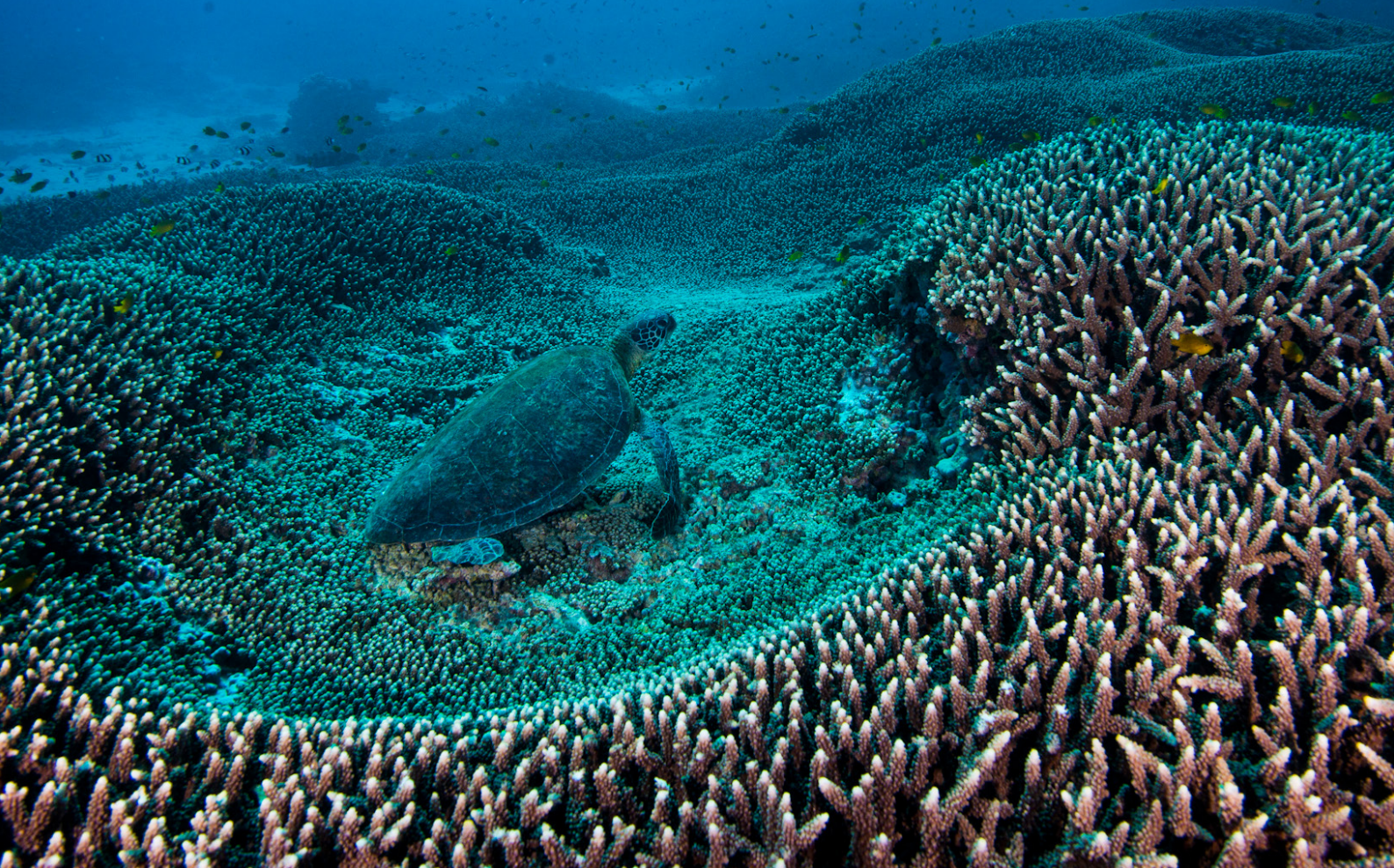


RRAP

REEF RESTORATION &
ADAPTATION PROGRAM

Governance Principles for Novel Reef Interventions



Great Barrier
Reef Foundation



Governance Principles for Novel Reef Interventions

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Marine turtle. Credit: GBRF.

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1. INTRODUCTION



Credit: Gary Cranitch, Queensland Museum.

Coral reefs are exceptionally diverse and support over 1 billion people. Coral reefs account for approximately 35% of all marine species globally,¹ and provide critical ecosystem services, including shoreline protection and food provisioning, supporting economies and livelihoods²⁻⁴. They are also important for human well-being, including spiritual and cultural connections for many Indigenous peoples and local communities⁵.

However, since 1950, global live coral cover has declined by 50%⁵. Coral reefs are being degraded by human activities, including unsustainable fishing practices and land-based pollution. Importantly, climate change poses the single greatest existential threat to these ecosystems. This includes increased sea surface temperatures that can lead to coral bleaching, ocean acidification and increases in severe weather events that further degrade reefs. Current Intergovernmental Panel on Climate Change (IPCC) projections predict that coral reefs as we now know them could mostly disappear at 2°C of warming, and up to 90% of reefs could be lost at 1.5°C warming.⁶

In the context above, restoration and adaptation are increasingly being regarded to help build coral reef resilience. Research in this area is giving rise to reef interventions based on cutting-edge science, including assisted evolution and cloud brightening (see [Section 2](#)). These *novel reef interventions* have the potential to enhance the efficiency and success of restoration and adaptation efforts^{7,8}. These new adaptation approaches are necessary compliments to (rather than substitutes for) global strategies to reduce greenhouse gas emissions.

Reef restoration and adaptation represent a paradigm shift from conventional approaches to the management and conservation of coral reefs. This is because they involve active interventions intending to help coral reefs resist, repair and recover from climate change and other human-induced impacts. Such a paradigm shift is compounded by key attributes of novel reef interventions, including radical innovation,

relatively fast development, and uncertainty concerning outcomes, risks and benefits (see [Section 2](#)). This shift presents unique challenges to conventional coral reef governance ([Box 4](#)), which was designed for traditional threats like pollution, shipping, tourism, and fishing. To address the complexities of these novel interventions, conventional governance will need to be supplemented with more innovative, participatory, flexible, adaptive, forward-thinking, and experimental approaches.

This document offers 6 principles that may assist in improving the governance of novel reef interventions. These principles, described in [Section 4](#), synthesise best practices identified in the literature on reef and marine restoration, and the governance of innovation. Such principles may better enable restoration and adaptation based on leading science and technology. Each principle is illustrated by an example from Australia's Great Barrier Reef, demonstrating their application in practice. The Great Barrier Reef is at the forefront of innovation in reef restoration and adaptation, and its established governance aligns well with the principles proposed.

This document is intended as an initial guide, offering insights into how to tailor governance to suit the unique aspects of novel reef interventions. While the examples given provide useful direction, they do not cover all possibilities. Readers are encouraged to seek further information and engage in dialogues with experts and practitioners about emerging best practices in governing reef restoration and adaptation.

The purpose of this guide is to:

1



Create awareness of the challenges regarding the governance of novel reef interventions.

2



Outline the benefits of using best practice principles and provide examples to inform governance.

3



Provide guidance to decision-makers, managers, scientists, Traditional Owners and the community.

2. NOVEL REEF INTERVENTIONS



Spawn slick capture pools at Wisteria Reef. Credit: SCU.

Reducing global greenhouse gas emissions is critical to maintaining healthy and functioning coral reefs in the face of a warming planet. However, emissions reductions alone will not be enough to prevent the continued decline of these ecosystems. Current restoration and adaptation practices are limited in their ability to safeguard coral reefs at scale, against current and anticipated impacts of climate change.⁹ The future predicted for coral reefs highlights the urgency for novel reef interventions that can build ecosystem resilience and help bridge the gap between the current, increased climate impacts and a distant future when ocean temperatures stabilise in response to reductions in emissions. In this context, a range of interventions are being explored and trialled worldwide. These include:

Cooling and shading

Interventions to prevent coral stress by reducing the heat load on waters around reefs, and methods to transfer heat away or cool water. This currently includes methods such as fogging, misting and cloud brightening.

Reproduction and recruitment

Actions that target reproduction, recruitment, and recruit survival to enhance recovery following disturbance. Methods include the seeding (or reseeded) of reefs with coral stocked from local reefs or from coral aquaculture (see [Box 1](#)).

Probiotics and enhanced bleaching survival

Interventions to reduce coral stress or enhance recovery following stress. These include the manipulation of corals' associations with symbionts to enhance performance and survival following stress, or through adaptation in temperature tolerance or other desirable traits. Methods may include feeding, inoculation, and symbiotic manipulations with beneficial microbes.


Assisted evolution

Interventions to enhance the temperature tolerance and/or other desirable traits of corals to facilitate adaptation of natural populations to environmental change. Methods include moving or breeding existing temperature-tolerant coral stock, and interbreeding coral species for enhanced vigour or conditioning through moderate stress exposure.

Synthetic biology and genetic engineering

Interventions aim to enhance the stress tolerance of the coral holobiont, or increase recovery potential following environmental disturbance. Methods that target the coral animal and its symbiotic microbial partners are included.

Novel reef interventions often present attributes of emerging technologies that distinguish them from typical past reef interventions. These new attributes, including novelty, speed of development, and uncertainty can create significant challenges to conventional governance ([Box 2](#)).



The future predicted for coral reefs highlights the urgency for novel reef interventions that can build ecosystem resilience and help bridge the gap between the current, increased climate impacts and a distant future when ocean temperatures stabilise in response to reductions in emissions.

BOX 1

Larval enhancement in the Great Barrier Reef

Larval enhancement (i.e., larval seeding/ reseeded) is currently being trialled in the Great Barrier Reef as part of the Reef Restoration and Adaptation Program (RRAP). Larval-based restoration involves collecting coral larvae, either during spawning events on the reef or from aquaculture facilities and moving them to allow larvae settlement onto damaged or degraded reefs. Larval-based restoration can increase

larval settlement and recruitment and reduce larval mortality during spawning events. There is also the potential that larval enhancement interventions could be paired with assisted evolution or synthetic biology trials in the future, such that corals with enhanced or desirable traits (e.g., thermal tolerance or improved growth) are seeded onto reefs.



BOX 2

Attributes of novel reef interventions

Radical novelty

Interventions may fulfil a given function by using a different basic principle as compared to what was used before to achieve a similar purpose (within coral reef management and conservation). This can involve repurposing existing technology for a new domain (e.g., marine cloud brightening to shade and cool reefs). Novelty may also be defined in relation to the domain in which the technology is arising (e.g., reef restoration and adaptation). Novelty can create a discrepancy between novel reef interventions and existing governance frameworks.

Relatively fast development

Emerging technologies show relatively fast growth compared to non-emerging ones. The pace of development may be gauged in relation to other technologies in the same domain, such as conventional reef interventions.

The development of emerging technologies often outpaces policy and regulatory change. This can lead to a gap where the technology has evolved beyond the scope of traditional governance.

Uncertainty and ambiguity

There is a degree of uncertainty surrounding the potential outcomes, uses, impacts, and benefits of novel reef interventions. In some cases, the impacts and benefits of emerging technologies will not be immediate but lie in the future; determining the probabilities of each potential outcome can be complex. This complexity is compounded by the lack of complete knowledge about other possible outcomes, such as unforeseen or undesirable consequences that could result from novel reef interventions¹⁰. Such uncertainty and ambiguity can make it challenging for governance to adequately cover all possible scenarios.

3. GOVERNING NOVEL REEF INTERVENTIONS



Governance includes formal and informal rules and processes, such as policies, regulations, community engagement practices, social norms and decision-making procedures that mediate our actions and decisions relating to the management and conservation of coral reefs^{11,12}.

It often involves various entities at multiple governance levels, from local to global, including individuals, community groups, Traditional Owners, reef-dependent industries, research organisations and government agencies. Governance arrangements guide societies in taking action to prevent, mitigate, and adapt to environmental change, including climate change, biodiversity loss and over-exploitation of natural resources. In this context, good governance is critical in maintaining the services provided by coral reefs to society (Box 3).

Governance frameworks are also critical in shaping the direction, location, and methods of restoration and adaptation interventions. The frameworks determine who should take responsibility, who should be involved, and who should benefit from these interventions¹³. Appropriate governance can also set up the groundwork for restoration and adaptation

by helping incorporate scientific knowledge into guidelines, organising community involvement, generating financial support, and promoting action^{14,15}. Additionally, governance frameworks can support the design and adoption of best practices, knowledge, and research in restoration and adaptation¹⁴.

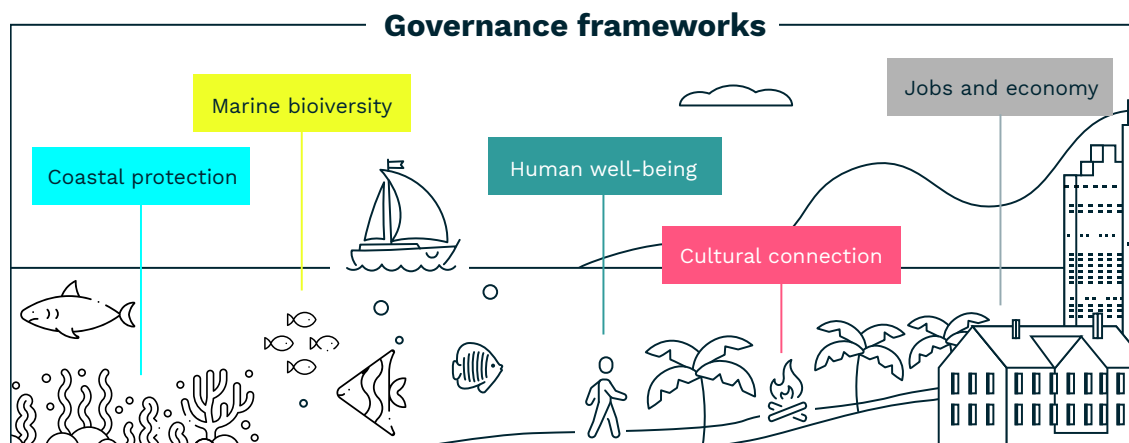
However, the governance of novel reef interventions may face multiple challenges given the paradigm shift in reef conservation and management that these interventions represent (see Section 2 and Box 4). Further challenges are associated with the nature of specific interventions, such as their radical novelty, fast pace of development and uncertainty concerning risks and benefits (see Box 2).

The principles suggested in Section 5 aim to help minimise these challenges. They emphasise adaptive, future-facing and participatory approaches to the governance of novel reef interventions.

BOX 3

Coral reef health and services depend on robust governance frameworks

Coral reefs are incredibly diverse and productive ecosystems that provide significant economic, social, cultural and biodiversity values to coastal communities around the globe. Coral reef health and good governance are inextricably linked. The array of ecosystem services provided by coral reefs are all underpinned by good governance. Governance plays a crucial role in protecting coral reef ecosystems by establishing effective policies, regulations, and management practices.



Governance challenges

Novel reef interventions often pose challenges to existing governance frameworks, including those associated with:

Uncertainty

Novel interventions may involve a high level of uncertainty given the lack of long-term data and an incomplete knowledge of potential social and environmental impacts. This uncertainty also extends to their outcomes, risks and benefits.

Missing frameworks

Tailored policy and regulatory frameworks for novel interventions may still be emerging or not yet exist. These frameworks may not have been designed to achieve net-benefit outcomes. Further, they may not incorporate counterfactuals as part of their approach.

Pace of innovation

Novel interventions can present a pacing problem, where the development of science and technology outpaces that of governance. This can create a dilemma: regulating too early may result in inappropriate regulations, while waiting for more certainty can lead to significant impacts that remain unregulated.

Novel risks and benefits

Novel interventions introduce a range of potential environmental, social, and economic risks. Some of these risks are not only hard to predict, but they might also be impossible to know before the interventions are deployed.

Governance landscape

The governance landscape for novel reef interventions is often complex and fragmented, involving numerous entities, policies, regulations and decision-making processes across multiple levels (local, national and international)¹⁶. In addition, the rapid development of both the concept and practice of such interventions suggests that current legislation and policy may hinder their appropriate consideration and development.

Expertise

Novel interventions often represent cutting-edge science. However, only a handful of agencies may have the necessary scientific knowledge to properly address these interventions. This expertise is typically concentrated within the scientific programs that develop these interventions, which complicates independent assessments.

Regulating innovation

Regulating novel interventions effectively can be difficult, as it involves striking a delicate balance. On one hand, regulations should not be so stringent that they stifle innovation. On the other hand, they should not be so permissive that they fail to effectively protect environmental, cultural, social and economic values.



Credit: Gary Cranitch, Queensland Museum.

4. GOVERNANCE PRINCIPLES

Coral spawning. Credit: Gary Cranitch, Queensland Museum.

FIGURE 1: GOVERNANCE PRINCIPLES FOR NOVEL REEF INTERVENTIONS.



The principles described in this section highlight the importance of inclusivity, adaptability, foresight, experimentation, nuanced risk assessment, and collaboration in governance (Figure 1).

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 governance.

Principle 3

Proactive forward-planning advocates for proactive approaches, such as horizon scanning and scenario planning. These can 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 novel interventions under controlled conditions. By doing so, we can better understand 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 government agencies. The complex nature of novel reef intervention governance requires a highly collaborative approach.

Principle 1

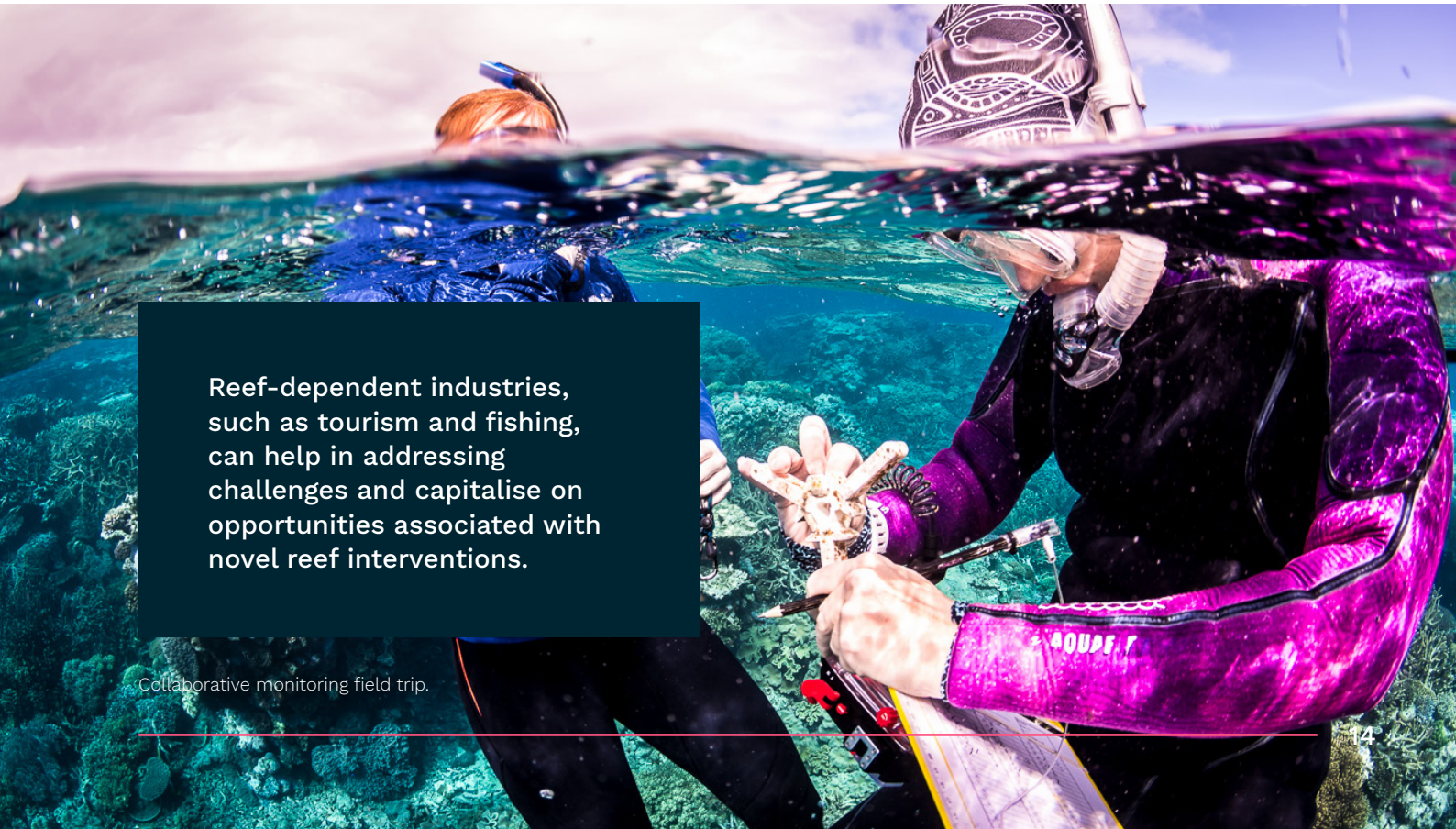
Inclusive participation

Effective participation by stakeholders and rightsholders is critical to governing novel reef interventions. This requires bringing together a diverse and inclusive group encompassing reef managers, regulatory agencies, researchers, community, reef-dependent industries, environmental groups, and, crucially, Traditional Owners.

Traditional Owners can offer valuable insights based on their deep connection to the sea country and their traditional knowledge. Traditional Owners and the general community can be involved in restoration and adaptation projects and participate in shared decision-making. In this way, they are not simply consulted, but actively involved in shaping the governance arrangements for novel reef interventions. Similarly, reef-dependent industries, such as tourism and fishing, can help in addressing challenges and capitalise on opportunities associated with novel reef interventions; research organisations and academic experts can offer insights on research into innovative restoration and adaptation science as it emerges. Overall, stakeholder and rightsholder participation can

aid in crafting appropriate governance arrangements, such as policies and regulations that are fit-for-purpose, credible, and capable of harnessing new ideas and knowledge.

In this context, various participatory strategies can be employed, such as workshops, roundtables, citizen juries, and public consultations. Open policy-making platforms also provide an opportunity for stakeholders to comment on the drafting of regulations. When expert advice is needed to inform decisions, participation can extend to expert panels or advisory committees convened to discuss specific issues or proposed governance arrangements. Participation can vary from consultation to a more collaborative process, to co-design ([Box 5](#)).

A split-level photograph showing two divers underwater. The diver on the right is wearing a black wetsuit with a purple sleeve and is holding a piece of coral. The diver on the left is wearing a blue wetsuit. They are in clear blue water above a coral reef.

Reef-dependent industries, such as tourism and fishing, can help in addressing challenges and capitalise on opportunities associated with novel reef interventions.

Regardless of the different forms of engagement that can be employed, engagement that is diverse, proactive, frequent, transparent and iterative will improve governance (Figure 2).

Diverse and inclusive

Meaningful engagement with a wide range of stakeholders, particularly with the Traditional Owners of sea country is crucial. The breadth of engagement needed stems from the wide-ranging ecological and ethical implications associated with novel reef interventions. Engagement as part of the decision-making process can help develop effective policies and regulations that directly respond to these implications. Inclusive approaches to engagement should address any previously excluded groups and create enabling conditions for their participation.

Proactive and frequent

Early engagement with stakeholders can support trust and acceptance, which is critical in situations where knowledge of novel reef interventions is limited. Proactive approach involves engaging stakeholders early, identifying and addressing their concerns, and ultimately supporting their informed decisions. Further, where implemented collaboratively (see [Principle 5](#)), engagement can support early identification of governance gaps that can then be timely addressed.

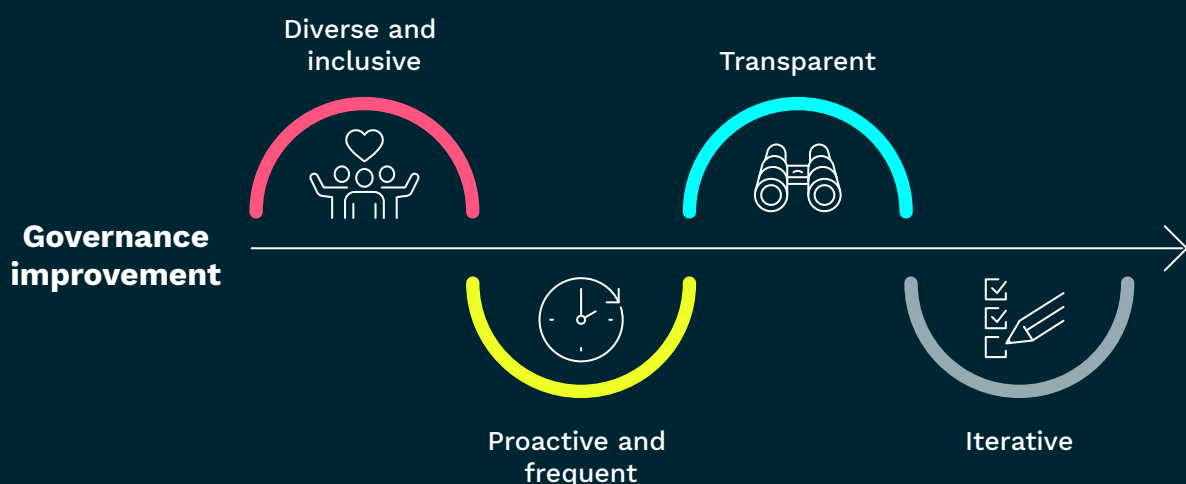
Transparent

Information regarding the development and deployment of novel reef interventions should be transparently communicated. In addition, who was involved in stakeholder engagement, how it was undertaken, issues and concerns raised, and how they might be addressed, should also be publicly available. Transparency can support an environment of trust and accountability in relation to decision-making processes for novel reef interventions.

Iterative

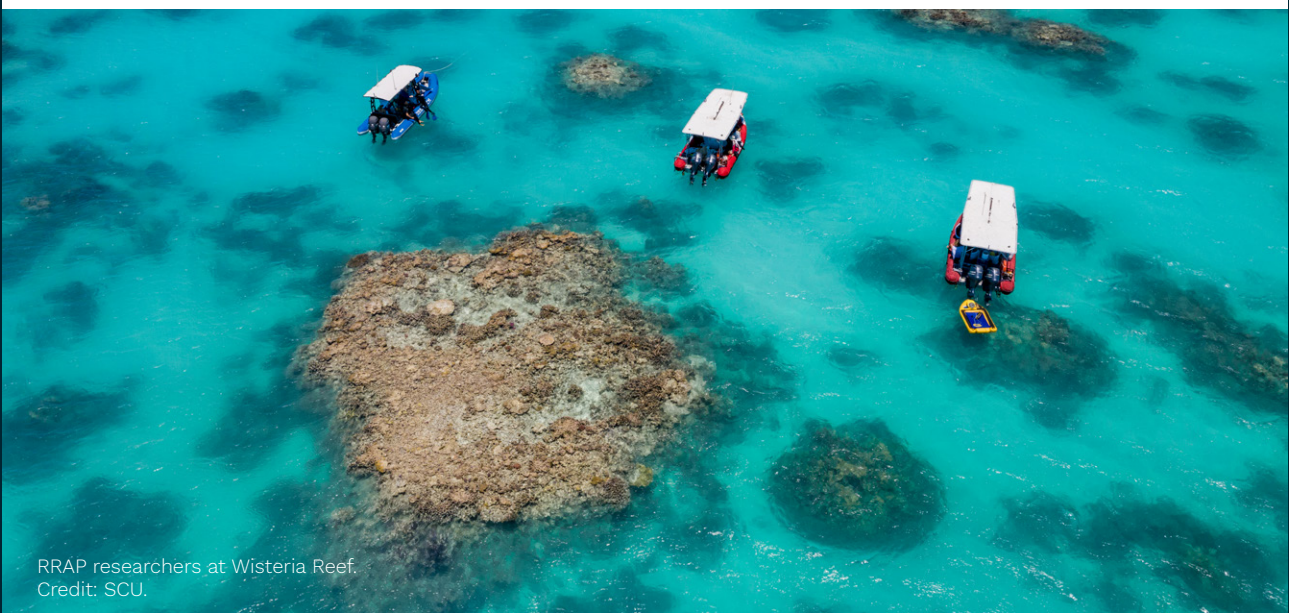
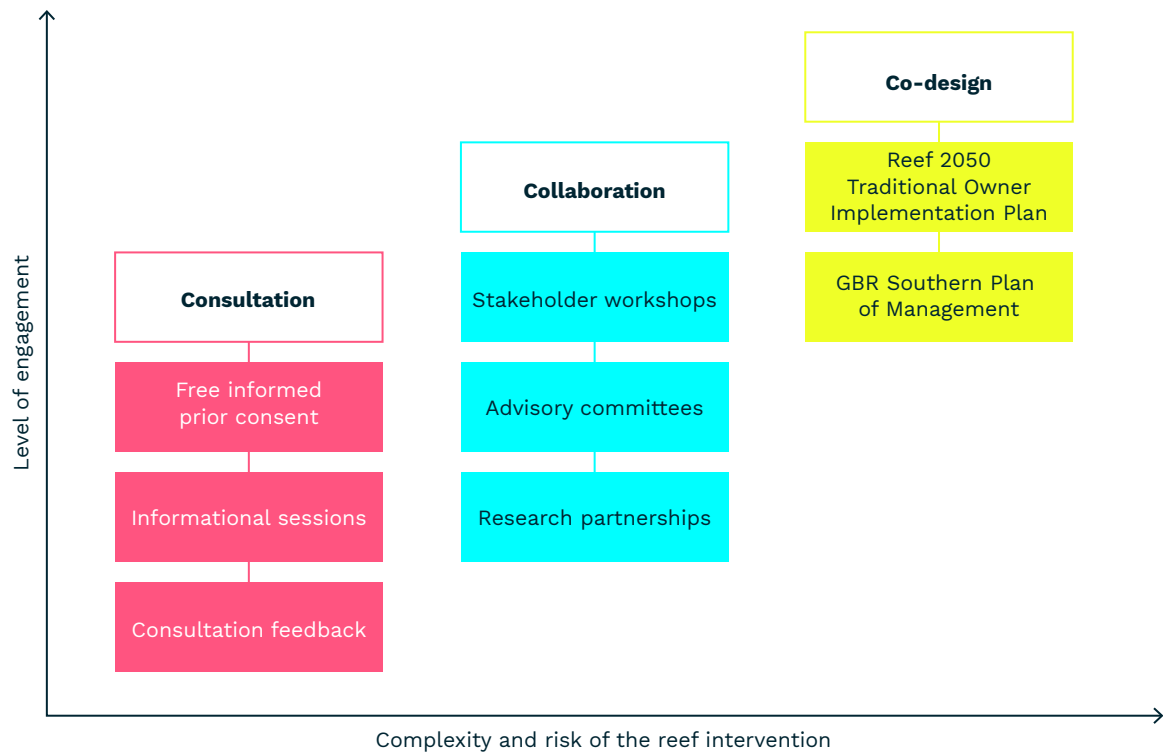
Iterative approaches to engagement may allow for meaningful involvement of relevant stakeholders and Traditional Owners in the decision-making process for novel reef interventions. This approach not only fosters a sense of ownership but may also support trust-building, where stakeholders understand how their input is being considered in governing such interventions.

FIGURE 2: STAKEHOLDER AND RIGHTSHOLDER ENGAGEMENT ATTRIBUTES FOR GOVERNING NOVEL REEF INTERVENTIONS.



Engagement in the Great Barrier Reef

The Great Barrier Reef Marine Park Authority has a long history of engagement with stakeholders and Traditional Owners. The diagram illustrates some of these forms of participation in the Great Barrier Reef. It suggests that the need for more meaningful approaches to engagement, such as collaboration and co-design, will increase as the complexity and risk of an intervention increases.



Principle 2

Flexible, responsive and adaptive

Governance should adopt a “test-and-evolve” approach, using iterative processes to address emerging issues related to novel reef interventions (see also [Principle 4](#)). This contrasts with a “solve-and-leave” approach where governance arrangements, such as policy and regulation, once established, remain unchanged.

This proposed approach is dynamic and experimental, promoting the creation of flexible arrangements that can adapt and evolve in response to the development and deployment of innovative approaches to restoration and adaptation. This is particularly relevant given, as noted previously, the novelty, uncertainty, and rapid evolution of some of the novel reef interventions currently being considered.

In this context, learning processes are critical, as it is only by learning from experiences, successes, and failures, that governance arrangements can be adjusted accordingly¹⁷. This learning-oriented approach enables proactive rather than reactive governance processes. Essentially, this ‘test-and-evolve’ approach cultivates a resilient governance environment that can keep up with scientific development and emerging challenges. It ensures that governance is not only robust but also relevant and effective in addressing the complex issues associated with novel reef interventions.

Stakeholders and rightsholders can provide valuable insights and feedback to inform adaptive governance processes. Additionally, regular reviews and updates can be instituted to ensure governance arrangements remain relevant in the face of rapidly evolving restoration and adaptation science.

Examples of flexible, responsive, and adaptive approaches to governance in terms of policy and regulation may include:

- **Guidelines** that can be amended and adapted more rapidly to keep pace with the development of novel reef interventions¹⁸.
- **Outcomes-based regulation** can create operational efficiencies for decision-makers by shifting the focus to outcomes or objectives rather than specifying how those outcomes are to be achieved¹⁹ (e.g., outcomes-based conditions guidance²⁰).
- **Continual policy and regulatory reviews** can help decision-makers respond to necessary changes as they arise, rather than undertaking reviews based on a fixed timeframe (e.g., every 5 years).
- **Staged testing and deployment** of novel reef interventions to reduce risk. This also includes responding to new information gathered during the testing and deployment of these interventions (see [Box 6](#)).
- **Codes of conduct and industry standards** can generate information on how the governance of interventions is functioning, anticipating issues as they arise and responding in a timely way.

A ‘test-and-evolve’ approach cultivates a resilient governance environment that can keep up with scientific development and emerging challenges.

Adaptive Governance in Practice

The Great Barrier Reef Marine Park Authority is committed to adaptive approaches for reef restoration and adaptation interventions, with the explicit aim of ‘enabling innovation while minimising risks from failures in this emerging area of science, technology and practice’²¹.

One key mechanism to operationalise such approaches is through staged approvals whereby low-risk interventions are initially encouraged and assessed, but these may be re-evaluated as new information becomes available. In this way, the Authority commits to using the ‘best available science and knowledge’ in providing guidance and oversight, which can be iteratively adapted based on emerging information. Higher-risk interventions will require closer assessment of risks and safeguards.

The use of guidelines is also a mechanism for best practice concerning the deployment of interventions in the Great Barrier Reef. For example, the *Guideline on Applications for restoration/adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park*, may allow decision-makers to more easily amend and respond to developments in restoration and adaptation science as they emerge without stifling innovation^{18,22}.



Principle 3

Proactive forward-planning

Future-facing approaches complement the flexible, responsive and adaptive approach proposed in [Principle 2](#). While the latter are more reactive, responding to emerging issues as they arise, future-facing approaches are proactive.

They seek to understand potential issues associated with novel reef interventions before these issues have even emerged. Such approaches involve iteratively developing strategies based on the evolving understanding of the implications of novel reef interventions for society and the environment. They also consider governance needs these implications might generate. By involving stakeholders and rightsholders ([Principle 1](#)) in foresight planning, research, and experimentation, future-facing approaches enable the early detection of areas where existing governance may be inadequate.

Several strategies can be used by decision-makers to support future-facing approaches including horizon scanning, foresight, and scenario planning. Each of them builds upon the insights gained from the previous strategy.

Horizon scanning

A strategy used to detect early signs of possible changes in the environment²³ and novel reef interventions landscape. It involves the continuous collection and interpretation of signals to monitor upcoming shifts. This is done through various methods such as data analysis, trend monitoring, and expert consultations. The purpose of horizon scanning is to identify new trends in reef interventions, which helps decision-makers prepare for future challenges and opportunities²⁴. However, the fast development pace of these interventions and the uncertainty in predicting the importance of these trends can make this process difficult. Despite these challenges, the aim is to maintain a continuous awareness of emerging changes. This awareness enables decision-makers to foresee changes before they occur, giving them valuable time to adapt and respond accordingly (see [Principle 2](#)).

Foresight exercises

May play a crucial role in shaping adaptive governance approaches for novel reef interventions. These exercises are used to visualise a spectrum of potential future scenarios. They involve a systematic approach to collecting information about current trends and possible future events²⁵. This information is then used to conceive various potential future outcomes²⁶. Techniques such as brainstorming sessions, expert consultation, and data analysis are used to pinpoint key uncertainties and potential impacts. The objective is to foresee future changes, and to prepare accordingly for them²⁷. In other words, foresight exercises enable decision-makers to proactively plan for a range of possible scenarios. Ultimately, foresight exercises are a valuable tool for anticipating and preparing for the future.

Scenario planning

A process that starts by pinpointing the key uncertainties and potential impacts associated with novel reef interventions. This leads to the creation of a set of plausible future scenarios that can be explored in detail. These scenarios can be used to prepare for uncertainty by identifying potential challenges and opportunities, and formulating strategies to respond to them²⁸. This approach ensures that governance is robust and adaptable (see [Principle 2](#)). Scenario planning also encourages innovative thinking about the future and offers a safe environment for investigating novel reef interventions. It is particularly useful in rapidly evolving areas, such as reef restoration and adaptation and often involves collaboration with stakeholders and rightsholders (see [Principle 1](#)).

Future-facing approaches, such as horizon scanning, foresight, and scenario planning have been used in the management and conservation of coral reefs. The Great Barrier Reef illustrates the case as described in [Box 7](#).

Future-facing approaches in the Great Barrier Reef

The Great Barrier Reef *Outlook Report*²⁹ is published by the Great Barrier Marine Park Authority every 5 years. It provides a comprehensive assessment of the Great Barrier Reef health, pressures, and likely future. The Outlook Report reflects the practice of horizon scanning as it continuously monitors the Great Barrier Reef to identify early signals of potential changes. It also demonstrates the use of foresight exercises by using data, including those from modelling capabilities, to envision a range of possible future scenarios and adapt management accordingly. The report uses

evidence from existing research and information across several years, making it a robust tool for preparing for various possible futures.

A prime example of future-facing approaches is the *Policy and Planning Strategic Road Map*³⁰ by the Great Barrier Reef Marine Park Authority. This Road Map serves as a guide, outlining desired future outcomes, such as 'Proactive resilience actions in place and adapted'. It further identifies the necessary policies, plans, or management strategies that need to be implemented to achieve these outcomes. Thus, it provides a path towards forward-thinking and effective action.



Corals on John Brewer Reef.
Credit: Matt Curnock, CSIRO.

Principle 4

Embrace experimentation

Experimentation can be critical in addressing the unique nature and associated challenges of novel reef interventions mentioned previously. It may involve testing interventions under controlled conditions or experimenting with new governance approaches. Such approaches should support learning from the different strategies and promote adaptive governance as the science of restoration and adaptation progresses.

Approaches that allow for experimentation include³¹:

Controlled testing

While it is challenging to create controlled conditions in open systems like coral reefs, this could involve selecting specific areas for testing new interventions, while closely monitoring the surrounding reefs to understand the broader impacts.

Performance-based regulation

Focuses on the outcomes of an intervention rather than how it is achieved. For instance, an agency might stipulate a certain level of coral health or biodiversity that must be maintained, allowing the relevant parties to develop the most effective methods to achieve these goals.

Co-governance

Given the complex and interconnected nature of coral reefs, co-governance involving multiple stakeholders may be considered. This approach ensures a broad range of perspectives and expertise are considered in the decision-making process, which can lead to more effective and holistic solutions (see [Principle 1](#)).

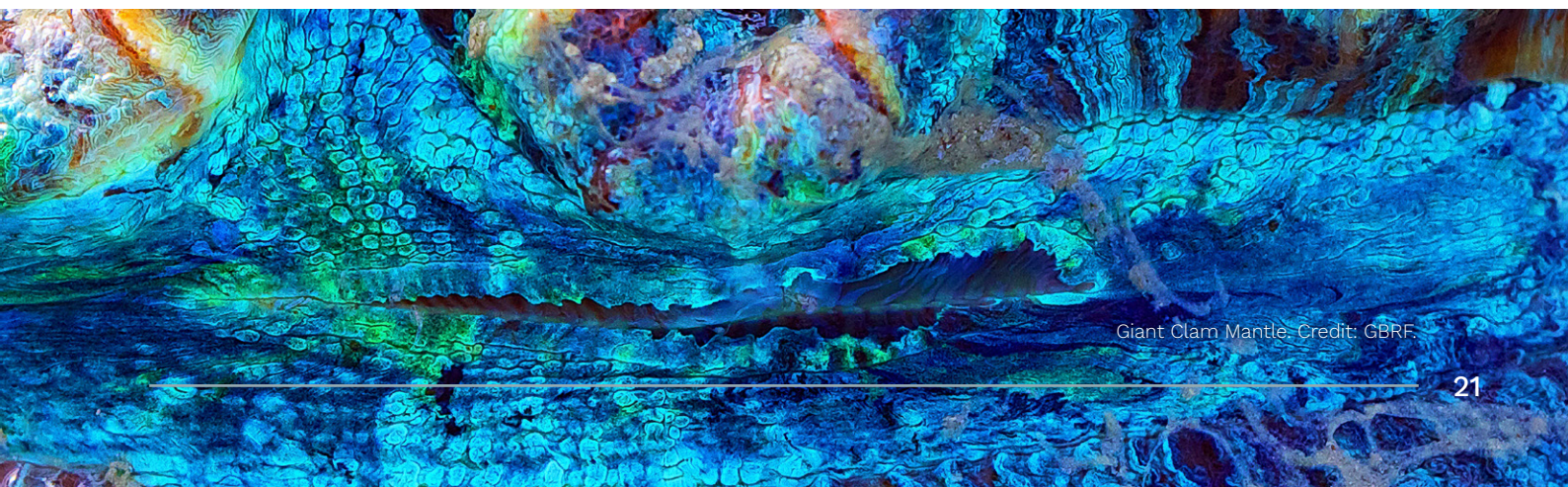
Adaptive approach

Given the dynamic nature of coral reefs and the rapid pace of scientific innovation, it is crucial that governance can adapt over time³². This involves regularly reviewing existing governance arrangements based on the latest developments in restoration and adaptation science (see [Principle 2](#)).

Regulatory sandboxes

A regulatory sandbox is a controlled environment set up with regulators, which allows the testing of innovative practices under special regulatory conditions³³. It allows for experimentation and learning, allowing scientists to assess the viability of interventions while simultaneously allowing decision-makers to monitor and evaluate potential risks and impacts. While common in the financial and business sectors, a similar model is being tested in the Great Barrier Reef (see [Box 8](#)).

Considering the varied scale and complexity of novel reef interventions, the implications of their testing and deployment can differ significantly. Therefore, it is likely that a combination of the approaches outlined above may be needed. This multi-faceted approach may help address both existing and potential governance gaps.



Giant Clam Mantle. Credit: GBRF.

Experimentation in the Great Barrier Reef

A staged approach to reef interventions and the use of a tailored risk assessment process can allow experimentation to occur in the Great Barrier Reef safely and effectively. For example, an intervention may be considered medium or high risk but may still be allowed; however, pilot studies and proof-of-concept are likely to be required before testing these interventions on the Reef. Initial, small-scale pilot studies may be conducted to evaluate feasibility, potential impacts, and gain important knowledge before full-scale deployment of an intervention. This could be part of a broader proof-of-concept assessment, regarding the feasibility of larger-scale implementation within the Reef.^{1,2}

The use of regulatory sandboxes also provides a mechanism for regulators to allow some experimentation. Regulatory sandboxes allow the opportunity to obtain evidence-based insights into potential risks to better inform regulatory frameworks. Currently, the ‘ReefWorks’ project—a partnership between the Australian Institute of Marine Sciences (AIMS), The Queensland Government, the Australian Maritime Safety Authority (AMSA), and the Department of Defence—has been granted regulatory sandbox approval to conduct an inshore test range near Townsville in the Great Barrier Reef. This approval allows for the testing of autonomous marine systems without the need to apply for complex permits and other approvals³⁴.



Reefworks project. Credit: Marie Roman.

Principle 5

Nuanced risk assessment

There exists a degree of uncertainty and ambiguity concerning the risks and benefits of novel reef interventions (see [Box 4](#)). This is compounded by the unpredictability of future climate conditions and how such interventions may work under such conditions. A significant challenge lies in determining whether traditional risk assessment approaches can adequately capture the distinct aspects of these novel reef interventions.

Risk assessments were traditionally developed to prevent the impacts of conventional activities on coral reefs, including fishing, tourism and pollution. These approaches typically rely on a relatively thorough understanding of risks associated with a proposed activity, usually excluding the analysis of benefits³⁵, such as ecological and biodiversity gains. However, conventional risk assessment approaches may prove limited³⁶ in assessing those novel reef interventions intended to produce benefits (positive impacts).

In this context, a complementary and more nuanced approach to assessing risks and benefits may be required to address these issues. Such approach could draw on concepts and tools, such as the notion of novel ecosystems and cost-benefit analysis.

Novel ecosystems or hybrid ecosystems, where some ecosystem functions persist, but species have changed relative to historical baselines, are becoming increasingly prevalent. This concept involves a shift in the perception of environmental values and their benefits. It implies adopting goals that prioritise maintaining ecological functions over preserving specific species or ecological communities³⁷. This approach could help address the limitations of conventional risk assessment by providing a complementary and more flexible and adaptive approach (see [Principle 2](#)). Focusing on ecological functions rather than specific species allows for a broader and more dynamic understanding of risks and benefits. This could be particularly useful in the face of high levels of uncertainty and rapid environmental change.

Environmental cost-benefit analysis (CBA) is a tool that can be applied to projects or policies aimed at environmental improvement or actions that indirectly affect the natural environment. This analytical tool requires an understanding of the costs (e.g., reductions in human well-being) in comparison to the benefits (e.g., increases in human well-being). It involves aggregating different environmental and social benefits and costs relative to the timing of an impact³⁸. CBA could help address some of the limitations concerning conventional risk assessment. By providing a more comprehensive view of both the costs and benefits, CBA allows for a more balanced and informed decision-making process. This could be particularly beneficial when dealing with situations characterised by high levels of uncertainty, where traditional risk assessments may fall short³⁸.

Alternative strategies could involve engaging stakeholders and rightsholders in risk assessments, which allows for incorporating diverse sources of information, such as local and traditional knowledge (see [Principle 1](#)). This may be particularly relevant in the initial development stages of novel reef interventions, when quantitative risk assessment data may be incomplete or limited.³⁹ Additional expert insights could help better characterise and balance the risks, benefits, costs, and societal and environmental implications of such interventions ([Box 9](#)).

The Intervention Risk Review Group (IRRG)

The development and deployment of novel reef interventions in the Great Barrier Reef requires a better understanding of the potential risks that those interventions might pose. Under the auspices of the Reef Restoration and Adaptation Program (RRAP), an Intervention Risk Review Group (IRRG) was formed to develop a holistic approach to understanding and evaluating risk. The IRRG is an independent and interdisciplinary panel of experts, tasked with familiarising themselves with the developing interventions, identifying potential risks and knowledge gaps, and providing expert advice on how to address them⁴⁰.

The use of independent, expert advisors is a best practice example of identifying and considering risks. The IRRG allows RRAP to feasibly consider a range of risks based on diverse backgrounds, experience and expertise, enabling the identification and evaluation of risk and uncertainties that may otherwise not be apparent. It also provides scientists, managers and decision-makers and opportunity to discuss and learn from experts, and to integrate expert advice into intervention development and decision-making.



Principle 6

Inter-agency collaboration

The governance landscape for reef restoration and adaptation is often complex, involving multiple agencies with responsibilities over different reef-related areas (e.g., fishing, tourism, biodiversity, world heritage and protected areas) at various levels (local, provincial, national and international). This landscape may be further complicated by jurisdictional fragmentation and overlaps. A single intervention might, therefore, need to meet multiple requirements under different guidelines, standards, policies and regulations. Such complexity can potentially cause delays in the development and deployment of novel reef interventions⁴¹ (Figure 3).

When multiple agencies are responsible for managing or regulating a particular reef intervention, collaboration becomes crucial. Collaboration can help identify and address issues such as fragmentation and duplication in approaches, inconsistencies in managing reef-related activities, and gaps in existing policy and regulatory frameworks. It also offers a platform for agencies to gain insights from each other's practices and standards. Moreover, collaborative approaches enable a coordinated response to challenges and opportunities associated with interventions that extend over multiple jurisdictions (see [Box 10](#)).

When reefs extend beyond jurisdictional or national boundaries, it becomes necessary for agencies from different countries to work together to address transnational implications. This can pave the way for establishing international standards and regulations, providing a consistent framework to ensure that novel interventions are safe and effective, irrespective of their place of development or deployment. International collaboration can also encourage knowledge exchange, promote best

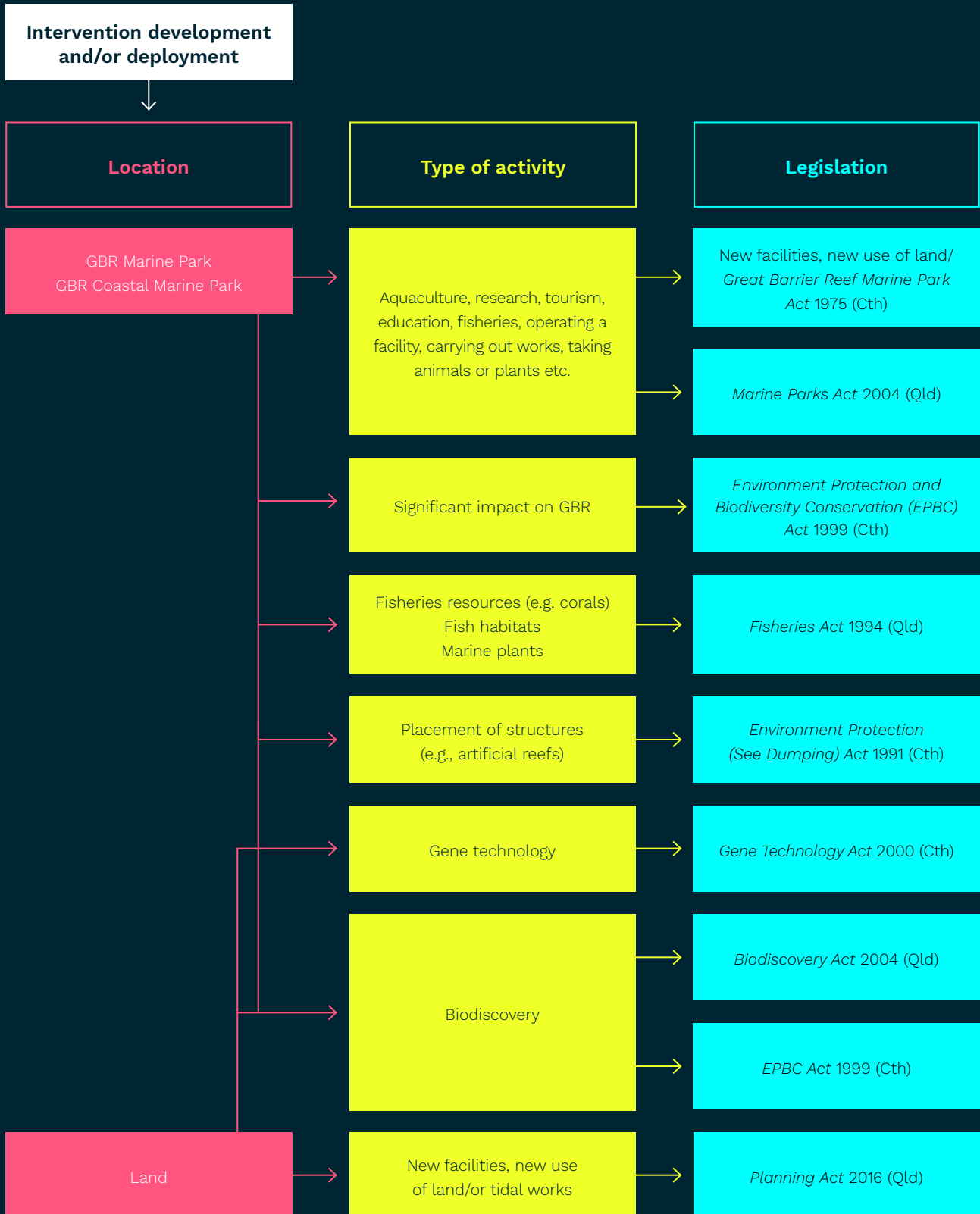
practices, and foster an international culture of jointly addressing restoration and adaptation. Ultimately, it can contribute to the responsible development and deployment of novel reef interventions beyond national borders.⁴²

Collaboration between government agencies and organisations responsible for the research and development of novel reef interventions is also important. This can assist reef managers and regulators better understand emerging issues related to innovative approaches to restoration and adaptation, and formulate appropriate governance responses. As such organisations are at the forefront of restoration and adaptation science, they can offer direct insights into the practical aspects of novel reef interventions. Close collaboration with research organisations can also ensure that the development and deployment of interventions align with regulatory standards, fostering an environment of responsible innovation. Similarly, collaboration with stakeholders and rightsholders can improve novel reef interventions governance (See [Principles 1](#) and [2](#)).

Collaboration between government agencies and organisations responsible for the research and development of novel reef interventions is also important.

Cryopreservation Fertilisation.
Credit: Dorian Tsai, QUT.

FIGURE 3: EXAMPLES OF KEY REGULATORY REQUIREMENTS FOR REEF RESTORATION AND ADAPTATION IN THE GREAT BARRIER REEF ACCORDING TO LOCATION AND TYPE OF ACTIVITY ASSOCIATED WITH THE INTERVENTION.⁴¹



Cross-agency collaboration in the Great Barrier Reef

Since 2022, agencies responsible for the Great Barrier Reef have been taking part in a “GBR Regulators Forum”, which is coordinated by the Reef Restoration and Adaptation Program (RRAP). It brings together representatives from various agencies, including the Great Barrier Reef Marine Park Authority, Queensland Department of Agriculture and Fisheries, Biosecurity Queensland, Queensland Department of Environment, Science and Innovation, and the Department of Climate Change, Energy, the Environment and Water.

The Forum serves as a platform where agencies can learn from researchers who are investigating novel reef interventions. It also provides an opportunity for these agencies to share updates

and discuss their respective strategies and challenges related to addressing novel reef interventions.

In addition to facilitating the exchange of information and experiences, inter-agency collaboration helps establish links between agencies that might not have been connected before. For instance, one Forum included the participation of the Australian Pesticides and Veterinary Medicines Authority, an agency not typically associated with reef regulation. This participation acknowledges that novel reef interventions might include semiochemicals to control Crown-of-Thorn starfish, which fall under the regulatory purview of such Authority.



Moving Corals Field Trip.
Credit: SCU.

5. IMPLEMENTATION IN PRACTICE



Research teams begin to release larvae from floating pools. Credit: SCU.

The principles in Section 4 offer guidance for improving the governance of novel reef interventions, emphasising engagement, flexibility, forward-thinking, experimentation, nuanced risk assessment, and collaboration. However, actualising these principles necessitates sufficient capacity and resources, and high-level support from senior levels of management.

Human resources

The principles suggest a range of associated activities that require dedicated personnel. These activities include engaging with stakeholders and rightsholders, collaborating across agencies, gathering and analysing data for risk assessments, foresight exercises, and scenario planning. Therefore, it is crucial to ensure that the teams are adequately staffed and resourced. This may involve hiring new employees with specific expertise, and/or reallocating staff time and responsibilities to prioritise these activities.

New skill sets

The implementation of governance principles for novel reef interventions necessitates the development of new skill sets. These include technical skills related to the interventions being considered, and skills in areas such as stakeholder and rightsholder engagement, risk assessment, and future and system thinking. It is important to foster a culture of continuous learning and adaptation within the agencies involved. This can ensure that the teams are equipped to navigate the complexities of implementing these governance principles in practice.

Funding


Operationalising the governance principles requires adequate financial commitment. Funding is necessary to support the associated activities, including hiring and training additional staff, as mentioned in “Human resources”, and developing new skill sets as outlined

in “New skill sets”. Therefore, securing adequate funding is a critical aspect of implementing these principles. This could involve exploring various funding sources, such as government grants, private sector investments, philanthropy, and international aid.

Innovation

Implementing the governance principles for novel reef interventions requires innovative approaches. This is not just about having the necessary human resources, funding, and new skill sets, but also changing how organisations operate. The principles call for organisations to be more proactive, experimental, and open to doing things differently. This means anticipating and responding to future changes, testing and evaluating new approaches to management and policy, and fostering a culture where new ideas are encouraged and failures are seen as opportunities for learning and improvement. These innovative approaches are not just beneficial but essential for the successful implementation of the governance principles.

In sum, the operationalisation of these governance principles hinges on the availability of human, financial, and technical resources, as well as the adoption of innovative approaches. These elements are fundamental to the successful implementation of the principles. They empower decision-makers, stakeholders and rightsholders to effectively navigate the governance challenges associated with novel reef interventions.



Fostering a culture where new ideas are encouraged and failures are seen as opportunities for learning and improvement.

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