



Reef Restoration and Adaptation Program

T2: REGULATORY ASSESSMENT FINDINGS

A report provided to the Australian Government by the Reef Restoration and Adaptation Program

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1. PREAMBLE

The Great Barrier Reef

Visible from outer space, the Great Barrier Reef is the world's largest living structure and one of the seven natural wonders of the world, with more than 600 coral species and 1600 types of fish. The Reef is of deep cultural value and an important part of Australia's national identity. It underpins industries such as tourism and fishing, contributing more than \$6B a year to the economy and supporting an estimated 64,000 jobs.

Why does the Reef need help?

Despite being one of the best-managed coral reef ecosystems in the world, there is broad scientific consensus that the long-term survival of the Great Barrier Reef is under threat from climate change. This includes increasing sea temperatures leading to coral bleaching, ocean acidification and increasingly frequent and severe weather events. In addition to strong global action to reduce carbon emissions and continued management of local pressures, bold action is needed. Important decisions need to be made about priorities and acceptable risk. Resulting actions must be understood and co-designed by Traditional Owners, Reef stakeholders and the broader community.

What is the Reef Restoration and Adaptation Program?

The Reef Restoration and Adaptation Program (RRAP) is a collaboration of Australia's leading experts aiming to create a suite of innovative and targeted measures to help preserve and restore the Great Barrier Reef. These interventions must have strong potential for positive impact, be socially and culturally acceptable, ecologically sound, ethical and financially responsible. They would be implemented if, when and where it is decided action is needed and only after rigorous assessment and testing.

RRAP is the largest, most comprehensive program of its type in the world; a collaboration of leading experts in reef ecology, water and land management, engineering, innovation and social sciences, drawing on the full breadth of Australian expertise and that from around the world. It aims to strike a balance between minimising risk and maximising opportunity to save Reef species and values.

RRAP is working with Traditional Owners and groups with a stake in the Reef as well as the general public to discuss why these actions are needed and to better understand how these groups see the risks and benefits of proposed interventions. This will help inform planning and prioritisation to ensure the proposed actions meet community expectations.

Coral bleaching is a global issue. The resulting reef restoration technology could be shared for use in other coral reefs worldwide, helping to build Australia's international reputation for innovation.

The \$6M RRAP Concept Feasibility Study identified and prioritised research and development to begin from 2019. The Australian Government allocated a further \$100M for reef restoration and adaptation science as part of the \$443.3M Reef Trust Partnership, through the Great Barrier Reef Foundation, announced in the 2018 Budget. This funding, over five years, will build on the work of the concept feasibility study. RRAP is being progressed by a partnership that includes the Australian Institute of Marine Science, CSIRO, the Great Barrier Reef Foundation, James Cook University, The University of Queensland, Queensland University of Technology, the Great Barrier Reef Marine Park Authority as well as researchers and experts from other organisations.

2. EXECUTIVE SUMMARY

The feasibility and viability of interventions to preserve and restore the Great Barrier Reef will depend, to a large extent, on the regulatory environment in which they are developed and deployed. Such environment influences what, where and how to restore, who should be responsible for, engaged in, and benefit from reef restoration and adaptation. The regulatory environment may enable preconditions of restoration, such as codifying scientific knowledge into restoration standards, structuring process for community participation, mobilising financial resources and incentivising action. Further, regulation may facilitate and support agencies and enterprises responsible for developing and implementing restoration best practice, knowledge and research. Conversely, a complex, multi-jurisdictional regulatory environment may adversely affect restoration and create confusion and conflict among stakeholders, if it lacks mechanisms for evaluating restoration success and fails to provide regulatory guidance. In sum, regulation may significantly affect restoration both positively and adversely. In this context, the objectives of this study were to:

1. Establish a systematic approach to identify and account for the regulatory issues of interventions (mapping of the current regulatory environment);
2. Interrogate RRAP interventions in-depth to identify the suite of direct (and potentially indirect) regulatory issues that arise; and
3. Provide preliminary advice to RRAP project leaders in relation to:
 - Potential regulatory or legal issues for RRAP interventions;
 - Capacity challenges in relation to initial implementation, as well as longer term monitoring and evaluation of interventions over time; and
 - Areas to focus on for 2019 and beyond.

The regulatory environment of the Reef consists of an intricate network of regulatory arrangements (international agreements, domestic laws, policies, plans and decision-making processes), and entities (e.g. government agencies, industry, environmental groups and scientists) spanning multiple levels (from local to international).

Activities in the Great Barrier Reef Marine Park and Great Barrier Reef Coastal Marine Park are regulated by multiple agencies mostly at federal and state government levels. As a result, a single RRAP intervention may require several permits from different regulators depending on where it is deployed, and the nature of the activities involved. Any intervention within the Marine Park (including those in the airspace up to 915m above the Marine Park) necessarily requires a permit under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth) and/or *Marine Parks Act 2004* (Queensland). Some interventions may require additional approval under other legislation, for instance:

- Interventions that may cause a significant impact on the environment of the Marine Park or other matters of national environmental significance require assessment under the *Environment Protection and Biodiversity Act 1999* (Commonwealth);
- Interventions involving fishery resources (including corals) and activities interfering with fish habitats and marine plants and algae may require permission under the *Fisheries Act 1994* (Commonwealth);
- Interventions involving placement of structures (e.g. artificial reefs) in the marine environment require assessment under the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth);

- Interventions involving genetic engineering may require permission under the *Gene Technology Act 2000* (Commonwealth);
- Interventions involving biodiscovery research, such as the analysis of molecular, biochemical or genetic information about native biological material for the purpose of commercialising the material may be regulated under the *Environment Protection and Biodiversity Act 1999* (Commonwealth) and *Biodiscovery Act 2004* (Queensland); and,
- Interventions involving a new use of land or construction of new facilities, or those involving tidal works as defined in the *Coastal Protection and Management Act 1995* (Queensland) may require approval under the *Planning Act 2016* (Queensland).

The Great Barrier Reef regulatory system is robust, but it may not be entirely fit for purpose for some of the interventions proposed by RRAP. This system, as it relates to RRAP interventions, is rather complex and fragmented. At the very least, this complexity combined with the likely increase in volume of activities requiring permits on the Reef in the coming years, may result in delays in the development and deployment of RRAP interventions.

RRAP interventions involving novel technologies may prove particularly challenging to the existing regulatory system. These technologies involve novel risks and impacts and, in some cases, a high level of uncertainty. For instance, currently, neither laws or agencies regulating impacts on the Reef nor laws or the agency regulating gene technology specifically address or have experience and expertise in assessing interventions that aim to enhance heat tolerance in corals using genetic manipulation.

Given the scale of RRAP funding, mechanisms to promote accountability and transparency should be fundamental considerations for the delivery of RRAP. RRAP researchers and project proponents will need to ensure there is a 'clear line of sight' to, and associated evidence in support of, the positive impact of their science and social responsibility for the Reef.

As the lead agency with responsibility for implementing the *Great Barrier Reef Marine Park Act 1975* (Commonwealth), the Great Barrier Reef Marine Park Authority needs to be sufficiently resourced as to be able to continue to provide robust regulatory oversight over the full range of activities undertaken in the Reef. RRAP will necessarily involve (1) more permit applications to the authority, and thus an associated increase in the volume of work for Authority staff, (2) the introduction of new un-tested science and technology, which will change the nature of assessments undertaken and the skills required to do assessments well.

Nine practical mechanisms are proposed below, which will collectively improve the regulatory system itself, and the accountability and capacity of key agencies and RRAP researchers to support the successful implementation of RRAP projects in the coming years:

1. Identify opportunities and adopt measures for enabling the permission system to better support reef restoration and adaptation. These include measures to reduce fragmentation and duplication (e.g. joint permit arrangements, clarification of certain definitions in the regulations, and development of joint policy positions), and options for developing policy and regulatory innovation and 'whole-of-government' reef restoration policy.
2. Establish a public register with all application and reporting documents related to funded projects (subject to strict exemptions for commercial-in-confidence documents) to ensure stakeholders are aware of, and can be engaged in discussions about, RRAP

interventions. This process would also ensure subsequent project proponents can learn from the successful permitting of previous proponents.

3. Require annual (or biennial) performance audits to publicly report on the integrity and cost-effectiveness of RRAP expenditure.
4. Expand the assessment criteria for the selection of RRAP interventions to include explicit mention of Reef 2050 indicators and outcomes, to ensure compatibility between RRAP and the overarching policy framework for protection of the Reef.
5. Design and deliver training modules for RRAP researchers, to ensure they are fully aware of the regulatory environment pertaining to the Reef, including reference to the *Gene Technology Act 2000* (Commonwealth) for those scientists working in the bio-engineering domain.
6. Undertake a thorough assessment of the Great Barrier Reef Marine Park Authority's capacity to deal with the increases in permitting that RRAP (and other investments) will demand, including with respect to the skills and training needs of authority staff.
7. Facilitate further cooperation between the Great Barrier Reef Marine Park Authority, the Office of the Gene Technology Regulator and other relevant regulators, with expert input from RRAP researchers, to kick-start discussions around the introduction of RRAP interventions that might trigger the *Gene Technology Act 2000* (Commonwealth).

We are also of the view that the 'ground breaker' nature of RRAP presents an opportunity for Australia to share lessons with other countries – good and bad – from its experience. In particular, the regulatory, institutional and governance challenges experienced on the Reef are likely to be replicated in multiple locations internationally as the science is adopted elsewhere. As such, we recommend RRAP:

8. Explore possibilities to extend existing networks to explicitly engage with other relevant reef restoration and adaptation actors over the coming six years, and
9. Develop a series of accessible and bespoke guidelines highlighting the decision-support process, stakeholder engagement and regulatory implications of a coral reef restoration and adaptation agenda (domestic and international)

Such an approach was pursued in the mid-2000s when Australia's national water policy reforms were of keen interest to governments in Africa, Asia, the United States, South America and Europe.

3. INTRODUCTION, BACKGROUND AND OBJECTIVES

The feasibility and viability of interventions to preserve and restore the Great Barrier Reef will depend, to a large extent, on the regulatory environment in which they are developed and deployed. In this report, **regulatory environment** refers to the regulations and the entities involved in their development, implementation and compliance. **Regulations** (or regulatory arrangements) broadly refer to laws, policies, plans and agreements relevant to different aspects of reef restoration. These could be at the local, state or federal level, or they may pertain to obligations under international law, for example the World Heritage Convention. **Entities** include in addition to government agencies (which are primarily responsible for development and

implementation of regulations), industry, community, Traditional Owners and environmental groups, which may participate in such development and implementation; but which must comply with the regulation. The regulatory environment plays a key role by determining what, where and how to restore, who should be responsible for, engaged in, and benefit from reef restoration and adaptation (Mansourian 2017a). The regulatory environment may enable preconditions of restoration, such as codifying scientific knowledge into restoration standards, structuring process for community participation, mobilising financial resources and incentivising action (Aronson et al. 2011; Richardson 2016). Further, regulation may facilitate and support agencies and enterprises responsible for developing and implementing restoration best practice, knowledge and research (Aronson et al. 2011). Conversely, a complex, multi-jurisdictional regulatory environment may adversely affect restoration and create confusion and conflict among stakeholders, if it lacks mechanisms for evaluating restoration success and fails to provide regulatory guidance. In sum, regulation may significantly affect restoration both positively and negatively (Mansourian 2017b).

Further, much of the work on regulatory implications of ecological restoration has been limited to the terrestrial domain (Aronson et al. 2011; Mansourian 2016). The present study extends the focus of the scholarship on regulation for ecological restoration to the marine domain. In addition, it adds to a growing debate on the use of emerging technologies for conservation (e.g. Redford et al. 2014; van Oppen et al. 2017), where the regulatory implications of these technologies are yet to be adequately addressed.

In the context above, the objectives of this study were to:

1. Establish a systematic approach to identify and account for regulatory issues of RRAP interventions (mapping of the current regulatory environment);
2. Interrogate a suite of interventions to identify direct (and potentially indirect) issues relating to the regulatory environment that arise; and
3. Provide preliminary advice in relation to:
 - Potential regulatory or legal issues for RRAP interventions;
 - Capacity challenges in relation to initial implementation and longer-term monitoring and evaluation of interventions over time; and
 - Areas to focus on for 2019 and beyond.

This study aimed, ultimately, to provide advice on:

- The extent to which the existing regulatory arrangements are sufficiently robust as to be able to assess the environmental and/or social implications of RAAP interventions now and over time.
- Where regulatory arrangements may be unnecessarily obstructive and/or redundant, or where regulatory uncertainty or confusion exists.
- Where regulatory arrangements may need to be reformed or supplemented to account for new activities in the Reef, which are currently not covered in existing arrangements.
- The extent to which existing regulatory arrangements are 'fit for purpose', insomuch as the supporting organisational, administrative and governing architecture relating to the Reef has sufficient power, capacity, and resources to ensure compliance with these arrangements, and to ensure they are reviewed and revised to account for new knowledge as and when it arises.

4. METHODS

This study drew on multiple sources of evidence (e.g. documents, focus groups and interviews), following standard protocols for qualitative research (Miles and Huberman 1994; Patton 2002). A **desktop review** of relevant legislation, policy documents and study reports was undertaken to develop a comprehensive ‘map’ of the regulatory environment of the Reef. Sources of documents for the review included legislation databases, such as the Queensland Legislation Website (www.legislation.qld.gov.au), Federal Register of Legislation (www.legislation.gov.au) and Australasian Legal Information Institute (www.austlii.edu.au), and government agencies websites (e.g. the Great Barrier Reef Marine Park Authority and Office of the Gene Technology Regulator). Drawing on the method developed in Ekstrom and Young (2009) and employed in Fidelman and Ekstrom (2012), network graphs – produced with NodeXL (Smith et al. 2010) – were used to depict the regulatory environment of the Reef. This method produced easy and quick access to baseline information on regulatory arrangements relating to the protection and management of the Reef. It also assisted in the identification of key clusters and relations between these arrangements.

Interviews and **workshops** were used to gain additional information on the regulatory environment and validate the mapping of such environment. Interviewees and workshop participants included staff from key federal and state agencies, with expertise in the regulatory environment of the Reef. Interviews and workshops including RRAP scientists were used to attain a better understanding of the proposed interventions (Table 1), with respect to their nature, likely evolution over time, the initial and on-going management requirements for their success, and the extent to which they were captured under existing regulatory arrangements (see Appendix B). Based on the key regulatory requirements established in section 5.2 (Figure 5), RRAP interventions were then examined in terms of the likely regulatory requirements for their development and deployment in the Reef.

Limitations

This report is intended for use by RRAP project leaders, including the Great Barrier Reef Foundation, AIMS and the Great Barrier Reef Marine Park Authority, to guide them on regulatory implications of RRAP interventions. However, it does not constitute legal advice on the regulatory requirements for any particular intervention or project within RRAP. It is inherently difficult to advise on approval requirements without knowing the exact nature and location of the proposed activity. What laws apply to any activity depends on many factors including:

- The nature of the activity (e.g. building a permanent structure);
- Its level of impact (e.g. more than negligible);
- What is impacted (e.g. activities that impacts on matters of national environmental significance);
- Where it is done or where the impacts occur (e.g. in different zones within the Marine Park); and
- Who is doing it (e.g. many laws apply differently to governments)?

Beyond possibly providing proponents of projects under RRAP with general checklists of matters to consider (e.g. biosecurity, workplace health and safety, etc.), caution should be exercised in

giving specific advice to proponents on regulatory requirements for their projects due to the potential for liability to arise in relation to such advice.

Table 1: Types of reef restoration and adaptation interventions considered within RRAP.

-
- A. **Cooling and shading** – Interventions aim to prevent coral stress by reducing the heat load on waters around reefs and methods to transfer heat away or cool water. This includes methods of pumping and shading including surface films and cloud brightening.
 - B. **Reef structures and stabilisation** – Methods that aim to enhance recovery through the addition of physical devices /processes designed to modify the reef structure. Examples include artificial reef surfaces and approaches to stabilise rubble.
 - C. **Reproduction and recruitment** - Actions that target reproduction, recruitment, and recruit survival to enhance recovery following disturbance. Methods include the reseeded of reefs with local coral stock.
 - D. **Biocontrol** – Non-coral focused interventions to enhance the recovery of reefs by maintaining health using bio-control approaches. Methods include reducing coral predation or competitors such as macro-algae.
 - E. **Probiotics and enhanced bleaching survival** - Interventions that aim to prevent coral stress or enhance recovery following stress. Interventions include the manipulation of corals' associations with eukaryotes, prokaryotes, fungi or viruses to enhance the performance and survival following stress or through adaptation in temperature tolerance or other desirable traits. Methods include feeding, inoculation and symbiotic manipulations with beneficial microbes.
 - F. **Assisted evolution** – Interventions that aim 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, interbreeding coral species for enhanced vigour or conditioning through sub-lethal stress exposure.
 - G. **Synthetic biology and genetic engineering** – Interventions aim to enhance the stress tolerance of the coral holobiont, or recovery potential following environmental disturbance. Methods that target the coral animal and its symbiotic microbial partners are included.
-

Source: RRAP (<http://gbrrestoration.org/>).

5. SUMMARY OF FINDINGS

5.1 Regulatory environment

The Reef regulatory environment consists of an intricate network of arrangements (international treaties, domestic laws, policies, plans and decision-making processes) and entities (government agencies, industry, environmental groups and scientists) spanning multiple levels (from local to international), as depicted in Figure 1. 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 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.

These four layers are directly or indirectly linked to each other by intricate regulatory arrangements, forming clusters (Figure 1). Further, they entail complex jurisdictional configurations across the land-marine profile (Figure 2).

Two clusters stand out in the regulatory environment: one at the Australian Government level, where regulatory arrangements are linked to the authority and Department of the Environment and Energy; another at the state government level, where these arrangements are linked to the Department of Environment and Science and Department of Agriculture and Fisheries. These clusters represent the key entities and arrangements involved in the protection and management of the Reef:

Australian Government (cluster)

The Great Barrier Reef Marine Park Authority, an independent statutory authority of the Australian Government, has primary responsibility over the Great Barrier Reef Marine Park (Figure 3). However, under an intergovernmental agreement, it shares the responsibility for day-to-day planning and management of activities (including compliance) within the Marine Park with relevant Queensland Government agencies.

The authority administers the *Great Barrier Reef Marine Park Act 1975* (Commonwealth), under which a multiple-use zoning system¹ and a permit system are in place. The permit system entails joint permit assessments and approvals by the authority and Queensland Parks and Wildlife Service when proposed activities involve both jurisdictions. The authority has in place several plans of management (e.g. Cairns Area Plan of Management), policies (tourism, protected species and environmental), strategies (e.g. for biodiversity conservation and climate change adaptation), guidelines (e.g. on coral transplantation), position statements (e.g. on the translocation of species within the Marine Park) and site-specific management arrangements (e.g. Lady Elliot Island and Reef) (Appendix C). Further, it manages 21 Commonwealth islands within the Reef.

¹ See Great Barrier Reef Marine Park Zoning Plan 2003 at http://www.gbrmpa.gov.au/_data/assets/pdf_file/0015/3390/GBRMPA-zoning-plan-2003.pdf

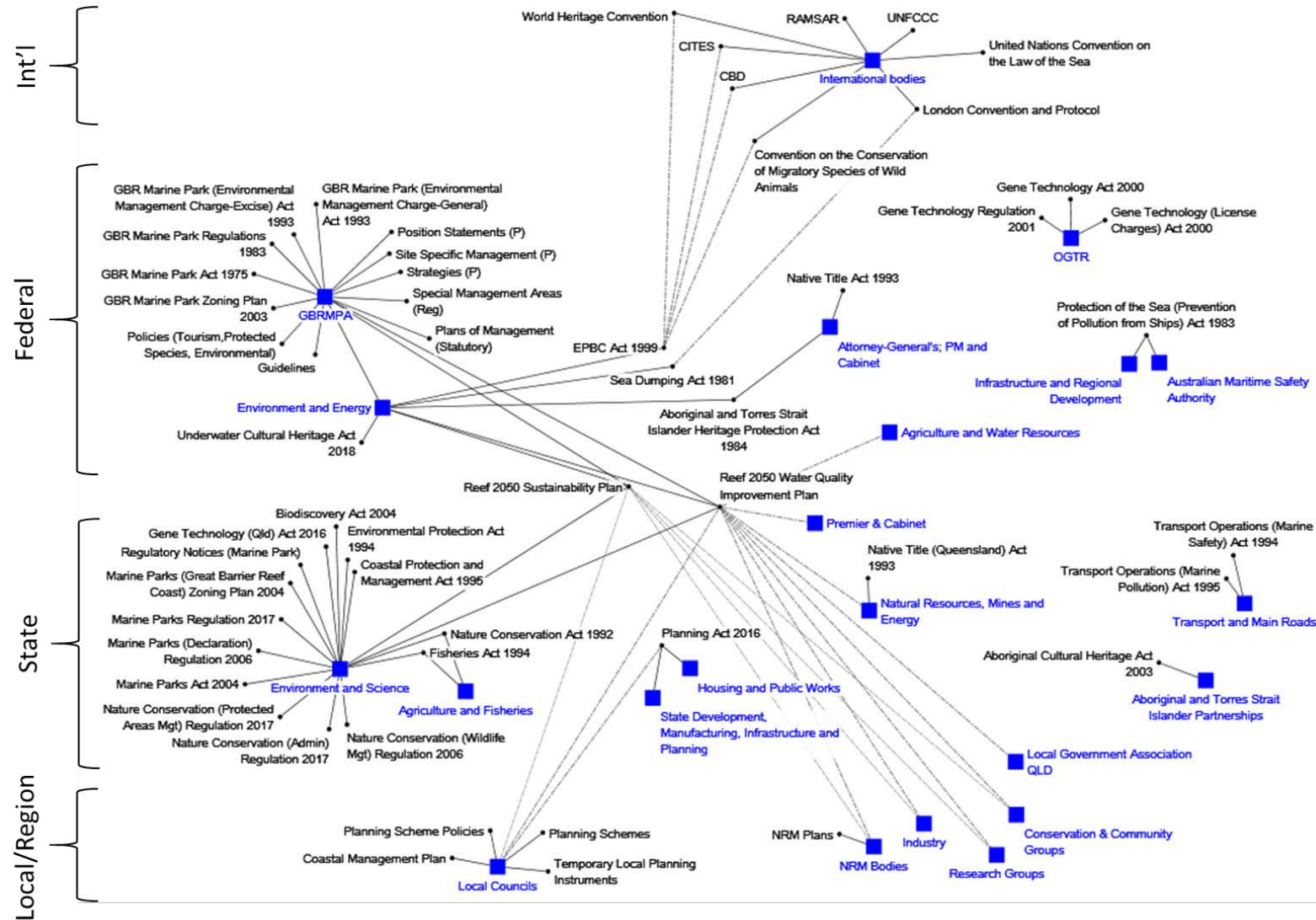


Figure 1: Key elements of the Great Barrier Reef regulatory environment

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).

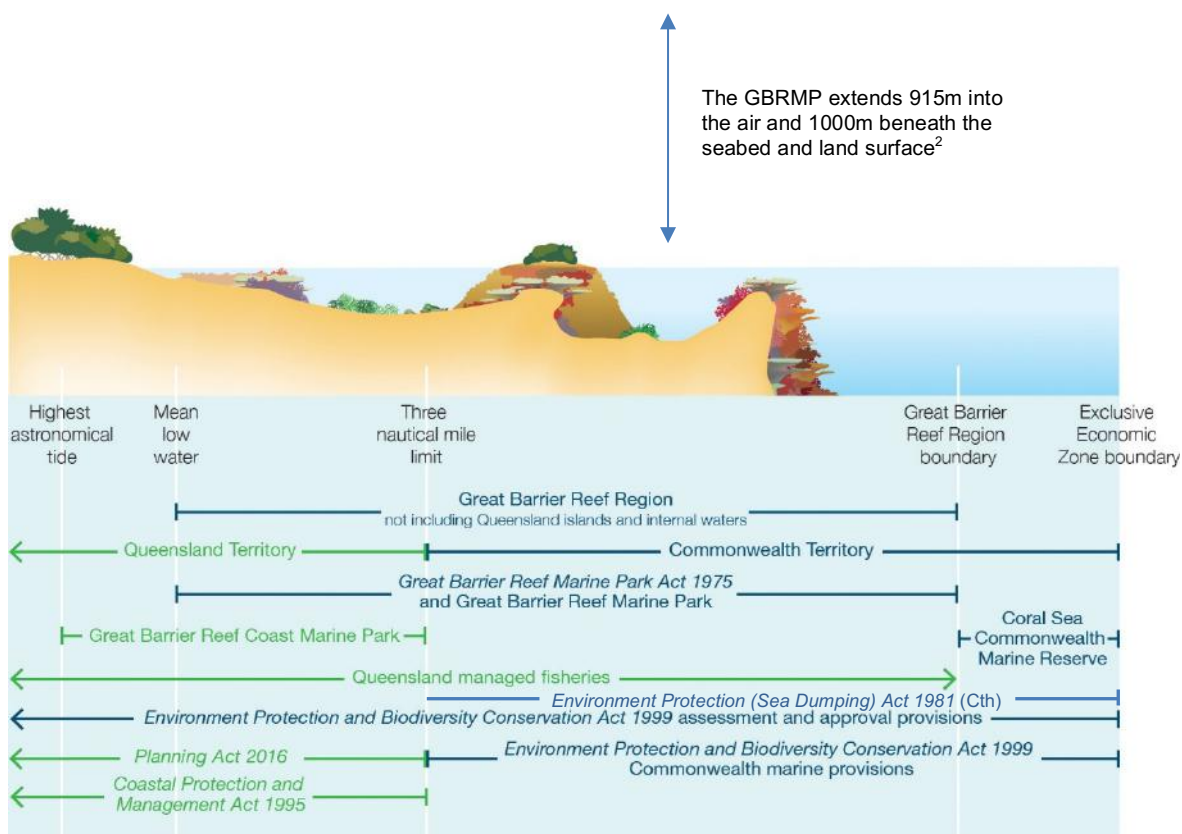


Figure 2: A summary of the complex jurisdictional boundaries in the Great Barrier Reef (adapted from GBRMPA 2014a)²

The Department of the Environment and Energy – under which the Great Barrier Reef Marine Park Authority operates – administers the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth), which regulates new development both within and outside the Great Barrier Reef World Heritage Area (Figure 4) likely to significantly impact on the environment on the Reef, outstanding universal value of the world heritage area, or other matters of national environmental significance, such as listed threatened species. The department also administers the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth), which may be relevant to RRAP projects that involve installing structures, including artificial reefs, outside the three nautical mile State limit³. In addition, the department is the principal federal government department responsible for the Reef 2050 Plan, released by the Australian and Queensland governments in March 2015 as the overarching framework for protecting and managing the Reef until 2050⁴.

² The extent of the GBRMP into the air and beneath the seabed was proclaimed under s 31 of the GBRMP Act by the *Great Barrier Reef (Declaration of Amalgamated Marine Park Area) Proclamation 2004* (Commonwealth).

³ See <http://www.environment.gov.au/topics/marine/marine-pollution/sea-dumping/sea-installations>

⁴ See <http://www.environment.gov.au/marine/gbr>

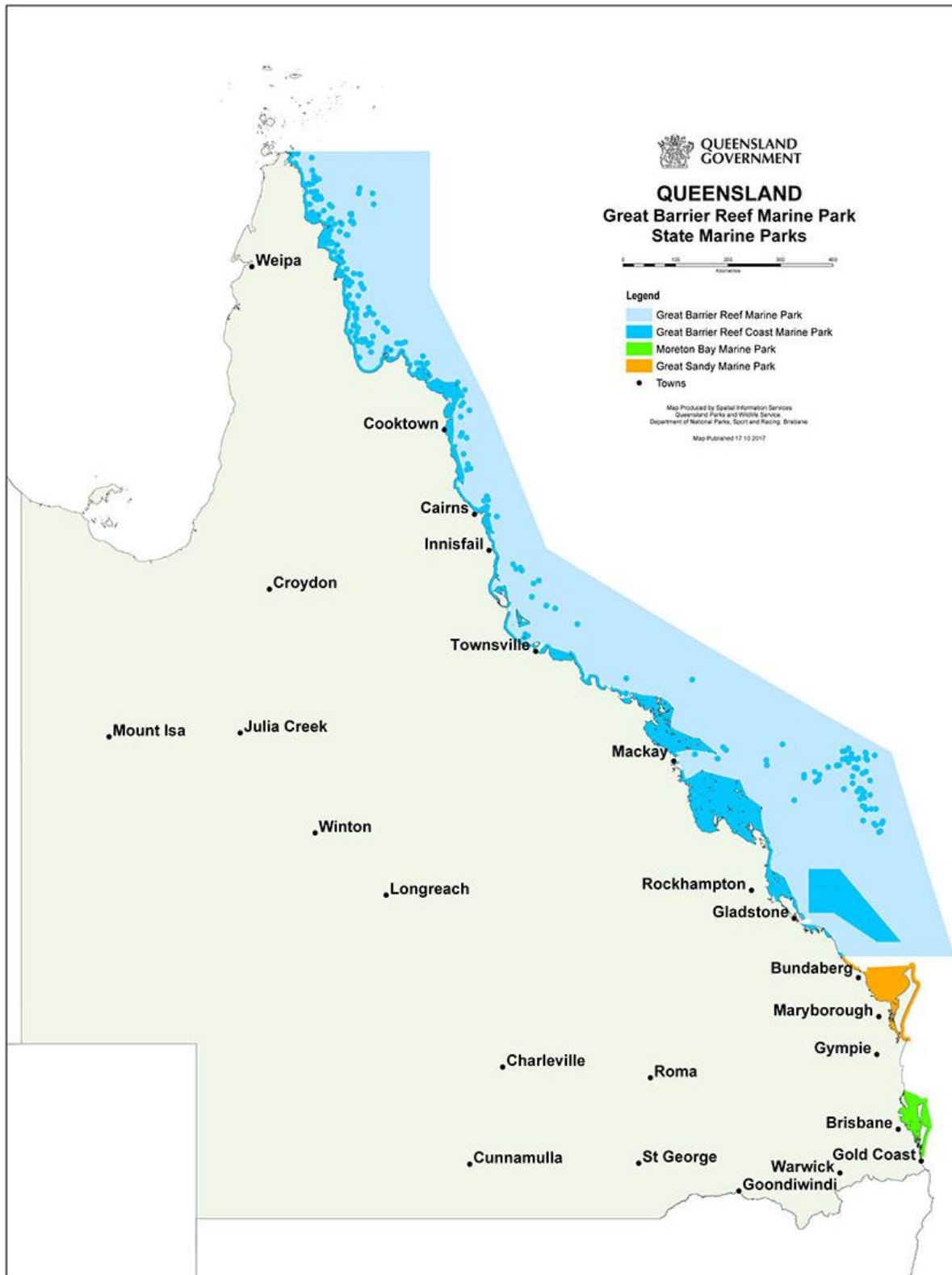


Figure 3: Great Barrier Reef Marine Park (Commonwealth) and Great Barrier Reef Coast Marine Park (State).

Note that the area in light blue is exclusively in the Great Barrier Reef Marine Park. The Marine Park and Great Barrier Reef Coast Marine Park overlap in the area in dark blue. Only the (generally small area) between mean low water and highest astronomical tide is exclusively in the Great Barrier Reef Coast Marine Park.

Reef Restoration and Adaptation Program, a partnership



Figure 4: The boundaries of the Great Barrier Reef World Heritage Area as inscribed on the World Heritage List under the *World Heritage Convention* and those of the Great Barrier Reef Marine Park (the Great Barrier Reef Marine Park Authority 2014b)

Reef Restoration and Adaptation Program, a partnership

State government (cluster)

At the state level, the Department of Environment and Science is the principal Queensland Government agency with portfolio responsibilities directly relevant to the protection and management of the Reef. It administers the *Marine Parks Act 2004*, which establishes the Great Barrier Reef (Coastal) Marine Park⁵ (Figure 2). Within the Department of Environment and Science, Queensland Parks and Wildlife Service has responsibility for the management of the Great Barrier Reef (Coastal) Marine Park. Queensland Parks and Wildlife Service and the Great Barrier Reef Marine Park Authority, through a joint field management program, deliver surveillance, compliance and enforcement activities under the *Marine Parks Act 2004* (Queensland) and *Great Barrier Reef Marine Park Act 1975* (Commonwealth). The Department of Environment and Science also includes the Office of the Great Barrier Reef and has an important role in implementing the Reef 2050 Plan and Reef 2050 Water Quality Improvement Plan⁶.

Department of Agriculture and Fisheries is the state government agency responsible for fisheries management on the Reef under the *Fisheries Act 1994* (Queensland). Within Department of Agriculture and Fisheries, the Queensland Boating and Fisheries Patrol (QBFP) has responsibility for enforcing fisheries laws.

Associated with the state government cluster is a less prominent – nevertheless important – local government cluster (Figure 1). Within the Reef catchment, 39 local governments have a major role in planning for development, particularly, on land. In this regard, they are responsible for planning schemes, which regulate development (other than mining and petroleum activities) within their local government areas. Further, local governments are the assessment manager under the *Planning Act 2016* (Queensland) (addressed below) for “prescribed tidal works”,⁷ such as the installation of pontoons within 50 m of the shore adjacent to a local government area.

Other relevant regulatory arrangements at federal and state levels outside the clusters described above (e.g. the *Gene Technology Act 2000* (Commonwealth) and *Planning Act 2016* (Queensland)) are addressed below, in Section 5.2.

International agreements (cluster)

While the Commonwealth and state governments are the most important for regulating activities on the Reef, several international agreements form a cluster that warrants special attention (Figure 1). Many international agreements, as well as the United Nations Sustainable Development Goals, are relevant to the Reef; but, are unlikely to trigger any specific legal obligations in relation to RRAP (see Appendix D).

In Australia, obligations under international agreements are given effect overall through national and state laws. For example, the Environment Protection and Biodiversity

⁵ The Great Barrier Reef Coastal Marine Park runs the full length of the Commonwealth Great Barrier Reef Marine Park, providing protection for Queensland tidal lands and tidal waters.

⁶ See <https://www.reefplan.qld.gov.au>

⁷ Defined in s 15 of the *Coastal Protection and Management Regulation 2017* (Queensland). See generally the code for prescribed tidal works available at https://www.ehp.qld.gov.au/coastal/development/tidal-land/prescribed_tidal_works.html

Conservation Act contains provisions that underpin compliance with the *Convention on Biological Diversity*, *Convention on International Trade in Endangered Species of Wild Fauna and Flora* and the *World Heritage Convention*. Similarly, the *Environment Protection (Sea Dumping) Act 1981* gives effect to the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention and Protocol). Most importantly in the context of RRAP, section 88Q(n) of the *Great Barrier Reef Marine Park Regulations 1983* requires the authority to consider any relevant international agreement to which Australia is a party when assessing permit applications for activities within the Marine Park.

In the context above, the *World Heritage Convention* is the preeminent international treaty in relation to the Reef. The outstanding universal value of the Great Barrier Reef World Heritage Area (Figure 4) is recognised and protected by its inscription on the World Heritage List under this convention. Under the World Heritage Convention, the World Heritage Committee plays an international oversight and assistance role. Despite not being directly involved in the day-to-day planning and management of activities within or affecting the Great Barrier Reef World Heritage Area, the Committee's decisions and recommendations can significantly affect the governance of the World Heritage Area⁸. In accordance with the *Operational Guidelines for the Implementation of the World Heritage Convention* (UNESCO 2017), the Australian Government regularly informs the Committee of development that may impact on the outstanding universal value of the Reef.

5.2 Accounting for regulatory requirements

This section presents an approach to account for regulatory requirements likely to apply to RRAP interventions, under the current legal framework (Appendix E). RRAP interventions may involve different such requirements depending, primarily, on if they occur: (1) within the Marine Park/Coastal Marine Park and/or on land, and (2) the nature of the activities associated with the interventions (Figure 5).

Many activities within the Marine Park, including those in the airspace up to 915m above the Marine Park, require approval under the *Great Barrier Reef Marine Park Act 1975* (Table 2). Activities may be prohibited or managed differently in different zones (e.g. fishing is prohibited in a marine park (green) zone) (Appendix F).

⁸ At its 2012 meeting the Committee expressed its concern at the unprecedented scale of coastal development proposed within and affecting the World Heritage Area. This led to substantial action by the Australian and Queensland Governments to address the Committee's concerns, including undertaking a strategic assessment of development adjacent to the World Heritage Area and adjacent coastal zone.

Table 2: Summary of activities requiring approval within the Great Barrier Reef Marine Park

-
- Aquaculture operations
 - Harvest and development fisheries
 - Research (other than limited impact research)
 - Tourism programs and developments
 - Educational programs (other than limited impact educational programs)
 - Vessel or aircraft charter operations
 - Navigating a managed vessel or aircraft
 - Operating a facility, including:
 - Discharging waste from a facility
 - Installation, operation and decommissioning of a facility
 - Moorings
 - Operating a landing area or a facility for aircraft
 - Carrying out works, including:
 - Dredging
 - Dumping of spoil
 - Reclamation
 - Beach protection works
 - Harbour works
 - Taking animals and plants that pose a threat to human life or safety, marine ecosystems of the Marine Park or use or amenity of a part of the zone or adjacent area.
-

Source: Great Barrier Reef Marine Park Authority (2004).

The *Great Barrier Reef Marine Park Regulations* 1983 (Commonwealth) establish the statutory requirements for applications and the assessment process for permissions. Overall, permit applications are assessed in terms of the nature and scale of the activities proposed and the acceptability of these activities on the environment. The permission assessment and decision process involve four broad phases; they are (Great Barrier Reef Marine Park Authority 2014b):

1. **Scoping phase** involves discussion about the initial concept and design of a proposed intervention and associated regulatory requirements (this may include such requirements from other government agencies);
2. **Assessment phase** considers the requirements of the permission system, i.e. criteria outlined in the *Great Barrier Reef Marine Park Regulations* 1983 (Commonwealth) and relevant Great Barrier Reef Marine Park Act and Environment Protection and Biodiversity Conservation Act guidance material. It includes procedural steps to assess risks (Table 3);
3. **Decision phase** involves deciding if a permission is granted or refused based on the information considered in the assessment phase; and
4. The **Audit and compliance phase** involves monitoring of permitted interventions against permit conditions. Compliance action may be pursued when such conditions are not met.

Table 3: Procedural steps for assessing risks.

Establish the context:

- What permission type?
- What activities?

Identify the risks:

- Hazards associated with each activity
- Factors - what has been proposed?
- Values that may be affected
- Risk event -sensitivity and exposure

Analyse the risks:

- Consequence -What is the worst-case impact?
- Likelihood - What is the probability and/or frequency of the risk event happening?
- Risk level - Consequence x Likelihood matrix

Evaluate the risks:

- Can the risk be accepted, or does it need further avoidance or mitigation?

Treat the risks:

- Avoid
 - Mitigate
 - Offset
-

Source: Great Barrier Reef Marine Park Authority and Queensland Government (2017).

The *Great Barrier Reef Zoning Plan 2003* and Plans of Management determine which and where activities are permitted on the Reef. For example, it is unlikely that intervention activities would be permitted in a Preservation (Pink) Zone. Further, as noted previously, the authority has in place various policies, agreements, position statements, strategies and guidelines relating to the Reef management (Appendix C). These are, depending on the activity proposed, taken into consideration during the assessment of permit applications. For example, Indigenous Land Use Agreement; interventions in areas where Indigenous Land Use Agreement applies, would be subjected to the terms of these agreements. Further, under the *Native Title Act 1993* (Commonwealth), the authority is responsible for notifying native title holders or claimants in relation to areas that will be affected by proposed permissions (Great Barrier Reef Marine Park Authority 2017). Another example is the *Guidelines for permit applications for restoration/adaptation projects to improve resilience of habitats in the Great Barrier Reef Marine Park* (Great Barrier Reef Marine Park Authority 2018), which refer to many of RRAP interventions. These guidelines provide an indication of the regulatory requirements and assessment approach to be adopted as part of the permission system. These are addressed below in Section 5.3.

As noted previously, interventions involving both Australian and Queensland jurisdictions would require a joint permit issued by the authority and Queensland Parks and Wildlife Service under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth) and the *Marine Parks Act 2004* (Queensland). In this case, the authority leads the processing of applications and the preparation of decision documentation. However, responsibility is shared between the authority and Queensland Parks and Wildlife Service at various stages (Great Barrier Reef Marine Park Authority 2014b).

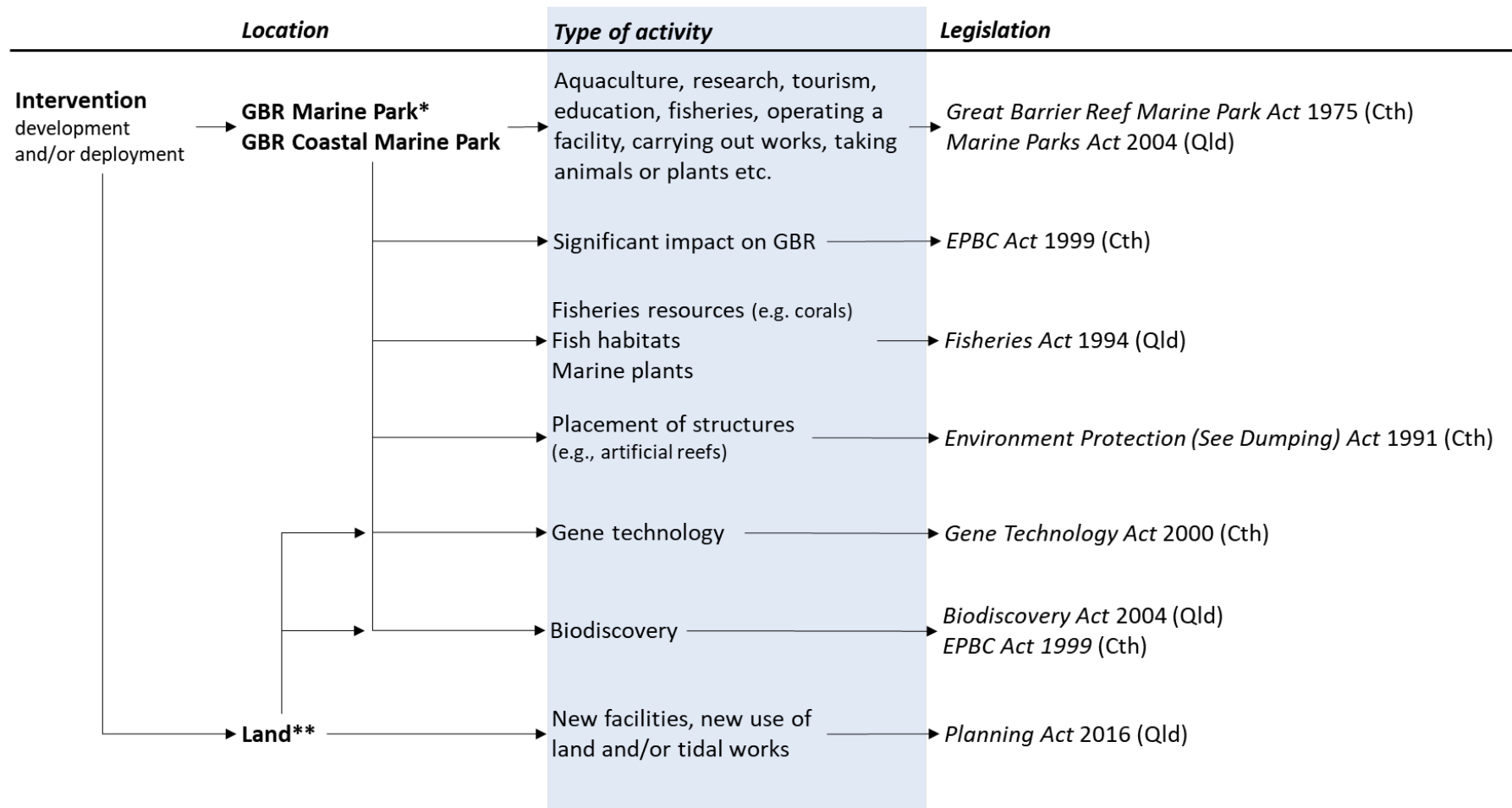
Certain interventions would require additional assessment and approval under other regulations, for instance:

- Interventions that may cause a significant impact⁹ on the environment of the Marine Park or other *matters of national environmental significance* requires assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). Current arrangements between the Great Barrier Reef Marine Park Authority and the Department of the Environment and Energy provide for a referral under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) to be considered as a permit application under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth);
- Interventions involving fishery resources (including corals) and activities interfering with fish habitats and marine plants and algae would require permission under the *Fisheries Act 1994* (Queensland). More specifically, the harvest of corals in State waters may trigger this Act;
- Interventions involving placement of structures (e.g. artificial reefs) in the Marine Park would require assessment under the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth). the Great Barrier Reef Marine Park Authority is delegate for this Act when it applies in the Marine Park.;
- Interventions involving genetic engineering requires permission under the *Gene Technology Act 2000* (Commonwealth);
- Interventions involving biodiscovery research, such as the analysis of molecular, biochemical or genetic information about native biological material for the purpose of commercialising the material is regulated under the *Biodiscovery Act 2004* (Queensland)¹⁰ and *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (Part 8 of the *Environment Protection and Biodiversity Conservation Regulations 2000*). Arrangements between the authority and the Department of the Environment and Energy provides for the authority to regulate access to biological resources under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth); however, the Department of the Environment and Energy deals with benefit sharing agreements; and
- Interventions involving a new use of land or construction of new facilities, or those involving tidal works as defined in the *Coastal Protection and Management Act 1995* (Queensland) may require approval under the *Planning Act 2016* (Queensland).

In addition, workplace health and safety aspects of RRAP interventions are generally regulated under the *Work Health and Safety Act 2011* (Queensland). RRAP interventions must, therefore, comply with all work, health and safety obligations.

⁹ For the purposes of the Act, a significant impact is defined as "...an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts".

¹⁰ See <https://www.ehp.qld.gov.au/licences-permits/plants-animals/biodiscovery.html>



* Includes air component < 915m of altitude; ** Includes coastal islands; EPBC: Environment Protection and Biodiversity Conservation

Figure 5: Examples of key regulatory requirements for RRAP interventions according to location of intervention and type of activity associated with the intervention

5.3 Regulatory implications of RRAP

This section examines the likely regulatory requirements of RAAP interventions (Table 1, Appendix H). For each of the interventions, the likely regulatory requirements for their development and deployment on the Reef is broadly considered by employing the approach described above (Figure 5).

The interventions examined feature different levels of regulatory complexity. Surface films and misting involve regulatory requirements mostly under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth); on the other hand, genetic engineering involve several such requirements under multiple Acts (Table 4). These are summarised below.

5.3.1 General (cross-cutting) implications

As would be the case with many activities to be undertaken within the Marine Park and/or in the Marine Coastal Park, all RRAP interventions require, under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth), a permit issued by the Great Barrier Reef Marine Park Authority, or a permit jointly issued by the authority and Queensland Parks and Wildlife Service (under the *Marine Parks Act 2004* (Queensland)) if these are deployed in areas involving both jurisdictions.

Further, the Great Barrier Reef Marine Park Authority guidelines for *permit applications for restoration/adaptation projects to improve resilience habitats in the Great Barrier Reef Marine Park* establish different levels of risk (low to high risk) to different reef interventions (Great Barrier Reef Marine Park Authority 2018). These would apply to RRAP interventions, as follows (Table 4):

Low risk interventions

- **Algal removal** using mechanical means; the introduction of biological control mechanisms for algal removal may be regarded as **high risk**
- **Rubble stabilisation**; however, substrate stabilisation using mineral accretion may be regarded as **medium risk**
- **Larval seeding** involving local scale larval collection and distribution within the same reef complex. It may be regarded as **high risk** if larvae are cultured through an aquaculture process and selected to have enhanced heat tolerance or other desirable traits.
- **Coral transplantation** within the same reef complex; translocation between reefs are considered as **medium risk**; translocation based on the propagation/cultivation of corals in aquaculture facilities may be regarded as **high risk**, particularly, if propagation/cultivation involves trading to entities doing reef restoration projects in the marine Park

Medium risk interventions

- **Surface films**
- **Artificial reefs** <20m²; medium (>50m²) and large (>100m²) are considered as **high risk**
- **Assisted gene flow** within the same species

High risk interventions

- **Cloud brightening**
- **Misting**
- **Mixing and pumping**
- **Symbiont manipulation** to reduce coral disease using coral microbiota as probiotics or through phage therapy
- **Interspecific hybridisation**
- **Coral hardening**
- **Genetic engineering**

Many of RRAP interventions, given their novel nature, may involve tailored approaches to assessment and permit. These approaches "... require the applicant to provide more information and require the authority to undertake a detailed assessment. These [...] are non-standard/non-routine in nature." (Great Barrier Reef Marine Park Authority 2018: 8).

Overall, interventions considered to be of medium risk or higher may require proof of concept or supporting rationale for likely success in the Marine Park. They may also require:

- A pilot study (considered as a research activity) involving tailored assessment and may require a deed of agreement. If such a pilot study is regarded as successful, a permit to deploy an intervention (rather than research) can be sought.
- Subject to the scale and risk involved, the operational application may require a Tailored or Public Information Package assessment, deed/bond, public advertising and/or an Environmental Management Plan.

The medium and high-risk interventions outlined above may trigger the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth), depending on the scale, location, magnitude and intensity of their activities. The Act regulates activities that may cause a significant impact on the environment of the Marine Park or other matters of national environmental significance (see section 4.2).

5.3.2 Specific implications

Coral translocation, hybridisation, hardening and genetic engineering involving harvest of corals in state waters and/or large-scale aquaculture processes may trigger the *Fisheries Act 1994* (Queensland). As mentioned previously, the *Fisheries Act 1994* (Queensland) also applies to marine plants and algae; accordingly, **macroalgal removal** may trigger this Act.

Artificial reefs and human-made structures placed in the Great Barrier Reef Marine Park may require consideration under the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth). The Authority position statement titled *No Structures Sub-zones* lists a number of locations (Appendix G) – those described in the former *Cairns Section Zoning Plan 1992* – that should remain: "(a) in a natural state, largely unaltered by human works; and (b) free from structures and permanently-moored facilities, except for approved vessel moorings, approved management, research and monitoring facilities and approved navigational markers which are essential for the protection, wise use, understanding and enjoyment of the Marine Park" (Great Barrier Reef Marine Park Authority 2016). Artificial reefs proposed in No Structures Sub-zone locations are considered in terms of their compatibility with the objective outlined in (a) and (b) referred to above. Further, construction

of reef structures on land before deployment in the marine environment may require approval under the *Planning Act 2016* (Queensland), depending on a range of factors such as the existing use and zoning of the land. If the artificial reefs are considered “tidal works” they may also require approval under the *Planning Act 2016* (Queensland).

Table 4: Examples of indicative regulatory requirements and levels of risk for RRAP interventions

Intervention	Nature of activity							Risk*
	GBRMP/GBRCMP	SIMP	FISH	STRU	BDIS	GTEC	NFAC	
Type 1								
Cloud brightening	◆	◆						High
Misting	◆	◆						High
Surface films	◆							Medium
Mixing and pumping	◆	◆						High
Type 2								
Rubble stabilisation	◆							Low-Medium
Artificial reefs	◆	◆		◆			◆	Medium-High
Type 3								
Larval seeding	◆	◆			◆			Low-High
Translocation	◆	◆	◆		◆			Low-High
Type 4								
Macroalgal removal	◆		◆					Low-High
Type 5								
Symbiotic manipulation	◆	◆			◆			High
Type 6								
Assisted gene flow	◆	◆						Medium
Interspecific hybridisation	◆	◆	◆		◆			High
Coral hardening	◆	◆	◆		◆			High
Type 7								
Genetic engineering	◆	◆	◆		◆		◆	High
Relevant legislation	GBRMP Act 1975 Marine Parks Act 2004 (QLD)	EPBC Act 1999	Fisheries Act 1994	Sea Dumping Act 1994 GBRMP Act 1975	Biodiscovery Act 2014 (QLD) EPBC 1999	Gene Technology Act 2000	Planning Act 2016 (QLD)	

GBRMP/GBRCMP: within Great Barrier Reef Marine Park/Great Barrier Reef *Coastal* Marine Park
 SIMP: involves significant impact on Great Barrier Reef
 FISH: involves fisheries resources, habitats, marine plants (including algae)
 STRU: involves installation (dumping) of structures

GTEC: involves gene technology
 NFAC: involves new facility, new use of land and/or tidal works
 BDIS: involves biodiscovery
 QLD: Queensland

* primarily based on the Great Barrier Reef Marine Park Authority (2018)

Interventions involving processes to enhance desirable traits (e.g. heat tolerance) of corals and their symbionts, such as **larval seeding, coral translocation, symbiotic manipulation, hybridisation, hardening** and **genetic engineering** may require consideration under the *Biodiscovery Act 2004* (Queensland), which regulates the collection and use of biological material native to Queensland and its waters for biodiscovery research (defined as “...*the analysis of molecular, biochemical or genetic information about native biological material for the purpose of commercialising the material*”). In this case, an agreement or permit may be required from the Queensland Department of Environment and Science. Similarly, Part 8 of the *Environment Protection and Biodiversity Conservation Regulations 2000* (Commonwealth) regulates biodiscovery on the Reef. In this case, permission may be assessed as part of an application under the *Great Barrier Reef Marine Park Act 1975* (Commonwealth).

Interventions involving **genetic engineering** may trigger the *Gene Technology Act 2000* (Commonwealth), if they involve such *dealings with* genetically modified organisms (genetically modified organisms)¹¹ as:

1. Conducting experiments with the genetically modified organism;
2. Making, developing, producing or manufacturing the genetically modified organism;
3. Breeding the genetically modified organism;
4. Propagating the genetically modified organism;
5. Using the genetically modified organism in the course of manufacture of a thing that is not the genetically modified organism;
6. Growing, raising or culturing the genetically modified organism;
7. Importing the genetically modified organism;
8. Transporting the genetically modified organism;
9. Disposing of the genetically modified organism; and,

includes the possession, supply or use of the genetically modified organism for the purposes of, or in the course of, a dealing listed in (a)-(i) (Part 2 of the *Gene Technology Act 2000* (Commonwealth)). A license is, therefore, required for genetic manipulation of corals in the lab, for field trials and final deployment in the Marine Park.

The likely assessment approach under the *Gene Technology Act 2000* (Commonwealth) for interventions involving genetic engineering requires the Office of the Gene Technology Regulator to prepare a risk assessment and risk management plan for the proposed intervention. This should consider advice from the states (e.g. Queensland Department of Environment and Science), the Gene Technology Technical Advisory Committee, relevant federal agencies (e.g. the Great Barrier Reef Marine Park Authority), the Environment Minister, any local council that the Regulator consider appropriate and written submissions from the public (see section 50, Part 5 of the *Gene Technology Act 2000* (Commonwealth)).

During consultation for this report, the Office of the Gene Technology Regulator indicated that prospective permit applications involving corals, with release of genetically modified organisms in the marine environment, would, in general terms, require the applicant to provide scientific peer-reviewed evidence on the associated risks, information about measures that could be implemented to reduce these risks, and identification of testing sites that are ‘isolated’ i.e. where

¹¹ Under the *Gene Technology Act 2000* (Commonwealth), a genetically modified organism is an organism that has been modified by gene technology.

the spread of propagules to surrounding reefs are unlikely. However, it is important to note that the Office of the Gene Technology Regulator is yet to deal with genetic manipulation of corals.

Overall, the Office has assessed genetically modified organism license applications for crops (e.g. wheat, canola and cotton) and certain virus for therapeutical purposes (e.g. vaccines)¹².

Last, a biotechnology code of ethics is in place in Queensland¹³, which compliance is mandatory for biotechnology research (including gene technology) funded by the Queensland Government.

6. GOVERNANCE CONSIDERATIONS

The research projects and interventions proposed by RRAP present a number of challenges for the various governments and agencies involved in protecting and managing the Reef. Four issues are likely to require considerable thought and consideration in the coming months and years, not least because RRAP interventions will be introduced into an already-busy governance landscape.

6.1 Fit-for-purpose regulation

The Reef regulatory system is robust in many regards (e.g. in relation to conventional interventions); but, the novel nature of RRAP means it may not be entirely fit for purpose for some of the interventions proposed by RRAP. This system – as it relates to RRAP interventions – is complex, involves multiple federal and state government agencies, and a good deal of fragmentation. As a result, as seen in Section 5.3, a single intervention may require several permits under different pieces of legislation. In addition, cases of duplication, such as those between the Great Barrier Reef Marine Park Authority and the Department of the Environment and Energy relating to the *Environment Protection (Sea Dumping) Act 1981* (Commonwealth), create a burden on regulators and those applying for permits alike. Regulatory fragmentation and duplication may result in delays in the development and deployment of RRAP interventions.

Regulatory fragmentation and duplication may be minimised by employing arrangements to streamline the permission process. For example, the authority and Queensland Parks and Wildlife Service have adopted arrangements for joint permit applications and assessments for activities involving both jurisdictions (i.e. the Marine Park and Coastal Marine Park). Likewise, the authority and the Department of the Environment and Energy developed arrangements to streamline permit applications and assessments involving the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). In this case, the authority permits may cover a range of requirements under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (e.g. listed threatened species, listed migratory species, listed marine species and cetaceans and biodiscovery). Similar arrangements are needed to simplify regulation and reduce duplication relating to RRAP interventions; ultimately, moving towards more timely and efficient permitting processes.

RRAP interventions involving novel technologies may prove particularly challenging to the current regulatory system. These technologies involve novel risks and impacts and, in some cases, high levels of uncertainty. In addition, they are yet to be deployed in the context of coral reefs. For instance, currently, neither Great Barrier Reef regulations nor gene technology regulations

¹² See record of GMO dealings at <http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/gmorec-index-1>

¹³ See <https://www.business.qld.gov.au/industries/science-it-creative/science/scientific-research/regulation-ethics>

contain provisions to specifically assess interventions aiming to enhance heat tolerance in corals using genetic manipulation. The Office of the Gene Technology Regulator, responsible for genetically modified organism licenses, deals mostly with permit applications relating to crops and viruses for therapeutic purposes. Nevertheless, the Authority has developed guidelines that address genetic engineering as part of its permission system. However, concerted action by relevant regulators (e.g. the Great Barrier Reef Marine Park Authority, Office of the Gene Technology Regulator, Department of the Environment and Energy, Department of Environment and Science, and Department of Agriculture and Fisheries) will be required to develop a robust permission system if genetic engineering is to be used for reef restoration and adaptation on the Reef.

In the context above, bringing the relevant regulators together to identify opportunities for developing a more robust regulatory system would be highly beneficial. In some cases, the system could be improved by developing policy statements and guidelines on the part of regulators and memoranda of understanding between regulators. In other cases, clarification of certain definitions contained in the regulations would be needed. For example, the definition of “aquaculture operation” in the Great Barrier Reef Zoning Plan does not mention corals directly. In any case, it would be paramount to afford the regulations some level of flexibility to account for new technologies and knowledge as and when they arise.

6.2 Accountability and transparency

Accountability and transparency are an important consideration for any government policy and expenditure, including RRAP.

The Department of Prime Minister and Cabinet recently published an important policy statement on the need for accountability and transparency in *Australia’s first Open Government National Action Plan 2016-18* (Department of Prime Minister and Cabinet 2016, 2018). It establishes a policy agenda across five broad areas:

- Transparency and accountability in business
- Open data and digital transformation
- Access to government information
- Integrity in the public sector
- Public participation and engagement

The commitments in the plan included:

- Release high-value datasets and enable data-driven innovation;
- Digitally transform the delivery of government services; and
- Enhance public participation in government decision making.

Australia’s second National Action Plan for open government was released in 2018 (Department of Prime Minister and Cabinet 2016; Department of Prime Minister and Cabinet 2018). These commitments reflect a great deal of published literature (see e.g. Lee et al. 2017) establishing the benefits of open government, including building public trust and promoting efficiency. In this context, and given the scale of RRAP funding, mechanisms to promote accountability and transparency should be fundamental considerations for the delivery of RRAP.

RRAP’s funding is tied to the 2018-19 Federal Budget, which sees the Government investing \$535.9 million over the 2018-2022 period to “secure the future of the World Heritage-listed Great Barrier Reef and the jobs it supports”. The funding commitment is described as:

Reef Restoration and Adaptation Program, a partnership

...\$443.8 million to enter into a tied partnership fund with the Great Barrier Reef Foundation, a not-for-profit organisation dedicated to supporting the Reef. The fund will work to deliver programs addressing the key challenges facing the Reef, including \$200.6 million to improve water quality, **\$100 million to unlock new scientific insights to help strengthen the resilience of the Reef through coral restoration and adaptation research** and \$58 million to advance programs to combat the crown-of-thorns starfish. The fund will also deliver \$40 million to enhance Reef health monitoring and reporting, and \$44.8 million will support delivery of the plan and engagement with Traditional Owners and the broader community to protect the Reef (Parliament of Australia 2018; emphasis by authors).

The Government will be required to provide evidence that the >\$443M investment – including but not limited to the provisional allocation of \$100M for RRAP – is fiscally responsible and delivering tangible outputs for the Reef. While such accountability is relevant to all government spending, the sheer size of this funding commitment – and arguably the unorthodox process through which it was committed – means that transparency and accountability will be especially important considerations in both (i) the process by which RRAP funds are allocated and prioritised and (ii) the measures and means for demonstrating efficient and effective use of government funds.

For these reasons, RRAP researchers and project proponents will need to ensure there is a ‘clear line of sight’ to, and associated evidence in support of, the positive impact of their science and social responsibility for the Reef. Similarly, the investments made in RRAP are likely to be strongly tied to the investments made in other Reef restoration and adaptation interventions. As such, RRAP investments cannot be considered in isolation from the full range of activities in the Reef. In other words, while the scientific community might like to treat RRAP as a distinct scientific project, which is required only to adhere to the norms of scientific research, it is highly likely that there will be expectations around demonstrated ‘impact’ and ‘outcomes’ on the Reef ecosystem, *within the six-year time frame* and well beyond the publication of journal articles. For RRAP executives, that means allocating at least some funding to interventions that are likely to deliver positive benefits sooner rather than later; and ensuring evidence of impact is collated from the outset.

We propose two mechanisms to promote transparency and accountability for RRAP:

1. Establish a public register with all application and reporting documents related to funded projects (subject to strict exemptions for commercial-in-confidence documents).
2. Require annual (or biennial) performance audits to report publicly on the integrity and cost-effectiveness of RRAP expenditure.

These mechanisms reflect common existing practices.

Two relevant, existing examples of online public registers are:

- The Great Barrier Reef Marine Park Authority’s permits website at <https://secure.gbrmpa.gov.au/permitsonline/> (although a limitation of this website is that it does not provide access to application documents, progress reports or documents submitted under requirements imposed by conditions of approval); and
- The Environment Protection and Biodiversity Conservation Act website for referrals at <http://epbcnotices.environment.gov.au/> (although a limitation of this website that should be avoided is that it only publishes application and approval documents, not documents submitted under requirements imposed by conditions of approval).

6.3 Capacity of the Great Barrier Reef Marine Park Authority

As the lead agency with responsibility for managing and protecting the Reef and implementing the Great Barrier Reef Marine Park Act, the Great Barrier Reef Marine Park Authority needs to be sufficiently resourced to be able to continue to provide robust regulatory oversight over the full range of activities undertaken in the Reef, to which RRAP will add. RRAP will necessarily involve:

- More permit applications to the authority, and thus an associated increase in the volume of work for the authority staff,
- The introduction of new un-tested science and technology, which will change the nature of assessments undertaken and the skills required to do assessments well, and
- Early support for work with the Indigenous Reef Advisory Committee to ensure compliance with Traditional Use of Marine Resources Agreements and Indigenous Land Use Agreement.

Consequently, it is highly likely that the authority will need to be allocated new resources – in the form of people and training - to maintain their strong regulatory and management oversight of the Reef. Further research and consultation with the authority on the most appropriate solution to this challenge would be beneficial.

6.4 Skills and training needs of research community and regulators

The novelty of some RRAP interventions means that many of the scientists involved are unfamiliar with the Reef's complex regulatory environment. So too, if interventions involving genetic engineering are pursued, then the Office of the Gene Technology Regulator will necessarily be involved alongside the Great Barrier Reef Marine Park Authority in determining the safety and feasibility of those research projects and interventions. Consequently, there is a strong argument for RRAP to facilitate the provision of training about the range of interventions proposed, targeting: regulators (e.g. Great Barrier Reef Marine Park Authority and Office of the Gene Technology Regulator), government actors (e.g. Queensland Department of Environment and Science and Department of the Environment and Energy), and key stakeholders (Traditional Owners, tourism industry, local governments). Ideally, this training would be developed by the social scientists in RRAP, which can incorporate it into the stakeholder engagement initiatives of RRAP. Conversely, researchers in RRAP will need to be trained in the authority's permitting procedures and requirements and in the provisions of the *Gene Technology Act 2000* (Commonwealth) and the requirements of the Office of the Gene Technology Regulator.

7. RECOMMENDATIONS

In summary, nine practical mechanisms to improve the regulatory system, accountability, transparency and capacity are to:

- 1. Identify opportunities and adopt measures for enabling the permission system to better support reef restoration and adaptation interventions.** These include measures to reduce fragmentation and duplication (e.g. joint permit arrangements, clarification of certain definitions in the regulations, and development of joint policy positions), and options for developing policy and regulatory innovation and 'whole-of-government' reef restoration policy.

2. **Establish a public register on the Great Barrier Reef Marine Park Authority’s website with all application and reporting documents related to funded projects** (subject to strict exemptions for commercial-in-confidence documents) to ensure stakeholders are aware of, and can be engaged in discussions about, RRAP interventions. This process would also ensure subsequent project proponents can learn from the successful permitting of previous proponents.
3. **Require annual (or biennial) performance audits to publicly report on the integrity and cost-effectiveness of RRAP expenditure.**
4. **Expand the assessment criteria for the selection of RRAP interventions to include explicit mention of Reef 2050 indicators and outcomes**, to ensure compatibility between RRAP and the overarching policy framework for protection of the Reef.
5. **Design and deliver training modules for RRAP researchers**, to ensure they are fully aware of the regulatory environment pertaining to the Reef, including reference to the *Gene Technology Act 2000* (Commonwealth) for those scientists working in the bio-engineering domain.
6. **Undertake a thorough assessment of the Great Barrier Reef Marine Park Authority’s capacity needs** to deal with the increases in permitting that RRAP (and other investments) will demand, including with respect to the skills and training needs of the authority staff.
7. **Facilitate further cooperation between the Great Barrier Reef Marine Park Authority, the Office of the Gene Technology Regulator and other relevant regulators**, with expert input from RRAP researchers, to kick-start discussions about the introduction of RRAP interventions that might trigger the *Gene Technology Act 2000* (Commonwealth).

The authors of this report are also of the view that the ‘first mover’ nature of RRAP presents an opportunity for Australia to share lessons – good and bad – from our experience. In particular, the regulatory, institutional and governance challenges experienced in the Reef are likely to be replicated in multiple locations internationally as the science is adopted elsewhere. As such, we recommend RRAP:

8. **Explore possibilities to extend existing networks** to explicitly engage with other relevant reef restoration and adaptation actors over the coming six years, and
9. **Develop a series of accessible and bespoke guidelines** highlighting the decision-support process, stakeholder engagement and regulatory implications of a coral reef restoration and adaptation agenda (domestic and international).

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APPENDIX A – RRAP DOCUMENT MAP



Reef Restoration and Adaptation Program, a partnership

APPENDIX B – GUIDE FOR INTERVIEWS WITH EXPERTS IN RRAP INTERVENTIONS

1. **TYPE:** What is the proposed intervention?
2. **INTENT:** How would the intervention help corals resist, repair and/or recover from climate change?
3. **OPERATION:** What would the intervention involve/how would it work? What activities and infrastructure would be involved in the implementation, maintenance, and termination of the intervention?

4. **GEOGRAPHIC LOCATION:** In which site/part of the Reef would the intervention occur?
5. **GEOGRAPHIC SCALE:** What would be the size of the geographic area involved in the intervention?

For example, small, medium or large. Please provide details e.g. area in sq. meters, kms etc.

6. **TEMPORAL SCALE:** How long would the intervention last?

Please consider different phases, e.g. implementation, maintenance, and termination of the intervention.

7. **TRANSBOUNDARY ISSUES:** How would the intervention affect other parts of the Reef and beyond (e.g. inter-state, international spread)?

For example, dispersal of organisms or substances and material beyond the Reef boundaries and how fast/slow such dispersal would be.

8. **RISKS/IMPACTS:** What would be the potential risks/anticipated adverse impacts of the intervention on:

Please consider general likelihood/probability of risks/impacts:

A. Biodiversity, species, ecosystems and/or habitats

B. Physical, chemical and ecological processes

- i. Physical and chemical, e.g. sedimentation, nutrient cycling, sea temperature, ocean pH, sea level etc.
- ii. Ecological, e.g. recruitment, predation, connectivity, reef building and herbivory etc.

C. Indigenous, historic and other heritage values

- i. Indigenous, e.g. cultural practices, observances, customs and Lore
- ii. Historic, e.g. historic shipwrecks

- iii. Other heritage, e.g. social, scientific and aesthetic aspects

D. National and universal heritage values

- i. National and universal heritage values: those relating to the Reef’s natural values, geomorphological significance and natural beauty, together with the strong ongoing links between Aboriginal and Torres Strait Islanders and their sea country
- ii. Commonwealth heritage values: Commonwealth Heritage List includes Shoalwater Bay Military Training Area; Low Island and Low Islets lightstation (including its significance to Kuku Yalanji and Yirriganjdi Traditional Owner groups); Dent Island lightstation; North Reef lightstation and Lady Elliot Island lightstation

E. Commercial and non-commercial use

- i. Tourism
- ii. Fishing
- iii. Recreation
- iv. Research and educational activities
- v. Traditional use of marine resources
- vi. Defence activities
- vii. Ports
- viii. Shipping

9. **Monitoring & Evaluation:** What would be required for monitoring and evaluation of the proposed information?

For example, information and resources needed for M&E. Please consider different timeframes (e.g. short, medium and long term).

10. **REVERSIBILITY:** Would it possible to reverse partially or totally the intervention once it is implemented?

11. **SCALABILITY:** Would it be possible to upscale the intervention to larger areas of the Reef? What would be the implications for questions 2-10?

12. **UNCERTAINTY:** What is the level of certainty/uncertainty of the technical/scientific information underpinning the intervention?

For example, low, medium or high certainty; please briefly explain.

13. **REGULATORY REQUIREMENTS** (If known)

APPENDIX C – EXAMPLES OF PLANS, POLICIES, AGREEMENTS AND GUIDELINES FOR THE GREAT BARRIER REEF

- Great Barrier Reef Biodiversity Conservation Strategy 2013
- Great Barrier Reef Climate Change Adaptation Strategy and Action Plan 2012–2017
- Great Barrier Reef Heritage Strategy 2005
- Dredging and spoil disposal
- Environmental impact management
- Managing activities that include the direct take of a protected species from the Great Barrier Reef Marine Park
- Managing scientific research in the Great Barrier Reef Marine Park
- Managing tourism permissions to operate in the Great Barrier Reef Marine Park (including allocation, latency and tenure)
- Moorings in the Great Barrier Reef Marine Park
- Operational policy on whale and dolphin conservation in the Great Barrier Reef Marine Park
- Sewage discharges from marine outfalls to the Great Barrier Reef Marine Park Structures

Site management arrangements

- Site plans for Raine Island, Moulter Cay and MacLennan Cay; Clump Point, Mission Beach; Low Isles, offshore from Port Douglas; Michaelmas Cay locality; Upolu Cay Reef; Bauer Bay; South Molle Island; Blue Pearl Bay, Hayman Island; Whitsundays Plan of Management setting 5 site plans; Tongue Bay; Hill Inlet and Whitehaven Beach; Fitzroy Reef; Keppel Bay and islands; Lady Elliot Island Reef; Lady Musgrave Island Reef

Traditional Use of Marine Resources Agreements (TUMRAs)

- Gunggandji Agreement
- Woppaburra Agreement
- Yirrganydji Agreement
- Lama Lama Agreement
- Yuku-Baja-Muliku Agreement
- Giringun Agreement
- Wuthathi Agreement
- Port Curtis Coral Coast Agreement

In addition to Traditional Use of Marine Resources Agreements, the Authority is a party to the Kuuku Ya'u People's Indigenous Land Use Agreement

Position statements

- Aquaculture within the Great Barrier Reef Marine Park
- Management of tourist flights in the vicinity of Magnetic Island
- Management of memorials within the Great Barrier Reef Marine Park
- Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay
- Marine tourism contingency plan for the Great Barrier Reef Marine Park
- No structures sub-zones
- Translocation of species in the Great Barrier Reef Marine Park

Guidelines

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- Coral transplantation
- Management of artificial reefs in the Great Barrier Reef Marine Park
- Managing visitation to seabird breeding islands
- Permits Information Bulletin — no structure sub-zones
- Use of hydrodynamic numerical modelling for dredging projects in the Great Barrier Reef Marine Park
- Environment Protection and Biodiversity Conservation Act referral guidelines for the outstanding universal value of the Great Barrier Reef World Heritage Area
- Traditional Owner Heritage Assessment

APPENDIX D – INTERNATIONAL ENVIRONMENTAL AGREEMENTS RELEVANT TO THE REEF

As noted in section 5, in addition to the *World Heritage Convention*, other international treaties, as well as the UN Sustainable Development Goals, are relevant to the Reef (Box 4); but, are unlikely to trigger any specific legal obligations in relation to RRAP. For example, the *United Nations Framework Convention on Climate Change* and associated agreements have particular importance given the threat posed by climate change to the Reef. In this regard, RRAP is consistent with Australia's commitments in relation to adaptation for climate change. The *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention) is relevant not only to dumping of wastes but also the construction of artificial reefs in the marine environment¹⁴. Under the *United Nations Convention on the Law of the Sea* (UNCLOS), Australia has the right to control fishing and other activities within the 200 nautical mile exclusive economic zone (EEZ) from the territorial sea baseline. This includes the Reef and a large area of the adjacent Coral Sea.

Box 4: Examples of international environmental agreements that apply to the Reef (the Great Barrier Reef Marine Park Authority 2014b)

- Convention concerning the Protection of the World Cultural and Natural Heritage, 1972
- Convention on Biological Diversity, 1992
- Convention on International Trade in Endangered Species of Wild Fauna and Flora, 1973
- Convention on the Conservation of Migratory Species of Wild Animals, 1979
- Convention on Wetlands of International Importance Especially as Waterfowl Habitats, 1971
- China–Australia Migratory Bird Agreement, 1986
- International Convention for the Prevention of Pollution from Ships, 1973
- Japan–Australia Migratory Bird Agreement, 1974
- Republic of Korea–Australia Migratory Bird Agreement, 2007
- United Nations Convention on the Law of the Sea, 1982
- United Nations Framework Convention on Climate Change, 1992

The *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity* is relevant to interventions in the Reef involving native title. This protocol ensures that where indigenous and local communities have the establish right to grant access to genetic resources, the contracting parties (including Australia) must take measures to ensure informed consent and fair and equitable benefit sharing.

While there are limited legal obligations to report in relation to RRAP, Australia would be expected to include information about RRAP in reports on compliance with treaty obligations at conferences of the parties (COPs) or other routine reports for a number of treaties. Australia also reports within the global indicator framework adopted by the UN General Assembly on 6 July 2017 on Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development¹⁵. However, while RRAP may be relevant to general aspects of some indicators, it does not appear to be necessary to report it, or any project within it, individually. For example, indicators 13.2.1 and 14.a.1 involve national level reporting about climate adaptation and the

¹⁴ See <http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx>

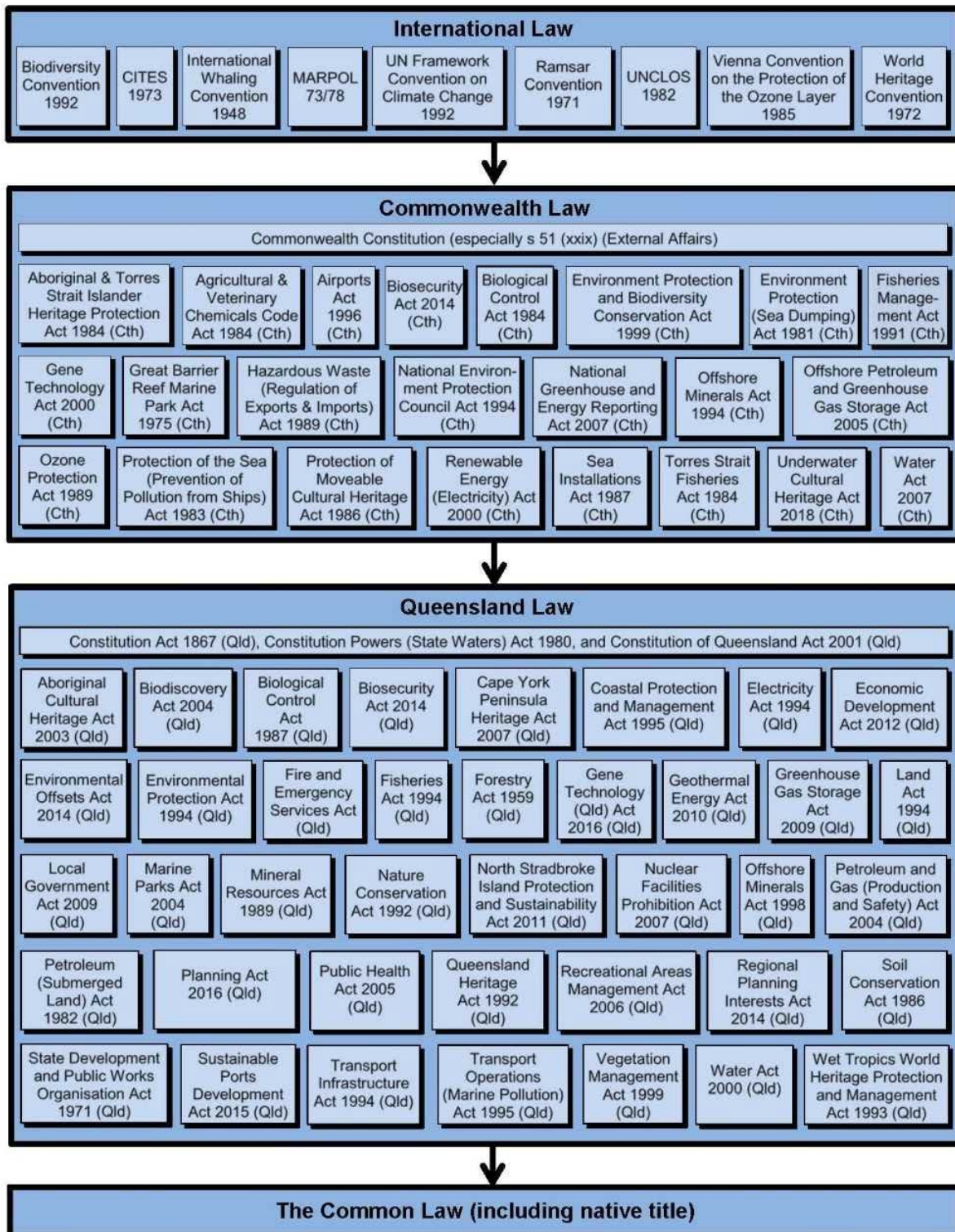
¹⁵ See <https://unstats.un.org/sdgs/indicators/indicators-list/>

research budget for marine research, which RRAP is an inherent part of but would not be reported separately under:

13.2.1 Number of countries that have communicated the establishment or operationalisation of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other).

14.a.1 Proportion of total research budget allocated to research in the field of marine technology.

APPENDIX E – MAJOR PIECES OF THE QUEENSLAND ENVIRONMENTAL LEGAL SYSTEM



APPENDIX F – ACTIVITIES GUIDE FOR DIFFERENT ZONES OF THE GREAT BARRIER REEF

ACTIVITIES GUIDE (see relevant Zoning Plans and Regulations for details)	ZONES						
	General Use Zone	Habitat Protection Zone	Conservation Park Zone	Buffer Zone	Scientific Research Zone 2	Marine National Park Zone	Preservation Zone
Aquaculture	Permit	Permit	Permit ¹	X	X	X	X
Bait netting	✓	✓	✓	X	X	X	X
Boating, diving, photography	✓	✓	✓	✓	✓ ²	✓	X
Crabbing (trapping)	✓	✓	✓ ³	X	X	X	X
Harvest fishing for aquarium fish, coral and beachworm	Permit	Permit	Permit ¹	X	X	X	X
Harvest fishing for sea cucumber, trochus, tropical rock lobster	Permit	Permit	X	X	X	X	X
Limited collecting	✓ ⁴	✓ ⁴	✓ ⁴	X	X	X	X
Limited spearfishing (snorkel only)	✓	✓	✓ ¹	X	X	X	X
Line fishing	✓ ⁵	✓ ⁵	✓ ⁶	X	X	X	X
Netting (other than bait netting)	✓	✓	X	X	X	X	X
Research (other than limited impact research)	Permit	Permit	Permit	Permit	Permit	Permit	Permit
Shipping (other than in a designated shipping area)	✓	Permit	Permit	Permit	Permit	Permit	X
Tourism programme	Permit	Permit	Permit	Permit	Permit	Permit	X
Traditional use of marine resources	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	✓ ⁷	X
Trawling	✓	X	X	X	X	X	X
Trolling	✓ ⁵	✓ ⁵	✓ ⁵	✓ ^{5,8}	X	X	X

PLEASE NOTE: This guide provides an introduction to Zoning in the Great Barrier Reef Marine Parks.

- Restrictions apply to aquaculture, spearfishing and harvest fishing for aquarium fish, beachworm and coral in the Conservation Park Zone.
- Except for One Tree Island Reef (SR-23-2010) and Australian Institute of Marine Science (SR-19-2008) which are closed to public access and shown as orange, all other Scientific Research Zones are shown as green with an orange outline.
- Limited to 4 catch apparatus per person (eg. crab pots, collapsible traps or dillies).
- By hand or hand-held implement and generally no more than 5 of a species.
- Maximum of 3 lines/rods per person with a combined total of 6 hooks per person.
- Limited to 1 line/rod per person and 1 hook per line. Only 1 dory detached from a commercial fishing vessel.
- Apart from traditional use of marine resources in accordance with s.211 of the *Native Title Act 1993*, an accredited Traditional Use of Marine Resources Agreement or permit is required.
- Pelagic species only. Seasonal Closures apply to some Buffer Zones.

Detailed information is contained in the *Great Barrier Reef Marine Park Zoning Plan 2003 and Regulations* and the *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004*.

- Permits are required for most other activities not listed above.
- Commonwealth owned islands in the Great Barrier Reef Marine Park are zoned "Commonwealth Islands Zone" - shown as cream.
- All Commonwealth Islands may not be shown.
- Special Management Areas may provide additional restrictions at some locations.
- The Zoning Plan does not affect the operation of s.211 of the *Native Title Act 1993*.

ACCESS TO ALL ZONES IS PERMITTED IN AN EMERGENCY.

APPENDIX G – NO STRUCTURE SUB-ZONE LOCATIONS

- | | |
|---|--|
| 1. Hilder Reef | 26. Ribbon Reef No. 7 to Williamson Reefs |
| 2. MacGillivray Reef | 27. Hope Islands |
| 3. Nymph Island Reef | 28. Cairns Reef to Gill Patches |
| 4. Eyrie Reef | 29. Cedar Bay (Obree Point to Fritz Creek) |
| 5. Two Islands Reef | 30. Cape Tribulation to Lake Reef (Weary Bay) |
| 6. Low Wooded Island Reef | 31. Noah Head |
| 7. Three Islands Reef | 32. Coastline adjacent to Mt Emmett |
| 8. Endeavour Reef complex | 33. Alexandra Bay – Cooper Creek to Bailey Creek |
| 9. Pearl Reef | 34. Bailey Point |
| 10. Pickersgill Reef | 35. Coastline adjacent to Black Rock |
| 11. Mackay Reef | 36. Cape Kimberley and Snapper Island |
| 12. 'unnamed reef' Chinamans Reef | 37. Undine Reef |
| 13. Saxon Reef | 38. Michaelmas Reef to Upolu Cay |
| 14. Escape Reef | 39. Euston Reef to North West Reef |
| 15. Opal Reef | 40. Elford and Briggs Reefs |
| 16. Channel Reef | 41. Sudbury Cay |
| 17. Cayley Reef | 42. Sudbury Reef (Flora Pass) |
| 18. Peart Reef | 43. High Island |
| 19. Feather Reef | 44. Frankland Islands (South) |
| 20. 'unnamed reef' Shark/Noreaster Reef complex | 45. North Barnard Islands |
| 21. Carter Reef to Ribbon Reef No. 10 | 46. South Barnard Islands |
| 22. The area of dugong habitat north of Lookout Point | 47. Beaver and Taylor Reefs |
| 23. The Turtle Group | |
| 24. Lizard Island | |
| 25. South Direction Island to Rock Islets | |

Source: Great Barrier Reef Marine Park Authority (2016)

APPENDIX H – DESCRIPTIONS OF RRAP INTERVENTIONS EXAMINED IN THIS REPORT

Source: *GBRrestoration.org*.

Interventions are further described in detail in [T3 Intervention Technical Summary](#).

Type 1. Cooling and Shading

Cloud brightening

Marine cloud brightening aims to increase the amount of solar radiation (light and heat) that clouds reflect back into space, cooling and shading the reef below. Cloud brightening replicates natural processes. It works by spraying microscopic sea water droplets into the atmosphere, allowing them to evaporate, resulting in clouds with a greater ability to deflect solar radiation. These 'brightened' clouds are less likely to produce rain and would, therefore, remain above the reefs much longer than typical clouds, providing increased protection. A cloud brightening unit would require a fan for initial dispersal of the droplets into the atmosphere. The inputs are seawater and energy, which could be derived from renewable sources such as solar, wave or current energy. Modelling shows that to be effective, the units would need to operate over weeks to months when bleaching risk was predicted to be high. Potential negative effects could include influencing local weather patterns – including potentially suppressing rain, reduced coral growth and impact on light-limited coral. Significant feasibility, engineering and experimental work is required.

Misting

Misting aims to mimic the effects of sea fog, which - like clouds - reduces the amount of sunlight and heat reaching the sea surface. It involves generating a mist by adding liquid particles to the atmosphere, similar to cloud brightening. Misting can be used at a local scale to provide shading or, at regional scale, to provide shading and cooling of the sea surface temperature. Preliminary modelling shows misting could be effective in protecting targeted areas, over short critical periods (days to weeks). It could be delivered through platforms mounted on small vessels. Potential negative effects include over-shading which may slow coral growth, and potential environmental impacts depending on the material used to generate the particles, of which there are many options. It would be ineffective during strong wind; however, bleaching is most likely to occur during calm conditions. Misting and cloud brightening may work well together to reduce solar radiation on reefs across a wide range of atmospheric conditions.

Ultra-thin surface films

Ultra-thin surface films made from calcium carbonate (a key component of coral skeletons) and supported at the surface by buoyant organic materials, could reduce solar radiation (similar technology is currently used to prevent evaporation in reservoirs and dams). Tests so far indicate surface films remain stable for at least two days, reduce light by more than 20 percent, are not harmful to coral, and protect some species from bleaching. Such films require no permanent infrastructure and need only be applied periodically, when bleaching conditions are predicted. The potential for negative effects such as over-shading, leading to reduced coral growth rate, are unlikely as the deployment periods are short. Further development and testing are required to improve light reduction, film longevity (stability and strength), deployment methods and to further

assess environmental safety. Surface films could be applied to specific, high-value tourism or seed-reefs (which may in turn improve recovery of nearby reefs) by drone, airplane, sea vessel or automated buoy.

Mixing and pumping of cool water

Mixing and pumping of cool water can reduce heat stress. The surface water that surrounds coral reefs is warmer than adjacent deeper water. If, during the warmest times of the year, deeper, cooler water is mixed with warmer surface water, thermal stress of coral will be reduced and potentially, coral bleaching avoided. This vertical mixing can occur naturally ('upwelling') with evidence it has reduced coral bleaching. On a smaller scale, engineering structures such as 'underwater fans' could enhance vertical mixing to reduce surface water temperature. The relatively fast currents across reefs, and engineering costs would likely constrain this method to localised high-value sites. Alternatively, cooler water from the deep sea could be drawn, through pumping, to cool reefs. The larger temperature variation means less water would be required than the mixing method, however the engineering costs and challenges would be greater. The input of nutrient-rich deep water may boost productivity of reef systems, if these nutrients can be effectively understood and managed. However, these nutrients also pose one of the main ecological risks of introducing this method, as they could lead to algal blooms. There is also a risk that some components of these nutrients could exacerbate bleaching. Reef systems would have to be extensively modelled, and the physiological mechanisms underpinning bleaching would need to be better understood to determine whether a safe balance of temperature reduction and nutrient limitation could be achieved. A solution could be to operate water cooling intermittently.

Type 2. Reef Structures and Stabilisation

Artificial reefs

Novel human-made structures aim to enhance reef structural complexity and provide surfaces of different materials, sizes and shapes for coral settlement and growth. They can range from micro-scale engineering to artificial reefs. These structures can promote coral settlement and growth. One method uses small, re-seeding units (such as the tetrapods developed by SECORE) that allow corals raised in aquaculture – or collected from wild spawn slicks – to be placed on natural reefs with minimal handling. This significantly reduces time spent re-locating and planting cultured corals. Millions of these types of units could be deployed to accelerate recovery at large scales. At local scales, artificial reefs have been constructed from a variety of materials to provide a suitable structure for coral settlement and reef function. They range in size from clusters of reef balls (1-3m diameter) to reef frameworks extending over hundreds of metres. Work is underway to test the effect of reef surface shape, aspect and other factors to maximise coral larval settlement and survival.

Rubble stabilisation

When reefs are damaged (for example by storms, ship groundings or coral bleaching) the dead or degraded coral can become loose and unconsolidated, making it difficult for coral to regrow. Mesh or netting is sometimes installed over the rubble to prevent further movement. Often, young corals are then transplanted onto the damaged area, or on artificial reef structures. This technique is relatively common in the US, funded by insurance claims following ship strikes; however, there is a lack of published information and research about this technique. To date these methods have been limited to small, localised sites. New approaches would need to be developed for this to be applied at larger scales.

Type 3. Reproduction and recruitment

Larval seeding

Larval seeding aims to speed up the return of coral cover to a disturbed or damaged reef by increasing the number of available coral larvae for natural settlement, particularly in cases where the reef has a low level of larval supply (e.g. following a large-scale bleaching event). Larvae could either come from wild populations – collected and relocated from other regions – or could be cultured through an aquaculture process, potentially selected to have desirable traits such as enhanced heat tolerance. This technique has been successfully trialled on small scales, mostly using the larvae of a single species, spawned and reared in an aquarium setting. Natural wild coral larval slicks – collected from annual mass spawning – have also been successfully relocated onto reef surfaces, within fine mesh enclosures to prevent the slick from dispersing. Harvesting natural slicks is likely to have minimal negative impact on Reef ecology, as the mortality rate of the larvae in a slick is naturally high. The method has the potential to capture a diverse suite of species, and allow the re-establishment of reef communities, compared with re-seeding just a few species. While coral spawn naturally travels long distances between reefs, relocation of both wild and cultured corals would require measures to ensure the introduced coral did not harm the local population. More research is needed into when and where slicks form, whether the wild larvae can be cultured, moved and re-distributed without negative effects on receiving populations. Such negative effects could occur if, for example, there is species bias within the slicks, or if pathogens and parasites are attracted to or retained by the moving process. Further research is also needed to devise methods to scale-up larval seeding for dispersal over larger areas. It is likely this method would be used in conjunction with some form of reef surface conditioning, to increase the subsequent success of released larvae to settle onto the reef.

Translocation

Coral fragments are harvested from donor reefs and transplanted onto degraded reefs; or coral colonies under threat (usually from dredging or construction activity) are relocated. For this method to be successful, the donor reefs need to be healthy enough to withstand harvesting, and the receiving reefs need to have conditions favourable for coral growth and reef establishment. Success is likely to depend on the size and health of the fragments, the methods of transport and attachment, and external factors such as the environmental conditions following the transplantation. Often fragments that have already been dislodged through a disturbance – ‘corals of opportunity’ – are used. Monitoring of the long-term results of coral fragment transplantation is required. Fragmentation is an asexual propagation method. If used on a large scale, care is required to ensure genetic diversity is not unacceptably reduced.

Type 4. Biocontrol

Macroalgal removal

Although naturally-occurring and offering positive contributions to reef ecology as a food, habitat and fish nursery, macroalgae – or seaweed – when excessive, can compete with, and threaten coral on nearshore reefs. Its volume on reefs can increase through excess nutrients from human disturbances and pollution, such as agricultural run-off. Macroalgae can negatively affect coral by competing for space and other resources, overshading and transmitting disease. It can also reduce coral larvae production, and inhibit young coral settlement, growth and survival. Because manual removal is labour-intensive, the greatest potential for large-scale and long-term management is through nurturing biological removal agents such plant-eating urchins and fish.

Type 5. Probiotics and enhanced bleaching survival

Symbiotic manipulation

Like all animals, corals are inhabited by a microbial community – the coral microbiome. The coral microbiome is essential for coral health and can have a large impact on coral bleaching tolerance. Scientific research suggests that manipulating corals' microbiome could further support coral health and increase corals' tolerance to environmental stress. The coral microbial community has large and diverse populations, very short generation times and a large metabolic range, compared with its coral host. Therefore, evolution can occur much more quickly within the coral microbiome than in coral. This method would aim to increase heat tolerance of the coral host (and potentially its subsequent progeny) through manipulating its microbiome.

Research suggests microbial symbionts are essential to corals' ability to acclimatise and maintain metabolic balance under changing environmental conditions. Proposed new research would focus on producing customised probiotic 'cocktails' to support the health and survival of corals. Potentially, corals could be inoculated with microbes at early stages of life, or later as adults during periods of stress and recovery. While probiotics may be easily administered during the breeding process, it may be challenging to deliver them on a large scale in the field, as delivery methods are labour-intensive, and probiotics would need to be grown at significant quantities. It is not fully understood if the introduced probiotics would need to be continuously re-applied to be effective, and whether they could be passed down to offspring as well as to neighbouring corals. While coral probiotics could be a very promising tool to mitigate coral disease and enhance coral heat tolerance, potential side-effects on both the coral and other reef organisms would need to be examined.

Type 6. Assisted evolution

Assisted gene flow

Assisted gene flow facilitates the natural dispersal of corals, to enhance the adaptation of local populations to expected future conditions. This can be achieved by moving naturally warm-adapted corals (adults, fragments, spawn, larvae or juveniles) to reefs with less heat-resistant individuals. Corals that survive mass-bleaching events, or those that thrive on naturally warm reefs, are likely to possess heat-resistant genes. Further, coral stock can also be directly identified with specific genetic markers that signal beneficial traits, such as bleaching tolerance. These desirable corals can then be propagated either through fragmentation methods or bred in an aquaculture facility before being placed onto receiving reefs. Early studies are promising, however further research is needed to assess the potential to introduce disease or pests; the growth, survival and heat-tolerance of introduced corals; and other impacts on both the donor and receiving reefs.

Interspecific hybridisation

Interbreeding different coral species can produce novel genetic outcomes. Hybrid individuals typically have an increased performance, compared with their parents, leading to greater 'fitness', including health and stress tolerance. Hybridisation has been used in plant and animal breeding for hundreds of years. Hybridisation can naturally occur in corals and is hypothesised to have played a major role in their evolution. A negative impact of this method is that some hybrids may be infertile. As individual corals can live for decades or centuries, even infertile hybrids may have benefits on the Reef's climate resilience for long enough to 'buy time', while greenhouse gases are reduced globally, and water temperatures stabilise.

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Coral hardening

This approach involves exposing adult corals, or their larvae or juveniles, to stressful environmental conditions such as increasing water temperature and ocean acidification. The exposure induces physiological responses that toughen corals and allow them to better withstand stress. Hardening responses are not normally genetic; but, can be inherited by future generations in a process called ‘transgenerational plasticity’. This can happen through ‘epigenetic’ mechanisms that change how DNA is read, without a change in the genetic sequence. Further research is needed to fully understand the potential for hardening to influence the stress tolerance of corals, and how this method could be applied in aquaculture-based propagation.

Type 7. Synthetic biology and genetic engineering***Genetic engineering***

Genetic engineering directly manipulates the genetic code of organisms to influence the expression of particular traits. These approaches have been widely used to understand the function of genes, to develop resistant agricultural species and to understand the nature of human disease. Recently developed gene editing technologies allow researchers to: precisely edit genetic material to examine the genetic basis to stress tolerance (such as coral bleaching tolerance); and, potentially change the genetic code to increase stress tolerance or other desirable traits in corals or their microbial partners. Genetic engineering research greatly facilitates a strong fundamental understanding of corals’ heat tolerance responses, which is required for most, if not all, assisted evolution approaches. The role of genetic engineering approaches in increasing heat stress tolerance in the coral host, its resident algae and through engineering its microbiome to increase beneficial probiotics, is not yet clear.

Reef Restoration and Adaptation Program

GBRrestoration.org

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Reef Restoration and Adaptation Program, a partnership:



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