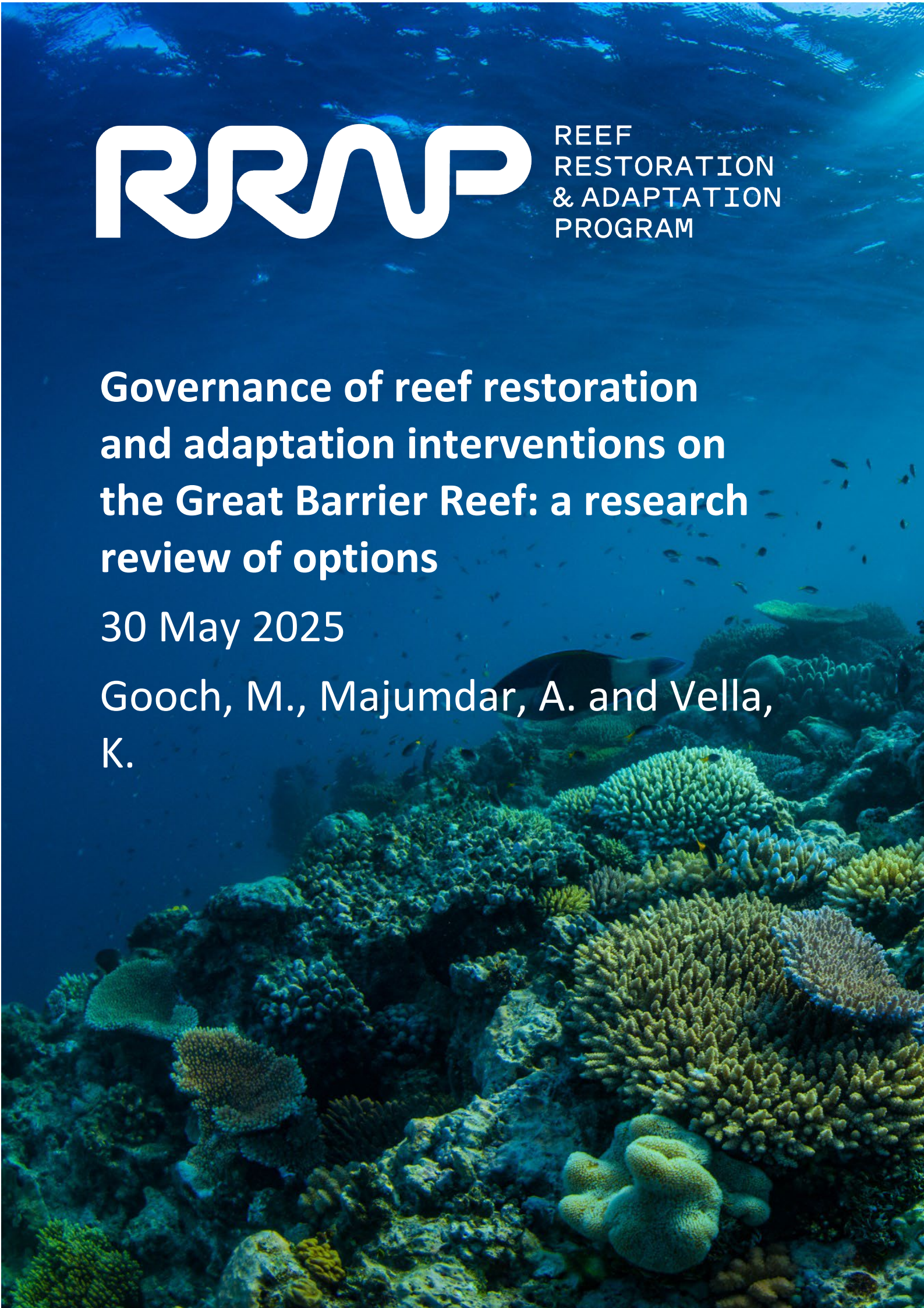
REEF RESTORATION & ADAPTATION PROGRAM

Governance of reef restoration and adaptation interventions on the Great Barrier Reef: a research review of options

30 May 2025

Gooch, M., Majumdar, A. and Vella, K.



Governance of reef restoration and adaptation interventions on the Great Barrier Reef - A research review of options

Enquiries should be addressed to: Professor Karen Vella, School of Architecture and Built Environment, Faculty of Engineering, Queensland University of Technology. Email karen.vella@qut.edu.au

Cover Page: Coral reef, Credit: Gary Cranitch, Queensland Museum

This report should be cited as

Gooch, M., Majumdar, A. and Vella, K. (2025) Reef Restoration and Adaptation Program – Governance of reef restoration and adaptation interventions on the Great Barrier Reef - A research review of options. (129 pp).

Disclaimer

While reasonable efforts have been made to ensure that the contents of this document are factually correct, AIMS does not make any representation or give any warranty regarding the accuracy, completeness, currency or suitability for any particular purpose of the information or statements contained in this document. To the extent permitted by law AIMS shall not be liable for any loss, damage, cost or expense that may be occasioned directly or indirectly through the use of or reliance on the contents of this document.

Acknowledgement

This work was undertaken for the Reef Restoration and Adaptation Program (RRAP). Funded by the partnership between the Australian Governments Reef Trust and the Great Barrier Reef Foundation, partners include: the Australian Institute of Marine Science, CSIRO, the Great Barrier Reef Foundation, Southern Cross University, the University of Queensland, Queensland University of Technology and James Cook University.

The RRAP partners acknowledge Aboriginal and Torres Strait Islander Peoples as the first marine scientists and carers of Country. We acknowledge the Traditional Owners of the places where RRAP works, both on land and in sea Country. We pay our respects to elders; past, present, and future; and their continuing culture, knowledge, beliefs, and spiritual connections to land and sea Country.

Table of Contents

List of Figures

List of Tables

Abbreviations and acronyms

AIATSIS Australian Institute of Aboriginal and Torres Strait Islander Studies
AIMS Australian Institute of Marine Science
AIMS IPG Australian Institute of Marine Science Indigenous Partnerships Group
AMPTO Association of Marine Park Tourism Operators
CoTS Crown-of-Thorns Starfish
CSIRO Commonwealth Scientific and Industrial Research Organisation
DCCEEW Department of Climate Change, Energy the Environment and Water
ENG Sub-Program Stakeholder and Traditional Owner Engagement Sub-program
FPIC Free, Prior and Informed Consent
GBR Great Barrier Reef
GBRF Great Barrier Reef Foundation
GBRIA 2024 Great Barrier Reef Intergovernmental Agreement 2024
GBRMP Great Barrier Reef Marine Park
GBRWHA Great Barrier Reef World Heritage Area
ICPR International Commission for the Protection of the Rhine
IEP Independent Expert Panel
ILUA Indigenous Land Use Agreements
IP Intellectual Property
IRRG Intervention Risk Review Group
JCU James Cook University
LEI Lady Elliot Island
LMAC Local Marine Advisory Committee
M&E Monitoring and Evaluation
MELS Monitoring Evaluation and Learning Strategy
NFP Not-for-profit
NGO Non-Governmental 0rganisation
NRM Natural Resource Management
OUV Outstanding Universal Value
QDPI Queensland Department of Primary Industries
QDESTI Queensland Department of Environment, Science, Tourism and Innovation
QILSRP Queensland Indigenous Land and Sea Ranger Program
QPWS Queensland Parks and Wildlife Service
R&D Research and development
RAC Reef Advisory Committee
Reef Authority Great Barrier Reef Marine Park Authority
Reef 2050 Plan Reef 2050 Long-Term Sustainability Plan
RIMReP Reef Integrated Monitoring and Reporting Program
RRAP Reef Restoration and Adaptation Program
RRRC Reef & Rainforest Research Centre
SER Society for Ecological Restoration
SDG Sustainable Development Goals
TUMRA Traditional Use of Marine Resources Agreements
UN United Nations
WQIP Water Quality Improvement Plan

Executive summary

Reef restoration and adaptation is a newly emerging objective within the suite of management actions that governments, Traditional Owners and stakeholders collectively undertake in the Great Barrier Reef (GBR). Much of that work is being undertaken through the Reef Restoration and Adaptation Program (RRAP), a transdisciplinary, multi-institutional research partnership that builds on many years of research here and internationally. RRAP's Research and Development (R&D) Program develops, tests and risk-assesses novel interventions to help sustain critical functions and values of the GBR. The goal is to provide managers, practitioners and decision-makers with a suite of safe, cost-effective interventions to help protect the GBR from the effects of climate change.

As a newly emerging area for management action, it is unclear which of the GBR's complex suite of policy and planning arrangements are relevant to restoration outcomes. When thinking about a restoration governance system, it is similarly not clear what the system should entail in terms of the critical components that underpin effective reef restoration. Thus our research was designed to contribute to a deeper understanding of how best to incorporate and develop new arrangements and actions to benefit the GBR, its stakeholders and Traditional Owners. It aimed to support GBR managers and decision-makers by:

- exploring perspectives held by Traditional Owners and stakeholders concerning governance arrangements and options for supporting reef restoration and adaptation in the GBR;
- considering case study examples from past management efforts in the GBR and elsewhere that provide insights for the future;
- developing a set of guiding principles for implementing reef restoration and adaptation activities for use by practitioners, researchers and other interested actors; and
- identifying governance pathways which can indicate (a) potential roles and responsibilities of those involved, and (b) appropriate decision-making processes for all actors involved in reef restoration and adaptation in the GBR.

Analysis of an online survey, in-depth interviews with key informants, a governance mapping exercise and reviewed literature revealed four elements that are needed for effective governance of GBR reef restoration and adaptation interventions: (a) a fit-for-purpose regulatory environment; (b) best practice engagement and social risk management; (c) a set of guiding principles within which to operate; and (d) governance pathways that maximise restoration and adaptation efforts through the collective action of diverse actors.

Due to the short time frame of this project (a twelve month scoping study) we focused our attention on (c) and (d) above – i.e. we identified seven pathways underpinned by the following five principles to guide the governance of GBR restoration and adaptation interventions:

1. Embrace an ecosystems-based approach.
2. Establish fit-for-purpose, transparent, accountable and adaptive restoration governance system.
3. Governance arrangements are inclusive and participatory; use timely best practice engagement processes and targeted capacity-building; and are sustainable.
4. Planning and risk assessment efforts are timely, proactive and coordinated with actors involved in reef restoration and adaptation.
5. Actors work together to build and implement effective systems for knowledge integration and decision support.

Although the seven pathways highlight key elements and who might be involved in each, we did not provide a prioritised list of actions to be undertaken by different reef restoration and adaptation actors. Each pathway did however, reveal new ways of working together to achieve mutual

outcomes and avoid unintended consequences. Some of these pathways already exist, although they may not be clearly visible. Some will (and do already) overlap at certain times and many participants will be involved in more than one pathway at any particular point in time. Roles and responsibilities will change over time and spatially, as circumstances dictate. As each pathway develops, it would be guided by the five governance principles.

The seven identified governance pathways are:

Financing pathway - emphasises the importance of sustained, equitable allocation of funding over time and at different spatial scales. Consideration of financing must be interwoven into each pathway, but it may also be a pathway in its own right.

Knowledge-sharing pathway - identifies the many ways that knowledge about reef restoration and adaptation is shared - horizontally, vertically and through diverse networks. This pathway may also be considered as integral to every other pathway, as well as a clearly-defined separate pathway.

Policy, planning and permissions pathway - highlights the need for certainty and clarity in decision-making for all actors involved in reef restoration and adaptation activities in the GBR. In the majority of instances, the regulators and management agencies would take a lead role, together with Traditional Owners where activities encroach upon or affect their sea Country.

Traditional Owner-driven pathway - based on traditional lore and customs; inherent rights and responsibilities; and statutory obligations and responsibilities to care for culture, people and Country. This pathway can enable Traditional Owners to make decisions about Country and set priorities on where they want to go as a community.

Research-driven pathway - aims to ensure all interventions (existing and future) are based on the best-possible science and maximise best possible outcomes for GBR health and ecosystem services, with broad social support.

Industry-driven pathway - includes a wide range of stakeholders and Traditional Owners employed (or potentially employed) in a variety of occupations such as coral harvest, aquaculture, marine contracting and reef tourism industries.

Community-driven pathway - most likely initiated through grassroots community action focusing on sites where reef restoration and adaptation objectives align with social, economic or cultural values.

Next steps for this governance research could include the following:

- Further explore Traditional Owner and stakeholder understandings of GBR governance arrangements;
- Clarify roles and responsibilities and work with key actors to identify prioritised actions for all involved in each pathway;
- Undertake formal evaluation of each pathway using an existing analytical framework e.g. the Governance Systems Analysis (GSA) Framework for the GBR developed by Vella et al. (2024).

1 Introduction

Extreme weather events, ocean acidification, increased water temperature and sea level rise together with deteriorating water quality, over-fishing and predation by Crown-of-Thorns Starfish (CoTS) have caused so much damage to coral reefs globally, that further deterioration could alter food supplies, coastal protection and livelihoods of up to one billion people (Klein et al., 2024). There may also be major disruptions to cultural and social connections and sense of identity among coastal communities (Lockie et al., 2024).

On the GBR, mass coral bleaching events in 1998, 2002, 2016, 2017, 2020, 2022 and 2024 have contributed to reef stress and degradation (WWF, 2024). According to the latest Living Planet Index, the GBR has shown remarkable resilience in the face of climate change and other stressors, but globally, 70–90% of all coral reefs may be lost in the near future if climate warming is not addressed (WWF, 2024).

Efforts towards reef restoration and adaptation have recently gained momentum in Australia and elsewhere, although these activities are relatively small scale compared with equivalent activities in terrestrial ecosystems (Bayraktarov et al., 2019; Omori, 2019). To date, most reef restoration interventions have been developed from applied research and subjected to real-world validation which potentially carries a range of social, economic and ecological risks. The work is subjected to a range of perspectives, voices and values that need to be included equitably to avoid power imbalances, lack of trust between collaborators and disruption to intervention efforts and project outcomes (Cvitanovic et al., 2022; Lockie et al., 2024).

Australia's Reef Restoration and Adaptation Program (RRAP) is a transdisciplinary, multi-institutional research partnership. It builds on many years of research in Australia and internationally to develop, test and risk-assess novel interventions to help sustain critical GBR functions and values. The goal is to provide managers, practitioners and decision-makers with a suite of safe, cost-effective interventions to help protect the GBR from the effects of climate change (RRAP, 2023b).

Research activities within RRAP's Stakeholder and Traditional Owner engagement sub-program (ENG sub-program) provide diverse opportunities for communities to participate, reflect and deliberate on positive outcomes for the GBR (Lockie et al., 2023). Deliberation about interventions and their potential social risks enables issues to be viewed and considered through varying social, cultural, technological and ecological lenses, and thus reduce the possibility of adverse outcomes (Paxton et al., 2024). Conversely, decision-making that excludes or favours particular groups can lead to a lack of trust, conflict among different parties, and inequities in benefits. Failure to recognise and manage real or perceived 'social risks' can result in implementation delay, increased costs and reduce options for the future (Cvitanovic et al., 2022; Lockie et al., 2024; Termeer et al., 2015).

Effective, responsive decision-making through best practice engagement processes can help to manage expectations, build transparency, facilitate social learning and promote reflexive deliberation (Baresi et al., 2025). Processes for deep engagement and reflexivity strengthen and diversify social learning, enhance a sense of belonging, engender environmental stewardship, promote inclusiveness and manage social risks (Baresi et al., 2025; Kiss et al., 2022; Lockie et al., 2024).

There are multiple opportunities for diverse voices to be heard within the GBR Marine Park, through formal and informal agreements, plans, strategies and programs. Many of these will be discussed throughout this report, including the latest Intergovernmental Agreement, a legally binding instrument, that commits both Commonwealth and state governments to ensuring the ongoing

protection, restoration and management of key ecosystems critical to GBR health (Commonwealth Government & Queensland Government, 2024).

To date, however, there is limited published guidance on operationalising the GBR's regulatory environment, to create effective decision-making and governance for novel reef interventions (Shumway et al., 2025). This scoping study contributes to this body of knowledge, building upon work previously undertaken by the RRAP's Regulatory Sub-Program – see for example Fidelman, McGrath, et al., 2019; Fidelman, Newlands, et al., 2019; Shumway et al., 2024.

The rest of this report is structured as follows:

- Section 2 provides key definitions and then describes the research design.
- Section 3 presents findings from reviewed literature on (a) lessons learned from global restoration cases. Examples include restoration of seagrass and eelgrass beds; shellfish reefs; mangrove forests; riverways and coral reefs; (b) selected GBR restoration and adaptation interventions and initiatives; (c) guiding principles of relevance for reef restoration and adaptation.
- Section 4 highlights results from the online survey, in-depth interviews and governance mapping. Together with the reviewed literature, these inform the development of five guiding principles for effective governance of GBR restoration and adaptation, and seven potential governance pathways for effective governance of GBR reef restoration and adaptation initiatives.
- Section 5 presents conclusions and next steps.

2 Definitions and research design

For our purposes, we adopt the definition of ' coral reef restoration' used by Hein et al. (2021) as:

… an active intervention aimed to assist the recovery of reef structure, function, and key reef species in the face of rising climate and anthropogenic pressures, promoting reef resilience and the sustainable delivery of reef ecosystem services. These interventions include reducing impacts, remediation, and rehabilitating ecosystem function, following standards developed by SER (Hein et al., 2021, p2).

The *United Nations Decade on Ecosystem Restoration 2021–2030* together with the Society for Ecological Restoration (SER) recognises the critical need to restore degraded ecosystems, recover biodiversity and mitigate climate-change for the health of the global biosphere and human well-being (FAO, SER & IUCN CEM., 2023; Society for Ecological Restoration, 1998). Ecological restoration is fundamentally an intrinsic, natural characteristic of ecosystems that enables them to recover after impact (Chazdon et al., 2024). Active restoration involves human interventions which assist the recovery of an ecosystem that has been degraded, damaged, or destroyed.

Globally, the total area of reefs actively restored annually is extremely small compared with the increasing scale of threats to coral reefs (Gibbs et al., 2024; Kong et al., 2024). Small-scale interventions that have been trialled in the GBR include the creation of artificial reefs; coral rubble stabilisation; rearing coral larvae in aquacultural facilities for settlement on degraded reefs; and out-planting of coral which has been propagated from fragments (Gibbs et al., 2024). To have lasting impact, however, current practices need to be scaled-up and scaled-out, and this requires method development; on-going, secure funding; and effective governance to enable deployment of appropriate, safe and responsible interventions (Gibbs et al., 2024; Morrison et al., 2020).

Out-scaling often refers to large-scale duplication and adaptation of innovations to benefit more people or across larger geographic areas, whereas scaling-up refers to is often used to identify the institutional changes required to enable larger scale innovations. Some of these changes include changes in availability of resources, incentives, career paths and capacity-building (Seifu et al., 2020). For this report we use the term 'up-scaling' or 'scaling-up' to encompass both types of scaling.

2.1 Governance

We define 'governance' as a broad concept that includes the wide range of intersecting and sometimes overlapping organisations, individuals, processes, plans, policies, agreements, laws and other factors (including levels of trust and transparency) that contribute to decision-making and actions at multiple scales (Haldrup, 2020; Kjaer, 2023; Mansourian, 2017; Vella et al., 2024). Participating individuals and organisations include Traditional Owners; government agencies with environmental managers, regulators and policy-makers; scientists; industry groups; investors; tourists; the media; international and local non-governmental organisations; and the global public. Each of these may all intentionally or unintentionally affect decision-making at a range of scales (Hughes et al., 2023; Vella et al., 2024).

This is a much broader definition than the traditional use of the term 'gover*nance*' often associated with rule-setting and decision-making by govern*ment*. In this narrower context, 'governance' is sometimes used interchangeably with the term 'management' (Haldrup, 2020; Kjaer, 2023; Mansourian, 2017). However, recent changes in governance arrangements including the trend towards increased involvement of the private sector in public service work programs, is resulting in new arrangements for decision-making and service delivery. These often involve self-organised action pathways and networks operating simultaneously in the pursuit of common goals, which may

be collectively termed ‘adaptive governance’ (Cosens et al., 2021, 2023; Kjaer, 2023). This broader definition of ‘governance’ focuses on the entities (i.e. organisations and individuals) involved in the development, implementation and compliance of regulations including laws, policies, plans and agreements at local, state or federal level, or international obligations (Fidelman, McGrath, et al., 2019; Kjaer, 2023). It includes consideration of *when* and *why* decisions are made, as well as *who* makes decisions and *how* decisions are made. Decision-making regarding reef restoration and adaptation requires scientific and technical knowledge as well as consideration and understanding of politics, values, ethics and who may affected by decisions (Lockie et al., 2024). This is particularly important for reef restoration and adaptation as the science and regulatory environment is generally far less mature than for terrestrial restoration, and novel experimental interventions are likely to generate several unfamiliar social, economic and environmental risks (Hughes et al., 2023). These decision-making processes may be considered as *pathways to outcomes,* and if carefully and transparently applied, can help actors organise themselves to achieve shared goals. Governance pathways can highlight decision-making processes to reflect on potential benefits, opportunities and challenges associated with interventions that are perceived by different actors within the broader governance system. Elements of governance pathways will likely change over time, involving different actors and engagement processes as circumstances dictate.

The International Union for the Conservation of Nature (IUCN) defines governance of natural resources as *‘the norms, institutions and processes that determine how power and responsibilities over natural resources are exercised, how decisions are taken, and how citizens — including women, men, youth, Indigenous peoples and local communities — participate in and benefit from the management of natural resources’* (Springer et al., 2021, p.3).

Further, the IUCN describes ‘good governance’ as recognising and promoting the rights of indigenous peoples and local communities; having clearly defined, legitimate, equitable and functional governance arrangements; fairly addressing the interests of rights holders and stakeholders; and implementing transparent decision-making processes with clearly defined roles and responsibilities for all involved (IUCN WCPA, 2018).

In many parts of the world, marine protected area governance is intertwined with Indigenous peoples' traditional ownership and associated cultural values, customs and lore. In Australia, this approach can be established through coastal land and sea indigenous protected areas (IPAs) which focus on the concept of Traditional Owner sea Country (Rist et al., 2019). IPAs enable Traditional Owner-led collaborative planning and governance of land and sea areas over which they would otherwise have limited rights (Rist et al., 2019). Several IPAs operate within the GBRWHA, along with other instruments such as Traditional Use of Marine Resource Agreements (TUMRAs) and Native Title claims which collectively contribute to Traditional Owner co-management of the GBR (Markwell and Associates, 2020; Rist et al., 2019).

2.1.1 Governance pathways

Governance pathways represent different types of decision-making processes that vary according to factors such as who is involved, equity and capacity in decision-making, collective and individual priorities and desired outcomes. Pathways may be intersecting, overlapping or operating in parallel at different points in time, and individuals may be involved in more than one pathway at any point in time. Governance pathways can explicitly map out decision needs and aspirations for stakeholders and Traditional Owners e.g. they can provide a way to actively respond to changes in GBR health and at the same time foster career development, direct participation in on-water interventions, strategy development and equity in decision-making. Differing priorities, values and perceptions associated with specific interventions at particular locations will influence the extent and type of involvement

by different actors (Lockie et al., 2024), as will the availability of resources, access to capacity-building opportunities, and the motivations and incentives for involvement (Gibbs et al., 2024).

Understanding who is involved in implementation processes and decision-making is an important aspect of understanding governance pathways. In the GBRWHA governance space, communities, Traditional Owners, NGOs, researchers, industry, and government agencies are all important actors who contribute to a greater or lesser extent to partnerships, agreements, policies, plans, and programs to undertake activities that impact GBR health. These mechanisms underscore the cross-scale interconnections between different actors from local to national and even international scales (Morrison, 2017). Different governance pathways may be taken by different actors for different reasons. For example, from a Traditional Owner perspective, restoration and adaptation pathways may prioritise opportunities for local leadership and/or strong partnerships with researchers and managers. From a manager's perspective, restoration and adaptation pathways may emphasise strategic planning or the implementation of policy that endures beyond the life of an individual research project. As illustrated in Figure 1 below, each pathway for the governance of reef restoration and adaptation has the potential to promote dialogue, co-learning and consensus-building; strengthen trust; and provide a platform for participants to:

- Understand a range of perspectives, values and perceptions;
- Identify potential risks, benefits and opportunities associated with decision-making;
- Build narratives and establish consistent messages;
- Resolve conflict; and
- Moderate expectations.

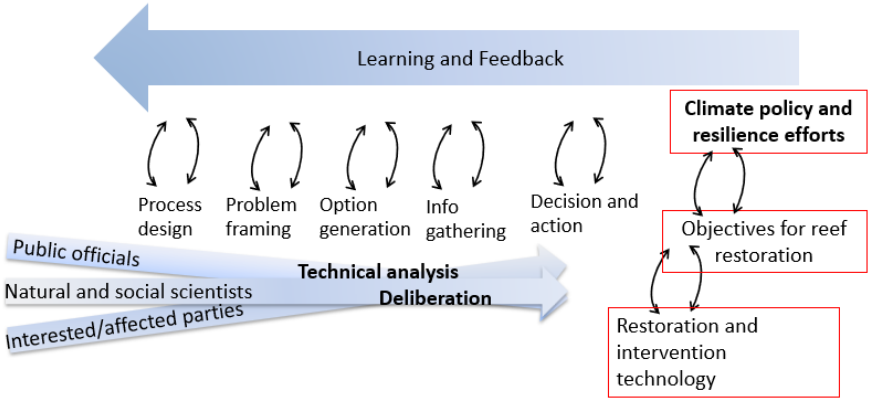


Figure 1: Common elements of governance pathways for reef restoration and adaptation

(Adapted from: National Research Council, 2008)

2.2 Research Design

2.2.1 Purpose

The purpose of this scoping study is to help prepare the existing governance system to incorporate and develop new arrangements and actions to benefit the GBR, its stakeholders and Traditional Owners.

2.2.2 Aim and scope

The aim is to identify essential components of the *reef restoration and adaptation domain* of the Great Barrier Reef World Heritage Area (GBRWHA) governance system, together with a set of guiding principles, that will provide clear governance pathways to optimise outcomes for reef restoration and adaptation. This governance domain or sub-section includes the set of decision-making processes, actors, institutions, policies, laws, processes, plans and agreements that operate within the much wider set of inter-connected governance arrangements for the whole of the GBRWHA (Dale et al., 2013).

Although it is widely recognised that impacts of human activities in the GBR catchment can affect GBRWHA health, the focus of this research is on the governance of restoration and adaptation interventions occurring within the world heritage area (Vella et al., 2024).

2.2.3 Objectives

(a) Reflect on lessons learned from global and local (GBR) case studies of ecological restoration that could inform governance strategies for GBR reef restoration and adaptation initiatives.
(b) Identify stakeholder and Traditional Owner perspectives on priorities and principles for the governance of GBR reef restoration and adaptation initiatives.
(c) Develop a set of guiding principles for effective and equitable governance of reef restoration and adaptation interventions
(d) Identify key governance pathways i.e. the different types of decision-making needs and opportunities for actors which are required to be factored into an effective governance system for GBR reef restoration and adaptation.

2.2.4 Research approach

The scoping study uses a multiple lines of evidence approach to develop a framework of guiding principles and governance pathways for effective reef restoration and adaptation. The work was progressed through the following steps:

Step 1: Literature review to:

(a) identify and reflect on lessons learned from global and local case studies of ecological restoration that could inform governance strategies for reef restoration;

(b) identify principles for reef restoration governance systems.

Step 2: Mapping of the current GBR reef restoration and adaptation governance system.

Step 3: Design, implementation and analysis of an online survey of stakeholder and Traditional Owner's to gain feedback on principles for reef restoration governance and further perspectives on priorities, barriers and opportunities for reef restoration governance.

Step 4: Design, implementation and analysis of key informant interviews to identify stakeholder and Traditional Owner perspectives on priorities, barriers and opportunities for reef restoration governance.

Step 5: Synthesis of the multiple lines of evidence to:

(a) develop a set of guiding principles for effective governance of reef restoration and adaptation interventions; and

(b) identify potential pathways (different types of decision-making needs) for GBR restoration and adaptation governance.

The research was conducted between August 2024 and May 2025. Figure 2 below provides the scoping study timeline.

Figure 2: Timeline for governance research scoping study

The following sections provide a more detailed overview of the key methods.

2.2.5 Literature review

The literature review and desk top study used national and international literature (grey and published) and has two components. The first component presents lessons learned from a variety of national and international case studies of marine and coastal restoration. The focus was on peer reviewed journals for the management and conservation of ecosystems such as *Coral Reefs* and *Restoration Ecology*. For the GBR-specific examples, Commonwealth and Queensland government websites were also included.

The second component of the literature review presents a wide range of guiding principles that could be useful for the governance of GBR reef restoration and adaptation. Guiding principles can provide a starting point for clarifying roles and responsibilities at different spatial and temporal scales. They can also help to coordinate and amplify efforts using professional judgment, best-available knowledge and innovation (Higgs et al., 2018). The IUCN describes natural resource governance principles as *'key elements that need to be in place to realise effective and equitable governance'* (Springer et al., 2021).

Guiding principles were derived from literature focusing on global, national, ecosystem and GBR scales of governance. Reviewed literature included peer reviewed journal articles on collaborative governance; ocean governance; ecological restoration; principles for restoring biodiversity; and GBR governance. The review also included a desk top study of guidelines presented in national and international conventions, government plans, strategies, agreements, policy documents and websites. Principles derived from the reviewed literature were analysed using content analysis of each unit of analysis (i.e. journal article, government document, international convention) to determine common themes of relevance to the governance of reef restoration and adaptation interventions (Kyngäs, 2020; Selvi, 2019). The analysis involved developing broad categories of description (attributes) based on the information provided about each principle. A final list of ten attributes were recorded, and these, together with accompanying text derived from the literature

review, became the ten draft principles. These were then presented in an online survey for feedback, and refined in light of the survey responses. The principles were further refined using the results on in-depth interviews of twenty-two key informants.

2.2.6 Mapping of GBR governance connections for reef restoration and adaptation

The purpose of the network mapping is to provide a visual representation of existing and potential pathways for effective governance of reef restoration and adaptation in the GBR. It builds on work previously undertaken to establish governance elements underpinning the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan). For the original mapping exercise, an online search was undertaken of all institutions and instruments directly referenced in the Reef 2050 Plan's Strategic Actions and the noted supporting policies and programs. However, the original mapping exercise was only a partial representation of the wider Reef governance system, including governance of reef restoration and adaptation initiatives (Vella et al., 2024).

For this current research, a desk top review of government and non-government websites added to the original maps by identifying governance elements used by different groups and organisations that could play a role in making decisions about GBR reef restoration and adaptation activities. Examples include legislation, agreements, formal partnerships, programs, policies, engagement mechanisms and funding programs. Engagement mechanisms (for example structures, agreements, processes and programs) have the potential to increase the social acceptability of a new proposal or intervention, as they enable stakeholders and rights holders to access and participate in community networks, formal advisory structures and decision-making processes (Taylor et al., 2019). Effective engagement is more likely to occur when different stakeholders and rights holders are identified and mapped according to the suitability of available engagement mechanisms (Nursey-Bray, 2020).

The desk top review built on previous work undertaken by the RRAP ENG Sub-program which identified four stakeholder and rights holder groups:

- *Traditional Owners* – i.e. First Nations people who hold traditional rights over GBR sea Country. Their rights and responsibilities mean they have a status distinct from stakeholders however they also share characteristics with GBR stakeholders.
- *Livelihood stakeholders* – including *Reef-dependent* and *Reef-associated* groups and industries;
- *Citizens and civil society* – broader public including communities, individuals or groups based inside or outside of the Reef and its catchment; and
- *Institutional stakeholders* – local, regional, state, national, and international governing bodies or organisations with responsibilities and interests in the Reef. These could be based inside or outside the GBR (Taylor et al., 2019; Vella et al., 2018).

Each have particular attributes that would enable them to participate meaningfully in reef restoration and pilot deployment activities. Potential roles for each are shown in Figure 15.

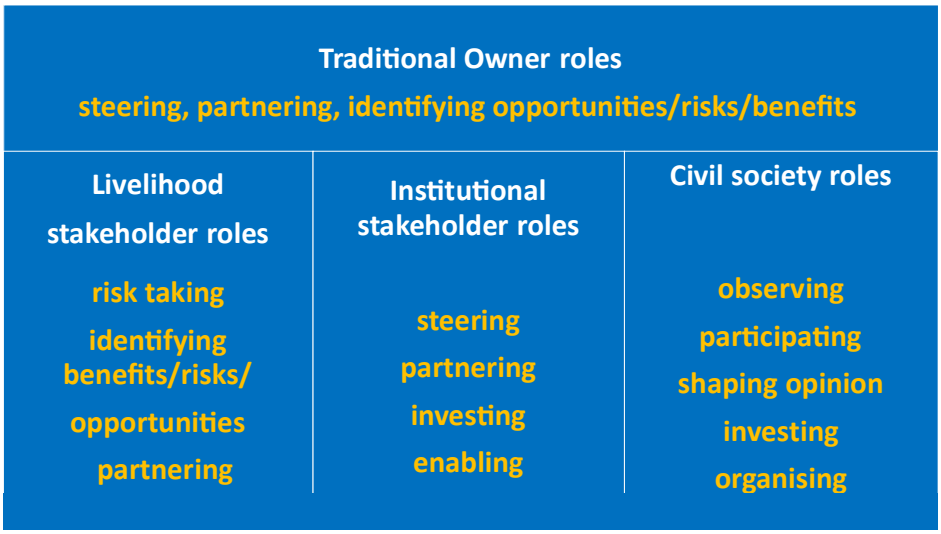


Figure 3: Types of rights holders/stakeholders and their potential roles in reef restoration and pilot deployment. (Adapted from Taylor et al., 2019.)

Software packages in the R programming language were used to create the maps. Information from the desk top study was imported into a database comprising networks links and nodes which help to visualise relationships between the various instruments, institutions, organisations and actors involved in GBR reef restoration and adaptation (Vella et al., 2024). Nodes are the main elements (e.g. organisation, legal instrument, agreement etc) of the map. Links record data about which nodes are connected and the nature of the connection such as its direction, relationship type, and strength.

2.2.7 Online surveys

The main purpose of the online survey was to obtain feedback on a set of ten draft principles derived from the literature review. Twenty-eight participants responded to the survey which was distributed via email to 122 individuals on Thursday 10/10/24 and reminders were sent on 8/11/2024. Participants were selected from the following:

- GBR managers and regulators – e.g. QDPI, the Reef Authority, QDESTI, DCCEEW
- RRAP staff – e.g. members of the Managing Entity; IRRG, Pilot Deployment Sub-Program; ENG Sub-Program
- Traditional Owner group representatives
- Community members e.g. LMAC members; members of the RRAP Stakeholder Advisory Group;
- livelihood stakeholders – e.g. AMPTO members, commercial fishers, aquaculturists.

Although the response rate was low, analysis enabled modification of the ten draft principles presented in the survey.

2.2.8 Key informant interviews

Twenty-two key informant interviews were undertaken between August 2024 and March 2025. Participants were selected based on their extensive experience in ecological restoration activities; and/or marine and coastal activities. The purpose of the interviews was to:

(a) Understand stakeholder and Traditional Owner perceptions of governance for reef restoration and adaptation;

(b) Identify barriers and opportunities for effective governance pathways for GBR restoration activities now and in the future;
(c) Gain insights into the viability of a future policy and governance forum for GBR reef restoration and adaptation.

Interviews were all conducted online, and transcribed. Each transcription was de-identified, and conducted in accordance with QUT ethics guidelines. A thematic analysis of the interviews, together with reviewed literature enabled the identification of a number of plausible governance pathways for GBR reef restoration and adaptation interventions. The analysis also provided some overarching considerations for governance arrangements going forward.

3 Literature Review

The reviewed literature covers a broad range of topics including national, national and ecosystem scale case studies; principles for ecological restoration; restoration and adaptation on the GBR including the regulatory environment and best practice engagement to maximise social, cultural and ecological outcomes.

3.1 Global restoration cases – key lessons

The need for ecological restoration has never been more urgent, with the latest Living Planet Index revealing that the average size of monitored wildlife populations has shrunk by 73% over the past fifty years (WWF, 2024). Freshwater populations have fallen the most (85%); terrestrial populations have declined by 69%, and marine populations by 56%. These figures suggest a corresponding global decline in ecosystem health and ecosystem services (WWF, 2024). In an effort to stem this global decline, governments, communities and non-government organisations (NGOs) across the world have focused attention on how best to undertake repair degraded areas, with the ultimate aim of restoring ecosystem processes and functions and to increase ecosystem services to those who depend on them for their livelihood, or for other economic, social and cultural benefits.

This section presents the results of a literature review of marine and terrestrial restoration and adaptation projects worldwide, including those in Australia and the GBR, to identify important lessons for the governance of ecological restoration projects. We covered both academic publications and grey literature including project reports, websites, and materials from apex bodies, practitioner networks and international organisations such as the IUCN. The review enabled us to identify past and ongoing efforts that are recognised as successful examples or cases of coastal and marine restoration.

3.1.1 Seagrass Restoration

Seagrass restoration projects have been carried out in the United States, Europe, parts of East Asia (Tan et al., 2020a), Australia, New Zealand and other Indo-Pacific regions (Seagrass Restoration Network, n.d.). The majority of these efforts have focused on the species *Zostera marina* or eelgrass (Katwijk et al., 2015), and have been small-scale—involving fewer than 500 shoots or seeds planted in one square meter or smaller-sized plots (Orth et al., 2020a; Statton et al., 2017). The high labour costs, logistical complexities of seagrass transplantation and propagation, and the high plant mortality rates that necessitate consistent monitoring and replantation, have impeded large-scale restoration initiatives (Tan et al., 2020a). Nevertheless, a growing number of projects have successfully achieved seagrass restoration at scale. These initiatives provide important insights into the techniques and governance structures needed for efficient, cost-effective and scalable seagrass restoration (Tan et al., 2020b).

This study reviewed lessons learnt from the following seagrass restoration projects:

- Eelgrass restoration, Virginia, United States
- Operation Posidonia, New South Wales, Australia.

A summary and key lessons from each project now follows.

3.1.1.1 Eelgrass restoration, Virginia, United States

An exemplary seagrass restoration initiative is the long-term program started in the 1990s to revive eelgrass (*Zostera Marina)* that had disappeared from the eastern coast of Virginia due to hurricanes,

disease and human activities in the 1930s (Orth et al., 2020a). Over the course of its 20-year lifespan, the program restored over 9000 acres of eelgrass meadows, leading to various ecosystem benefits such as improved water quality and habitat complexity, and enriched biodiversity (Orth et al., 2020a). Notably, wild populations of the Bay Scallop (*Argopecten irradians*) rebounded in the Virginian bays.

This commercially important scallop had been locally extinct due to a 'wasting disease' pandemic and the loss of vital eelgrass habitats (Oreska et al., 2017; VIMS, 2024). The return of the Bay Scallop prompted further programs for the restoration and protection of this scallop species (Oreska et al., 2017; VIMS, 2024), thereby maximising conservation opportunities and outcomes in the local area.

The planning and governance of the eelgrass restoration project is noted as a key reason for its success. Firstly, by selecting the seed-based restoration technique, the project capitalised on a natural regeneration pathway i.e., the rate of sexual reproduction or seed production of eelgrass (Marion & Orth, 2010; Unsworth et al., 2024). This eelgrass characteristic supported the mass capture of seeds from healthy meadows during natural reproductive cycles, for the purposes of starting new meadows. Secondly, the project's large scale i.e., its large and densely-seeded restoration plots facilitated the establishment of critical ecosystem services or positive feedback loops. Newly established meadows of eelgrass reduced water turbidity and stabilised sediments on the seafloor. These conditions further supported seagrass expansion and resilience, continuing to benefit water quality and sediment stability (Orth et al., 2020a). Thirdly, the long-term restoration commitment or 20-year-long duration of the project facilitated longitudinal research and monitoring, and annual seeding efforts. The latter helped build the resilience of newly established meadows to environmental stressors, future climate change impacts, and restoration impediments (Orth et al., 2020a). Fourthly, the program's model of collaboration between academics, coastal managers, nonprofits, industry and community enabled conservation actions to complement restoration (Orth et al., 2020a). These conservation measures included the implementation of no-take reserves and management actions at the watershed and catchment-level management that directly or indirectly benefitted eelgrass restoration (Lefcheck et al., 2018). For example, mandatory and voluntary codes of conduct were introduced to reduce water pollution, encourage low-impact livelihoods, and support sustainable tourism and fishing practices in eelgrass restoration sites and surrounding areas (Unsworth et al., 2024).

Key lessons

- Long-term commitment facilitates adaptive restoration: The project's more than 20-years of research, monitoring and annual seeding activities reinforced new eelgrass meadows, boosting their resilience to stressors, restoration challenges, and future climate impacts.
- Collaboration boosts restoration outcomes: Stakeholder partnerships helped address the root causes of eelgrass disappearance through the regulation of no-take reserves, pollution, and tourism and fisheries practices, and mandatory and voluntary codes of conduct for bay users.
- Appropriate methods can enhance restoration outcomes: The seed-based restoration technique leveraged a 'natural regeneration pathway' (i.e., eelgrass' high seed production) to enable cost-effective, species-appropriate and mass collection of donor material. The project's large and densely-seeded restoration plots further enabled meadow expansion and resilience.
- Complementary/ combined restoration projects can reinforce restoration outcomes: The eelgrass no-take reserves enabled Bay Scallop revival, whilst the subsequent Bay Scallop restoration efforts reinforced the health and adaptive resilience of eelgrass meadows. The latter project restricted commercial dredging and scraping in areas distinct from the no-take eelgrass reserves, thereby preserving the density and continuity of eelgrass meadows beyond the original eelgrass restoration sites (Oreska et al., 2017).

3.1.1.2 Operation Posidonia, New South Wales, Australia

Operation Posidonia was started in 2018 to reverse the damage caused by boat moorings on Strapweed (*Posidonia australis)* meadows in the urbanised central coast estuaries of New South Wales (Australia). Strapweed are unsuitable for large-scale seed-based restoration due to low rates of sexual reproduction or seed production. Strapweed meadows are also prone to collapse and unsuited to the collection of donor materials. To overcome these barriers, *Operation Posidonia* employed the wrack-based technique of seagrass restoration. This method uses seagrass wrack or post-storm beached live fragments of seagrass (with still-attached rhizomes) as donor material for transplantation. This method had previously been successfully used in the Mediterranean but had not been trialled elsewhere (Balestri et al., 2011; Ferretto et al., 2019; Piazzi et al., 2021).

Overall, *Operation Posidonia* showed that wrack-based restoration is a feasible restoration method in southeastern Australia, where tidal ranges can reach up to two meters and seagrasses are often exposed to air for extended periods (Ferretto et al., 2019; Piazzi et al., 2021). One year after translocation, 70 percent of translocated *P*. *australis* fragments were still alive, whilst 36.3 percent were producing new shoots (SIMS, 2022). These promising results were attributed not just to the project's species-appropriate choice of restoration method but also its model of community collaboration that enhanced conservation outcomes. Wrack-drop of points/ receptacles were set up all along the coastal region, and community members were engaged as citizen scientists and volunteers in the collection and transplantation of strapweed. By engaging the community, the project was able to cost-effectively boost its human resources and restoration outcomes, whilst also building environmental awareness and community support for restoration efforts (Ferretto et al., 2019). Additionally, the project's innovative model of engaging citizen in the collection of wrack was cited as a possible way to minimise the high costs and the socio-environmental issues associated with vast quantities of marooned and (eventually) rotting seagrasses on coastal shores (Macreadie et al., 2017; Misson et al., 2020).

Key lessons

- Appropriate methods reduce risk and understand communities: The wrack-based restoration method enabled *Operation Posidonia* to offset the low-seed production and challenges of collecting donor plants from existing Strapweed meadows.
- Community collaboration can reduce costs, secure community buy-in and enhance conservation outcomes: The engagement of local community members as citizen scientists and volunteers in the collection and transplantation of strapweed helped cost-effectively boost restoration capacity.
- Possible co-benefits for coastal managers and communities: By enlisting community support, the project highlights how wrack-based restoration can potentially reduce the removal costs and other socio-environmental issues associated with large swathes of beached and rotting seagrass.
- The project demonstrates the potential suitability of wrack-based restoration in other parts of southeastern Australia with tidal ranges of up to two metres, where marooned seagrass shoots may be exposed to the elements for lengthy periods.

3.1.2 Shellfish reef restoration (oyster, scallop and giant clam)

Shellfish reefs are intricate ecosystems comprised of the living colonies and empty sterile shells of bivalve molluscs such as oysters, mussels, and clams (Howie & Bishop, 2021). Shellfish occur in the intertidal and upper subtidal zones of both temperate and tropical areas—in bays, estuaries, and nearshore coastal waters (Gillies et al., 2015). Today, most shellfish reefs are critically endangered or

'functionally extinct', due to unsustainable fisheries practices and overharvesting of oysters, mussels and clams for food and other uses (Beck et al., 2009; Gillies et al., 2018; NSW Marine Estate, 2024). Their disappearance has adversely impacted critical ecosystem services such as shoreline fortification; sediment deposition; marine-based carbon dioxide removal (mCDR); microplastics capture; water filtration (and therefore improved water clarity, quality and nutrient balance). The decline of the habitats and sustenance provided by shellfish reefs has also hindered biodiversity (Beck et al., 2009; Flagel, 2024; Gillies et al., 2018; Grabowski & Peterson, 2007).

To reverse their loss, shellfish restoration initiatives have been undertaken in the United States, Australia, New Zealand, Europe, and Asia. Traditionally, these projects were driven by goals of water quality and fisheries improvement rather than ecological conservation—for example, in the United States, the harvesting of Eastern and Olympia oysters in the Gulf and eastern coastal waters was only restricted when high toxin levels and harmful bacteria were found in fisheries products (Coen & Luckenbach, 2000). However, in recent years, shellfish reef restoration has been acknowledged as an important conservation strategy. That is, due to their moisture retention and shading properties, shellfish reefs are seen as important thermal refuges that can increase the climate resilience and adaptability of heat-stressed and vulnerable aquatic species (Fitzsimons et al., 2020; Flagel, 2024)..

This study reviewed lessons learnt from the following key shellfish reef restoration projects:

- Glenelg reef Australian Flat Oyster restoration, Adelaide, Australia
- Chesapeake Bay Oyster reef restoration, Maryland and Virginia, United States
- Restoration of the True Giant Clam, Philippines
- Clam Garden Eco-Cultural Restoration, Southern Gulf Islands, British Columbia, Canada.

A summary and key lessons from each project now follows.

3.1.2.1 Glenelg reef Australian Flat Oyster restoration, Adelaide, Australia

The Glenelg reef restoration project was started in late 2020 as a collaborative effort between the not-for-profit agency, the *Nature Conservancy*, and the South Australian Government. The project involved the construction of 14 limestone boulder-reefs over a 2.5 hectare area of sandy seafloor (expanded to five hectares in 2021) (McAfee et al., 2024). The goal of the project was to restore the reefs of the Australian Flat oyster (*Ostrea angasi*) in the metropolitan coastline of Adelaide. Over 1,500 kilometres of these reefs had disappeared from the local area due to intensive harvesting by European settlers in 1836 (Kenny et al., 2023; McAfee et al., 2017).

The Glenelg reef restoration effort is considered 'an evidence-based bright spot for marine restoration' (McAfee et al., 2024). In just 2.5 years, the project succeeded in transforming the area's Flat Oyster reefs from functionally extinct to a restored structurally diverse and dynamic reef ecosystem with a Society for Ecological Restoration (SER) rating of 3.9/5. A SER rating is used to track the progress of restoration projects. A rating of 4/5 on this scale reflects the 'presence of a substantial subset of characteristic native biota, evidence of developing community structure and commencement of ecosystem processes, improved ecological connectivity establishing, and surrounding threats being largely managed or mitigated' (McAfee et al., 2017, p. 4).

The Glenelg reef project was exemplary in its strategic planning and use of natural regeneration pathways to maximise restoration outcomes. For instance, to minimise the uncertainties in the frequency and density of oyster recruitment, the boulder reefs were installed in late-October to April, to coincide with and make the most of the peak recruitment season for Flat Oyster larvae. The project also involved the public early on through comprehensive and regular public consultations

and a dedicated online platform. The public consultations and online platform, which featured a scientist-moderated discussion forum, offered timely and relevant information and updates, ensuring transparency around project achievements and challenges. The thorough communication, reporting, and prompt response to community queries and concerns helped raise local awareness of environmental issues and the reef restoration initiative. The consideration of local knowledge and recommendations in project decisions such as site selection, further established trust and community support for the restoration effort. For example, the public's desire to maintain coastal access around the restoration site was given equal weightage as the conservation goals of the Glenelg project (Kenny et al., 2023).

Key lessons

- Strategic planning and the use of natural regeneration pathways can minimise risks and maximise restoration outcomes: By installing the boulder reefs during the peak recruitment season for Flat Oyster larvae, the project was able to exploit a natural regeneration pathway and circumvent the uncertainties in the frequency and volume of oyster recruitment.
- Multi-stakeholder collaboration can enhance restoration efforts: The project's partnership between the *Nature Conservancy* and South Australian Government, along with early and ongoing public engagement through consultations, an online platform, transparent communications, and community input-informed decisions, built environmental awareness, trust and support.

3.1.2.2 Chesapeake Bay Oyster reef restoration, Maryland and Virginia, United States

Modern efforts to restore the Bay Oyster (*Crassostrea virginica*) in the Chesapeake Bay commenced in 1993. Bay oyster reefs are found in the temperate estuaries of the North American Gulf and eastern coasts. Intensive oyster harvests over a hundred years had, however, caused a 64 percent decline in reef-covered areas in the Chesapeake Bay, and an 88 percent drop in the biomass of these Bay oyster reeds (Anchondo et al., 2024). The Bay Oyster project sought to revive Bay Oyster reefs in 10 tributaries with different latitudinal and salinity gradients, across the Chesapeake Bay (Anchondo et al., 2024; Beck et al., 2009).

The Bay Oyster is noted for its equal prioritisation of conservation and restoration actions, its multi-sectoral collaborations and holistic ecosystem approach. The project worked with local stakeholders, managers, and regulators to facilitate the creation of a no-take oyster sanctuary and aquaculture programs aimed at reducing fishing pressure on natural reefs and wild species. These measures, in combination with the development of nutrient reduction programs and measures for the restoration of surrounding wetlands and seagrass beds, led to the rebounding of Bay Oyster reefs. The return of these reefs in turn led to improved water quality, habitat recovery and enriched biodiversity in the Chesapeake Bay (Chesapeake Bay Program, 2024; U.S. National Parks Service, 2023).

Key lessons

- Multi-sectoral collaborations, conservation measures and an ecosystem-level approach can boost restoration: By working with local stakeholders, managers and regulators, the project was able to address the original causes of Bay Oyster disappearance through measures such as the regulation of no-take reserves and nutrient pollution, the implementation of watershed restoration actions, and the development of aquaculture to alleviate harvesting pressures in the bay area.

3.1.2.3 Restoration of the True Giant Clam, Philippines

The True Giant Clam (*T. Gigas)* restoration project began in the Philippines in the early 1980, to restore this clam species that had become locally extinct since the 1970s, due to overharvesting and climate change. The aim of the restoration project was to use hatchery-cultivated *T.Gigas* to restock over 40 reef sites around the Philippines, whilst also promoting mariculture as an additional source of income for fisher and coastal communities in the local area (Cabaitan & Conaco, 2017)

The *T.Gigas* project achieved both these objectives and is regarded as a highly successful example of the use of mariculture for restoration. As a result of the initiative, the island reefs around the Philippines are now teeming with tens of thousands of the once critically endangered/ locally extinct *T. Gigas* and other clam species (Cabaitan & Conaco, 2017). Juvenile *T.gigas*, which due to their age are the likely spawn of restocked clams have also been sighted up to 20 kilometres from the closest restoration sites. The presence of these juveniles has affirmed the dispersal capacity of hatched larvae and therefore the restorative potential of clam seeding (Cabaitan and Conaco, 2017). In addition to benefitting reef health, fisheries, and tourism through the return of True Giant Clam and other clam species, the *T.Gigas* project has facilitated the establishment of community-based hatcheries that actively cultivate clams for income generation and restoration purposes (Gomez & Mingoa-Licuanan, 2006).

Many factors contributed to the success of the *T. gigas* revival initiative. The project's multi-sectoral partnerships, community engagement and diversified funding model are amongst these factors. The project was led by the University of Philippines' Marine Science Institute in collaboration with the country's Department of Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources. Additionally, various national non-profits and international organisations such as the World Wildlife Fund (WWF), the Australian Agency for International Development (AusAID), and the United Nations Environment Program (UNEP), were also involved as collaborators and/ or funders. The involvement of these varied groups in addition to local communities, ensured the project's access to cutting-edge scientific expertise and infrastructure, regulatory and advocacy support, as well as community manpower, resources and buy-in (Cabaitan & Conaco, 2017; Gomez & Mingoa-Licuanan, 2006; Stiefel, 2019). For example, the clams reared at the mariculture facilities at the University of Philippines' Marine Science Institute, were augmented by stocks from community - based hatcheries that were supported by Local Government Units (LGU) and non-profits (Gomez & Mingoa-Licuanan, 2006). Similarly, the sourcing of funds from diverse agencies helped maintain financial stability and project continuity even when grant cycles and individual donor contracts were completed (Cabaitan & Conaco, 2017; Gomez & Mingoa-Licuanan, 2006; Stiefel, 2019).

The efforts of the *T. gigas* project to enhance economic and social ecosystem services in addition to ecological values was also exemplary. The project trained local fishers and community members in clam culture and rearing, through a 'users pay' model (Gomez & Mingoa-Licuanan, 2006). That is, those benefitting from clam restoration contributed to the program's costs in the form of fees for mariculture training and/or setting aside a portion of their cultivated clams for restoration. This 'users pay' approach incentivised sustainable fishing and farming whilst simultaneously promoting local ownership and pride in the restoration effort and *T. gigas* revival as a viable livelihood pursuit for coastal communities (Gomez & Mingoa-Licuanan, 2006).

Key lessons

- An ecosystem approach can maximise restoration opportunities: By aiming to revive *T. Gigas* and promote sustainable clam farming as an additional livelihood for fisher and coastal communities, the project enhanced not only the ecological values but also economic and social ecosystem services (Gomez & Mingoa-Licuanan, 2006).

- Multi-sectoral collaboration can strengthen restoration efforts: The collaboration between academia, government, civil society and local communities, ensured the project's access to scientific expertise, regulatory backing, advocacy support, and community buy-in and support.
- Diversified funding sources can reduce financial uncertainty and ensure project continuity: The funding of the *T. Gigas* restoration effort by various national and international agencies such as the University of Philippines' Marine Science Institute, national government agencies in the Philippines, and international bodies such as the WWF, AusAID and UNEP, helped minimise financial risks and ensure project stability and continuity at the termination of grant cycles and individual donor contracts.
- Making restoration profitable for investors and practitioners can boost restoration outcomes: The project's 'users pay' model incentivised clam cultivation for fisher and coastal communities, who paid in cash or kind to build their capacities as mariculturists. The uptake of clam cultivation as an additional livelihood in turn boosted the availability of lams for restoration, and local socioeconomic conditions.

3.1.2.4 Clam Garden Eco-Cultural Restoration, Southern Gulf Islands, British Columbia, Canada

The Clam Garden Eco-Cultural Restoration project is a unique example of how ocean science can be merged with Indigenous environmental knowledge and stewardship to maximise restoration outcomes. This project was carried out between 2008-2015 in the Southern Gulf Islands in the Salish Sea, in British Columbia, Canada (Fediuk & Thom, 2003; Nelson, 2018). The project was a collaborative effort between ten First Nations communities, Parks Canada, Royal Roads University, Simon Fraser University, the University of Saskatchewan, and the Clam Garden Network, that aimed to revitalise Traditional clam gardens on two Canadian islands namely Salt Spring Island and Russel Island in the Gulf Islands National Park Reserve (Nelson, 2018). Clam gardens were an ancient mariculture technique practised by the Kwakwaka'wakw, WSÁNEĆ Hul'q'umi'num coastal peoples of the Salish sea for thousands of years, prior to the disruption of their communities by European colonisation (Fediuk & Thom, 2003; Nelson, 2018). The practise involved the building of several kilometres of rock walls along the low tide line of the intertidal zone, to trap sediment and expand the zone of productive clam growth near First Nations' settlements (Groesbeck et al., 2014). Historically, clam gardening has been known to facilitate over 400 percent increases in clam production, thereby improving local food sovereignty, flora and fauna, and ecosystem adaptive capacities (Nelson, 2018).

The Clam Garden Eco-Cultural Restoration effort achieved many important results: Firstly, the project facilitated better ecosystem health and productivity, as seen in the higher clam densities and biomass within the clam gardens in comparison to non-walled beaches. The clam gardens had quadruple more butter clams, twice more littleneck clams and higher numbers of baby clams, native species, and squirting clams (W̱SÁNEĆ Leadership Council, 2020). The survival rates of smaller clam species were also higher, with juveniles of transplanted species such as the *L. staminea* growing 1.7 times faster, when protected from competitors and predators within the gardens (Groesbeck et al., 2014). The clam gardens also enriched habitat quality and local biodiversity by elevating water quality and providing shelter, protection and sustenance for a number of marine species such as red sea cucumbers, red rock crabs, and seaweed (Nelson, 2018). The improvements in clam production and marine biodiversity in turn promoted First Nations' food sovereignty and livelihood security.

Secondly, the project not only enhanced scientific knowledge on ancient clam production and harvesting techniques but also restored Kwakwaka'wakw, W̱SÁNEĆ and Hul'q'umi'num knowledge of clam gardens and their socioenvironmental benefits. For example, the project involved the setting up of Traditional knowledge workgroups that included Native experts in Coast Salish languages,

cultures, and harvesting techniques. These working groups and science camps organised for elders and youth facilitated the sharing of knowledge on how to build and maintain clam gardens, methods and times for clam harvesting, clam storage and preparation techniques and other Traditional stories and aspects of Kwakwaka'wakw, Hul'q'umi'num and WSÁNEĆ cultures such as communities' intrinsic and continuing connections to the land and sea and role as environmental stewards (Nelson, 2018). Thus, activities such as the relocation of large boulders for clam gardens and the assessment of ecosystem health were carried out through the guidance of Coast Salish knowledge holders, supplemented by contemporary scientific methods (Nelson, 2018). In this manner, the project enhanced the scientific understanding of ancient clam production, harvesting techniques and benefits, whilst simultaneously filling in the gaps in Traditional knowledge that had occurred due to the destruction of Indigenous cultures and practices during colonisation (W̱SÁNEĆ Leadership Council, 2020). By blending of the wisdom of elders and traditional knowledge holders on one hand, and scientists, on the other, and ensuring the active participation of First Nations' communities in clam garden restoration, the project also helped reinstate the important role of First Nations' communities in natural conservation and stewardship (Cardinal et al., 2015).

Thirdly, the clam gardens enhanced beach aesthetics and provided a natural means of mitigating wave energy. In doing so, the gardens showcase an important strategy for enhancing the adaptive capacity of not just clams but also coastal communities, in the face of rising seas (Clam Garden Network, n.d.; Nelson, 2018).

Key lessons

- Combining ocean science with Indigenous environmental knowledge and stewardship can enhance restoration knowledge: By blending Traditional and scientific knowledge, the project was able to enhance the scientific understanding of restoration techniques, whilst also filling in Indigenous knowledge gaps and reinstating the role of First Nations' communities in environmental conservation.
- Restoration efforts can serve as a means of fostering Indigenous pride and building bridges between mainstream and First Nations' communities: The project brought together Coastal Salish knowledge holders to share clam gardening practices, harvesting techniques, and cultural teachings through workgroups and camps. These camps enabled Hul'q'umi'num and WSÁNEĆ elders and youth to explore their languages, stories, and deep cultural ties to land, sea, and environmental stewardship. Some of the camps were also tailored to enable sharing with and learning from ocean scientists and researchers.
- Learning from the ancient stewardship practices of Indigenous communities can improve climate adaptation: The ancient shellfish engineering technique of building clam gardens that the Kwakwaka'wakw, WSÁNEĆ Hul'q'umi'num peoples had practiced for thousands of years, offered ocean scientists with an alternative strategy for arresting wave action and thereby improving the adaptive capacity of marine biodiversity and coastal communities faced with rising sea levels.

3.1.3 Mangrove forest restoration

Ambitious targets for mangrove restoration to deliver significant ecosystem services has captured global attention in recent years, especially through the current United *Nations Decade of Ecosystem Restoration (2021 to 2030)* (Lovelock et al., 2022). Mangrove forests comprise highly biodiverse, productive, transitional habitats between terrestrial and marine ecosystems. They protect coastal landscapes and provide a range of benefits to local and global communities. These include the provision of habitat and nursery grounds for several species and economically viable seafood; contributions to climate regulation through carbon capture and storage; provision of timber for firewood and building materials, and medicines (Bhagarathi & DaSilva, 2024; Su et al., 2021). Overexploitation of mangrove forests' ecosystem services; conversion of mangrove forests for other

purposes such as farming or urban development; pest species invasion; and pollution have all contributed to destruction, fragmentation and degradation of mangrove ecosystems around the world (Bhagarathi & DaSilva, 2024; Gerona-Daga & Salmo, 2022; Lovelock et al., 2022; Sam et al., 2023; Su et al., 2021). This decline, in turn has caused several social problems such as reduced fisheries and livelihoods, increased conflicts, and reduced coastal protection leaving communities vulnerable to property and infrastructure damage and even loss of life during extreme weather events. Ecologically, the loss of mangrove ecosystems has diminished carbon sequestration processes and decreased nutrient cycling and other ecological processes important for marine nurseries and adjacent coral reefs and seagrass beds (Lovelock et al., 2022).

Global efforts over the past forty to fifty years to restore these degraded systems have had mixed results. Su et al. (2021) conducted a meta-analysis to quantify the outcomes of mangrove restoration through analysis of reviewed literature on (a) the ecological function of restored mangroves compared with natural mangroves, naturally regenerated mangroves, degraded mangroves or unvegetated tidal flats; (b) effects of diverse factors including restoration age, species composition, method, and global region on restoration outcomes; and (c) economic costs and benefits of restoration. In general, their analysis suggested that restoration efforts do yield positive results. For example, they found that the ecological functions of restored mangrove forests were similar to naturally regenerated mangrove forests and provide higher functioning systems than unvegetated tidal flats. Their study revealed that mangrove restoration can be cost effective, however, they stressed that outcomes vary widely according to restoration age, species composition and restoration method (Su et al., 2021). The size of the restoration area is also critically important.

As part of their review of global mangrove restoration efforts, Lovelock et al (2022) compared the advantages and disadvantages of small scale versus large scale restoration efforts, as summarised in Table 1 below. They claim that over the past fifty years, some large-scale afforestation projects (1000s of hectares) have been demonstrably successful, delivering carbon sequestration and coastal protection, especially where there is strong government support and where there are unaltered tidal flows. Unfortunately, they also found that while some are successful, many large projects fail due to short-term investment, complex governance arrangements, poor site selection and little community involvement and support. Additionally, some large-scale successful restoration efforts that were previously successful (e.g. the Mekong Delta) are now threatened by economic policies favouring industries such as aquaculture (Lovelock et al., 2022). Loss of mangroves in the Mekong Delta may also be attributed to poor policies; insufficient funding and limited financial incentives for conservation; inconsistent land-use planning; weak coordination between sectors; lack of community involvement in decision-making; and inconsistencies between development priorities and environmental protection (Pham et al., 2022).

Table 1: Summary of benefits and problems associated with larger and smaller mangrove restoration projects

(SOURCE: Lovelock et al. 2022)

Project size	Potential benefits	Potential problems
Larger projects	Potential for restoration and rehabilitation over large scales Economies of scale Attractive to investors Can support high levels of biodiversity	Inappropriate biophysical conditions Limited engagement with large number of stakeholders Complex governance

	Landscape scale ecosystem service provision	Failure to address underlying causes of degradation Monospecific plantings Large but short-term investment
Smaller projects	Empowerment of landholders/ communities Simple governance Appropriate sites selected by landholders Addresses underlying causes of degradation and allows experimentation Long-term commitment to land management	Small patches may not deliver ecosystem services Higher costs of implementation per area of habitat Unattractive and often invisible to investors Limited biodiversity benefits

Lovelock et al., (2022) suggest it may be more effective to target locally degraded areas than large ecosystem scale tree-planting, especially where communities are actively involved, as local people can create opportunities for sustainable extraction of resources from the forests. However, such small, isolated patches are unlikely to deliver landscape-scale benefits, unless coordinated as part of an overall landscape scale plan (Lovelock et al., 2022). A similar conclusion was reached by Gerona-Daga & Salmo (2022) who analysed 335 publications on mangrove restoration efforts in South East Asia. They found that up-scaling and acceleration of restoration requires an overarching organisation to realign existing policies across institutions to articulate clear, shared objectives, options for long-term funding and investment opportunities. Their study also found that there needs to be integration of mangrove restoration activities into national and local coastal management plans, and ongoing monitoring and evaluation of restoration activities. Critical to enduring success is the establishment and maintenance of relationships between individuals, communities, institutions to work towards shared goals through knowledge and resource sharing and collaborative problem solving (Gerona-Daga & Salmo, 2022).

Key lessons

- Global declines in mangrove forests social, economic and environmental problems: They create social and economic problems for coastal communities; reduce landscape scale biodiversity and ecosystem function; and diminish coastal protection and carbon sequestration processes.
- Economic and political priorities are often at odds with environmental objectives. This can reverse previously successful restoration efforts.
- Mangrove restoration can be cost effective, especially if there is effective governance in place and there is strong community support.
- Across the globe, both large- and small-scale restoration projects would benefit from a coordinated approach. This approach should include:
    - shared vision and objectives across all stakeholders and rightsholders;
    - long-term funding and investment opportunities;
    - consistent policies and land-use planning at national and local scales to enable the benefits of small-scale projects to be amplified at a landscape scale;
    - opportunities and capacity-building for community participation in decision-making;

- simple rather than complex governance arrangements;
- opportunities for networking and collaboration among all actors to relationships to maximise knowledge and resource sharing and collaborative problem solving.

3.1.4 River Restoration

People have always settled near rivers and today more than 500 million people live near rivers for the range of social, cultural and economic benefits they supply. Rivers also play a critical role in sustaining adjacent ecosystems such as wetlands, lakes, mangroves and coastal waterways. Increasing populations, overexploitation, pollution and effects of climate change have caused devastating impacts on riverine systems and the people who depend on them (Basak et al., 2021). This widespread degradation has led to large and small scale river restoration activities across the globe. Activities include physical modifications such as bank stabilisation to rivers; repair of adjacent habitats and flood plains; and numerous activities to improve fish habitat, water quality, river recreation and livelihoods (Basak et al., 2021; England et al., 2021; Fenten & Dieperink, 2024; The Everglades Foundation, 2021).

The *United Nations 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention)* is a widely accepted international legal framework to ensure sustainable use of transboundary water resources, including lakes and rivers. The Water Convention can be used to accelerate progress towards several *2030 Agenda for Sustainable Development* goals including the United Nations (UN) Sustainable Development Goal 6 (SDG) 6 (clean water and sanitation) and target 6.5 to implement integrated water resources management at all levels by 2030, including through transboundary cooperation (United Nations Economic Commission for Europe, 2022). Despite the UN Water Convention, evidence suggests that current restoration efforts may not be sufficient to reach SDG 6 or other relevant UN goals that depend upon healthy freshwater ecosystems such as zero hunger (SDG2), sustainable food production (SDG target 2.4) and fisheries (SDG 14) by 2030 (Basak et al., 2021).

In their review of river restoration projects completed around the world, Basak et al. (2021) found that very few measured or described social benefits, and most were only concerned with biophysical outcomes. Initially, this seemed to be the case for the UK, where a River Restoration and Biodiversity Programme was established in 2013 to provide robust evidence for the biodiversity benefits of restoring rivers (England et al., 2021). In their review of UK river restoration projects England et al. (2021) found that:

- Many UK river restoration projects lacked rigorous data to determine whether restoration objectives were met and to learn lessons for future projects;
- Very few project were monitored beyond the life of the project, resulting un unclear outcomes, including biodiversity benefits and ecosystem services;
- Methods for valuing and appraising ecosystem services varied across projects, and according to different stakeholder perspectives – e.g. Economic values may be misaligned with cultural or social values; and
- There were frequent mismatches between restoration locations and societal benefits.

They concluded that biodiversity focused restoration is likely to enhance riverine ecosystem services and that community participation in decision-making together with inclusion of social values are integral to the success of river restoration efforts, and can augment future restoration efforts as shown in Figure 3.

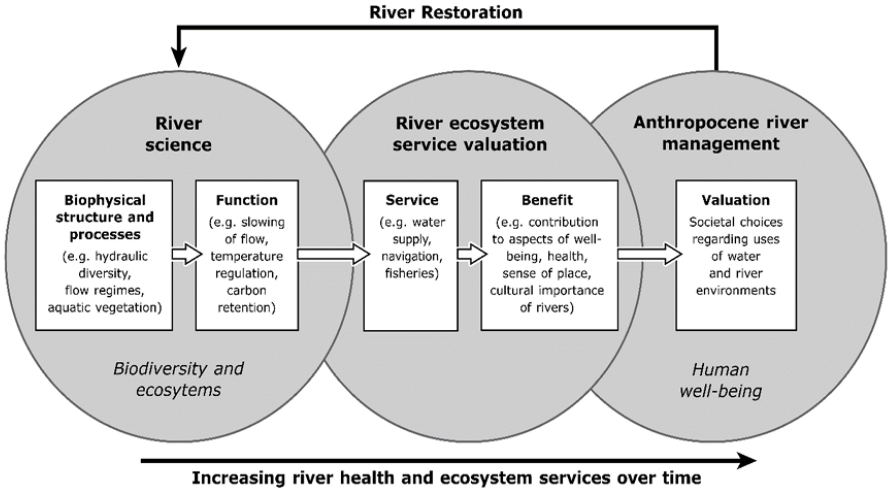


Figure 4: Links between societal choices and values in river management and restoration

To ensure social, cultural and economic benefits of river restoration are clearly identified and acted upon, Basak et al., (2021) propose the framework depicted in Figure 4, which is constructed around a modified Drivers-Pressures-Impact-State-Response Model. For this framework, policy development and river restoration plans are identified as actions, which affect the provision of ecosystem services, which in turn, influence or impact upon social benefits and human wellbeing. Impacts are enhanced through community participation and articulation of values as ecosystem services, as well as inclusion of SDGs in each action plan. Deliverables resulting from impacts (i.e. benefits) enable adjustment to the identified drivers. The proposed framework can be applied at different spatial and temporal scales (Basak et al., 2021).

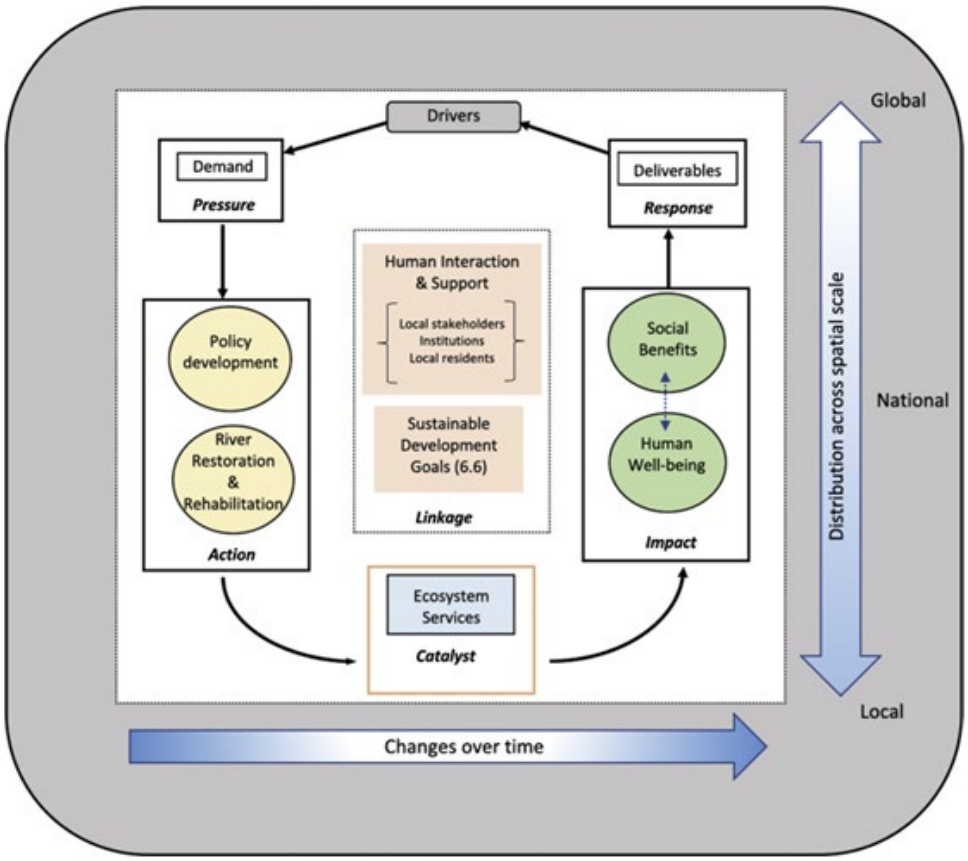


Figure 5: A conceptualised framework to include social benefits as outcomes for river restoration projects

(Source: Basak et al., 2021)

Key lessons

- Formal multi-lateral arrangements including binding agreements that clarify roles and responsibilities are needed for large scale restoration efforts that cross international boundaries;
- Shared vision, clearly defined objectives, rigorous, consistent data gathering and sharing are needed, especially for large-scale projects;
- Ongoing, rigorous monitoring and evaluation - beyond the life of individual projects - is needed to clarify, record and promote benefits of restorations efforts;
- Ongoing funding is critical to achieve long-term benefits and to avoid costs of disaster mitigation;
- Political science experts play an important role in governance
- Site selection: Ensure sites selected for ecological restoration align with social, cultural and economic values

3.1.4.1 Rhine River restoration

According to Fenten & Dieperink (2024) successful riverine restoration projects require large geographical areas (often across several jurisdictions) to repair ecological functions and processes. This requires particular governance arrangements including a shared vision and coordination of activities within and between the communities who depend on the riparian ecosystem. Using the Rhine River as an example they provide an assessment of the governance conditions prevailing throughout the restoration of the Rhine River (Fenten & Dieperink, 2024). The Rhine River traverses several European nations and has been the focus for restoration activities since 1986. These activities are principally governed through the International Commission for the Protection of the

Rhine (ICPR) with members from the Rhine basin states (Switzerland, Germany, France, Luxemburg, The Netherlands, and the European Community) (Fenten & Dieperink, 2024).

The assessment of the governance arrangements for the Rhine River restoration began with a review of the literature that revealed nine principles for the effective governance of river restoration projects. The principles created a framework for analysis of policy documents, reports and peer reviewed scientific journals. The analysis was also informed by seven key informant interviews (Fenten & Dieperink, 2024).

Table 2 Performance of governance arrangements for the restoration of the Rhine River

Red font indicates that the governance condition is absent, orange font indicates that it is partly present and green font indicates that the condition is fully met (Fenten & Dieperink, 2024).

Dimension	Governance Condition
Legislation	Ecosystem restoration is protected by and embedded in institutional arrangements and legislation The ecosystem restoration organization has the power to transform existing or to institutionalize new restoration arrangements. The ecosystem restoration organization has the power to enforce the breaching of institutional restoration arrangements legislatively.
Governance structure	Ecosystem restoration management takes place at a cross-border, fluvial scale to ensure synergy between individual restoration measures. Room is given to bottom-up, grassroots participation in the restoration process through designated communication platforms. There is a clear attribution and division of tasks and responsibilities for all partaking actors in the restoration process. Employees of the ecosystem restoration organization have multi-disciplinary backgrounds, thus accounting for the multi-dimensionality of the restoration challenge. The ecosystem restoration organization has a concise conflict-resolving strategy aimed at achieving consensus.
Financing	Actors contributing to ecosystem restoration are financially rewarded. Ecosystem restoration has economic benefits for partaking actors, in addition to possible direct reward structures (e.g., business development; protection of natural capital). Clear, viable, and long-term agreements are present to finance ecosystem restoration projects.
Information	There is a clearly demarcated and designated role for scientists and research in the governance structure of the ecosystem restoration organization. Potential ecosystem restoration measures are compared with alternative measures in order to optimize their societal impact. The ecosystem restoration process is actively supported by research to reduce and cope with uncertainties in the restoration process.
Stakeholder support	Stakeholders, especially politicians, support and actively broker for the ecosystem restoration project.

	The ecosystem restoration organization deploys an active capacity-building process to increase the support base of the restoration project by including more actors and stakeholders.
Leadership	Strong, inspiring leadership of individuals with experience and relevant backgrounds is present. Collaboration is coordinated and ensures that all partaking actors in the ecosystem restoration process share the same goals and vision. Actors are held accountable for the timely implementation of restoration measures.
Discourse	The ecosystem restoration organisation enables stakeholder discourses, thus accounting for the inclusion of different values and opinions on ecosystem restoration.
Adaptation	The ecosystem restoration project has clear long-term goals, which are flexible to anticipate future uncertainties. The ecosystem restoration organization continually improves its restoration policies and measures by evaluating the outcomes of existing policies and measures.
Innovation	The ecosystem restoration organization has an organizational culture open for innovation, where experimentation policies and measures are implemented to test new ideas.

Key informants criticised the time consuming procedures of discussion and negotiation within the ICPR and the lack of clarity around national roles and responsibilities. There was also concern around the lack of incentives for individual nations to contribute financially to restoration.

Key Lessons

With respect to the Rhine River restoration, there is a need to:

- Formalise binding agreements that clearly articulate responsibilities for each nation;
- Strengthen enforcement mechanisms to encourage adherence to restoration objectives;
- Develop funding schemes that promote national investment by highlighting the long-term economic benefits of restoration and the avoided costs of disaster mitigation; and
- Integrate political science experts and leaders with relevant political experience into the ICPR working and strategy groups (Fenten & Dieperink, 2024).

3.1.5 Coral reef restoration

A global resurgence of reef restoration programs is underway in response to the accelerating degradation of the world's tropical coral reefs, and in anticipation of future declines (Hein et al., 2021; Hughes et al., 2023; Shaver et al., 2022; Suggett et al., 2024; Vardi et al., 2021). In order to assess the effectiveness of such initiatives, Boström-Einarsson et al., (2020) undertook a comprehensive review of coral restoration methods around the world, including peer-reviewed scientific publications (221 peer-reviewed articles) and grey literature (78 sources including reports, web-sites and other materials). This analysis together with the results of an online survey of 63 coral restoration practitioners revealed that globally, coral reef restoration case studies are dominated by short-term projects - more than half are completed within 18 months; and most are small scale, with

a median restored area of 100 m^2. This study also highlighted that the field of coral restoration has been plagued by (1) a lack of clear and achievable objectives, (2) a lack of appropriate and standardised monitoring and reporting and, (3) poorly designed projects in relation to stated objectives (Boström-Einarsson et al., 2020).

These findings are in agreement with Hein et al. (2020) who examined the effects of coral restoration on five ecological indicators common to four regional locations: (1) New Heaven Reef Conservation Program (NHRCP) on the island of Koh Tao, Thailand; (2) Reefscapers program on the island of Landaa Giraavaru, Maldives; (3) Coral Restoration Foundation in Key Largo, Florida Keys, USA; and (4) The Nature Conservancy on the island of St Croix, US Virgin Islands. Results indicated increased coral cover and structural complexity in each of the four locations compared with unrestored sites. There were however, differences in program objectives, methodologies, and the state of nearby coral communities, which influenced the extent to which restoration was successful. Results of this study also suggest that site selection is a major influencing factor. Further, Hein et al., (2020) noted that there is often a mismatch between the objectives of coral restoration programs and parameters used to assess their effectiveness, with many restoration projects (due to their short-term nature) having limited monitoring and evaluation programs, thus not reflecting long-term outcomes.

In their analysis of global coral reef restoration efforts, Hughes et al. (2023) note that setting clear objectives, having neighbouring control sites, and measuring appropriate variables – for example measuring the recovery of ecological function and/or measuring species diversity rather than just the extent of coral cover *per se* - could substantially improve restoration efforts. They recommend that reef restoration programs be underpinned by the principle of ecological succession, which is driven by larval recruitment and growth of surviving corals, together with principles that promote the responsiveness and resilience of ecological systems to stress. As part of this approach, testing the effectiveness of restoration requires long-term monitoring of both the intervention site and adjoining areas where recovery is allowed to occur naturally (Hughes et al., 2023). This approach aligns with project designs and practices promoted by Shaver et al. (2022) including resilience principles incorporating careful consideration of coral selection, site selection, and the broader ecosystem context to support enhanced outcomes for coral reefs in response to climate change. They state that long-term success however, requires global reduction in carbon emissions; as well as new partnerships, community involvement, and the development of new industries (Shaver et al., 2022).

Despite the numerous challenges facing reef restoration, Hein et.al, (2021) believe that coral reef restoration is useful at local scales in locations where coral recruitment is limited and further deterioration can be curtailed. This is echoed by Hughes et al. (2023) who claim that some small scale reef rehabilitation may be feasible, affordable, and ethical. They assert however, that larger scale initiatives are likely to fail unless greenhouse gas emissions and other drivers of reef degradation are mitigated. They also stress that the contribution of small-scale restoration projects can be enhanced by adaptive governance that anticipates and reduces the risk of ecological surprises and societal conflict (Hughes et al., 2023).

Key lessons

- Most coral restoration projects are short-term and small scale, typically around 100 m^2, which is inadequate to address the global degradation of coral reefs. Many do, however, address small scale, local reef degradation.
- Even though many intervention projects report successful outcomes, success is not monitored beyond the spatial and temporal scale of the project. Testing the effectiveness of restoration

requires long-term monitoring of both the intervention site and adjoining areas where recovery is allowed to occur naturally.
- Many coral restoration efforts lack clear and achievable objectives; standardised monitoring and reporting; and are poorly designed.
- Restoration efforts should be underpinned by the principle of ecological succession and principles that promote the responsiveness and resilience of ecological systems to stress.
- Site selection is becoming recognised as a critical factor in determining success.
- Benefits of coral restoration projects can be amplified through better coordination and adaptive governance. There is a need for coordinated communication and information exchange to translate relatively short-term R&D programs into long-term interventions involving scientists, industry, community and others.

3.2 GBR restoration and adaptation interventions and initiatives

This section begins with an overview of the regulatory environment for GBR restoration and adaptation initiatives. This context is important for understanding some of the challenges associated with developing novel interventions, and also provides insights into how some of these challenges are being addressed through policy development and other initiatives.

3.2.1 GBR regulatory environment

The regulatory environment for conducting GBR reef restoration and adaptation interventions can be daunting, as researchers and practitioners need to navigate an intricate network of legislation, regulations, agreements, policies, plans, position statements, strategies, site management arrangements, guidelines and engagement mechanisms, which operate at a range of scales and jurisdictions. Each align with the main object of the Great Barrier Reef Marine Park Act (1975) which is …

> '*…to provide for the long term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region'* (Great Barrier Reef Marine Park Authority, 2014, p1-6).

Four layers of governance have overlapping roles:
- **International**: Australia has obligations under multiple international treaties, particularly the *World Heritage Convention*
- **Australian Government**: multiple departments and agencies of the Australian Government, particularly the Great Barrier Reef Marine Park Authority ('the Reef Authority') and the Department of the Environment and Energy
- **State Government**: involving multiple departments of the Queensland Government, particularly the Department of Environment and Science and the Department of Agriculture and Fisheries
- **Local government**: involving 39 local governments within the Reef catchment (Fidelman, Newlands, et al., 2019).

A bilateral arrangement signed in 1979 between the state of Queensland and the Commonwealth government (known as the 'Emerald Agreement') laid the foundation for effective collaborative management of the Great Barrier Reef Marine Park, which continues to this day (Commonwealth Government & Queensland Government, 2024). The Great Barrier Reef Ministerial Forum, consisting of two Australian and two Queensland government ministers, oversees implementation of the intergovernmental agreement's objectives. As part of this arrangement, a jointly-funded Field Management Program undertakes day-to-day management activities in the Marine Park, the adjacent Queensland Great Barrier Reef Coast Marine Park and on national park islands (Great Barrier Reef Marine Park Authority, 2014).

Early marine park management focused on direct threats such as over-fishing and mass tourism using specific tools such as zoning plans (Day, 2008). In recent decades however, it has become apparent that the health of marine and coastal ecosystems is influenced by multiple external factors such as declining terrestrial water quality and the impacts of climate change. Heatwaves, tropical cyclones, flood events and increasing ocean acidification due to greenhouse gas emissions negatively affect the ability for many marine organisms including corals to build future reef ecosystems (Great Barrier Reef Marine Park Authority, 2024a, 2024b). These and other stressors on reef health such as impacts from crown-of-thorns starfish (CoTS) outbreaks and poor water quality, all challenge the capacity of current governance arrangements to protect large complex systems such as the GBR (Great Barrier Reef Marine Park Authority, 2024a, 2024b). To address these issues, both the Commonwealth and Queensland governments (under the latest Intergovernmental Agreement signed in September, 2024) have committed to achieving net zero emissions by 2050 under their respective legislations – i.e. the *Climate Change Act 2022* (Cth) and the *Clean Economy Jobs Act 2024* (Qld). One of the stated objectives under this agreement, is *to ensure the ongoing protection, restoration and management of key ecosystems critical to the Great Barrier Reef health* (Commonwealth Government & Queensland Government, 2024, p.8).

Other documents supporting positive action to foster GBR health include *Good Practice Management for the Great Barrier Reef* and the *Net Benefit Policy,* two policy documents under the Reef 2050 Plan (Dyer et al., 2021). The joint policy on *Great Barrier Reef Interventions* (2020) aims to guide the Reef Authority and Queensland Parks and Wildlife Service on matters related to interventions that directly support conservation efforts at a range of scales, and to inform Traditional Owners, proponents, partners and other key stakeholders about these arrangements (Great Barrier Reef Marine Park Authority, 2020c). Similarly the *Reef Blueprint 2030* supports activities that enhance GBR resilience, including opportunities to test and evaluate restoration methods, and to foster active community and industry participation in restoration efforts (Great Barrier Reef Marine Park Authority, 2024b). The evolution of GBR regulations, policy documents and the approval processes for specific GBR restoration and adaptation interventions is enabling more targeted responses to declining coral cover. See Appendix 1 for relevant national legislation, policies, plans and agreements.

Until recently there have been few active interventions implemented in GBR waters, although many GBR islands have been subjected to active management for decades. The following examples of GBR restoration and intervention activities were selected through a review of grey and published literature, and cover:

- Coral reef restoration and adaptation interventions led by RRAP;
- The Crown of Thorns Starfish (cots) control program; and
- Management interventions on two GBR islands.

These particular examples were chosen as they each present challenges and learning opportunities that may be applied to the governance of reef restoration and adaptation in the GBR.

3.2.2 GBR Coral reef interventions – RRAP

In 2017 a newly formed, multi-institutional collaborative program, the Reef Restoration and Adaptation Program (RRAP) for the GBR, undertook an 18-month concept feasibility study that included a rigorous and comprehensive investigation into medium and large scale reef interventions. The study involved over 150 scientists from more than 20 organisations around the globe (AIMS, 2022). As part of that study, an RRAP Investment Case provided a long-term vision and workplan for how GBR reef restoration and adaptation could be affordably achieved at scale and within a narrowing window of opportunity for action in the face of climate change. Authors of the Investment Case emphasised the need for a new set of on-reef management options to provide the

best chances for reef survival and resilience in a warmer future (Hardisty et al., 2019). The feasibility study proposed, and subsequently enabled, the establishment of an unincorporated joint venture as the preferred governance model for RRAP, as depicted in Figure 5.

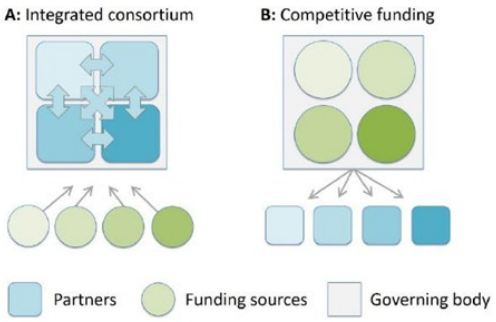


Figure 6: Conceptual representations of contrasting governance models

A: Recommended model for RRAP, which will require an unprecedented level of project integration and coordination, and partner alignment, and, **B:** classical competitive funding model. While model **B** can produce science excellence, model **A** will be necessary for mission-driven program delivery. The unincorporated joint venture would be governed by a board with an independent chair, supported by an independent peer review panel and a Traditional Owners advisory sub-committee. A steering committee run by an executive director would be responsible for directing the implementation of the R&D program. The R&D effort would be managed by a program director (Hardisty et al., 2019).

The feasibility study also identified a number of key governance elements considered critical for the R&D phase of RRAP including:

- Ability to take risks and move quickly to identify prospective interventions;
- Need to include a wide range of diverse stakeholders;
- Ability to bring in new partners and drive effective collaboration;
- Ensure strong engagement and alignment of partners;
- Ability to raise additional funding; and
- Make decisions quickly in response to changing conditions (Hardisty et al., 2019).

From this work, the RRAP R&D program began in 2020, building on many years of research conducted in Australia and overseas including projects on coral gardening, stabilisation of disturbed reefs, coral transplantation, coral recruitment and coral seeding (McLeod et al., 2022; RRAP, 2023a).

As one of the world's largest coral reef research and development programs, RRAP aims to provide reef managers with a range of options that are '*scientifically proven, ecologically effective, socially acceptable, technically feasible, and economically … to intervene at scale on the GBR and other reefs to enhance their resilience and accelerate adaptation to climate change'* (Lockie et al., 2024, p.2).

RRAP was founded on seven intervention research areas supported by cross-cutting research areas as shown in Figure 6. It aims to provide reef managers and decision-makers with safe, acceptable and cost-effective interventions to contribute to site-specific GBR protection as well as larger scale efforts which target core ecosystem functions and social, cultural and economic values at multiple GBR sites (McLeod et al., 2022; RRAP, 2023b). Since the development of complementary state and Commonwealth government policies and guidelines for interventions (Great Barrier Reef Marine Park Authority, 2020c), RRAP has been able to move towards scalable efforts across sites, enabling a more holistic and coordinated approach to restoration and adaptation initiatives.

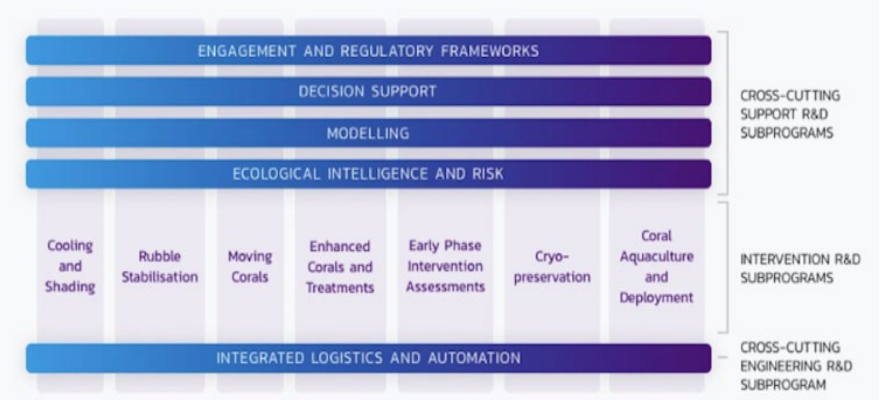


Figure 7: Core areas of the RRAP program
(SOURCE: McLeod et al., 2022).

The R&D phase of RRAP has been able to demonstrate success at local scales including high early survival rates of a variety of coral species, implemented through a range of different methods. The success of some local scale projects has also been attributed to high levels of stakeholder and Traditional Owner participation through best practice community engagement processes (McLeod et al., 2022).

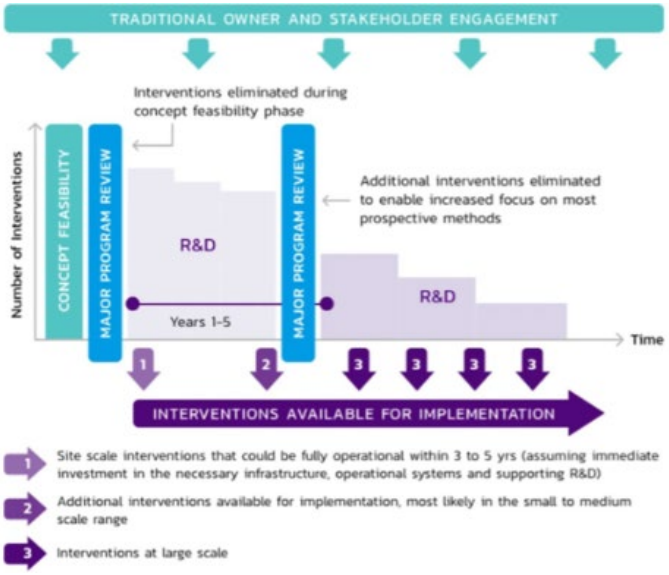


Figure 8: RRAP strategy to progressively deliver interventions and refine the focus of the R&D program as research findings improve knowledge of feasibility, risks, efficacy, social acceptance and regulatory compliance.

(SOURCE: McLeod et al., 2022.)

In recent years, the RRAP has been able to shift towards an implementation phase – the Pilot Deployment Program (PDP) - that involves Traditional Owners, reef managers, tourism operators, marine contractors, the aquaculture industry and other stakeholders (Gibbs et al., 2024; McLeod et al., 2022). RRAP's PDP comprises large field trials to operationalise selected R&D interventions. It is creating new platforms for open and constructive dialogue with Traditional Owners, industry and communities on how and where interventions can best be deployed. It aims to build regional and local delivery capacity within Traditional Owner groups and local industries (such as tourism, fishing, aquaculture) and create opportunities for future upscaling of interventions (RRAP, 2023a).

Key lessons

- Evolving bilateral policy development has helped RRAP to have a more coordinated and holistic approach to restoration and adaptation initiatives.
- Some local scale successes have been characterised by high levels of stakeholder and Traditional Owner participation through best practice community engagement processes.
    - RRAP works closely with multiple partners including Traditional Owners, reef managers, tourism operators, marine contractors, the aquaculture industry and other stakeholders, and aims for open and constructive dialogue with partners whenever possible.
    - RRAP aims to identify opportunities to build capacity including training and career paths for Traditional Owner groups in areas such as tourism and aquaculture to create the foundations for future upscaling of interventions.

3.2.3 GBR Crown-of-Thorns Starfish control program

Along with tropical cyclones and mass bleaching events, Crown-of-Thorns Starfish (CoTS) remain one of the most significant contributors to loss of hard coral cover across the whole of the Indo-Pacific (Pratchett et al., 2017; Westcott et al., 2020). An adult CoTS consumes about 10 m^2 of coral every year, so major population explosions (outbreaks) can have devastating consequences for coral reefs and these impacts may persist for several years (Miller et al., 2015). Although native to the GBR, they become extremely destructive when their populations boom. CoTS outbreaks are one of the major causes of coral mortality across the whole GBR (Great Barrier Reef Marine Park Authority, 2020a).

The first widely documented CoTS outbreak on the GBR occurred at Green Island in 1962. There have been three major outbreaks since, each lasting for 10-15 years resulting in large declines in coral cover across much of the GBR (Matthews et al., 2024).

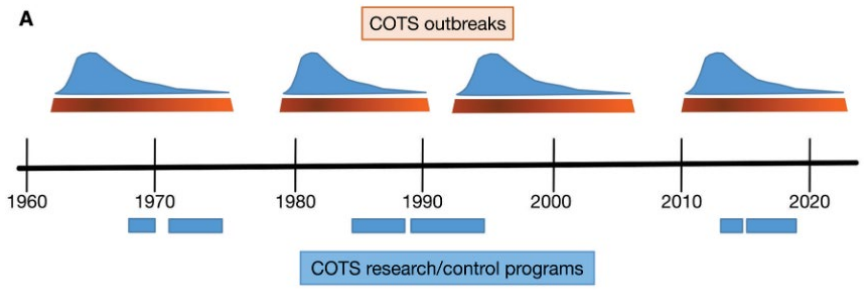


Figure 9: CoTS outbreaks and associated funding programs.

Schematic representation of duration and intensity of CoTS outbreaks and funding programs on the GBR. Curves above the timeline denote relative total population size of CoTS during each outbreak (but not between outbreaks), while shaded orange bars represent duration and intensity of outbreaks. Blue bars below the line indicate the duration of funding programs listed above (Babcock et al., 2020).

Management interventions to suppress or contain CoTS have evolved over each outbreak, mostly focusing on manual removal of individual animals (Babcock et al., 2020; Matthews et al., 2024; Pratchett et al., 2017). The first systematic, dedicated CoTS Control Program began in 2002 in response to the third major outbreak. This labour intensive but effective process involved GBR managers, tourism operators, researchers and others injecting each CoTS several times with a lethal injection of sodium bisulphate at high value tourism sites. By 2012, with the prediction of an imminent fourth outbreak, the CoTS control program was reactivated with increased resources,

leading to the development of highly effective ‘single shot’ injections (of either ox bile or vinegar) enabling a much larger scale of operations.

Long-term funding (from 2022-2030) secured through the Australian Government’s commitment to protecting the GBR means that large scale CoTS control is now a core priority for the Reef 2050 Plan and the Reef Authority’s Blueprint for Resilience 2030 (Matthews et al., 2024). The funding has augmented the capacity of Program partners including contractors and vessel crew to conduct CoTS control activities safely and efficiently. It has also enabled the Program to grow beyond the protection of high value tourism sites to contain regional scale outbreaks in line with objectives of the CoTS Strategic Management Framework. For example, long-term funding enables the annual process of identifying and targeting priority reefs at risk from CoTS. Program partners and contractors work together at the selected sites to ensure coral growth outpaces levels of CoTS predation. Although it may not be possible to prevent new outbreaks, long-term funding for the CoTS Control Program provides on-going sustained efforts to stop the progression of outbreaks, and significantly reduces coral predation (Matthews et al., 2024). The CoTS Control Program is critically important to reef health, as it significantly reduces coral mortality, which in turn improves the capacity of the GBR to cope with additional stressors such as declining water quality and the impacts of climate change (Matthews et al., 2024; Pratchett et al., 2017)

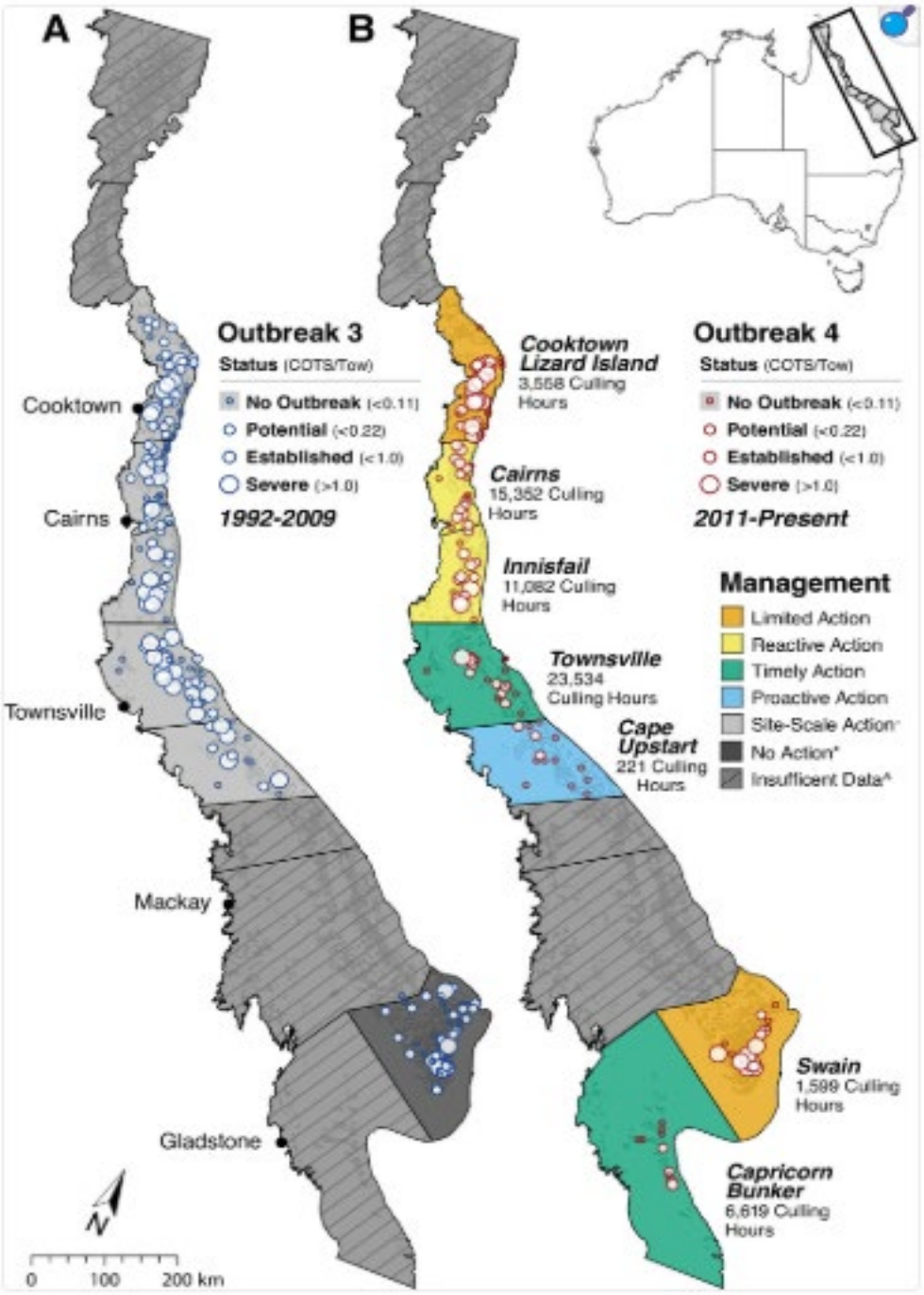


Figure 10: CoTS outbreaks, spatial extent and management action.

Maximum CoTS density and the corresponding outbreak category at each reef during the 3rd outbreak wave (A) (1992–2009) and the 4th outbreak wave (B) (2011-Present) at Long Term Monitoring Program (LTMP) reefs. Sector-scale colour coding depicts the management action taken during the 4th outbreak wave with the number of culling hours (total of all cull divers bottom time) listed below the sector labels. + Site-Scale Action refers to CoTS culling conducted at high-value tourism sites during the 3rd outbreak wave, which had no discernible impact on sectoral level outbreak dynamics. * No Action refers to sectors where no control was implemented. ^Insufficient Data reflects sectors where time series data was insufficient to determine Outbreak periods or no distinct outbreak wave was observed (Matthews et al., 2024).

Key lessons

- Long-term funding is critical to maintain sustained efforts to suppress outbreaks and to enable the annual process of identifying and targeting priority reefs at risk from CoTS.
- A commitment to strong partnerships and ongoing management are vital for successful large-scale intervention programs: The Program is a good example of a successful, labour intensive process coordinated across large areas of the GBR that is delivered through strong partnerships between management agencies, Traditional Owners, tourism operators, researchers and volunteers. Through persistent efforts over many years, CoTS control is now a core management priority for the Reef 2050 Plan and GBRMP managers.

3.2.4 GBR Island habitat restoration

3.2.4.1 Lady Elliott Island

Lady Elliot Island (LEI) is a Commonwealth coral cay within the Capricorn-Bunker group of islands and reefs, and is the GBR's most southern island (Rae & Carter, 2007). LEI is managed as a GBR Commonwealth island. This is enacted through *The Great Barrier Reef Intergovernmental Agreement*, which ensures the continuation of the Australian and Queensland governments' Reef Joint Field Management Program to manage land and water within the World Heritage Area. The Intergovernmental Agreement also enables a collaborative lease arrangement for the cooperative management with the island's resort, and for lease arrangements with the Australian Maritime Safety Authority for the management and operation of the island's lighthouse (Great Barrier Reef Marine Park Authority, 2022a).

LEI is a highly modified cay due to decades of destruction from guano mining, feral goats and human occupation leading to the introduction of many exotic plant species (Great Barrier Reef Marine Park Authority, 2020b). The island was mined for guano between 1863 and 1873, resulting in a rocky barren landscape. Regrowth of naturally occurring vegetation was severely curtailed by the presence of goats, introduced to LEI as a food source for stranded sailors (Cooper, 2023; Gash et al., 2013; Rae & Carter, 2007). Active restoration of vegetation began in the late 1960s when a small eco-resort was established on the island (Cooper, 2023; Gash et al., 2013; Rae & Carter, 2007). Today Lady Elliot Island Eco-Resort is a world famous diving destination, renowned for its conservation efforts and is considered to be one of the world's most sustainable examples of marine ecotourism. The focus of the ecotourism business is on active island restoration (Phelan, 2020).

Rehabilitation work on LEI has increased significantly since 2018, with funding from the Great Barrier Reef Foundation (GBRF)'s Reef Islands Initiative bolstering vegetation restoration activities across the island to rehabilitate seabird and turtle nesting habitat (Buck, 2023; Cooper, 2023). The Initiative is delivered in partnership with Lady Elliot Eco-Resort, Queensland Parks and Wildlife Service, the Reef Authority and the University of the Sunshine Coast. Through the Initiative 17.2 hectares has been rehabilitated to date, and efforts are monitored through a *Leaf to Reef* research program, which investigates the island's role as a climate refuge. Findings from this research will help to inform future management of LEI. The Initiative supports the delivery of the Reef 2050 Plan by protecting, rehabilitating and restoring islands and habitats (DCCEEW, 2024).

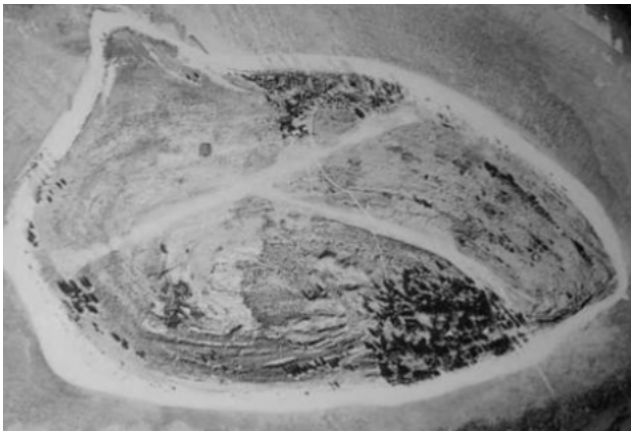


Figure 11: Lady Elliot Island in the 1950s

(SOURCE: Rae & Carter, 2007).

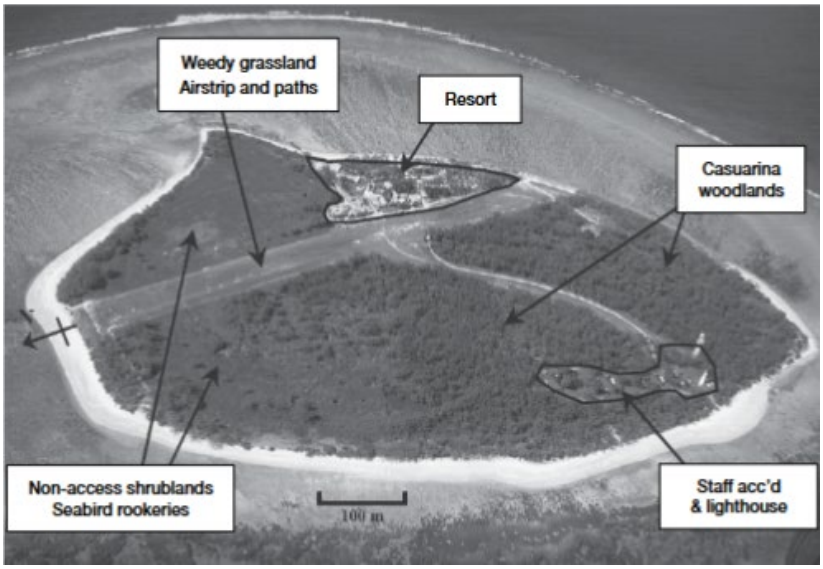


Figure 12: Lady Elliot Island in 2005

(SOURCE: Rae &Carter 2005).

Figure 13: LEI Revegetation Progress 2023

NB: Light blue areas are the current focus of restoration efforts. (SOURCE: Buck, 2023)

Key lessons

- Private investment in conservation, together with active field management enables conservation progress. Evolution from grew from exploitation to active conservation with the development of a small island resort in the 1960s. Conservation enhanced through day-to-day management of the GBRMP, established in 1975.
- Strong partnerships between funders, researchers, managers and resort staff is key to success. GBRF funding since 2018, together with well-established partnerships between JFMP, researchers and resort staff has enabled expansion of conservation and active rehabilitation of island vegetation including seabird and turtle nesting habitat.

3.2.4.2 Raine Island turtle rookery

In the 1890s Raine Island, a northern GBR coral cay of about 27ha, was mined for guano. Today it is managed as a Scientific Zone to protect and conserve its exceptional natural, cultural, ecological and scientific values (Smithers & Dawson, 2023).

For over 1,000 years, green turtles have been nesting on Raine Island – the world's largest green turtle rookery. As many as 60,000 turtles have been known to make the journey in a single season (Queensland Government, 2022). Green turtles are listed as *vulnerable* under Queensland's Nature Conservation Act 1992 and the Commonwealth's Environment Protection and Biodiversity Act, 1999. Internationally, they are classified as *endangered* by the International Union for the Conservation of Nature (IUCN) (Smithers & Dawson, 2023). Since the 1990s there has been a dramatic decline in turtle hatchlings from Raine Island, most likely due to flooding caused by tidal inundation and/or raised water tables (Smithers & Dawson, 2023). These and other changes to the island's geomorphology have also caused many hundreds of adult turtles to die from entrapment in rocky cliffs (Queensland Government, 2022).

Concerns over these population declines led to the Raine Island Recovery Project (RIRP), which aims to protect and restore the island's critical habitats, to ensure the future of key marine species, including green turtles and seabirds. RIRP Phase 1 was established in 2014 as a 5-year $AUS 7.95 million collaborative project involving the Queensland Government, the Reef Authority, the GBRF, BHP and two Traditional Owner groups - the Wuthathi People from Cape York and Meriam Nation (Ugar, Mer, Erub) People from the eastern Torres Strait. These two groups have been visiting Raine Island for thousands of years (Queensland Government, 2022, 2024; Smithers & Dawson, 2023). RIRP Phase 2 is a collaboration between the Queensland Government, the Australian Government

and the two Traditional Owner groups (Queensland Government, 2022). The Project is also supported by James Cook University, Auckland University, the University of Queensland, AIMS, the Department of the Environment and Energy, the Department of the Environment, Tourism, Science and Innovation and Department of Natural Resources and Mines (Queensland Government, 2022).

Since its inception, RIRP partners have worked to shift more than 40,000m^3 of sand, raising it above the tidal inundation zone, and have increased viable nesting habitat from 21% to 79%. The RIRP team have also installed cliff-top fencing at strategic locations around the island to prevent turtles becoming trapped in rocks or falling from cliff edges. These actions have potentially produced as many as 640,000 extra hatchlings, and saved the lives of hundreds (and potentially thousands) of adult turtles. Such deliberate interventions signal a shift from passive conservation to direct action in response to climate change and other major stressors (Queensland Government, 2022, 2024; Smithers & Dawson, 2023).

Key lessons

- A shared vision, reinforced by strong partnerships and active field management, enables conservation progress. The program is characterised by enduring partnerships between state and Commonwealth government agencies, the GBRF (a large NGO), two Traditional Owner groups, volunteers and a large multinational sponsor (BHP).
- Ongoing multi-lateral funding enables long-term planning.
- Intentional move from passive conservation to active intervention can dramatically increase protection for individual species and improve ecosystem health.

3.3 Guiding principles of relevance for reef restoration and adaptation

Key lessons from the case studies described in the previous sections provide valuable insights for researchers, managers and practitioners. Together with reviewed literature, they have contributed to the development of guiding principles for GBR reef restoration and adaptation initiatives.

Section 3.3 covers a wide range of literature including peer reviewed journal articles on collaborative governance; ocean governance; ecological restoration; principles for restoring biodiversity; and GBR governance. It also includes a desk top study of guidelines presented in national and international conventions, government plans, strategies, agreements, policy documents and official websites.

3.3.1 Global scale governance principles

3.3.1.1 Kunming-Montreal Global Biodiversity Framework

The Kunming-Montreal Global Biodiversity Framework (KMGBF) comprises four goals and 23 targets to identify options/pathways for maintaining biodiversity across the globe. The document urges government and other enabling organisations to foster '*full and effective contributions*' (CBC, 2022, p.2) by all sections of civil society including private and financial entities and other stakeholders and Traditional Owners in achieving these goals and targets (CBD, 2022). In essence, the goals and targets together with supporting annexes provide guiding principles for governance of conservation, restoration and sustainable use of biodiversity at a global scale (CBD, 2022; Hughes & Grumbine, 2023). Four KMGBF targets are of particular significance for GBR restoration and adaptation interventions:

TARGET 2 Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and marine and coastal ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity (CBD, 2022, p.9).

TARGET 3 Ensure and enable that by 2030 at least 30 per cent of terrestrial and inland water areas, and of marine and coastal areas, especially areas of particular importance for biodiversity and

ecosystem functions and services, are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean, while ensuring that any sustainable use, where appropriate in such areas, is fully consistent with conservation outcomes, recognizing and respecting the rights of indigenous peoples and local communities, including over their traditional territories (CBD, 2022, p.9).

TARGET 8 Minimize the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions, including through nature-based solutions and/or ecosystem-based approaches, while minimizing negative and fostering positive impacts of climate action on biodiversity (CBD, 2022, p.10).

TARGET 11 Restore, maintain and enhance nature's contributions to people, including ecosystem functions and services, such as the regulation of air, water and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature (CBD, 2022, p.10).

3.3.1.2 Ocean Governance

Thirteen principles were developed to *'strategically and critically connect transformative ocean research to transformative ocean governance, as a basis for developing and nurturing the 'partnerships' for 'scaling up ocean action based on science and innovation' for Sustainable Development Goal (SDG) 14 (Life Below Water)* (Lombard et al., 2023). The principles were designed to support the implementation of current and future ocean governance policies and practices, while at the same time enabling diverse actors to work together to navigate potential barriers and achieve mutual benefits (Lombard et al., 2023). The principles, described next, are not mutually exclusive.

Transformative ocean governance…

…maintains and restores biological diversity, which is key for resilient ocean ecosystems. Biological diversity is critical for ecosystem structure, function and productivity, which underpin the ecosystem services that are essential for healthy societies.

…upholds human rights approaches, which are essential for human well-being. Responsible agencies overseeing activities in the marine environment should implement public participation processes together with social impact assessments prior to commencement to ensure that no human rights infringements arise.

…adopts social-ecological systems approaches. Ocean governance needs to recognise complex linkages between social and environmental components of the system, so as to better understand consequences of changes in the system.

…integrates cross-sectoral policies to achieve social and ecological connectivity. Governance and information exchange is coordinated and integrated across international boundaries and land–sea boundaries.

…uses simple, robust and diverse metrics of social-ecological systems status. Metrics can support accountability, effective reporting and learning, and can be used for evidence-based decision-making and scenario planning.

…requires inclusive and transparent Integrated Ocean Management (IOM) processes. Management processes at all levels need to avoid silo-based decision-making and instead strive for integrated, dynamic, inclusive and adaptive approaches that operate in transparent frameworks.

…coordinates engagement between ocean businesses and other diverse ocean stakeholders. Coordinated, transparent engagement with stakeholders and rights holders is needed to address impacts of businesses on oceans and societies and to promote positive outcomes for both.

…encourages diverse incentives to promote and enable sustainable ocean-use practices. Rigorously designed, functionally integrated and diverse incentives can help ensure that sectors are managed and governed appropriately.

…promotes sustainable and inclusive technological and other innovation. Technological innovation needs to be codeveloped with end users and affected stakeholders and rights holders.

…leverages international mechanisms that support inclusive decision-making for sustainable development. This is especially critical in places where national priorities lag behind international obligations on marine biodiversity, the protection of the marine environment and human rights.

…advocates for dynamic, inclusive and adaptive approaches to governance. Enables respectful integration and inclusion of multiple knowledges including Indigenous and local knowledge for timely responses to shifts in ocean systems.

…requires appropriate responses to existing and potential power dynamics. Power issues can create barriers which impede transformative approaches to ocean governance.

…requires urgent action across governance levels. The demand for ocean resources and services has increased and at the same time, cumulative impacts on the ocean have amplified. The resulting rapid deterioration of ocean health requires urgent action to prevent further ecosystem health decline for both the ocean and all who depend on it (Lombard et al., 2023).

3.3.1.3 IUCN Natural Resource Governance Framework

The following ten principles articulate elements of good governance and underpin the IUCN's Natural Resource Governance Framework (Springer et al., 2021). By seeking good governance in conservation, the IUCN argue that prospects for nature will improve through more effective management of protected areas, and benefits will also accrue to people (Borrini et al., 2013). The ten principles are designed to be broad and flexible and contain elements that can be assessed to highlight the strengths and weaknesses of a governance system, approach or intervention. They were developed to:

- Draw upon existing knowledge and experience;
- Consider other governance principles used by IUCN;
- Integrate on-ground experience and perspectives of diverse rights-holders and stakeholders;
- Provide a basis for assessment;
- Be sufficiently broad to ensure relevance in multiple contexts; and
- Be comprehensive without being duplicative (Springer et al., 2021).

Principle 1: Inclusive decision-making. Decision-making regarding natural resource policies and practices is based on the full and effective participation of all relevant actors, with particular attention to the voice and inclusion of rights-holders and groups at risk of marginalisation

Principle 2: Recognition and respect for tenure rights. Rights to lands, resources and waters are recognised and respected, with particular attention to the customary, collective rights of Indigenous peoples and local communities, and to women's tenure rights.

Principle 3: Recognition of and respect for diverse cultures, knowledge and institutions. Natural resource governance is grounded in sound and diverse forms of knowledge and respect for diverse cultures, values and practices.

Principle 4: Devolution. Decisions are taken at the lowest possible level appropriate to the social and ecological systems being governed, with particular attention to empowering the roles and authority of Indigenous peoples and local communities in natural resource governance.

Principle 5: Strategic vision, direction and learning. Natural resource governance is guided by an overall vision of desired environmental and social outcomes, and allows for adaptation in response to learning and changing conditions.

Principle 6: Coordination and coherence. Actors involved in or affecting natural resource governance coordinate around a coherent set of strategies and management practices.

Principle 7: Sustainable and equitably shared resources. Actors responsible for natural resources have the means necessary to carry out sustainable management and governance activities, including from the equitable sharing of benefits generated from natural resources.

Principle 8: Accountability. Actors responsible for or affecting natural resource governance are accountable for their actions and the environmental and social impacts they produce.

Principle 9: Fair and effective rule of law. Natural resource-related laws and their application are fair and effective and protect fundamental rights.

Principle 10: Access to justice and conflict resolution. People are able to seek and obtain remedies for grievances and resolve conflicts regarding land and natural resources (Springer et al., 2021).

3.3.1.4 UN Decade on Ecosystem Restoration 2021-2030

Partners for the *United Nations Decade on Ecosystem Restoration 2021–2030* developed ten principles for ecosystem restoration to create a shared vision and optimise the best possible outcomes for nature conservation and people:

1. Contributes to the UN SD goals and the goals of the Rio Conventions.
2. Promotes inclusivity and participatory governance, social fairness and equity from the start and continues throughout the process and outcomes.
3. Includes a continuum of restorative activities.
4. Aims to achieve highest level of recovery for biodiversity, ecosystem health and integrity and human well-being.
5. Addresses the direct and indirect causes of ecosystem degradation.
6. Incorporates all types of knowledge and promotes their exchange and integration throughout the process.
7. Based on well-defined short, medium and long-term ecological, cultural and socioeconomic objectives and goals.
8. Tailored to the local ecological, socioeconomic and cultural contexts while considering the larger landscape or seascape.
9. Includes monitoring, evaluation and adaptive management throughout and beyond the lifetime of the project or programme.
10. Enabled by policies and measures that promote its long-term progress, fostering replication and scaling up (FAO, SER & IUCN CEM., 2023).

3.3.2 National scale governance principles

3.3.2.1 Blueprint to Repair Australia's Landscapes

The Wentworth Group of Concerned Scientists recently produced a technical report *Blueprint to Repair Australia's Landscapes* which states the case for a national investment in ecological

restoration to ensure a healthy, productive and resilient Australia. Underpinning the proposed actions and objectives outlined in the report are a number of guiding principles:

1. Significant and measurable benefit
2. Systematic
3. Practical
4. Evidence-based
5. Additional and complementary to current efforts
6. Nation-wide scale
7. Integrated with Indigenous people and knowledge (Wentworth Group of Concerned Scientists, 2024)

3.3.2.2 Principles for partnering with Indigenous Australians

GBR Traditional Owners have inherent rights including full and fair participation in any processes, projects and activities that may impact on them, as articulated in the United Nations Declaration on the Rights of Indigenous Peoples (AIATSIS, 2012, 2020). As such, they are not stakeholders but rights holders, and their participation is pivotal to successful social, cultural and ecological outcomes of GBR reef restoration and adaptation interventions. The following two sets of principles of relevance at a national scale are presented next. Other processes for successful partnering with GBR Traditional Owners are mentioned throughout this report.

AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research

The AIATSIS code of ethics is underpinned by four overarching principles: Indigenous self-determination; Indigenous leadership; impact and value; and sustainability and accountability. These principles create a framework of responsibilities for researchers and others when conducting Aboriginal and Torres Strait Islander research, as depicted in Figure 13. Importantly, the AIMS Indigenous Partnerships Plan (AIMS IPP) is underpinned by the these principles of ethical (Evans-Illidge et al., 2020).

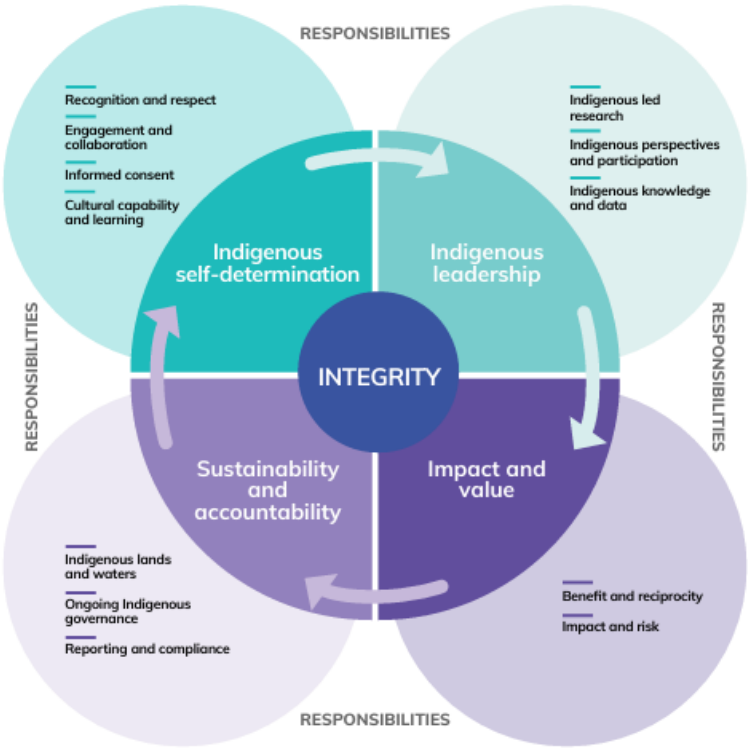


Figure 14: The AIATSIS research ethics framework

(SOURCE: AIATSIS, 2020)

Core principles for synthetic biology scientists to consider when partnering with Aboriginal and Torres Strait Islander peoples in Australia

Australia's CSIRO has a strong commitment to create Indigenous-driven science solutions that support sustainable futures for Indigenous peoples, cultures and Country. This has led to the development of core principles for partnering with Indigenous Australians to enable their valuable contributions to novel scientific research (Wissing et al., 2025).

1. **Relationships**
- Identify appropriate Aboriginal and(/or) Torres Strait Islander partners, participants and wider communities
- Face-to-face interactions matter
- Build in flexibility and adaptability
- Determine partnership details
- Consider oversight and governance structures
- Determine roles and responsibilities (which may change over the project)

2. **Respect**
- Create two-way knowledge sharing and learning
- Ensure Free, Prior and Informed Consent (FPIC)
- Clarify and be transparent about risks and benefits: manage expectations as an obligation
- Respect 'no'
- Respect and protect Indigenous Cultural and Intellectual Property (ICIP)
- Factor in payment for time

3. **Opportunities**
- Align with Indigenous determined values and priorities

- Consider younger and future generations
- Reflect on, and measure, opportunities in culturally considered ways
- Share information back to communities (in ways useful to communities)
- Make time and space to (re)learn (Wissing et al., 2025).

3.3.2.3 Principles for Australian coastal and marine landscape scale restoration

A national scale program of engagement with restoration practitioners, decision makers, industry, researchers, community groups, and Indigenous groups in Australia on landscape scale coastal and marine restoration efforts revealed ten guiding principles that were consistently applied across a range of landscapes.

1. Co-design is central
2. Fit-for purpose governance
3. No-gap funding
4. Access to social, economic and biophysical data
5. Evidence-based and transparent decision making
6. Restoration is coordinated and at scale
7. Robust monitoring, evaluation and reporting
8. Clear strategy to adapt to climate change
9. Nature-based solutions are implemented
10. Knowledge is shared effectively (Saunders et al., 2024)

3.3.3 Ecosystem scale governance principles

Reviewed literature on the restoration of coastal and marine ecosystems around the world revealed that ecologically resilient and socially-just restoration initiatives are typically underpinned by ten golden rules or best practice governance principles. These governance principles are universal across marine and terrestrial ecosystems (Di Sacco et al., 2021) including seagrasses (Unsworth et al., 2024) and coral reefs (Quigley et al., 2022), with only slight modifications needed to accommodate ecosystem peculiarities.

1. **Prioritise conservation before restoration** – restoration efforts are often costly, labour-intensive and outcome-uncertain. Consequently, it is important to first focus on the natural resilience and recovery of ecosystems through management actions that directly or indirectly remove the acute and chronic pressures on them. Such measures include the implementation of sanctuaries and no-take reserves and regulations promoting low-impact livelihoods, tourism and fisheries practices. Improving the connectivity between fragmented habitats can also boost 'natural regeneration pathways', thereby using existing natural capital to facilitate ecosystem self-revival (Quigley et al., 2022, p. 4).
2. **Develop collaborations and partnerships** – collaborations between restoration teams and ecosystem rights holders and stakeholders from diverse sectors such as industry, government, civil, society and community, can build environmental awareness, social buy-in and regulatory support for restoration. Additionally, partnerships with communities as citizen scientists and volunteers can improve local-area knowledge, expertise, and capacity; enhance restoration outreach and outcomes and ensure equitable benefit sharing (Quigley et al., 2022; Unsworth et al., 2024).
3. **Adopt a holistic ecosystem approach** – focusing on achieving successful outcomes for the entire ecosystem, rather than just one species or habitat, can help to preserve and maximise any vital environmental, social and economic services that are preexisting within an ecosystem. Adopting a holistic ecosystems approach can also help restoration projects minimise the risks of

stakeholder conflicts and project failure (Orth et al., 2020b; Quigley et al., 2022; Unsworth et al., 2024).

4. **Select suitable sites** – as site selection metrics from successful restoration projects around the world are only generalisations, site selection decisions must consider local and rights holder knowledge and concerns, including historical knowledge and data (Katwijk et al., 2015).
5. **Select the best methods** – as there are no one-size-fits-all restoration methods, both tried-and-tested and novel techniques must be critically assessed for their applicability to each ecosystem. Additionally, it is vital to clearly understand the efficacy, cost effectiveness, scalability and long-term impacts of different methods, including whether conservation rather than restoration is a better approach in an ecosystem (Orth et al., 2020b; Tan et al., 2020a).
6. **Future-proof restoration efforts** – restoration strategies must be adaptive. That is, they must account for and enable ecosystems and communities to adapt to the anticipated further impacts of climate change. Adaptive strategies include the removal of existing anthropogenic pressures, improvement of ecosystemic genetic diversity and the establishment of resilient social and ecological structures to support ecosystem survival (Govers et al., 2022; Quigley et al., 2022; Unsworth et al., 2024).
7. **Maximise restoration opportunities** – restoration actions must occur at multiple scales to maximise the ecological functionality and benefits. For example, complementary measures to reconnect anthropogenically or naturally fragmented habitats can enhance ecosystem restoration. Habitat continuity improves genetic flows and diversity, thereby strengthening ecosystem resilience and regenerative capacity (Di Sacco et al., 2021; Unsworth et al., 2024)
8. **Plan thoroughly and strategically** – strategic plans are vital for project adaptability, risk minimisation and long-term success. For example, a well-planned development phase informed by local data can help establish and mobilise the requisite infrastructure, expertise and legal frameworks to address existing ecosystem pressures and execute restoration. A strategic plan can also facilitate clear timelines and project goals, effective intra-project coordination and fruitful collaborations between restoration proponents and stakeholders (Quigley et al., 2022; Unsworth et al., 2024).
9. **Develop realistic and informed goals and communicate both successes and failures** – to minimise risks and secure public confidence, restoration projects must be adaptive in nature and progress iteratively from small-scale trials to larger, long-term objectives. Firstly, it is essential to develop a tailored monitoring plan with specific goals, deadlines, and benchmarks, and secure the necessary resources and funding for project adjustments. Such an adaptive management approach ensures cost-effectiveness and project scalability, whilst also ensuring accountability and communication about restoration successes and failures. Clear communications about project progress against goals is essential for public trust and successful knowledge transfers (Gibbs et al., 2021; Quigley et al., 2022; Vardi et al., 2021).
10. **Make restoration profitable and attractive to investors** – restoration must be cost-effective, scalable and profitable, and ensure the equitable sharing of benefits amongst rights holders and stakeholders. Initiatives should also leverage partnerships with economists and ecosystem valuators to understand and highlight the monetary value of ecosystems' services. This data can raise awareness about the ecological and socioeconomic costs of ecosystem loss, inform restoration funding decisions, and attract investment from related industries. For example, data on the impacts of reef loss on tourism and fisheries can be used to encourage restoration financing from these sectors (Quigley et al., 2022).

3.3.4 GBR scale governance principles

3.3.4.1 Relevant GBRMP Policies

There are a number of recent policies of relevance to the governance of GBR reef restoration and adaptation initiatives which outline specific principles of relevance to the deployment of interventions on the GBR. Of direct relevance is the bilateral *Policy on Great Barrier Reef Interventions* developed to guide GBR managers on matters related to reef restoration and/or adaptation interventions (Great Barrier Reef Marine Park Authority, 2020c).

In addition, there are three bilateral policy documents approved by the GBR Ministerial Forum and attached to the Reef 2050 Plan. They provide guiding principles for effective implementation of the Reef 2050 Plan (Great Barrier Reef Marine Park Authority, 2023d). The *Good Practice Management for the Great Barrier Reef* policy document outlines foundational considerations for making decisions or undertaking actions that may impact the GBR. The *Net Benefit Policy* and the *Reef 2050 Cumulative Impact Management Policy* complement each other by providing guidance on how to reduce threats and improve GBR resilience in the face of climate change.

One of the most recent (December 2022) GBRMP policies is the *Policy on Co-Management Principles* that reinforces a committed to co-partnership with Traditional Owners to ensure protection of biocultural values and to maintain enduring connections of Traditional Owners to the GBR (Great Barrier Reef Marine Park Authority, 2023c). Principles derived from each policy are presented next.

Policy on Great Barrier Reef Interventions

This policy document reiterates the bilateral position that **effective global emissions reduction** remains the most urgent and critical need for the Great Barrier Reef's future, irrespective of the success of any interventions. It stresses that the main purpose of GBR interventions must be to help **directly support ecosystem** recovery, although GBR managers encourage reef interventions that also provide secondary benefits to Indigenous and **historic heritage, and social, biocultural and economic values** of the GBRMP. Interventions may be done with or by other government agencies, Traditional Owners, researchers, other experts, industries, communities, other organisations and individuals as long as these are approved by GBR management agencies (Great Barrier Reef Marine Park Authority, 2020c). Under this policy, GBR managers will provide strategic guidance and oversight of current and future reef interventions including environmental, ethical, social and cultural considerations, such as:

- **Ensuring collective efforts focus on maximising ecosystem resilience** i.e. Encouraging interventions that: benefit one or more species, habitat or ecological process; minimise harm; do not increase vulnerabilities; repair damage; remove marine debris; or increase adaptability to climate change.
- **Using reference ecosystem sites** in reef intervention research i.e. describing specific ecosystem attributes requiring reinstatement before the restored state can be said to have been achieved.
- **Supporting and encouraging the consideration and involvement of Traditional Owners** in all stages of GBR reef interventions including FPIC for any proposed intervention.
- **Guiding what reef interventions are deployed**, where and when, to maximise conservation outcomes.
- **Setting priority targets** for reef intervention efforts.
- **Considering the ability of species, habitats and the ecosystem to withstand, or recover from, damage.** In instances where recovery to a pre-disturbance condition is not realistic or possible, interventions may focus instead on rehabilitation to meet the needs of species and/or people at a given site.

- **Working with partners** to identify reef interventions with the highest likely positive outcomes for the GBR and all the values connected to it.
- **Reducing uncertainty** around the reef intervention performance, costs and risk.
- **Engaging with risk** to progress reef interventions including considering the social and cultural acceptability, ethics and other trade-offs.
- **Encouraging collaborations, activities and innovation** to develop, trial, demonstrate, improve and, where appropriate, scale-up interventions for potential application across more of the GBR.
- **Adapting management of interventions to respond to new information.**
- Coordinating across existing programs (e.g. Compliance, cots control) to maximise synergies and efficiencies that help the gbr and avoid duplication (great barrier reef marine park authority, 2020c).

Good Practice Management for the Great Barrier Reef
This document is written for all stakeholders and Traditional Owners involved in delivering actions, plans, policies, strategies or programs that may influence GBR health (Great Barrier Reef Marine Park Authority, 2018b). It is shaped by the following principles:

Future-looking, dynamic and adaptive Forecasting tools together with the results of targeted research and monitoring should be used to evaluate the performance of actions and drive continuous improvement, in line with Reef 2050 Integrated Monitoring and Reporting Program (RIMReP) objectives.

Avoidance of impacts is the highest priority Potential actions should be clearly documented as part of an avoid-mitigate-offset hierarchy, along with feasible alternatives, and consideration of how the action could be redesigned to avoid or minimise likely impacts.

Take a systems perspective GBR health is fundamental to maintaining ecological, social, cultural and economic values of the whole system.

Use the best available information from the most appropriate sources This includes scientific and historical data and data from monitoring and modelling activities; Traditional Owner and stakeholder knowledge, observation, expert judgement, citizen science, and peer reviewed literature.

Understand and manage risk Risk-management processes should be integrated into decision-making, using the GBR Outlook Report as a guide to the types and level of risks.

Assess vulnerability and resilience The vulnerability and resilience of the GBR ecosystem should be considered when assessing risk, urgency of action, cost-effectiveness of options, and for engaging and empowering stakeholders.

Promote collaboration and innovation Inclusive approaches based on international best practice should be adopted to facilitate effective stakeholder and Traditional Owner engagement.

Ensure open, transparent governance This is needed to promote intergovernmental alignment and reduce duplication, as well as enable timely and understandable exchanges of information between all involved, while at the same time upholding privacy, security and confidentiality as required.

Monitor, evaluate and report Monitoring and reporting should be consistent with Reef 2050 RIMReP protocols and demonstrate progress towards Reef 2050 outcomes.

Cumulative Impact Management Policy

Adopt a consistent approach to cumulative impact management terminology and methods This includes the adoption of terms listed in this policy document and used in outlook reporting.

Methods for assessing cumulative impacts should reflect recent scientific advances and build on those used in the Great Barrier Reef Region Strategic Assessment Report.

Understand issues of scale, and cause and effect Decisions about cumulative impacts on GBR health should be guided by the Driver Pressures State Impact Response framework (Figure 14). Decisions need to consider:

- Spatial and temporal scales of impacts;
- Cause and effect relationships between drivers, pressures, impacts;
- Identified risks to social, cultural, ecological and economic values;
- Scope of response that is required to adequately address impacts; and
- Available resources.

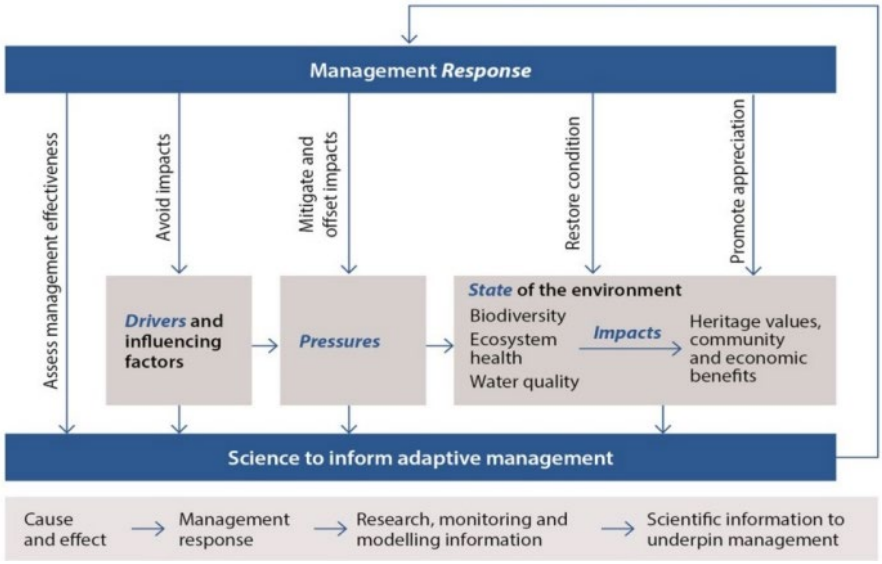


Figure 15: Reef 2050 Plan adaptive management framework

(SOURCE: Great Barrier Reef Marine Park Authority, 2018a).

Assess against desired state, current condition, thresholds and standards If a proposed project or action is likely to have a significant impact on current and/or desired condition of affected values, then the impact assessment will determine the acceptability of a proposed project. Current condition of affected values is determined through five-yearly outlook reporting, and through advice from stakeholders and Traditional Owners. This provides the reference point and context for assessing and managing cumulative impacts. Desired states for these values are stated in the Great Barrier Reef Strategic Assessment Program Report.

Use integrated approaches and a range of management mechanisms Cumulative impacts should be considered at all scales of decision-making. Assessment should consider the broader context for the management of cumulative impacts including the likely consequences of local, national and global decisions that affect GBR planning, programs processes and on-ground actions. Management of impacts should be guided by transparent risk assessment processes to identify the most sustainable and effective options.

Net Benefit Policy

Principles for operationalising net benefit outlined in this policy include:

Identify relevant GBR values Identify specific values (as listed in the policy) that will benefit from a proposed activity.

Seek to understand pressures and impacts affecting values Consider the range of drivers, pressures and impacts potentially affecting values relevant to the proposal.

Consider the scale required to deliver the desired positive outcome i.e.

- Number of drivers and pressures impacting on the values and any interactions
- Cause and effect relationships between drivers, pressures and impacts on values, should be considered together with any irreversible impacts
- Timeliness of actions
- Effects of a changing climate
- Spatial and temporal scale of drivers, pressures and impacts
- Scale at which decisions or actions are required to improve values or processes
- Partner and stakeholder collaboration that can strengthen and facilitate enduring outcomes (Great Barrier Reef Marine Park Authority, 2018c).

Reef Authority's Policy on Co-management Principles
This policy emphasises the Reef Authority's aspiration and commitment to co-management in partnership with Reef Traditional Owners communities (Great Barrier Reef Marine Park Authority, 2023c).

Principle 1 Recognises that Traditional Owners' rights and interests extend beyond those of stakeholders, and respects these in all actions and decisions taken regarding sea Country.

Principle 2 Recognises the Traditional Owner aspiration of co-governance to be delivered through meaningful relationships, partnerships, and empowerment in decision-making.

Principle 3 The Reef Authority will include members of the public, including commercial and non-commercial marine park users in collective co-management arrangements.

Principle 4 Integrating Traditional Owner expertise into GBR management increases protection and conservation of all GBR values and is necessary to enhance GBR resilience under a changing climate.

Principle 5 Co-management requires a place-based approach to Traditional Owner estate boundaries and provides a holistic, joined up approach to co-management of Country.

Principle 6 Recognises and respects the cultural authority, aspirations and diversity of GBR Traditional Owners and commits to working together in a culturally safe and appropriate way, adhering to cultural protocols, best practice, and fit-for-purpose engagement.

Principle 7 Partnerships with Traditional Owners are co-designed, equitable, and transparent. Formal partnership success is predicated by shared risk, decision-making and the management and maintenance of effective, robust, and mutually beneficial relationships.

Principle 8 Recognises that people and Country are connected, and that long-term partnerships are needed to deliver benefits for the GBR and communities (Great Barrier Reef Marine Park Authority, 2023c).

3.3.4.2 Great Barrier Reef Intergovernmental Agreement Guiding Principles

The latest Intergovernmental agreement signed by both Commonwealth and state governments in 2024 recognise several guiding principles with respect to managing the world heritage listed GBRMP.

- Collaborative and cooperative management approach
- Application of the *precautionary principle*

- Focus on supporting resilience and managing threats through localised approaches
- Integrated, ecosystems-based management
- Partnerships with Traditional Owners
- Economic sustainability and the long-term health of the Great Barrier Reef ecosystem are interconnected
- Regular monitoring and reporting of trends in the health, use of and risks to the GBRWHA
- On-going, co-ordinated long-term monitoring and research and data collection and sharing
- On-going access to location specific data and information for use by Traditional Owners
- Collection and governance of Aboriginal and Torres Strait data should be aligned with
- the Framework for Governance of Indigenous Data and the FAIR/CARE Principles.
- Regular, periodic review of the resources necessary for the long-term management of the marine and national parks within the GBRWHA
- Shared funding arrangements for joint Commonwealth-State initiatives agreed on a case-by-case basis
- Encourage the mobilisation of private sector effort and financing including through market mechanisms (Commonwealth Government & Queensland Government, 2024).

3.3.4.3 Reef 2050 Plan Decision-making Principles

The Reef 2050 Plan is underpinned by guidelines to ensure that relevant agreements, policies, plans, strategies and programs support Reef 2050 Plan targets, objectives and outcomes. The guidelines provide decision-makers with steps to take when updating or developing policy instruments or building partnerships (Commonwealth of Australia, 2016). As well, the Reef 2050 Plan includes a set of principles to consider in all decision-making that affects the GBR as follows:

1. **Protecting the Outstanding Universal Value (OUV) of the World Heritage Area** is the prime consideration when planning development and management decisions are made. Economic growth is consistent with protecting OUV. Values and ecological processes in poor condition are restored and values and ecological processes in good condition are maintained.
2. **Basing decisions on the best available science** Decisions are based on the full range of knowledge, including scientific understanding, Traditional Owner and community knowledge. Decisions take into consideration information on current and emerging climate change risks. Management is adaptive and continually improving, informed by monitoring.
3. **Delivering a net benefit to the ecosystem** Decisions are underpinned by the principles of ESD, including the precautionary principle. Impacts are avoided and residual impact mitigated. Offsets are considered only where impacts cannot be avoided or mitigated. Actions to restore ecosystem health and resilience—delivering an overall improvement in GBR health —are fostered.
4. **Adopting a partnership approach to management** Governance arrangements are transparent and accountable. Decisions support opportunities for sustainable economic, social, and cultural activities including traditional use. Management is cooperative and innovative, fostering stewardship and strong community support (Commonwealth of Australia, 2016, 2021).

3.3.4.4 Integrated monitoring of the GBRWHA

Hedge et al., (2017) propose the following principles for integrated monitoring of the GBRWHA. These principles were used to guide the development of the Reef 2050 RIMReP, which evaluates how the Reef 2050 is progressing in relation to its targets and outcomes. Established in 2014, RIMReP informs the Reef Authority's five-yearly Outlook reports (Australian Government & Queensland Government, 2022).

1. Adaptive management of matters of national environmental significance is the primary outcome of integrated monitoring.
2. Collaboration between policymakers, park managers, scientists and data managers is essential.
3. A common language and logic is necessary to facilitate collaboration.
4. Explicit links between monitoring, management and scientific understanding are required.
5. Integrated monitoring needs an effective governance structure that is supported by institutions, does not depend on individuals, and provides ongoing access to essential data streams.
6. Prioritisation of objectives, indicators, programs, etc. is essential and needs to be completed in a transparent manner that can be reviewed and updated.
7. It is better to monitor fewer high priorities well than to monitor many interests poorly.
8. Priorities and decisions need to be well documented and readily accessible, including the data supporting those decisions.
9. Integrated monitoring needs to build on existing infrastructure and processes, recognising that not all existing values will become part of the integrated monitoring program.
10. The integrated monitoring program needs to have a lifespan at least as long as the pressures that it is designed to monitor.
11. The integrated monitoring program needs to be supported by research so that it can adapt to changing pressures, environmental conditions and knowledge.
12. The integrated monitoring program needs to be reviewed on a regular basis (Hedge et al., 2017).

3.3.4.5 Reef 2050 Plan Governance System Framework

Vella et el., (2024) recently developed and tested a framework to evaluate the governance system bounded by the Reef 2050 Plan. The framework comprises four main clusters, each with five descriptive attributes, as shown in Table 3.

Table 3: Key clusters and attributes of the Reef 2050 Plan governance system monitoring framework

Coherence	Connectivity and Capacity	Knowledge	Operational Governance
– Shared vision	– Transparency of processes and trust among actors	– Knowledge quality, availability, and access	– Efforts deliver effective and efficient outcomes
– An integrated legal framework	– Actor capacities and skills	– Informed consent about the use of knowledge	– Sustainability of actions taken
– Aligned, multi-scale and prioritised strategies	– Equity in collaboration and genuine partnerships	– Diversity of knowledge	– Application of risk management
– Cohesive implementation	– Open and diverse communication flows	– Knowledge integration and decision support	– Timeliness of effort taken
– Adaptive MERI systems	– System subsidiarity	– Knowledge storage and management systems	– Adequacy of resources

The four main clusters – coherence, connectivity and capacity, knowledge and operational governance – together with their attributes can be used as guiding principles for the effective governance of reef restoration and adaptation interventions (Vella et al., 2024).

3.3.4.6 Novel reef interventions

The RRAP Regulatory Sub-Program drafted a set of best practice guidelines titled 'Governance Principles for Novel Reef Interventions', which synthesise best practices identified in the literature on reef and marine restoration, and governance of innovation. The guidelines were intended as a preliminary guide, and consist of six principles:

Principle 1: Inclusive participation emphasises the importance of involving all relevant parties, including those with traditional rights, in decision-making. It ensures that diverse perspectives are considered, leading to more inclusive and effective governance.

Principle 2: Flexible, responsive, and adaptive highlights the need for governance that can adapt to changing circumstances. As our understanding of the environment and novel interventions evolves, so too should our approaches to governing it.

Principle 3: Proactive forward-planning advocates for proactive approaches, such as horizon scanning and scenario planning. These help anticipate future changes and prepare accordingly, helping ensure good governance in the face of uncertainty.

Principle 4: Embrace experimentation encourages the testing and evaluation of new interventions under controlled conditions. By doing so, we can better understand their risks, benefits, and impacts, and develop appropriate safety measures.

Principle 5: Nuanced risk assessment calls for a nuanced approach to assessing the risks and benefits of novel reef interventions. Given the high levels of uncertainty involved in some of these interventions, it is important to consider a wide range of potential outcomes and impacts.

Principle 6: Inter-Agency Collaboration stresses the importance of collaboration across different agencies. The complex nature of novel reef intervention governance requires a more collaborative approach (Shumway et al., 2024).

4 Results and discussion

Here we present findings from reviewed literature together with results from the online survey and in-depth interviews. We also present the updated governance mapping of different policies, plan and agreements which revealed the complexity of GBR actors, institutions and policy arrangements involved in reef restoration and adaptation governance in the GBR.

Taken together, these lines of evidence inform the development of five guiding principles for effective governance of GBR restoration and adaptation, and seven potential governance pathways for effective governance of GBR reef restoration and adaptation initiatives.

4.1 On-line survey results

Twenty-eight participants responded to an online survey which was sent to 122 individuals via email on 10 October, 2024. The survey remained open until 30 November, 2024. Participants were selected from the following:

- GBR managers and regulators – e.g. QDPI, Reef Authority, QDESTI, DCCEEW
- RRAP staff – e.g. Members of the Managing Entity; IRRG, Pilot Deployment Sub-Program; ENG Sub-Program
- Traditional Owner representatives e.g. Members of IRAC; GBRF TOAG; GBRF TWG; Qld Indigenous Land and Sea Ranger Program (QILSRP); Traditional Owner Reef 2050 Task Force; AIMS Indigenous Partnerships Group (IPG)
- Community members e.g. LMAC members; members of the RRAP Stakeholder Advisory Group;
- Livelihood stakeholders – e.g. AMPTO members, Commercial fishers.

Most respondents (24) have more than five years of experience in marine and coastal activities and/or ecological restoration. Over half of the respondents (16/28) listed their occupation as 'manager' which included more specific terms such as board member, scientist and manager, managing director, director, retired senior executive, policy manager, reef manager. Six respondents listed their occupation as either researcher or scientist (as distinct from scientist and manager); one was a science communicator; one listed their occupation as aquaculture; one listed reef tourism operator as their main occupation, and three were either environmental consultants or environmental professionals.

Survey participants were presented with ten draft principles drawn from published literature. These are presented in Box 1. Each principle is in bold, with supporting text under each one. NB: These are not prioritised.

Box 1: Ten draft principles for effective governance for reef restoration and adaptation initiatives

Restoration and adaptation activities embrace an ecosystems-based approach

The focus is on protecting the structure, processes and functions of an ecosystem and its component parts. Within the Great Barrier Reef the prime focus is on protecting the Outstanding Universal Value of the Great Barrier Reef World Heritage Area.

Consider the wider social, economic and cultural context of restoration

Restoration promotes inclusive and participatory governance. Social fairness, legitimacy and voice are central in the distribution and consideration of opportunities, benefits and risks.

Co-design with Traditional Owners

Restoration researchers, practitioners and decision-makers effectively engage Traditional Owners and where possible, aim for co-design with Traditional Owners on their sea Country.

Implement effective knowledge integration and decision support

Decisions about restoration are based on the full range of knowledge, including scientific understanding, Traditional Owner knowledge and community knowledge. Decisions draw upon standardised data sets to represent ecological, social and cultural values.

Establish fit-for-purpose, transparent, accountable and adaptive governance

This principle highlights the need for governance that can adapt to changing circumstances, while maintaining transparency and accountability and striving for continuous improvement, informed by monitoring and evaluation.

Ensure proactive, coordinated planning efforts

Wherever possible, planning for reef restoration and adaptation should provide opportunities to: (a) build on and align with existing plans, programs, infrastructure and processes; (b) learn from the past; (c) create options for the future.

Foster cooperation and collaboration

This principle stresses the importance of cooperation and collaboration across different entities including a common language to facilitate communication.

Restoration activities strive for significant and measurable benefit

This principle aims to achieve the highest possible level of biodiversity, ecosystem health and human well-being. It promotes long-term progress, fostering replication and scaling up.

Undertake risk assessment

Emphasises the need to identify, monitor and evaluate potential risks and benefits to the condition and trend of the Great Barrier Reef's values, including ecological, social, economic, cultural, and heritage values. Includes precautionary approach and considers implications of trade-offs. Priorities and decisions will be informed by risk analyses and be well documented and readily accessible.

Build capacity and capability where needed to ensure equitable decision-making between all levels of government and partners.

This principle stresses the need to support capacity-building priorities for stakeholders, rights holders, researchers, reef managers, policy-makers and others involved in reef restoration decision-making.

In the first section of the survey respondents were asked to consider how important each is in relation to governance of reef restoration and adaptation initiatives. A summary of specific responses to each of the draft principles is presented in Table 4.

Table 4: Summary of responses to the ten draft principles for the governance of reef restoration and adaptation interventions

EI = Extremely Important; I = important; U = Unimportant; EU = Extremely unimportant; NS = not sure

	Number of respondents selecting each level of importance					
Draft Principle	**EI**	**I**	**U**	**EU**	**NS**	**Key messages from respondents**
Restoration activities embrace an ecosystems-based approach	22	4	0	0	1	Most agreed that this is extremely important, but could be difficult to implement. There is a realisation among respondents that it may not be possible to save all components of the GBR ecosystem. Some respondents noted that an ecosystems-based approach can help to create decision frameworks for identifying and prioritising actions that provide multiple benefits across interconnected systems. One respondent noted: *There is an important issue that needs to be teased out under this principle - what constitutes the Outstanding Universal Value of the Great Barrier Reef and how it might change as the ecosystem adapts to climate change?*
Establish fit-for-purpose, transparent, accountable and adaptive governance	20	8	0	0	0	This was mostly seen as essential for dealing with rapidly changing circumstances, diverse actors and existing complex governance arrangements for the GBR. Some noted the importance of identifying who is responsible for different aspects of reef restoration and adaptation. Several mentioned the critically important role of transparency in all aspects of governance to build trust and ensure longevity of a broad social license. Adaptive management which could also be strong and robust in the face of uncertainty and 'political whim', was seen as critically important, as reflected in this comment: *The regulatory side of restoration governance needs to provide the head of power for activities to be conducted, while not getting into the detail of the specific interventions being applied. This information should be contained withing schedules which can be amended without the changes to Acts or Regulators or Management plans.*
Undertake risk assessment	19	8	0	0	1	One person suggested combining this principle with the planning principle. Several acknowledged the critically important role of risk assessment and the value of a precautionary approach. Yet there is resistance to not let risk assessment override or delay actions.
Implement effective knowledge integration and decision support	19	7	1	0	1	Most agreed that it is important for governance systems to incorporate and organise diverse knowledge sets within and between disciplines, and that the information be assigned levels of importance relative to objectives. One respondent noted that the process should include clear multiple-objective scenario testing that considers a loss or reduction in several

						values across the Reef. Others commented that restoration and adaptation should be purpose-driven, evidence based, and include 'safe-to-fail' opportunities. Reasons for thinking it is important varied from gaining community support and buy-in; mainstream science doesn't have all the answers; decisions should be based on the best available information from all sources; and TEK backed by science and our understanding of changing climate can give new insights to old and new problems. Some respondents warned against the spread of misinformation and personal opinions masquerading as 'community knowledge'.
Restoration activities strive for significant and measurable benefit	16	11	0	0	1	Most agreed that this was very important but some felt that it would be difficult to achieve at scale and may limit innovation and participation, especially if there is no scope to learn from failure. One suggested re-wording as …*'significant' and 'measurable' may be two different things…just because something is measurable does not mean it is significant. The principle also lacks a 'cost' aspect…at what cost does a benefit become significant.'* Another noted that it is important to recognise the sum of benefits accrued from many small place-based projects as well as those from much larger scale activities.
Ensure proactive, coordinated planning efforts	16	8	0	1	2	Several respondents indicated that the current wording is confusing. Some remarked on the importance of building on, aligning and integrating with existing and past efforts, but only if these are effective. One person reflected: *…'need to take an approach that starts early, and adapts often, asking 'what is the minimum information required to take the next step', rather than seeking perfect information'* An important consideration is scale as stated in this comment: '*…. most restoration efforts to date are small scale using methods that do not select for coral resilience and are not suitable for the scale of restoration proposed by RRAP.'*
Co-design with Traditional Owners	15	9	1	0	3	Overall, there is consensus that this principle is very important, and that '*restorative justice matters'* but needs re-wording and should include a clear definition of 'co-design'. Some felt that it may be better to have a staged for co-design. Several noted that the process would incur additional time and money to do properly, and this could delay interventions. Some also thought it might take the focus away from ecosystem health, although there is an opportunity to draw on TEK and provide potential economic opportunities for TOs. One person commented that re-wording could be along the lines of *'meaningful engagement with Traditional Owners in line with co-design principles'* with a supporting statement that would include something about capacity building for Traditional Owners. Another stated…*co-design should also capture input from stakeholder groups like commercial / collection fisheries and the tourism industry as well as community members with extensive experience with the current and historical state of the Reef.*

Foster cooperation and collaboration	13	14	0	0	1	Most felt that it is important to being all players along on the journey, as long there are no major delays. Several commented on the many existing silos that can lead to inefficient, fragmented efforts. Reasons for silos include competition for funds, lack of communication at senior leadership levels, commercial-in-confidence approaches, institutional rivalries, use of complicated scientific language and jargon, and different objectives for different actors. Others cautioned against 'group think' and taking focus from the main aim of restoring Reef health.
Consider the wider social, economic and cultural context of restoration	13	10	3	0	2	Most considered this principle to be important, but opinions varied about the extent to which the wider context should be considered. Some observed that to be enduring, interventions need to be culturally, economically and socially acceptable, and at the same time enable stakeholders and Traditional Owners to have a voice and consider matters of equity. On the other hand, several noted that the primary concern is Reef health, and that participation may result in decisions based on social or political popularity rather than ecosystem health.
Build capacity and capability where needed to ensure equitable decision-making between all levels of government and partners.	12	11	1	0	2	Some thought this was important but not at the expense of taking action. Others thought it was foundational to good governance, and some suggested regular opportunities for learning new skills and knowledge sharing. Some respondents commented that capacity-building could be incorporated into some of the other principles, rather than be a stand-alone principle. One person remarked: *Of course it is important but how will it be resourced? What are the priorities and what is equitable decision-making noting we do have elected governments?*

When respondents were asked if any of the ten draft principles should be omitted, six said no, while several others suggested that some could be combined and prioritised. The wording was not clear for several of the draft principles. One person suggested that the principle about *strive for significant and measurable benefit* could be omitted and several suggested that it could be re-worded. A few respondents suggested that the principle about building capacity could be re-worded or integrated with other principles. Several suggested careful re-wording of the principle around co-design, as mentioned in Table 4 above. One person suggested that the principle on risk assessment could be removed and risk assessment could be incorporated into a principle on decision-making. Several commented that some principles could be condensed.

Some respondents offered additional principles or supporting text for a principle as follows:

- A principle to acknowledge that reef restoration and adaptation is operating in an environment of significant climate change that will impact the viability of restoration, and that there is a need to also address the underlying causes of reef degradation – i.e. efforts should also be backed by measures to dissolve or reduce the source of stressor and supported by policy changes where possible.
- A principle or supporting text for a clear legal and regulatory framework that is oriented towards positive action to improve reef resilience.

- A principle or supporting text to prioritise natural adaptation and recovery where it may be occurring (i.e. the inherent capacity of the GBR to adapt/recover). This could be part of an ecosystem-based approach or risk assessment principle.

Other broad suggestions were:

- Marine tourism and marine industry should play an important role in any decisions made.
- More transparency is needed around financial investment by environmental outcomes.
- Governance arrangements are needed to support the establishment of a new marine industry (and associated workforce training) to move forward with scalable interventions designed and monitored by science, allowing researchers to move on to the next project to improve interventions even more.
- Governance arrangements need to align with goals of the Reef Blueprint 2030.
- Governance principles need to be cross-checked with attributes of good governance derived from the IMR GBR Governance Project.

According to respondents the most significant governance challenges facing reef restoration and adaptation in the future include:

- Complexity and size of the GBR
- Increasing uncertainty and rapid change due to climate change vs slowness of approvals and other processes
- Inability to influence international action on climate change
- Issues of scale for intervention/deployment including a lack of enabling industries to support large scale deployment
- Poor integration of reef restoration and rehabilitation efforts with broader conservation and development goals
- Current complex and inflexible regulatory environment
- Ethical risks associated with intervention
- Lack of sustained funding and resources
- Investment in emerging options/actions vs existing options.
- Lack of viable interventions
- Misaligned objectives
- Lack of cooperation, transparency and communication among some key actors
- Lack of clear commitment to the principle of collaboration and effective leadership
- Lack of clarity around roles and responsibilities
- Lack of political will
- Balancing whole of Reef ecosystem health and local (high value reefs) restoration
- Lack of a robust governance/legislative framework that allows for timely decision-making on reef restoration interventions

One respondent asked: *Who is going to pay for it? Who is going to manage and deliver it? How will we decide when we need to do it?*

Suggested innovative governance approaches that could improve reef restoration and adaptation outcomes include:

1. **Enable genuine participatory governance arrangements**

- Enable genuine participatory governance and collaborative co-management by governments, community, Traditional Owners and industry, which decentralise management responsibility, allowing for local leadership

- Involve First Nations peoples at the outset
- Enable citizen science practitioners, Traditional Owners, research, government to share knowledge via collaborative spaces/platforms
- Embrace the role of industry and the importance of science working with industry to achieve real in- water results
- Prioritise collaboration; building and maintaining trust; and effective communication among all actors.
- Encourage 'tinkering' by individuals outside research institutes to work on ideas
- Empower stakeholders to deliver in the future
- Community led restoration projects have potential and sustainable as the community feels more involved and responsible if they are inspired.

2. Clarify roles and responsibilities for all involved

- Identify which organisations need to be involved in the overarching future governance of the R, D and Implementation program
- Promote education programs, renewable energy development and responsible stewardship by Marine Parks tourism organisations

3. Develop and implement adaptive yet robust governance arrangements

- Ensure governance arrangements are dynamic, flexible and responsive.
- Implement frameworks that allow flexible decision-making and faster permitting processes
- Clarify what legislation is relevant and what does not need to be referenced
- Senior leadership needs to provide clearer direction
- Build on existing arrangements - i.e. Reef 2050, GBRMP Act 1975
- Develop an agreed regulatory plan e.g. Great Sandy Marine Aquaculture Plan to prioritise different activities in different contexts and to redirect funding dollars from assessment to implementation.

4. Seek long-term sustainable funding

- Implement payment for ecosystem services
- Strive for long-term funding
- Prioritise and maximise investment in what has already been proven to work in sustaining ecosystem function

5. Prioritise research, development and implementation (RDI) efforts

- Prioritise health and longevity of the GBR first.
- Implement clear and factual messaging about research and development (R&D) objectives
- Investigate realistic expected outcomes and scope to generate positive outcomes for reef futures
- Diversify deployment options
- Prioritise agreement on restoration techniques that could be applied at scale
- Prioritise climate neutral research and climate neutral restoration (and measure fuel and GG inputs)
- Establish a coordinated, cooperative R&D program that spans ALL interventions not just COTS and RRAP separately
- Engage with higher levels of risk in current trials (e.g. use of modified corals).

<u>Valuable insights from the respondents include:</u>

'Identifying the scope of a program and determining clear deliverables are key to success. Map everything out in a program logic and benefits map so everyone inside and outside the organisation knows what should be happening. The program manager can then make it happen.'

‘Look at the evolution of fisheries management from top down to co-management. Queensland fisheries strategy is a good starting point for background information. The collection fisheries have had industry led responses to bleaching events for over 2 decades which showcases how the co-management can have positive benefits.’

‘Use the RACI exercise to identify who is responsible for the outcomes will be key to effective future governance. Without it the Reef space will remain congested and often contested limiting the opportunity to focus on and implement key actions to protect ecosystem function that ultimately underpins all other values’.

‘I think a lot could be learnt from the programs and policies that the Wet Tropics WHA have in place. They inherited a WHA that required restoration so they have far more inclusive approaches (protection through partnerships) and practical guidelines (repairing the rainforest) etc. Also there legilsation is built around concepts such as 'integrity' as it informed by the World Heritage Operational Guidelines whereas the GBRMP Act was drafted/enacted in the 70's before it was declared a WHA’.

‘Great Sandy Marine Aquaculture Plan and Queensland Fisheries Strategy are good starting points for background information’.

4.2 In-depth interview results

Twenty-two key informant interviews were undertaken between August 2024 and March 2025. Participants were selected based on their extensive experience in ecological restoration activities; and/or marine and coastal activities. Interviewees were drawn from RRAP, state and Commonwealth management agencies, conservation, industry, NGOs, Traditional Owner organisations and community groups. The purpose of the interviews was to:

(d) Understand stakeholder and Traditional Owner perceptions of governance for reef restoration and adaptation;
(e) Identify barriers and opportunities for effective governance pathways for GBR restoration activities now and in the future;
(f) Gain insights into the viability of a future policy and governance forum for GBR reef restoration and adaptation.

Interviews were all conducted online, using a semi-structured interview schedule and transcribed verbatim. Each transcription was de-identified, and analysis was conducted in accordance with QUT ethics guidelines (See Appendix 2 for interview schedule.)

Initially interviewees were to consider governance arrangements for GBR restoration and adaptation initiatives, and whether the following definition adequately described these arrangements:

…..all of the organisations, processes, policies, plans, agreements and other factors that contribute to who makes decisions and how decisions are made. Effective governance arrangements should maximise opportunities for meaningful collaboration and co-learning among researchers, Traditional Owners and stakeholders, and for successful deployment of restoration and adaptation interventions in the Great Barrier Reef

<u>Responses to the definition of governance</u>

Most respondents agreed that the definition was adequate, although several suggested elements of governance that should be included for reef restoration and adaptation including:

Reporting requirements

- Reporting and evaluation needs to be explicit
- Transparency and accountability must be included
- Needs to adhere to all of the required reporting including climate risk disclosures
- Could include guidelines for how to operate in a low carbon environment.

Stakeholder/rights holder engagement

- Name specific groups (stakeholders/rights holders) so it sounds more inclusive
- Identify the customer/entity who will pay/support restoration and adaptation in the long-term
- The role of markets and market institutions
- Include explicit reference to business opportunities
- Include a sense of ownership, that it is meaningful and people are engaged
- Identify engagement mechanisms including how and at what level engagement is occurring
- Need the right people in the room with clear roles and responsibilities and then a continual process of taking action, learning and revising.

Decision-making

- Context for decision-making e.g. Time frames, legal requirements, relevance, who has a role to play in decision-making and why.
- Consider strategic decision-making for most effective outcome and strategic deployment for most effective outcome
- Identify *when* management needs to change
- Ensure an integrated, coordinated set of activities

There was concern by some interviewees that the definition implies that everyone needs to approve of what's going on, and that this may cause delays in deployment.

Specific comments on what 'good governance' means to different interviewees:

'Effective governance needs to be minimally sufficient and connected – not building isolated forms of governance for specific functions, but a form of governance that isn't duplicative. It is appropriately inclusive and thinks at a system scale, taking an evidence-based approach. '

'From a TO point of view governance is based on LORE and inherent rights and responsibilities to look after and care for country. And then governance can also mean that governmental framework that we have to work in. We acknowledge both systems and take key aspects from both and blend them. Sometimes the paths would overlap and sometimes they'd go off separately.'

'The process of co-learning, co design, understanding each other, developing empathy and then solving the right problem the right way, that is good governance or best practice.'

Responses comparing governance of reef restoration and adaptation initiatives with other types of ecological restoration and adaptation initiatives

Regulatory environment

Some interviewees commented that terrestrial systems can be easier to manage than marine parks as there are fewer stakeholders/rights holders involved in managing a particular parcel of land that has only one type of tenure – e.g. a national park has a less complex regulatory environment than a multiple use marine park. On the other hand, several noted that both marine and terrestrial

restoration involve a wide range of rights holders and stakeholders, if done over a range of jurisdictions.

One person observed that a zoning plan offers a more coordinated and whole of ecosystem approach as opposed to fragmented landscape management across leases, freehold, protected areas etc. From that perspective, terrestrial restoration/adaptation may be difficult to coordinate and implement at large scale but potentially much easier at small scale.

A few interviewees commented on the diverse actors involved in reef restoration/adaptation which increases complexity in terms of governance arrangements. One respondent commented that the 'Wet Tropics' legislation (more recent than GBRMP Act) strongly reflects protection through partnerships. A key focus is rehabilitation reflected in their programs, policies and procedures.

Physical environment
Comments included the observation that both types of restoration/adaptation rely on clear ecological criteria, and that efforts need to consider, and where possible, align the management regime of adjacent landscapes so restoration efforts are not counter-productive. However, some noted that this can be challenging in dynamic, connected marine environments. This characteristic of marine ecosystems can also be challenging for managing restoration/adaptation projects. For example, a few people commented that it is often easier to observe impacts/deterioration on land than in water. Others cited challenges including cost of equipment, boats and other resources, lack of trained personnel and ready access to restoration sites.

<u>Comments on barriers to effective governance for the reef for reef restoration</u>

Comments are summarised under common themes/topics as follows:

Scale
- We don't have tools and processes needed to support large scale restoration
- Need appropriate and effective repair methodologies that are that are scalable.
- Expensive to operate at scale on the water.
- Due to connectivity, something done in one place may affect the whole of the Reef.
- National & international interest can protect the Reef.
- Marine Park management focus is on a strategic comprehensive management paradigm rather than smaller scale adaptation.
- Big unknowns is at what scale a normalized restoration adaptation program actually operate at? Could be very small scale and need to focus on genetic rescue and/or sites of particularly high cultural and economic value.
- Need multiple restorations occurring simultaneously – but the biggest challenge is the coordination of the large amount of project teams.

High turnover of staff in management agencies
- There's a lot of new people who don't have a good handle on Marine Park management or the rules and the legislation, how it all works together.
- Huge turnover of staff makes it very hard to build lasting relationships – made worse by election cycles and departmental re-structures

Clear roles, responsibilities and accountability of organisations & individuals – at spatial & temporal scales
- Need to be careful not to raise expectations about input into decision-making by stakeholders and Traditional Owners

- Need clear plan/processes for decision-making and clear roles and responsibilities at different levels of government and between different parties and over spatial and temporal scales.
- Could be modelled on CoTS program which includes a very direct connection between research, management policy & program deployment – e.g. operational considerations – there is a very clear pathway to impact in trying to protect hard coral and increase Reef resilience. CoTS has clear ecological criteria, and an aspiration to incorporate social and cultural criteria.
- How does reef restoration/adaptation fit within the broader Australian restoration community e.g. oyster reefs, wet tropics? What is the broader role for nation, state and local government agencies and for Traditional Owner organisations?

Shared vision

- Everyone needs to know what they're working towards.
- Need to harmonise decision-making processes with risk assessment and permitting processes - unless they move in the same direction, they'll undermine each other.
- Need processes to ensure all voices are heard – verbally or written.
- Concern over wasting too much time on trying to get perfect engagement/involvement. And in the meantime, we're slowly losing community support. That social license for what we're doing is getting eroded.
- Individuals/groups promoting/changing priorities according to political, financial interests – i.e. conflicts of interest among participants.

Financing mechanisms

- Funding cycles are a big problem.
- Lack of markets – e.g. environmental repair industry – going beyond corals.
- Need to promote the role of environmental assets in broad regional futures and how that connects to livelihoods and other social and cultural values.
- Lack of financial incentives.
- Need clear pathway linking workforce, workforce development and industry emergence – i.e. knowledge to develop and safely employ methods at scale & the financial incentives and markets that are needed to support that.
- Who pays for this beyond government - the Australian taxpayer will only pay for this for so long.

Need to break down silos

- Organisations tend to work in isolation.
- Individuals and groups not understanding or knowing who's doing what, where, when, how, and at what scale.
- Lots of silos and no effective mechanism to bring them together for a common purpose.

Lack of flexible, timely regulatory environment

- Lack of action/decision-making at a national level on frameworks needed to support restoration/adaptation e.g. Nature Positive legislation; carbon pricing; targets for emissions reduction.
- Permitting is an issue –for on-water deployment and land-based aquaculture facilities.
- Not transitioning away from fossil fuels quickly enough.

Lack of trained workforce

- Even if we have the methods, have we got the workforce to implement them?
- Not much training available for coral harvest/aquaculture.
- Current skills shortage.

Lack of knowledge/understanding, complexity of science

- You can't manage unless you understand values and threats.
- Need good exemplars of what can work and actually feeding that up into the system.
- Reef managers need to adopt a learning posture rather than a knowing posture and welcome a broad range of perspectives.
- A challenge is how to take very complex science and synthesize it into some key statements which are easy for people to digest and understand.
- If you don't interpret the science for them, there is a risk that they will interpret it incorrectly.

Opportunities or benefits resulting from effective governance

One respondent summarised benefits of effective governance as follows:

'Implies enough resources are available; good principles are in place; there is meaningful engagement beyond information exchange; and there is benchmarking against best practice governance including transparency, accessibility'

Other comments about benefits resulting from effective governance are summarised under common themes/topics as follows:

Enhances funding/financing opportunities

- If restoration efforts are well governed and have positive outcomes, you have a greater chance of securing further funds.
- Better understanding of costs.

Enhances opportunities for diverse actors to work together

- Collective decision-making approaches and markets working in concert.
- Enables a collaborative rather than a competitive approach.
- Creates a united front, shared vision and strengthens partnerships.

Enhances economic opportunities and strengthens regional economies

- Can help to create industry development systems.
- Not just about regulatory approvals but also linking to industry development and opportunities for structural change in regional economies.

Builds trust through openness and accountability

- Provides a good foundation to strengthen personal relationships which can then build trust and open doors.
- Promotes openness and transparency through a structured process including performance indicators that are reported against.
- Promotes transparency and participation.
- If you have effective governance arrangements with transparency, accountability, you get the public support for the work you're doing.

Importance for knowledge-building, informed decision-making and targeted actions

- Critical for effective knowledge production systems.
- Provides opportunities to learn and apply strategies/actions from other contexts e.g. fisheries management - resource assessment groups.

- Critically considers information received through formal and informal arrangements – possibly through modelling and decision support and risk assessment processes.
- Provides greater surety that actions are needed, well- considered and beneficial for Reef health.
- Enables robust assessment of real threats and how they may behave at different scales which then guides actions.
- Provides linkages between knowledge creation and mobilising people to act on Reef health.

Applies best practice engagement processes

- Uses best practice engagement processes to enable participants to be partners, not just service providers.
- Engagement and involvement horizontally and vertically to really understand diverse interests, benefits and opportunities – e.g. regional report card partnerships for multi-sectoral conversations.
- Can provide a collective voice for Traditional Owners especially at the whole of GBR scale.

Provides a robust, flexible operating environment

- Better understanding of management levers that are best to pull and when.
- Provides a realistic operating framework – e.g. knowledge about current and future condition of Reef health including changes in structure, function and processes of ecosystems over time.
- Enables better coordination/cooperation between State and Commonwealth entities.
- Enables a balance between top-down and bottom-up involvement.
- Can offer an opportunity to look more holistically at governance interactions between mainstream science projects and Traditional Owner interests more broadly.
- Would need clear Terms of Reference (ToR) agreed to by all participants.

Interviewees were next asked to consider whether a policy and governance forum (defined below) complement and align with reef restoration adaptation activities on the reef.

Policy forums are issue-based intermediary organizations where diverse types of political and societal actors repeatedly interact. Policy forums are important elements of modern governance systems as they allow actors to learn, negotiate, or build trust. They can vary in composition, size, membership logic, and other distinct features.

General reflections on a fit-for-purpose policy forum are summarised here:

- What are you seeking from it - decisions, advice, influence? If it's advice and influence, then it could become a regular standing item on a Reef 2050 Plan RAC agenda. But it has to be a purposeful, timely conversation to be useful – not just a set of briefings.
- Could operate at two levels – strategic (senior executive) and operational.
- Need to know who are the other players you need to be talking to and make sure you have a complimentary policy stance to provide complementarity and consistency,
- Can alert decision-makers of issues, opportunities and challenges that demand actions which may otherwise remain unrecognised.
- A forum that is specifically for reef restoration but can have some interaction with the existing advisory bodies is probably a useful way to go.
- Issues-based is OK, but from a TO perspective, definitely needs to be values-based as well.
- Unless you have those foundations that are really relationship dimensions, then I don't think it would succeed.
- It's needed to make sure that everybody is on the same page - getting the right groups of people around the table would be really useful to elevate actions within different agencies.

- Complexity of reef restoration problems require a variety of perspectives, knowledge and understanding that can be gleaned well-structured, well-focused and well-framed discussions.
- Provides opportunities to build relationships/networks across different organisations which helps facilitate communication and build a common vision for the Reef.
- Great, provided that policymakers are prepared to listen and act on things that have been said.
- Would be important to have Traditional Owners involved because their voice is becoming stronger and harder to ignore.
- Need to have the people who are providing solutions – could include Carbon Market Institute
- Policy forums are good, but you'd have to be very clear about what's negotiable, what's not negotiable.
- Needs good facilitation to stay focussed and have clear goals and meet regularly.
- Risk is that participants may self-censor and don't build the relationships and trust to have really robust policy discussions – may need a reasonably contained group under strict Chatham House rules.
- Structure needs to include vertical (bottom-up and top-down) and horizontal lines of communication.
- Structure needs to be strong enough, inviting enough and accommodating enough for people to feel comfortable, to know that their voices will be heard.
- Policy forum sounds great, but don't let that get in the way of progress and getting some actual stuff happening - how do we balance it with timely action? E.g. must consider risk of not acting versus acting - that context has changed dramatically over the last 10 years. Need to make decisions based on imperfect information.
- Something focused on restoration/adaptation probably needs to be added into the mix.
- Could work with a clearly defined audience, purpose and Terms of Reference.

<u>Benefits of a fit-for-purpose policy forum</u>

One person commented:

'The policy forum space is a sandbox and the governance structure is how to execute a scalable solution with inclusive governance arrangements. Right now, across natural resource restoration is the absence of a sandbox.'

Other comments have been summarised under specific topics/themes as follows:

- Provides opportunities for people to share and explore science, evidence, policy ideas.
- Can help to build inter-agency trust as a safe space for policy discussions.
- Restoration stakeholders/rights holders need a mechanism to influence funders, regulators, managers and policy-makers.
- Can manage risk e.g. social license and provide an avenue for understanding/respecting decision-making processes.
- Provides a space for stakeholders/rights holders to understand all of the options that were explored and to show links between knowledge and selecting and making decisions.
- Stakeholders/rights holders are more likely to accept decisions/outcomes if they are involved in discussions.
- Provides the opportunity to be creative and risk-taking. When decisions need to be made, the broader suite of possibilities have been well considered rather than just doing what has been done before.

<u>Preference to maintain existing structures and processes</u>

One interviewee remarked:

‘I would like to see it (restoration and adaptation) embedded into the existing Reef governance because I think that's the only way it's gonna be effective because we're moving into a future where decision making for managing the Reef cannot be separate to decisions around how we will intervene - it has to just be part of our bread and butter.’

Other comments have been summarised under specific topics/themes as follows:

- The key is how to work with existing organizations and community groups - NOT creating more structures would be really good.
- GBR is characterized by an overabundance of existing policy forums – e.g. advisory committees, LMACs etc – don’t need another one.
- Existing structures should feature in the developing RRAP engagement strategy.
- Already many layers of governance over the Reef at the moment.
- There's many more things that need to be considered on balance or priority.
- Utilise existing structures and arrangements within the GBR governance system – e.g. a policy forum could sit under the intergovernmental agreement.
- Create closer ties between RRAP & RIMReP – or beyond RIMReP to consider what are the most important management needs for the Reef going forward and where.
- Modify existing forums to integrate/normalise restoration/adaptation conversation as core business, and go beyond advisory role.

<u>Suggested alternatives to a policy forum</u>

- At times, working groups could form around specific topics – e.g. climate policy, reef restoration policy – need the right people for each topic.
- Maintain a regular flow of useful communication into policy and management agencies.
- Establish one-on-one relationships and encourage involvement from agencies in particular projects or events.
- Organize ad hoc events, specifically targeting management agencies.
- Develop a portfolio of materials that make it easy for new people entering management agencies to pick up on what RRAP is doing.
- Create more opportunities for collaboration and cooperation.
- Enable individuals/groups to build connections and learn by doing.
- Develop a parallel alliance to the recently formed Wet Tropics Restoration Alliance, recognising that cost of entry into marine restoration is much higher than terrestrial restoration.
- Develop a complimentary policy across all agencies that is built into the Reef 2050 Plan e.g. when the first version of Reef 2050 Plan was produced, a net Benefits Policy and Cumulative Impact Policy were produced at the same time. Can provide buy-in for all management agencies, and be publicly available.
- Identify elements in the system that are currently missing or need augmenting. e.g. there may be need for an occasional space for deeper, more robust dialogue with managers, researchers other stakeholders and TOs, around specific topics – e.g. emerging technologies.
- Need core competencies to facilitate potentially difficult conversations within existing structures/forums – e.g. brokering consensus-building, conflict resolution, scenario development, managing uncertainty, consolidating ideas. Not all conversations would need to be formally recorded so as to create a safe space for potentially robust discussions.
- Work with policy agencies to provide support for the writing of a Green Paper comprising options for a minister to consider positive and negative outcomes from a decision.
- Develop a non-hierarchical ‘community of practice’ where people meet regularly, build trust, strengthen relationship , but can also come and go as they need. Can develop strong collaborative partnerships over time and can create smaller groups based around areas of

interest. Creates space of knowledge exchange and social learning as well as co-design of new activities. A reflexive governance approach.
- Work through governance implications of plausible scenarios with specific groups/agencies.

General comments about clarification of purpose, function, role, scale and timing of restoration/adaptation initiatives within the GBR governance system

There were a lot of reflections about different aspects of effective governance for reef restoration and adaptation and these are summarised as follows:

- How rapidly do we need to change management paradigms around restoration? How hard do we need to go?
- Need clarity about whether it's about R&D or whether it's about intervention e.g. implementing a program of work that will change over time e.g. proven feasible techniques beyond R&D that can be used as a management intervention like CoTS control, then there's a governance need for that. Who leads it and drives it will likely change over time and location.
- Where might restoration/adaptation sit formally? What is its relationship to the Marine Park Authority board or to research? Who are the drivers of needing or wanting it and for what purpose? E.g. is the RRAP unincorporated joint venture equivalent to a Policy Forum?
- Need more clarity on the function and purpose of existing forums. E.g. the Regulators Forum is great to get a group together to have a chat. Those people then deal with issues within their established roles according to statutory management responsibilities and requirements. So there are already good ways of sharing ideas, and maybe it is just about what is the purpose of them as well.
- Reef symposium - good way of discussing and showcasing relevant work
- Need to understand that transition from research through to intervention management changes over time, and different entities are involved at different stages, spatially and temporally.

Some selected quotes about governance in general

'We tend to think of governance arrangements as sometimes cold and functional, but they are essentially people that need to work together, trust each other and build on each other's strengths.'

'I think about how to have influence, and that's different from setting up governance mechanisms which are often designed to make influence diffuse…. I'd want to have influence with key actors who may not have positional power but have performative power.'

'Unless you're forced together, sometimes you don't actually know what the other person is thinking, right? So where there's more opportunities for more touch points, we should do that.'

'So whilst I think a policy forum will work, you need the worker bees and the worker bees need a leader to take what's discussed in the policy forum and turn it into a product which is then steps through every level of the bureaucratic process to result in a decision.'

'….the only way it's really gonna happen in a genuine way is if people actually understand that they need to be part of the solution …. You don't get that just by shouting at them. You don't get that just by publishing a policy.'

'…if we let perfection get in the way of progress, we're gonna be in trouble…. If we bind ourselves to something that is aspirational and perfect, we will miss the boat with making an actual on reef difference.'

4.3 Guiding principles for effective governance of GBR restoration and adaptation interventions

As described previously, ten draft principles were presented in an online survey for feedback, and refined in light of the survey responses. These were further refined into five guiding principles using the results of the in-depth interviews. These five principles operate together to form a framework that can be applied to guide reef restoration and adaptation interventions within the GBRMP at a range of scales from whole-of-Reef to site specific locations.

1. **Embrace an ecosystems-based approach** The focus is on protecting the structure, processes and functions of an ecosystem and its component parts.

This means that effective governance of GBR restoration and adaptation should:

- Protect structure, processes and functions of ecosystems and component parts, within the limitations of accelerating climate change.
- Reduce sources of multiple stressors.
- Prioritise health and longevity of the GBR first and natural adaptation/recovery.
- Agree on restoration techniques that could be applied at scale.
- Invest in what has already been proven to work.
- Wherever feasible, promote climate neutral research/restoration and account for emissions.

2. **Establish fit-for-purpose, transparent, accountable and adaptive governance** This principle highlights the need for governance that can adapt to changing circumstances, while maintaining transparency and accountability and striving for continuous improvement, informed by monitoring and evaluation.

This means that effective governance of GBR restoration and adaptation should:

- Create robust yet flexible governance that can adapt to changing circumstances, while maintaining transparency and accountability.
- Avoid unwieldly governance structures.
- Where possible, identify/clarify roles and responsibilities for each phase of reef restoration/adaptation.
- Implement frameworks that create realistic expectations through certainty; enable flexible decision-making; and generate faster approvals processes.

3. **Governance arrangements are inclusive and participatory; use timely best practice engagement processes and targeted capacity-building; and are sustainable.** To enable full participation, capacity-building priorities need to be identified and implemented where possible.

This means that effective governance of GBR restoration and adaptation should:

- Encourage strong, enduring partnerships based on mutual learning, trust and best practice engagement processes that are cost effective and promote timely two-way flow of critical information.
- Allow for local leadership where possible.
- Involve First Nations peoples at the outset. Work towards co-design with Traditional Owners and stakeholders, while maintaining critical timelines.
- Promote opportunities for appropriate knowledge sharing
- Emphasise cooperation, communication and collaboration across different entities to streamline and amplify efforts.

- Seek long-term funding for investment in resources and regular capacity-building.

4. **Ensure proactive, coordinated planning efforts which include timely risk assessment** Emphasises the need to identify, plan for, monitor and evaluate potential risks and benefits to the condition and trend of the Great Barrier Reef's values, including ecological, social, economic, cultural, and heritage values. Includes precautionary approach and considers implications of trade-offs. Priorities and decisions will be informed by risk analyses and be well documented and readily accessible.

This means that planning for effective governance of GBR restoration and adaptation should:

- Be coordinated across a range of actions for GBR health.
- Build on existing arrangements.
- Strive for continuous improvement, informed by monitoring and evaluation.
- Seek long-term funding and implement payment for ecosystem services.
- Develop a clear regulatory framework focused on positive action to improve reef resilience.
- Be informed by risk analyses; well-documented and readily accessible.
- Encourage innovation and include opportunities to learn from failure – i.e. 'safe to fail' approaches.
- Develop an agreed regulatory plan to prioritise different activities in different contexts and to redirect funding dollars from assessment to implementation.

5. **Actors work together to continue building and implementing effective systems for knowledge integration and decision support.** This principle stresses the importance of making decisions based on the full range of knowledge, including scientific understanding, Traditional Owner knowledge and community knowledge. Decisions draw upon standardised data sets to represent ecological, social and cultural values.

This means that effective governance of GBR restoration and adaptation should:

- Ensure that decision-making is collaborative and evidence-based using the full range of available knowledge where possible.
- Enable citizen science practitioners, Traditional Owners, research, government to share knowledge via collaborative spaces/platforms.
- Embrace industry-science-management collaboration and two-way knowledge sharing.
- Implement and clearly communicate consistent, factual messaging about research and development (R&D) objectives and desired outcomes – needs to be consistent with an achievable work plan and a targeted engagement strategy.
- Provide information to key decision-makers within useful time frames.

4.4 Identifying potential governance pathways

We begin this section with results of the governance mapping exercise, which contributes to the identification of key elements required for each pathway, then describe each of the seven potential governance pathways.

4.4.1 Governance mapping

A database comprising nodes (main elements) and links (connections between nodes) was populated through the results of an online search of government agencies, rights holder organisations, not-for-profit organisations and community groups. Three main nodes were identified- (1) relevant stakeholder/rights holder groups; (2) instruments and engagement

mechanisms; and (3) operational scale (local, state, national, international). Figure 16 shows a static map of links between stakeholders, rights holders and agencies and key plans, policies & engagement mechanisms of relevance to GBR reef restoration and adaptation interventions. The data sets can be manipulated to highlight various relationships between nodes. The links describe the connection between two nodes with key words such as guides, enables, partners and so on. For example a line on the governance map between the Reef Authority and a Local Marine Advisory Group (LMAC) may be described as 'Reef Authority enables LMAC'. In this way, the governance map can highlight different networks and relationships between different actors in the GBR space, and identify which instruments or engagement mechanisms are most appropriate for enabling reef restoration and adaptation activities (Vella et al., 2024).

Figure 16: Stakeholder, Traditional Owners, agencies, key plans, policies & engagement mechanisms of relevance to GBR reef restoration and adaptation interventions

(CREDIT: Map created by N. Abeysinghe, QUT)

The mapping exercise, together with results of the key informant interviews, online surveys and reviewed literature, has resulted in the identification of seven overarching pathways that describe how individuals and organisations might get involved in reef restoration and adaptation over time.

These are:

- Financing pathway
- Knowledge-sharing pathway
- Policy, planning and permissions pathway
- Traditional Owner-driven pathway
- Research-driven pathway
- Industry-driven pathway
- Community-driven pathway

The first two of these pathways (financing and knowledge-sharing) may be viewed as individual pathways, though each are also integral components of each pathway. Together, these pathways can form the basis for GBR reef restoration and adaptation governance arrangements. Some of these pathways already exist, although they may not be clearly visible. As each pathway develops, it would be guided by the five governance principles. Some pathways will (and do already) overlap at certain times and many participants will be involved in more than one pathway at any particular point in time. Roles and responsibilities will change over time and spatially, as circumstances dictate.

However they may be configured, each pathway would need to be augmented by opportunities for participants to explore conflicting views and create plausible options for the future through reflection and discussions with each other, and with Traditional Owners, experts and others (Baresi et al., 2025; Curnock et al., 2024; Lockie et al., 2024; Paxton et al., 2024).

4.4.2 Financing pathway

An important component of decision-making (and hence governance) is about where and how to spend money and how to allocate limited resources fairly (Haldrup, 2020; Sarkki et al., 2017; Wang et al., 2024). With respect to decisions about how to allocate funds for reef restoration and adaptation interventions, there are many challenges including a dearth of knowledge about the costs of scaling up different restoration methods; on-going costs of monitoring of restoration efforts; and frequent under-reporting of the full costs underpinning restoration project feasibility (Bayraktarov et al., 2016, 2019; Kong et al., 2024; Scott et al., 2024).

According to Suggett et al. (2023), restoration effectiveness, governance and financing are all inherently interconnected as shown in Figure 17. Thus financing must be interwoven into each pathway, but may also be a pathway in its own right. A finance-driven pathway has the potential to identify how different sources of funding can be utilised over time and at different spatial scales.

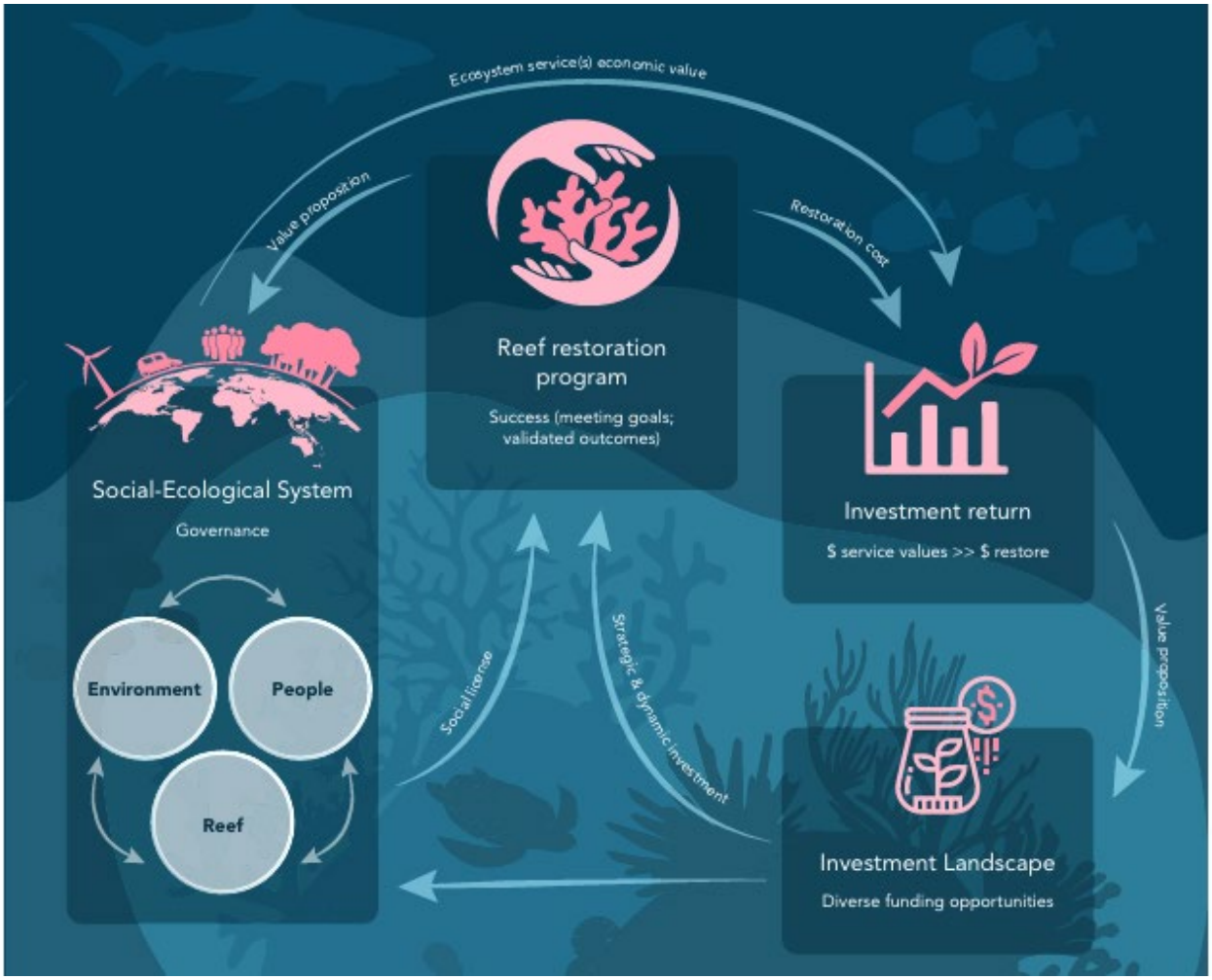


Figure 17: Propositional integrated framework for sustainable reef restoration

(SOURCE: Suggett et al., 2023).

A global study of small-scale, short-term projects on restoring coral reefs, seagrass, mangroves, saltmarshes, and oyster reefs found that the average reported costs for marine coastal habitat restoration were around US$80 000/ha (2010) and US$1 600 000/ha (2010), though the real total costs were likely to be much higher. The study found that restoration of coral reefs and seagrass beds were most expensive, and mangroves forests were least expensive per hectare. However restoration projects involving volunteers were much cheaper than other comparative projects (Bayraktarov et al., 2016). Coral restoration efforts are often more expensive than other types of ecological restoration due to methods requiring labour- and resource-intensive on-water activities – e.g. attaching coral fragments to the reef substrate using chemical adhesives (Howlett et al., 2023). Globally, the average cost of a short-term, small-scale coral restoration project ranges from $6,000 US/ha for the nursery phase of coral gardening to $4,000,000 $/ha for substrate to build an artificial reef (Bayraktarov et al., 2019). Wang et al., (2024) identify three options that could be applied to the long-term financing of restoration and adaptation interventions:

- Green bonds which allow investors to support green projects while earning rewards;
- Cap and trade pricing to incentivise emission reductions and invest in clean technology; and
- Impact investing where cash is allocated to pro-environmental initiatives (Wang et al., 2024).

In Queensland an innovative market-based program called the 'Reef Credit Scheme' provides farmers with additional income and incentives to improve catchment water quality (Queensland Government, 2023b). A reef credit represents a quantifiable volume of pesticide, nutrient or sediment that is prevented from entering the GBR lagoon, which can be sold to those seeking to invest in water quality improvements – i.e. governments or philanthropists (Ecomarkets Australia, 2024). The Reef Credit Scheme represents a tangible way for corporate entities to meet their corporate responsibility charters, and at the same time enables landholders to create and sell reef credits through positive actions to reduce pollutants in waterways flowing to the GBR (Queensland Government, 2023b). The scheme was originally established with financial support from the Queensland Government through the Wet Tropics Major Integrated Project, and in partnership with GreenCollar and NQ Dry Tropics (Queensland Government, 2023b). It is now managed by an independent secretariat, Eco-Markets Australia, who records and maintains the reef credits through a public registry and issues credits once water quality outcomes are achieved and verified. A Technical Advisory Committee acting independently from Eco-Markets provides technical advice on all stages of the scheme's development and implementation (Green Finance Institute, 2024). The program is recognised globally as a trusted high-integrity finance mechanism that has potential to deliver measurable environmental outcomes (Ecomarkets Australia, 2024). To be enduring, this type of 'payment for ecosystem services' requires ongoing investment in developing and building community capacity (Suggett et al., 2023).

In many ways, a trial using novel techniques for coral reef restoration and adaptation shares some characteristics of a startup, which is.. *… a recently founded company (novelty) that possesses no or few assets (small) and is not strategically linked to an established company (independence). Its initial investments cannot yet be compensated by cash inflows and this results in large negative cash flows (negative financial results). The unknown technological, financial, and general development of a startup leads to a high level of uncertainty (uncertainty)* (Bauer et al., 2024, p1373).

Different stages of a startup's life cycle have different requirements. In the early stages, startups require adequate funding, and over time, should start to generate its own revenue. With respect to interventions, the initial research is usually sourced from research grants or philanthropic sources, although NGOs may be able to provide some seed funding to initiate interventions (Gibbs et al., 2024). However, there has been limited exploration of methods to generate ongoing revenue from coral restoration and adaptation interventions. Suggett et al. (2023) provide one suggestion in the form of a community-based coral restoration project on the GBR (the Coral Nurture Program). The Program was initiated in 2018 to build the stewardship capacity of reef tourism operators to maintain and improve hard coral cover at tourism reef sites. Since 2018, the Program has been propagating, out-planting and monitoring corals on local reefs, and building knowledge about the cost-effectiveness of coral out-planting at scale across high-value tourism sites. From this work, Suggett et al., (2023) determined that every $1 spend in coral restoration work could retain up to $10 of tourism value, providing economic stability and motivation to reef tourism operators to remain involved in the reef restoration activities (Suggett et al., 2023).

Summary implications of the financing pathway for reef restoration governance:

- Options for financing must be interwoven into each pathway, but may also be a pathway in its own right.
- Options that could be applied to the long-term financing include green bonds, cap and trade pricing, and impact investing.
- Provides opportunities to consider where and how to spend money and how to allocate limited resources fairly – may be able to identify how different sources of funding can be utilised over time and at different spatial scales.

- Barriers to financing include a dearth of knowledge about the costs of scaling up different restoration methods; on-going costs of monitoring of restoration efforts; and frequent under-reporting of the full costs underpinning restoration project feasibility.
- To be enduring, 'payment for ecosystem services' such as the Queensland government's 'Reef Credit Scheme' requires ongoing investment in developing and building community capacity.
- Reef restoration/adaptation initiatives may be financed as startups, if initial investment can be secured. However the challenge is to secure ongoing revenue from coral restoration and adaptation interventions.
- Partnerships between communities, researchers, practitioners and tourism operators may be able to secure long-term funding at small scale, high value tourism sites, especially if activities lead to measurable and visible improvements in reef health.

4.4.3 Knowledge-sharing pathway

Knowledge-sharing is integral to each pathway but could also be considered a pathway in its own right. The complexities of knowledge-sharing involve interwoven strands that connect all of the current and proposed ways in which knowledge about reef restoration and adaptation is shared – horizontally, vertically and through networks. A knowledge pathway enables diverse individuals and groups to collectively combine their knowledge and learning for a specific action or purpose (van Kerkhoff & Szlezák, 2016). Insights from different knowledge systems may generate contradictory evidence, and this needs careful negotiation to create a rich body of knowledge to inform decisions and identify potential risks and benefits (Tengö et al., 2014).

Opportunities for knowledge sharing within the GBR governance system are many and varied. For example, information from the AIMS Long-Term Monitoring Program (LTMP) about how coral reefs work and what affects their health, is generated annually and is publicly available on the web (Emslie et al., 2020). A comprehensive computer-based platform, *eReefs* is an inter-governmental integrated system of ecological data, models, mapping and decision-support tools that provides information and generates knowledge about the GBR to scientists, managers, industry and local communities (Steven et al., 2019). The Reef Authority's Reef Knowledge System comprises an online data search engine tool, a dashboard, and interactive maps, to provide a wide range of information and knowledge about the GBR (Great Barrier Reef Marine Park Authority, 2022b). Individuals and groups can also access and share information from international sources such as the International Coral Reef Initiative (ICRI)'s Restoration Hub which provides an online centre for all information related to restoration of coral reefs and their related ecosystems (ICRI, 2021).

Aside from these and many other online sources of information, there are myriad opportunities for individuals and groups to share knowledge through existing advisory committees, new or existing communities of practice, alliances, forums or regular get togethers – e.g. an annual or biannual Reef symposium. In some instances, there may be locally-based knowledge hubs or networks where like-minded individuals share knowledge and experience such as the Cairns-Port Reef Douglas Hub, or be modelled on the newly formed Wet Tropics Restoration Alliance based in Cairns (Wet Tropics Restoration Alliance, 2024).

Governance arrangements promoting knowledge-sharing and co-learning by utilising context-specific, diverse knowledge sets is known as 'knowledge co-production', and includes consideration of stakeholders' and rights holders' needs, and their interests and beliefs in relation to an issue or topic (Norström et al., 2020).

A knowledge-sharing pathway can contribute to standardised procedures and protocols for data collection, handling and interpretation. It also recognises that GBR Traditional Owners have complex

knowledge systems and values associated with the GBR, and that they are the experts and primary source of information on these values. A knowledge-sharing pathway respects the rights of Traditional Owners to protected, manage and safeguard their heritage. It should include Traditional Owner-led protocols on how (or if) information about cultural values is stored, accessed, used and shared with researchers, managers and others. The *Safeguarding Indigenous Heritage and Knowledge Project* (the Project) establishes protocols for formalising arrangements with management agencies and other parties for sharing information for improved management practices (Markwell and Associates, 2020). The Project includes a set of protocols, guidelines and an Indigenous Knowledge Sharing Agreement Template together with a set of internationally recognised principles for developing and implementing partnerships and agreements with Traditional Owners. Indigenous Knowledge Sharing Agreements aim to safeguard knowledge that is shared by Traditional Owners. They are created through negotiation with participating partners and help to build relationships that are sustained through trust and mutual respect. Each Agreement establishes negotiated benefits as well as the terms, agreements and processes for sharing knowledge. The agreements also inform RIMReP under the Reef 2050 Plan (Markwell and Associates, 2020). The key steps in developing an Indigenous Knowledge Sharing Agreement is shown in Figure 18 below.

Summary implications of the knowledge-sharing pathway for GBR reef restoration/adaptation governance:

- Knowledge-sharing is integral to each pathway but could also be considered a pathway in its own right.
- A knowledge-sharing pathway enables diverse individuals and groups to collectively combine their knowledge and learning for a specific action or purpose.
- Insights from different knowledge systems may generate contradictory evidence, and this needs careful negotiation to create a rich body of knowledge to inform decisions and identify potential risks and benefits.
- Opportunities for knowledge sharing within the GBR governance system are many and varied including one-way transmission of information via publicly available websites, as well as a range of formal and informal committees operating at local regional and national scales.
- A knowledge-sharing pathway can contribute to standardised procedures and protocols for data collection, handling and interpretation.
- A knowledge-sharing pathway respects the rights of Traditional Owners to protected, manage and safeguard their heritage.

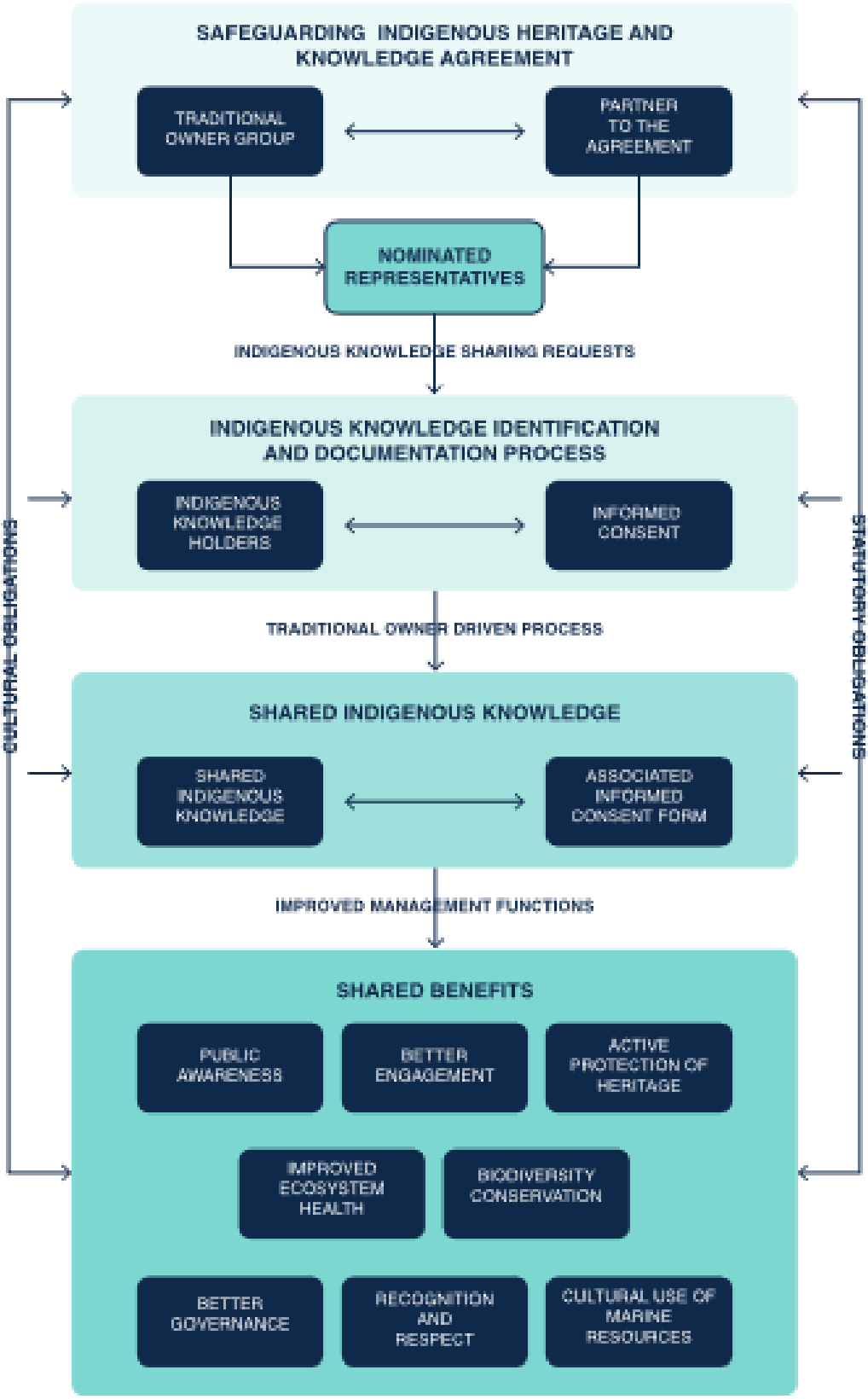


Figure 18: The Safeguarding Indigenous Heritage and Knowledge Agreement process

(SOURCE: Markwell and Associates, 2020)

4.4.4 Policy, planning and permissions pathway

This policy, planning and permissions pathway highlights the need for certainty and clarity in decision-making for all actors involved in reef restoration and adaptation activities in the GBR. Planning needs to be coordinated across a range of prioritised activities; informed by on-going monitoring and evaluation; encourage innovation; include opportunities to learn from failure; be informed by risk analyses; well-documented and readily accessible. Planning for reef restoration/adaptation needs to include opportunities for individuals and groups to monitor, evaluate and if feasible, act on potential risks and benefits to the condition and trend of GBR ecological, social, economic, cultural, and heritage values. A key component of this pathway is the identification of actor roles and responsibilities, as well as openness and accountability of all involved, whenever possible.

In the majority of instances, the regulators and management agencies could take a lead role, together with Traditional Owners where activities encroach upon or affect their sea Country. Alternatively, one key informant suggested governance for reef restoration/adaptation could be modelled on the *Queensland Sustainable Fisheries Strategy 2017–2027* which provides guiding principles for co-management of GBR fisheries between government, industry, Indigenous communities and the broader community. It also sets clear sustainable limits for fish stocks; maintains ten working groups and a Sustainable Fisheries Expert Panel to engage stakeholders; establishes harvest strategies for all fisheries, provides triggers for action and clear decision rules for the actions that will be taken; pilots regionally based fisheries management; and helps facilitate industry-led structural adjustment (Queensland Government, 2023a). This collaborative approach could see different actors and organisations taking lead roles, depending on the purpose of each working group. It maximises opportunities for best practice engagement including deliberation and reflection on social risks associated with proposed activities.

Some interviewees suggested ways of modifying current GBRMP planning instruments to provide certainty over location of proposed interventions – perhaps through the allocation of specific zones for particular types of interventions, that are determined through a deliberative decision-making process involving all interested parties.

With respect to deliberation about new or existing policies for interventions, interviewees generally agreed it would efficient to use existing governance structures such as the Independent Expert Panel (IEP) and the Reef Advisory Committee (RAC) which underpin the Reef 2050 Plan, and which sit within existing bi-lateral arrangements, as shown in Figure 19. The next review of the Reef 2050 Plan could provide a timely opportunity to sharpen the focus of these policy discussions.

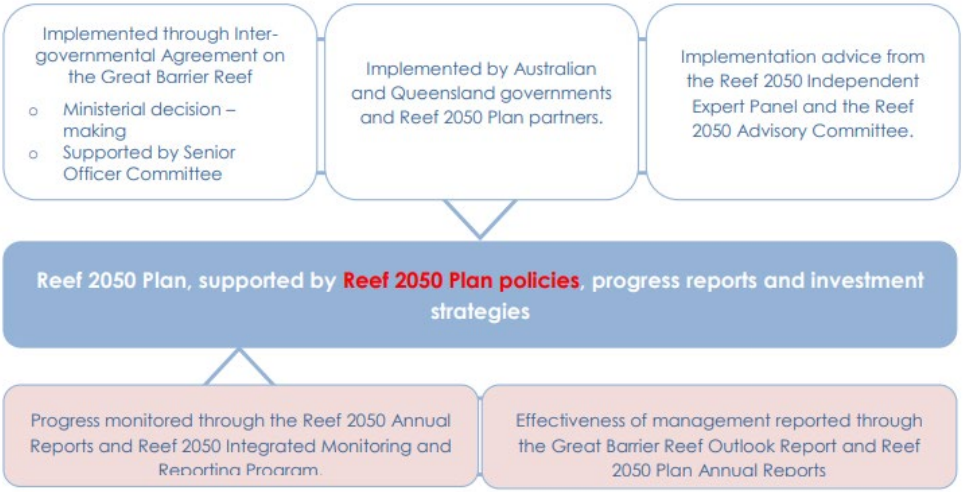


Figure 19: Framework supporting the implementation of the Reef 2050 Plan

(SOURCE: Great Barrier Reef Marine Park Authority, 2018).

When used effectively, the Reef 2050 Plan arrangements ensure that interdepartmental policies and approvals align within and between different government agencies; are reviewed collaboratively; and may be resolved before involving a wider group of stakeholders and Traditional Owners. The arrangements could be broadened to include policy staff in relevant local, state and Commonwealth government agencies to collaborate more closely to update existing policies and develop supporting materials for restoration and adaptation interventions – e.g. guiding principles, 'as-of-right' permissions e.g. for Traditional Owners. Overseeing this broader role could be a strategic policy decision-maker role led by one government agency.

Summary implications of the policy, planning and permissions pathway for reef restoration governance:

- Certainty and clarity around roles and responsibilities is needed for effective planning and decision-making
- Transparency, accountability, monitoring and evaluation is central to good planning
- Risk assessment is central to good planning and involves all who may be affected by potential interventions
- Collaboration and coordination of effort can be enhanced through existing governance structures, or through fit-for-purpose working groups as required.

4.4.5 Traditional Owner-driven pathway

The Traditional Owner-driven pathway can enable Traditional Owners to make decisions about Country and set priorities on where they want to go as a community. Traditional Owner use and custodianship of the GBR and its islands transcends past ice ages as chronicled through ancient rock art sites and related in oral histories (Great Barrier Reef Marine Park Authority, 2017). From a Traditional Owner perspective, governance may be based on traditional lore and customs; inherent rights and responsibilities; and statutory obligations and responsibilities to care for culture, people and Country.

Key informant interview analysis revealed several emerging tools and processes to support GBR Traditional Owner-led governance of restoration. New and emerging arrangements include:

- The Traditional Owner Technical Working Groups (TWGs) established as a Traditional Owner oversight and steering mechanism for RRAP and the CoTS Control Program, funded by the partnership between the Australian Government's Reef Trust and the Great Barrier Reef Foundation (For more information see https://www.ourreefstories.com.au/technical-working-groups/);
- The Traditional Owner *Deadly Reef Environmental Adaptation Murri Scientists (DREAMS) team* supporting RRAP PDP decision-making processes;
- The relatively recent agreement between Traditional Owners and government agencies to establish the ReefTO Taskforce and coordination unit now running since 2024 (see Taskforce | REEFTO).

The last-mentioned arrangement (i.e. the Reef TO Taskforce) grew out of the *Reef 2050 Traditional Owner Implementation Plan* created through analysis of the Reef 2050 Plan actions and what the implications of each are for Traditional Owners. This process also revealed additional actions that are needed from a Traditional Owner perspective to manage sea Country (Reef 2050 Traditional Owner Steering Group, 2020).

In parallel, the Marine Park permit system is beginning to align with Traditional Owner decision-making processes, and the requirement to obtain FPIC before research is undertaken. The requirement for FPIC is now an integral part of AIMS research approvals processes, as the AIMS 2030 Strategy states that projects to be implemented on Sea Country will only proceed with FPIC of the Traditional Owners. Further, the Strategy aims to develop more projects that are co-designed and co-delivered with Traditional Owners (Australian Institute of Marine Science, 2023). Opportunities for co-design and co-delivery have also been provided through TUMRAs. These agreements between Traditional Owners, the Reef Authority and Queensland government enable Traditional Owners to manage activities on their sea Country, and recognise and support the Native Title rights, interests and responsibilities of Traditional Owners (Great Barrier Reef Marine Park Authority, 2024c).

A recent Traditional Owner-led initiative is the development of a Biocultural Framework - a collaborative project between RRAP researchers, GBR Traditional Owners and the AIMS Indigenous Partnership Team. The Framework can help to clarify what kind of partnerships Traditional Owners want to pursue, including those that might lead to new restoration based economies or industries (Baresi et al., 2025; Maclean et al., 2022).

Another recent Traditional Owner-led initiative, the Kul-bul Decision Tree, was created through a project that developed a particular methodology to identify and use biocultural indicators together with existing monitoring programs such as Eye on the Reef and Reef Check to make decisions and recommendations about a particular reef site (Singleton et al., 2023). It comprises five sections - cultural awareness, cultural engagement, biological indicators, natural resilience indicators and site stewardship recommendations. Each section has a set of questions that can be discussed, reflected upon and used to develop a site-specific stewardship plan. As part of the process, Traditional Owners and others can determine whether a reef site may recover after a disturbance, or whether an intervention such as coral predator control, rubble stabilization, coral gardening or coral larval seeding is needed (Singleton et al., 2023). Using the Kul-Bul Decision Tree, site stewardship plans for sites have been created on Hastings, Saxon and Norman Reefs within Yirrganydji Sea Country. Importantly, the Kul-Bul Decision Tree enables non-Traditional Owners to plan for the engagement and inclusion of Traditional Owners in site stewardship projects (Singleton et al., 2023)

A strong collaboration between AIMS, Traditional Owners and GBR managers in the Keppel Group of islands and reefs demonstrate a possible way forward for a Traditional Owner-led governance pathway. The Woppaburra Coral Project depicted in Figure 20 is a co-designed and co-funded collaboration between Traditional Owners, science, and an industry partner who provided a mobile coral aquaculture setup. Through this work, Traditional Owners participated in the design and delivery of the research. The partnership led to a better understanding of costs, benefits, and risks of reef restoration and adaptation at that site (Bay et al., 2023).

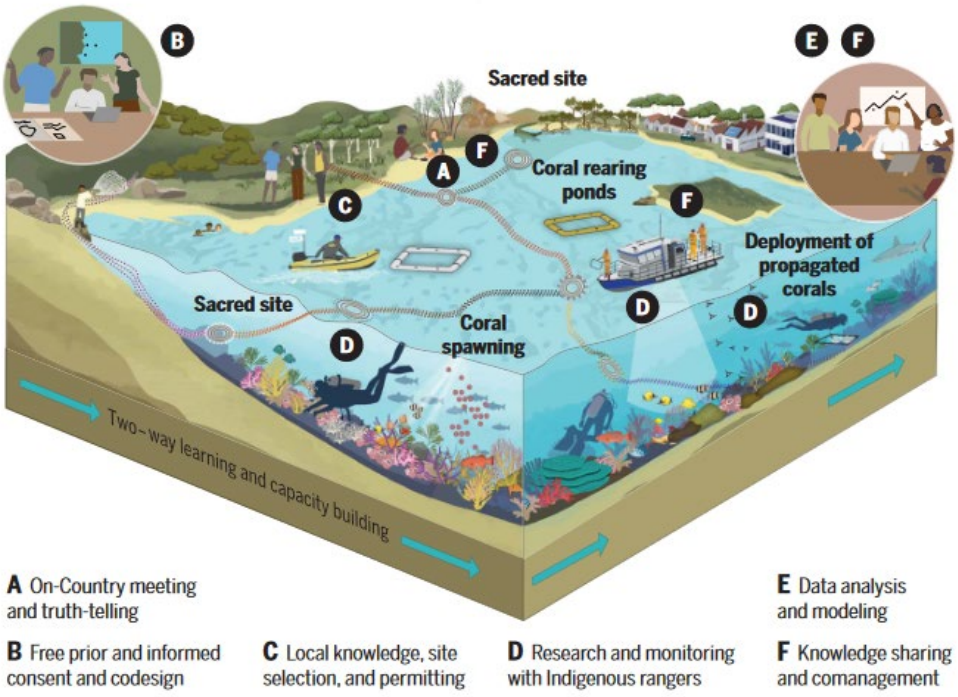


Figure 20: A process that could be used to develop a Traditional Owner-led pathway that involves engagement and collaboration between Traditional Owners, scientists, industry and managers.

(SOURCE: Bay et al., 2023).

A Traditional Owner-driven pathway can implement agreements, partnerships and protocols that benefit Traditional Owners and GBR health. It can be used to identify opportunities for capacity-building, employment opportunities and career paths, as well as options for long-term secure funding of Traditional Owner-led initiatives. It may also establish formalised arrangements and protocols for information sharing; use and access to sea Country; protection of Traditional Owner heritage; and the maintenance of inherent rights (Mandubarra Aboriginal Land and Sea Inc & Regional Advisory and Innovation Network (RAIN) Pty Ltd, 2024).

Summary implications of the Traditional Owner-driven pathway for reef restoration governance:

- Provides opportunities for Traditional Owners to make decisions about Country and set priorities on where they want to go as a community.
- Provides structure and certainty around decision-making.
- Provides opportunities for co-delivery and co-design of restoration/adaptation activities
- Strengthens partnerships between managers, researchers and Traditional Owners

- Provides a deeper understanding of benefits and risks.
- May instigate agreements, partnerships and protocols that benefit Traditional Owners and GBR health.
- May identify opportunities for capacity-building, employment opportunities and career paths.
- May establish formalised arrangements and protocols for information sharing; use and access to sea Country; protection of Traditional Owner heritage; and the maintenance of inherent rights.

4.4.6 Research-driven pathway

This pathway possibly requires one scientific agency/management agency to lead, which would integrate efforts of all scientific agencies (within and beyond RRAP). It could be funded by government and/or non-government sources, or a combination of both. A research-driven pathway aims to ensure all interventions (existing and future) are based on the best-possible science and maximise best possible outcomes for GBR health and ecosystem services, with broad social support. This pathway, initiated and driven by the best available science and would inform where and how interventions are deployed, and at what scale. It would incorporate feedback from ongoing monitoring of R&D programs to continually improve the whole process. As McLeod et al. (2022) point out, many coral restoration projects are still at the stage of trialling novel methods. Most require assessments of cost-effectiveness and scalability, together with risk assessments for social, cultural, economic and ecological values. Further, any research-driven approach needs to include a detailed proposal for how implementation can be sustainably managed into the future.

Coral rubble stabilisation

Coral rubble is produced from the breakdown of dead coral into smaller fragments and sand. This process known as reef erosion, is intensifying in places exposed to extreme weather (e.g. cyclones, severe storms) or direct human activities such as blast fishing (Wolfe et al., 2021). Affected areas can recover, but recovery may be delayed where the coral fragments are unconsolidated and subjected to repeated disturbances, preventing natural cementation and stabilisation processes. This in turn, prevents larval settlement and survivorship of new coral recruits (Ceccarelli et al., 2020; Kenyon et al., 2023; Wolfe et al., 2021). A variety of approaches have been trialled to address the issue e.g. placing rocks over the rubble, or using mesh to stabilise coral fragments, however, there is limited understanding of how such interventions may successfully restore local reefs (Ceccarelli et al., 2020). Newly published guidelines to support decision-making for the application of rubble stabilisation techniques may help fill knowledge gaps by summarising technical information and facilitating knowledge sharing among stakeholders, including practitioners, managers and researchers (RRAP, 2024).

The CoTS Control Program

A research-driven pathway could be modelled on the existing RRAP R&D program (discussed earlier), together with aspects of the CoTS Control Program.

This well-established Program is highly collaborative and involves managers, researchers, marine contractors and the reef tourism industry all working together to undertake reef health surveys, manual culling of starfish and research support (Great Barrier Reef Marine Park Authority, 2023a). The Program targets reefs based on their ecological and economic priorities and to date has prioritised around 500 reefs for CoTS control efforts. Every year, Program partners use the best available, latest information to target between 200-250 of the 500 prioritised reefs to manage CoTS

outbreaks. The prioritisation process is supported by the latest research delivered by the CoTS Control Innovation Program (CCIP) (Great Barrier Reef Marine Park Authority, 2023a).

CCIP is a scientific consortium coordinated by the GBRF and funded initially by the Commonwealth government's Reef Trust Partnership (RTP). The aim is to deliver innovative solutions to predict, manage and respond effectively to CoTS outbreaks. The collaboration involves over 90 scientists and experts within AIMS, CSIRO, JCU and UQ and other research institutions (Fletcher et al., 2021; Great Barrier Reef Foundation, 2024b). CCIP began in 2020 with a Feasibility and Design Phase (2020 – 2021). This phase focused on prioritising and designing a research program by assessing the feasibility (technical, social and regulatory) and benefit (impact) at scale of a range of possible interventions. Six cross-institutional teams were created to represent key research themes for achieving CCIP goals: population control; monitoring and surveillance; decision support and modelling; proximal causes of outbreak; COTS biology and ecology, and social acceptability, regulatory and institutional arrangements. These are shaded blue in Figure 21 below (Fletcher et al., 2021; Sivapalan, 2021).

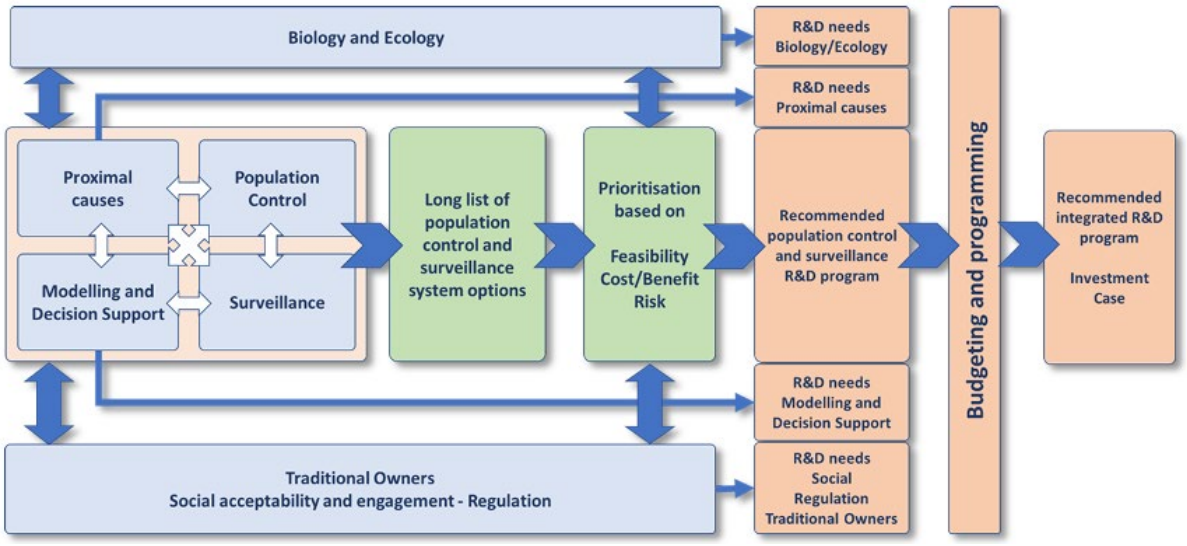


Figure 21: CCIP Feasibility and Design Phase Approach Framework

(SOURCE: Sivapalin, 2021).

Phase 2 of the CCIP is the R&D Program, which implements recommendations of Phase 1, and identifies pathways for trialling and integration of research outcomes into the COTS Control Program (Fletcher et al., 2021). Figure 22 below shows the structure of the CCIP, which comprises a Steering Committee chaired by the GBRF with members derived from the core partner research institutions; a Traditional Owner; a member appointed by RRRC; and observers from the Reef Authority, the Commonwealth government (DCCEEW) and the tourism industry. The Steering Committee provides strategic advice and oversees design and delivery of the program (Fletcher et al., 2021).

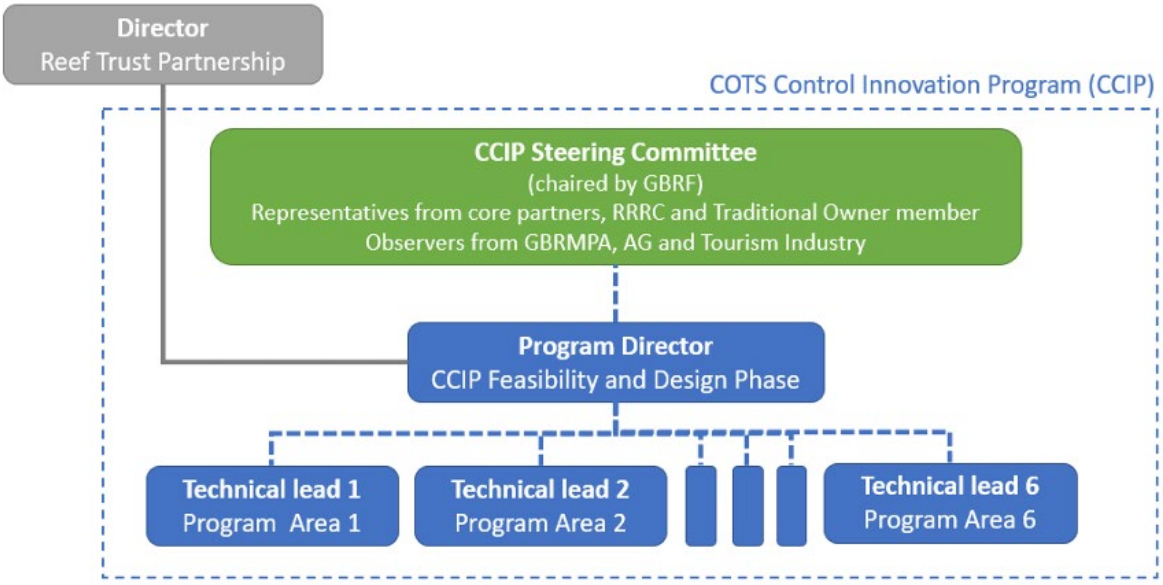


Figure 22: Structure of the CCIP

(SOURCE: Fletcher et al., 2021).

Summary implications of the research-driven pathway for reef restoration governance:

- Possibly requires one scientific agency/management agency to lead, which would integrate efforts of all scientific agencies (within and beyond RRAP).
- Could be funded by government and/or non-government sources, or a combination of both.
- Aims to ensure all interventions (existing and future) are based on the best-possible science and maximise best possible outcomes for GBR health and ecosystem services, with broad social support.
- Would inform where and how interventions are deployed, and at what scale.
- Would incorporate feedback from ongoing monitoring of R&D programs to continually improve the whole process.
- Needs to include a detailed proposal for how implementation can be sustainably managed into the future.
- Participants in this pathway could facilitate knowledge-sharing
- Could be modelled on aspects of the highly collaborative cots Control Program.

4.4.7 Industry-driven pathway

Opportunities for the development of new industries is critical for the scaling up of global reef restoration efforts, which currently lack affordable scalable solutions including off-the-shelf technologies (Roch et al., 2023). Part of the problem is a disconnect between research and development (R&D) and commercialisation and availability of inventions. Understanding the link between science and industry is essential but challenging, as there are often issues related to the coordination of knowledge sharing between the two which is exacerbated by intellectual property (IP) rights; the patenting of new products; and protocols regarding copyright. Further, new IP does not always correlate with practitioner requirements, leading to the development of technologies that may not be fit-for-purpose. A recent global review revealed that only 16 of 194 countries hold patents targeting coral restoration. China, the US and Japan hold more than 80% of all patents, and

these tend to be dominated by artificial reef structures (Roch et al., 2023). In contrast, most active restoration projects focus on coral gardening and transplantation, and more recently, coral rubble stabilisation (Kenyon et al., 2023; Roch et al., 2023).

Several key informants believed that well-regulated interventions that were proven to be successfully deployed through small scale trials could be managed cooperatively by a range of lead agencies, stakeholders (community and industry) and Traditional Owner groups, perhaps along the lines of the CoTS control program. (Refer back to Figure 22). One respondent proposed the establishment of a new marine industry (and associated workforce training) that could be based upon scalable deployments designed and monitored by the intervention researchers. At the same time new interventions could be trialled by scientists as part of an R&D program, which if successful, could be scaled up and deployed by industry, with oversight by GBR managers and monitored by researchers. Lead agencies could provide the regulatory environment and field management, and general oversight of implementation, while reef-based industries could provide resources, staff, expertise and career paths. A well-regulated, on-going implementation program (post the initial R&D phase) could provide opportunities for the establishment of new industries while up-skilling those employed in existing industries.

New industries supporting intervention research, coral harvest and propagation could be initially developed through startups, which are often funded by highly motivated individuals or groups wanting to develop a particular product themselves (Bauer et al., 2024). The reef restoration equivalent is that motivated individuals, industries or communities collaborate to raise funds to initiate interventions that could ultimately be sustained through new restoration industries. The startup founders would lead and manage all aspects of the intervention including working with management agencies, fund-raisers, Traditional Owners and stakeholders to ensure smooth implementation of all aspects of the business. This may be difficult if the founders are not used to multi-faceted collaborations (Gibbs et al., 2024).

An industry-driven pathway could include a wide range of stakeholders and Traditional Owners employed in a variety of occupations such as coral harvest, aquaculture, marine contracting and reef tourism industries. At this point in time there are few marine contractors specialising in reef restoration, although this could change as interventions scale up (Gibbs et al., 2024). On the other hand, McLeod et al. (2022) state that at least ten tourism businesses have been actively involved in GBR coral restoration projects since 2018, motivated by the desire to protect the reefs that they use. According to Gibbs et al. (2024), GBR tourism operators' high value reef destinations are central to their business, and some are marketing the opportunity for clients to work with marine biologists to participate in restoration activities. Such marketing strategies aim to enhance reputations as 'ecotourism' operators, encourage repeat visitation, and provide on-water workers for the labour-intensive activities (Gibbs et al., 2024).

'Boats4Corals' is a small-scale trial of such a collaboration that has been operating in the Whitsundays Region since 2020. The project involves boats and crews from the tourism industry working with Traditional Owners and researchers to undertake larval restoration operations, using modified larval culture pools on reefs. Through this pilot study, robust operating standards and training materials were developed and some equipment was modified to be more easily and safely used by participants (McLeod et al., 2022). In the longer term, however, the focus on such small scale sites may become a barrier for tourism operators to participate in up-scaling activities as there is little incentive for the operators to expand their efforts beyond the high value tourism destinations (Gibbs et al., 2024).

Summary implications of the industry-driven pathway for reef restoration governance:

- Need to close the gap between R&D and commercialisation and availability of inventions.
- Coordination of knowledge sharing for commercialisation of interventions is hampered by intellectual property (IP) rights; the patenting of new products; and protocols regarding copyright.
- New IP does not always correlate with practitioner requirements, leading to the development of technologies that may not be fit-for-purpose.
- Well-regulated interventions successfully deployed through small scale trials could be managed cooperatively by a range of lead agencies, stakeholders (community and industry) and Traditional Owner groups.
- New marine industries (and associated workforce training) could be based upon scalable deployments designed and monitored by the intervention researchers, and overseen by GBR management agencies.
- An industry-driven pathway could include a wide range of stakeholders and Traditional Owners employed in a variety of occupations such as coral harvest, aquaculture, marine contracting and reef tourism industries.

4.4.8 Community-driven pathway

Small-scale interventions, particularly at sites where ecological restoration objectives align with social, economic or cultural values may be initiated through community action. A community-driven pathway could include options that embrace transparency and participation while building community capacity to undertake interventions. It could involve a range of stakeholders and Traditional Owners in co-design of activities, and managed as a series of locally-led projects that are coordinated and supported by an umbrella organisation such as the GBRF or a collective alliance, along the lines of the Wet Tropics Restoration Alliance.

A community-driven pathway could incorporate existing structures created by management agencies or NGOs. For example, regional report card partnerships comprising government and local communities are one of a number of partnerships under the Reef 2050 Plan. Regional Report Card Partners include state and Commonwealth governments, regional NRM bodies, Traditional Owners, farmers, recreational and commercial fishers, scientists, tourism operators and conservation groups. Each partnership produces an annual report card on regional water quality of waterways flowing to the GBR (Australian Government & Queensland Government, 2020). The Reef Authority's Reef Guardians program promotes stewardship through community, industry local government action, and these could be harnessed to focus on restoration and adaptation activities. The Authority has also established Local Marine Advisory Committees (LMACs) along the catchment which provide a forum to discuss and act on local marine and coastal issues that affect the GBR (Dyer et al., 2021). Further, a number of Traditional Use of Marine Resource Agreements (TUMRAs) have been developed in partnership with GBR Traditional Owner groups (Great Barrier Reef Marine Park Authority, 2021; Smyth et al., 2016; Zurba, 2009).

Communities could apply for funding from NGOs or government agencies to establish local restoration initiatives. For example, in recent years, the GBRF has initiated and funded several community-led projects to promote opportunities for community-led citizen science projects involving active restoration and monitoring of local habitats. These Community Reef Protection projects support place-based stewardship actions that strengthen connections between local and GBR-wide protection. Collectively, the projects have involved over 60,000 community members including more than 4,000 Indigenous people. Through this funding, the first community-led *Eye on the Reef* monitoring program was trialled on Yunbenun (Magnetic Island) (Great Barrier Reef Foundation, 2024a). *Eye on the Reef* is a monitoring and assessment program developed by the Reef

Authority that enables all GBR visitors to collect and record valuable information about reef health, marine animals and incidents (Great Barrier Reef Marine Park Authority, 2023b). There are many other GBR-focused stewardship programs along the length of the catchment that all aim to encourage voluntary engagement in diverse actions to protect or care for the GBR. Many would provide suitable foundations for a community-driven pathway focusing on restoration and adaptation initiatives. Some focus on building motivation or capacity to engage in direct actions while others provide opportunities for 'learning by doing' and social interaction (Church et al., 2025; Hobman et al., 2025). However, if the pathway requires participants for on-water activities, participation may be limited to those with specific underwater skills (e.g. snorkelling, diving) and access to boats, dive gear and other equipment. If an intervention relies on expensive complex technology, this could also limit participation by community groups and other interested parties (Gibbs et al., 2024). Nevertheless, several options exist that are less expensive, and less focused on particular skills, as discussed above.

Summary implications of the community-driven pathway for reef restoration governance:

- A community-driven pathway could incorporate existing structures created by management agencies or NGOs, and at the same time create opportunities for capacity-building to enable broad participation in restoration and adaptation initiatives.
- Small-scale interventions, particularly at sites where ecological restoration objectives align with social, economic or cultural values may be initiated through community action.
- A community-driven pathway could include options that embrace transparency and participation while building community capacity to undertake interventions.
- It could involve a range of stakeholders and Traditional Owners in co-design of activities, and managed as a series of locally-led projects that are coordinated and supported by an umbrella organisation such as the GBRF or a collective alliance, along the lines of the Wet Tropics Restoration Alliance.

5 Conclusions and next steps

Lessons learned from global and local (GBR) case studies of ecological restoration, together with the results of a GBR governance mapping exercise; analysis of the online survey; and insights from key informant interviews, have highlighted four elements needed for effective governance of reef restoration and adaptation interventions in the GBR:

(a) best practice engagement and social risk management;
(b) a fit-for-purpose regulatory environment;
(c) a set of guiding principles within which to operate; and
(d) governance pathways that maximise restoration and adaptation efforts through the collective action of diverse actors.

To be most effective, both (a) and (b) above depend on (c) and (d).

Best practice engagement enacted through adherence to guiding principles can provide opportunities for collaborative learning, building relationships and participation in decision-making resulting in positive social outcomes (Baresi et al., 2025; Church et al., 2025; Plummer et al., 2017). Critical decision-making that excludes particular groups can lead to conflict as well as inequities in financial or capacity-building opportunities. Further, a lack of trust in governance arrangements can hinder progress especially if there are perceptions of inequitable participation in decision-making, and little consideration of community aspirations (Curnock et al., 2024; Lockie et al., 2024; Vella et al., 2024). Thus, a critical component of effective governance is the provision of a variety of engagement processes to maximise optimal, equitable decision-making for reef restoration and adaptation activities.

Having a fit-for-purpose regulatory environment together with a set of guiding principles is essential for successful interventions at a range of spatial and temporal scales. Regulations are critical in determining the feasibility of interventions, as they can influence processes such as community engagement and decision-making. Regulations can enable the codification of science into effective policy, provide structure for community engagement and public participation, help to mobilise financial and other resources, and incentivise actions (Fidelman et al., 2019). However, they do not necessarily provide adequate guidance on how to address social risks and the potential lack of public trust in intervention science (Curnock et al., 2024). Guiding principles, on the other hand can define operational boundaries and provide key elements to coordinate and realise effective governance, especially in relation to optimising outcomes for all actors.

Governance pathways can identify clear regulatory boundaries; roles and responsibilities for all involved; and enhance decision-making processes and delivery mechanisms. Pathways are influenced by participating individuals and organisations, and their levels of trust, transparency, and involvement in planning and/or implementation. Pathways may comprise a number of overlapping institutions, community groups and individuals, who are all working towards a common cause.

When considered together, each of the seven pathways identified through this scoping study could form the basis for GBR reef restoration and adaptation governance arrangements going forward. Some of these pathways already exist, although they may not be clearly visible. Some pathways will (and do already) overlap at certain times and many participants will be involved in more than one pathway at any particular point in time. Roles and responsibilities will change over time and spatially, as circumstances dictate. As each pathway develops, it could be guided by the five governance principles presented in this report.

Rather than specify priority actions to improve governance readiness over time, each pathway provides a rich description of how the perspectives of different actors - gleaned from reviewed literature, the governance mapping exercise, key informant interviews and the online survey – may best inform decision-making processes, and each can identify new ways of working together to achieve mutual outcomes. The next task is to sharpen the focus on the many ways that governance for reef restoration and adaptation unfolds, to maximise beneficial outcomes and avoid unintended consequences. Applying a theory of change can help to gain an understanding of the impact of each governance pathway, by identifying the different elements of each pathway that lead to changes over time (Funnell & Rogers, 2011; Murphy & Jones, 2021). Change elements include what happens, why, and how as well as consideration of who instigates change. These can then create an understanding of the implications of change, and help to shape the desired outcomes for each governance system. This process of ongoing monitoring, evaluation, reflection and adaptation can contribute positively to GBR health and provide equitable outcomes for stakeholders and Traditional Owners (Borrini et al., 2013; Lockie et al., 2024). A multi-pronged approach may facilitate the process as follows:

- Work with scientists, communities, industries, Traditional Owners, managers, regulators and others to operationalise each pathway with specific roles and responsibilities for all involved. Include opportunities for best practice engagement processes. Apply the five governance principles to guide each pathway.
- Explicitly link these pathways to the broader GBR governance system – perhaps through actors' understandings of GBR governance networks – gleaned from analysis of interviews with key actors on their understanding of governance mapping;
- Apply a Theory of Change using a rigorous monitoring, evaluation and learning (MEL) regime to each pathway.

A Theory of Change can be implemented by applying the Governance Systems Analysis (GSA) Framework for the GBR developed by Vella et al. (2024). The GSA Framework was originally developed by Dale, Vella and Potts (2013) and has since been modified by Vella et al. (2024). It recognises that different components of a governance system are highly inter-connected, both between and within particular spatial and times scales. The GSA Framework identifies themes, domains and sub-domains to build a systemic and holistic understanding of governance systems, as shown in Figure 23 below (Dale et al., 2013).

For the next stage of this research we are interested in the domain of *reef restoration and adaptation* within the wider GBR governance system. Sub-domains would include all of the instruments, institutions and actors involved in reef restoration and adaptation activities within the GBRWHA. The GSA framework can highlight areas of strengths and weaknesses within sub-domains and pathways, using Table 5 in Appendix 3 as the basis for the analysis. As shown in Table 5, the GSA framework comprises four clusters and each cluster has five attributes. GSA attributes can be systematically analysed through appreciative inquiry, which is founded on positive beliefs about people and organisations. Appreciative Inquiry includes a basic tenet that clear articulation of the future can guide individual and collective action towards common goals (Bushe, 2011; Cooperrider et al., 2003).

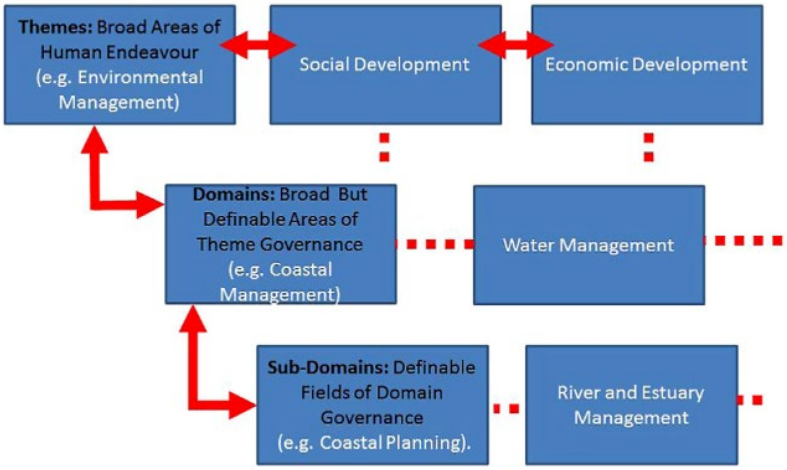


Figure 23: Definitions & relationships between governance themes, domains and sub-domains, not showing integrated links across all three areas and scales
(Source: Dale et al., 2013).

6 References

AIATSIS. (2012). *Guidelines for Ethical Research in Australian Indigenous Studies*. Australian Institute of Australian and Torres Strait Islanded Studies. https://aiatsis.gov.au/sites/default/files/2020-09/gerais.pdf

AIATSIS. (2020). *AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research*. https://aiatsis.gov.au/sites/default/files/2022-02/aiatsis-code-ethics-jan22.pdf

AIMS. (2022, March 24). *Reef Restoration and Adaptation Program | AIMS*. https://www.aims.gov.au/research/reef-recovery/RRAP

Anchondo, Z. B., Tracy, A. M., Raza, A., Meckler, K. A., & Ogburn, M. B. (2024). Reefs in no-take reserves host more oysters, macroparasites, and macrofauna than harvested reefs across an estuarine salinity gradient. *Marine Ecology Progress Series*, *739*, 65–83. https://doi.org/10.3354/meps14615

Australian Government, & Queensland Government. (2020). *Regional report cards | Reef 2050 Water Quality Improvement Plan*. https://www.reefplan.qld.gov.au/tracking-progress/regional-report-cards

Australian Government, & Queensland Government. (2022). *Reef 2050 Integrated Monitoring and Reporting Program—Business Strategy 2020-25* [Report]. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/jspui/handle/11017/3918

Australian Institute of Marine Science. (2023). *AIMS Strategy 2030*. https://www.aims.gov.au/sites/default/files/2023-07/AIMS751_Strategy30-Report_July2023web.pdf

Babcock, R. C., Plagányi, É. E., Condie, S. A., Westcott, D. A., Fletcher, C. S., Bonin, M. C., & Cameron, D. (2020). Suppressing the next crown-of-thorns outbreak on the Great Barrier Reef. *Coral Reefs*, *39*(5), 1233–1244. https://doi.org/10.1007/s00338-020-01978-8

Balestri, E., Vallerini, F., & Lardicci, C. (2011). Storm-generated fragments of the seagrass *Posidonia oceanica* from beach wrack – A potential source of transplants for restoration. *Biological Conservation*, *144*(5), 1644–1654. https://doi.org/10.1016/j.biocon.2011.02.020

Baresi, U., Eberhard, R., Vella, K., Gooch, M., Piggott-McKellar, A., Calibeo, D. L., Lockie, S., Taylor, B., Bohensky, E., Brooksbank, L., Curnock, M., Graham, V., Kong, T., Lyons, I., Maclean, K., Paxton, G., Schmitt, K., Siehoyono Sie, L., & Stone-Jovicich, S. (2025). Community Engagement for Novel Ecosystem Restoration and Assisted Adaptation Interventions: Observations and Lessons from the Australian Reef Restoration and Adaptation Program. *Society & Natural Resources*, *0*(0), 1–20. https://doi.org/10.1080/08941920.2025.2463088

Basak, S. M., Hossain, M. S., Tusznio, J., & Grodzińska-Jurczak, M. (2021). Social benefits of river restoration from ecosystem services perspective: A systematic review. *Environmental Science & Policy*, *124*, 90–100. https://doi.org/10.1016/j.envsci.2021.06.005

Bauer, D., Junge, S., & Reif, T. (2024). May the resources be with you: A systematic review and framework of startup funding options. *Management Review Quarterly*, *74*(3), 1365–1396. https://doi.org/10.1007/s11301-023-00336-6

Bay, L. K., Gilmour, J., Muir, B., & Hardisty, P. E. (2023). Management approaches to conserve Australia's marine ecosystem under climate change. *Science*, *381*(6658), 631–636. https://doi.org/10.1126/science.adi3023

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J., & Lovelock, C. E. (2016). The cost and feasibility of marine coastal restoration. *Ecological Applications*, *26*(4), 1055–1074. https://doi.org/10.1890/15-1077

Bayraktarov, E., Stewart-Sinclair, P. J., Brisbane, S., Boström-Einarsson, L., Saunders, M. I., Lovelock, C. E., Possingham, H. P., Mumby, P. J., & Wilson, K. A. (2019). Motivations, success, and cost of coral reef restoration. *Restoration Ecology*, *27*(5), 981–991. https://doi.org/10.1111/rec.12977

Beck, M., Brumbaugh, R., Airoldi, L., Carranza, A., Coen, L., Crawford, C., Defeo, O., Edgar, G., Hancock, B., Kay, M., Lenihan, H., Luckenbach, M., Toropova, C., & Zhang, G. (2009). *Shellfish Reefs at Risk: A Global Analysis of Problems and Solutions*.

Bhagarathi, L. K., & DaSilva, P. N. B. (2024). Impacts and implications of anthropogenic activities on mangrove forests: A review. *Magna Scientia Advanced Research and Reviews*, *11*(1), 040–059. https://doi.org/10.30574/msarr.2024.11.1.0074

Borrini, G., Dudley, N., Jaeger, T., Lassen, B., Pathak, N., Phillips, A., & Sandwith, T. (2013). *Governance of protected areas: From understanding to action*. IUCN. https://portals.iucn.org/library/node/29138

Boström-Einarsson, L., Babcock, R. C., Bayraktarov, E., Ceccarelli, D., Cook, N., Ferse, S. C. A., Hancock, B., Harrison, P., Hein, M., Shaver, E., Smith, A., Suggett, D., Stewart-Sinclair, P. J., Vardi, T., & McLeod, I. M. (2020). Coral restoration – A systematic review of current methods, successes, failures and future directions. *PLOS ONE*, *15*(1), e0226631. https://doi.org/10.1371/journal.pone.0226631

Buck, J. (2023, April 4). 2023 Lady Elliot Island Revegetation Update. *Lady Elliot Island Eco Resort Great Barrier Reef*. https://ladyelliot.com.au/blog/2023-revegetation-update/

Bushe, G. R. (2011). Appreciative Inquiry: Theory and critique. In *The Routledge Companion to Organizational Change*. Routledge.

Cabaitan, P., & Conaco, C. (2017). Bringing back the giants: Juvenile Tridacna gigas from natural spawning of restocked giant clams. *Coral Reefs*, *36*. https://doi.org/10.1007/s00338-017-1558-9

Cardinal, N., Skye, A., WSÁNEĆ Nation, & Hul'q'umi'num Nation. (2015). *Clam Garden Eco-cultural Restoration in the southern Gulf Islands*. https://wmacns.ca/documents/23/409_Clam_Garden_ecocultural_restoration_-_YNS_presentations_reduced.pdf

CBD. (2022). *Decision adopted by the conference of the parties to the convention on biological diversity 15/4. Kunming-montreal global biodiversity framework.* https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf

Ceccarelli, D. M., McLeod, I. M., Boström-Einarsson, L., Bryan, S. E., Chartrand, K. M., Emslie, M. J., Gibbs, M. T., Rivero, M. G., Hein, M. Y., Heyward, A., Kenyon, T. M., Lewis, B. M., Mattocks, N., Newlands, M., Schläppy, M.-L., Suggett, D. J., & Bay, L. K. (2020). Substrate stabilisation and small structures in coral restoration: State of knowledge, and considerations for management and implementation. *PLOS ONE*, *15*(10), e0240846. https://doi.org/10.1371/journal.pone.0240846

Chazdon, R. L., Falk, D. A., Banin, L. F., Wagner, M., J. Wilson, S., Grabowski, R. C., & Suding, K. N. (2024). The intervention continuum in restoration ecology: Rethinking the active–passive dichotomy. *Restoration Ecology*, *32*(8), e13535. https://doi.org/10.1111/rec.13535

Chesapeake Bay Program. (2024). *Chesapeake Bay*. Chesapeake Bay. https://www.chesapeakebay.net/

Church, E. K., Wilson, K. A., Loder, J., & Dean, A. J. (2025). From citizen science experiences to stewardship action: The importance of both nature and social experiences. *Marine Policy*, *173*, 106537. https://doi.org/10.1016/j.marpol.2024.106537

Clam Garden Network. (n.d.). *Clam Garden Network*. Clam Garden Network. Retrieved December 9, 2024, from https://www.clamgarden.com

Coen, L. D., & Luckenbach, M. W. (2000). Developing success criteria and goals for evaluating oyster reef restoration: Ecological function or resource exploitation? *Ecological Engineering*, *15*(3), 323–343. https://doi.org/10.1016/S0925-8574(00)00084-7

Commonwealth Government, & Queensland Government. (2024). *Great Barrier Reef Intergovernmental Agreement 2024*.

Commonwealth of Australia. (2016). *Reef 2050 Plan: Policy Guideline for Decision Makers*.

Commonwealth of Australia. (2021). *Reef 2050 Long-Term Sustainability Plan 2021 2025*. Department of Agriculture, Water and the Environment.

Cooper, S. (2023). *Lady Elliot Island: An Example of Effective Habitat Restoration – National Parks Association of Queensland*. https://npaq.org.au/lady-elliot-island-an-example-of-effective-habitat-restoration/

Cooperrider, D. L., Whitney, D., & Stavros, J. M. (2003). *Appreciative Inquiry Handbook: The First in a Series of AI Workbooks for Leaders of Change*. Berrett-Koehler Publishers.

Cosens, B., Doremus, H., Ruhl, J. B., Soininen, N., & Gunderson, L. (2023). Operationalising adaptive governance: A research agenda. In *Handbook on Adaptive Governance* (pp. 15–34). Edward Elgar Publishing. https://www.elgaronline.com/edcollchap/book/9781800888241/book-part-9781800888241-11.xml

Cosens, B., Ruhl, J. B., Soininen, N., Gunderson, L., Belinskij, A., Blenckner, T., Camacho, A. E., Chaffin, B. C., Craig, R. K., Doremus, H., Glicksman, R., Heiskanen, A.-S., Larson, R., & Similä, J. (2021). Governing complexity: Integrating science, governance, and law to manage accelerating change in the globalized commons. *Proceedings of the National Academy of Sciences*, *118*(36), e2102798118. https://doi.org/10.1073/pnas.2102798118

Curnock, M. I., Nembhard, D., Smith, R., Sambrook, K., Hobman, E. V., Mankad, A., Pert, P. L., & Chamberland, E. (2024). Finding common ground: Understanding and engaging with science mistrust in the Great barrier reef region. *PLOS ONE*, *19*(8), e0308252. https://doi.org/10.1371/journal.pone.0308252

Cvitanovic, C., van Putten, E. I., Tuohy, P., & Annand-Jones, R. (2022). Normalizing failure: When things go wrong in participatory marine social science fieldwork. *ICES Journal of Marine Science*, *79*(8), 2184–2195. https://doi.org/10.1093/icesjms/fsac153

Dale, A., Vella, K., & Potts, R. (2013). Governance Systems Analysis (GSA): A Framework for Reforming Governance Systems. *Journal of Public Administration and Governance*, *3*(3), Article 3. https://doi.org/10.5296/jpag.v3i3.4385

Day, J. (2008). The need and practice of monitoring, evaluating and adapting marine planning and management—Lessons from the Great Barrier Reef. *Marine Policy*, *32*(5), 823–831. https://doi.org/10.1016/j.marpol.2008.03.023

DCCEEW. (2024, November 26). *Restoring Reef Islands—DCCEEW*. https://www.dcceew.gov.au/about/news/restoring-reef-islands

Di Sacco, A., Hardwick, K. A., Blakesley, D., Brancalion, P. H. S., Breman, E., Cecilio Rebola, L., Chomba, S., Dixon, K., Elliott, S., Ruyonga, G., Shaw, K., Smith, P., Smith, R. J., & Antonelli, A. (2021). Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Global Change Biology*, *27*(7), 1328–1348. https://doi.org/10.1111/gcb.15498

Dyer, M., Newlands, M., Bradshaw, E., & Hernandez, S. (2021). *Stewardship for the Great Barrier Reef: A review of concepts and definitions of stewardship for the Great Barrier Reef* [Report]. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3781

Ecomarkets Australia. (2024). Reef Credits—Water Quality Improvement Market. *Eco-Markets Australia*. https://eco-markets.org.au/reef-credits/

Emslie, M. J., Bray, P., Cheal, A. J., Johns, K. A., Osborne, K., Sinclair-Taylor, T., & Thompson, C. A. (2020). Decades of monitoring have informed the stewardship and ecological understanding of Australia's Great Barrier Reef. *Biological Conservation*, *252*, 108854. https://doi.org/10.1016/j.biocon.2020.108854

England, J., Angelopoulos, N., Cooksley, S., Dodd, J., Gill, A., Gilvear, D., Johnson, M., Naura, M., O'Hare, M., Tree, A., Wheeldon, J., & Wilkes, M. A. (2021). Best Practices for Monitoring and Assessing the Ecological Response to River Restoration. *Water*, *13*(23), Article 23. https://doi.org/10.3390/w13233352

Evans-Illidge, E., Forester, T., Depczynski, M., Duggan, E., & Souter, D. (2020). *AIMS Indigenous Partnerships Plan*. Australian Institute of Marine Science.

FAO, SER & IUCN CEM. (2023). *Standards of practice to guide ecosystem restoration: A contribution to the United Nations Decade on Ecosystem Restoration*.

Fediuk, K., & Thom, B. (2003). *Contemporary & Desired Use of Traditional Resources in a Coast Salish Community: Implications for Food Security and Aboriginal Rights in British Columbia*. 21.

Fenten, T., & Dieperink, C. (2024). Governance Conditions for a Successful Restoration of Riverine Ecosystems, Lessons from the Rhine River Basin. *Water*, *16*(20), Article 20. https://doi.org/10.3390/w16202983

Ferretto, G., Glasby, T., Housefield, G., Poore, A. G. B., Statton, J., Sinclair, E. A., Kendrick, G., & Verges, A. (2019). Threatened plant translocation case study: Posidonia australis (Strapweed), Posidoniaceae. *Australasian Plant Conservation*, *28*, 24–26.

Fidelman, P., McGrath, C., Newlands, M., Dobbs, K., Jago, B., & Hussey, K. (2019). Regulatory implications of coral reef restoration and adaptation under a changing climate. *Environmental Science & Policy*, *100*, 221–229. https://doi.org/10.1016/j.envsci.2019.04.016

Fidelman, P., Newlands, M., McGrath, C., & Hussey, K. (2019). *T2: Regulatory Assessment Findings. A report provided to the Australian Government by the Reef Restoration and Adaptation Program*.

Fischer, M., & Leifeld, P. (2015). Policy forums: Why do they exist and what are they used for? *Policy Sciences*, *48*(3), 363–382. https://doi.org/10.1007/s11077-015-9224-y

Fitzsimons, J. A., Branigan, S., Gillies, C. L., Brumbaugh, R. D., Cheng, J., DeAngelis, B. M., Geselbracht, L., Hancock, B., Jeffs, A., McDonald, T., McLeod, I. M., Pogoda, B., Theuerkauf, S. J., Thomas, M., Westby, S., & zu Ermgassen, P. S. E. (2020). Restoring shellfish reefs: Global guidelines for practitioners and scientists. *Conservation Science and Practice*, *2*(6), e198. https://doi.org/10.1111/csp2.198

Flagel, J. (2024, February 15). *The importance of reef restoration—And how giant clams can help*. International Marine Science and Carbon Sequestration (IMARCS) Foundation. https://imarcs.org/blog/the-importance-of-reef-restoration-and-how-giant-clams-can-help

Fletcher, C. S., Bonin, M. C., Caballes, C. F., Kroon, F. J., Mankad, A., Pratchett, M. S., & Westcott, D. A. (2021). *Design of the COTS Control Innovation Program: A technical report and recommendations*.

Fukuyama, F. (2016). Governance: What Do We Know, and How Do We Know It? *Annual Review of Political Science*, *19*(1), 89–105. https://doi.org/10.1146/annurev-polisci-042214-044240

Funnell, S. C., & Rogers, P. J. (2011). *Purposeful Program Theory: Effective Use of Theories of Change and Logic Models*. John Wiley & Sons.

Gash, P., Carter, S., & Miller, W. (2013). Pathway to sustainability: The lady Elliot Island hybrid solar power station. In *Sustainable Engineering Society (SENG) 2013 conference: Looking back...looking forward* (pp. 23–31). https://doi.org/10.3316/informit.794978274280317

Gerona-Daga, M. E. B., & Salmo, S. G. (2022). A systematic review of mangrove restoration studies in Southeast Asia: Challenges and opportunities for the United Nation's Decade on Ecosystem Restoration. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.987737

Gibbs, M., Jackel, K., Ames, J., & McLeod, I. (2024). How the incentives of participating organizations influence the current scales of coral reef restoration activities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *34*(1), e4077. https://doi.org/10.1002/aqc.4077

Gibbs, M. T., Gibbs, B. L., Newlands, M., & Ivey, J. (2021). Scaling up the global reef restoration activity: Avoiding ecological imperialism and ongoing colonialism. *PLOS ONE*, *16*(5), e0250870. https://doi.org/10.1371/journal.pone.0250870

Gillies, C., McLeod, I., Alleway, H., Cook, P., Crawford, C., Creighton, C., Diggles, D. B. K., Ford, J., Hamer, P., Heller-Wagner, G., Lebrault, E., Le Port, A., Russell, K., Sheaves, M., & Warnock, B. (2018). Australian shellfish ecosystems: Past distribution, current status and future direction. *PLOS ONE*, *13*, e0190914. https://doi.org/10.1371/journal.pone.0190914

Gillies, C., McLeod, I., & Creighton, C. (2015). *Shellfish reef habitats: A synopsis to underpin the repair and conservation of Australia's environmentally, socially and economically important bays and estuaries*.

Gomez, E. D., & Mingoa-Licuanan, S. S. (2006). Achievements and lessons learned in restocking giant clams in the Philippines. *Fisheries Research*, *80*(1), 46–52. https://doi.org/10.1016/j.fishres.2006.03.017

Govers, L. L., Heusinkveld, J. H. T., Gräfnings, M. L. E., Smeele, Q., & Heide, T. van der. (2022). Adaptive intertidal seed-based seagrass restoration in the Dutch Wadden Sea. *PLOS ONE*, *17*(2), e0262845. https://doi.org/10.1371/journal.pone.0262845

Grabowski, J. H., & Peterson, C. H. (2007). Restoring oyster reefs to recover ecosystem services. In K. Cuddington, J. E. Byers, W. Wilson, & A. Hastings (Eds.), *Ecosystem Engineers: Plants to Protists* (4th ed.). Academic Press.

Great Barrier Reef Foundation. (2024a). *Great Barrier Reef: Year In Review 2023-24*. https://www.barrierreef.org/uploads/GBRF-Year-In-Review-2023-24-Digital-A3.pdf

Great Barrier Reef Foundation. (2024b, January 17). *COTS Control Innovation Program*. Great Barrier Reef Foundation. https://www.barrierreef.org/cots-control-innovation-program

Great Barrier Reef Marine Park Authority. (2014). *Great Barrier Reef Region Strategic Assessment: Strategic assessment report* [Report]. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/2861

Great Barrier Reef Marine Park Authority. (2017). *Traditional Owner heritage assessment (Document No. 100434)*. https://elibrary.gbrmpa.gov.au/handle/11017/3241

Great Barrier Reef Marine Park Authority. (2018a). *Cumulative impact management policy*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3389

Great Barrier Reef Marine Park Authority. (2018b). *Good practice management for the Great Barrier Reef*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3390

Great Barrier Reef Marine Park Authority. (2018c). *Net benefit policy*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3388

Great Barrier Reef Marine Park Authority. (2020a). *Crown-of-thorns starfish Strategic Management Framework*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3621

Great Barrier Reef Marine Park Authority. (2020b). *Lady Elliot Island ecosystem resilience plan*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3622

Great Barrier Reef Marine Park Authority. (2020c). *Policy on Great Barrier Reef interventions (Document no. 100513)*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3674

Great Barrier Reef Marine Park Authority. (2021). *Determined Native Title and Traditional Use of Marine Resources Agreement (TUMRA) areas in the Great Barrier Reef Marine Park* [Map]. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/3840

Great Barrier Reef Marine Park Authority. (2022a). *Managing Commonwealth islands | Reef Authority*. https://www2.gbrmpa.gov.au/our-work/managing-activities-and-use/managing-commonwealth-islands

Great Barrier Reef Marine Park Authority. (2022b). *Reef Knowledge System*. https://reefknowledgesystem.gbrmpa.gov.au/

Great Barrier Reef Marine Park Authority. (2023a). *Crown-of-thorns starfish control program*. https://www2.gbrmpa.gov.au/our-work/programs-and-projects/crown-thorns-starfish/Crown-of-thorns-starfish-control-program

Great Barrier Reef Marine Park Authority. (2023b). *Eye on the Reef*. https://www2.gbrmpa.gov.au/help/eye-on-the-reef

Great Barrier Reef Marine Park Authority. (2023c). *Policy – Co-management Principles*. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/handle/11017/4006

Great Barrier Reef Marine Park Authority. (2023d). *Reef 2050 Policies | Reef Authority*. https://www2.gbrmpa.gov.au/our-work/reef-management-strategies/reef-2050-policies

Great Barrier Reef Marine Park Authority. (2024a). *Great Barrier Reef Outlook Report 2024*. https://www2.gbrmpa.gov.au/news/great-barrier-reef-outlook-report-2024-ecosystem-under-pressure

Great Barrier Reef Marine Park Authority. (2024b). *Reef Blueprint 2030—Great Barrier Reef Blueprint for Climate Resilience and Adaptation*. https://elibrary.gbrmpa.gov.au/jspui/handle/11017/4035

Great Barrier Reef Marine Park Authority. (2024c). *Traditional Use Of Marine Resources Agreements: Providing Traditional Owner-led sea Country management*.

Green Finance Institute. (2024). *Nature-based Models for Unlocking Private Investment into Water Quality and Availability Part 1*. https://hive.greenfinanceinstitute.com/gfihive/revenues-for-nature/guidebooks

Groesbeck, A. S., Rowell, K., Lepofsky, D., & Salomon, A. K. (2014). Ancient Clam Gardens Increased Shellfish Production: Adaptive Strategies from the Past Can Inform Food Security Today. *PLOS ONE*, *9*(3), e91235. https://doi.org/10.1371/journal.pone.0091235

Haldrup, S. (2020). *How to measure governance: A new assessment tool | Oxford Policy Management*. https://www.opml.co.uk/blog/how-to-measure-governance-a-new-assessment-tool

Hardisty, P., Roth, C., Silvey, P., Mead, D., & Anthony, K. (2019). *Reef Restoration and Adaptation Program – Investment Case. A report provided to the Australian Government from the Reef Restoration and Adaptation Program*. AIMS.

Hedge, P., Molloy, F., Sweatman, H., Hayes, K. R., Dambacher, J. M., Chandler, J., Bax, N., Gooch, M., Anthony, K., & Elliot, B. (2017). An integrated monitoring framework for the Great Barrier Reef World Heritage Area. *Marine Policy*, *77*, 90–96. https://doi.org/10.1016/j.marpol.2016.12.014

Hein, M. Y., Vardi, T., Shaver, E. C., Pioch, S., Boström-Einarsson, L., Ahmed, M., Grimsditch, G., & McLeod, I. M. (2021). Perspectives on the Use of Coral Reef Restoration as a Strategy to Support and Improve Reef Ecosystem Services. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.618303

Hobman, E. V., Dyer, M., Stone-Jovicich, S., Newlands, M., Schultz, T., Maclean, K., Benham, C., Jones, N., & Dean, A. J. (2025). Understanding and monitoring Reef stewardship: A conceptual framework and approach for the Great Barrier Reef. *Australasian Journal of Environmental Management*, *0*(0), 1–21. https://doi.org/10.1080/14486563.2024.2439839

Howie, A. H., & Bishop, M. J. (2021). Contemporary Oyster Reef Restoration: Responding to a Changing World. *Frontiers in Ecology and Evolution*, *9*. https://doi.org/10.3389/fevo.2021.689915

Howlett, L., Camp, E. F., Edmondson, J., Hosp, R., Taylor, B., Coulthard, P., & Suggett, D. J. (2023). Active coral propagation outcomes on coral communities at high-value Great Barrier Reef tourism sites. *Biological Conservation*, *279*, 109930. https://doi.org/10.1016/j.biocon.2023.109930

Hughes, A. C., & Grumbine, R. E. (2023). The Kunming-Montreal Global Biodiversity Framework: What it does and does not do, and how to improve it. *Frontiers in Environmental Science*, *11*. https://doi.org/10.3389/fenvs.2023.1281536

Hughes, T., Baird, A., Morrison, T., & Gergely, T. (2023). Principles for coral reef restoration in the anthropocene. *One Earth*, *6*(6), 656–665. https://doi.org/10.1016/j.oneear.2023.04.008

ICRI. (2021). Restoration Hub of the International Coral Reef Initiative. *ICRI*. https://icriforum.org/restoration/

IUCN WCPA. (2018). *Applying IUCN's Global Conservation Standards to Marine Protected Areas (MPA). Delivering effective conservation action through MPAs, to secure ocean health & sustainable development.*

Katwijk, M., Thorhaug, A., Marba, N., Orth, R., Duarte, C., Kendrick, G., Althuizen, I., Balestri, E., Bernard, G., Cambridge, M., Cunha, A., Durance, C., Giesen, W., Han, Q., Hosokawa, S., Kiswara, W., Komatsu, T., Lardicci, C., Lee, K.-S., & Verduin, J. (2015). Global analysis of

seagrass restoration: The importance of large-scale planting. *Journal of Applied Ecology*, *53*, n/a-n/a. https://doi.org/10.1111/1365-2664.12562

Kenny, I., Connell, S. D., Drew, G., Wright, A., Carruthers, S., & McAfee, D. (2023). Aligning social and ecological goals for successful marine restoration. *Biological Conservation*, *288*, 110357. https://doi.org/10.1016/j.biocon.2023.110357

Kenyon, T. M., Doropoulos, C., Wolfe, K., Webb, G. E., Dove, S., Harris, D., & Mumby, P. J. (2023). Coral rubble dynamics in the Anthropocene and implications for reef recovery. *Limnology and Oceanography*, *68*(1), 110–147. https://doi.org/10.1002/lno.12254

Kiss, B., Sekulova, F., Hörschelmann, K., Salk, C. F., Takahashi, W., & Wamsler, C. (2022). Citizen participation in the governance of nature-based solutions. *Environmental Policy and Governance*, *32*(3), 247–272. https://doi.org/10.1002/eet.1987

Kjaer, A. M. (2023). *Governance*. John Wiley & Sons.

Klein, S. G., Roch, C., & Duarte, C. M. (2024). Systematic review of the uncertainty of coral reef futures under climate change. *Nature Communications*, *15*(1), 2224. https://doi.org/10.1038/s41467-024-46255-2

Kong, T. M., Taylor, B., & Graham, V. (2024). Why partner? Harnessing value from collaborative sustainable business models to restore coral reefs at scale. *PloS One*, *19*(12), e0315094.

Lefcheck, J. S., Orth, R. J., Dennison, W. C., Wilcox, D. J., Murphy, R. R., Keisman, J., Gurbisz, C., Hannam, M., Landry, J. B., Moore, K. A., Patrick, C. J., Testa, J., Weller, D. E., & Batiuk, R. A. (2018). Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. *Proceedings of the National Academy of Sciences*, *115*(14), 3658–3662. https://doi.org/10.1073/pnas.1715798115

Lockie, S., Graham, V., Taylor, B., Baresi, U., Maclean, K., Paxton, G., & Vella, K. (2024). Conceptualizing social risk in relation to climate change and assisted ecosystem adaptation. *Risk Analysis*, *n/a*(n/a). https://doi.org/10.1111/risa.17635

Lockie, S., Vella, K., & Taylor, B. (2023). *Annual Report 2023: RRAP-ENG-01 Stakeholder and Traditional Owner Engagement Sub-program. Prepared for the Reef Restoration and Adaptation Program 28 February 2023.*

Lombard, A. T., Clifford-Holmes, J., Goodall, V., Snow, B., Truter, H., Vrancken, P., Jones, P. J. S., Cochrane, K., Flannery, W., Hicks, C., Gipperth, L., Allison, E. H., Diz, D., Peters, K., Erinosho, B., Levin, P., Holthus, P., Szephegyi, M. N., Awad, A., … Morgera, E. (2023). Principles for transformative ocean governance. *Nature Sustainability*, 1–13. https://doi.org/10.1038/s41893-023-01210-9

Lovelock, C. E., Barbier, E., & Duarte, C. M. (2022). Tackling the mangrove restoration challenge. *PLOS Biology*, *20*(10), e3001836. https://doi.org/10.1371/journal.pbio.3001836

Macreadie, P. I., Trevathan-Tackett, S. M., Baldock, J. A., & Kelleway, J. J. (2017). Converting beach-cast seagrass wrack into biochar: A climate-friendly solution to a coastal problem. *Science of The Total Environment*, *574*, 90–94. https://doi.org/10.1016/j.scitotenv.2016.09.021

Mandubarra Aboriginal Land and Sea Inc, & Regional Advisory and Innovation Network (RAIN) Pty Ltd. (2024). *Mandubarra Sea Country Cultural Values 2nd Edition* [Report]. Mandaburra Aboriginal Land and Sea Inc. https://elibrary.gbrmpa.gov.au/handle/11017/4099

Mansourian, S. (2017). Chapter 27: Governance and Restoration. In S. K. Allison & S. D. Murphy (Eds.), *Routledge Handbook of Ecological and Environmental Restoration*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/qut/detail.action?docID=4862547

Marion, S., & Orth, R. (2010). Innovative Techniques for Large-scale Seagrass Restoration Using Zostera marina (eelgrass) Seeds. *Restoration Ecology*, *18*, 514–526. https://doi.org/10.1111/j.1526-100X.2010.00692.x

Markwell and Associates. (2020). *Toolkit for safeguarding Indigenous heritage and knowledge* [Report]. Great Barrier Reef Marine Park Authority. https://elibrary.gbrmpa.gov.au/jspui/handle/11017/3681

Matthews, S. A., Williamson, D. H., Beeden, R., Emslie, M. J., Abom, R. T. M., Beard, D., Bonin, M., Bray, P., Campili, A. R., Ceccarelli, D. M., Fernandes, L., Fletcher, C. S., Godoy, D., Hemingson, C. R., Jonker, M. J., Lang, B. J., Morris, S., Mosquera, E., Phillips, G. L., … Quincey, R. (2024). Protecting Great Barrier Reef resilience through effective management of crown-of-thorns starfish outbreaks. *PLOS ONE*, *19*(4), e0298073. https://doi.org/10.1371/journal.pone.0298073

McAfee, D., O'Connor, W. A., & Bishop, M. J. (2017). Fast-growing oysters show reduced capacity to provide a thermal refuge to intertidal biodiversity at high temperatures. *Journal of Animal Ecology*, *86*(6), 1352–1362. https://doi.org/10.1111/1365-2656.12757

McLeod, I. M., Hein, M. Y., Babcock, R., Bay, L., Bourne, D. G., Cook, N., Doropoulos, C., Gibbs, M., Harrison, P., Lockie, S., Oppen, M. J. H. van, Mattocks, N., Page, C. A., Randall, C. J., Smith, A., Smith, H. A., Suggett, D. J., Taylor, B., Vella, K. J., … Boström-Einarsson, L. (2022). Coral restoration and adaptation in Australia: The first five years. *PLOS ONE*, *17*(11), e0273325. https://doi.org/10.1371/journal.pone.0273325

Miller, I., Sweatman, H., Cheal, A., Emslie, M., Johns, K., Jonker, M., & Osborne, K. (2015). Origins and Implications of a Primary Crown-of-Thorns Starfish Outbreak in the Southern Great Barrier Reef. *Journal of Marine Sciences*, *2015*(1), 809624. https://doi.org/10.1155/2015/809624

Misson, G., Mainardis, M., Incerti, G., Goi, D., & Peressotti, A. (2020). Preliminary evaluation of potential methane production from anaerobic digestion of beach-cast seagrass wrack: The case study of high-adriatic coast. *Journal of Cleaner Production*, *254*, 120131. https://doi.org/10.1016/j.jclepro.2020.120131

Morrison, T. H. (2017). Evolving polycentric governance of the Great Barrier Reef. *Proceedings of the National Academy of Sciences*, *114*(15), E3013–E3021. https://doi.org/10.1073/pnas.1620830114

Morrison, T. H., Adger, N., Barnett, J., Brown, K., Possingham, H., & Hughes, T. (2020). Advancing Coral Reef Governance into the Anthropocene. *One Earth*, *2*(1), 64–74. https://doi.org/10.1016/j.oneear.2019.12.014

Murphy, R. J. A., & Jones, P. (2021). Towards Systemic Theories of Change: High-Leverage Strategies for Managing Wicked Problems. *Design Management Journal*, *16*(1), 49–65. https://doi.org/10.1111/dmj.12068

National Research Council. (2008). *Public Participation in Environmental Assessment and Decision Making* (T. Dietz & P. C. Stern, Eds.). The National Academies Press. https://doi.org/10.17226/12434

Nelson, A. (2018). Lessons from Indigenous Traditions and Innovation / Cultivating Connection: Restoring Clam Gardens. *Biohabitats*, *XVI*(2). https://www.biohabitats.com/newsletter/ecology-culture-and-economy-lessons-from-indigenous-traditions-and-innovation/cultivating-connection-restoring-clam-gardens/

Norström, A. V., Cvitanovic, C., Löf, M. F., West, S., Wyborn, C., Balvanera, P., Bednarek, A. T., Bennett, E. M., Biggs, R., de Bremond, A., Campbell, B. M., Canadell, J. G., Carpenter, S. R., Folke, C., Fulton, E. A., Gaffney, O., Gelcich, S., Jouffray, J.-B., Leach, M., … Österblom, H. (2020).

Principles for knowledge co-production in sustainability research. *Nature Sustainability*, *3*(3), Article 3. https://doi.org/10.1038/s41893-019-0448-2

NSW Marine Estate. (2024, October 4). *Oyster reef restoration and research* [Web page]. NSW Government: NSW Marine Estate; scheme=AGLSTERMS.AglsAgent; corporateName=DPI NSW; https://www.marine.nsw.gov.au/projects/oyster-reef-restoration-research

Omori, M. (2019). Coral restoration research and technical developments: What we have learned so far. *Marine Biology Research*, *15*(7), 377–409. https://doi.org/10.1080/17451000.2019.1662050

Oreska, M. P. J., Truitt, B., Orth, R. J., & Luckenbach, M. W. (2017). The bay scallop (*Argopecten irradians*) industry collapse in Virginia and its implications for the successful management of scallop-seagrass habitats. *Marine Policy*, *75*, 116–124. https://doi.org/10.1016/j.marpol.2016.10.021

Orth, R. J., Lefcheck, J. S., McGlathery, K. S., Aoki, L., Luckenbach, M. W., Moore, K. A., Oreska, M. P. J., Snyder, R., Wilcox, D. J., & Lusk, B. (2020a). Restoration of seagrass habitat leads to rapid recovery of coastal ecosystem services. *Science Advances*, *6*(41), eabc6434. https://doi.org/10.1126/sciadv.abc6434

Orth, R. J., Lefcheck, J. S., McGlathery, K. S., Aoki, L., Luckenbach, M. W., Moore, K. A., Oreska, M. P. J., Snyder, R., Wilcox, D. J., & Lusk, B. (2020b). Restoration of seagrass habitat leads to rapid recovery of coastal ecosystem services. *Science Advances*, *6*(41), eabc6434. https://doi.org/10.1126/sciadv.abc6434

Paxton, G., Lockie, S., & Backhaus, V. (2024). Articulating futures: Community storylines and assisted ecosystem adaptation in the Great Barrier Reef. *Environmental Science & Policy*, *162*, 103944. https://doi.org/10.1016/j.envsci.2024.103944

Pham, T. T., N.N, V., Q.T, V., T.K.H, T., T.L, N., N.M.H, T., T.T.A, N., T.V.A, N., & N.Q, N. (2022). *Opportunities and challenges for mangrove restoration in the Mekong Delta: Status, policies and stakeholder outlook*. CIFOR.

Phelan, A. (2020, May 14). *Leaving A Place Better Than You Found It; Making A Difference And Restoring Ecosystems On The Great Barrier Reef – The Solutions Journal*. https://thesolutionsjournal.com/leaving-place-better-found-making-difference-restoring-ecosystems-great-barrier-reef/

Piazzi, L., Acunto, S., Frau, F., Atzori, F., Cinti, M. F., Leone, L., & Ceccherelli, G. (2021). Environmental Engineering Techniques to Restore Degraded Posidonia oceanica Meadows. *Water*, *13*(5), Article 5. https://doi.org/10.3390/w13050661

Plummer, R., Dzyundzyak, A., Baird, J., Bodin, Ö., Armitage, D., & Schultz, L. (2017). How do environmental governance processes shape evaluation of outcomes by stakeholders? A causal pathways approach. *PLOS ONE*, *12*(9), e0185375. https://doi.org/10.1371/journal.pone.0185375

Pratchett, M. S., Caballes, C. F., Wilmes, J. C., Matthews, S., Mellin, C., Sweatman, H. P. A., Nadler, L. E., Brodie, J., Thompson, C. A., Hoey, J., Bos, A. R., Byrne, M., Messmer, V., Fortunato, S. A. V., Chen, C. C. M., Buck, A. C. E., Babcock, R. C., & Uthicke, S. (2017). Thirty Years of Research on Crown-of-Thorns Starfish (1986–2016): Scientific Advances and Emerging Opportunities. *Diversity*, *9*(4), Article 4. https://doi.org/10.3390/d9040041

Queensland Government. (2022). *Raine Island Recovery Project | Department of the Environment, Tourism, Science and Innovation, Queensland*. https://parks.desi.qld.gov.au/raineisland

Queensland Government. (2023a). *Queensland Sustainable Fisheries Strategy 2017–2027*. https://www.daf.qld.gov.au/business-priorities/fisheries/sustainable/sustainable-fisheries-strategy-overview

Queensland Government. (2023b). *Reef Credit Scheme | The Great Barrier Reef* [Text]. corporateName=The State of Queensland; jurisdiction=Queensland. https://www.qld.gov.au/environment/coasts-waterways/reef/reef-credit-scheme

Queensland Government. (2024). *Protecting the world's largest green turtle rookery on Raine Island | Recovery in action* [Text]. corporateName=The State of Queensland; jurisdiction=Queensland. https://www.qld.gov.au/environment/plants-animals/conservation/threatened-species/recovery-in-action/protecting-the-worlds-largest-green-turtle-rookery-on-raine-island

Quigley, K. M., Hein, M., & Suggett, D. J. (2022). Translating the 10 golden rules of reforestation for coral reef restoration. *Conservation Biology*, *36*(4), e13890. https://doi.org/10.1111/cobi.13890

Rae, N. L., & Carter, S. J. B. (2007). Rock to Riches: The Revegetation of Lady Elliot Island. *Australian Journal of Multi-Disciplinary Engineering*, *5*(1), 33–38. https://doi.org/10.1080/14488388.2007.11464754

Reef 2050 Traditional Owner Steering Group. (2020). *Reef 2050 Traditional Owner Implementation Plan*. Queensland Department of Environment and Science. https://reefto.au/wp-content/uploads/2023/09/DES_GBR_TO-Report_WEB.pdf

Rist, P., Rassip, W., Yunupingu, D., Wearne, J., Gould, J., Dulfer-Hyams, M., Bock, E., & Smyth, D. (2019). Indigenous protected areas in Sea Country: Indigenous-driven collaborative marine protected areas in Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(S2), 138–151. https://doi.org/10.1002/aqc.3052

Roch, C., Schmidt-Roach, S., & Duarte, C. M. (2023). Coral restoration patents are disconnected from academic research and restoration practitioners. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.1093808

RRAP. (2023a). Pilot Deployments Program. *Reef Restoration and Adaptation Program*. https://gbrrestoration.org/rrap-about-us/pilot-deployments-program/

RRAP. (2023b). The Reef Restoration and Adaptation Research and Development Program. *Reef Restoration and Adaptation Program*. https://gbrrestoration.org/rrap-about-us/the-program-new/

RRAP. (2024). *A Practical Guide to Restoration and Rehabilitation of Rubble on Coral Reefs. Reef Restoration and Adaptation Program/The University of Queensland.* https://gbrrestoration.org/program/ rubble-stabilisation/

Sam, K., Zabbey, N., Gbaa, N. D., Ezurike, J. C., & Okoro, C. M. (2023). Towards a framework for mangrove restoration and conservation in Nigeria. *Regional Studies in Marine Science*, *66*, 103154. https://doi.org/10.1016/j.rsma.2023.103154

Sarkki, S., Jokinen, M., Nijnik, M., Zahvoyska, L., Abraham, E. M., Alados, C. L., Bellamy, C., Bratanova-Dontcheva, S., Grunewald, K., Kollar, J., Krajčí, J., Kyriazopoulos, A. P., Porta, N. L., Monteiro, A. T., Munoz-Rojas, J., Parpan, T., Sing, L., Smith, M., Sutinen, M.-L., … Zhyla, T. (2017). Social equity in governance of ecosystem services: Synthesis from European treeline areas. *Climate Research*, *73*(1–2), 31–44. https://doi.org/10.3354/cr01441

Saunders, M. I., Cannard, T., Fischer, M., Sheppard, M., Twomey, A., Morris, R., Bishop, M. J., Mayer-Pinto, M., Malcolm, F., Vozzo, M., Steven, A., Swearer, S. E., Lovelock, C. E., Pomeroy, A. W.

M., McLeod, I., & Waltham, N. J. (2024). A roadmap to coastal and marine ecological restoration in Australia. *Environmental Science & Policy*, *159*, 103808. https://doi.org/10.1016/j.envsci.2024.103808

Scott, R., Suggett, D., Hayward, C., Chatterton, B., Edmondson, J., Gaskell, J., Gillette, G. M., Howlett, L., Monacella, E., Roper, C. D., Strudwick, P., Unsworth, J., Veltri, M., Woodcock, S., & Camp, E. F. (2024). Early-stage outcomes and cost-effectiveness of implementing tourism-led coral propagation and outplanting in the Whitsundays (Great Barrier Reef). *Frontiers in Marine Science*, *11*. https://doi.org/10.3389/fmars.2024.1418784

Seagrass Restoration Network. (n.d.). *Seagrass Restoration Network*. Seagrass Restoration Network. Retrieved November 5, 2024, from https://seagrassrestorationnetwork.com

Seifu, M., van Paassen, A., Klerkx, L., & Leeuwis, C. (2020). Anchoring innovation methodologies to 'go-to-scale'; a framework to guide agricultural research for development. *Agricultural Systems*, *182*, 102810. https://doi.org/10.1016/j.agsy.2020.102810

Shaver, E. C., McLeod, E., Hein, M. Y., Palumbi, S. R., Quigley, K., Vardi, T., Mumby, P. J., Smith, D., Montoya-Maya, P., Muller, E. M., Banaszak, A. T., McLeod, I. M., & Wachenfeld, D. (2022). A roadmap to integrating resilience into the practice of coral reef restoration. *Global Change Biology*, *28*(16), 4751–4764. https://doi.org/10.1111/gcb.16212

Shumway, N., Foster, R., & Fidelman, P. (2024). *Reef Restoration and Adaptation Program – Regulatory Sub-program Annual Report 2024*.

Shumway, N., Foster, R., & Fidelman, P. (2025). The governance of marine and coral reef restoration, lessons and paths forward for novel interventions. *Environmental Science & Policy*, *164*, 103999. https://doi.org/10.1016/j.envsci.2025.103999

SIMS. (2022, October 3). Operation Posidonia. *Sydney Institute of Marine Science*. https://sims.org.au/projects/operation-posidonia, https://sims.org.au/projects/operation-posidonia/

Singleton, G., Donnelly, R., Fisher, E., Singleton, T., Saparwan, Kish, H., & Bovery-Spencer, J. (2023). *Kul-bul Decision Tree Manual.*

Sivapalan, M. (2021). *CCIP Feasibility and Design Phase: Application of Structured Decision Making to Guide Investment Prioritisation and Program Design, a summary report prepared for the Great Barrier Reef Foundation*. Adaptus. https://www.barrierreef.org/uploads/CCIP-Design-Phase-Prioritisation-Process.pdf

Smithers, S. G., & Dawson, J. L. (2023). Beach reprofiling to improve reproductive output at the world's largest remaining green turtle rookery: Raine Island, northern Great Barrier Reef. *Ocean & Coastal Management*, *231*, 106385. https://doi.org/10.1016/j.ocecoaman.2022.106385

Smyth, D., Gould, J., Ayre, M., Bock, E., & Dulfer, -Hyams Melanie. (2016). Indigenous-driven co-governance of sea country through collaborative planning and indigenous protected areas. *Indigenous Law Bulletin*, *8*(26), 15–20. https://doi.org/10.3316/informit.462561955710412

Society for Ecological Restoration. (1998). *The SER primer on ecological restoration. Society for Ecological Restoration, Science & Policy Working Group, Tucson*.

Springer, J., Campese, J., & Nakangu, B. (2021). *The Natural Resource Governance Framework*. IUCN. https://doi.org/10.2305/IUCN.CH.2021.16.en

Statton, J., Montoya, L. R., Orth, R. J., Dixon, K. W., & Kendrick, G. A. (2017). Identifying critical recruitment bottlenecks limiting seedling establishment in a degraded seagrass ecosystem. *Scientific Reports*, *7*(1), 14786. https://doi.org/10.1038/s41598-017-13833-y

Steven, A. D. L., Baird, M. E., Brinkman, R., Car, N. J., Cox, S. J., Herzfeld, M., Hodge, J., Jones, E., King, E., Margvelashvili, N., Robillot, C., Robson, B., Schroeder, T., Skerratt, J., Tickell, S., Tuteja, N., Wild-Allen, K., & Yu, J. (2019). eReefs: An operational information system for managing the Great Barrier Reef. *Journal of Operational Oceanography*, *12*(sup2), S12–S28. https://doi.org/10.1080/1755876X.2019.1650589

Stiefel, K. (2019, August 20). *Raising Giants*. Hakai Magazine. https://hakaimagazine.com/videos-visuals/raising-giants/

Su, J., Friess, D. A., & Gasparatos, A. (2021). A meta-analysis of the ecological and economic outcomes of mangrove restoration. *Nature Communications*, *12*(1), 5050. https://doi.org/10.1038/s41467-021-25349-1

Suggett, D. J., Edwards, M., Cotton, D., Hein, M., & Camp, E. F. (2023). An integrative framework for sustainable coral reef restoration. *One Earth*, *6*(6), 666–681. https://doi.org/10.1016/j.oneear.2023.05.007

Suggett, D. J., Guest, J., Camp, E. F., Edwards, A., Goergen, L., Hein, M., Humanes, A., Levy, J. S., Montoya-Maya, P. H., Smith, D. J., Vardi, T., Winters, R. S., & Moore, T. (2024). Restoration as a meaningful aid to ecological recovery of coral reefs. *Npj Ocean Sustainability*, *3*(1), 1–4. https://doi.org/10.1038/s44183-024-00056-8

Tan, Y. M., Dalby, O., Kendrick, G. A., Statton, J., Sinclair, E. A., Fraser, M. W., Macreadie, P. I., Gillies, C. L., Coleman, R. A., Waycott, M., van Dijk, K., Vergés, A., Ross, J. D., Campbell, M. L., Matheson, F. E., Jackson, E. L., Irving, A. D., Govers, L. L., Connolly, R. M., … Sherman, C. D. H. (2020a). Seagrass Restoration Is Possible: Insights and Lessons From Australia and New Zealand. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00617

Tan, Y. M., Dalby, O., Kendrick, G. A., Statton, J., Sinclair, E. A., Fraser, M. W., Macreadie, P. I., Gillies, C. L., Coleman, R. A., Waycott, M., van Dijk, K., Vergés, A., Ross, J. D., Campbell, M. L., Matheson, F. E., Jackson, E. L., Irving, A. D., Govers, L. L., Connolly, R. M., … Sherman, C. D. H. (2020b). Seagrass Restoration Is Possible: Insights and Lessons From Australia and New Zealand. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00617

Taylor, B., Vella, K., Maclean, K., Newlands, M., Richie, B., Lockie, S., Lacey, J., Baresi, U., Barber, M., Siehoyono Sie, L., Martin, M., Marshall, N., & Koopman, D. (2019). *T1: Stakeholder, Traditional Owner and Community Engagement Assessment. A report provided to the Australian Government by the Reef Restoration and Adaptation Program*.

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. *AMBIO*, *43*(5), 579–591. https://doi.org/10.1007/s13280-014-0501-3

Termeer, C. J. A. M., Dewulf, A., Breeman, G., & Stiller, S. J. (2015). Governance Capabilities for Dealing Wisely With Wicked Problems. *Administration & Society*, *47*(6), 680–710. https://doi.org/10.1177/0095399712469195

The Everglades Foundation. (2021, July 29). *Kissimmee River Restoration Completed*. EF Everglades. https://www.evergladesfoundation.org/post/kissimmee-river-restoration-completed

United Nations Economic Commission for Europe. (2022). *The Water Convention: 30 Years of Impact and Achievements on the Ground*. United Nations. https://doi.org/10.18356/9789210018647

Unsworth, R. K. F., Jones, B. L. H., Bertelli, C. M., Coals, L., Cullen-Unsworth, L. C., Mendzil, A. F., Rees, S. C., Taylor, F., Walter, B., & Evans, A. J. (2024). Ten golden rules for restoration to secure resilient and just seagrass social-ecological systems. *Plants, People, Planet*, *n/a*(n/a). https://doi.org/10.1002/ppp3.10560

U.S. National Parks Service. (2023). *Chesapeake Bay Restoration—Chesapeake Bay Watershed (U.S. National Park Service)*. https://www.nps.gov/locations/chesapeakebaywatershed/restoration.htm

van Kerkhoff, L., & Szlezák, N. A. (2016). The role of innovative global institutions in linking knowledge and action. *Proceedings of the National Academy of Sciences*, *113*(17), 4603–4608. https://doi.org/10.1073/pnas.0900541107

Vardi, T., Hoot, W. C., Levy, J., Shaver, E., Winters, R. S., Banaszak, A. T., Baums, I. B., Chamberland, V. F., Cook, N., Gulko, D., Hein, M. Y., Kaufman, L., Loewe, M., Lundgren, P., Lustic, C., MacGowan, P., Matz, M. V., McGonigle, M., McLeod, I., … Montoya-Maya, P. H. (2021). Six priorities to advance the science and practice of coral reef restoration worldwide. *Restoration Ecology*, *29*(8), e13498. https://doi.org/10.1111/rec.13498

Vella, K., Dale, A., Calibeo, D., Limb, M., Gooch, M., Eberhard, R., Babacan, H., McHugh, J., & Baresi, U. (2024). *Monitoring the governance system underpinning the implementation and review of the Reef 2050 Plan: A preliminary benchmark*. Queensland University of Technology and James Cook University. https://eprints.qut.edu.au/254729/

Vella, K., Taylor, B., Baresi, U., & Lockie, S. (2018). *Engagement structures in the Great Barrier Reef: Findings from PD2 Activity 2—Identify and 'map' significant engagement, advisory or deliberative structures.* Unpublished internal report of the RRAP engagement subprogram.

VIMS. (2024). *Bay Scallop Restoration: Bay Scallop Restoration in the Coastal Bays*. Virginia Institute of Marine Science. https://www.vims.edu/esl/research/bay_scallop_restoration/

Wang, Y., Han, L., Sun, J., & Sun, Z. (2024). Financing the green transition: Mobilizing resources for efficient natural resource management. *Resources Policy*, *89*, 104522. https://doi.org/10.1016/j.resourpol.2023.104522

Wentworth Group of Concerned Scientists. (2024, July 24). *Blueprint to Repair Australia's Landscapes*. https://wentworthgroup.org/2024/07/blueprint-repair-australias-landscapes/

Westcott, D. A., Fletcher, C. S., Kroon, F. J., Babcock, R. C., Plagányi, E. E., Pratchett, M. S., & Bonin, M. C. (2020). Relative efficacy of three approaches to mitigate Crown-of-Thorns Starfish outbreaks on Australia's Great Barrier Reef. *Scientific Reports*, *10*(1), 12594. https://doi.org/10.1038/s41598-020-69466-1

Wet Tropics Restoration Alliance. (2024). *Wet Tropics Restoration Alliance*. https://www.restorationwettropics.org/

Wissing, K., Scanlan, L., Maclean, K., & Webb, T. (2025). *Recommendations for partnering with Aboriginal and Torres Strait Islander peoples in synthetic biology in Australia*. CSIRO. https://doi.org/10.25919/b039-nq81

Wolfe, K., Kenyon, T. M., & Mumby, P. J. (2021). The biology and ecology of coral rubble and implications for the future of coral reefs. *Coral Reefs*, *40*(6), 1769–1806. https://doi.org/10.1007/s00338-021-02185-9

W̱SÁNEĆ Leadership Council. (2020, March 10). The Clam Garden Restoration Project. *W̱SÁNEĆ Leadership Council*. https://wsanec.com/the-clam-garden-restoration-project/

WWF. (2024). *Living Planet Report 2024 – A System in Peril*. WWF. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/3k4y2duybz_WWF_SWIO_Elinor_Governance_Report_Web.pdf

Zurba, M. (2009). Bringing local synthesis into governance and management systems: The Girringun TUMRA case in Northern Queensland, Australia. *Journal of the Royal Society of New Zealand*, *39*(4), 179–182. https://doi.org/10.1080/03014220909510575

Appendix 1 Great Barrier Reef Marine Park Legal/ Policy Instruments

(Updated from Fidelman et al. 2019)

LEGISLATION

Commonwealth
Climate Change Act 2022
Environment Protection and Biodiversity Conservation Act 1999
Environment Protection (Sea Dumping) Act 1981
Great Barrier Reef Marine Park Act 1975
Historic Shipwrecks Act 1976
Native Title Act 1993
Protection of the Sea (Prevention of Pollution from Ships) Act 1983
Sea Installations Act 1987

Queensland
Clean Economy Jobs Act 2024
Coastal Protection and Management Act 1995
Environmental Offsets Act 2014
Environmental Protection Act 1994
Fisheries Act 1994
Marine Parks Act 2004
Native Title (Queensland) Act 1993
Nature Conservation Act 1992
Planning Act 2016
Regional Planning Interests Act 2014
Transport Operations (Marine Pollution) Act 1995
Transport Operations (Marine Safety) Act 1994
Work Health and Safety Act 2011
Safety in Recreational Water Activities Act 2011
State Development and Public Works Organisation Act 1971
Sustainable Ports Development Act 2015
Vegetation Management Act 1999

International Conventions
Convention for the Protection of the World Cultural and Natural Heritage, 1972 (the World Heritage Convention)
Convention on Biological Diversity, 1992 (the Biodiversity Convention)
Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1973 (CITES)
Convention on the Conservation of Migratory Species of Wild Animals, 1979 (the Bonn Convention)
Convention on Wetlands of International Importance Especially as Waterfowl Habitats, 1971 (the Ramsar Convention)
International Convention for the Prevention of Pollution from Ships, 1973 (the MARPOL Convention)
United Nations Convention on the Law of the Sea, 1982 (the Law of the Sea Convention)

United Nations Framework Convention on Climate Change, 1992 (the FCCC)

REGULATIONS
Great Barrier Reef Marine Park Regulations 2019

AGREEMENTS
Great Barrier Reef Intergovernmental Agreement 2009: framework for cooperation between Queensland and Commonwealth governments. Supported by the 2024 Intergovernmental Agreement (reflecting commitments to the GBR World Heritage Area).
Traditional Use of Marine Resource Agreements (TUMRAs)

POLICIES, PLANS, PROTOCOLS AND POSITION STATEMENTS

Protocols
Toolkit for safeguarding Indigenous Heritage and Knowledge

Policies and plans
Policies that are explicitly provided to be made for the purposes of s7(4) *GBRMP Act 1975* (Cth) must be considered in decisions relating to assessment approaches (reg 92(c)) and about whether to grant a permit (reg 103(o)). Five yearly outlook reporting is required under Great Barrier Reef Marine Park Act 1975 (section 54) and aims to provide a regular and reliable means of assessing the Reef's health and management in an accountable and transparent way.

Joint Commonwealth/State policies, plans and guidelines
- Reef 2050 Long-Term Sustainability Plan
    - Cumulative Impact Management Policy
    - Net Benefit Policy
    - Good Practice Management for the Great Barrier Reef policy
- Reef 2050 Traditional Owner Implementation Plan
- Policy on Great Barrier Reef Interventions
- Reef 2050 Water Quality Improvement Plan

Reef Authority policies and guidelines
- Great Barrier Reef Outlook Report 2024
- Internal Guidelines on the use of Section 5.4 of the Zoning Plan, November 2022
    - Tourism Policies and Plans
        - Cruise Shipping Policy for the Great Barrier Reef Marine Park
        - Managing Tourism Permissions to Operate in the Great Barrier Reef Marine Park (including Allocation, Latency & Tenure)
        - Policy on Managing Bareboat Operations in the Great Barrier Reef Marine Park
        - Marine Tourism Contingency Plan
            - Marine Tourism Contingency Plan application form for operations impacted by a severe environmental incident
        - Policy on Moorings in the Great Barrier Reef
            - Supporting information on the policy on moorings
        - Tourism Management Action Strategy
- Protected Species Policies and Plans

    - Policy on Managing Activities That Include the Direct Take of a Protected Species From the Great Barrier Reef Marine Park
    - Operational Policy on Whale and Dolphin Conservation in the Great Barrier Reef Marine Park
- Environmental Policies and Plans
    - Dredging coral reef habitats
    - Dredging and Spoil Disposal Policy
    - Environmental Impact Management - Permission System
    - Sewage Discharges From Marine Outfalls To The Great Barrier Reef Marine Park
    - Fish Aggregation Devices (FADs) and Artificial Reef Interim policy

Position statements

- Position Statement - Fishing
- Position Statement - Climate change
- Position Statement - Coastal ecosystems
- Position Statement - Marine debris
- Position Statement - Water quality

STRATEGIES

Queensland

- Queensland Aquaculture Strategy
- Great Sandy Marine Park Aquaculture Strategy

Commonwealth/Reef Authority

- Blueprint 2030
- Great Barrier Reef Marine Park Commonwealth Heritage Listed Places and Properties Heritage Strategy 2018-21
- Aboriginal and Torres Strait Islander Heritage Strategy for the Great Barrier Reef Marine Park
- Great Barrier Reef Climate Change Strategy and Adaptation Plan 2012-17
- Great Barrier Reef Biodiversity Conservation Strategy 2013
- Great Barrier Reef Marine Park Recreational Strategy 2012
- Tourism Management Action Strategy

ZONING PLAN

- Great Barrier Reef Marine Park Zoning Plan 2003, supported by plans of management setting specific protection measures in popular & high-use areas or areas of conservation concern:
    - Cairns
    - Whitsunday
    - Hinchinbrook
    - Shoalwater Bay

- No Structure sub-zones

SITE MANAGEMENT ARRANGEMENTS

- Far Northern site-specific management
- Cairns/Cooktown site specific management
- Townsville/Whitsunday site specific management
- Mackay/Capricorn site specific management

GUIDELINES

- Applications for restoration/adaptation projects to improve resilience of habitats in the GBRMP – 2018
- Applications for joint permissions
- Permission assessment and decision
- Permit applications for restoration/adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park
- Seagrass value assessment
- Historic heritage assessment: WWII features and sites, and voyages and shipwrecks
- Historic heritage assessment: other places of historic and social significance
- Historic heritage assessment: maritime cultural heritage protection special management area
- Social value assessment
- Traditional Owner heritage assessment
- Woppaburra Traditional Owner heritage assessment
- Managing research in the Great Barrier Reef Marine Park
- Activity Assessment: photography, filming and sound recording
- Activity Assessment: tourism program involving whale watching or swimming with whales
- Activity Assessment - Activity not mentioned or considered in the preparation of a Plan of Management
- Activity Assessment - No or low adverse impact activity under clause 2.3B of the Whitsundays Plan of Management 1998
- Water quality guidelines for the Great Barrier Reef Marine Park
- Guidelines for commercial dugong watching
- Guidelines on Coral Transplantation
- Guidelines for the Emergency Disposal of Foreign Fishing Vessels
- Guidelines for Managing Visitation to Seabird Breeding Islands
- Guidelines for the Use of Hydrodynamic Numerical Modelling for Dredging Projects in the Great Barrier Reef Marine Park (August 2012)
- Memorial management within the Great Barrier Reef
- Translocation of species within the Great Barrier Reef
- Tourist flights within the vicinity of Magnetic Island
- Commercial jet-ski operations around Magnetic Island
- Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and Maclennan Cay
- Indigenous participation in tourism and its management
- Dugong conservation in the Great Barrier Reef Marine Park
- Aquaculture within the Marine Park

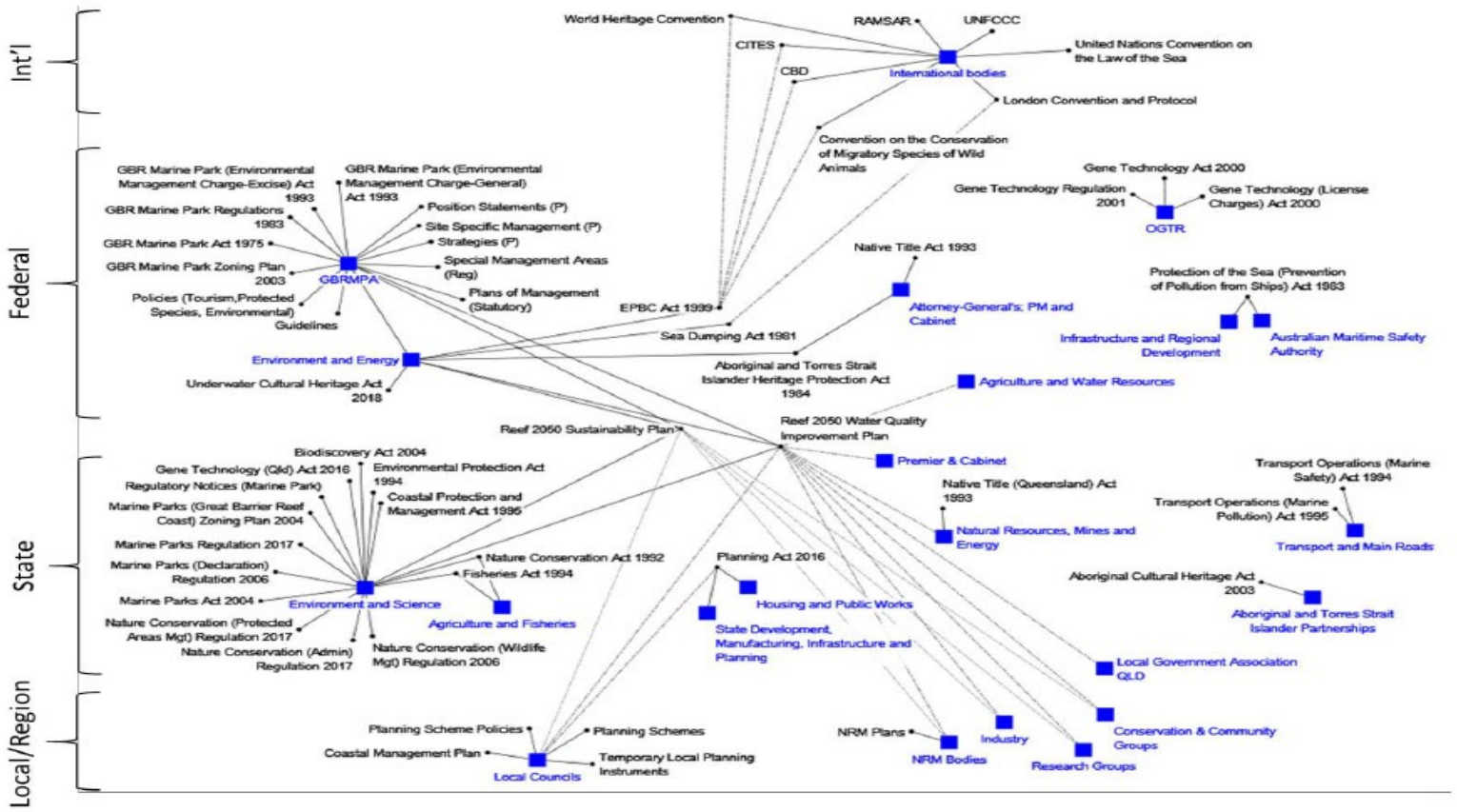


Figure 24: Key elements of the Great Barrier Reef regulatory environment

(Source: Fidelman et al., 2019)

Note: squares represent organisations, circles represent legislation, regulations, policies and plans; black lines link legislation with organisations responsible for that legislation; dashed grey lines illustrate links between international agreements and national legislation that give effect to these agreements or illustrate engagement of stakeholders in selected plans (i.e. Reef 2050 Sustainability Plan and Reef 2050 Water Quality Improvement Plan).

Appendix 2 Interview schedule for in-depth interviews

1. To begin, can you *very briefly* describe your role in reef management or ecological restoration? (could be reef restoration or other types of ecological restoration) E.g. research, policy, community group, industry participation, or in some other capacity? How long have you been involved?

The term governance means different things in different contexts. For our research, we are defining governance as:

…..all of the organisations, processes, policies, plans, agreements and other factors that contribute to who makes decisions and how decisions are made. Effective governance arrangements should maximise opportunities for meaningful collaboration and co-learning among researchers, Traditional Owners and stakeholders, and for successful deployment of restoration and adaptation interventions in the Great Barrier Reef (Fukuyama, 2016; Haldrup, 2020; Sarkki et al., 2017).[1]

2. Is this definition consistent with governance arrangements that you are familiar with in your work? Why or why not?
3. In your view, how might the governance of reef restoration be similar/different to other types of ecological restoration?
4. Do you see particular barriers, opportunities or benefits related to the effective governance of reef restoration?

For the next couple of questions, I'd like you to consider this definition of policy forums:

Policy forums are issue-based intermediary organizations where diverse types of political and societal actors repeatedly interact. Policy forums are important elements of modern governance systems as they allow actors to learn, negotiate, or build trust. They can vary in composition, size, membership logic, and other distinct features[2] (Fischer & Leifeld, 2015).

5. How might a fit-for-purpose policy and governance forum complement and align with reef restoration and adaptation activities on the GBR? Would it work? (Why? Why not?) The aim would be to provide a safe space for all involved to understand and negotiate the best policy and governance pathways to achieve mutual benefits for stakeholders, rights holders and policy-makers.

---

[1] Mansourian, S., & Sgard, A. (2021). Diverse interpretations of governance and their relevance to forest landscape restoration. *Land Use Policy*, *104*, 104011;

[1] Haldrup, S. (2020). How to measure governance: a new assessment tool. *Oxford Policy Management* https://www.opml.co.uk/blog/how-to-measure-governance-a-new-assessment-tool;

[1] Sarkki, S., Jokinen, M., Nijnik, M., Zahvoyska, L., Abraham, E. M., Alados, C. L., Bellamy, C., Bratanova-Dontcheva, S., Grunewald, K., Kollar, J., Krajč, J., Kyriazopoulos, A. P., Porta, N. L., Monteiro, A. T., Munoz-Rojas, J., Parpan, T., Sing, L., Smith, M., Sutinen, M. L., . . . Zhyla, T. (2017). Social equity in governance of ecosystem services: Synthesis from European treeline areas [Article]. *Climate Research*, *73*(1-2), 31-44. https://doi.org/10.3354/cr01441

[2]

6. If you think it might exist in future, who might participate?
7. What might be the forum's strengths? What could be some weaknesses?
8. Can you give examples of alternatives to such a forum?
9. Can you sum up how you would like to see governance for GBR reef restoration and adaptation in future?
10. Any final comments about governance for reef restoration and adaptation?

Thank you for your time.

Appendix 3 Key definitions of the Governance Systems Analysis Framework

Table 5: An outline of key definitions behind clusters and the individual attributes.

Cluster	Attribute Descriptions	Measurement Guidance
1. Coherence: How cohesive is the governance system across vision goal setting, strategy development, implementation, and monitoring and review?	**1.1 Shared vision:** All actors involved in the development and implementation of the Reef 2050 Plan share complementary visions for the GBR. This includes consideration that: • A shared vision indicates a governance system built on the notion of collective responsibility where a system's actors are working toward common goals and setting common priorities (Howes et al., 2015). This often involves evidence of key actor convergence toward long-term goals and the alignment of norms and behaviours (Lindley & Wheeler, 2000); and • A shared vision building approach mitigates ambiguities and conflicts of interest (Alt et al., 2015), and is a key method for fostering inclusion (Doten-Snitker et al., 2021).	Measurement can be guided by: • Social research (interviews, survey, focus groups) and strategic discussions on long-term goals and expectations for the future (Trutkowski et al., 2022). This might include text analysis of plans and subordinate documentation and/or interviews with key actors about their vision of the GBR; and • The Social and Economic Long-Term Monitoring Program (SELTMP) measuring human dimensions indicators for the GBR Management Effectiveness Survey.
	1.2 An integrated legal framework: From global to the state scale, there is an impactful set of legislative and policy instruments integrated across key issues affecting the GBR, and across global, national, state, and local scales. This includes consideration that: • Integrated legal frameworks are useful to mitigate conflict between different instruments such as regulations, policies, and institutional frameworks; and • Integrated legal frameworks require 'cross-sectoral inter-connectivity and coordination' between those instruments (Global Water Partnership, 2017, p. 1)	Measurement can be guided by asking questions like: • Is the framework transparent? • Is the framework flexible? • Can the framework evolve and adapt to changing conditions? (Global Water Partnership, 2017); • Are elements of the framework complementary; and • Are there legislative gaps or overlaps?

Cluster	Attribute Descriptions	Measurement Guidance
	1.3 Aligned, multi-scale and prioritised strategies: Reef 2050 strategies and associated delivery arrangements are diverse and well targeted enough to achieve Plan goals. This includes consideration that: • Policy, strategy and program development should be coherent and aligned with national and local policy objectives to improve policymaking (European Commission, 2009); and • There should be alignment of priorities, vision, and objectives at diverse scales within a governance system (Dale et al., 2013a; Potts et al., 2016b).	Measurement can be guided by: • Text analysis of strategy and policy objectives; and • Diagnostic reviews assessing systems, institutions, and procedures across scales (European Commission, 2009).
	1.4 Cohesive implementation: Strategies are effectively coordinated, delivered and maintained on the ground. This includes consideration that: • A healthy governance system requires the integration of existing and sometimes competing instruments into combined sets of delivery instruments that support each other to achieve desired outcomes (Howlett & Rayner, 2007); and • Strong delivery institutions foster policy cohesion through how they structure authority, attention, relationships, and knowledges in support of a policy regime (Jochim & May, 2010).	Measurement can be guided by: • Survey questionnaires, for example, using a Likert type scale to establish key actor agreement with statements concerning strategy implementation and delivery (Amoo et al., 2019). An example of question to ask might be: is the implementation of policy arrangement cohesive across the system?
	1.5 Adaptive MERI systems: There is active monitoring, evaluation, and review of Reef Plan efforts across scales, resulting in continuous improvement. This includes consideration that: • The acronym 'MERI' stands for: monitoring, evaluation, reporting, and improvement. It is a 'learning by doing' approach to evaluation that supports improvement in policy design to achieve desired outcomes (Australian Government, 2009); and • Healthy governance systems have deeply embedded MERI processes.	Measurement can be guided by identifying boundaries for the evaluation through key questions. These might include (Australian Government, 2009): • What will be evaluated? • Who is the evaluation for? • What is the purpose of the evaluation? and • What are the resources available and necessary to enable the evaluation?

Cluster	Attribute Descriptions	Measurement Guidance
2. Connectivity and Capacity: Are system components deeply connected vertically and horizontally, with equitable capacity across all actors?	**2.1 Transparency of process and trust among actors**: Across scales, decision making processes are transparent and accountable and there are high levels of trust between the actors involved. This includes consideration that: • Transparency of process refers to availability of information on activities and the performance of one or more actors, allowing other actors to monitor such activities (de Fine Licht & Naurin, 2022; Lyrio et al., 2018); • Trust among actors requires belief in the reliability of other actors in the system (Cairney & Wellstead, 2019); and • There is a need for a positive perception about actions among actors (OECD, 2022).	Measurement can be guided by: • Survey data analysis (Piotrowski & Van Ryzin, 2007; Yavuz & Welch, 2014); • Availability of information about decisions and performance in the public sector (da Cruz et al., 2016; Tavares & da Cruz, 2020; Wilde et al., 2015). For example, the: - availability of government websites that enable dialogue and foster informal interactions between citizens and decision-makers; - availability of mechanisms for citizens to express feedback about decisions; - public availability of accounting reports to ensure financial transparency; - availability of information regarding tenders or funding applications; - use of perception surveys (Kumagai & Iorio, 2020; OECD, 2022); - the use of surveys such as the World Value Survey on trust (Johnson & Mislin, 2012); - use of open questions (Brosius et al., 2022); - differentiation of interpersonal vs institutional trust and measure accordingly (Morrone et al., 2009).

Cluster	Attribute Descriptions	Measurement Guidance
	2.2 Actor capacities and skills: All key actors in the GBR have the capacities and skills needed to fulfil their responsibilities and they are actively supported. This includes consideration that: • There is a set of conditions or infrastructure supporting and/or encouraging innovation (Lewis et al., 2018); ability of a government or system to generate new ideas to address public problems (Meijer, 2019); • Capacities and skills refer to resources (routinised behaviours and practices) upon which public sector organisations rely when acting (Mayne et al., 2019); the presence of capabilities (skills, information, capacities, and resources) within a governance system is key to successful ecosystem management (Fernandez et al., 2000; Termeer et al., 2015); and • Four governance capabilities are important: reflexivity (the ability to deal with unstructured problems); resilience (the ability to flexibly adapt); responsiveness (the ability to respond to unlimited concerns); and revitalising (the ability to unblock stagnations) (Termeer et al., 2015)	Measurement can be guided by: • Questionnaires that employ Likert scales to self-assess innovation capacity (Meijer, 2019). The FINCODA model (Marin-Garcia et al., 2016), for example, considers three dimensions: - **creativity**: Is there ability to think beyond traditional patterns and generate alternatives? - **critical thinking**: is there ability to analyse issues with the purpose of estimating risks and foresee how events might develop? - **initiative, teamwork, and networking**: taking decisions to operationalise ideas for change, work with others in a group, and engage with outside actors (Marin-Garcia et al., 2016). • Developing theories of change around identified problems; • The application of conceptual frameworks for environmental stewardship that identify social, cultural, financial, physical, human and institutional capabilities as key assets for enabling environmental stewardship Bennett et al. (2018); • Data analysis of text and data generated through meetings (Mayne et al., 2019).

Cluster	Attribute Descriptions	Measurement Guidance
	2.3 Equity in collaboration and genuine partnerships: There is demonstrable power sharing across all GBR actors leading to genuine partnership effort. This includes consideration that: • Institutions have sufficient knowledge and resources to undertake meaningful external engagement and partnerships with other institutions, Traditional Owners, end-user groups, and the broader community; • Partnerships involve mutual benefits built on shared vision and values, mutual contribution, and co-production of added value. Partnerships are an integral part of institutional capacity (Jooste et al., 2015). When collaborative, institutional capacity enables mutual learning (Scott, 2004); • Genuine and equal collaborations are established through meaningful engagement between government institutions, local government, industry players, Traditional Owners, end-user groups, and the broader community; • There is inherent fairness within system decision making' (Dale et al. 2013a); • That equity refers to fair distribution of benefits, burdens, and risks (distributional) and equipping all key actors with tools to impact on decision making through procedural collaboration (Dobbin et al.; Sarkki et al., 2017).	Measurement can be guided by: • Use of the partnership evaluation self-assessment tool (PSAT) (Loban et al., 2021), adapted to GBR governance. This could include questions around partnerships, information sharing, communication, decision-making, management, financial arrangements, and resource use; • Adoption of people-centred approach through active participation of all sectors of society in decision making; • Surveys and interviews; participatory instruments such as assessments, evaluation, and budgeting (Rice & Hancock, 2016); and • Document scans to identify cross-sectoral collaborations (Lyon & Henig, 2019).
	2.4 Open and diverse communication and flows: Policies, plans, information, and progress is freely shared across all actors and the broader community. This includes consideration that: • Integrated use of knowledge available within the system (Dale et al., 2013a) depends on the availability of reliable information that is understandable by those accessing it (Fazekas & Burns, 2012).	Measurement can be guided by: • Questionnaires/surveys to measure cooperative culture in the system; and • Measuring knowledge creation and knowledge sharing (Sun et al., 2019).

Cluster	Attribute Descriptions	Measurement Guidance
	2.5 System subsidiarity: The power to make the right decisions rests with those actors closest to the policy, planning, or delivery problem being addressed. This includes consideration that: • Solid approaches are used to allocate powers or decision making 'between spheres of authority' (Jachtenfuchs & Krisch, 2016, p. 6); • Decision making occurs 'at the most appropriate scale' to effect societal positive outcomes (Dale & Dale, 2022); and • There is a deference of governance at the lowest possible level, closest to individuals affected by decisions (Reinold, 2019).	Measurement can be guided by: • Third party assessment within the governance system (i.e. a 'systems doctor'); • Exploring independent, collaborative actions bringing key actors together to analyse and address issues in policy delivery and outcomes (Dale & Dale, 2022); and • Understanding that subsidiarity means strongly empowering lower-level actors in the government system (Jachtenfuchs & Krisch, 2016).
3. Knowledge: Are all forms and knowledge, data and research, development and innovation appropriately considered in decision making?	**3.1 Knowledge quality, availability, and access:** The knowledge needed in decision making at all scales has high integrity, is readily available and can be accessed. This includes consideration that: • Knowledge is an 'intrinsic' component of governance systems in which knowledge, values, and social order are coproduced (van der Molen, 2018); and • Quality of knowledge is 'negotiated' across a multitude of knowledge systems and relates to how well it fits decision making (Bremer & Glavovic, 2013a).	Measurement can be guided by: • Procedural measures of participation in open, transparent, and accountable processes; and • Cross system, collective evaluation of knowledge according to credibility, salience, and legitimacy criteria (Bremer & Glavovic, 2013b).
	3.2 Informed consent about the use of knowledge: Free, prior informed consent is well negotiated when collecting and using knowledge and data from human sources. This includes consideration that: • Individual agreement that is not coerced or given under threat to a proposed research or clinical process, following the disclosure of relevant information and the ability of individuals to comprehend that information (Appelbaum, 2015);	Measurement can be guided by interviews, conversations, and surveys with actors to ask if informed consent form have been provided in plain language, typically in writing (Manti & Licari, 2018)

Cluster	Attribute Descriptions	Measurement Guidance
	3.3 Diversity of knowledge: Decision making in the governance system uses a diverse range of social, cultural, economic, biophysical, traditional, historical, and industry knowledge. This includes consideration that: • A governance system includes different and sometimes conflicting knowledges (scientific, local, indigenous) in a knowledge system (van der Molen, 2018).	Measurement can be guided by interviews, conversations, and surveys with key actors asking, for example: • What is the governance system's capacity to integrate diverse knowledges and perspectives for collaborative action (integrative capacity)? and • How does the system deal with conflicting knowledge claims embedded in diverse social settings? (van der Molen, 2018).
	3.4 Knowledge integration and decision support: Data and knowledge is well integrated in effective modelling and decision support systems. This includes consideration that: • Integrated use of knowledge improves the functionality of governance systems; new, improved knowledge must be linked to decision making arrangements (Dale et al., 2013a; van der Molen, 2018)	Measurement can be guided by participant interviews, surveys, participants observation and text analysis (Dale, Vella, & Potts, 2013).
	3.5 Knowledge storage and management system: There are strong knowledge management and sharing platforms in place, enabling effective decision making. This includes consideration that: • The creation and utilisation of knowledge is needed to promote performance of an organisation (Wen, 2009); • Knowledge assessment can be achieved by identifying knowledge holders, optimising knowledge retention and minimising knowledge loss (Ragab & Arisha, 2022)	Measurement can be guided by: • Consultations with experts (scholars, knowledge management practitioners, specialists); • Surveys to assess knowledge management; • Focus groups and or interviews (Wen, 2009); and • Literature scan and data gathering through interviews (Ragab & Arisha, 2022).

Cluster	Attribute Descriptions	Measurement Guidance
4. Operational governance: Operationally, is the system adaptive and robust enough to achieve is vision?	**4.1 Efforts deliver effective and efficient outcomes:** The Reef Plan governance system delivers the right (effective) interventions well (efficiently), delivering intended Plan outcomes. This includes consideration that: • Efficiency refers to the 'relationship between inputs and outputs in governance' (using the least amount of inputs while maximising the amount of outputs) (Dale et al., 2013a, p. 177); • Economic efficiency can be achieved when individuals' utility is maximised given the resources available (e.g., policy intervention improves community wellbeing) (Commonwealth of Australia, 2013a); • Effectiveness of the interventions developed and delivered are the right ones to achieve outcomes. Effectiveness refers to 'doing the right thing', in relation to the appropriateness or worthiness of the intervention taken to achieve meaningful outcomes (Crawford & Bryce, 2003; Dale, et al., 2013a); • Output measurements could be an indication of governance performance. Measuring governance through outcome achievement is a way to diagnose if governance systems is delivering necessary and desirable results (Rotberg, 2014); • Conformance/performance evaluation is important (Limb et al., 2021); and • Interventions are designed and selected based on their efficient return on investment.	Measurement can be guided by: • Surveys, questionnaires and interviews; • Content analysis of documents (Limb et al., 2021); • Both quantitative and qualitative measures being employed to measure efficiency (Dale, Vella, & Potts, 2013). For example, quantitative measures can be employed to measure costs (e.g., of labour, capital, and resources). Qualitative measures can be surveys to gauge governance efficiency in relation to, for example, smooth functioning of bureaucratic procedures (Huther & Shah, 2003); or social trust in institutions (Zhang & Gu, 2021); Other assessment tools examples include governance assessment tools analysing, for example: • If outputs had been adopted; • If there was strong institutional capacity to implement the outputs; and • The availability of adequate funding. Data collection can include text analysis and interviews (Haldrup, 2020), Quality of Government Expert Survey (QoG Expert Survey) and web survey gathering data on bureaucratic behaviour (Nistotskaya et al., 2020).

Cluster	Attribute Descriptions	Measurement Guidance
	4.2 Sustainability of actions taken: Reef 2050 Plan actions can be continued adaptively until they achieve their goals and targets. This includes consideration that: • Effective and efficient interventions have the long-term resourcing, commitment, and social consent necessary to enable their consistent operation; and • Sustainability of action refers to the extent to which actions taken can be sustained in the long term (Dale et al., 2013a; Grindle, 2011); can be referred to as 'sustainment' (Cooper et al., 2022; Moullin et al., 2020).	Measurement can be guided by quantitative scales, surveys and interviews (Moullin et al., 2020). Many tools exist, for example, the Program Sustainability Assessment Tool (PSAT). This explores the capacity of programs to be sustained across eight domains including environmental support, organisational capacity, and program evaluation (Hall et al., 2021; Moullin et al., 2020). The monitoring of budget and length of projects/programs against outcomes can also be a useful guide.
	4.3 Application of risk management: Risks are adequately considered and managed across scales within the design and implementation of GBR interventions. This includes consideration that: • Risk management refers to assessment and control of risks within a system (Fuller & Drawer, 2004); • Assessment is needed through the identification of emergent risks, which arise from the interaction of phenomena in a complex system (Oppenheimer et al., 2014).	Measurement can be guided by: • The application of the Australian Standard for risk management (AS ISO 31000) to assess risks to the Reef's ecosystem and natural values; • Identifying key risks by applying specific criteria including magnitude, probability, irreversibility, persistence (Oppenheimer et al., 2014); • Developing a risk inventory, develop assessment and data gathering methodology, and develop scales and scores (Hancock, 2015); and • Application of the GSA framework to assess governance risk (Dale et al., 2016a).
	4.4 Timeliness of effort taken: Interventions across the Reef 2050 Plan are timed to maximise successful goal achievement. This includes consideration that: • Timeliness of effort, which is linked to effectiveness of intervention (see above) refers to intervention delivery that is 'timely' within the intended or reasonably adjusted timeframe (OECD, 2021a).	Measurement can be guided by: • Purposive sampling for interviews with state and local government agencies, managers and non-governmental organisations; • Text analysis of available documents (Amirkhanyan, 2011); and • The application of active (forecasting) management approaches as well as reactive (monitoring).

Cluster	Attribute Descriptions	Measurement Guidance
	4.5 Adequacy of resources: Sufficient resources are allocated to enable the success of all Reef 2050 Plan interventions. This includes consideration that: • Resources refer to natural, financial, human, cultural, and social aspects of a system (Zhang & Pan, 2022); • Governance of resources refers to how well power and responsibilities are exercised over the resources in a system and how actors access and are impacted by resource management (Nunan et al., 2018); and • Resource interdependency: state power and non-state resources combined to carry out public policy (Zhang & Pan, 2022).	Measurement can be guided by asking: • How do resources work together in a system? • Whether project reviews assess inputs against outputs and outcomes; and • Whether negotiations are in place between resource owners to integrate them (Zhang & Pan, 2022). Actionable Governance Indicators (or AGI developed by the World Bank) can also be used to determine quality and level of resources to sustain performance (Erkkilä, 2016; Kaufmann & Kraay, 2007).