow	yellow	yellow
	Modelled climatic reconstructions	green	green	green	green
Estimate nearshore hydrodynamics	Bathymetry	red	red	green	green
Estimate effect of ecosystems on hydrodynamics	Habitat mapping	yellow	yellow	yellow	yellow
	Reef crest height	yellow	yellow	yellow	yellow
	Vegetation density	red	red	red	red
	Vegetation species (architecture)	yellow	red	red	red
Estimate flooding and erosion	Land use, permeability, roughness	green	green	green	green

*Data availability legend: red = difficult to acquire, yellow = often but not always available, green = data freely available

8.3.2 Cost-benefit analysis

Many projects are often assessed in part or even entirely using cost-benefit analysis techniques. Simplistically, such an analysis seeks to weigh the costs of a project against the benefits that the project will provide over the life of the project. The benefits are required to be converted to a monetary value. Whilst there are existing challenges with cost-benefit analyses for traditional coastal protection strategies, these challenges are exacerbated for NbS. To accurately assess a NbS, it is necessary to assess (as a minimum) the:

- cost of implementation, maintenance, and monitoring
- cost of maintenance to offset ecosystem losses
- amount of benefit provided, i.e., the ecosystem services of coastal protection and other co-benefits
- the economic valuation of the ecosystem services
- cost of project failure, i.e., ecosystem collapse

This data is difficult to obtain for two reasons, 1) there are few NbS projects implemented specifically for coastal protection and even fewer have quantified and published the costs incurred during design, implementation/maintenance and monitoring, and 2) monetarily quantifying ecosystem services typically only consider the desired project objective and do not holistically consider all co-benefits. Consequently, for the restoration of blue ecosystems, previous CBA's have suggested that the cost of these projects can outweigh the benefits (De Groot et al., 2013; Stewart-Sinclair, Klein, Bateman, & Lovelock, 2021). Furthermore, the absence of this data can hinder the attractiveness of NbS as a viable alternative to traditional coastal defence strategies rendering them to the 'too hard basket'.

8.3.3 Timescales

Uncertainty in the ecosystems' state and function increases with time due to the dynamic nature of coastal and marine environments hindering the applicability of nature-based solutions (Toimil et al., 2020). For example, there may be increased uncertainty surrounding a restoration project in an area susceptible to sea-level rise, which may require 'assisted migration' for an undefined period into the future compared with the restoration of an ecosystem to reduce risk to coastal assets where sea-level rise is less of a threat. In addition, climate change predictions beyond the year 2050 are uncertain, which creates further complexity for selecting the correct NbS (Toimil et al., 2020).

While single events such as large storms can contribute to extreme sea levels, a combination of non-extreme processes can often also be important. Seasonal variability, tides, storm surge, wave setup and wave runup contribute to extreme water levels occurring over a range of temporal and spatial scales. Therefore, at any given location, the contribution of each process will vary (see McInnes et al. (2016) for a full review). Ultimately, many coastal protection strategies have a specified 'design life' or 'immediate level of protection'. The dynamic evolution of NbS rarely fits into these two project parameters, and there is little guidance to understand how to measure a NbS project for these purposes.

8.3.4 Quantification of interactions and processes

One of the most obvious limitations to the implementation of NbS is the absence of a clear understanding of how different NbS interact with the coastal environment and how these interactions dissipate energy, ultimately shaping coastlines. For many studies, the influence of NbS on coastal processes is accounted for through the inclusion of bathymetry differences (e.g., a reef form) and bulk dissipation factors (i.e., a friction factor). The latter is usually calibrated to field measurements. Once calibrated, these transformed hydrodynamics are often directly used to estimate sediment transport rates as well as changes in shoreline morphology either analytically or using numerical models. Whilst this approach has yielded important insight into how different ecosystems influence the physical environment, it is often difficult to define key variables a priori because ecosystems (and by extension NbS) are often complex in physical form, and the complex processes encapsulated by these bulk parameters are difficult to predict.

Several recent studies have sought to understand and describe the interactions between different ecosystems and the physical environment. Much of the emphasis has been on how to describe how waves propagate across coral reefs (Young, 1989), seagrass meadows (Infantes et al., 2012) or mangrove fields (Massel, Furukawa, & Brinkman, 1999) as well as impact shorelines via wave runup (John, Shirlal, Rao, & Rajasekaran, 2016). However, considerable uncertainty remains even for bulk parameters such as dissipation factors that typically span up to several orders of magnitude. Some studies have also explored how ecosystems affect the flow structure (i.e., within a seagrass (Pujol, Serra, Colomer, & Casamitjana, 2013) or coral (Reidenbach, Monismith, Koseff, Yahel, & Genin, 2006) canopy), which can be important for suspension and transport of sediment (Pomeroy et al., 2017). While substantial progress has been made, considerable uncertainty remains, particularly for the purposes of the design of coastal protection. For example, there is little guidance on how species, density, structural flexibility, complexity or geometric arrangement of different ecosystems affect these physical processes. Such guidance is critical to enable the relationship between NbS and hazard reduction to be evaluated, as well as coastal protection performance reliably quantified.

8.3.5 Ecosystem connectivity and facilitation

Coastal and marine ecosystems are termed 'ecosystem engineers', because they alter the physical environment (Jones, Lawton, & Shachak, 1997). More recently, these ecosystems have been shown to not only engineer their local environments but to influence energy (wave) and material (sediment) fluxes over distances large enough to affect the function of other ecosystems (Meijer et al., 2021; Mishra & Apte, 2020; Saunders et al., 2014; van de Koppel et al., 2015). For example, seagrass meadow size, density and longevity were found to increase when the ecosystem was associated with mangroves, compared to sites without mangroves, which was partially attributed to changes in sediment composition, suggesting that the connectivity of these ecosystems increased resilience for seagrass (Mishra & Apte, 2020). This connectivity can both positively and negatively affect an ecosystem's contribution to coastal protection; positive influences on other ecosystems are termed ‘facilitation.’

While the connectivity of ecosystems can amplify the effects of coastal protection (Spalding et al., 2014), so can they reduce them. Each coastal and marine ecosystem has unique thresholds for survival, and so if these are breached in a neighbouring ecosystem, this can negatively affect the function of the ecosystem in question (Saunders et al., 2014). This is most apparent when multiple ecosystems are amplifying coastal protection, and then one of them is lost. For example, the wave attenuation provided by seagrass may be reduced if a neighbouring mangrove forest died, causing peat collapse resulting in an increase in surface elevation loss (increased water depth) (Sherman, Fahey, & Battles, 2000). The strength of the interaction between ecosystems is expected to change with climate change. For instance, if vertical accretion of coral reefs does not keep pace with sea-level rise, then the wave sheltering function provided to inshore seagrass, for example, will diminish (Saunders et al., 2014).

While ecosystem connectivity is known to be an important factor in predicting the coastal protection benefits provided by an area (Guannel et al., 2016), there appear to be no practical examples of the combined effect of multiple ecosystems on coastal protection being considered in restoration projects (Gillis et al., 2017). This may be due to the practical challenges of measuring and quantifying energy and material fluxes between sites (Melià et al., 2016) and determining the two-way implications of these. Consequently, not accounting for ecosystem connectivity in restoration projects may lead to uncertainty by 1) underestimating the amplifying effect of multiple ecosystems 2) overestimating the surety of an outcome if the ecosystem function relies on the health of adjacent ecosystems.

8.3.6 Absence of guidelines and methods

The absence of detailed quantitative guidelines as well as techniques or methods to guide the design of NbS is an important limitation to their application. Many coastal protection strategies are scoped, designed, and developed to achieve a particular outcome or level of performance. Often these outcomes and performance metrics are contractually agreed upon, and in doing so, project risk is transferred from the proponent to the person or organisation that is designing, developing and in some cases implementing the strategy. The absence of accepted guidelines and methods increases project risk and decrease the attractiveness or even viability of NbS as an option.

9 The "Roadmap" to restoration – Road test version

Section Leads: Nathan Waltham, Toni Cannard & Megan Saunders

9.1 Executive Summary / Summary for Policy Makers

Goal of the roadmap: To articulate principles which should be considered at a programmatic level when considering and planning scaled coastal and marine restoration. Within these principles we provide context on the current state in Australia, the future we would like to aim for, where the current NESP research aligns with these principles, research needs and required actions.

Key needs:

- A national Coastal and Marine Restoration Strategy that cascades across multiple scales of government, private and community sectors. This strategy needs to be developed in consideration of other strategies such as Strategy for Nature, National Climate Resilience and Adaption Strategy.
- Investment into overcoming barriers to engagement with Traditional Custodians, including best-practice guidelines. Co-design is central when determining the where, what and how of coastal and marine restoration projects.
- A review of policies and legislation which apply to coastal and marine restoration. Regulatory impediments challenge restoration projects, and have delayed project starts, incurred major costs that can be unanticipated, or have prevented projects from moving beyond concept co-design phase. Fit-for-purpose permitting for restoration is required, noting that there is still a clear need for provision for checks and balances on projects.
- Develop full project lifecycle costing and blended finance.
- Develop guidance on how to plan for climate change within restoration projects.

9.2 Methods

To develop the road map, data that were generated during the surveys with stakeholders (encompassing a wide cross section of restoration participants) were collated and distilled into key headline topics that built the narrative around the current state, desired future, recent relevant NESP research, research gaps and key actions. As part of this road map development, the team engaged assistance of a graphic facilitator to capture and articulate the overall road map visualisation for the project (See Figure 52). This is a first pass effort based on our understanding at the present time, and the roadmap is designed as a starting point for a conversation nationally about where we want to get to, and what steps are required to get there. It requires further consultation with a wide variety of stakeholders from different jurisdictions and backgrounds. Further, the context of future direction requires some consideration for unknown future climate (e.g., higher temperature, more frequency weather systems, rainfall, sea level rise) which requires close consideration in delivering a road map for restoration.

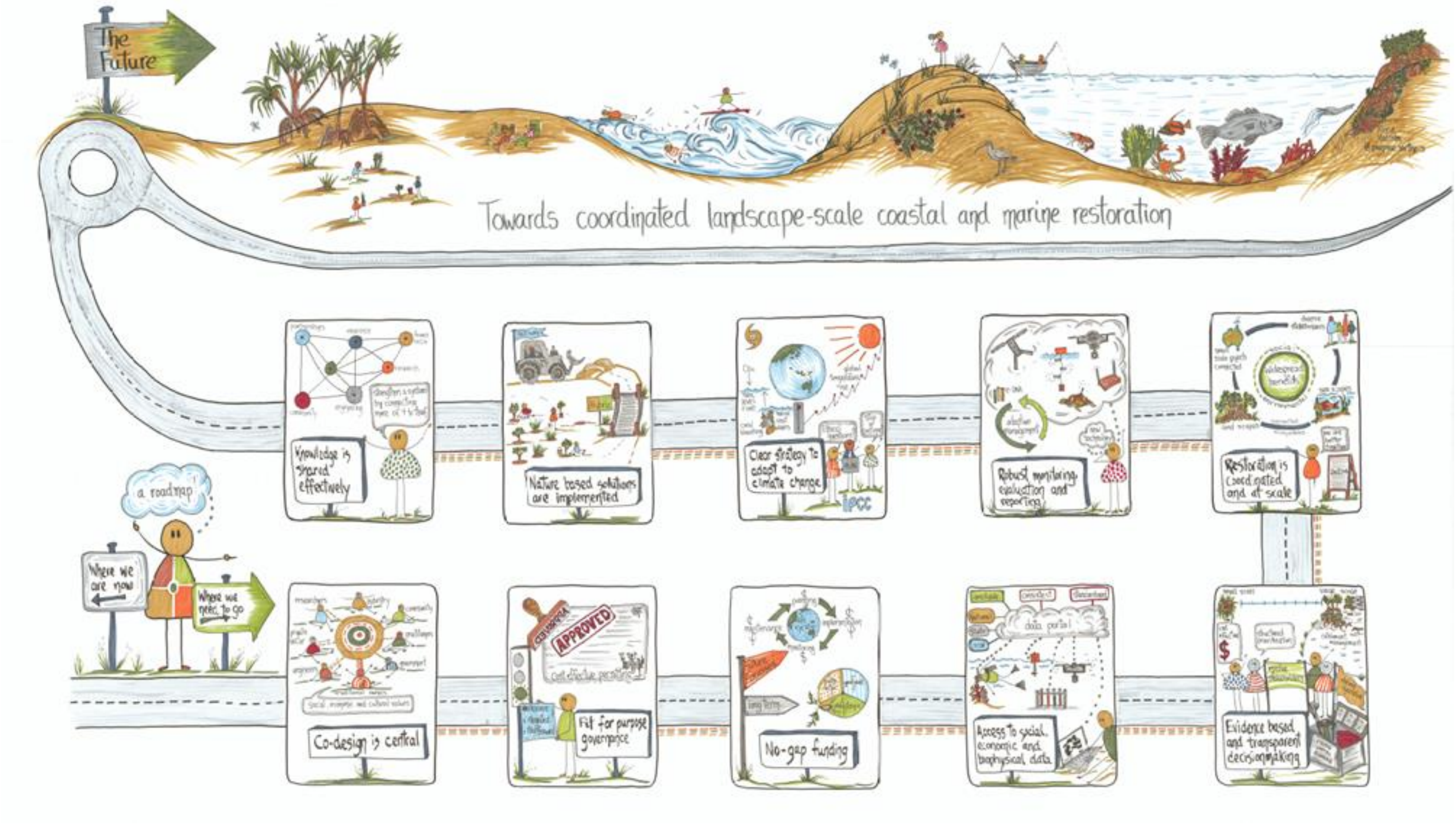

Figure 52: Ten guiding principles towards a roadmap for coordinated landscape scale coastal and marine restoration

9.3 Co-design is central

Underlying principle

Inclusion of diverse stakeholders in the design of restoration projects is important and necessary before any restoration project commences (Figure 53). Inclusion and agreement set's the trajectory for project success and insures a clear line of sight to the restoration goals. Partnerships which include diverse stakeholders is one of the keys to restoration success (Statton et al., 2012)(Saunders et al. 2020). Principles 1 & 2 of 8 of the Society for Ecological Restoration International Standards on ecosystem restoration state that restoration 'engages stakeholders' and 'draws on many types of knowledge.'

Aboriginal and Torres Strait Islander people are a particularly important stakeholder group in Australia as they are rights holders. The rights and interests of Aboriginal and Torres Strait Islander people in land and waters according to their traditional laws and customs are recognised in The Native Title Act 1993 (Cth) (NTA). Meaningful and transparent engagement and co-design with Aboriginal and Torres Strait Islander people for restoration projects and programs acts as a step towards: *Recognising that respect for indigenous knowledge, cultures and traditional practices contributes to sustainable and equitable development and proper management of the environment* (UN Declaration on the Rights of Indigenous People: https://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf). It also supports the Uluru Declaration from the Heart.

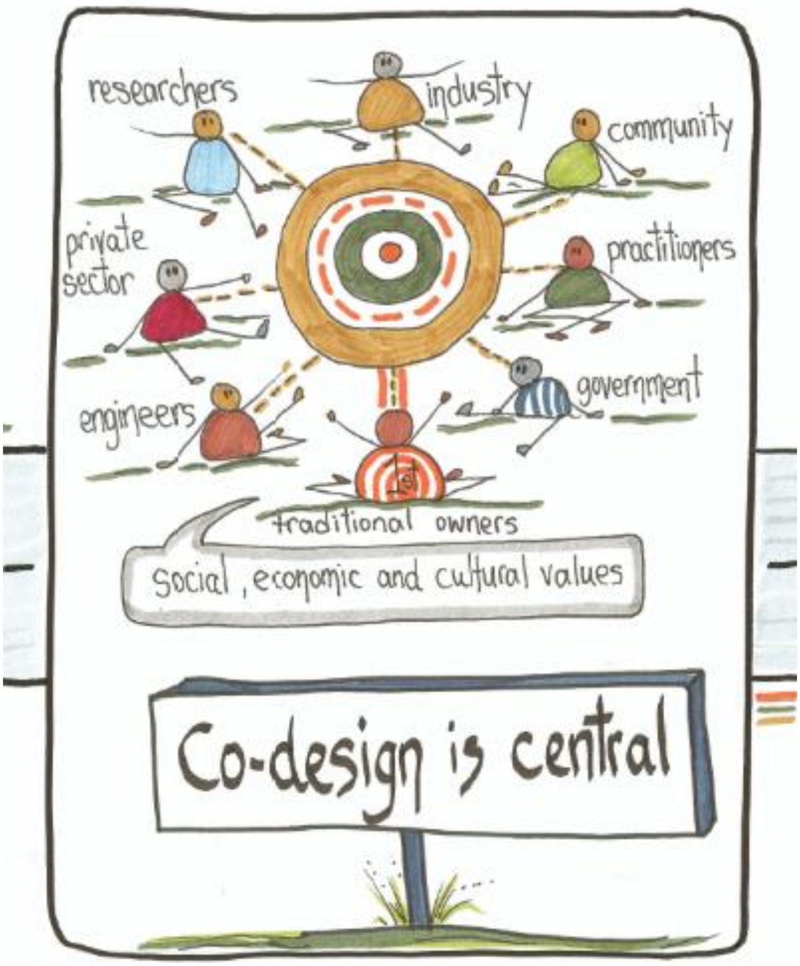

Figure 53: Roadmap to restoration principle 1: Co-design is central. Image: Fiona Malcolm.

Current

Coastal and marine restoration activities in Australia are being conducted by a wide range of stakeholder groups, with many working together (e.g. see case studies). However, there is some divide among sectors, with somewhat siloed communities (e.g. researchers, practitioners, decision makers, Traditional Custodians). There is an overall desire to bridge these gaps so that co-design can bring many types of knowledge together.

The survey results outlined that Aboriginal and Torres Strait Islander peoples are being included in about 80% of coastal restoration projects, mostly through paid employment and co-design. Traditional Custodians bring a wealth of knowledge, in particular with respect to biodiversity monitoring. However, there is variability in how they are involved – the level and type of involvement depends on the project, the level of maturity of the organisation's process and policies for Indigenous engagement. The perspective from respondents of the Traditional Custodian survey is very different: that Aboriginal and Torres Strait Islander peoples are not commonly involved in restoration in a meaningful way, and that tokenisms and cultural biases are present. However, non-Indigenous end-users also articulated a lack of confidence about the most effective and appropriate methods for engaging with community groups. Some stakeholders explained that they had attempted but had had low success in prior efforts to involve communities. Otherwise stated, the expectations of Aboriginal and Torres Strait Islander peoples with respect to co-design and collaboration is different to what researchers and practitioners have had experience and success in conducting or perceive as good practice. While Traditional Ecological Knowledge has started to be valued by researchers and practitioners as a concept, the cultural values associated with Country are not often explicitly linked to coastal and marine restoration objectives or outcomes.

Future

In the future, meaningful and effective co-design among multiple stakeholders will occur (*see also Knowledge is shared effectively*, below). In particular, here must be a reconciliation of the differences in perspectives among Aboriginal and Torres Strait Islander peoples and Non-Indigenous viewpoints, and a development of cohesion and shared vision. For instance, ideally, all coastal restoration projects will include cultural values, ecological values (from Traditional Custodians perspective) and economic opportunities for Aboriginal and Torres Strait Islander people. Benefits to groups will be clearly defined and articulated. Traditional Custodians will be involved in co-design from the start, middle and end of projects including maintenance, monitoring and reporting. The priorities of Aboriginal and Torres Strait Islander peoples will sit alongside the creation of benefits for local communities. Restoration practices that are underpinned by Traditional Knowledge will have the capacity to identify and deliver nature-based solutions put forward as best practice coastal restoration. This engagement as part of a co-design process aligns with the United Nations Declaration of the Rights of Indigenous Peoples (UNDRIP).

Relevant Recent NESP MAC Research

- NESP MAC 1.2 Mapping critical habitat in Yanyuwa Sea Country
- NESP MAC 1.31 Scoping study: Indigenous participation and research needs

Research Gaps

- Who are the Traditional Custodians, what are their priorities, how should researchers get in touch with them, who is already working with who? (Researcher/contact fatigue)

- Co-designed principals for restoration activities on Country (multiple habitats, governance situations)
- Case studies of effective co-designed processes in various 'governance' landscapes (Native Title Bodies, Ranger groups, community-led organisations, Indigenous councils etc.)
- See Research Gaps in *Knowledge is shared effectively* subsection

Key Actions

- Articulate the mechanisms/steps you need to use for engagement and meaningful consultation with Aboriginal and Torres Strait Islander people. What tools are available? Communicate a conceptualisation of Indigenous Worldview of the landscape.
- Implement a well-funded National scale Coastal Restoration & Nature-based Solutions Indigenous Advisory Panel to whom researchers and practitioners can go to for advice on engagement and to make appropriate connections. Connect to the Australian Coastal Restoration Network.
- Support the incorporation of planning for long-term iterative processes and commit to Aboriginal and Torres Strait Islander peoples engagement in funding programs and proposals.
- Develop training for Aboriginal and Torres Strait Islander people to understand coastal restoration processes (e.g., restoration works, monitoring and maintenance as other fee-for-service activities on Country benefits of being included in reporting).
- Increase funding availability for Indigenous-led restoration on Country.
- Include Aboriginal and Torres Strait Islander peoples in permitting processes for restoration and NbS activities.
- Include support for restoration practitioners and researchers to work co-develop restoration plans with Aboriginal and Torres Strait Islander peoples in restoration proposals.
- See Key Actions in *Knowledge is shared effectively* subsection.

9.4 Fit-for-purpose governance

Underlying principle

Legislative barriers delay, or indeed prevent, projects. This contributes to increased costs and causes delays in timelines to deliver projects. Developing a fit-for-purpose governance that is straight-forward for practitioners to obtain relevant approvals, including creating a set of easy, clear, guidelines/requirements, even where multiple approvals are necessary, is necessary and will lead to more projects and improved cost-effectiveness (Figure 54). Importantly, there is the need to still recognise the need for checks and balances on restoration projects e.g. in the form of permitting. Once restoration projects are completed there is a need to ensure that they are protected from future harm.

Figure 54: Roadmap to restoration principle 2: Fit for purpose governance. Image: Fiona Malcolm

Current

There are different policies and legislation in every state/territory; every Local Council has their own variation on by-laws and regulations (or interpretation of these) (Shumway et al., 2021). Knowledge of how to navigate these processes requires specialised skills (e.g., engaging environmental consultants) and could take projects away from landholders or community (including Aboriginal and Torres Strait Islander organisations). For the survey results in this project, permitting criteria and approval processes were identified strongly in responses as being overly difficult (e.g. some approvals are intended to reduce or prevent environmental harm from coastal developments), lengthy (several years in some cases), and expensive, which affected the cost-effectiveness of projects. In addition, there is presently some fragmentation within state government departments with many different aspects of restoration being the responsibility of different and sometimes multiple departments. There are also conflicting goals of different departments in relation to (a) protecting the environment vs (b) economic growth. This creates a situation where it is important to include the principals of Ecological Sustainable Development (including environmental accounting) by agencies with a focus on growth, which then might prevent destruction of habitats important for species, rather than a focus on restoration after the destruction or loss of habitats.

Future

All levels of government will acknowledge the importance of scaled coastal and marine restoration for the nation. There will be fit-for-purpose governance which mitigates permitting barriers to coastal restoration and NbS projects. Permitting processes for restoration and NbS will be tailored to these 'net-positive' activities rather than being aimed at preventing negative impacts on environments. This would include Commonwealth policies that include coordinated and scaled coastal and marine restoration approaches intended to combat coastal hazards from climate change. There will be an adequate process to ensure that natural values are not disrupted, for instance in Ramsar sites or Matters of National Environmental Significance, or upstream or downstream of restoration sites. There will be a national set of standards for restoration and NbS, that will still require consideration for local policies and laws, and flexibility for local contexts, that provides guidance for prospective project proponents. Restoration projects will be under some form of protection against future harm. In particular, there will be a clear strategy will be in place to mitigate issues around land tenure and coastal ecosystem that are generated by rising seas. Finally, Council's will have confidence to take up innovative approaches to coastal restoration (e.g., NbS), which could be facilitated with engagement with professional bodies such as the Australian Institute for Engineers.

Relevant Recent NESP MAC Research

No projects align with this headline

Research Gaps

- Horizon scan to identify how to de-risk restoration in protected areas such as Ramsar sites and Marine Parks, and well as how to manage for multiple landowners and impacts on industries. This will involve: 1) scoping research on risks; and 2) accepting some risk and attempting large scale experimental projects which are then monitored, maintained, learned from and communicated (e.g. see subsections *Robust Monitoring, Evaluation and Reporting* and *Restoration is Coordinated and at Scale*). The scoping will need to ensure that restoration works are beneficial and appropriate to specific conservation aims (see *Evidence-based and transparent decision makin*g, below).
- In the short term, create tools to support projects through the regulatory environment.
- There is a gap in the understanding relating to *climate ready conservation frameworks*, which requires further consideration when improving policy, regulation and non-statutory approaches to restoration.

Key Actions

- Evaluate and make recommendations on how to increase the coordination and transparency of the policy and legislative environment underlying the implementation of coastal and marine restoration and NbS to ultimately promote uptake and adoption across national, state and local boundaries.
- Develop fit-for-purpose policies for restoration which are transparent and accountable that dissects national, state and local authority boundaries.
- Integrated reporting structures to feed all levels of government (e.g., up to State of the Environment reports).

9.5 No-Gap funding

Underlying principle

Ecological restoration is a long-term process, with recovery taking many years-decades. Funding for restoration projects needs to move beyond ad hoc and short-term arrangements, and to be more coordinated and considering of the full project cycle costs [including maintenance, monitoring and sharing outcomes) (Figure 55). This needs to occur over meaningful time scales and not just a few years during the project and then concluding when the project (funding) is finished]. Recent literature (Canning et al., 2021; Lester et al., 2020) calls for more catchment wide and spatial planning approaches to project funding, to ensure returns from restoration are more coordinated and connected.

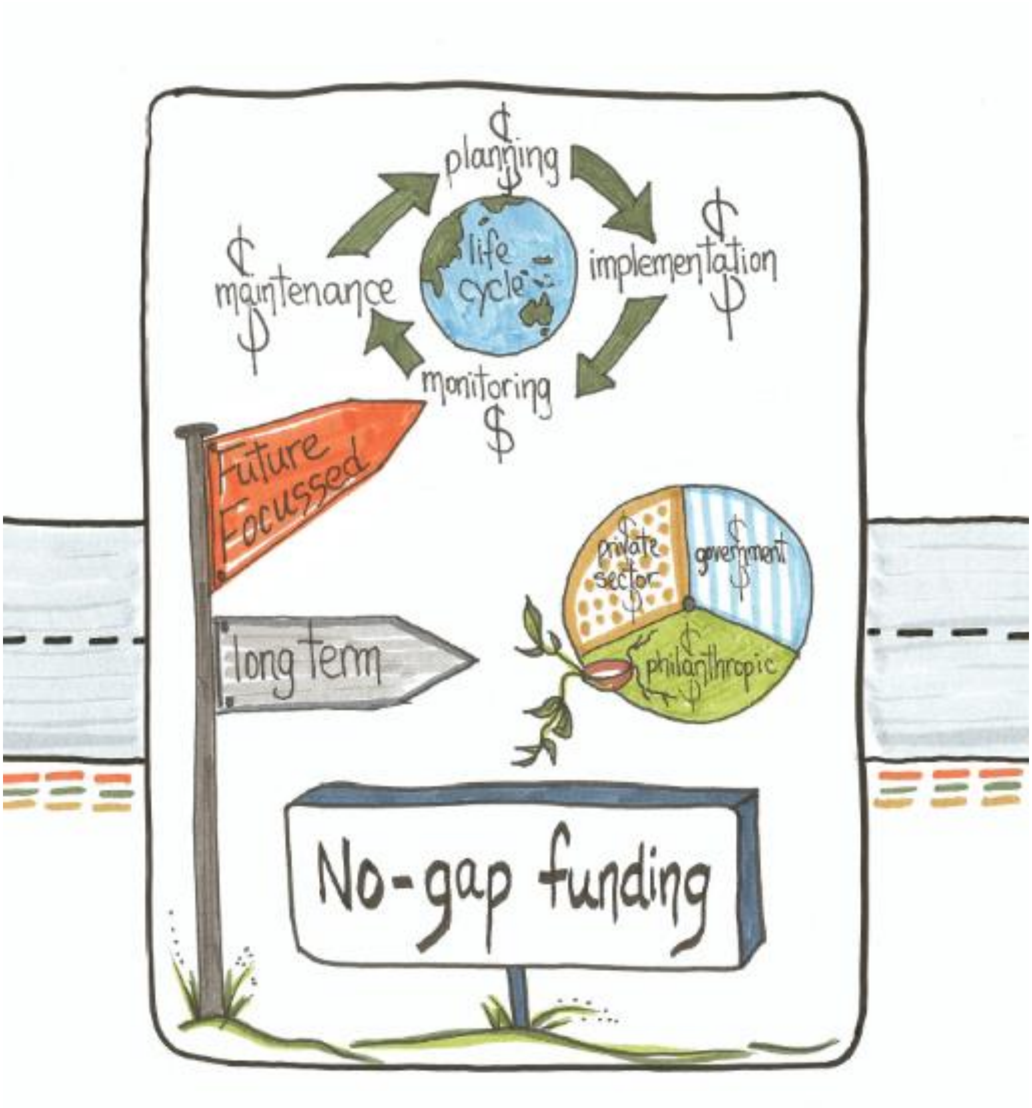

Figure 55: Roadmap to restoration principle 3: No-gap funding. Image: Fiona Malcolm

Current
Project funding tends to be limited to a few years. Practitioners express that they have to seek repeated funding from different sources to continue with projects, as the funding time frames are substantively shorter than the duration of restoration activities. Nationally, the availability of funding is very small compared to the level of impacts and relative to the value of coastal wetland ecosystem services. There are often tight eligibility conditions with respect to the jurisdictions in which funding can be delivered, for instance, commonwealth funding often cannot be used in areas under the jurisdiction of state governments. This make sense from the perspective of legislation but may be limiting in terms of scaling up and achieving the best possible social, ecological and economic outcomes from restoration. There are often clauses for a specifically defined budget allocation for maintenance – (e.g., *10% of project costs to be allocated only for monitoring*, which may not allow for suitable monitoring and maintenance and reduces the ability to evaluate appropriately restoration project success towards the goals).

There is no clear certainty as to when funding might or might not be available which limits the ability for organisations to retain skilled employees once projects are finished. This creates additional costs to organisations when starting a new project to employee and train new staff. In some instances there is a lack of willingness to fund projects in the same geographic area as previously funded projects, which limits the ability to continue scaling up and expanding on previous investment in restoration efforts. Short term funding for monitoring and evaluation prohibits the capture of long-term data for a more complete understanding of the restoration success (Abbott et a., 2020).

Currently, financial institutions and companies lack the information needed to accurately incorporate nature-related risks and opportunities into their strategic planning, risk management and asset allocation decisions. Building off the success of the Taskforce on Climate-related Financial Disclosures (TCFD), the Taskforce on Nature-related Financial Disclosures (TNFD) was formally launched in June 2021 to develop a global risk management and disclosure framework for organisations to report, and act on evolving nature-related risks and opportunities.

Future

Ideally, coastal and marine restoration projects will not have gaps in funding for the duration of the project. This could include self-renewing and strategically planned funding streams. Examples of long-term investment for restoration are slowly emerging. An example is the Mars coral restoration in Great Barrier Reef lagoon – building on their overseas program in Indonesia and USA. There will be large scale investment into restoration by the commonwealth, for instance, as financial stimulus similar to infrastructure investment schemes as well as biodiversity offset funds (developers' contributions) and the Emissions Reduction Fund (ERF) may occur.

- Funding for restoration projects is long term – carbon has this potential (25yrs for ERF projects, but projects may have 100yr permanence period), but if it's for biodiversity it would be still long-term commitments for maintenance for example (e.g., removing aquatic weeds from restored, connected, coastal floodplains).
- Funding for maintenance, in perpetuity, that is built into project planning phase to ensure restoration asset protection – e.g., riparian management agreements developed and supported by stakeholders (local Council, water board, landholders and NRM group) to annually fund the control of aquatic weeds on small creek system Burdekin floodplain (Sheep Station Creek, Queensland), which has been in place for 20yrs (see Waltham et al. (2020)).
- A portfolio approach will be taken to restoration research and funding will be allocated to both low and high-risk projects.

It is also acknowledged that the TNFD's overarching objective is to enable and promote global consistency in nature-related reporting and thereby support a shift in global financial flows towards nature-positive outcomes. The TNFD is working with leading international organisations as key knowledge partners to ensure that the TNFD framework builds upon existing expertise, definitions, data, analytical tools and disclosure standards. The Taskforce released a beta version of the framework in early 2022. The beta framework will need to be tested globally with financial institutions and corporates, in close collaboration with participating financial regulators. During the testing period, the Australian Government will work with different businesses and sectors to understand what data and information is needed going forward

Relevant Recent NESP MAC Research

No projects align with this headline

Research Gaps

- Research into the advantages and disadvantages of innovative finance, such as blue bonds, and how they could be effectively used to fund restoration and deliver economic returns to investors.
- Mapping the beneficiaries of restoration outcomes and the return on investment of restoration. This requires locally relevant data on the value of ecosystem services resulting from restoration.
- Focused research to quantify the restoration costs for different coastal ecosystems and the full lifecycle costs for asset protection. This activity must also quantify the feasibility of restoration (the likelihood that it will achieve stated goals).
- Using the above, quantifying the cost-effectiveness and cost-benefit analysis of restoration. Ultimately this information can inform us of how much restoration saves society financially.
- Research to identify the role of philanthropy, private enterprise and government capital within blended funding models.
- Look at examples of successful blended finance models, for instance, through the IUCN facility in Philippines, Belize long term revenue through ecotourism, seaweed farming programs in Vietnam. What is the scale of these types of blended finance? How did the economic and political factors in the region influence success?
- For NbS, cost-benefit assessment of combining grey-infrastructure with green-infrastructure solutions. Green infrastructure may not only save tax-payers, but also deliver healthy environments for wildlife and people.

Key Actions

- Review the financial mechanisms for restoration – project funding is often piecemeal, small, with inadequate funding for long term monitoring or large-scale implementation. At present, Practitioners have to justify why additional efforts are required in locations where previous efforts have occurred, which precludes scaling up to landscape scales.
- Focused examination into the role of the Taskforce on Nature-related Financial Disclosures (TNFD), and the Australian Government's Future Fund or superannuation funds in terms of ways that financial institutions report on risk. We need to upskill the private sector to ensure they have the knowledge and information needed to engage with these risk and opportunities. NbS is a potential way that businesses can act to mitigate nature related risk, however, there is still a lack of confidence to embrace this practice – i.e., there is limited data or guidance to inform the engineering and infrastructure industries.
- Developing a prototype Natural Capital Investment tool which can demonstrate the costs, benefits and viability of integrating nature-based solutions in coastal and marine infrastructure.
- Explore options for a mandatory requirement that NbS is incorporated into infrastructure proposals, with justification provided if they cannot be used.

9.6 Access to social, economic and biophysical data

Underlying principle

The success of restoration is underpinned by siting projects in places which are biophysically. economically and socially feasible (Saunders et al. 2020). Suitable data with appropriate extent, resolution, and indicators are required to inform these decisions (Figure 56).

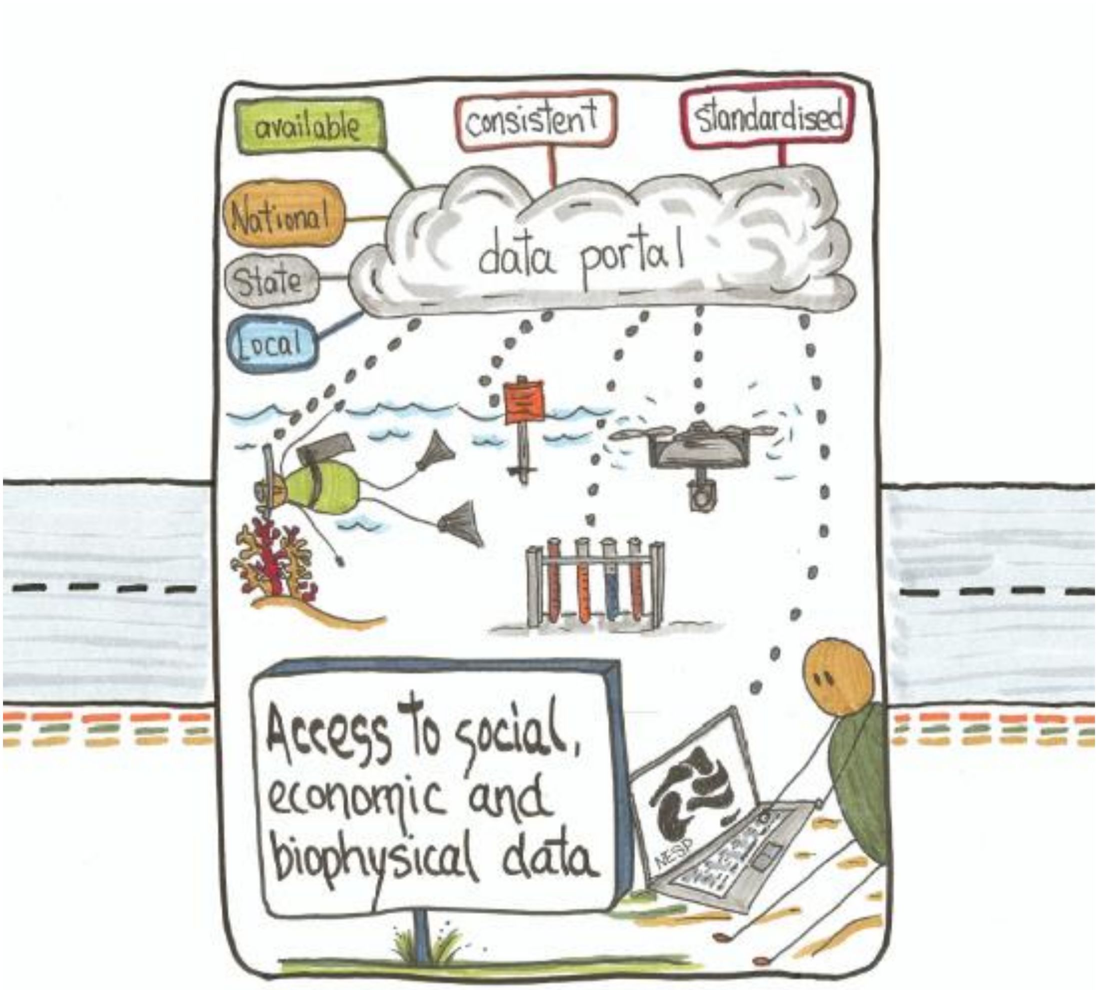

Figure 56: Roadmap to restoration principle 4: Access to social, economic and biophysical data. Image: Fiona Malcolm

Current

Recent efforts to collate and harmonize data to underpin Blue Carbon research (e.g., current CSIRO projects), and assess gaps in habitat data (e.g., NESP MAC 1.5) have uncovered a large amount of relevant data, such as habitat and bathymetry data, but also significant gaps in coverage. Data coverage in the intertidal zone is particularly challenging, because it is often not represented in either terrestrial or marine data assets. Those seeking to develop national scale spatial models to inform restoration decision making are presently faced with a substantial challenge due to inconsistencies and gaps in coverage. There is no central repository of high resolution coastal and marine environmental data in Australia (acknowledging Atlas of Living Australia and some state governments have their own repositories, such as WetlandInfo in Queensland, however, these are not specific to restoration or linked/coordinated across states sufficiently).

Data are collected during restoration projects and are used for a range of local specific purposes and communications. The most common use is for reporting to funding agencies/bodies, as a means of ensuring the projects are on track to delivering on the objectives stated in the project application. Data are also used for education and training, social media to project broadly the project outcomes, and raising public awareness.

The Australian Coastal Restoration Network previously (in ~ 2019) invited its members to contribute to the generation of a central repository for restoration information, where more than 230 responses were received. This total number of responses is not inclusive of the full number of projects completed or underway, but outlines both the desire to contribute to a central repository, while also the need to maintain this asset with ongoing base funding for collation, maintenance and to showcase the range of projects underway.

The eAtlas is the primary data and knowledge repository for the National Environmental Science Program Tropical Water Quality Hub (and the Marine and Coastal Hub), and historically for the NERP Tropical Ecosystems Hub projects, Reef Rescue Marine Monitoring Program projects and the Marine and Tropical Science Research Facility. This research covers a wide range of topics some of which include: seagrass, coral reefs, turtles, dugongs, seabirds, bathymetry, fish abundance, Crown Of Thorns Starfish, rainforest revegetation, and wet tropics species distributions, but most projects are specific to the Great Barrier Reef catchments and lagoon. The eAtlas is a website and mapping system for presenting environmental research data in an accessible form that promotes greater use of this information. The eAtlas has been funded under a number of projects, and relies presently relies on funding from the NESP Marine and Coastal Hub.

The Australian Ocean Data Network (AODN) is a marine data collection that is freely available to the public. Data stored in this repository covers a wide range of parameters in different ocean environments collected from ocean-going ships, autonomous vehicles, moorings and other platforms. The scope of observations, geographically spanning ocean to coast, and across disciplines (physical, biogeochemical, biological), provides a challenge to deliver an intuitive easy-to-use robust information infrastructure enabling users to efficiently obtain the data they need.

A key barrier to scaling up marine and coastal restoration and improving connectivity with adjacent ecosystems is the need for biophysical data at different scales, such as dispersal patterns and pathways, connectivity between physical and biological components within the ecosystem and with adjacent ecosystems. Another tool identified as beneficial for planning and implementing restoration is characterisation of ecosystems with common attributes.

Future

Availability of open access data is critical to ensure that future planned projects consider and include any lessons learned. Raw data are useful, however, the ability for some organisations to manage and access these data is difficult (e.g., requiring specialised computer software or domains skills to interpret information). Instead access to data should include synthesised information to allow all people to access and use the data. For example, DES in Queensland Government has a WetlandInfo website that contains detailed information on coastal wetlands, ranging from spatial data, technical reports, conceptual and education material, to photo libraries. From a modelling perspective, a national scale repository of cleaned and collated data would be ideal, such as in a data cube or other digital platform, however, there would be considerable challenges to overcome to achieve this. A centralised portal would require a quality assurance and quality control system as well as a plan for maintenance and continuity.

Relevant Recent NESP MAC Research

- NESP MAC 1.5 Scoping study: Identify knowledge gaps and solutions for extent mapping of Australian marine and coastal wetlands

- NESP MAC 1.2 Scoping study: National areas of interest for seabed mapping, characterisation and biodiversity assessment
- NESP MAC 1.17 Scoping study research needs for a national approach to socio-economic values of the marine environment
- NESP MAC 1.9 Quantifying the ecosystem services of the Great Southern Reef
- There are a number of NESP MAC projects which focus on ecology of coastal marine systems in Australia (NESP MAC 1.2, 1.4, 1.14, 1.20, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 1.30, 1.33)

Research gaps

- Fill gaps in availability of spatial data on fundamental environmental and ecological components and processes at national extent at a resolution which is required for informing local scale restoration activities. For instance:
    - habitat maps
    - bathymetry
- Develop spatial data on ecological processes and functions which are required to estimate ecosystem service delivery from restoration actions
- Develop spatial datasets on social and economic indicators relevant to restoration decision making (e.g., alternative land use mapping and economic analysis in the GBR catchments; see Waltham et al. (2021))

Key Actions

- Currently there are several database repositories where coastal restoration data resides or could reside (e.g., Atlas of Living Australia, AODN, eAtlas). Reconcile how these different data assets complement or compete with one another.
- Consider and potentially develop a platform to collate and make data available
- Development of standards and guidelines in a tool-box that are regularly updated and freely accessible for practitioners, managers, policy, industry, Traditional Custodians, community and academia. For instance, potentially through the *EcoCommons*.
- Understand and development a framework for the data capture of social and cultural values.

9.7 Evidence-based and transparent decision making

Underlying principle

Evidence-based approaches to inform the type and location of restoration activities are required moving forward as we move from often uncoordinated project scale activities to coordinated scaled restoration and NbS (Figure 57). Evidence-based and transparent decision making informed by science can in theory produce more effective policy decisions, and as a result, lead to better social, economic, engineering and ecological outcomes**.** Restoration decisions must be made using a combination of best science (data) and best knowledge (stakeholder knowledge) (Laestadius et al., 2014). Transparent decision-making facilitates stakeholder engagement and confidence in the process. Systematic processes to inform decision underpin equitable, rational and cost-effective resource distribution. Restoration activities occur amidst a suite of potential coastal management interventions such as habitat protection, pollution management, and fisheries regulations. Science can help us make informed decisions as to whether desired outcomes be achieved most cost-effectively through active marine restoration, or instead through catchment management or the implementation of protected areas (e.g. Saunders et al., 2017). There is a continuum of risk and evidence which underpin restoration decision making – with more information we can in theory be more confident in outcomes, but increased information comes at a cost (e.g. value of information).

Structured decision making is one approach to evidence-based and transparent decision making. For this approach, 7 steps are followed: 1) decide on goals, 2) set objectives [ideally they are SMART - Specific, Measurable, Achievable, Relevant and Timebound], 3) identify actions which can be used to meet those objectives, and parameterise their costs, feasibility (likelihood of meeting the objectives) and constraints; 4) predict the benefits that the actions can achieve relative to the objectives; 5) identify trade-offs, 6) make a decision, 7) act, monitor and learn (Gleason et al., 2021). These approaches to coastal and marine restoration are rarely communicated in the literature, but variations on these steps are being adopted by some practitioners (e.g. uptake of the Restoration Opportunities Assessment Methodology, ROAM, by mangrove practitioners (Laestadius et al., 2014)) and have analogies in decision support frameworks used in other fields, such as Management Strategy Evaluation frameworks used by fisheries scientists and managers (Punt, Butterworth, de Moor, De Oliveira, & Haddon, 2016), or analogous frameworks used by engineers to inform project design.

Figure 57: Roadmap to restoration principle 5: Evidence-based and transparent decision making. Image: Fiona Malcolm

Current

Scaled ecological restoration in Australia is still in arguably somewhat experimental phases, which means that the evidence base is in development. Consistent restoration decisions and prioritisation (places, practices, monitoring) are not common, due to the opportunistic nature of current funding and political environments. For example, a project may proceed because there is political support for implementation in a particular place, although ecological requirements or rational for restoration may be just as large in other places or systems. There are no agreed standards for coastal restoration or Nature-based Solutions, and no agreed ways to make decisions around coastal restoration locations, actions, spatial extent, monitoring, or data collection – practitioners and decision makers express that this would be useful moving forwards. However, it is worth noting that a number of frameworks to support coastal and restoration and climate change adaptation have been developed (e.g. (Palutikof et al., 2019; Sivapalan & Bowen, 2020)).The lack of a systematic planning approach to coastal and marine restoration can in theory raise several risks, including inequitable distribution of resources, lack of confidence in decision making, and the inability to reconcile trade-offs in different objectives. Short timelines on restoration decision making and funding often preclude data collection and modelling which can be used for prioritisation of actions or site selection. Already global markets are increasingly seeking data-led decision-support-tools (DST) to inform risk assessments and the financial viability of green/blue investments. Supporting the development of fit-for-purpose DSTs, data collection and sharing arrangements will be crucial in the future.

Future

Systematic approaches to evidence-based and transparent decision-making will have been developed and projects and programs with the best chance of achieving desired outcomes will be funded. The most appropriate approaches to coastal management, which will include restoration in some instances, will be tailored to habitat types and certain spatial scales. There will continue to be an emphasis on protecting intact habitats, although there will be increased capacity to strategically allocate restoration investment where required. There will be a portfolio of coastal and marine restoration and NbS projects which collectively realise cumulative restoration outcomes that are greater than the sum of their parts. Proactive strategies that incorporate risks from climate change to restoration and NbS projects will be incorporated into decision making. There will be broad scale spatial planning across jurisdictions and seascapes which includes representation of natural assets as well as hardened coastal infrastructure; this will allow identification of where the opportunities and limitations for NbS exist.

Relevant Recent NESP MAC Research

- NESP MAC 1.8 National framework for seagrass restoration
- NESP MAC 1.15 Coastal wetland restoration for Blue Carbon in northern Australia
- NESP MAC 1.32 Scoping study: Supporting regional planning in northern Australia
- NESP MAC 1.1 Scoping study: Protected place management mission
- Several project which are loosely related and which broadly speaking examine pollutants, contaminants and multiple uses management (NESP MAC 1.16, 1.18, 1.19)

Research Gaps

- Development of models to underpin structured and evidence-based approaches decision-making and prioritisation for coastal and marine restoration and NbS (refer to Section 8). These will need to consider comparisons among restoration actions (e.g., transplanting vs seeding) and also to consider restoration compared to other actions, such as implementation of protected areas or implementation of social-economic initiatives which can enable restoration, such as community payment for ecosystem services. This will require systems

models which can represent hydrodynamic processes in coastal and catchment areas, and which can be used to generate a scenario approach to guiding restoration decision making.
- Reconcile how to deal with land-based inputs to coastal water quality in a coastal restoration framework, or by working out how to do multiple restoration projects in a catchment with a wide range of landholders in a catchment led process.
- Identify what is required to de-risk restoration in protected areas such as RAMSAR sites and Marine Parks. In an ideal world we will use science to help ensure that perverse outcomes of restoration don't eventuate. Due to the current state of the evidence base, there will need to be some application of expert stakeholder knowledge and some tolerance of risk in attempting new strategies, with this information used to inform adaptive management and knowledge sharing.
- Develop a process to decide which decision-making tools to use and what services they result in. e.g., tool which can help to decide which actions to take and what is the evidence to show those approaches achieve different outcomes?
- Adapt and implement the Restoration Opportunities Assessment Methodology (ROAM) at either national or state scales to commence a systematic approach to prioritisation of restoration.
- Identify trade-offs in ecosystem service delivery from different restoration approaches.

Key Actions
- Develop standards for coastal and marine restoration and NbS, or adopt already available international standards (e.g IUCN global standards for nature based solutions - https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard-nbs; SER National Standards for the practice of ecological restoration in Australia https://www.seraustralasia.com/standards/National%20Restoration%20Standards%202nd%20Edition.pdf) . The Standards can help to guide the prioritisation of where, when and how coastal restoration should occur or particular ecosystems and geographies.
- Adapt and implement the Restoration Opportunities Assessment Methodology (ROAM) at either national or state scales to commence a systematic approach to prioritisation of marine and coastal restoration.
- Use data, models, expertise and stakeholder input to develop a portfolio of potential restoration projects which are *shovel ready*. New investments can be quickly allocated to these projects.
- Identify how to Incorporate Traditional knowledge into decision making and move towards more holistic coastal restoration and management.
- Develop standards that recognise the value of restoration of ecosystems for which there is little knowledge and certainty (e.g. extinct oyster reefs) of outcomes. Along the continuum of evidence and certainty of restoration success, room is needed for pioneering trials such as reviving ecosystems that were extinguished before the advent of modern science.

9.8 Restoration is coordinated and at scale

Underlying principle

Coordinated landscape-scale restoration is required to reverse the large scales of ecological degradation and loss of natural capital which has occurred (Figure 58). Economies of scale can be reached when projects are coordinated, for instance through aggregation of adjacent land holders in wetland restoration projects. Coordination of multiple projects allows assessment of the suite of benefits that the projects are providing as well as assessment of potential trade-offs which may arise (e.g., some projects may be of high recreational fishing benefit, but provide poor coastal protection, and vice versa). Ecological facilitation among ecosystems occurs, such as coral reefs protecting seagrass from wave energy (Saunders et al., 2014); consideration of connected ecosystems in the land-seascape can leverage outcomes of one project towards other (e.g., restoring coral could benefit seagrass or mangroves (Gillis et al., 2017)).

Figure 58: Roadmap to restoration principle 6: Restoration is coordinated and at scale. Image: Fiona Malcolm

Current

Globally, the vast majority of marine and coastal restoration projects are typically small or experimental scale (Bayraktarov et al. 2016). Globally, there are differences among ecosystems in terms of the size of restoration or afforestation achieved to date, with the largest extents achieved for saltmarshes and mangroves (maximum size of 1000s-100,000s ha) occurring in the USA and Bangladesh, respectively (Saunders et al., 2020). We do not know the extent of restoration to date in Australia, although the Australian Coastal Restoration Network database does link to a number of past projects; this database is not currently funded for upkeep and maintenance, and there is no mechanism for new projects to be contributed. This precludes an assessment of how much has been accomplished. There is a sense that most restoration is conducted at project scale rather than at program scale, and that there is a fundamental lack of coordination among projects – both within ecosystem types and among ecosystem types.

The majority of projects in the literature report on single habitat restoration (e.g. seagrass, or mangroves). Coastal systems exist within a mosaic of interacting habitat types in natural systems, and there are facilitative interactions among ecosystems, such as wave sheltering by corals to seagrass, or nutrient filtration by mangroves to coral (Gillis et al., 2017; Saunders et al., 2014).There are few examples of explicitly restoring multiple different connected habitat types in practice either in Australia (Iram et al., 2022; Waltham et al., 2019) or internationally (but see *Living shorelines* approaches). Notably, there are proof of concept examples of how facilitation can be harnessed to maximise restoration outcomes in Australia, such as through kelp facilitating recruitment of oysters (McAfee, Larkin, & Connell, 2021).Our survey suggests that most practitioners are considering ecosystem connectivity in some way, for instance, by considering biophysical connections, or by leveraging socio-cultural drivers such as legislation or policy that requires consideration of adjacent habitats. Socio-cultural barriers such as permitting and legislation, land tenure, as well as community perceptions remain barriers to conducting coordinated multi-ecosystem restoration.

Despite the challenges, new ideas around scale and connections are being actively developed. New frameworks are being developed which articulate the need for consideration of how management actions link across spatial and temporal scales, for instance, understanding how catchment land uses might affect river run off processes and their influence on coastal systems such as mangroves. For example, the QLD DES Wetlands Team ‘Whole of Ecosystem Values Based Framework’. In South Australia, the loss of kelp forests in urban catchments (Daniel Gorman & Connell, 2009; D. Gorman, Russell, & Connell, 2009) can be reversed by managing the process driving loss (80% reduction of nitrogen loads) to restore multiple ecosystems (e.g. 5000 hectares of seagrass: (Fernandes et al., 2022).

Future

Coastal and marine restoration projects and NbS for coastal hazards will be implemented at seascape-landscape scales, with resultant delivery of services and benefits to society at socially and environmentally meaningful scales. There will be coordination among actors across multiple spatial scales and organisational levels. The facilitative connections among multiple habitats will be well understood and represented in multi-habitat restoration projects. There will be a central repository for recording outcomes of restoration projects. International agreements relevant to ecological restoration and the oceans will be signed and actions will be taken to proactively and systematically find ways to optimise meeting the commitments under those agreements.

Relevant Recent NESP MAC Research

- NESP MAC 1.8 National framework for seagrass restoration
- NESP MAC 1.15 Coastal wetland restoration for Blue Carbon in northern Australia

Research Gaps

- Design technologies for larger scales of restoration (for instance, feasibility of harvesting wild coral spawn slicks (Doropoulos, Elzinga, ter Hofstede, van Koningsveld, & Babcock, 2019); developing plastic free materials to attach coral to substrates (Suggett et al., 2020))
- Quantify the business case for scaling restoration and identify the economies of scale that are possible with coordination
- Quantify facilitative processes among ecosystems to move towards seascape scale restoration (i.e., not habitat in silos but considering multiple habitat type and ecosystems and connectivity simultaneously).

Key Actions

- Fund a coordinator position to permanently administer and facilitate the Australian Coastal Restoration Network in order to maintain knowledge sharing and a point to connect with others working on similar projects/research. Included in this position would be to maintain the database of members and website content to ensure it remains updated with latest data, technology and learning. Data could be also deposited in international open source portals for restoration such as Restor (https://restor.eco/).

9.9 Robust Monitoring, Evaluation and Reporting

Underlying principle
Monitoring and evaluation are required to learn what worked and didn't work in natural resource management (Figure 59). Adaptive management (revising the interventions if poor results are observed) is a key determinant of restoration success (Saunders et al., 2020), and can only occur if well planned and suitably resourced monitoring and evaluation processes are in place. Publicly-available reporting of restoration monitoring outcomes is essential to learn from past successes and failures, but to also inspire innovation and new technology development in restoration (Eger et al., 2022). This theme has a strong link to the *Co-Design in Central* and *Knowledge is Shared Effectively* themes.

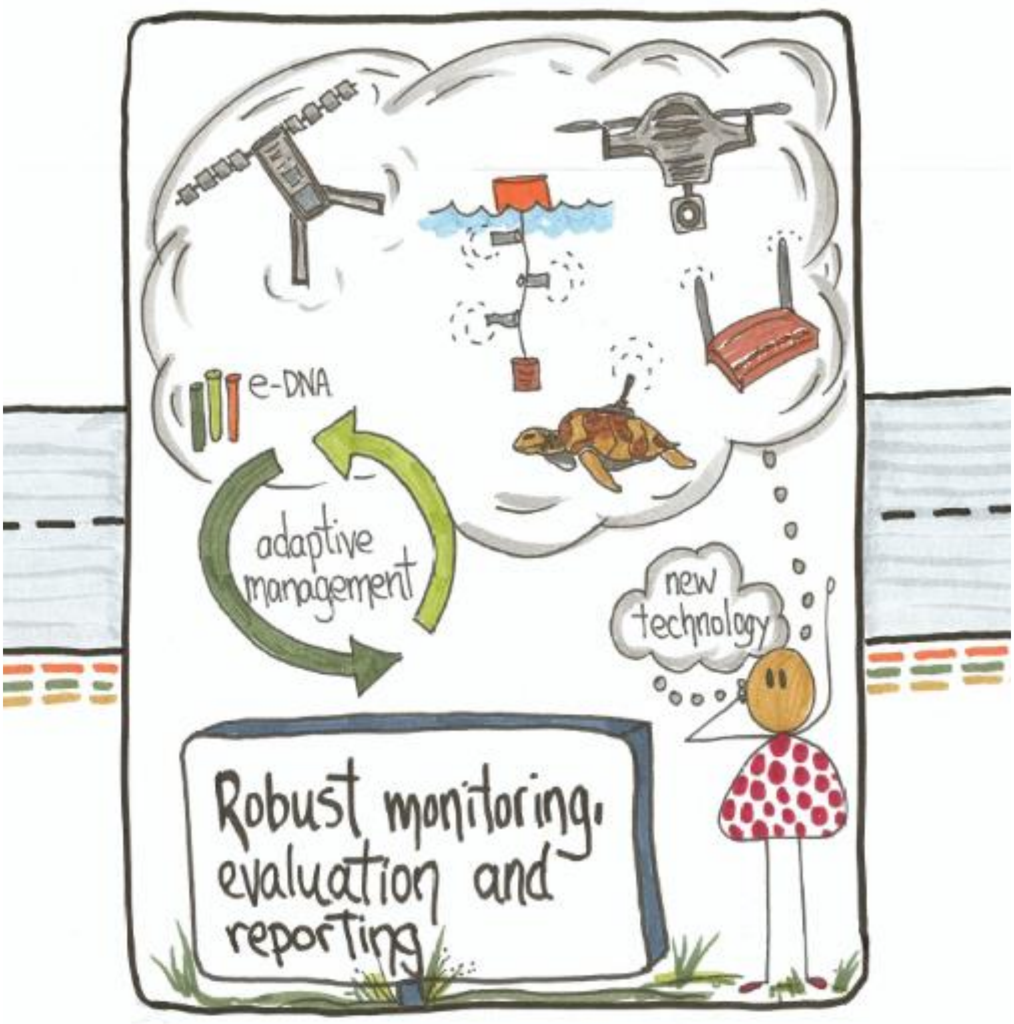

Figure 59: Roadmap to restoration principle 7: Robust monitoring, evaluation and reporting. Image: Fiona Malcolm

Current

The majority of restoration and NbS projects do consider requirements for monitoring in some form during the planning and implementation stages. However, monitoring requirements differ geographically and by funding program, so different data are collected in different ways and stored in different places. The data reporting outcomes of restoration are not usually published or otherwise made publicly available. For example, a lot of monitoring data is provided by consulting companies to state governments resulting from development applications, and a lot of data is communicated internally within organisations to inform future works, but restoration outcomes are not typically published or communicated publicly. Adequate funding for monitoring and evaluation was identified as a major barrier to the implementation of monitoring activities. Lack of time, resources and organisational support was identified as a major barrier to the publication of monitoring outcomes.

Of the various type of outcomes that can be achieved by restoration and NbS, biodiversity outcomes are the most likely to be evaluated, both among survey respondents and the international peer reviewed literature (Bayraktarov et al., 2020; Bayraktarov et al., 2019). Ecological (processes, functions, and services) and social-economic outcomes are much less commonly reported but are key elements of the ‘business case’ for restoration (Bayraktarov et al., 2020; Morris et al., 2019).

Interestingly, over half of our survey participants were considering monitoring economic, social and cultural outcomes, however these are very rarely reported in the peer reviewed literature (Saunders et al., 2020). Monitoring for social and cultural benefits is increasingly important and is noted as best practice by agencies like IUCN. However, practitioners note a lack of information on the best approaches for monitoring social and cultural outcomes, and identify a strong need for new methodologies for social and cultural monitoring (e.g., Aboriginal Carbon Foundation).

New technologies are beginning to be used in restoration monitoring. For instance, eDNA, animal tagging, underwater remote vehicles, remote-sensed monitoring using satellite, and drone technologies are starting to be used for identifying improvements in coastal restoration projects. However, the applications of many of these techniques are still experimental and uncoordinated, and dealing with the massive datasets created in the process is challenging.

Future

Monitoring and research of project outcomes will be a key aspect of projects rather than an ‘add on’. The systematic and long-term monitoring and reporting of engineering outcomes of NbS projects will feed into the knowledge base of the effectiveness and risks of these projects The planning and funding for monitoring, maintenance and communication of outcomes of restoration projects will be universal. All projects will have monitoring data that cover ecologically relevant time spans, and these data will be fed into centralised repositories which are publicly available. Data will be proactively incorporated into the decision-making and prioritisation process through adaptive management. Monitoring and evaluation will consist of ecological, social, engineering, and economic outcomes. Traditional Custodians will have a key role in conducting monitoring and this will result in livelihood opportunities for communities. New monitoring systems and smart sensors that enable real-time monitoring will be linked to Wi-Fi systems to report data back in real time. Sensors will be sensibly deployed with key questions and interpretation/outcomes in mind.

Relevant Recent NESP MAC Research

- NESP MAC 1.7 Towards a consolidated and open-science framework for restoration monitoring

- NESP MAC 1.29 Scoping study: New approaches to marine monitoring
- NESP MAC 1.3 Support for Parks Australia's Monitoring, Evaluation, Reporting and Improvement System for Australian Marine Parks

Research Gaps

- Early testing of smart technology in both coastal and marine environments (e.g., extreme weather conditions).
- Identify the role that artificial intelligence and deep learning can have in restoration evaluation and monitoring.
- Quantify cost-effectiveness of restoration interventions.
- Quantify ecosystem functions and services provided by restoration with links to relevant indicators.
- Identify and document social and cultural outcomes from restoration.

Key Actions

- Development of the architecture for building a linked network of national monitoring. For example, fund a platform for the collation of data on coastal and marine restoration projects, and build a requirement for groups to enter information into the platform as a condition of funding.
- Develop a strategy to facilitate connection of researchers to practitioners to leverage opportunities for sharing data for purpose of collaborative publications.
- Make the reporting of restoration actions data publicly available. For instance, specify that outcomes of offsetting projects must be publicly available in a central repository.
- Fund a coordinator, on-going, for the Australian Coastal Restoration Network to maintain presence and interface for knowledge sharing and capture

9.10 Clear Strategy to Adapt to Climate Change

Underlying principle

Symptoms of climate change such as warming temperatures, heat waves, stronger cyclones, drought and floods, ocean acidification and sea-level rise are a major threat to coastal ecosystems (Babcock et al., 2019). Planning ahead for restoration in the context of climate change will result in more cost-effective interventions and better outcomes for coastal ecosystems and for the people who rely on them. The recent IPCC report advises that NbS should be implemented at scale in the next decade to mitigate and adapt to climate change (IPCC, 2022). There is a need for a clear strategy to guide restoration in the context of climate change (Figure 60).

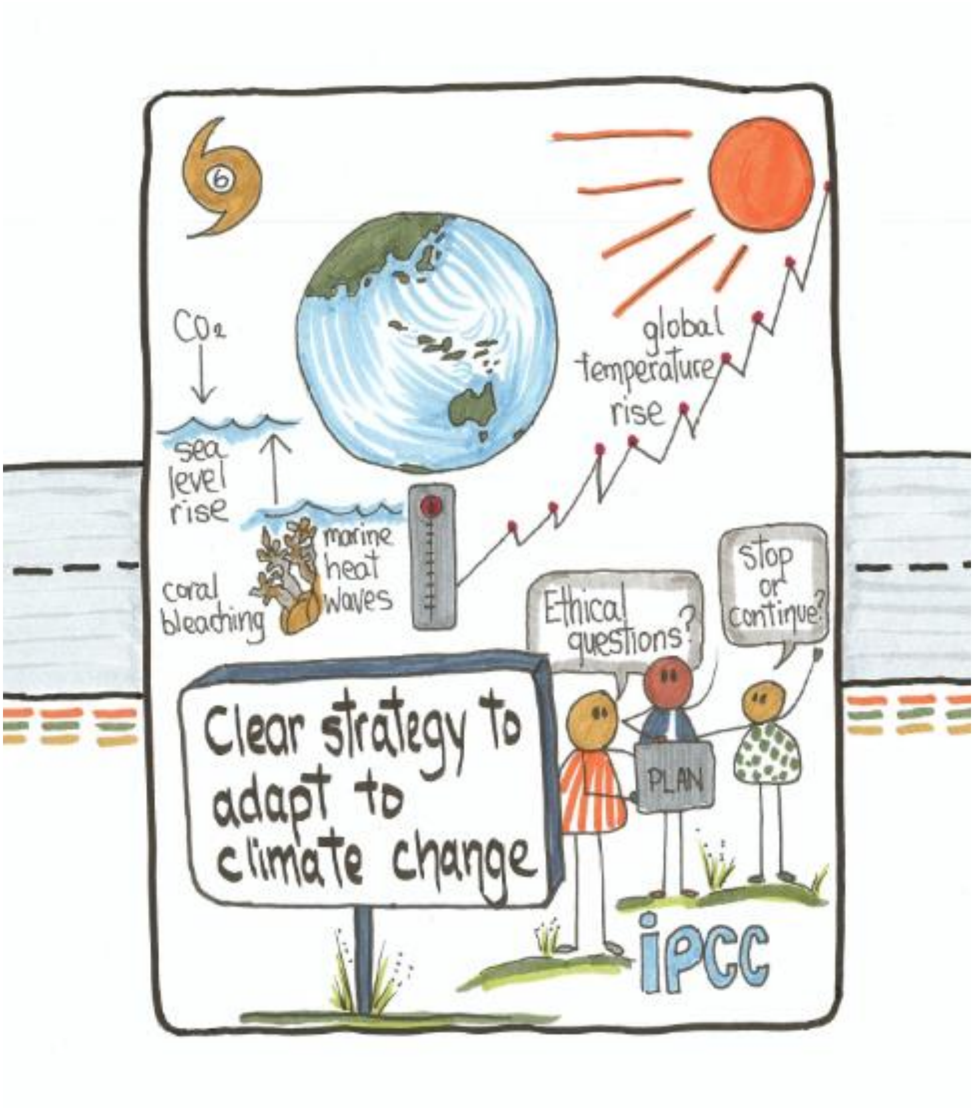

Figure 60: Roadmap to restoration principle 8: Clear strategy to adapt to climate change. Image: Fiona Malcolm

Current

While many are considering the impacts of climate change in restoration planning, there is no clear guidance on how to explicitly account for climate change. The climate change impacts considered seem to mainly be at a local scale and aligned to the habitat types being restored. Projects are not necessarily considering climate change hazards at a landscape/ catchment scale which may impact on the restoration site, for example increase in drought and floods, or bushfire hazards causing increased sedimentation and pollutant run off. There is recognition that SLR in particular will affect coastal ecosystems, but there is high uncertainty and no consistent guidance on how to plan for it in the restoration context. There is one well-funded research program for impacts of climate change on corals in the GBR and implications for restoration (Reef Restoration Adaptation Program), but none for other geographies or systems. Advice or consensus on how to plan for the impacts of heatwaves and warming temperature on restoration projects is absent. There remains a gap with respect to practical application actions – for example methodologies exist, but data are rare (e.g., Coast Adapt (Palutikof et al., 2019), Ramsar vulnerability assessment method).

Future

The impacts of climate change on coastal ecosystems and society will intensify. Ideally, coastal and marine restoration will be used as a mechanism to help ecosystems and society adapt to climate change at scale (see Nature-Based Solutions will be Implemented, below). Tools such as restoration suitability modelling need to based not only on present-day conditions but projected future conditions. This will involve reconciling challenging issues, such as species translocations (Seddon, 2010), novel ecosystems, and decisions around under what circumstances to give up on restorations actions as the environmental conditions have changed too much. Coastal restoration decision makers and practitioners will have clear guidance on how to account for climate change in restoration planning. Coastal planning will proactively account for landward migration of coastal ecosystems, and there will be clear rules that relate to climate change impacts of coastal restoration – for instance, what restoration actions should and should not happen in high coastal hazard zones, and how to account for changing land tenure as sea-levels rise. Funding and reporting will include conditions on managing impacts of climate change. There will be substantial investment into R&D on climate change and how to restore coastal ecosystems for all coastal systems across Australia. Researchers and practitioners will have a platform to share thinking on restoration in the context of climate change.

Relevant Recent NESP MAC Research

NESP MAC 1.28 Future-proofing restoration and thermal physiology of kelp

- NESP MAC 1.11 OzSET: Integration and publication of the Australian Surface Elevation Table dataset
- NESP MAC 1.30 National assessment of climate-driven species redistribution using citizen science data

Research Gaps

- Develop the narrative for when to keep going with restoration and NbS actions vs stop when ecosystems are impacted by increasing frequency and intensity of climate stressor events, such as floods or heatwaves. This is a crucial gap in understanding and policy disclosure, as NbS are commonly treated as a panacea without any recognition of their limitations or the contingencies of further climate change (IPCC, 2022).
- Understanding the timing of restoration is also important, and the scale necessary when considering climate changes in the future.
- How to generate climate resilient restoration & NbS projects? For instance, breeding warm tolerant genotypes in the anticipation of future warmer environmental conditions.
- Articulating the rational and ethics of conducting assisted migration and developing climate tolerant novel ecosystems.
- Development of case studies for adaptation actions – what did they do and why? What were the lessons?

Key Actions

- Implementation of well-funded research programs designed to increase knowledge and capacity for restoration in the context of climate change for a variety of coastal ecosystem types outside of GBR Coral reefs, e.g., temperate-tropical coastal wetlands; kelp and temperate reefs, oyster reefs; beaches and dunes.
- Develop guidelines for restoration decision making within the context of climate change – these would need to be supported by case studies.
- Fund monitoring and research programs designed to detect early climate change signals for contingency planning and quick responses.
- There is recognition of the National Climate Resilience and Adaptation Strategy (NCRAS) as a high-level policy that exists, but more targeted strategies are needed to support ecosystems adapt to climate change.

9.11 Nature-based solutions are implemented

Underlying principle

Coastal structures such as seawalls and levees protect coastal assets from inundation and erosion. The need for these functions will increase as climate change progresses. Traditional 'grey' infrastructure all too often harms biodiversity through loss of habitat and alteration to natural environmental processes. Where possible, nature-based solutions or hybrid (green-grey) solutions to coastal protection promote biodiversity and ecosystem functions as well as providing coastal protection should be implemented (Figure 61). However, some care is needed to ensure such solutions are not counterproductive owing to broader coastal geomorphological processes. The recent IPCC report suggests that restoration should occur at scale in the next decade. Due to impacts of climate change on coastal ecosystems the IPCC also expects that that hard limits will be imposed on coastal communities relying on NbS only once temperatures surpass 1.5C (IPCC, 2022) – therefore action to keep temperatures below 1.5C of warming are is necessary for NbS to succeed.

Figure 61: Roadmap to restoration principle 9: Nature-based solutions are implemented. Image: Fiona Malcolm

Current

There is significant support for NbS in the groups that responded to the survey, with 95% percent of survey respondents stating that there is support for NbS within their organisation. However, only 60%

of respondents are actually implementing NbS, suggesting that there are barriers to implementation. There's a recognition that NbS provide a range of benefits and co-benefits, biodiversity being the most highly valued followed across organisations. The benefit and co-benefits associated with new and emerging methodologies, like carbon sequestration and NbS for coastal hazard protection, are less valued by practitioners, i.e., NRM and community groups, than the research community. Coastal works are conducted by engineering companies for many of these ecological principles are not deeply engrained. Engineers have to design projects with confidence of the levels of impact that they can withstand over a design lifetime, which is challenging when using nature-based methods (see section 8). Both of these considerations limit the capacity to apply NbS for coastal hazards. Accordingly, there is a strong need for improved understanding of the efficacy and risk in applying Nature-based solutions, including fairness and justice as well which need to be included. The indirect and unclear relationship between beneficiaries and blue natural capital contributes to a financing problem as it can be challenging to establish which actors benefit from restoration and NbS activities and therefore have an imperative to contribute.

Future

Nature-based or hybrid solutions will be implemented as the first option where possible. Policy mechanisms will support the implementation of NbS. Private sector and communities will strive for NbS. Decision makers will help to remove barriers to NbS. Hard infrastructure will be explicitly accounted for in landscape scale coastal restoration planning; this recognises that not all hard infrastructure can have a NbS component. The possibilities of nature-based solutions will be well known and recognised by communities. New ideas about NbS will emerge especially when linked with Traditional Knowledge. Political and policy support will mean that opportunities to try new nature-based and hybrid solutions (engineering-based and NBS) will evolve, and more citizen scientists will become involved. There will be coordinated approached to NbS for instance facilitated by the ACRS and associated partners.

Relevant Recent NESP MAC Research

- NESP MAC 1.10 A national inventory of implemented nature-based solutions to mitigate coastal hazards (ongoing)

Research Gaps

- What is the efficacy of NbS for local-specific coastal hazards? What and where are the risks involved in implementing NbS?
- How do NbS for coastal hazard protection relocate existing risks? For instance, do NbS projects behave similarly to grey infrastructure, where some sections of the shoreline are protected, whereas others erode? How do we deal with situations where risk is transferred rather than removing the risk?
- How will climate change symptoms, such as increased intensity of cyclones, affect efficacy of NbS projects?
- Research into concepts of liability - who is responsible if the NbS project fails?
- What is the scale at which NbS should be happening?
- What happens if NbS projects have negative effects on other systems due to the connections among ecosystems?
- Is there a way to de-risk processes while NbS come into fruition in coastal planning and infrastructure upgrade decisions?

Key Actions

- Further engagement with the engineering sector and local councils to understand their barriers and constraints on implementing NbS and identify useful ways forward.

- Development of training material in modular format in language accessible to engineers on ecological concepts and Nature-based solutions. This tool-box needs to be supported by local data and challenges; what works in one region will not likely work in another region of Australia.
- Demonstrate to policy makers how NbS can be used to mitigate coastal hazards. For example, disaster relief/recovery funding following hurricanes has required that NbS be utilised where feasible on the east coast of the USA, while in the UK a requirement to achieve 10% net biodiversity is being met by incentivising NbS on all new development.

9.12 Knowledge is shared effectively

Underlying principles

Coastal and marine restoration requires input from many actors. Effectively sharing knowledge about causes of success or failure of restoration among different stakeholders is essential to learn from past experiences and to move forward in a coordinated and effective way (Figure 62). Knowledge sharing is one of the key determinants of relationship building, and the development of meaningful partnerships is one of the key determinants of restoration success (Saunders et al., 2020).

Knowledge sharing is not limited to within the immediate 'ecosystem' of restoration. To scale up restoration will require a step change to engage a much broader suite of actors. For instance, engagement with diverse market sectors such as the engineering sector, where there is capability to implement nature-based solutions at scale, and finance, where there is building momentum to make supply chains more transparent and sustainable. Ecological restoration is not necessarily the top priority for these sectors, therefore education, knowledge sharing, empowerment is required.

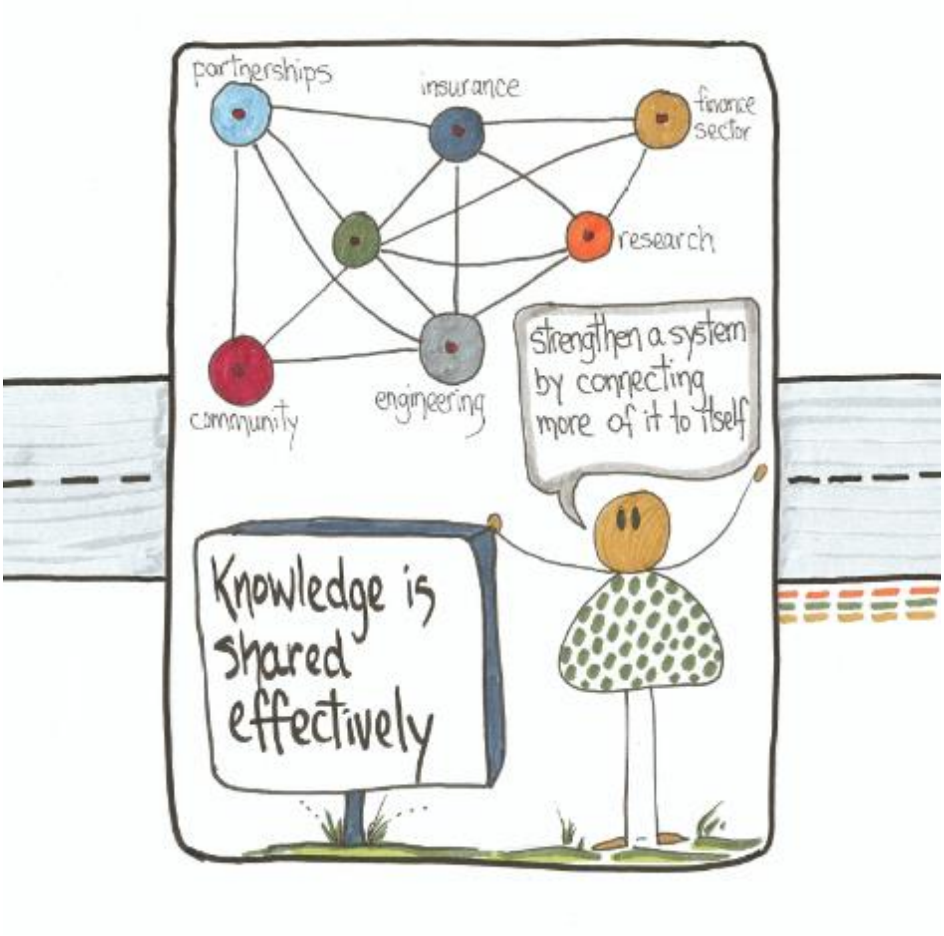

Figure 62: Roadmap to restoration principle 10: Knowledge is shared effectively. Image: Fiona Malcolm

Current

There is a sentiment that there is a need for a better mechanism/structure to communicate among geographies, ecosystem types, organisations, and stakeholder groups. At present, several research/practitioner coastal restoration and ecological networks exist (Australian Coastal Restoration Network, Shellfish Restoration Network, Seagrass Restoration Network, Mangrove Watch). There are community-based groups and various other natural resource management groups, as well as NGO's such as OzFish and regional management non-profits such as Healthy Land and Water in Southeast Queensland. There is a need to better connect researchers and practitioners in particular, as these groups tend to have different focuses and priorities than practitioners, and vice versa. Researchers tend to conduct more experimental restoration techniques at smaller scales and are more involved with emerging methodologies in monitoring and evaluation such as carbon sequestration, social and cultural monitoring.

There is a sense of pressure to not attempt risky projects, or to make public any failures in restoration, for fear that future funding might be held back. This holds the field back as risky projects are required to learn how to use new techniques and how to scale up, and these are not necessarily encouraged in most funding schemes. Lack of data on restoration failure makes it is hard for the community to learn from mistakes, and to determine the cost-effectiveness of restoration projects.

Some stakeholders articulate a perspective that there is a relatively low level of basic ecological knowledge in the general community, and that this an impediment to coastal restoration. Support from local communities is: a) required for 'social license to operate' and to support political leadership, b) involvement and leadership from local communities is one of the top predictors of restoration success (Saunders et al., 2020). Permitting barriers and lack of leadership and coordination preclude communities from taking small actions to contribute towards low-risk coastal restoration activities, such as planting native vegetation on dunes to prevent erosion.

Important 'scale' sectors with connections to healthy functioning ecosystems and access to substantial funding, such as finance, insurance, fishing, and engineering, are not currently well connected to the ecological restoration community. Scaling up will require the engagement, education, and empowerment of these potential scale partners

Future

A vision of the future is based on coastal restoration networks that are well-resourced, and link researchers with practitioners, community groups and policy makers. Those involved in restoration will continue learning from each other and best practice will be continually improved. Thriving coastal communities will be proud of their achievements and equally proud to share practices that have not been as successful as hoped. Coastal communities will have high ecological knowledge and be able to identify coastal values and see the need for restoration. Relevant private sector areas such as engineering will have high ecological literacy and accordingly seek to incorporate Nature-Based solutions into practice. There will be well defined pathways for communities and market sectors to call on science, and coastal restoration experts for further advice. Scale partners will see value in supporting, financing and implementing coastal restoration, and nature-based solutions. Implementation of restoration at scale will deliver large scale social and economic benefits back to communities and organisations.

Relevant Recent NESP MAC Research

- NESP MAC 1.10 A national inventory of implemented nature-based solutions to mitigate coastal hazards

Research Gaps

- Research to quantify and communicate the 'business case' for restoration, including the social, economic and ecological benefits that marine and coastal restoration provides. For instance, estimate the effect of wetland restoration on water quality benefits.
- Learn from how restoration groups in Australia or other countries harness social capitol to scale restoration. For instance, in Australia OzFish or Greening Australia, or in the Caribbean restoration ecologists and practitioners training local fishermen to conduct coral transplanting. Identify barriers to communities who wish to engage with coastal and marine restoration.

Key Actions

- Work with scale partners, such as the insurance, finance, and engineering sectors, to understand the needs and barriers towards sustainable funding and implementation relevant to coastal marine restoration. Translate ecological principles into sector-relevant language to increase knowledge and capability.
- Identity and support partnership champions who can lead community groups and develop effective scalable models for low-risk community led restoration.
- Identify opportunities to incorporate ecological restoration into school curriculums and school extension activities.

10 Recommendations and Conclusion

The findings in this project are intended to form the basis of a conversation around transformational change in the implementation of coastal and marine restoration, and NbS, in Australia. Doing so will ultimately enable Australia to help meet national and international commitments which implicitly or explicitly include coastal and marine restoration, such as the Sustainable Development Goals, the Convention on Biological Diversity Aichi Targets, the Paris Agreement, The United Nations Decade on Ecosystem Restoration, and the Ramsar Convention. Following through on the Roadmap has the potential to elevate the state, condition and function of Australia's coastal and marine assets, to substantively increase Australia's capacity to adapt to climate change, and to increase the social, cultural and economic wellbeing of the Australian people. It would position Australia as a world leader with international standing in the restoration of coastal and marine ecosystems, and implementation of coordinated, scaled restoration and Nature-based Solutions.

The three key recommendations here are:

- Large scale and coordinated restoration of coastal and marine ecosystems will improve the environment and our valued natural assets, while also generating jobs and providing communities with economic and social benefits.
- Scaling up restoration nationally requires
    - a new economic model which is blended between government funding as well as investment pipelines from the private sector and philanthropy.
    - a national scale science-based plan adopted at state and local levels which helps deliver economic recovery and climate change adaptation. This does not necessarily imply that legislative responsibility towards all coastal and marine restoration is taken onboard by the commonwealth, but rather that the conversation starts at that level and cascades across scales.

    - Mechanisms and a willingness to increase the coordination of coastal and marine restoration projects.
- Coastal and marine restoration projects would benefit from co-designed with diverse stakeholders (e.g., research, practitioner, community, Aboriginal and Torres Strait Islander Organisations), and in particular recognising Traditional Custodians as rights holders.

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APPENDIX A – END-USER SURVEY

Participant Information Sheet – National Survey

About the project – A roadmap for coordinated landscape-scale coastal and marine ecosystem restoration

The Marine and Coastal Hub is funded through the Australian Government's National Environmental Science Program to carry out research that will inform the management of Australia's marine and coastal environments. CSIRO is one of several partner organisations in the Marine and Coastal Hub, more information on the Marine and Coastal Hub can be found here: https://nespmarinecoastal.edu.au/

This project aims to develop a roadmap to guide research and investment into the use of landscape-scale (large spatial scale, usually including a range of ecosystem processes) and Nature-based Solutions (the creation or restoration of coastal habitats for hazard risk reduction) in coastal marine restoration. This survey will help understand the enabling factors, opportunities and barriers faced by restoration practitioners and decision makers when planning and implementing coastal and marine restoration projects, and how research can be better targeted to help this decision-making processes.

What does participation involve?

Participation in this survey is via the SurveyMonkey platform and will take around 5-10 minutes. The survey involves answering a range of questions on motivations and barriers faced by restoration practitioners and decision makers when implementing coastal and marine restoration projects based on professional experience.

The survey is designed to allow you to remain anonymous to both CSIRO and SurveyMonkey.

You are also invited to contact MarineNbS@csiro.au if you would like to be involved in future engagement about nature-based solutions (brief interviews or discussions, surveys).

How will my privacy be protected?

Your personal information is protected by the Privacy Act 1988 (Cth) and CSIRO will handle your information in accordance with this Act and the National Health & Medical Research Council (NH&MRC) National Statement on Ethical Conduct in Human Research (2007, updated 2018).

The survey is designed to allow you to remain anonymous to CSIRO and SurveyMonkey. If you choose to contact CSIRO to register your interest in future engagement about nature-based solutions, your personal information, including your name and email address, will be collected for the purpose of contacting your about future engagement opportunities, and related scientific research. This may also imply to CSIRO that you participated in the survey, however, your identity will not be directly linked to your survey responses.

The anonymous survey responses will be aggregated and published in a publicly available peer-reviewed technical report and related communication material, as well as peer-reviewed publications. The information will be used to help prioritise and inform future research into landscape scale and nature-based solutions for coastal and marine restoration, and will also inform future stakeholder workshops under this project.

The CSIRO Privacy Policy available at https://www.csiro.au/en/About/Access-to-information/Privacy outlines how your personal information will be handled, including details about how you can seek access or correction of the personal information we hold about you, how you can lodge a complaint about a breach of the Australian Privacy Principles (APPs) and how CSIRO will deal with the complaint. If you require further information on how your personal information will be handled, please contact privacy@csiro.au.

Risks and benefits

There are no foreseeable risks in participating in this survey. Participation in the survey is voluntary.

APPENDIX B – ENGAGEMENT WITH TRADITIONAL CUSTODIANS

Aboriginal and Torres Strait Islander Insights into coastal and marine ecosystem restoration

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Start of Block: Block 5

Q1 Participant information

About the project – *A roadmap for coordinated landscape-scale coastal and marine ecosystem restoration.* The Marine and Coasts Hub is funded through the Australian Government's National Environmental Science Program to carry out research that will inform the management of Australia's marine and coastal environments. CSIRO is one of a number of partner organisations in the Marine and Coasts Hub, more information on the Marine and Coasts Hub can be found here: https://www.environment.gov.au/science/nesp/hub-marine-coastal

This project aims to develop a roadmap to guide research and investment into the use of landscape-scale (large spatial scale, usually including a range of ecosystem processes) and Nature Based Solutions (the creation or restoration of coastal habitats for hazard risk reduction) in coastal marine restoration. This survey will help understand the enabling factors, opportunities and barriers faced by restoration practitioners and decision makers when planning and implementing coastal and marine restoration projects, and how research can be better targeted to help this decision-making processes.

What does participation involve?
Participation in this survey is via Qualtrics and will take around 10 minutes. The survey involves answering a range of questions on motivations and barriers faced by Aboriginal and/or Torres Strait Islander organisations and communities when it comes to coastal and marine restoration projects. Your responses will be anonymously collected.

If you want to be involved in future engagement on Nature-based Solutions (brief interviews or discussions, future surveys), please contact the project team via MarineNbs@csiro.au

How will my information be used?
Your responses will be used to help prioritise and inform future research into landscape scale and

Nature based Solutions for coastal and marine restoration. The survey results will be aggregated and analysed. The results will also be used to prepare a publicly available peer-reviewed technical report and related communication material, as well as peer-reviewed publications. All information collected through the survey will be remain anonymous and we will not disclose the identities of survey respondents or individual organisations in the project outputs.

Risks and benefits

There are no foreseeable risks in participating in this survey. Participation in the survey is voluntary and responses are anonymous. Participation in this survey will improve the understanding of decision makers and restoration practitioners' needs when planning and implementing coastal and marine restoration projects. This will allow better tailored research outputs to inform effective decision making.

Withdrawal from the research project

Please note that participation in this survey is voluntary and you can withdraw by stopping the survey at any time. Your decision whether to participate will not affect your current or future relationship with the researchers, CSIRO or any organisations participating in the Marine and Coasts Hub.

Confidentiality

All information provided by you will be treated confidentially, in accordance with CSIRO Privacy Policy and securely stored as per CSIRO's Recordkeeping Procedure.

Ethics clearance and contacts

This study has been approved by CSIRO's Social Science Human Research Ethics Committee (approval number 139/21) in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018).

If you have any questions concerning your participation in the study, please contact the researchers on the below details. Alternatively, any concerns or complaints about the conduct of this study can be raised with the Executive Manager of Social Responsibility and Ethics on +61 7 3833 5693 or by email at csshrec@csiro.au.

If you have any questions about this project or would like more information about our research, please contact:

Dr Megan Saunders
megan.saunders@csiro.au
+61 7 3214 2228

By clicking continue you are consenting that you agree to the collection, use and disclosure of your personal information in the ways described above.

End of Block: Block 5

Start of Block: About your organisation

Q2 What is the main type of organisation you work for?

○ Federal government (1)

○ State government (2)

○ Local government (3)

○ Prescribed Body Corporate (4)

○ Native Title Body (5)

○ Non-government organisation (6)

○ Individual consultant (7)

○ University (8)

○ Research organisation (9)

○ Other (10) ____

Q3 Is your organisation an Aboriginal and/or Torres Strait Islander owned organisation?

○ Yes (1)

○ No (2)

Q4 Do you currently work in a co-management situation? (for the purposes of this survey, co-management is a partnership arrangement between Traditional Owners and another external body i.e. university, government, NGO)

- ◯ No (1)
- ◯ Yes (2)

Display This Question:

If Do you currently work in a co-management situation? (for the purposes of this survey, co-manageme... = Yes

Q5 If yes, can you select how co-management is arranged? (For the descriptions we have used the word 'government' however this word can be changed for the type of organisation you have co-management arrangements with)

- ◯ Consultative co-management (Government consults with the community, they do not have to implement any suggestions) (1)
- ◯ Instructive co-management (Top-down management from the government) (2)
- ◯ Cooperative co-management (Responsibility of the resource is shared between the government and Traditional Owners) (3)
- ◯ Advisory co-management (Traditional Owners decide what should be done and advises the government) (4)
- ◯ Informative co-management (Government delegated responsibility to Traditional Owners and Traditional Owners inform government of their decisions) (5)
- ◯ Community-based management (Traditional Owners have complete control over resource, but it is included within national/state legislation or government policies, therefore can be considered co-management) (6)
- ◯ Mix of the above (Multiple co-management arrangements) (7)

Display This Question:

If Do you currently work in a co-management situation? (for the purposes of this survey, co-manageme... = Yes

Q6 If yes, what kind of organisation/s do you work with in regards to co-management?

- ☐ Federal government (1)
- ☐ State government (2)
- ☐ Local government (3)
- ☐ University (4)
- ☐ NGO (5)
- ☐ Research organisation (6)

End of Block: About your organisation

Start of Block: About coastal or marine ecosystem restoration

Q7 At what scale are your restoration projects (or aspirations for restoration)?

- ☐ Local (within Country) (1)
- ☐ Regional (within Country or multiple Countries/groups) (2)
- ☐ State (3)
- ☐ National (4)
- ☐ International (5)

Q8 What state/s is your restoration based?

- ☐ ACT (1)
- ☐ NSW (2)
- ☐ NT (3)
- ☐ QLD (4)
- ☐ SA (5)
- ☐ TAS (6)
- ☐ VIC (7)
- ☐ WA (8)

Q9 What habitats are you currently restoring or have aspirations to restore and what time scale have you been/would you be working at for each habitat?

- ☐ Beaches (1)
- ☐ Dune (2)
- ☐ Saltmarshes (3)
- ☐ Mangroves (4)
- ☐ Tidal Flood Plains (5)
- ☐ Seagrass (6)
- ☐ Macroalgae/Kelp Forests (7)
- ☐ Coral (8)
- ☐ Shellfish (9)
- ☐ Other (10) ____

Q10 What is the main motivation for restoring ecosystems? (e.g. Caring for Country work, restoring culturally important sites, biodiversity)

- ○ Caring for Country (1)
- ○ Restoring culturally important sites (2)
- ○ Restoring habitats for culturally important species (3)
- ○ Biodiversity (4)
- ○ Climate change (5)
- ○ Other (6) ____

End of Block: About coastal or marine ecosystem restoration

Start of Block: Barriers and Indigenous contributions

Q11 What has your overall experience been with working with researchers and practitioners in coastal and marine ecosystem restoration?

____

Q12 What can researchers do better?

____

Q13 What can practitioners do better?

____

Q14 In regards to engagement by coastal and marine ecosystem restoration practitioners and researchers, on a scale of 1-8, where 1 is not at all and 8 is in every way, how do you feel about the following:

	0 1 2 3 4 5 6 7 8
Traditional Owners are adequately engaged? ()	
Researchers and practitioners understand Traditional protocols? ()	
Traditional Owners are listened to and valued? ()	
Traditional Owner engagement feels genuine? ()	
Traditional Owners are enabled (i.e. capability development, data for environmental management for input into plans like ILUAs) ()	

Page Break

Q15 What is the main challenge you experience when working with researchers/practitioners in coastal and marine restoration?

____

Q16 There are many challenges when working with researchers and practitioners, some of them are identified below, if you could rank the below list of challenges from most challenging to least challenging, where 1 is most challenging and 8 is least.
______ Lack of respect for Traditional Knowledge (1)
______ Lack of knowledge of Traditional protocols (2)
______ Inadequate leadership opportunities for Traditional Owners within projects (3)
______ Inadequate acknowledge of Traditional Owner knowledge and inputs (4)
______ Misunderstanding of needs for Traditional Owners to work on Country (5)
______ Inadequate timeframes for Traditional Owners to work with (6)
______ Inadequate funding available to Traditional Owners for their time and knowledge (7)
______ Challenges in working on Country due to national, state and local government regulations (8)

Q17 What are some of the barriers to Indigenous-led coastal and marine ecosystem restoration?

- ☐ Limited funding grants/opportunities for Traditional Owners to apply for (1)
- ☐ Resourcing difficulties i.e. Ranger groups are already busy with other Caring for Country activities (2)
- ☐ Inexperience in leading restoration activities (3)
- ☐ Capability of staff members/individuals to carry out restoration (4)
- ☐ Restoration activities are already being conducted on Country by non-Indigenous groups, so Indigenous-led opportunities are limited (5)
- ☐ Legislation/regulation difficulties (6)
- ☐ Reduced/limited capacity to write project proposals for grants/funding opportunities (7)
- ☐ Other (8) ____

Q18 What level of overall capacity do you believe your community has to participate in restoration activities? With 1 being limited capacity and 8 being ample capacity.

▼ 1 (1) ... 8 (8)

End of Block: Barriers and Indigenous contributions

Start of Block: Frameworks and future restoration

Q19 Are you aware that restoration activities go through a permitting process?

○ Yes (1)

○ No (2)

Q20 As Traditional Owners are you currently included in the permitting process?

○ Yes (1)

○ Unsure (2)

○ No (3)

Q21 Are you aware of Indigenous-led or co-management frameworks that work with restoration projects?

○ Yes (1)

○ No (2)

○ Unsure (3)

Display This Question:

If Are you aware of Indigenous-led or co-management frameworks that work with restoration projects? = Yes

Q22 If yes, can you list some of the frameworks you are aware of?

____

Q23 If your community was to work with restoration researchers and practitioners what do you believe they could contribute to increase capacity or capability? 1 being most preferred and 7 least preferred.
______ Training/education in western theories and practices of restoration (1)
______ Training/education on monitoring and evaluation of restoration (2)
______ Funding to conduct own restoration practices (3)
______ Funding to employ more Traditional Owners to participate in restoration of Country (4)
______ Inclusion of Traditional Owners in multiple project components (5)
______ Inclusion of Traditional Owners in reporting (6)
______ Assist in accessing data from current (and past) research on Country for use in planning and decision-making (7)

Q24 What do you think should occur moving forward with coastal and marine ecosystem restoration that involves Traditional Owners?

____

End of Block: Frameworks and future restoration

APPENDIX C – END USER WORKSHOP INFORMATION

Invitation to Coastal Science Endusers workshop

We would like to invite you to a workshop entitled **End-User Research Needs for Coordinated Landscape-scale Coastal & Marine Ecosystem Restoration.**

We have designed this workshop as an early point of contact and engagement between our research team and those who conduct, are involved with, interested in, or intend to develop, coastal and marine restoration projects. The project commenced in Sep 2021 and we would like to understand the research needs of the community early on in the project. Our research focusses on restoration for the purpose of coastal protection, but the overall ideas and concepts will be relevant to other motivations for restoration (e.g. fisheries, water filtration, social benefits, etc). The participants will mainly be from, or have interests including Queensland, but participants from other jurisdictions are welcome.

Why attend

- Network with other interested in coastal and marine restoration.
- Learn about restoration ecology, structured decision-making, and coastal engineering, and how this information might be used to inform planning for coastal restoration.
- Help establish a roadmap for our future research. You may even have a question that our future research can help you solve!

About the Project

A roadmap for Coordinated Landscape-scale Coastal & Marine Ecosystem Restoration is a project approved under the first Marine and Coastal Research Plan. It brings together interdisciplinary expertise in coastal engineering, decision theory, marine ecology, modelling and ecosystem services to examine decision support needs and opportunities to restore coastal marine ecosystems at scale. The research will focus on the ecosystem services of coastal protection and climate resilience with the recognition that this Nature-based Solution (NbS) approach provides co-benefits such as biodiversity, fisheries production, carbon sequestration, and nutrient cycling. The research will be accomplished through surveys and workshops/meetings with input from key end user groups in industry, NGO, Indigenous and Governmental organisations. *The Marine and Coastal Hub is funded through the Australian Government's National Environmental Science Program to carry out research that will inform the management of Australia's marine and coastal environments. CSIRO is one of a number of partner organisations in the Marine and Coastal Hub, more information on the Marine and Coastal Hub can be found here:* https://www.environment.gov.au/science/nesp/hub-marine-coastal

About the Workshop

- Date/time: **Tuesday 16 Nov2021 9:30-12:30 (latest) QLD time**. It is short notice, and we welcome attendance of a portion of the workshop as well as full attendance. Agenda to follow.
- This workshop will be held **online on Webex**. - A link will be provided when you confirm attendance.
- More details about what's involved in participating is included in the attached participant information sheet.
- Prior to the workshop

- please locate and send us a photo with a single sentence that tells the story about a coastal area in your jurisdiction that has been, is currently in process of, or could be restored. Please indicate if you have ownership or permission for the image to be reproduced in our project reports and communication materials.
- Please complete a short 10-15 min online survey (link to follow)

Workshop aims

- Early engagement among the research team and potential end users of the research
- Discuss a survey that we are circulating nationally. Is there nuance or details that we should know about?
- Gain insights into:
  - how coastal and marine restoration planning decisions are made
  - key challenges or barriers to using structured decision-making for restoration planning
  - data needs for scaling up restoration from local to regional through to national scales, with some emphasis on the ecosystem service of coastal protection

If you are unable to attend, please think about nominating one of your team members and let us know how you may like to be involved in the project/ research going forward.

Any questions?
Feel free to email or phone us.

RSVP
Please respond to MarineNbS@csiro.au **by COB Thurs 11 Nov 2021**

Many thanks,
Megan

Workshop Participant Information Sheet

Participant Information Sheet – Stakeholder Workshops

About the project – A roadmap for coordinated landscape-scale coastal and marine ecosystem restoration

The Marine and Coastal Hub is funded through the Australian Government's National Environmental Science Program to carry out research that will inform the management of Australia's marine and coastal environments. CSIRO is one of several partner organisations in the Marine and Coasts Hub, more information on the Marine and Coastal Hub can be found here: https://www.environment.gov.au/science/nesp/hub-marine-coastal

This project aims to develop a roadmap to guide research and investment into the use of landscape-scale (large spatial scale, usually including a range of ecosystem processes) and Nature-based Solutions (the creation or restoration of coastal habitats for hazard risk reduction) in coastal marine restoration. This workshop will share understanding of the enabling factors, opportunities and barriers faced by restoration practitioners and decision-makers when planning

What does participation involve?

Participation in this workshop will involve several informative presentations on the project topic and participation in conversations on a range of questions about motivations and barriers faced by restoration practitioners and decision makers when implementing coastal and marine restoration projects. Information will also be presented on the preliminary results from our project survey. After the workshop has closed participants who are interested in being contacted by project members for additional information or to be informed of project outcomes will have the opportunity to provide their details to research project members.

How will my privacy be protected?

Your input into the conversations will be used to help prioritise and inform future research into landscape scale and Nature based Solutions for coastal and marine restoration. The workshop outcomes and results will be summarised and distributed to participants and other interested stakeholders. The results will also be used to prepare a peer-reviewed technical report, a conceptual model and potential communication materials. All information collected through the workshop will be deidentified and we will only disclose the identities of workshop participants with their permission. It is a requirement of the grant that all data is submitted to e-atlas (eatlas.org.au). The data collected for this scoping project may be used in future projects that are related to this project through the NESP Marine and Coastal Hub.

Risks and benefits

There are no foreseeable risks in participating in this workshop. Participation in the workshop is voluntary and responses will be deidentified.

Participation in this workshop will improve the understanding of decision makers and restoration practitioners' needs when planning and implementing coastal and marine restoration projects. This will allow better tailored research outputs to inform effective decision making.

Withdrawal from the research project

Please note that participation in this workshop is voluntary and you can withdraw by leaving the workshop at any time. Your decision whether to participate will not affect your current or future relationship with the researchers, CSIRO or any organisations participating in the Marine and Coastal Hub. However, information you have provided prior to you leaving, if already included in summarised notes by researchers may continue to be included in the study without identifying you.

Confidentiality

All information provided by you will be treated confidentially, in accordance with CSIRO Privacy Policy and securely stored

as per CSIRO's Recordkeeping Procedure.

Ethics clearance and contacts

This project has been approved by CSIRO's Social Science Human Research Ethics Committee (approval number **139/21**) in accordance with the National Statement on Ethical Conduct in Human Research 2007 (Updated 2018). If you have any questions concerning your participation in the project, please contact the researchers on the below details. Alternatively, any concerns or complaints about the conduct of this project can be raised with the Executive Manager of Social Responsibility and Ethics on +61 7 3833 5693 or by email at csshrec@csiro.au.

If you have any questions about this project or would like more information about our research, please contact:

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IMAGE: Google Maps

Marine and Coastal

National Environmental Science Program

Reef & Rainforest RESEARCH CENTRE

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