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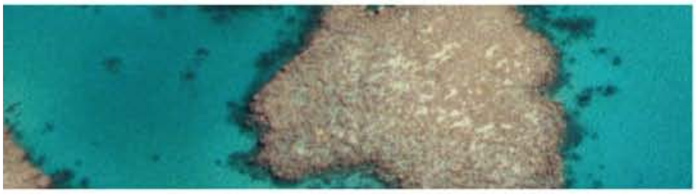

An integrated monitoring framework for the Great Barrier Reef World Heritage Area

Paul Hedge, Fergus Molloy, Hugh Sweatman, Keith Hayes, Jeffrey Dambacher, Julia Chandler, Margaret Gooch, Andrew Chinn, Nic Bax and Terry Walshe.

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Nic Bax (Chair)	NERP Marine Biodiversity Hub
Peter McGinnity	Great Barrier Reef Marine Park Authority
Jamie Oliver	Australian Institute of Marine Science
Hugh Possingham	NERP Environmental Decision Hub
Peter Doherty	NERP Tropical Ecosystems Hub
Mary Colreavy	Department of the Environment, Australian Government
Dave Johnson	Department of the Environment, Australian Government
Chris Chinn	Department of Premier and Cabinet, Queensland State Government

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Executive summary

This project was commissioned to establish a framework for a standardised and integrated ecological, social and economic monitoring program. In undertaking this project, the team developed and tested practical guidance that would help partners involved in a strategic assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to establish a framework for integrated monitoring. The Integrated Monitoring Framework (IMF) guidance identifies the steps and provides clear direction to develop efficient and effective monitoring and reporting on the condition of nationally protected matters – Matters of National Environmental Significance (MNES) – and support adaptive management of these assets. The guidance was applied to the Great Barrier Reef World Heritage Area (GBRWHA) with the intention that the approach could be used to inform the potential development of other integrated monitoring programs in other coastal and marine regions of Australia.

Integrated monitoring and its benefits

For the purpose of this project, integrated monitoring is defined as *the objective and systematic integration of interests, data and knowledge across policy, management and science sectors to monitor, analyse and report on the effectiveness of management for maintaining and enhancing MNES values.* It involves drawing together existing monitoring efforts and providing a big-picture view of future monitoring needs and requirements. In this context, integrated monitoring, when planned and implemented effectively, will provide two primary benefits. The first is a better understanding of cause-and-effect relationships within social-ecological systems and the response of these systems to management actions (represented by a Driver-Pressure-State-Impact-Response model). The second benefit of integrating is cost-effective use of available resources for monitoring the status of MNES, which is achieved through building on, and enhancing existing monitoring efforts and clearly setting out the priorities and gaps to be addressed by any future monitoring. Other important benefits of integrated monitoring include better insights into the effects of cumulative pressures and impacts on MNES values and how to respond to fluctuations in resources available for monitoring (e.g. reductions and increases in monitoring budgets).

This report has two main sections: the guidance for developing an IMF (Parts 1 and 2 of the report), and an IMF for the GBRWHA (Part 3).

Guidance to establish an Integrated Monitoring Framework (IMF)

The guidance articulates a set of overarching-principles and processes that when applied set the direction, prerequisites and essential functions for integrated monitoring. It is used to instigate thought about why, what and how integrated monitoring will support adaptive management of MNES values. Once complete, an IMF will provide partners and regulators with a systematic and clearly articulated description of the purpose, requirements, priorities and functions of integrated monitoring for a specific focus area. The process for developing an IMF also helps to identify the opportunities and gaps that arise when integrating monitoring. The guidance for establishing an IMF sets out the prerequisites for monitoring and the essential monitoring functions to be addressed (Table 1) and explains what is required in each of these steps to integrate existing and future monitoring programs.

Table 1 Prerequisites and essential monitoring functions that form the guidance for establishing an integrated monitoring framework

Prerequisites
• Management objectives—to provide clarity about management needs and priorities and inform the identification of monitoring priorities and objectives
• Governance—to provide a foundation for performance of the program and conformance to law, regulations, standards and community expectations of probity, accountability and openness
• Principles of integrated monitoring—to guide the many discussions and decisions that need to be made to establish an integrated monitoring program
Essential monitoring functions
1. Clearly defining the purpose of the integrated monitoring program and the monitoring objectives
2. Compiling and analysing relevant information on existing monitoring programs
3. Developing conceptual models
4. Developing overall sampling design for integrated monitoring a. Selecting indicators b. Selecting monitoring programs c. Developing sampling design
5. Developing monitoring protocols
6. Managing data
7. Analysing data
8. Reporting and communicating
9. Reviewing and auditing

Applying the guidance establishes an IMF by identifying:

- options and preferences for governance arrangements and the principles to guide decision-making for integrated monitoring
- the purpose of integrated monitoring, specific monitoring objectives for the focus area and integrated monitoring priorities (set in the context of management needs), which provide the basis for determining the adequacy of existing monitoring and identifying potential gaps in current monitoring effort that should to be addressed
- the requirements for the overall sampling design for integrated monitoring, including high-level indicators, required monitoring programs, a broad approach to developing a sampling design, and how existing monitoring programs can contribute to a sampling design for integrated monitoring. This provides the basis for determining the adequacy of existing monitoring for collecting data that addresses the integrated monitoring priorities as well as the outstanding gaps in sampling design that need to be addressed, and opportunities to fill them

- the purpose and scope of monitoring protocols, data management, data analysis, reporting and communication, as well as auditing and review processes necessary to support integrated monitoring. This provides the basis for determining the adequacy of existing monitoring and management initiatives for supporting these essential functions and the outstanding gaps that need to be filled, and opportunities to fill them.

Establishing an IMF is an important first step in implementing an integrated monitoring program (IMP). An IMF provides the foundation to develop an IMP. An IMP requires appropriate governance to be in place and adequate and sustained funding and resources. Although the primary focus of this project is on establishing an IMF, general guidance is provided to assist the transition from an IMF to an IMP.

Part 3 of the report represents an IMF for the GBRWHA, and employs the guidance from Parts 1 and 2.

An IMF for the Great Barrier Reef World Heritage Area

Context

In recognition of its Outstanding Universal Value, the Great Barrier Reef (GBR) was inscribed on the World Heritage list in 1981. In addition to biophysical values, the GBR Region also contains important elements of cultural heritage, Indigenous heritage, and supports a variety of community and economic benefits.

As highlighted in the *GBR Outlook Report 2009*, the GBR Region is under increasing pressure from many sources. A recent analysis of monitoring data has raised concern in view of further development plans for the GBR coast. Analysis of 27 years of monitoring data revealed that the amount of living coral on the GBR is declining with average coral cover falling by half between 1985 and 2012 (De'ath et al. 2012). While the effects of cyclones, crown-of-thorns starfish and coral bleaching are the main disturbances causing coral mortality, most long-term declines occurred in the central and southern regions of the GBR where human pressures are more intense. This indicates that human activities may be affecting the Reef's ability to recover by increasing cumulative impacts—the combined effects of all the natural and man-made pressures acting on the Reef—and this has reduced the Reef's health and resilience.

A strategic assessment of the GBRWHA and adjacent coastal zone is underway to evaluate and improve the management of existing and emerging risks to the GBRWHA, focusing on relevant MNES. The management program that arises from the GBRWHA strategic assessment process will require monitoring of MNES values of the GBRWHA to facilitate adaptive management, and to assess and report on MNES and management effectiveness.

Over many decades, monitoring in the GBR Region has been initiated in response to emerging issues (such as crown-of-thorns starfish in the 1980s), to understand long-term trends or for compliance with legislative requirements. However, monitoring needs for the overall management of the property have not been articulated and monitoring results have rarely been brought together to analyse cumulative impacts and inform management actions. Furthermore, social and economic monitoring has not previously been given a high priority and is currently not well integrated with ecological monitoring in the Great Barrier Reef.

The IMF articulates the monitoring priorities for the entire property and has determined the adequacy of existing monitoring programs for addressing these priorities for the first time. It represents a great step towards more effectively and efficiently monitoring the GBR. Three broad types of management-related monitoring are identified for the GBRWHA: long-term monitoring; short- to medium-term issue-specific monitoring; and compliance monitoring (meeting legislative requirements). The focus of the IMF is long-term monitoring and those short-term and compliance-related monitoring programs that should be integrated for more effective and efficient monitoring of the GBRWHA. Integrating these programs and explicitly linking them to management needs in an adaptive management context provides the necessary insights to determine the adequacy and sustainability of funding and resources for monitoring the GBRWHA.

Management objectives, governance and decision-making principles

The IMF identifies three prerequisites for integrated monitoring: 1) management objectives, 2) options and preferences for governance arrangements, and 3) principles to guide decision-making for integrated monitoring.

High-level **management objectives** for the GBRWHA are articulated in legislation, management and operating plans and strategies. Draft operational management objectives have been developed through the strategic assessment process for both biophysical values and threats/pressures. These will remain as draft objectives until the strategic assessment and the program report (the report outlining the future management arrangements for the GBRWHA) have been finalised.

The preferred **governance arrangement** for integrated monitoring for the GBRWHA is to make use and build on consultative and advisory structures and processes established under the Reef Plan. **Principles** to guide decision-making for integrated monitoring draw on the guidance (Parts 1 and 2 of this report), and are fully described in the context of the IMF for the GBRWHA.

Purpose of the integrated monitoring program

The IMF for the GBRWHA provides the foundation for developing an overarching IMP that would meet the following purposes:

- to monitor, evaluate and report on the condition and trends of the relevant MNES, including Outstanding Universal Value (OUV) of the GBRWHA as well as derived community benefits
- to monitor, evaluate and report on the influence of drivers and the impacts of activities and pressures, including the effectiveness of management policies, plans and programs to adequately protect the relevant MNES
- to improve spatial and temporal compatibility of monitoring data across long-term, short-term and compliance monitoring requirements
- to improve discoverability and accessibility of government-funded monitoring data for managing agencies and the general public
- to integrate monitoring, evaluation and reporting across biophysical, social and economic values, pressures and impacts to better understand and address the threats, including cumulative threats, facing the relevant MNES.

Monitoring priorities

The identification and prioritisation of monitoring needs for the GBRWHA took into account the long history of identifying the important values of the GBR through management, research and monitoring. Work conducted up to and including the *Outlook Report 2009* and commissioned after the *Outlook Report*, has focused management thinking on the high priority values in the GBRWHA and their interactions with pressures. This knowledge was captured using the prioritisation criteria that were established as part of this project.

Monitoring priorities have been identified for values, pressures, processes and drivers to meet long-term integrated monitoring needs for management (see Table 2). An extensive list of specific monitoring objectives has also been identified against each of these monitoring priorities. These are set in an objectives hierarchy that provides clear links between management objectives, targets and monitoring objectives.

Review of existing monitoring

The review of existing monitoring programs in the GBRWHA undertaken as part of this project identified more than 65 privately and publicly funded monitoring programs that are relevant to MNES. While some of these monitoring programs have been specifically designed to meaningfully inform management of MNES values (e.g. the Reef Rescue Marine Monitoring Program), there is no overarching framework to ensure these various programs are aligned with each other so that their findings can be integrated to better inform management of the property.

There are gaps in existing monitoring both spatially and in regards to some of the identified monitoring priorities. For example, the far northern GBR is generally poorly covered by monitoring, as are deep-water portions of seagrass meadows and deep-water reefs. Furthermore, for many cause-effect interactions, only the cause or the effect is monitored; there are very few instances where both the pressure and the value are adequately monitored. Consequently, the cause-effect relationship is poorly understood which compromises the ability to adequately assess management efforts.

Some values, such as coral reefs, are the focus of multiple monitoring programs with differing objectives. There is an opportunity to better draw together, evaluate, interpret and report the relevant results for these groups of programs.

Conceptual models and sampling design for integrated monitoring

The report uses seagrass and corals (two values unpinning MNES) to demonstrate how conceptual models will be used to capture broader ecosystem understanding, link pressures and values, make initial assessments of cumulative impacts, select indicators and guide overall sampling design of an IMP.

Table 2 Proposed priority values, pressures, processes and drivers for long-term core integrated monitoring

Values underpinning MNES	Pressures	Processes
• coral reefs and corals • seagrass meadows and seagrasses • open waters • islands • beaches and coastline • mangrove diversity • marine turtles • seabirds • shorebirds • dolphins • dugongs • bony fish • sharks and rays, including sawfish • other invertebrates • sea snakes • income, economic contribution and employment • understanding of the GBR • access to reef resources • appreciation, enjoyment and aesthetics (natural beauty) • personal attachment • health benefits	Climate change • increased sea and air temperature • cyclone activity • ocean acidification • rising sea level • altered ocean currents and smaller scale circulations • increased freshwater flow • outbreaks of disease Water quality and pollution • nutrients from catchment run-off • sediments from catchment run-off • pesticides from catchment run-off • crown-of-thorns starfish • outbreaks of disease • marine debris Coastal habitat degradation • dredging and spoil disposal • clearing and modifying coastal habitats • coastal reclamation • artificial barriers to flow Direct use of the Region • extraction of predators • death of discarded species • illegal fishing and poaching • crown-of-thorns starfish • noise pollution • fishing/spawning aggregations	• connectivity • recruitment • primary production - pelagic **Drivers** • climate change • economic growth • population growth • technological developments • societal attitudes

Sampling design needs to build effectively on past and present monitoring. While the guidance in Part 2 favours a probabilistic approach to sampling design, existing monitoring in the GBR does not generally conform to this approach. Further consideration of an overall sampling design for integrated monitoring will occur during development of the IMP, at which time management objectives will have been finalised through the strategic assessment process, thus providing clarity about objectives and indicators. An overall approach to sampling design may enhance capacity to understand cause-and-effect relationships and make regional-scale inferences about maintenance and enhancement of MNES values.

Selecting monitoring programs for inclusion in integrated monitoring for the GBRWHA includes identifying existing programs that will meaningfully address the monitoring priorities (there are many reasons why monitoring occurs in the GBR and not all existing monitoring will need to be integrated to inform management) and may also include development of proposals (new programs or refinements to existing programs) to address gaps in monitoring priorities. Criteria are identified for selecting monitoring programs for inclusion in integrated monitoring for the GBRWHA.

Monitoring protocols and managing data

Developing monitoring protocols and managing data are essential monitoring functions that will enable data collected from different monitoring programs to be more comparable. While many existing monitoring programs in the GBRWHA do not publish easily accessible descriptions of methods and procedures there are several existing guides and procedures that could provide a basis for monitoring protocols for integrated monitoring. Capturing protocols of existing programs is identified as an early priority in the development of an IMP.

The framework identifies the principles and characteristics of the approach to data management that is necessary to support integrated monitoring for the GBRWHA. The approach acknowledges that relevant monitoring data are generated by numerous parties including management, research and industry sectors and that both distributed and centralised approaches to hosting data are required. A range of existing data management initiatives is identified along with potential linkages and collaborations between initiatives that could enable data to be more easily located and accessed to facilitate use of this data for integrated analysis, reporting and review.

Data analysis, reporting and review

Integrated monitoring implies the need for an overarching analysis group whose task it is to draw together the results from all the individual monitoring programs to provide the most complete information possible as a basis for adaptive management of the GBRWHA. The GBRWHA *Outlook Report* is identified as the primary and legislated reporting mechanism for managing the GBR that brings together all of the most relevant monitoring and other information for management. The GBRMPA also has an extensive array of established communication and engagement programs that will be used to disseminate the information from integrated monitoring.

Review and auditing of integrated monitoring is essential to ensure it continues to be effective and meet the needs of management. The GBRMPA has adopted the International Union for the Conservation of Nature (IUCN) management cycle as its management effectiveness assessment system. Monitoring and reporting will be included as a management topic to be assessed for effectiveness under this system.

Moving towards an integrated monitoring program

Through this project and for the first time, the monitoring needs for management, legacy of past monitoring programs and the capacity of existing monitoring programs have been brought together in a multidisciplinary, multi-institutional effort to provide a blueprint for an integrated approach to monitoring the GBR. The framework, as presented in Part 3 of this report, explicitly links management objectives, monitoring objectives and monitoring programs in a driver, pressure, state, impact and response framework to provide a solid foundation for an IMP for the GBRWHA.

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Glossary of Terms

Adaptive management — a systematic process for continually improving management practices through learning from the outcomes of previous management actions.

Conceptual model — a summary of current understanding of, and assumptions about ecosystems and the effect of pressures on those ecosystems.

Cumulative impact — the combined effect of on the environment resulting from the incremental effects of individual impacts.

Essential functions of monitoring — the functions that are deemed necessary for an effective monitoring program.

Governance — the set of responsibilities and practices, policies and procedures, exercised by an agency's executive, to provide strategic direction, ensure objectives are achieved, manage risks and use resources responsibly and with accountability.

Integrated monitoring— objective and systematic integration of interests, data and knowledge across policy, management and science sectors to monitor, analyse and report on the effectiveness of management.

Integrated monitoring framework (IMF) — a document providing strategic assessment partners and regulators with a systematic and objective understanding about the purpose, priorities, functions and requirements of integrated monitoring in a focus area.

Integrated monitoring program — a funded program with a clear purpose and priorities for integrated monitoring that provides certainty about how the program will be commenced, developed and reviewed.

Management objective — a statement that clearly articulates what management needs to achieve.

Matter of National Environmental Significance (MNES) — matters protected under national environmental law, as defined under Part 3 of *the Environment Protection and Biodiversity Conservation Act 1999.*

Monitoring objective —a statement that clearly articulates what monitoring needs to achieve.

Strategic Assessment — landscape scale assessments of classes of actions defined under Part 10 of *the Environment Protection and Biodiversity Conservation Act 1999.*

Part 1 Introduction

1.1 The project

This project was commissioned by the Department of the Environment to develop and test practical guidance that would help partners involved in a strategic assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to establish a framework for integrated monitoring. The establishment of a framework would provide a foundation for partners to develop efficient and effective monitoring and reporting on the condition of nationally protected matters and support adaptive management of these assets. The project team developed guidance on establishing an integrated monitoring framework and applied it to Great Barrier Reef World Heritage Area (GBRWHA) to test the approach, with the intention that the approach could be used as a model to inform the development of other integrated monitoring programs for strategic assessments in other coastal and marine regions in Australia. A summary of the approach to this project is provided in Appendix 1.

This report is divided into three parts:

- Part one provides a background and introduction to the project.
- Part two provides guidance on a recommended approach to establishing an integrated monitoring framework (IMF) and general guidance for transitioning from an IMF to an integrated monitoring program (IMP). The development of an IMP is outside the scope of this project.
- Part three applies the guidance to the GBRWHA to produce an integrated monitoring framework for ecological, social and economic monitoring to inform the GBRWHA strategic assessment.

The IMF for the GBRWHA provides one of a number of key inputs to inform the monitoring and adaptive management approach for the strategic assessment of the GBRWHA.

1.2 Adaptive management and monitoring in strategic assessments

The EPBC Act is the Australian Government's central environmental legislation. It provides the legal framework to protect and manage national and internationally important flora, fauna, ecological communities and heritage places – defined in the Act as matters of national environmental significance (MNES). The EPBC Act offers two pathways to achieve approval for actions that are likely to have a significant impact on MNES (SEWPaC, 2012). The first is a project-by-project assessment of actions of a single proponent or developer one action at time. The second is through strategic assessments that look at, and potentially approve, a series of new proposals or developments over much larger spatial and temporal scales.

In a strategic assessment under the EPBC Act, the Australian Government seeks to maximise conservation of the MNES that occur within the strategic assessment area in the most practical and achievable way. To achieve this, those undertaking strategic assessment consider four mechanisms: avoidance of impacts, mitigation of impacts, offsets and ongoing adaptive management.

As the proposals undergoing strategic assessment typically have long time horizons, the Australian Government identifies adaptive management as a particularly important mechanism to maintain and enhance MNES values in a changing environment. Monitoring is identified as a key characteristic of the adaptive management approach.

Monitoring to support adaptive management of MNES values is not a trivial task. At worst monitoring data can be costly and of little use to management while at best it provides valuable information to managers about the effectiveness of their management interventions. Conceptually, monitoring to support adaptive management presents a challenge that is addressed by good logic and sufficient resources. But in application there are a broad range of considerations and challenges that require much more than good logic and resources to establish and sustain a fit-for-purpose monitoring program supporting adaptive management. For example, there are different motivations for monitoring (Walters 1986 in Douvere and Ehler 2011; Possingham et al. 2012), and a diverse range of opinions and advice from policymakers, managers and scientists on what to monitor, how it should be done and who should pay for it. There is an extensive literature providing numerous examples and summaries that outline the successes and failures of monitoring; a useful summary is provided in Lindenmayer and Likens (2009).

One of the most important initial challenges in setting up a fit-for-purpose monitoring program is having a clear understanding about the context of adaptive management and monitoring. The *guide to undertaking strategic assessments* (Department of the Environment 2012) describes adaptive management as ‘a systematic process for continually improving management practices through learning from the outcomes of previous management.’ The Guide describes the key characteristics of adaptive management as:

- acknowledgement of uncertainty about what management practices are ‘best’ for a particular issue
- thoughtful selection and design of the management practices to be applied
- careful implementation of a management plan designed to reveal the critical knowledge that is currently lacking
- monitoring of key response indicators
- analysis of the management outcomes against the original objectives for maintaining and improving MNES values
- incorporation of the results into future management plans.

The general process for adaptive management is shown in Figure 1.1 and the indicative process for strategic assessments in shown in Figure 1.2.

Thus monitoring is a critical step in the adaptive management process for ensuring positive outcomes for MNES. Ensuring monitoring is coordinated and targeted is particularly challenging in the context of strategic assessments with large geographic scope, complex issues, cumulative impacts and limited resources.

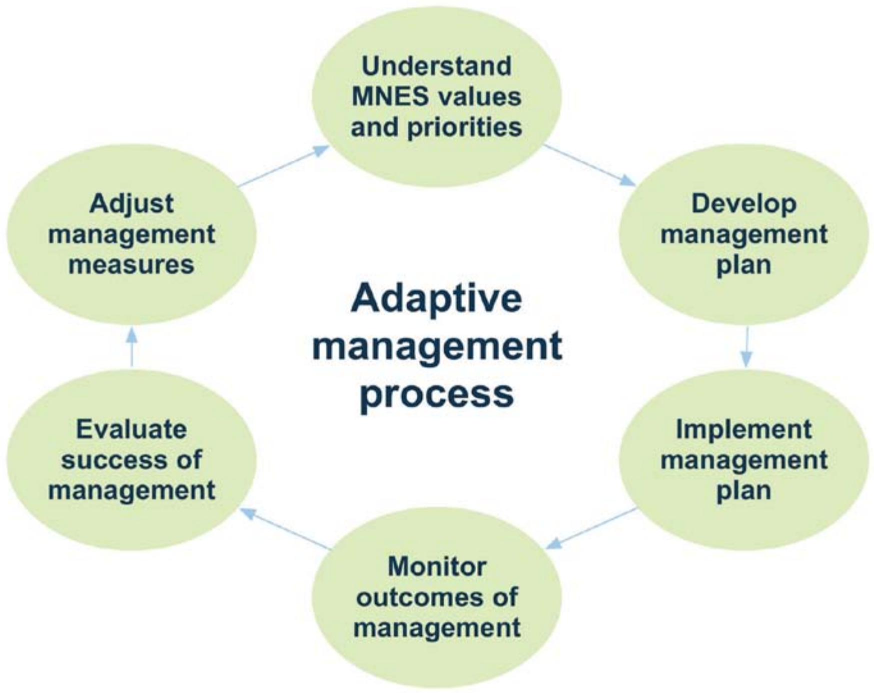


Figure 1.1 Adaptive management process (Source: SEWPaC 2012)

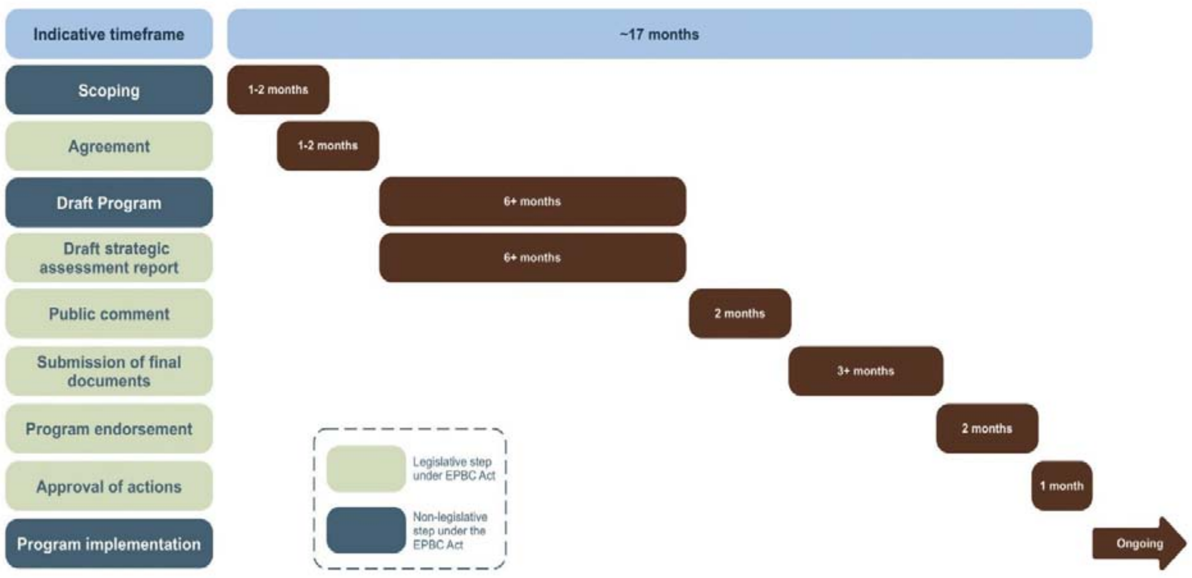


Figure 1.2 Indicative process for strategic assessment under Part 10 of the EPBC Act (Source: SEWPaC 2012)

1.3 The Great Barrier Reef World Heritage Area

The GBR is one of Australia's greatest national assets. The GBRWHA covers approximately 348000 km^2, an area larger than the United Kingdom. As an ecosystem, the GBR and adjacent coastal regions form a rich, interconnected mosaic of habitat types ranging from rivers and estuaries to coral reefs, islands and coral cays, deep-water reefs, open ocean habitats and deep-water habitats off the continental shelf. These habitats house great biological diversity with species counts of 1500 fishes, 360 corals, up to 8000 molluscs, and species of special interest such as six species of marine turtles, 22 seabird species, the dugong, and over 30 whale and dolphin species (GBRMPA 2009). The 2900 coral reefs of the GBR comprise 10 per cent of the world's coral reefs, and are among the best managed reefs in the world (Wilkinson 2008).

In recognition of its Outstanding Universal Value, the GBR was inscribed on the World Heritage list in 1981. The GBR is one of the world's most beautiful natural assets, a system of extraordinary natural, social, cultural and economic value, and of exceptional size, diversity and beauty. For these and other reasons, it has been declared a World Heritage Area and Marine Park.

In addition to biophysical values, the GBR Region also contains important elements of cultural heritage such as historical places of significance, and is very significant to Traditional Owners who hold past and present cultural heritage values for the surrounding land and sea country. Reef-dependent communities include commercial fishing and tourism, while other commercial activities like ports, residential developments, industrial installations and agriculture occur adjacent to the GBR and have links to its habitats and ecosystems. In 2011–12, reef-dependent industries were worth an estimated AUD $5.7 billion to the national economy, with tourism activities accounting for $5.2 billion (Deloitte Access Economics 2013). Aside from its economic value, the GBR has important social and cultural value to regional communities and the wider Australian community who value it for recreation, aesthetics, health and wellbeing, and as part of their identity.

As highlighted in the *GBR Outlook Report 2009*, the GBR Region is under increasing pressure from many sources. In March 2012, representatives from the UNESCO World Heritage Centre visited the GBRWHA to assess these growing pressures, and the mission raised concerns over increasing threats to the area. Recent analyses of monitoring data have raised further concerns. A 2012 analysis of 27 years of monitoring data revealed that the amount of living coral on the GBR is declining (Figure 1.3), with average coral cover on reefs of the GBR falling by half between 1985 and 2012 (De'ath et al. 2012). While cyclones, crown-of-thorns starfish and coral bleaching are the main disturbances causing coral mortality, the long-term declines occurred mostly in the central and southern regions of the GBR where human pressures are more intense. This indicates that human activities may be affecting the Reef's ability to recover by increasing cumulative impacts—the combined effects of all the natural and man-made pressures acting on the Reef—and has reduced the Reef's health and resilience.

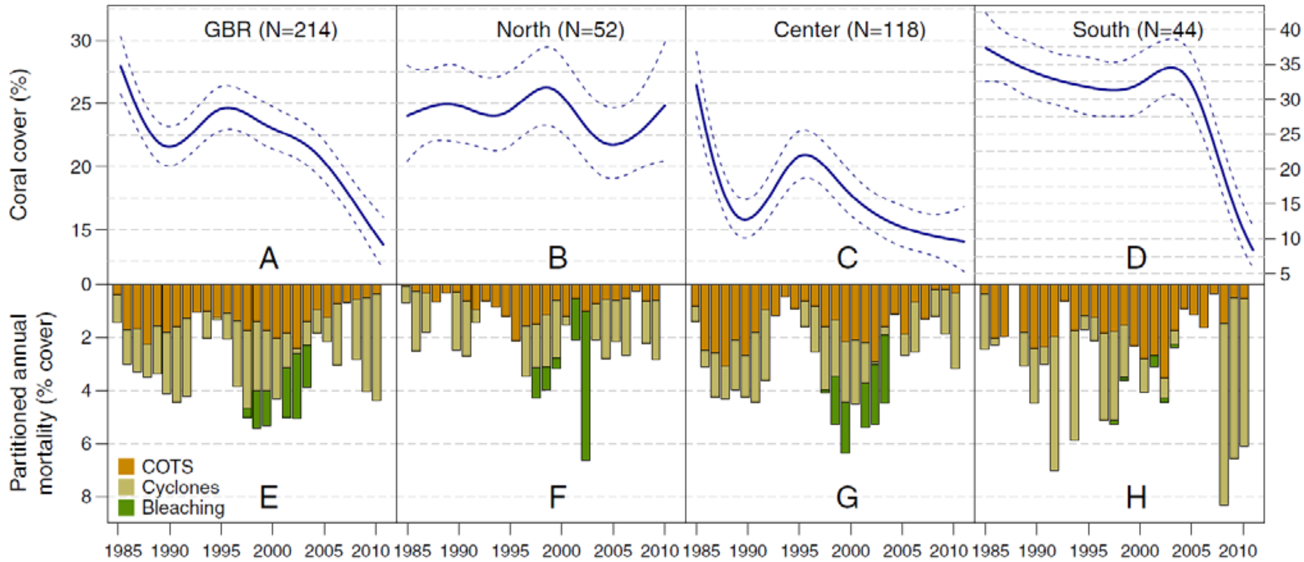


Figure 1.3 Temporal trends in coral cover (A–D) and annual mortality due to crown-of-thorns starfish (COTS), cyclones, and bleaching (E–H) for the whole GBR and the northern, central, and southern regions over the period 1985–2012 (N = number of reefs). (A–D) Trends in coral cover, with blue lines indicating estimated means (±2 SEs) of each trend. (E–H) Composite bars indicate the estimated mean coral mortality for each year, and the sub-bars indicate the relative mortality due to COTS, cyclones, and bleaching. The periods of decline of coral cover in A–D reflect the high losses shown in E–H. (Source: De'ath et al. 2012)

The declines in coral cover illustrate an alarming trend that underscores the importance of the need for an integrated approach to managing values underpinning MNES of the GBR Region, an approach that enables cumulative pressures to be identified and managed. It also demonstrates the importance of monitoring data to:

a) inform adaptive management

b) predict, prepare for, and, where possible, limit the impacts of new pressures and drivers of change

c) restore and enhance reef values where possible.

The Australian and Queensland Governments are currently preparing a comprehensive strategic assessment of the GBRWHA and adjacent coastal zone in accordance with the EPBC Act. The strategic assessment will help to identify, plan for and manage existing and emerging risks to the GBR Region and thus maintain and enhance the MNES values of the GBRWHA.

The management program developed through the GBRWHA strategic assessment requires effective arrangements for adaptive management and monitoring of MNES values of the GBRWHA. There are currently numerous monitoring programs in the GBRWHA which are designed to provide data for a variety of different purposes. A review of existing monitoring programs in the GBRWHA (see Section 3.5) identified more than 65 privately and publicly funded monitoring programs that are relevant to MNES values. While some of these monitoring programs have been designed to meaningfully inform management of values underpinning MNES (e.g. the Australia Institute of Marine Science Long-Term Monitoring Program (LTMP) provides useful monitoring data to determine trends in the coral communities of the Great Barrier Reef and to assess management outcomes – see Wilkinson 2008, GBRMPA 2009, McCook et al. 2010, De'ath et al. 2012), there is no overarching framework to ensure the various programs are integrated with each other, or are linked to and inform management of the property. This project has been commissioned to produce an integrated framework for ecological, social and economic monitoring that may support the implementation of the GBRWHA strategic assessment.

1.4 What is integrated monitoring and what are the benefits?

To *integrate* means *to make whole by bringing all parts together, to unify*. The terms *integrated* and *monitoring* are common terms in environmental policies, strategies and management plans and in scientific publications and reports. The term *integrated monitoring* is a more specific use of these terms but its use and definition does not appear to be commonplace in the literature compared to terms like *integrated management* and *integrated planning*.

Parr et al. (2002) describe *integrated monitoring* as 'the systematic, consistent, and simultaneous measurement of physical, chemical, biological and socio-economic variables of different ecosystem compartments, over time and specified locations'. On the surface, this definition suggests that the art of integrated monitoring lies with integrating the measurement of variables from different scientific disciplines over time and space—i.e. it is primarily a technical exercise. However, the authors' elaboration of *integrated monitoring* based on the experience of, and future challenges for, developing a long-term integrated terrestrial and freshwater monitoring program in Europe, clearly indicates that a range of interests, skills, resources and data needs to be integrated to develop an effective integrated monitoring program. Many of these same interests, resources, data and knowledge are also identified as important for effective adaptive monitoring (Lindenmayer and Likens 2009), ecological monitoring (Field et al. 2007, Fancy et al. 2009), biodiversity monitoring (Lindenmayer et al. 2012) and adaptive maritime spatial planning (Douvere and Ehler 2011). For the purposes of this project we extend the definition of integrated monitoring of Parr et al. (2002) to:

> *The objective and systematic integration of interests, data and knowledge across policy, management and science sectors to monitor, analyse and report on the effectiveness of management for maintaining and enhancing MNES values.*

The benefits of integrated monitoring

Integrated monitoring, when planned and implemented effectively, provides two primary benefits. The first of these benefits is a better understanding of cause-and-effect relationships within socio-ecological systems and the response of these systems to management actions (represented by a Driver-Pressure-State-Impact-Response [DPSIR] model; Antunes and Santos 1999). Targeting monitoring to management priorities and establishing mechanisms to integrate interests, data and knowledge are fundamental to this primary benefit.

The second primary benefit is cost-effective use of available resources for monitoring the status of MNES. This requires a good understanding of the management priorities and the costs and benefits of existing and/or proposed monitoring programs. Maximising cost-effectiveness may present challenges for strategic assessment partners, particularly if they do not have responsibility for resourcing existing monitoring interests and efforts.

Other important benefits of integrated monitoring include better insights about how to respond to fluctuations in resources available for monitoring (e.g. how to respond to reductions and increases in monitoring budgets) and the effects of cumulative pressures and impacts on MNES values.

Integrating interests

The integration of interests across policy, management and science sectors is a cornerstone to successful integrated monitoring (Rogers and Biggs 1999, Parr et al. 2002, Field et al. 2007, Fancy et al. 2009, Lindenmayer et al. 2012). Although there are many aspects of integrated monitoring where the need for this type of integration is apparent, arguably the most important is the crafting of realistic, specific and measurable monitoring objectives (see Section 2.3.1) and directly linking these to management objectives (see Section 2.2.1). This is a priority area for integration because so many, if not all, of the activities and tasks associated with integrated monitoring flow from clearly articulated and measurable objectives. The challenge is to ensure that collectively the management and monitoring objectives are structured hierarchically to provide clarity on the mandate of policymakers and the priorities for resource managers, and are scientifically testable (Rogers and Biggs 1999).

Integrating data

We identify two important considerations for integrating data and analyses: first, integrating similar data streams to build understanding about environmental change and trends at a range of spatial scales (local, regional and national) and over time; second, integrating different types of data (e.g. economic, social and environmental) to produce understanding and insights to determine the effectiveness of management for maintaining and enhancing MNES values.

The design of an integrated monitoring program (see Section 2.3.4), data collection protocols (see Section 2.3.5) and data management standards (see Section 2.3.6) are all important mechanisms to facilitate integration of monitoring data and improve understanding of environmental change or trends across spatial and temporal scales (Parr et al. 2002, Fancy et al. 2009). For example, these mechanisms are critical for ensuring data collected at local scales can be discovered, stored, accessed and used to make confident inferences, where required, at regional and larger scales. They are also important for integrating new monitoring programs with existing programs, where required. Parr et al. (2002) point out the need to integrate across existing sites and facilities to make the best possible use of existing long-term historic data sets and new statistical analysis.

The use of conceptual models (see Section 2.3.3) provides an important means for understanding how the diverse components of natural systems and humans interact (Parr et al. 2002, Fancy et al. 2009, Lindenmayer et al. 2012). Graphical conceptual models can also provide a mechanism to integrate the beliefs of diverse groups of scientists and stakeholders into a coherent and scientifically testable structure, and they guide the analysis and interpretation of data (see Section 2.3.7) from monitoring programs (Dawsey et al. 2006). Conceptual models also complement the DPSIR framework (Antunes and Santos 1999) linking indicators to pressures, and subsequently management response. The learning that accompanies the design, construction and revision of the models contributes to a shared understanding of system dynamics, and the process of developing conceptual models is often more important that the model itself (Fancy et al. 2009).

Integrating new information and knowledge

Integrated monitoring operates in a world that is not static. Advances in ecosystem understanding and the effects of pressures, changes in environmental drivers, new technologies and innovation and new priorities for policymakers all have the potential to justify changes to an integrated monitoring program (Parr et al. 2002, Lindenmayer and Likens 2009, Lindenmayer et al. 2012) and potentially the management objectives themselves. It is therefore essential that mechanisms to integrate new information and knowledge into existing monitoring programs are designed into an integrated monitoring program.

Important mechanisms for integrating new information and knowledge into existing monitoring programs are regular program reviews (see Section 2.3.9) and the identification of research priorities designed to improve performance monitoring. Lindenmayer and Likens (2009) promote regular program reviews as a means of integrating new information and knowledge to continually improve monitoring programs. Clearly articulated research priorities designed to improve capacity to monitor management performance provide a means of integrating research with monitoring. For example research priorities can be specified to improve understanding of cause-and-effect relationships or to improve the cost-effectiveness of the monitoring program.

1.5 Differences between a framework and a program

An integrated monitoring *framework* is a document providing strategic assessment partners and regulators with a systematic and clearly articulated understanding about the purpose, priorities, functions and requirements of integrated monitoring in a specific focus area. It identifies the opportunities and gaps that should be considered to integrate monitoring. It requires a short-term commitment with a one-off investment of funds and resources. Establishing an IMF instigates thought about why, what and how integrated monitoring will support adaptive management and for clear articulation of those reasons in the strategic assessment and ongoing long-term management of the area of focus. An IMF provides the foundation to develop an IMP, it does not integrate monitoring.

An integrated monitoring *program* operationalises the planning and assessment undertaken as part of establishing the IMF and requires appropriate governance and adequate and sustained funding and resources. The IMP has a clear purpose and priorities for integrated monitoring in the focus area(s) and provides certainty about how the program will be commenced, developed and reviewed. The governance roles of leadership, decision-making and support for the IMP are defined, particularly as they relate to the functions of an IMP. The IMP identifies the existing monitoring programs that will participate in integrated monitoring and the infrastructure, initiatives, processes, standards and protocols that will be used to integrate monitoring in the focus area(s). It identifies the actions that need to be completed over the short, medium and longer term, and who will be responsible for actions, to commence, develop and review the IMP. The important outcomes sought from an IMP are:

- clear understanding about the ecological, social and economic monitoring priorities required to determine the effectiveness of management for maintaining and enhancing MNES values
- clear understanding about how monitoring activities are prioritised, selected and funded and how these decisions are made

- clear understanding of how monitoring data are analysed to inform adaptive management of MNES values, research and modelling
- clear understanding of the agreed standards and protocols for collecting, managing, analysing and reporting monitoring data
- an agreed sampling design to ensure the efficient and effective implementation of various monitoring activities
- that monitoring, analysis and reporting informs managers about:
    - the effectiveness of management for maintaining and enhancing MNES values
    - the effects of pressures and cumulative impacts of pressures on MNES values
    - early warning signals for emerging management issues in time to develop effective mitigation measures
- effective cooperation and understanding between regulators, managers and scientists to ensure that trends in monitoring data are understood and used to adapt management
- efficient use of resources available for integrated monitoring
- clarity on research needs to support integrated monitoring.

Part 2 Guidance to establish an Integrated Monitoring Framework

2.1 Overview of the guidance and its application

This part of the report provides practical guidance that could be used by strategic assessment partners to establish an integrated monitoring framework for a particular region. The guidance has been applied to establish an IMF for the Great Barrier Reef World Heritage Area in Part 3 of this report.

This guidance draws on knowledge and advice from a broad range of experts from the fields of policy development, natural resource management, science and data management. Literature reviews, a series of workshops and numerous targeted meetings were used to harvest knowledge and advice. It is important to recognise that the framework described in this report is not radically different from many of the predecessors. Indeed the framework described here is based on the seven essential monitoring steps identified by the United States National Park Services (Fancy et al. 2009). This report endeavours to add value by describing in more detail the 'why', 'what' and 'how' for integrated monitoring.

The guidance for establishing an IMF sets out the prerequisites for monitoring including the essential monitoring functions to be addressed (see Figure 2.1). Prerequisites to establish an IMF include:

- management objectives—to provide clarity about management needs and priorities
- governance arrangements—to provide a foundation for performance of the program and conformance to law, regulations, standards and community expectations of probity, accountability and openness
- principles of integrated monitoring—to guide the many discussions and decisions that need to be made to establish an IMP.

The essential monitoring functions that should be addressed by an IMF are:

1. Clearly defining the purpose of the IMP and the monitoring objectives
2. Compiling and analysing relevant information on existing monitoring programs
3. Developing conceptual models
4. Developing overall sampling design for integrated monitoring
    a. Selecting indicators
    b. Selecting monitoring programs
    c. Developing sampling design
5. Developing monitoring protocols
6. Managing data
7. Analysing data
8. Reporting and communicating
9. Reviewing and auditing.

The guidance is designed to be applied during the development of a program that is the subject of a strategic assessment (see Figure 1.2) and intended to instigate thought about why, what and how integrated monitoring will support adaptive management and for that thought to be clearly reflected in the program. Applying the guidance establishes an IMF by identifying:

- options and preferences for governance arrangements and principles to guide decision-making for integrated monitoring
- the purpose of integrated monitoring, specific monitoring objectives and integrated monitoring priorities (set in the context of management needs)
- the requirements for the overall sampling design for integrated monitoring, including high-level indicators, required monitoring programs, an overview of the sampling design approach, an understanding of how existing monitoring programs can contribute to overall sampling design, the outstanding gaps that need to be addressed and opportunities to fill them
- the purpose and scope of monitoring protocols, data management, data analysis, reporting and communication and auditing, as well as auditing and review required to support integrated monitoring, an understanding of how existing monitoring programs and initiatives can support integrated monitoring, the outstanding gaps that need to be filled and opportunities to fill gaps.

Table 2.1 lists the prerequisites and essential functions of an IMF and provides an overview of the outputs that are generated by applying the guidance to establish the IMF.

Establishing an IMF is an important first stage to implementing an IMP (see Figure 2.1). Although the primary focus of this project is on developing an IMF, general guidance is provided to assist the transition from an IMF to an IMP.

Important notes for applying the guidance to establish an IMF:

- Apply the guidance to establish the IMF in a step-wise fashion and note the need for iteration between some steps (see Table 2.2 for an overview).
- Compiling and analysing relevant information on existing monitoring programs provides important information for completing steps 4–9 (see Figure 2.2).
- If time and resources are limited, focus efforts on clearly defining goals and objectives for management and monitoring (essential function 1). This will help to focus efforts for completing the other essential functions. It will also provide a clear basis to return to when (if) further resources become available.
- The diversity in monitoring language and logic has the potential to significantly impede progress toward establishing the IMF. There are many different, sometimes synonymous, terms used to describe and explain environmental monitoring. It is important that a common lexicon and logic is developed early. The IMF provides a structured approach for forming the common lexicon and logic.
- A diverse spectrum of knowledge and information is required to establish an IMF. Integrated monitoring draws on a variety skills and expertise. Establishing the IMF will require information and advice from policymakers, managers and scientists.

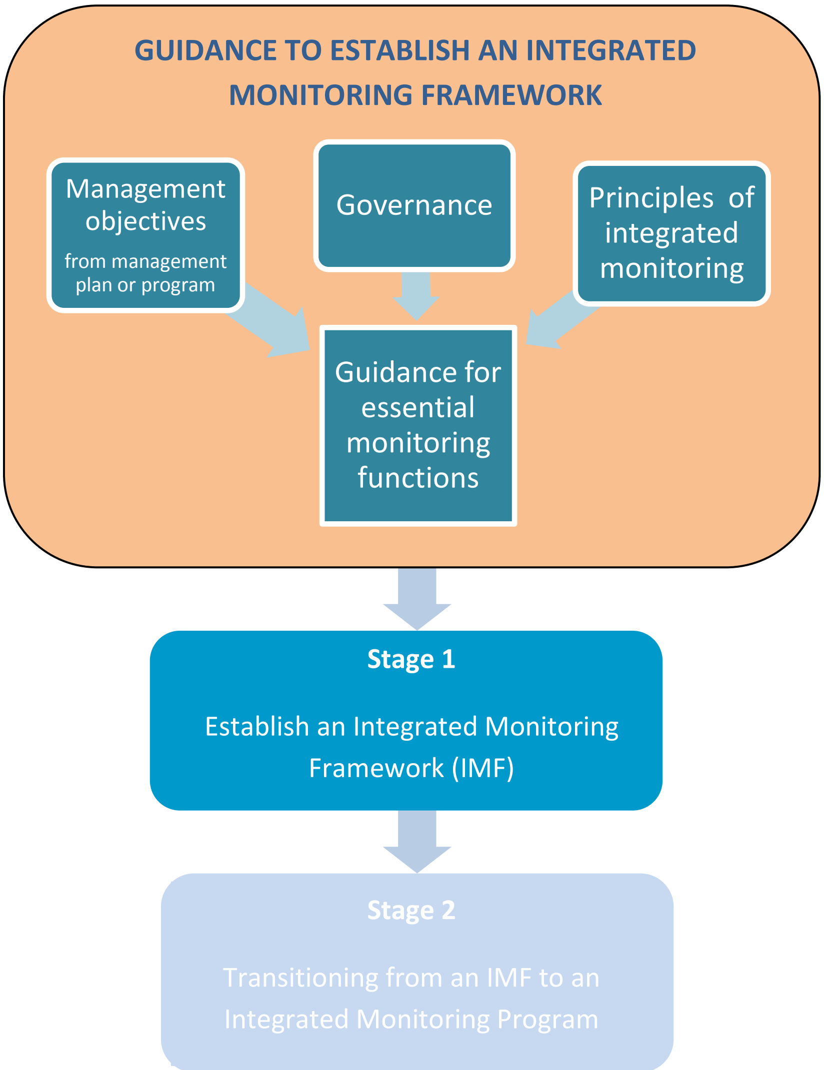
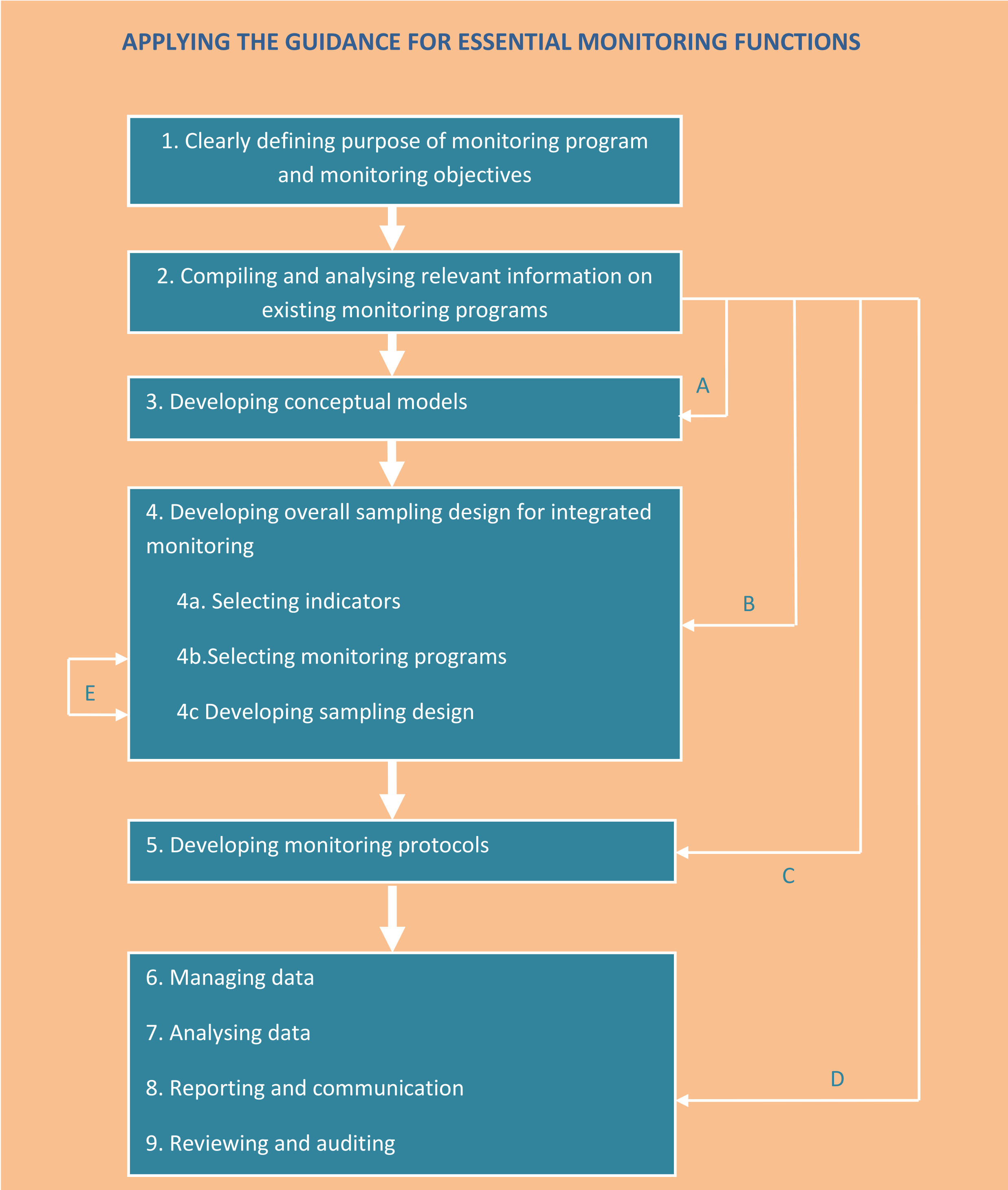


Figure 2.1 An overview of the guidance relating to establish an IMF to support the adaptive management arrangements of programs being assessed under the strategic assessment provisions of the EPBC Act 1999. Stage 1 is focused on establishing an IMF and stage 2 on transitioning from the IMF to an IMP



A – existing conceptual models and known gaps; **B** – existing monitoring programs and known gaps; **C** – existing monitoring protocols and known gaps; **D** – existing infrastructure, processes or protocols and known gaps; **E** – Iteration will be required as sampling design informs, and is informed by, selection of monitoring programs.

Figure 2.2 An overview of how to apply the guidance for essential monitoring functions identifying the relationships, links and need for iteration between functions

Table 2.1 An overview of outputs generated by applying the guidance to establish an IMF. Collectively the outputs form the IMF

Guidance to establish IMF	Outputs from applying the guidance
Prerequisites for an Integrated Monitoring Framework	
Management objectives	Management objectives are provided through policies and/or management strategies and plans (Section 2.2)
Governance	Options for existing governance models (including existing governance models) that could support the IMF (Section 2.3)
Principles of integrated monitoring	Proposed principles to guide decision-making for the IMF (Section 2.3)
Essential monitoring functions	
1. Clearly defining the purpose of monitoring and the monitoring objectives	Purpose of the integrated monitoring program and a prioritised list of monitoring objectives (Section 2.3.1)
2. Compiling and analysing relevant information on existing monitoring programs	Review of existing monitoring programs (Section 2.3.2)
3. Developing conceptual models	Identification of existing conceptual models that would support the integrated monitoring plan, gaps in conceptual models required for integrated monitoring and opportunities to address gaps (Section 2.3.3)
4. Developing overall sampling design for integrated monitoring a) Selecting indicators b) Selecting monitoring programs c) Developing sampling design	a) Selected high-level indicators to support high priority monitoring objectives (Section 2.3.4a) b) Identify existing monitoring programs (based on costs and benefits) that should be included in integrated monitoring, and proposals to address gaps (Section 2.3.4b) c) Identification of sampling design requirements for integrated monitoring and an assessment of how existing monitoring programs identified for inclusion in integrated monitoring meet these requirements, and how sampling design could be integrated across selected programs to produce efficiencies (Section 2.3.4c)
5. Developing monitoring protocols	Identification of purpose and scope of monitoring protocols, existing monitoring protocols, gaps and opportunities to address gaps (Section 2.3.5)
6. Managing data	Identification of purpose and scope of data management for discovery, storage and access to monitoring datasets, including preferred model for data management, existing infrastructure, processes and standards that could support supporting the proposed model, key gaps and opportunities to address gaps (Section 2.3.6)
7. Analysing data	Identification of purpose and scope of data analysis to support integrated monitoring, together with options and preferences for undertaking and completing data analysis, examples of integrated data analysis, gaps and opportunities to address gaps (Section 2.3.7)
8. Reporting and communication	Identification of purpose and scope of reporting and communication to support integrated monitoring, sources of data and key audiences, options and preferences for reporting and communication, existing initiatives to support integrated monitoring, significant gaps and opportunities to address gaps (Section 2.3.8)
9. Reviewing and auditing	Identification of purpose and scope of reviewing and auditing to support integrated monitoring and a preferred model for reviewing and auditing (Section 2.3.9)

2.2 Prerequisites to establish an IMF

Clearly defined management objectives, governance and principles for integrated monitoring are prerequisites for establishing an IMF. Collectively they provide clarity about what management seeks to achieve, the arrangements for decision-making and provision of expert advice, and guidance for decision-making to establish an IMF.

2.2.1 Clearly defined management objectives

Aims of this section

- To explain the importance of clearly defined management objectives.
- To identify considerations for management objectives in the context of integrated monitoring.
- To provide guidance to establish an IMF.

Importance

Clearly defined management objectives are a fundamental prerequisite to successful management. The policymaker's mandate for MNES and operational focus areas for natural resource managers are explicitly expressed through the management objectives which in turn provide a 'straight line of site' for identifying monitoring objectives, indicators and necessary data analysis for the IMF.

Considerations

Management objectives are defined by policymakers and managers during the process of planning and management. In the case of strategic assessment under the EPBC Act, this means management objectives are defined while developing the draft strategic assessment program and draft strategic assessment reports. It is important that management objectives are defined early in the process to inform an IMF as they are essential for focusing effort and prioritising.

To meaningfully inform the IMF, management objectives must be able to inform the operational level (i.e. provide direction to on-ground managers). It is not enough to provide broad objectives and expect that on-ground managers will be comfortable with a lack of detail and potential ambiguities (Rogers and Biggs 1999). This means they should meet criteria of being *realistic, specific* and *measurable* (NPS 2012). An alternative test is that objectives should be *specific*, *measureable*, *achievable, results-oriented* and applicable over relevant *time frames* (SMART; Reynolds 2012). Management objectives that are high-level statements of strategic intent lack the necessary detail required by on-ground managers, particularly in terms of what needs to be achieved, where and by when. Where existing management objectives are not articulated at an operational level, it is critical that further work be undertaken to ensure they are realistic, specific and measureable. Failure to do this may severely limit the capacity of the monitoring program to inform adaptive management for MNES.

Defining clear, unambiguous operational objectives is not a trivial task. It requires considerable thought and time from policymakers and managers and the outputs need to be logical and transparent. Rogers and Biggs (1999) recommend the development of an objectives hierarchy (hereafter referred to as the management objectives hierarchy). The management objectives hierarchy begins at the broadest level with the organisation's vision, mission statement or strategic objectives (hereafter referred to as the high-level management objectives). These high-level objectives are then broken down into a suite of lower-level statements which have increasing focus, rigour and achievability. The lowest level of the management objectives hierarchy provides on-ground managers with realistic, specific and measurable direction that is delimited in space and time. Examples of poor, acceptable and preferred specifications for the lowest level of the management objectives hierarchy are provided in Table 2.2.

There are numerous terms that are used to label the different levels of management objectives hierarchies, for example: goals, aims, high-level objectives, fundamental objectives, operational management objectives, means objective, outcomes, targets, endpoints and so forth. There is no one right structure (i.e. set of terms or number of levels in the hierarchy) but it is important to define the terms used for the different levels in a hierarchy for a particular IMF, understand how they relate to each other and ensure the lowest level of the hierarchy provides on-ground managers with realistic, specific and measurable direction. Figure 2.3 identifies a hypothetical hierarchy that would meet the needs of strategic assessment under the EPBC Act.

Guidance to establish an IMF

I. Test management objectives to determine if they provide direction at the operational level (i.e. are they realistic, specific and measurable). If they meet the test, organise objectives into a management objectives hierarchy.

II. If management objectives do not provide the detail required to provide operational goals this should be noted and management informed with a view to developing more operational objectives.

III. Circulate management objectives hierarchy to appropriate governance committees.

Table 2.2 A hypothetical example of poor, acceptable and preferred operational management objectives to restore coral cover and condition in a marine reserve

Management objective	Is it a clearly defined operational management objective?
High-level management objective To provide for the protection, conservation and restoration of biodiversity and heritage values in the marine reserve	**NOT OPERATIONAL – not realistic, specific or measurable** Objective is aspirational and provides no insight about whether it is operationally realistic, specific or measurable.
Lower-level management objective To restore coral cover and condition in the marine reserve	**NOT OPERATIONAL – not specific or measurable** Objective is realistic about focus for management effort (to restore coral cover) but provides no specific insights about how management effectiveness could be measured (e.g. restore to what?)
Operational management objective 1 To increase coral cover and condition in the marine reserve	**POOR – not specific** Objective is realistic about the focus for management effort (increasing coral cover in the marine reserve) but is ambiguous about how the effectiveness of management should be measured.
Operational management objective 2 To increase live coral cover and condition in the marine reserve within 5 years of implementing the plan	**ACCEPTABLE – realistic, specific and measurable** Objective is specific about the focus for management effort (increasing live coral cover and condition in the marine reserve) and the period of time (5 years) to determine the effectiveness of management but is ambiguous about how much of an increase in coral extent would constitute effective management.
Operational management objective 3 To increase the live coral cover and condition in the marine reserve by 5%, from current conditions, within 5 years of implementing the plan.	**PREFERRED – realistic specific and measurable** Objective is specific about the focus of management effort (increasing live coral cover and condition in the marine reserve) and provides clarity about how the effectiveness of management can be measured by identifying the amount of increase (5% above current conditions) within a specified period of time (5 years).

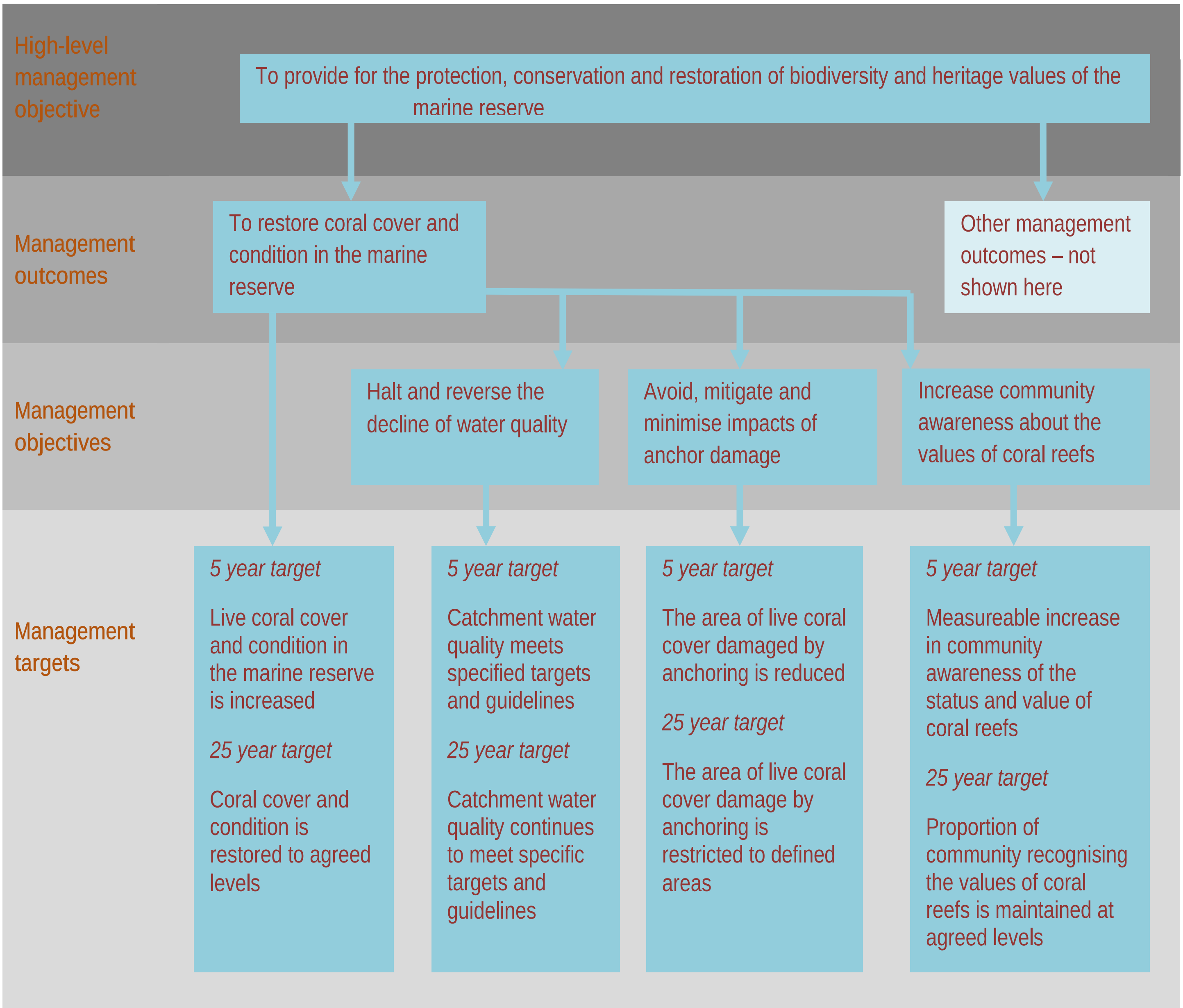


Figure 2.3 A hypothetical management objectives hierarchy. In this hypothetical example *high-level management objective* defines what the collective management effort should achieve; *management outcome* defines the desired outcome for values underpinning a Matter of National Environmental Significance—in this example coral reef; *management objective* defines what the managers will do to achieve the management outcome; *management target* (the lowest level in the hierarchy) provides the realistic, specific and measurable direction to on-ground managers – in this example providing short- and long-term targets

2.2.2 Governance and principles for integrated monitoring

Aims of this section

- To explain the importance of good governance
- To identify considerations when establishing governance arrangements
- To provide guidance to establish an IMF

Importance

Good governance is a prerequisite for an effective IMF. Governance provides the foundation for focus and performance of the program and conformance to law, regulations, standards and community expectations of probity, accountability and openness (APSC 2007). It encompasses the important role of leadership to ensure that sound governance practices are instilled throughout the program and the wider responsibility of adopting sound governance practices and procedures. It will also provide an important role in establishing and maintaining the oversight, coordination, partnerships and scientific credibility required of integrated monitoring.

Considerations

The governance arrangements for an IMF should be documented and endorsed early in the process of establishing the IMF. Generally there are two options for establishing governance for integrated monitoring: establish new governance arrangements, or build on what already exists. Existing monitoring programs (expected to be a critical element of integrated monitoring) may have established governance that could provide a nucleus or useful starting point for a governance structure. There is no 'one size fits all' approach to governance but there are common themes that are fundamental to successfully implementing good governance (APSC 2007). The basic building blocks that need to be considered when establishing or reviewing governance arrangements are:

- strong leadership, culture and communication
- appropriate governance committee structures
- clear accountability mechanisms
- effective collaboration across organisational boundaries
- comprehensive risk management, compliance and assurance systems
- strategic planning, performance monitoring and evaluation
- flexible and evolving principles-based systems (see Box 1 for examples of principles for integrated monitoring).

The committee structure, functional roles and key participants in a governance model will depend entirely on the scope and purpose of integrated monitoring. Table 2.3 provides an overview of governance functions required to provide leadership, direction and accountability for integrated monitoring.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to generate the following outputs:

    a. a list of key participants in governance

b. options for establishing a governance structure

c. preferred governance model for integrated monitoring, including broad terms of reference for governance, committee structure (e.g. oversight, coordination, provision of expert advice) and key participants (e.g. government, industry, science and community)

d. principles to guide decision-making about integrated monitoring (see example at Box 1).

II. Key inputs to the process are:

a. background information on existing governance arrangements for critical monitoring programs in the focus area

b. a general model of governance committee functions for monitoring programs

c. participation by key organisations (e.g. government, industry, science and community) likely to participate in the governance arrangements for integrated monitoring.

III. Document and summarise findings from targeted meetings/workshops and circulate to the manager overseeing the strategic assessment process.

Functional groups	Primary purpose and roles
Oversight and decision-making	A group of decision-makers from participating governments and agencies with responsibility and authority for decision-making. Roles include providing a forum for oversight and decision-making for integrated monitoring and agreeing on approaches for resource allocation for integrated monitoring.
Coordination and partnerships	A group(s) of representatives from participating governments, agencies and key stakeholders established for the primary purpose of coordination and identifying partnerships for integrated monitoring. Roles include: providing a forum(s) for promoting and coordinating integrated monitoring; facilitating collaboration and coordination for integrated monitoring through maintaining partnerships; providing advice on opportunities for wise use of resources allocated for monitoring; and periodically considering the effectiveness of integrated monitoring and its resourcing.
Scientific credibility and advice	A group(s) of scientists established with the primary purpose of providing advice to ensure integrated monitoring is scientifically defensible, credible and designed and implemented according to the best scientific standards. Roles include: providing advice on how to meet monitoring priorities and fill gaps, conducting scientific reviews of integrated monitoring; and convening temporary working groups to provide scientific advice.
Implementation	A group(s) of practitioners established with the primary purpose of implementing the integrated monitoring program. Roles include: communicating and promoting integrated monitoring; providing the central point for implementing the integrated monitoring plan day-to-day; ensuring participating monitoring programs are using appropriate monitoring protocols for data collection and data management; ensuring data analysis and reporting are undertaken in accordance with required protocols and schedules; convening temporary working groups to provide technical advice where required (e.g. integrating data management or data analysis); and reporting regularly to responsible agencies and other governance groups.

Table 2.3 An overview of governance functions required to provide leadership, direction and accountability for integrated monitoring. Arrows indicate the need for interaction between functional groups

Box 1 Principles for integrated monitoring

Principles are a useful tool to guide the many discussions and decisions that need to be made to establish an integrated monitoring program. The following principles are designed to guide discussions and decision-making to establish an integrated monitoring program.

a. Adaptive management of Matters of National Environmental Significance is the primary focus of integrated monitoring for an EPBC strategic assessment.

b. Collaboration between policymakers, park managers, scientists and data managers is essential.

c. A common lexicon and logic is necessary to facilitate collaboration.

d. Explicit links between monitoring, management and scientific understanding are required.

e. Integrated monitoring needs an effective governance structure that is supported by institutions, does not depend on individuals and provides ongoing access to essential data streams.

f. Prioritisation of objectives, indicators, programs, etc. is essential and needs to be completed in a transparent manner that can be reviewed and updated.

g. It is better to monitor fewer high priorities well than to monitor many interests poorly.

h. Priorities and decisions need to be well documented and readily accessible, including the data supporting those decisions.

i. Integrated monitoring needs to build on existing infrastructure and processes, recognising that not all existing elements will become part of the integrated monitoring program.

j. The integrated monitoring program needs to have a lifespan at least as long as the pressures that it is designed to monitor.

k. The integrated monitoring program needs to be supported by research so that it can adapt to changing pressures, environmental conditions and knowledge.

l. The integrated monitoring program needs to be reviewed on a regular basis.

2.3 Essential monitoring functions that should be addressed by an IMF

The following subsections explain the importance of essential monitoring functions that should be addressed by an IMF and provide specific guidance on each function. Additional considerations for each of the essential monitoring functions are also provided, including suggestions and examples drawn from the experience of monitoring practitioners and scholars.

2.3.1 Clearly defining the purpose of monitoring and the monitoring objectives

Aims of this section

- To explain the importance of clearly defining the purpose of the monitoring program, monitoring objectives and monitoring priorities
- To highlight additional considerations for definition of monitoring objectives and priorities
- To provide guidance to establish an IMF

Importance

Clearly defining the purpose of integrated monitoring objectives and monitoring priorities is an essential function as it provides clarity about the desired outcome of the collective monitoring effort and the specifics of what should be monitored (Fancy et al. 2009). This function seeks to maximise certainty and minimise potential ambiguities about why integrated monitoring is required and the specific objectives monitoring seeks to address. Clarity on the purpose of integrated monitoring and the monitoring objectives becomes important in managing potential differences in opinion during the sampling design and implementation phases of the monitoring program.

Considerations

It is important to define the purpose of integrated monitoring in the IMF. The guidelines for undertaking strategic assessment (Department of the Environment 2012) point out that the Australian Government seeks to maximise conservation of MNES values that occur within the strategic assessment area; ongoing adaptive management is critical to ensuring that MNES values can be maintained and enhanced over time; and monitoring is a key characteristic of the adaptive management approach. In this context, the purpose of integrated monitoring to support a strategic assessment under the EPBC Act should be:

> *The objective and systematic integration of interests, resources, data and knowledge across policy, management and science sectors to monitor, analyse and report on the effectiveness of management to maintain and enhance MNES values.*

Monitoring objectives must be derived directly from the operational management objectives (see Section 2.2). They essentially provide additional details about what the monitoring program and sampling protocol (see Section 2.4.5) will do, and often identify boundaries or limits of the monitoring program by specifying particular areas, species or measures (NPS 2012). Table 2.4 provides an example of clearly defined monitoring objectives using the example of a clearly defined operational management objective provided in Table 2.2. An effective set of monitoring objectives should meet the test of being realistic, specific and measurable. NPS (2012) suggest the use of the following checklist of questions to determine if monitoring objectives meet the test:

- Is each of the monitoring objectives measurable?
- Are they achievable?
- Is the location and spatial bounds of the monitoring specified?
- Is the species or asset being monitored specified?
- Will the reader be able to anticipate what the data will look like?

The process to clearly define monitoring objectives requires collaboration between managers and scientists—compare with the process to define management objectives in Section 2.2 requiring collaboration between policymakers and managers. The key role of managers is to ensure that monitoring objectives link directly to the operational management objectives and to be satisfied that the anticipated data and analyses will meet the managers' needs to measure management success. The key role of scientists is to provide knowledge and understanding about the options and issues for addressing the checklist of questions outlined above, particularly with regard to measurability and achievability. They also are well positioned to suggest refinements to more clearly define monitoring objectives. It should also be noted that, in most cases, the collaboration will not be starting with a clean slate and some of the monitoring objectives may already be clearly defined and sufficiently linked to operational management objectives.

Table 2.4 Hypothetical examples of clearly defined monitoring objectives for the extent of coral in a marine reserve (operational management objective taken from Table 2.2 – preferred operational management objective)

Type of objective	**Operational management objectives versus monitoring objectives**
<u>Clearly defined operational management objective</u> To increase the live coral cover and condition in the marine reserve by 5%, from current conditions, within 5 years of implementing the plan	A clearly defined objective to direct management effort. It is specific about the focus for management (increasing the extent of coral reefs) and provides clarity about how the effectiveness of management can be measured by identifying the amount of increase (5% above current conditions) within a specified period of time (5 years).
<u>Clearly defined monitoring objective</u> To measure live coral coverage in the marine reserve at a level that has a 90% probability of detecting a 5% increase in spatial extent over 5 years and its regional variation.	A clearly defined objective to direct monitoring effort. It is specific about the asset to be monitored (cover of live coral), provides detail about the bounds of measurement and also spatial and temporal bounds.

To manage expectations it is important to prioritise monitoring objectives because monitoring budgets are limited and it may not be possible to implement sustained monitoring at the highest level for all the monitoring objectives. Prioritisation should involve some form of structured decision-making. The use of ad hoc, unstructured approaches to prioritisation are not recommended. Formalised approaches such as Delphic methods or multi-attribute value theory are recommended because they improve the rigour and transparency of the decision-making process and they help minimise the possibility of unwanted group dynamics such as anchoring around initial estimates and dominance by particular individuals (NPS 2012). The process and outcomes of identifying monitoring priorities should be documented for transparency.

Guidance to establish the IMF

I. Instigate a collaborative process with experts to generate:
   a. An articulation of the purpose of integrated monitoring
   b. A list of monitoring objectives identifying relative priorities
   c. A hierarchy of monitoring objectives and management objectives that identifies the explicit links between each management objective and the monitoring objectives supporting it.

II. Key inputs to the process are:
   a. Hierarchy of management objectives (see Section 2.2.1)
   b. List of important experts (scientists and senior managers) with whom to engage in the process
   c. Participation of skilled scientists with knowledge about what is measurable and achievable for MNES (e.g. species, ecosystems or human wellbeing) and drivers and pressures that may affect MNES
   d. Participation of senior managers (those responsible for delivering on the operational management objectives). Consideration should be given to engaging key stakeholders, particularly those involved in monitoring
   e. Criteria to check that monitoring objectives are realistic, specific and measurable.

III. Document a summary of findings from the process and circulate to those who participated and the appropriate governance committees.

2.3.2 Compiling and analysing relevant information on existing monitoring programs

Aims of this section

- To explain the importance of compiling and analysing relevant information on existing monitoring programs.
- To highlight additional considerations around compiling and analysing relevant information and existing monitoring programs.
- To provide guidance to establish an IMF.

Importance

It is expected that many areas that are the focus of a strategic assessment will have a history of diverse development and conservation activities and therefore a legacy of past and present monitoring programs. It is important that integrated monitoring builds on this legacy if these programs generate monitoring data that can meaningfully inform the adaptive management of MNES values. This function is essential from the perspectives of pragmatism and cost-effectiveness.

Considerations

An important initial step in compiling information is identifying boundaries to the review. The objectives hierarchy and spatial and temporal bounds of the integrated monitoring should have already provided a clear set of boundaries for this task (see Section 2.4.1). This should ensure that only relevant monitoring programs are included in the inventory of monitoring programs.

There are a number of ways to go about compiling information on existing monitoring programs. In some cases there may be existing reviews of monitoring programs that could provide a sound basis to start this work. Another approach is to search metadata within institutional, or ideally national, data centres, such as the Australian Ocean Data Network, Atlas of Living Australia and the Terrestrial Ecosystem Research Network. Searches can be performed using keywords and/or by providing a bounding box around the study area to retrieve all records that intersect with this box. Completing this step requires very little time and expertise if relevant metadata records are provided to central data repositories. Considerably more time and effort will be required to complete this work if there are no existing reviews of monitoring programs and if existing monitoring programs do not publish metadata records for their monitoring data. If this is the case, the discovery, summary and analysis in these circumstances will need to rely on internet searches, supported by the experience, tenacity and networking skills of the analyst concerned.

If structured well (see Box 2), the findings of the analysis will provide important inputs to complete the remaining steps on the IMF, particularly in terms of identifying existing infrastructure, resources, protocols and standards that are already supporting monitoring.

Guidance to establish IMF – information on existing monitoring programs

I. Produce a project outline for compiling, analysing and summarising information on existing monitoring programs defining purpose of review, spatial boundaries and required outputs (see Box 2 for an example of a project outline).

II. Seek endorsement of project outline from the appropriate governance committee(s).

III. Appoint a suitably qualified analyst(s) to complete project and produce report.

IV. Provide copy of report to appropriate governance committee(s).

Box 2 Example questions for analysis of existing monitoring programs

Example question	Purpose
1. Describe the context to the compilation and analysis. Identify the thematic, spatial and temporal scope of the IMF.	Sets the focus of the analysis and summary to meet the needs of the strategic assessment.
2. Identify the objectives of existing monitoring programs. Are they clearly stated? How do objectives align with the management and monitoring objectives for the IMF?	Provides important insights for selection of existing monitoring programs for inclusion in integrated monitoring (see Section 2.3.4b).
3. Do existing monitoring programs use conceptual models to identify the links between the monitoring components and the monitored system? If so, do the conceptual models inform the management and monitoring objectives for the IMF? Provide metadata or link (e.g. URL or reference).	Identifies existing conceptual models (see Section 2.3.3) that could be used to support integrated monitoring.
4. Assess monitoring design of existing monitoring programs. Which indicators do they use? How long have they been running? Which data are collected, how where survey sites selected and at what spatial and temporal scales are data collected? How do the indicators used in existing monitoring plans align with the management and monitoring objectives of the IMF? Provide metadata or links (e.g. URL or reference).	Establishes the adequacy of existing monitoring programs to support integrated monitoring, including identifying potential gaps in coverage and opportunities for efficiencies (see Section 2.3.4a, 2.3.4b and 2.3.4c).
5. Do existing monitoring programs use data collection protocols? Is so, how do these align with the proposed objectives of the IMF. Provide metadata or links (e.g. URL or reference).	Provides important information about the potential of existing monitoring protocols to contribute to integrated monitoring, as well as gaps (see Section 2.3.5).
6. Do existing monitoring programs include analysis of data? If so, describe and provide metadata or link (e.g. URL or reference).	Provides information about data analyses of existing monitoring programs and how they could support integrated monitoring (see Section 2.3.7).
7. Do existing monitoring programs report results of monitoring? If so identify time and frequency of reporting? Provide metadata or links (e.g. URL or reference).	Identifies existing reporting mechanisms and how they could support integrated monitoring (see Section 2.3.8).
8. Do existing monitoring programs get reviewed? If so by whom and at what intervals? Provide metadata or links (e.g. URL or reference).	Identifies existing review mechanisms and how they could support integrated monitoring (see Section 2.3.9).
9. How do existing monitoring programs manage their data? Are they available to the public? If so how are they discovered, stored and accessed? Provide metadata or links (e.g. URL or reference).	Provides important insights about data management of existing monitoring programs and how it could support integrated monitoring (see Section 2.3.6).
10. What are the approximate costs and funding sources for existing monitoring programs?	Helps select existing monitoring programs for inclusion in integrated monitoring (see Section 2.3.4b).
11. What existing monitoring programs are likely to be a critical part of the IMF (i.e. selected monitoring programs)? Explain why.	Summarises reasons for selection of existing monitoring programs for inclusion in integrated monitoring (see Section 2.3.4b).

2.3.3 Developing conceptual models

Aims of this section

- To explain the importance of developing and refining conceptual models.
- To highlight additional considerations when developing conceptual models.
- To provide guidance to establish an IMF.

Importance

Conceptual models are an essential component of successful monitoring programs because programs that are not motivated and supported by clearly stated conceptual models risk being insufficiently focused or relevant to management objectives (Manley et al. 2000, Maddox et al. 1999, Lindenmayer and Likens 2010). Furthermore, whether recognised or not, all monitoring programs are implicitly based on a conceptual model of the system. Even for the simplest mental construct of a system, it is essential that understanding is explicitly stated and clearly recorded so that it is available for discussion, evaluation, and refinement (Lindenmayer and Likens 2010). Some forms of conceptual modelling also provide an opportunity to identify indicators, and thereby assist in completing another essential function of the IMF. Conceptual models also provide a pragmatic insight into how to integrate monitoring data, particularly the interpretation and synthesis of numerous monitoring data streams.

Considerations

Conceptual models represent a working hypothesis about how the ecosystem works. They should: a) identify the important components and processes in the system; b) document assumptions about how these components and processes are related; c) identify the linkages between these components/processes and anthropogenic pressures; and d) identify knowledge gaps or other sources of uncertainty (Manley et al. 2000, NPS 2012, Hayes et al. 2012). It is important that the formulation of a conceptual model occurs at the beginning of a monitoring program, as it drives the collation of system knowledge and understanding about how the system works and how it might respond to anthropogenic pressures, and thereby ensures that relevant components are included in the project design.

Maddox et al. (1999) recognise three general roles of ecological modelling in monitoring programs:

- to summarise the most important ecosystem descriptors, spatial and temporal scales of biological processes, and current and potential threats to the system
- to identify indicators for monitoring by identifying aspects of the ecosystem that should be measured (but see Section 3.4b)
- to interpret monitoring results and explore alternative courses of management.

While an explicitly stated model is a summary of current understanding of, and assumptions about, the ecosystem, it is important to recognise that the model: (a) does not represent 'the truth'; (b) is not final or unmodifiable; and (c) is not expected to be complete or include the entire ecosystem. It is a flexible construct that should evolve as understanding of the ecosystem increases. If a long-term monitoring and research program is successful, understanding and knowledge of the system will increase with time, which will then necessitate model revision and refinement (e.g. Cloern 2001, Groffman et al. 2004).

Conceptual models come in many different forms including simple narrative descriptions, schematic diagrams, box-and-arrow flowcharts, or even cartoons that pictorially illustrate physical and biological processes and the effects of anthropogenic pressures (see for example Bormann and Likens 1967, Manley et al. 2000, Lindenmayer and Likens 2010, Woodward and Beever 2011). Even though there are many forms of conceptual models, they all hold common elements and can be constructed using a common set of steps (see Box 3).

Beyond narratives and cartoons is an array of mathematical models that can be used to address complex physical and biological processes, often via exact equations or numerical simulation. Mathematical models that have guided monitoring programs include population viability models, small-scale forest gap models, spatially explicit population- community- and landscape-level process models, and regional-scale whole-of-system models (Maddox et al. 1999). With their increased sophistication, these models are expensive to develop and maintain, and if their inner workings and output are overly complex, they can run the danger of alienating managers and the public (Lindenmayer and Likens 2010).

The most useful level of model complexity is difficult to decide when working across large biological and spatial scales and with multidisciplinary teams; a key challenge will be to achieve a workable level of model generality, reality and precision (*sensu* Levins 1998, 2006). A key outcome from the Australian national indicators project (Hayes et al. 2012, Dambacher et al. 2012) is the use of qualitative modelling, or loop analysis, to develop conceptual models and identify indicators. Qualitative modelling merges the advantages of a simple graphical system representation, with some of the utility and predictive capacity of numerical, process-based models.

Guidance to establish the IMF

I. Instigate a collaborative process with experts to generate the following outputs:

   a. List of conceptual models required to address monitoring priorities identifying existing models and gaps

   b. List of opportunities to fill conceptual model gaps

   c. Conceptual models to fill gaps (where opportunities exist)

II. Key inputs to the process are:

   a. List of priority conceptual models required for the IMF, based on the monitoring objectives identified in 2.3.1.

   b. List of existing conceptual models (produced by analysis of existing monitoring programs—see Section 2.3.2).

   c. Expertise in developing conceptual models (see Box 3 for suggested steps to developing conceptual models). Simple approaches to conceptual modelling should be used to fill gaps, unless time and resources permit a more sophisticated approach. More sophisticated models may be the subject of future research supporting integrated monitoring.

III. Compile conceptual models in a summary report and circulate to participants in the process and the appropriate governance committee(s).

Box 3 Suggested steps to developing conceptual models

Gross (2003) provides a series of nine steps or tasks in constructing conceptual models for monitoring programs:

1. Clearly state the goals of the conceptual models
2. Identify bounds of the system of interest
3. Identify key model components, subsystems, and interactions
4. Develop control models (qualitative and quantitative process models - see Table 2.5) of key systems and subsystems
5. Identify natural and anthropogenic stressors (pressures)
6. Describe relationships of stressors, ecological factors, and responses
7. Articulate key questions or alternative approaches
8. Identify inclusive list of indicators and prioritise them
9. Review, revise and refine.

2.3.4 Developing overall design for integrated monitoring

Developing the overall sampling design for integrated monitoring is comprised of three inter-related functions: selecting indicators (Section 2.3.4a); selecting monitoring programs (Section 2.3.4b); and developing sampling design for integrated monitoring (Section 2.3.4c). Establishing the IMF seeks to:

- select high-level indicators
- identify the existing monitoring programs that should be included in integrated monitoring on the basis of their capacity to address high priority monitoring objectives
- propose monitoring program options to address gaps in high priority monitoring objectives
- provide an overview of desired sampling design requirements for monitoring programs that are selected for inclusion in integrated monitoring and assess if existing monitoring programs meet them.

2.3.4a Selecting indicators

Aims of this section

- To explain importance of selecting indicators.
- To highlight considerations for selecting indicators.
- To provide guidance to establish an IMF.

Importance

Selecting indicators is an essential function of an IMF because it provides a mechanism to reduce a large set of variables that might possibly be measured down to a small set of variables which represent the most useful measures of the status of MNES values and effectiveness of management in maintaining and enhancing those values. There needs to be clear links from management objectives to monitoring objectives to selected indicators). Well-defined indicators are also an important means for communicating monitoring results to a wider audience.

Considerations

The various definitions of indicators in the literature allude to their desirable characteristics: they should provide unambiguous signals of change in MNES values before these changes become severe or irreversible; they should be sensitive to a range of pressures; and they should allow managers to take timely actions to minimise the impacts of these pressures (Hayes et al. 2012).These characteristics, however, are just a few of the many 'ideal characteristics' typically used to select indicators from the large number of potential candidates. The most common selection criteria are that the indicators chosen:

- have a strong scientific and conceptual basis - i.e. indicators based on well-defined or validated cause-and-effect chains linking anthropogenic pressures to ecosystem response
- provide signals that can be measured in simple, cost-effective ways with available resources, and analysed in a fashion that allows unambiguous interpretation
- have well established links with specific management objectives and are responsive to related management actions over policy-relevant time frames

- are easily understood by stakeholders and/or target audience.

The challenge of selecting ecological indicators can be approached empirically and/or theoretically.

Empirical approach to indicator selection

Empirical indicators can be selected, and evaluated, in one of two ways. The ***reference site approach*** compares the biological and physical conditions of pristine, unperturbed reference (baseline) sites to impacted sites (Coysh et al. 2000). The ***disturbance gradient approach*** typically uses regression-based methods to select indicators by measuring ecosystem responses along stress gradients (Link et al. 2002; Methratta and Link 2006; Hewitt et al. 2005). In practice, elements of both approaches are often used (Kuhnert et al. 2007).

The principal advantage of empirical approaches to indicator selection is that they do not rely on a detailed understanding of the cause-and-effect mechanisms that link anthropogenic activity and ecosystem response. The approach relies on large datasets, systematically compiled over many sites and years, and is therefore less sensitive to limited understanding of ecosystem dynamics and the subjectivity of theoretical, expert-based systems.

The greatest challenge of the empirical approach is the limited availability of large datasets that are relevant to a particular problem. Other potential issues include the difficulty of selecting reference sites (Frost et al. 1992; ICES 2005), lack of power to detect changes within policy-relevant timeframes (Nicholson and Jennings 2004) and the inability to assign causes and effects to observed changes without substantial experimentation. It may therefore be difficult to compare indicators across studies that use different ordination or regression methods, or across different spatial or temporal scales, without additional experimentation or provision of mechanistic explanations for observed changes in the system.

Theoretical approach to indicator selection

The theoretical approach to selecting indicators aims to develop a conceptual understanding of the cause-and-effect mechanisms that link anthropogenic activity and pollution to the response of valued components or processes of the ecosystem. This approach is usually embedded within a DPSIR framework (Antunes and Santos 1999) or variants thereof (Langmead et al. 2007; Niemeijer and de Groot 2008).

The DPSIR framework is intuitively appealing and popular; it does not, however, select indicators. The cause-and-effect presumption embodied within the framework implies that useful indicators will co-vary in some (potentially complex) fashion with the presumed source of pressure or stress. The practical application of this framework therefore requires managers to monitor pressure indicators, but thereafter it provides no further guidance.

Over the years, different studies have filled the methodological vacuum within the DPSIR framework with many different theoretical methods to select indicators, including: unstructured lists, objectives-indicators matrices, cartoons, influence diagrams, Bayesian Belief Networks, fuzzy cognitive maps, qualitative process models (loop analysis) and quantitative process models (Ward 2000; Ozesmi and Ozesmi 2003; Fulton et al. 2005; Ramsey and Veltman 2005; IOC 2006; Dambacher et al. 2007; Kuhnert et al. 2007; Pollino et al. 2007; Niemeijer and de Groot 2008; USEPA 2008).

The key scientific challenges faced by all of these methods are: a) the utility and realism of the conceptual models that support the methodology; b) understanding and untangling the confounding effects of multiple, simultaneous pressures; and c) how to propagate the effects of variability and knowledge uncertainty. Each of the methods satisfies these challenges to a greater or lesser extent (Table 2.5).

Qualitative (Levins 1998; Dambacher and Rossignol 2002) and quantitative (Fulton et al. 2005) process models are able to mimic the complex feedback cycles that occur in real ecosystems and can address the effects of multiple simultaneous pressures. The reliability of indicators selected using these models depends on the extent to which the model is: realistic (how well does it reflect the real world); precise (how precise are its predictions); and generalisable (how well does it work in other situations). We contend that the best approach is one that combines both qualitative and quantitative approaches, then verifies and/or parameterises its predictions through statistical inference.

The theoretical approach to identifying indicators can be based upon the conceptual modelling stage of the IMF (Section 2.4.3) subject to the constraints imposed by sufficiency of the conceptual modelling methods (Table 2.5). For some methods, identifying informative indicators may require a more detailed understanding and subsequent refinement of the models.

Prioritising indicators

It is important to note that selected indicators will need to be prioritised because monitoring budgets are limited and typically it will not be possible to implement a sustained monitoring at high level for all selected indicators. Prioritisation occurs in the transition from an IMF to an IMP (see Section 2.5) and should involve some form of structured decision-making.

Guidance to establish the IMF

I. Instigate a collaborative process with experts to generate the following outputs:

   a. A list of selected indicators to support monitoring objectives (see Section 2.3.1)

   b. A hierarchy of monitoring objectives, management objectives and selected indicators that identifies the explicit links between each monitoring objective and the selected indicator(s) that support it. There should be clear links from management objectives to monitoring objectives to selected indicators.

II. Important inputs to the process are:

   a. Hierarchy of management objectives and monitoring objectives

   b. Participation of scientists, managers and other stakeholders with knowledge of cause-and-effect relationships and indicator selection methods

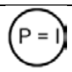
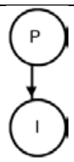
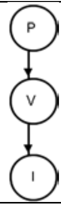
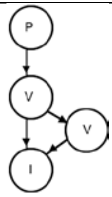
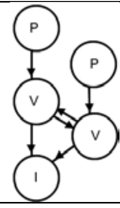
   c. Participation from organisations with responsibility for selected monitoring programs (or programs that are likely to be selected)

   d. Preliminary conceptual models (see Section 2.4.3)

   e. Criteria for indicator selection

III. Produce summary of finding documenting the list of selected indicators and the methods used and circulate to participants and the appropriate governance committee(s).

Table 2.5 Theoretical methods for selecting ecological indicators within the Pressure State Impact Response (PSIR) framework across a range of conceptual cause-and-effect models, from simple abstractions to more realistic and complex models (adapted from Hayes et al. 2012). For directed graphs, arrows denote causal effects and circles denote indicator variables (I), pressures on system (P), or general system variables (V)

	Complexity of cause-effect relationship				
	None[1]	**Simple[2]**	**Directed[3]**	**Diffuse[4]**	**Feedback[5]**
Methods					
1. Unstructured list	✔	✔			
2. Objective-indicator matrix	✔	✔			
3. Structured list		✔	✔		
4. Value-impact matrix		✔	✔		
5. Conceptual diagram or cartoon		✔	✔		
6. Influence diagram		✔	✔	✔	
7. Fuzzy cognitive map		✔	✔	✔	
8. Statistical model		✔	✔	✔	✔[6]
9. Bayesian network			✔	✔	✔[7]
10. Qualitative process model				✔	✔
11. Quantitative process model				✔	✔

[1]No cause-effect relationship, the pressure is the indicator; methods beyond objective-indicator matrices not needed.
[2]Pressure directly impacts indicator variable; methods beyond statistical models not needed.
[3]Pressure directly impacts a variable that has knock-on effects to indicator variable; methods beyond Bayesian networks not needed.
[4]Pressure indirectly impacts an indicator variable via multiple interaction pathways.
[5]Multiple pressures simultaneously impact complex system with feedbacks between variables.
[6]Explicit analysis of feedback not possible with classic statistical techniques (e.g. general and generalized linear models, multilevel models, structural equation models). Incorporation of process models within statistical analyses of time series (e.g. state-space modelling) can account for system feedbacks; such techniques, however, require extensive data, especially for large systems.
[7]With difficulty; standard Bayesian networks limited to acyclic graph structures. Dynamic Bayesian networks can account for feedbacks, but are difficult to parameterise and analyse, typically making them impractical for complex systems (but see Box 4 for application with qualitative process models).

2.3.4b Selecting monitoring programs

Aims of this section

- To explain the importance of selecting monitoring programs for integrated monitoring.
- To highlight considerations for selecting monitoring programs for inclusion in integrated monitoring.
- To provide guidance to establish an IMF.

Importance

Selecting monitoring programs is an essential function of integrated monitoring because it identifies the suite of monitoring programs that should collectively form the founding set of monitoring programs for integrated monitoring. The selected programs form the cornerstones of integrated monitoring by providing the data to determine the effectiveness of management in enhancing and maintaining MNES values. Selected monitoring programs generate the relevant monitoring data (to meaningfully address the monitoring objectives and indicators—see sections 2.3.1 and 2.3.4a), demonstrate how monitoring is integrated and provide a nucleus for integrating other transient or shorter-term monitoring programs (e.g. compliance or incident monitoring).

Considerations

Areas subject to a strategic assessment are likely to have a legacy of past and current monitoring programs and these programs are likely to exist for good reasons. Selecting monitoring programs for inclusion in integrated monitoring includes identifying existing programs that would meaningfully support integrated monitoring. It is also likely to involve the development of proposals (new programs or refinements to existing programs) to address gaps in priority monitoring objectives and indicators that are not addressed by existing monitoring programs, or to create efficiencies in addressing priorities for integrated monitoring (which is further considered in Section 2.3.4c). Gaps in priority monitoring objectives should be identified through systematic and transparent processes that seek to identify:

- monitoring objectives and indicators that are not addressed by existing monitoring programs
- monitoring objectives and indicators that are addressed by existing monitoring programs but not at the spatial scales or locations required for a strategic assessment (e.g. data may be collected at a local scale only or in areas that are not of primary interest to managers)
- monitoring objectives and indicators that are addressed by existing monitoring programs that will not be sustained for the period of time required for a strategic assessment (e.g. data may be collected by short-term monitoring programs or research programs).

Objectively and transparently exploring the cost-effectiveness of the range of monitoring program options is important for informing decisions about if and what to monitor (McDonald-Madden et al. 2010; Possingham et al. 2012). This logic equally applies to selecting monitoring programs for integrated monitoring, regardless of whether or not programs are existing or proposed. This function becomes particularly important if numerous monitoring priorities are identified and available resources for monitoring are insufficient to meaningfully address all the identified priorities. There are a number of factors that can be taken into consideration in an analysis of cost-effectiveness of monitoring program options, including:

- alignment with monitoring objectives and selected indicators
- alignment with spatial and temporal scales of management interest
- level of certainty required by managers
- public availability and access to monitoring data
- the source of funding for a monitoring program and whether or not it is already costed into existing budgets
- sustainability of funding for the program
- average annual cost of the program
- sustainability of monitoring program (i.e. expertise, technology and quality control)
- legacy value of monitoring program data.

Possingham et al. (2012) point out that expected total costs of monitoring program options, although rarely reported, can be calculated by accountants. The relative cost-effectiveness of existing and proposed monitoring options can be addressed by broad multi-criteria analysis, noting that some monitoring options may inform more than one monitoring priority.

Cost-effectiveness of monitoring program options can be compared from several perspectives. The first is comparing the cost-effectiveness of servicing different monitoring objectives (e.g. comparing the cost-effectiveness of monitoring seagrass versus monitoring corals or human wellbeing). It is vitally important that these comparisons are predicated on the prioritised monitoring objectives (Possingham et al. 2012).

The second comparison of cost-effectiveness for monitoring is focused on determining how much to invest in servicing a specific monitoring priority (i.e. the decision to monitor seagrass has been made but there is a need to determine the level of investment to be allocated to monitoring seagrass versus another asset). This type of comparison recognises that:

- the costs of monitoring are significantly affected by the type of data collected and the sampling intensity for data collection
- the benefits of monitoring (e.g. power to confidently detect environmental change or attribute cause for a detected change) are significantly affected by the type of data collected and the sampling intensity for data collection.

At one end of the spectrum of options is a monitoring program which requires relatively low investment but may have low power to detect environmental change or attribute cause of a detected change, while at the other end of the spectrum is a program which requires relatively high investment but is likely to have higher power to detect change and attribute cause.

It is important to keep in mind that selecting monitoring programs to include in the IMF is not the sole mechanism to determine what monitoring data are collected in the area subject to strategic assessment. For example, there may be a number of existing monitoring programs that are not considered important for the IMF but are important for other reasons and will therefore continue.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to produce an outline of the purpose and scope of selected programs to support integrated monitoring. The outline should identify:

   a. the existing monitoring program options that should be selected to include in integrated monitoring, based on their cost-effectiveness, in particular their capacity to address the high priority monitoring objectives

   b. the gaps in priority monitoring objective that are not addressed by a. above

   c. options to address gaps in high priority monitoring objectives and an analysis of the cost-effectiveness of each option.

II. Key inputs to the process include:

   a. appropriate facilitator/supervisor to guide process

   b. prioritised monitoring objectives

   c. criteria to assess and compare the cost-effectiveness of monitoring program options

   d. expertise and information on the cost-effectiveness of monitoring program options, including new or refined monitoring program options where appropriate

   e. participation from governance committee representatives and those sectors, agencies and institutions that manage monitoring programs.

III. Document and summarise findings from process and circulate to participants and appropriate governance committee(s).

2.3.4c Developing sampling design for integrated monitoring

Aims of this section

- To identify the importance of developing sampling design for integrated monitoring.
- To highlight additional considerations that are important when developing sampling design for integrated monitoring.
- To provide guidance to establish the IMF.

Importance

Developing a sampling design is an essential function in integrated monitoring because it describes how, where and when data are to be collected to monitor the effectiveness of management to maintain and enhance MNES values. It is important that sampling designs address the needs of strategic assessment, in particular the need to make inferences from monitoring data at regional spatial scales and over periods that may exceed 25 years. Monitoring programs that are not carefully designed may be unable to separate emerging patterns and trends from natural variation and may fail to provide early warning signals about the effect of management interventions and environmental change. Sampling design is a pragmatic means of integrating monitoring across monitoring programs, particularly in terms of data collection.

Considerations

The sampling design for integrated monitoring is shaped by a variety of factors including: priority indicators (see Section 2.3.4a); the existing monitoring legacy (Section 2.3.4b); advice from experts in sampling design; and the constraints of budgets, resources and logistics. Selected monitoring programs for the IMF (see Section 2.3.4b) are likely to include a mixture of existing, refined and proposed monitoring programs. In the context of strategic assessment, it is important that selected monitoring programs use a sampling design that meets the needs of strategic assessment, that is, collecting data that addresses the priority indicators (see Section 2.3.4a), and provides for inferences with a known level of confidence (statistical power) at regional scales and over reasonably long time periods that may exceed 25 years.

The adequacy of sampling design for selected programs (existing, refined or proposed monitoring programs) should be assessed before they are incorporated into the IMF. Opportunities to integrate sampling designs across monitoring programs (e.g. co-location of sample sites for pressure and value monitoring, or complementary site selection of monitoring sites for the same type of monitoring to generate better insights from the collective monitoring effort) can also be considered. This can produce benefits in both cost savings and data analysis. The following questions on sampling design should be used to evaluate the adequacy of existing monitoring programs and to develop sample designs for proposed monitoring programs.

The sampling design phase of a monitoring program must address three critical questions:

1. What is an appropriate level of statistical power to inform management decisions in a timely manner?
2. How are sample sites to be selected?
3. How often should we take measurements at these sites or at sub-sets of sites?

These three questions address the fundamental issues of where, and how often, data should be collected.

Question 1 – What level of statistical power is required for integrated monitoring?

> Informally, statistical power is the probability of making the right decision when it matters most. Environmental managers face two options when presented with data from a monitoring program—act upon the information, or do nothing—and this entails the possibility of two types of errors. The first (Type I error, with probability α) occurs if the manager acts in the belief that a significant trend or change is occurring, when in fact no such change is occurring or has occurred. The second error (Type II error, with probability β) occurs when the manager fails to act in the erroneous belief that no significant change is occurring when in fact a change has occurred or is occurring.
>
> The question of appropriate statistical power has been traditionally approached using the '5–80' convention, which fixes the Type I error rate at 5 per cent and seeks a sample size such that statistical power (1- β) is 80 per cent (the Type II error rate is 20 per cent). This approach however places the burden of proof disproportionately on those trying to demonstrate environmental change, and undermines the fundamental aim of many monitoring programs,

which is to ensure that real change is detected and acted upon as early as possible (Field et al. 2007).

Mapstone (1995) recommends that the relative weighting of the two error rates be set according to the costs associated with each. In the absence of this information he recommends that the two error rates should simply be set equal to each other. We believe that this is a sensible proposition. Importantly the selection, and desired ratio, of the two error rates provides a means to tailor the monitoring design to the priorities of management objectives, for example, selecting lower Type II error rates for higher priority objectives, and vice versa.

Question 2 – How should sample sites be selected?

There are two important challenges that must be met in order to answer the second critical question in the context of a strategic assessment under the EPBC Act:

- strategic assessments take a regional, whole-of-system, perspective which implies inference must be made at greater spatial scales and higher levels of ecological organisation—regional populations and communities—than that typically associated with impact assessments for individual developments
- integrated monitoring programs must integrate the existing monitoring legacy with any new initiatives in order to be cost efficient and to generate the long time series of observations that are typically necessary to detect changes in ecological systems.

Stevens (1994) identifies two approaches to decide where to locate sample sites for region-scale evaluation of environmental status or trends. The first approach is judgemental sampling when sites are selected for their anticipated ability to reflect regional characteristics. The second approach is probability sampling characterised by three distinguishing features: (i) the population being sampled is explicitly described; (ii) every element of the population has some opportunity of actually being sampled; and (iii) the sample selection procedure includes an explicit random element.

Judgemental sampling has been applied for many decades to environmental and social problems, and has demonstrably failed on many occasions (Edwards 1998). We strongly recommend that this approach be avoided in any new monitoring program initiated through strategic assessment. It is therefore important that existing monitoring programs selected for the IMF (see essential function 2.3.4 b) are evaluated to identify the basis for site selection and transparently clarify any assumptions of existing monitoring programs based on judgemental sampling.

Examples of probability-based approaches to survey design include systematic sampling, simple random sampling, two-stage sampling, stratified random sampling (Gilbert 1987) and Generalised Random Tessellation Stratified (GRTS) sampling (Stevens and Olsen 2003). When choosing a sampling design for the purposes of a strategic assessment it is important that it seeks to meet key criteria for selecting sampling sites (see Box 4).

Currently only one sampling design approach—GRTS— meets all of these criteria. GRTS is a spatially balanced, probability-based design that has significant practical advantages over other probabilistic approaches, and forms the basis of current plans for a sustained national environmental monitoring strategy for Australia's marine planning regions. Moreover, GRTS designs incorporate elements of systematic and random site selection, and in this context provide no additional barriers to incorporating existing legacy sites than alternative designs.

Question 3 – How often should sample sites be monitored?

Monitoring programs designed to meet the needs of a strategic assessment will typically seek to identify trends and change points in regional (rather than local) populations (Section 2.4.1). This type of monitoring objective implies that sites will be re-surveyed with a specified periodicity that depends on the defined management need. In this context it is important to recognise that the ability to detect trends in regional populations is influenced by variability in populations, space, time and the way data are collected (Larsen et al, 1995; Urquhart et al. 1998). See Box 5 for an explanation of these four sources of variance. The ability to detect regional trends is more sensitive to the magnitude of the temporal variation, or year effect, than to the other three sources of variance. To detect real regional trends with confidence it is important to quantify the relative magnitude of each source of variance.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to generate an overview of sampling design requirements for the IMF and an initial assessment of selected monitoring programs that includes:
    a. statements about the desired level of statistical power and preferred approach to sample site selection for the IMF
    b. an assessment of selected monitoring programs to determine their capacity to address the needs of strategic assessment. The assessment should consider the level of statistical power, basis of site selection (judgemental sampling or probability sampling) and spatial extent of inferences
    c. identification of opportunities to integrate sampling design across selected monitoring programs to produce cost saving and/or efficiencies for data analysis.

II. Key inputs to the process include:
    a. list of selected monitoring programs for the IMF (see Section 2.3.4b)
    b. advice and participation from individuals with expertise in sampling design and data analysis
    c. participation from organisations with responsibility for selected monitoring programs.

III. Document a summary of findings from the process and circulate to participants and appropriate governance committee(s).

Box 4 - Criteria for Selecting Sampling Sites

The following criteria are suggested as an objective means of choosing a sample design to meet the needs of integrated monitoring:

1. The sampling design formally recognises the population of interest (e.g. all coral reefs in the GBR), identifies members of this population (e.g. individual reefs), includes a frame that represents the population of interest (e.g. a list or map of individual reefs) and uses probability methods for selecting samples from the frame (Larsen et al. 1995).

2. Samples sites are spatially distributed to capitalise on the fact that members of a population that are close together tend to be influenced by the same set of natural and anthropogenic factors, and hence tend to be more alike than members of the population that are far apart. Designs which capitalise on this fact tend to be more efficient (Stevens and Olsen 2003).

3. The inclusion probability of an individual member of the population is known *a priori* and can be amended to reflect existing knowledge or management objectives. For example, in selecting coral reefs scientists and managers may wish to sample large reefs with a greater probability than small reefs because they contribute disproportionately to management values (Stevens and Olsen 2004).

4. The sampling design has well established procedures for handling non-response—i.e. situations where observations cannot be taken at a particular site because for example of bad weather or lack of access—and has good variance properties under these circumstances.

Box 5 – Sources of variance that affect ability to detect trends

1. Population variance: differences in observations across the members of a regional population (such as all coral reefs in the GBR) or sub-populations (such as all coral reefs in the northern sector of the GBR).

2. Temporal variance: the amount by which observation across all members of a population or sub-population are high or low in a particular time period (e.g. a year). Over time, the value of any observation will fluctuate around a trend, or in the absence of a trend, around a central value. This variance component measures the amount by which all members of the population are above or below a long term trend line or curve, or central value. Larsen et al. (1995) call this a 'year effect'.

3. Space-time interaction effects: the amount by which observations taken on an individual member of a population (e.g. at a single reef) fluctuate over time around a trend line, trend curve or central value. These fluctuations are caused by localised factors that operate at small scales, such as individual coral reefs, or a localised group of reefs.

4. Index variation: a composite of several sources of variation, some natural and some introduced by the differences in the way data are collected. It includes sources such as differences caused by imprecise measuring devices and differences among survey teams. Standard operating procedures outlined in monitoring protocols (Section 2.4.5) are typically designed to minimise this source of variance.

2.3.5 Developing monitoring protocols

Aims of this section

- To explain the importance of developing monitoring protocols.
- To highlight considerations for developing monitoring protocols.
- To provide guidance to establish an IMF.

Importance

Monitoring protocols provide the necessary instructions and standards for ensuring monitoring data are collected, managed, analysed and reported consistently across space and time. They are important for integrated monitoring as they enable the development of data time series and the integration of similar data from different programs (e.g. they specify how seagrass data should be collected, managed, analysed and reported to ensure data from local seagrass monitoring programs can be integrated to provide a regional perspective). They also enable the integration of results from different types of monitoring (e.g. long-term, short-term and compliance monitoring).

Considerations

At minimum a monitoring protocol details operational instructions about how data are to be collected. For integrated monitoring is it preferable that monitoring protocols provide operational instructions for the entire data life-cycle including how individual programs are to collect, manage, analyse and report data in a consistent and comparable fashion over space and time. Monitoring protocols must be sufficiently well documented that different people or new programs can complete these procedures in exactly the same way. Monitoring protocols are important for ensuring monitoring data are robust to changes in personnel, technology and management needs. They set minimum standards for issues such as observer training, data collection and storage, and are therefore a key component of quality assurance and quality control for integrated monitoring to support strategic assessment.

Oakley et al. (2003) provide generic guidance on developing monitoring protocols, and recommend that protocols include:

- a narrative that gives background information on why a particular component or process of the ecosystem was selected for monitoring, together with an overview of the various components of the monitoring protocol, including the objectives, the sampling design, field methods, data analysis, data archiving and reporting, personnel requirements, training procedures and operational requirements
- a set of Standard Operating Procedures (SOPs) that provide detailed, step-by-step instructions on how each step of the protocol is to be completed, including instructions for how any of the SOPs are to be amended
- supplementary materials that provide additional guidance and support, which can include items such as reports, photographs and data analysis examples.

Brown et al. (2009) provide a good example of a monitoring protocol for marine fish. The six chapters cover background, sample design, field methods, data handling, analysis and reporting, personnel requirements and training and operational requirements.

To establish an IMF, the most important focus for data management is identifying the purpose and scope of monitoring protocols and the role of the governance committee(s) in protocol development, approval and refinement. For example, it may be preferable that monitoring protocols are developed to include collection, management, analysis and reporting of monitoring data from selected programs. Acknowledgement and consideration should be given to the relationship between monitoring protocols and data management processes and standards (see Section 2.3.6), data analysis (see Section 2.3.7) and reporting and communication (see Section 2.3.8). It is also important to identify existing monitoring protocols that could be used as a basis to develop monitoring protocols for integrated monitoring and a preferred monitoring protocol standard.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to generate an outline of the purpose and scope of monitoring protocols for integrated monitoring. The outline should identify:
    a. the relationship between monitoring protocols for integrated monitoring and
        i. data collection
        ii. data management processes and standards for integrated monitoring (see Section 2.3.6)
        iii. data analysis for integrated monitoring (see Section 2.3.7)
        iv. reporting and communication for integrated monitoring (see Section 2.3.8)
    b. existing monitoring protocols that could be used as a basis to develop monitoring protocols for integrated monitoring, in particular their alignment with selected indicators (see Section 2.3.4a) and selected programs (see Section 2.3.4b)
    c. significant gaps in monitoring protocols for integrated monitoring that would need to be filled and potential opportunities to fill gaps
    d. preferred monitoring protocol standard for the IMF
    e. role of governance committee(s) in developing, approving and refining monitoring protocols.

II. Key inputs to the process include:
    a. list of existing monitoring protocols that could be used to support the IMF (identified as part of compiling and analysing information on existing monitoring programs – see Section 2.3.2)
    b. list of selected indicators (see Section 2.3.4a)
    c. participation from organisations with responsibility for critical monitoring programs
    d. template options for monitoring protocols.

III. Document and summarise findings from the process and circulate to participants and appropriate governance committee(s).

2.3.6 Managing data

Aims of this section

- To explain the importance of managing data
- To highlight considerations for managing data
- To provide guidance to establish an IMF

Importance

Data management is an essential function of integrated monitoring because it provides the necessary infrastructure, processes and standards that enable storage, discovery and access to data generated by the selected monitoring programs (see Section 2.3.4b) and other relevant programs. Data management is fundamental to the reliable and timely flow of fit-for-purpose data from data collectors to data analysts, reporters and communicators. A properly designed and documented data management system must be a central feature of an integrated monitoring program, as the lifespan of the data set will span across the careers of many scientists, and will most likely be subject to numerous changes in information technology (Fancy et al. 2009; White et al. 2009).

Considerations

Australia already has an established and developing national data infrastructure with the supporting processes and standards suitable to support integrated monitoring in coastal and marine regions. This includes national data stores and metadata stores to access data (e.g. Australian Ocean Data Network, Atlas of Living Australia and the Terrestrial Ecosystem Research Network) and national standards for data management (e.g. ISO Standard and Marine Community Profile for metadata). Data standards are very important for discovery, storage and accessibility of data, particularly in decentralised systems where differences in vocabularies can hamper discovery and access to data.

The US National Parks and Wildlife Monitoring Program provides a detailed website for data management including guidance to develop data management plans that support integrated monitoring. This centralised approach to data management is thorough, extending beyond the boundaries of managing accumulated monitoring data to include records management (e.g. management of monitoring samples and reporting outputs). NPS (2008) outlines how the format, presentation and use of monitoring data will change over the life of a monitoring program, which is referred to as the data life-cycle and is characterised by a series of 14 steps (Figure 2.4).

Data management for monitoring programs all too often receives insufficient attention and support (Caughlan and Oakley 2001, Lindenmayer and Likens 2010). The costs of adequate data management systems to support monitoring are typically underestimated and can be expected to be about 20–30 per cent of the total monitoring program budget (Fancy et al. 2009, Lindenmayer and Likens 2010).

In establishing an IMF, the most important focus for data management is identifying the preferred model for discovering, storing and accessing monitoring data (the primary asset) generated from the selected programs (see Section 2.3.4b). At one end of the spectrum is a centralised data management model (data discovery, storage and access managed by a single institution), while at the other end is a decentralised data management model (data discovery, storage and access managed by a network of institutions connected by common goals, interoperable systems and network standards). A decentralised model may be attractive if selected monitoring programs (see

Section 2.3.4b) involve numerous institutions. It is also important to identify the existing data management infrastructure, processes and standards and opportunities to establish the preferred model for data management. Acknowledgement and consideration should also be given to the relationship between data management processes and standards and monitoring protocols (see Section 2.3.5). Guidance on data management processes and standards needs to be embedded in monitoring protocols to ensure data are discoverable, stored securely and made accessible.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to generate an outline of the purpose and scope of data management for integrated monitoring. The outline should identify:

   a. options and preferred data management model for discovery, storage and access to monitoring data

   b. overview of existing data management infrastructure, processes and standards that would support discovery, storage and access to monitoring data to support the IMF

   c. significant gaps in data management that would need to be filled and potential opportunities to fill gaps

   d. relationship between data management processes and standards and monitoring protocols (see Section 2.3.5)

   e. role of governance committee(s) in data management for integrated monitoring.

II. Key inputs to the process include:

   a. background information on existing data management arrangements for selected monitoring programs in the IMF (identified as part of compiling and analysing information on existing monitoring programs – see Section 2.3.2)

   b. hierarchy of management objectives, monitoring objectives and selected indicators (see Section 2.2.1, 2.3.1 and 2.3.4a)

   c. advice and participation from experts in data management, particularly those leading existing and relevant data management initiatives

   d. participation from organisations with responsibility for selected monitoring programs (see Section 2.3.4b).

III. Document and summarise findings of process and circulate to workshop participants and appropriate governance committee(s).

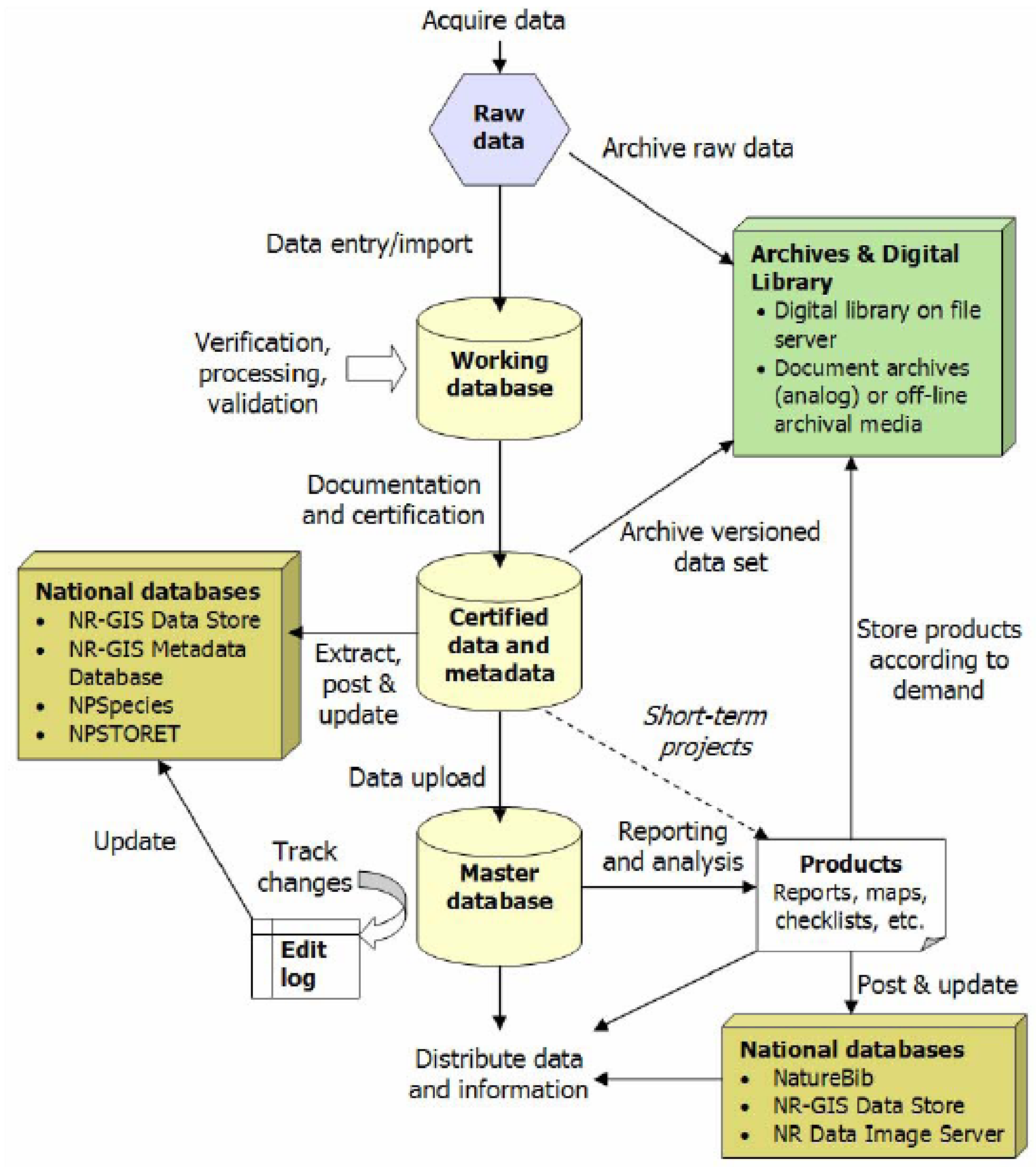


Figure 2.4 Fourteen steps relevant to data discovery, storage and access, starting the acquisition of raw data and ending with distribution of data and products, in the life-cycle of data acquired from a monitoring program (source: NPS 2008)

2.3.7 Analysing data

Aims of this section

- To explain the importance of analysing data
- To highlight considerations for analysis of data
- To provide guidance to establish an IMF

Importance

Data analysis for integrated monitoring has the important role of collating datasets from selected monitoring programs and completing analyses at regional and local scales to understand the effectiveness of management in enhancing and maintaining MNES values. Data analyses essentially transform ecological, social and economic monitoring data to knowledge and understanding about trends in MNES values and the pressures at regional and local scales.

Considerations

Existing monitoring programs (see Section 2.3.4b) selected for inclusion in the IMF may have established data analysis mechanisms and outputs designed to meet specific needs. The IMP requires a data analysis mechanism(s) that meets the specific needs identified by a strategic assessment. More than likely this means collating a number of similar datasets (e.g. seagrass cover data) from selected monitoring programs and combining these data to complete analyses at a broader scale, subject to the survey design consideration discussed in Section 2.3.4c. The integrated analysis would also need to consider data on pressures, drivers and impacts to understand the effectiveness of management for enhancing and maintaining MNES values. For example, a monitoring program collecting data on seagrass cover may be established to generate knowledge and understanding at the scale of a port or bay. By comparison, an IMP established under a strategic assessment would require:

- analyses combining numerous data sets from local seagrass monitoring programs to generate knowledge and understanding of trends in seagrass cover at a regional scale
- analyses of data on pressures (e.g. pressures acting on the seagrass, such as pressures from storms, human activities, grazing and disease), drivers of pressures (e.g. drivers of human activity and climate change) and management responses (e.g. compliance with water quality guidelines and education programs)
- a synthesis of similar data analyses for other MNES values (i.e. not just seagrass cover) to understand and the state and outlook of the region subject to strategic assessment.

The resulting integrated data analyses need to be interpreted in the context of the conceptual models (see Section 2.3.3) that are specifically designed to capture understanding about the relationships between drivers, pressures, state of the MNES values and management responses. Interpretation also needs to consider predictions from the conceptual models, particularly whether or not trends in monitoring data accord with the predictions.

There are a broad range of methods to analyse monitoring data. Regardless of the methods used it is important that results are accompanied by contextual information that will help scientists and managers interpret the results. It is recommended the results of each analysis explicitly report on:

- analysis method used
- uncertainty (an important aspect of data analysis is the capacity to report the level of uncertainty in the conclusions that may vary spatially and with time. All efforts should be made to communicate uncertainty in a constructive manner)
- spatial dependence
- temporal dependence for time-series data
- the method for site selection
- precision achieved
- data trends in relation to reference points or thresholds for management
- data trends in relation to ecosystem understanding, effect of pressures and predictions captured in conceptual models
- whether or not the data collected were sufficient to address the monitoring objective(s).

To establish an IMF it is important to identify the purpose and scope of the integrated data analysis and the options and preference for undertaking and completing it. For example, it may be preferable to set up a specific mechanism with responsibility to undertake a periodic comprehensive integrated analysis (e.g. as a working group under the governance structure). Alternatively, the comprehensive integrated data analysis could be outsourced or broken down into discrete parts and completed within selected monitoring programs (see Section 2.3.4b). Regardless of the approach, it is important that requirements, directions and standards for integrated data analysis are embedded in documented guidance (e.g. SOPs or part of a monitoring protocol – see Section 2.3.5) to ensure a consistent approach is maintained over time or that if changes occur they are clearly documented and communicated. This type of guidance should provide clear process directions in the event of specific findings; for example, whom to contact within a specific timeframe if trends in data trigger management reference points or thresholds, or if data trends do not accord with the understanding or predictions captured in conceptual models.

Guidance to establish an IMF

I. Instigate a collaborative process with experts to generate an outline of the purpose and scope of the integrated data analysis for integrated monitoring. The outline should identify:

    a. general options and preferences for undertaking and completing an integrated data analysis and role of guidance for the integrated data analysis

    b. relationship between integrated data analysis and conceptual models (see Section 2.3.3) and governance committees (see Section 2.1.2)

    c. existing examples of integrated data analysis in the focus area

    d. significant gaps in integrated data analysis that would need to be filled and potential opportunities to fill gaps.

II. Key inputs to the process should include:

   a. background information on existing data analysis arrangements for selected monitoring programs for the IMF programs (identified as part of compiling and analysing information on existing monitoring programs – see Section 2.3.2)

   b. advice and participation from experts in data analysis

   c. participation from organisations with responsibility for selected monitoring programs

   d. knowledge on how data will be used to inform managers.

III. Document and summarise findings from the process and circulate to participants and relevant governance committee(s).

2.3.8 Reporting and communication

Aims of this section

- To explain the importance of reporting and communication
- To highlight considerations for reporting and communication
- To provide guidance to establish the IMF

Importance

Reporting and communication is an essential function of integrated monitoring because it focuses on providing key messages and the appropriate level of supporting information about monitoring results to the right people at the right time. Reporting and communicating often complex information to managers in clear and easily understood formats is fundamental if monitoring is to trigger a management response (Varcoe 2012). A commitment to regular reporting is important to maintain the relevance of program objectives and data collection (Sergeant et al. 2012). Reporting and communication are a pragmatic means of integrating monitoring programs by delivering messages that are founded on the integration of monitoring data from numerous monitoring programs.

Considerations

Monitoring results need to be clearly communicated to a number of different audiences. The primary audience and users of the monitoring results are policymakers, managers, planners, interpreters and scientists. Monitoring results also need to be communicated to the general public, members of parliament and those responsible for accountability and performance management (Fancy et al. 2009). The content and detail included in specific communication products and reports will differ depending on the target audience. Sergeant et al. (2012) suggest the use of a customer-centric approach for defining reporting products before data collection begins.

Varcoe (2012) points out that much work has been recently undertaken by the US National Park Service (USNPS) to develop frameworks for matching different types of monitoring information to different target audiences. For example, the USNPS has documented its conceptual understanding of data sources and key audiences (Figure 2.5) and developed an information pyramid (Figure 2.6) to guide understanding about the type and level of information required by different audiences. Rogers and Biggs (1999) suggest the objectives hierarchy identifies the different types and levels of information and language for communication products required by different audiences.

The types of monitoring reports and information products released are highly variable and may include data summary reports, trend analysis and synthesis reports, score cards, report cards, simple summary reports (annual) and in depth periodic reports (inter-annual) that synthesise long-term trends from larger data ranges. Varcoe (2012) warns that while report cards have become a standard reporting tool for many monitoring programs, users of this information need to look beyond the traffic lights and arrows and ask 'what is the information based on?' He points to the need to recognise the direct link between raw data and aggregated reporting.

The timing and sequencing of release of reports and communication products is an important consideration for integrated monitoring, particularly if the monitoring is founded on a decentralised model (numerous self-governing jurisdictions/institutions/agencies agreeing to cooperate to implement integrated monitoring). In these cases, effective reporting and communication will rely on development of a common language and logic so that target audiences are not confused if multiple jurisdictions/agencies are releasing reports or if reports are released at different times.

An integrated monitoring communication plan would provide the necessary clarity, certainty and transparency for internal and external users. The plan would need to identify clear aims and target audiences, match reports and communication products to targeted audiences, identify any necessary standards (e.g. templates for communications or reports) and identify necessary roles and responsibilities.

Guidance to establish the IMF

I. Instigate a collaborative process with experts to generate an outline of the purpose and scope of reporting and communication for integrated monitoring. The outline should identify:

   a. key sources of information and target audiences
   b. general options and preferences for reporting and communications
   c. existing reporting mechanisms and outputs that could support integrated monitoring
   d. significant gaps in reporting and communication that would need to be filled and potential opportunities to fill gaps
   e. relationship between reporting and communication and monitoring protocols (see Section 2.3.5)
   f. role of governance committee(s).

II. Key inputs to the process should include:

   a. background information on existing reporting arrangements for selected monitoring programs (identified as part of compiling and analysing information on existing monitoring programs – see Section 2.3.2) and related management initiatives that would support the IMF

b. hierarchy of management objectives, monitoring objectives and selected indicators (see Section 2.2.1, 2.3.1 and 2.3.4a)

c. advice and participation from individuals involved in existing reporting from monitoring programs likely to be included in the IMF

d. management requirements and sensitivities.

III. Document and summarise findings from the process and circulate to participants and appropriate governance committee(s).

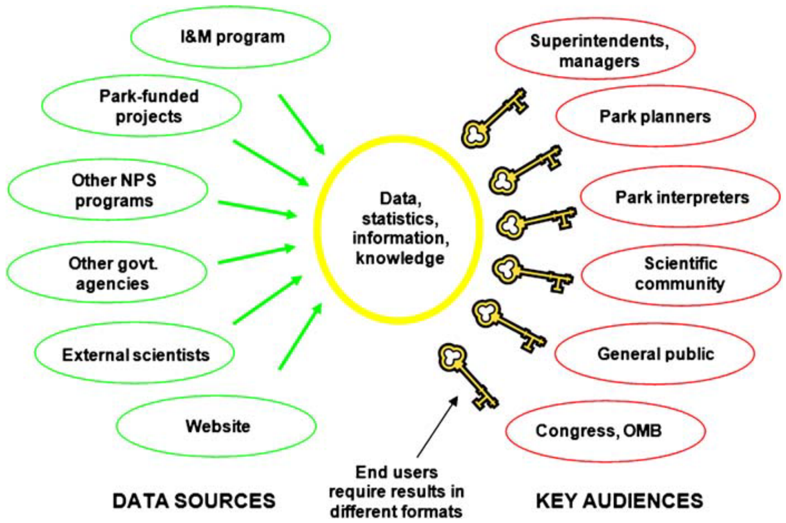


Figure 2.5 An example of mapping the relationship between data sources, data analysis and key audiences for reporting and communicating the results from monitoring (source: Fancy et al. 2009)

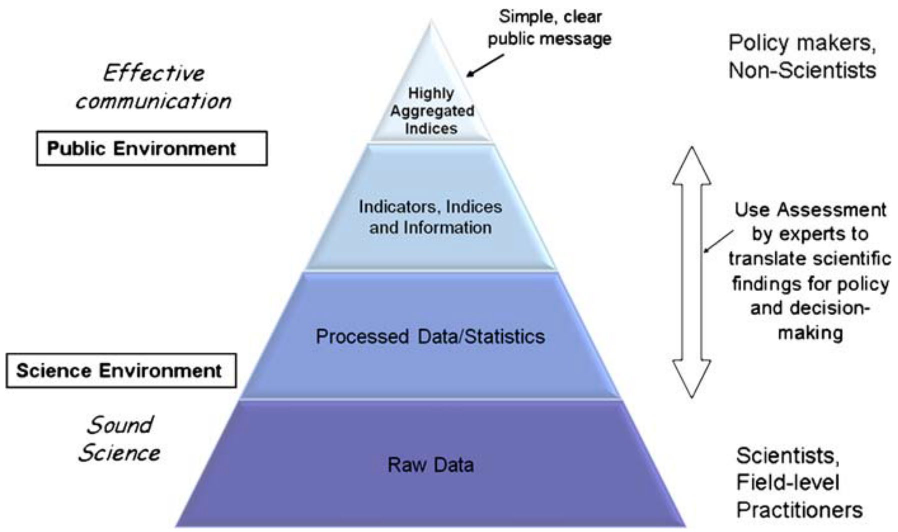


Figure 2.6 An example of an information pyramid showing how the amount of detail and scale of analysis of scientific data will differ depending on the intended audience for reporting and communication (source: Fancy et al. 2009).

2.3.9 Reviewing and auditing

Aims of this section

- To explain the importance of reviewing and auditing
- To highlight considerations for reviewing and auditing
- To provide guidance to establish the IMF

Importance

Periodic review and audit of integrated monitoring is an essential function to check if the monitoring is operating as intended and meeting the needs of management. Periodic reviews of integrated monitoring provide a formal mechanism for recommending changes and revisions to the program. Periodic reviews are essential for program effectiveness and efficiency and for quality assurance.

Considerations

Integrated monitoring is likely to represent a substantial investment from governments, industry and the community and therefore should be reviewed and audited periodically. Reviews provide the opportunity to formally consider how the integrated program is progressing against the program purpose and objectives (see Section 2.3.1) and decision-making principles (see Section 2.1.2) (Patterson et al. 2008). Reviews also provide an opportunity to consider new opportunities such as increases in monitoring budget and advances in technology or new issues such as reduction in monitoring budget, significant change to ecosystem understanding for areas monitored or new monitoring priorities. Periodic reviews of integrated monitoring may be comprehensive and cover a broad spectrum of considerations including:

- purpose of the IMP and monitoring objectives and priorities
- changes in understanding about the systems being monitored or the effects of pressures acting on the systems
- efficiency/adequacy of overall sampling design for integrated monitoring
- governance arrangements (e.g. effectiveness and consistency with agreed principles)
- accountability (e.g. delivery of outputs and efficient use of resources)
- scientific rigour of data collection and integrated data analyses
- effectiveness/adequacy of data management and monitoring protocols including cost-effectiveness
- cooperation and partnerships supporting integrated monitoring (e.g. existence of common goals, degree of collaboration, resource sharing and efficiencies/duplications).

On occasions more specific technical reviews or audits that focus on specific monitoring functions, such as monitoring protocols data management, data analysis and reporting may be needed. For example, periodic reviews of data management arrangements or data collection protocols may be required to take account of advances in technology, while audits may be required to assess conformance with SOPs or monitoring protocols.

Appointed governance committees (e.g. oversight and coordination group, expert group and operational group) are instrumental in providing the leadership and direction for the focus, timing and sequence of reviews and audits for integrated monitoring. The USNPS typically conduct a start-up review three years after an integrated monitoring plan has been approved and implemented; thereafter program reviews are conducted every 5 years (Patterson et al. 2008).

It is important to identify the purpose, scope and preferred model of reviewing and auditing in the IMF. The role of governance committee(s) and principles to guide decision-making about integrated monitoring (see Section 2.2.2) should be specified. The relationship with audits and reviews for existing monitoring plans should also be explained. For example, it is likely that reviews and audits of selected programs (see Section 2.3.4b) could inform, and be informed by, the reviews and audits of integrated monitoring.

Guidance to establish the IMF

I. Instigate a collaborative process with experts to generate an overview of the purpose and scope of review and auditing procedures for integrated monitoring. The overview should identify:

   a. a preferred model for reviewing and auditing, including the nature, timing and level of independence of program reviews and periodic audits of the IMP

   b. the role of governance committee(s) and principles to guide decision-making for integrated monitoring (see Section 2.1.2)

   c. relationship with existing reviews of selected programs.

II. Key inputs to the process include:

   a. background information on existing review and audit mechanisms of selected monitoring programs (identified as part of compiling and analysing information on existing monitoring programs – see Section 2.3.2) and related management initiatives that would support the IMF

   b. advice and participation from agencies, institutions and stakeholders that are proposed participants on governance committees.

III. Document and summarise findings the process and circulate to participants and appropriate governance committee(s).

2.4 Transitioning from an IMF to an IMP

Sections 2.1 to 2.3 provide detailed guidance to establish an IMF. An IMF is a document providing strategic assessment partners and regulators with a systematic and objective understanding about the purpose, priorities, functions and requirements of integrated monitoring in a specific focus area. This section provides general guidance to strategic assessment partners about transitioning from an IMF to an IMP.

An IMP is the vehicle to operationalise the planning and assessment undertaken as part of establishing the IMF. It requires suitable governance structures and adequate and sustained funding and resources. The IMP has a clear purpose and priorities for integrated monitoring in the focus area(s) and provides certainty about how the program will be commenced, developed and reviewed. The roles of governance in leadership, decision-making and support for the IMP are defined, particularly as they relate to the essential monitoring. It identifies the existing monitoring programs that will participate in integrated monitoring and the infrastructure, initiatives, processes, standards and protocols that will be used to integrate monitoring in the focus area. It identifies the actions that need to be completed over the short, medium and longer term, and who will be responsible for actions, to commence, operate, develop and review the IMP.

There are two parts to the guidance: comments on establishing appropriate governance arrangements for an IMP; and guidance on how to develop and implement a plan to provide certainty about how and when the program will be commenced, developed and reviewed.

Establish governance arrangements for the IMP

Effective governance is a prerequisite for integrated monitoring because it provides the necessary leadership, and accountability for commencing, developing and reviewing the IMP (see Section 2.2.2). It is important to establish governance arrangements soon after the Australian Government Minister endorses the proposed management plan of the strategic assessment (see Figure 1.2 for indicative steps in the strategic assessment process). Temporary governance or approval structures established to steer and progress the strategic assessment process or to establish the IMF will not meet the requirement for enduring governance arrangements to transition from an IMF to an IMP.

The IMF identifies committee structures and functions, specific expertise and partners that are required for an enduring IMP. The first step is to finalise the composition of an oversight and decision-making committee and initiate its work. The committee will then guide the development of the governance structure. For example, specifying leadership and direction in technical areas or specifying processes to increase collaborative reach (e.g. managers of selected monitoring programs—see Section 2.3.4b) or experts in sampling design (see Section 2.3.4c), data management (see Section 2.3.6), data analysis (see Section 2.3.7), reporting and communication (see Section 2.3.8) or reviewing and auditing (see Section 2.3.9). The governance arrangements for the IMP must be clearly specified in terms of reference and participant lists and endorsed by the oversight and decision-making committee.

Develop and implement an Integrated Monitoring Plan

The IMF defines the purpose and priorities for integrated monitoring in the focus areas. The IMP goes further by specifying:

- defined roles and identified participants for governance in leadership, decision-making and support for the IMP
- which existing (and new) monitoring programs will participate in integrated monitoring and infrastructure, initiatives, processes, monitoring standards and protocols that will be used to integrate monitoring in the focus area
- a clear timeline for identified activities over the short, medium and longer term, and who will be responsible for each action
- specific dates to report and review results of the integrated monitoring
- sources of adequate and sustained funding and resources to implement the IMP (see Box 6).

Box 6 Principles for a viable funding model for integrated monitoring

Viable options for long-term funding of critical monitoring programs will need to satisfy a number of key criteria. The following five general principles were proposed by the Alberta Environmental Monitoring Working Group in Canada (AEMWG 2012), to guide the establishment of a viable funding model:

a) Funding must be sufficient to support a science-based program commensurate with its mandate.

b) Funding must be predictable, stable and sustainable.

c) The funding model should strive to achieve economic efficiency.

d) The funding model should be fair and equitable.

e) The funding model should be administratively simple and cost-effective.

We recommend that an implementation plan be developed and implemented to clearly define the process and timelines for transition from an IMF to an IMP. The implementation plan will provide certainty about what integrated monitoring will achieve along with how and when this will be achieved. Table 2.6 provides general guidance about providing certainty at the level of essential monitoring functions. A draft integrated monitoring plan should be developed and submitted to the appropriate governance committee(s) for endorsement.

The actions, and timing for completion of actions, should be informed by the relative ranking of priority monitoring objectives and formal assessment of risks to, and opportunities for, successful commencement and development of an IMP. It is important to initiate the IMP with the highest priority monitoring objectives, recognising that this will inform further development of the complete IMP. There is a range of risks that will need to be managed in the early stages of development of the program which include:

- insufficient resources or capacity to commence and develop integrated monitoring to address the monitoring priorities of the IMP
- inability to demonstrate benefits of integrated monitoring because the focus of integrated monitoring is spread across too many priorities
- lack of collective understanding, confidence or support from the managers of selected monitoring programs.

A staged approach to implementing the program would provide an effective means of managing these and other risks. For example, the IMP could commence with a pilot stage that focuses on a relatively small number of high priority monitoring objectives, followed by a formal review. This type of approach could be used effectively to demonstrate the benefits, functions and costs of an IMP. It would also provide a useful mechanism to test governance and integrated monitoring functions, and a firm basis to develop a business case for expanding the IMP to include other monitoring priorities.

Table 2.6 General guidance about transitioning from an IMF to a functional IMP

Essential functions of integrated monitoring	Requirements for a functional IMP
1. Clearly defining the purpose of the monitoring program and the monitoring objectives	A clear articulation of the purpose of the integrated monitoring program and a prioritised list of monitoring objectives. A clear understanding about the role of governance committee(s) in endorsing the purpose of the program and the prioritised list of monitoring objectives.
2. Compiling and analysing relevant information on existing monitoring programs	Information on existing monitoring programs is stored in a database for future use.
3. Developing conceptual models	A list of conceptual models that will be used in the IMP that also identifies priority conceptual models for development.
4. Developing overall sampling design for integrated monitoring	A clear articulation of overall sampling design including:
a) Selecting indicators	Priority indicators for integrated monitoring, the monitoring programs that collect the monitoring data and the gaps that are not addressed by existing monitoring programs.
b) Selecting monitoring programs	A clear articulation about the different levels of integration for inclusion in the IMP and the benefits and incentives available to these programs. A list of selected monitoring programs targeted for inclusion in the IMP and the priority indicators they address.
c) Developing sampling design for integrated monitoring	A clear articulation of the overall sampling design for integrated monitoring. A clear understanding about the role of governance committee(s) in selecting and prioritising indicators, selecting monitoring programs and securing their participation and developing and endorsing sampling designs.
5. Developing monitoring protocols	A list of existing monitoring protocols for the IMP, a preferred monitoring protocol template and list of priorities for developing new protocols.
6. Managing data	A clear articulation of the purpose and scope of data management for the IMP including: • data management model for data discovery, access and secure long-term storage of monitoring data • operational guidance for data collectors and data analysts articulating standards for data discovery, access and storage • a clear articulation of responsibilities for managing monitoring data, including a data map identifying the spectrum of monitoring data, data custodians and primary data contacts.
7. Analysing data	A clear articulation of purpose and scope of data analysis for the IMP, including: • arrangements, procedures and standards for undertaking and completing integrated data analysis, • a clear articulation of responsibilities for integrated data analyses.
8. Reporting and communication	A clear articulation of the purpose and scope of reporting and communication for the IMP, including: • key targeted audiences for reporting and communication • arrangements, procedures and standards for reporting and communication, including a projected schedule • a clear articulation of responsibilities for reporting and communication.
9. Reviewing and auditing	A clear articulation of the purpose and scope of reviewing and auditing for the IMP, including: • arrangements, procedures and standards for reviewing and auditing, including a project schedule • a clear articulation of responsibilities for reviewing and auditing.

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Part 3 An integrated monitoring framework for the Great Barrier Reef World Heritage Area

3.1 Introduction and background

This part of the report details how the guidance to develop an integrated monitoring framework described in Part 2 has been applied to the Great Barrier Reef World Heritage Area and is intended to demonstrate the practical application of the guidance. The guidance has been used to develop an IMF for the property that identifies long-term monitoring requirements for the GBRWHA and outlines the gaps and opportunities presented by current monitoring activities. The framework is intended to be used as the basis for developing a long-term and integrated monitoring program that will inform an assessment of the adequacy of management to protect matters of national environmental significance, including Outstanding Universal Value, in the GBRWHA, and deliver the information needed for adaptive management of the area.

The Great Barrier Reef is one of the world's most important natural assets, a system of extraordinary natural, social, cultural and economic value, and of exceptional size, diversity and beauty. For these and other reasons, it has been declared a World Heritage Area and Marine Park.

The Great Barrier Reef Marine Park Authority is the lead government agency responsible for the care and development of the Great Barrier Reef Marine Park, on behalf of the Australian Government and community. The GBRMPA's primary goal is long-term protection, ecologically sustainable use, understanding and enjoyment of the Great Barrier Reef Region. The GBRMPA is not solely responsible for achieving the desired outcomes for the Region. The Authority works in partnership with local, state, national and international agencies to achieve long-term protection for the Great Barrier Reef.

The GBRMPA applies the best available science to decision-making processes and policies underpinning the management of the Marine Park, including information provided by the suite of monitoring programs occurring in the park. Cumulative pressures on the Marine Park are increasing and a strategic and integrated approach to acquisition, management, analysis, interpretation, dissemination and application of information for decision-making is essential to understand and guide future management decisions in this very complex environment.

3.1.1 The strategic assessment of the Great Barrier Reef World Heritage Area.

Under the Australian Government's national environmental law—the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)—a strategic assessment of a policy, plan or program may be conducted as an alternative to project-by-project assessments.

The Australian and Queensland Governments are jointly undertaking a comprehensive strategic assessment of the GBRWHA and adjacent coastal zone. There are two components to the comprehensive strategic assessment: a marine component and a coastal component.

The GBRMPA is responsible for undertaking the marine component (Great Barrier Reef Marine Park Authority 2013b) and the Queensland Government is leading the development of the strategic assessment of the Great Barrier Reef coastal zone. Together the two strategic assessments will evaluate and improve the effectiveness of managing existing and emerging risks to the Great Barrier Reef, focusing on the MNES relevant to the Reef.

Strategic assessments require an effective system of monitoring and adaptive management of MNES (as outlined in Section 1.2). This project illustrates a method for establishing an IMF for the GBRWHA that builds on and integrates existing monitoring activities.

The Great Barrier Reef Region Strategic Assessment describes the GBRWHA values underpinning MNES and the pressures impacting those values. Significant work, including stakeholder consultation, went into developing an agreed lexicon for values and pressures. The project team has used the same descriptions and terminology as a basis for development of the IMF.

Matters of national environmental significance

The following are the MNES that apply in the GBRWHA and the Marine Park:

- **World Heritage properties.** The Great Barrier Reef Region (the Region) makes up the majority of the Great Barrier Reef World Heritage Area which was inscribed in 1981. The property is recognised as having OUV because of its natural beauty and natural phenomena, its representation of major stages in the Earth's evolutionary history, its ecological and biological processes, and its habitats for the conservation of biodiversity. These attributes are exhibited throughout the property.
- **National heritage places.** The Great Barrier Reef was listed as a national heritage place in 2007, based on its recognition as a World Heritage property.
- **Wetlands of international importance.** The Shoalwater and Corio Bays Area was listed under the Convention on Wetlands of International Importance (the Ramsar Convention) in 1996. Part of this area is within the Region. It is the largest wilderness area within the Central Mackay Coast biogeographic area and is representative of coastal, sub-coastal, aquatic landscapes and ecosystems which are relatively undisturbed habitat areas for significant plants and animals, including rare and threatened species (Department of Defence et al. 1999). Another wetland listed under the convention, Bowling Green Bay, is directly adjacent to the Region.
- **Listed threatened species and ecological communities.** Twenty-six species listed as threatened under the EPBC Act occur in the Great Barrier Reef Region*.* There are six marine turtle species, eight seabird and shorebird species, five marine mammal species and seven shark and ray species. There are also listed Endangered Ecological Communities such as littoral rainforest and coastal vine thickets present in the Region.
- **Listed migratory species.** The Great Barrier Reef Region supports 77 listed migratory species comprising six marine turtle species, 11 mammal species including the dugong and two inshore dolphins, five species of shark, 54 species of shorebirds and seabirds and the estuarine crocodile.
- **Commonwealth marine areas.** All parts of the Great Barrier Reef Region beyond Queensland State waters (i.e. greater than three nautical miles from low water) are a matter of national environmental significance as a Commonwealth marine area. The Commonwealth marine

area also extends beyond the Region into the Torres Strait, Coral Sea and to the south of the Region.

- **The Great Barrier Reef Marine Park.** The Region includes the Great Barrier Reef Marine Park (the Marine Park). The Marine Park is managed to protect and conserve the environment, biodiversity and heritage values of the Region. As a multiple-use protected area, community benefits derived from the environment are also relevant.

Values

Management outcomes for the GBRWHA are achieved through managing activities and pressures that impact on the values of the Region. These are the values that underpin the MNES. There is overlap between each of individual MNES. For example, the listing of the Great Barrier Reef as a national heritage place is based on its World Heritage listing and, as a result, these two matters correspond exactly. The Great Barrier Reef Marine Park makes up almost all (about 99 per cent) of the Great Barrier Reef World Heritage Area. The listed threatened and listed migratory species range throughout the Region and some are also present in the adjacent coastal zone or marine areas beyond the Region.

In addition, the MNES do not occur in isolation. They are interconnected, each one a part of the rich and complex Great Barrier Reef environment. For example, the Region's habitats, species and processes are the basis of the Region's World Heritage status (one of the listed MNES), but are also the basis of listings of threatened and migratory species which are other, separate MNES. The set of habitats and species recognised in the Shoalwater and Corio Bays Ramsar Area (another MNES) are fundamental to the functioning of the broader environment, and are important for the conservation of some threatened species, as well as being typical of the interaction of coastal and marine environments along the Region's coast.

As the GBRWHA has a long history of scientific research and management, many of the values that underpin MNES and the impacts on those values have been identified. Lists of important values as well as activities, pressures and impacts exist and have been published through reports such as the *Outlook Report 2009*. These lists were updated through the strategic assessment process and this project and mapped to MNES (Appendix 2 Tables 1–3).

Pressures and impacts

The Great Barrier Reef Region is a large and complex natural system with multiple uses and many pressures. The state of the Region's biodiversity and heritage values and the benefits derived from the environment are constantly changing in response to a complex suite of interactions between drivers, activities and pressures acting on values. To develop a full understanding of the pressures and their likely impacts on the Region's values, it is necessary to consider both the individual impacts and the cumulative effect of all impacts.

The strategic assessment process identified pressures through consultation with stakeholders. Those discussions generated a list which was consolidated into 41 pressures based on the descriptors used in the *Outlook Report 2009* (Great Barrier Reef Marine Park Authority 2009a), with some amendments and updates. The list of pressures and their likely causes, both for direct drivers and activities are in Appendix 2 Table 4.

3.1.2 Sources of knowledge for management of the GBR

There are four broad sources of knowledge that are used to inform management of the GBR: scientific research and monitoring, community knowledge, stakeholder knowledge and Traditional Owner knowledge (Figure 3.1). Collectively, these sources of knowledge inform the development of management actions and policies and, where feasible, are used to monitor and assess the effectiveness of management strategies to allow ongoing improvement or adaptive management.

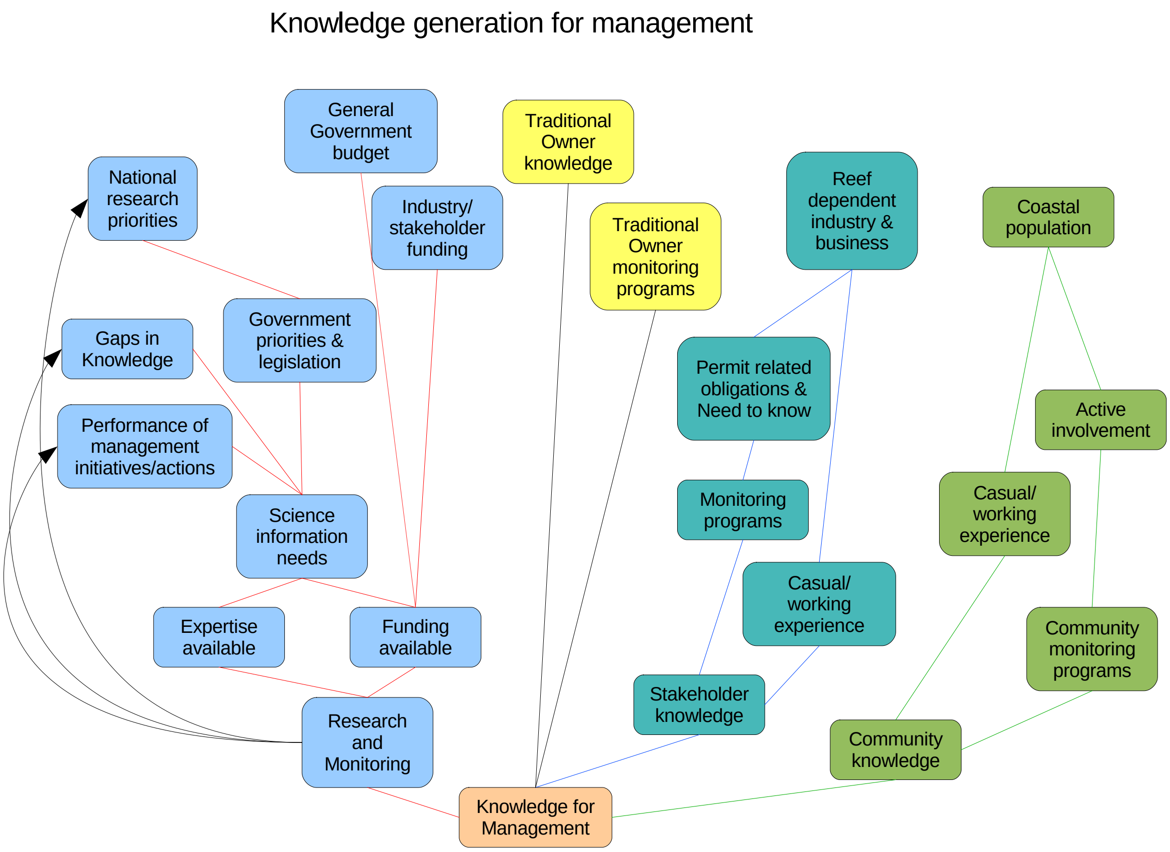


Figure 3.1 Knowledge used in management of the GBRWHA

Monitoring

Monitoring contributes to understanding of the condition and trend of GBRWHA values, the community benefits derived from the values, and status of the drivers, pressures and activities affecting these values over time. Monitoring may detect trends and changes at an early stage and also plays a fundamental role in evaluating the effectiveness of management actions.

Monitoring is also critical for informing the development and refinement of models. Adaptive management must not only consider trends based on past and current condition, but also future predictions based on systems understanding and modelling. Management strategies address uncertainty by considering the range of possible scenarios and using a risk-based approach to defining management actions. Such approaches are used in statutory documents such as the *GBR Outlook Report* (Great Barrier Reef Marine Park Authority, 2009a). Risk assessments and predictive scenarios are particularly relevant for management of the GBRWHA given the uncertainty surrounding the major drivers of pressures/activities currently impacting MNES, including OUV. Drivers such as climate change, population and economic growth, societal attitudes and technological advances are constantly changing, and monitoring and modelling is necessary to inform adaptive management in an uncertain future. Various types of models can inform structured decision-making processes and allow exploration of sensitivities and probable management outcomes. All models should be based on current knowledge gained from research and monitoring and are improved or falsified using primary and secondary monitoring data (see Section 3.2.5).

Existing monitoring programs in the GBRWHA have largely been designed to address and report on a specific issue, a location or a management initiative mostly in isolation of others. They generally provide one or more of the following:

- '*situational awareness*' of the condition of, trends in, and pressures on the health of a component of ecosystems, communities and industries, to inform the development and implementation of management strategies
- a basis for *adaptive management*: the ability to review and adapt management actions in response to new information on condition, trends and pressures, and on the effectiveness of existing management actions
- accountability for effectiveness of protection and management measures
- a basis for community engagement with, education about, and participation in the assessment of the status of the Marine Park and its management
- a basis for the identification of gaps in knowledge of Marine Park ecosystems, their processes, biodiversity and values.

An IMF for the GBRWHA leading to an IMP will allow managers to assess the effectiveness of the management program to address both individual and cumulative impacts, and to inform adaptive management and strategic planning. An integrated approach can also maximise efficiencies among programs, ensure collection of appropriate data for priority management needs, add value to existing information and facilitate long-term funding commitment.

The focus of this framework is long-term monitoring and those short-term and compliance-related monitoring programs that should be integrated for more effective and efficient monitoring of the GBRWHA. Integrating these monitoring programs and explicitly linking them to management needs in an adaptive management context provides the necessary insights to determine the adequacy and sustainability of funding and resources for monitoring the GBRWHA. Three broad types of management-related monitoring are identified for the GBRWHA:

- *Long-term integrated monitoring* informs management of the condition and long-term trend of values underpinning MNES, including OUV, and trends in community benefits derived from the values at local, national and international levels. Core monitoring also assesses long-term management effectiveness of management instruments such as the Zoning Plan, Reef Water Quality Protection Plan, Reef-wide regulations, standards and policies. Priority and ecosystem values (see Section 3.2.3.2) are monitored consistently over the long term (25+ years) and reported regularly against 25- and 5-year management outcomes, objectives and targets. More regular reporting may be required to inform adaptive management if appropriate for particular ecosystem values/pressures/activities.

- *Short- to medium-term issue-specific monitoring* informs management of the condition, extent of impact and/or recovery rate of species, habitats and/or community benefits over the short to medium term (5–10 years). The time frame needed to detect changes in drivers affecting the system and community benefits derived from the system is likely to be much shorter in some instances.

  This category of monitoring is often triggered by an event and/or designed to assess the effectiveness of a particular management action. Issue- or site-specific monitoring can contribute to a broader assessment of cumulative impacts, improve understanding of cause-and-effect relationships and contribute to understanding the longer-term trends of priority values. For example, monitoring impact to and recovery of seagrass meadows following a cyclone may inform management about increased risks to dugong and green turtle populations in the Region, and the capacity for commercial fishers to earn income at the affected sites.

- *Compliance monitoring* is sometimes included as a requirement in Marine Parks permit conditions. Its duration may be for the life of the permit term, a portion of the permit term or well beyond the permit term. The Permittee (which may be an individual, company or joint Permittee) is responsible for funding the monitoring. Typically in these cases, an environmental management plan is required and submitted by the Permittee. All parties enter into a deed of agreement which clearly defines the monitoring consultant, program, and environmental management plan.

No monitoring programs for the GBR have secure, ongoing funding and no one agency is responsible for funds. Instead, monitoring programs are generally delivered through publicly funded short- and medium-term (up to 10 years) national and regional programs such as the National Environmental Research Program and Reef Rescue. Funding core long-term monitoring programs through cyclical research budgets regularly exposes important monitoring programs to funding reductions or cuts and reduces the pool of funds available for other important research. A significant proportion of funding is supplied by Australian and Queensland Government agencies such as the Australian Institute of Marine Science and the Queensland Department of Agriculture, Forestry and Fisheries, which operate within their own budget cycles.

Research

Research contributes to understanding how the Great Barrier Reef's social, economic, cultural and ecological systems function, and thus to identifying and predicting benefits, impacts and future trajectories which help guide management planning. This information is applied to help set management objectives and to inform conceptual models, which together guide the development of monitoring objectives, indicators and subsequent sampling protocols. Investment in Great Barrier Reef research is delivered through a range of programs and government initiatives, as well as through co-investment from research organisations and the private sector. A large proportion, but not all, of the research conducted on the Great Barrier Reef is intended to inform and support management and protection of the ecosystem and the goods and services that it provides.

The priority monitoring and research needs for the GBRWHA are identified and reviewed every five years in the context of findings from the *Outlook for the Great Barrier Reef Report* (Great Barrier Reef Marine Park Authority, 2009a). Scientific information needs for management of the GBRWHA, identified in the context of the 2009 *Outlook Report* can be found at http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/science-and-research/scientific-information-needs.

Major research programs relevant to the GBRWHA include:

- National Environmental Research Program
- Reef Rescue Research and Development Program
- the Queensland Government Reef Protection Package Research and Development Program
- Australian Research Council Centres of Excellence
- the Great Barrier Reef Foundation and eReefs
- the National Climate Change Adaptation Research Facility
- Research and Development Corporations (RDCs)
- Australian Institute of Marine Science
- various Queensland Government departmental research programs.

Community knowledge

There is an extensive pool of knowledge and expertise held by communities adjacent to the GBR (Fernbach and Nairn 2007). This information is used by management through processes such as rezoning and Outlook Reporting, but there is opportunity to mine this resource more fully. A scoping study on 'citizen science' projects has recently revealed numerous barriers and constraints that reduce the discoverability, accessibility and useability of these data. A number of steps could be taken to address these barriers and constraints but there are very few projects and resources focused on resolving these issues.

Traditional Owner knowledge

Traditional Owner groups of the GBR and its adjacent lands retain information on changes in environmental condition and trend that is generally informed by multi-generational observations. Some of these groups are well organised and resourced and are in a position to use their traditional knowledge not only to inform research and monitoring at the local level, but also to address information needs relevant to broader management concerns. In the GBR, Traditional Owner groups are capitalising on partnership agreements such as Commonwealth-funded and GBRMPA-administered Traditional Use of Marine Resources Agreements (TUMRAs) to establish the necessary technical and governance support to deliver research assistance and ecosystem monitoring services. However, Traditional Owner natural resource management programs are primarily funded through a combination of government programs and grants. This leaves them vulnerable to short-term funding processes and jeopardises long-term monitoring outcomes so important to management agencies and other end-users, as well as the groups themselves. More work is needed to realise the full potential of opportunities presented by partnership arrangements between Traditional Owners, management agencies and research institutions. It will be important for research and monitoring efforts in this space to have some level of formal integration with mainstream programs in order to remain viable.

3.1.3 Research and monitoring providers in the GBRWHA

Effective research and monitoring programs bring together research and monitoring providers with end-users of research and monitoring (e.g. management agencies and stakeholders). Governance structures and engagement activities are required to align monitoring and research activities with management needs. Program governance structures that connect monitoring providers with end-users create implicit information networks that provide managers with regular updates about emerging issues, and trends and changes detected though monitoring activities.

There are many institutions and groups involved in research and monitoring in the Great Barrier Reef. Research is mostly conducted through research institutions and government agencies and the results are made available to management through publication in peer-reviewed articles and reports, through scientific meetings and symposia, and sometimes also through dedicated policy briefings and meetings. Parties responsible for such research include the AIMS, Queensland Government Departments, James Cook University, the University of Queensland, the University of Central Queensland, the University of the Sunshine Coast, CSIRO, a number of museums and the GBRMPA.

Monitoring providers include:

- Research institutions and government agencies (as identified above) – where monitoring is carried out by scientists and technicians that are highly trained in the relevant fields.
- Reef-based industries – where monitoring may be conducted by individuals with a high level of training or with minimal training. It may be a voluntary contribution to management, undertaken to meet a permit condition or a compulsory reporting obligation.
- Members of the community – typically on a voluntary basis, and by people associated with a recognised 'citizen science' monitoring program that also provides training.
- Traditional Owners – through TUMRAs and through natural resource management initiatives.

3.1.4 What is meant by 'integration'?

Integration is a broad term that can have many meanings in natural resource management (see Section 1.4 and 1.5). For the purposes of the GBRWHA IMF, integration is the process of objective and systematic combination of interests, data and other resources across policy, management and science sectors into a unified approach to monitor, analyse and report on the status, trends and patterns in the GBRWHA. Specifically, integration will result in:

- monitoring programs that feed into management so that the information gathered is explicitly linked to management objectives and outcomes that in themselves combine policy, management and science
- an explicit process for assessing, prioritising, resourcing, implementing, managing and periodically reviewing monitoring programs
- combination of different monitoring programs that may have been set up for different reasons but are monitoring similar attributes/variables
- unifying monitoring under a Driver-Pressure-State-Impact-Response framework to provide analysis and insights from data including biophysical, social and economic data

- provision of multidisciplinary and integrative analyses that inform assessments of cumulative impacts
- coordination of sensitivity (state and trends of values) and exposure (impacts and pressures) data collection so that this happens concurrently and in the same sites as far as possible
- incorporation of new information and knowledge into monitoring
- coordination of communication and reporting across programs where appropriate.

3.1.5 Relationship between drivers, activities, pressures, values and community benefits in the Great Barrier Reef World Heritage Area

This section describes the modified DPSIR framework used as the basis of the Great Barrier Reef Region Strategic Assessment and therefore being used to inform the IMF for the Region.

The Great Barrier Reef Region contains both biodiversity and heritage values that underpin MNES, including the OUV of the Great Barrier Reef. In turn, the condition of those values determines the quality and security of the cultural, social and economic benefits the community derives from the values (such as income, understanding and enjoyment). As a result of both external drivers and activities within the Region and beyond its boundaries, a range of impacts are diminishing the condition of the Region's values and therefore affecting the quality of the benefits derived. This chain of cause and effect is illustrated in Figure 3.2.

Understanding these causal relationships helps forecast likely changes in the benefits derived from the Region and therefore potential changes in human wellbeing. Communities and activities with a strong dependence on ecosystem services (hereafter referred to as 'Reef-dependent activities' or 'Reef-dependent communities') have high exposure to impacts arising from changes in the condition of the Region's values.

A driver can indirectly affect the environment by changing the way people interact with the environment (indirect drivers), or directly affect the environment by changing conditions in the environment itself (direct drivers). Drivers can also work in concert with one another. Drivers most relevant to the Great Barrier Reef Region were identified by examining those used in the national *State of the Environment Report 2011* and relevant peer-reviewed literature, and through input from key Great Barrier Reef natural and social scientists. The five drivers are:

- climate change
- economic growth
- population growth
- technological developments
- societal attitudes.

Climate change is a direct driver that has direct and ongoing effects on the environment as well as indirect effects mediated by other processes or activities. The other four drivers are indirect drivers, influencing peoples' activities that in turn affect the environment. The GBRWHA strategic assessment is based on the DPSIR framework for interactions between ecological and human systems.

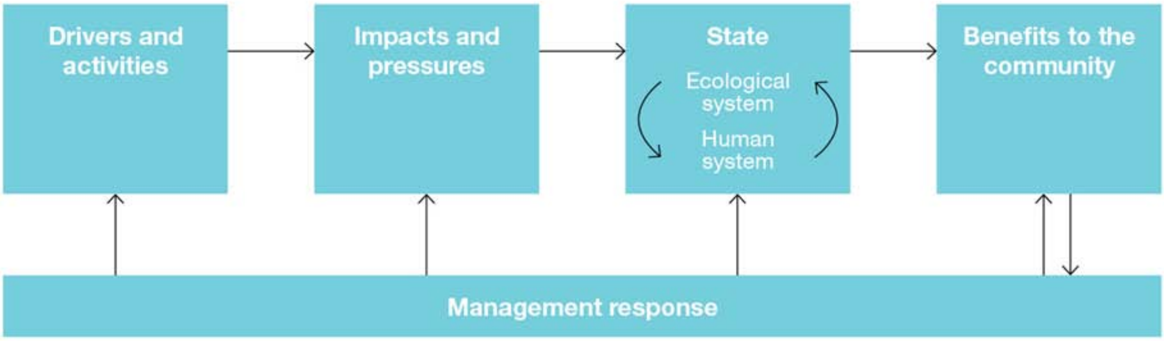


Figure 3.2 Modified DPSIR framework used by the GBRMPA in the Great Barrier Reef Region Strategic Assessment

It is important to understand causal links in the DPSIR framework because identifying these relationships is fundamental to guiding management interventions. Management responses, or actions—in this instance the GBRMPA's management program— can target (Figure 3.3):

- drivers or activities
- pressures or impacts
- the state or condition of the environment (including both ecological and human systems)
- benefits to the community.

Management responses which target drivers and activities are the most effective as they act on the source of impacts and enable impacts to be **avoided**. Management actions which target pressures or impacts are focused on reducing or **mitigating** the magnitude of the impact and are fundamental to allowing use to occur within ecologically sustainable limits. Management actions which target the condition of the environment are least effective and often most costly. Such actions are aimed at improving or **restoring** the state or the condition of the environment itself once the impact has occurred. These actions are necessary to address legacy impacts where values are currently in poor or declining condition. Lastly, interventions which target community benefits are focused on promoting understanding and awareness of the benefits derived from the Region (e.g. enjoyment, income) or ascribed to the World Heritage Area (e.g. OUV). An understanding of these benefits is necessary to justify and support management actions at all other levels and promote **adaptive management**.

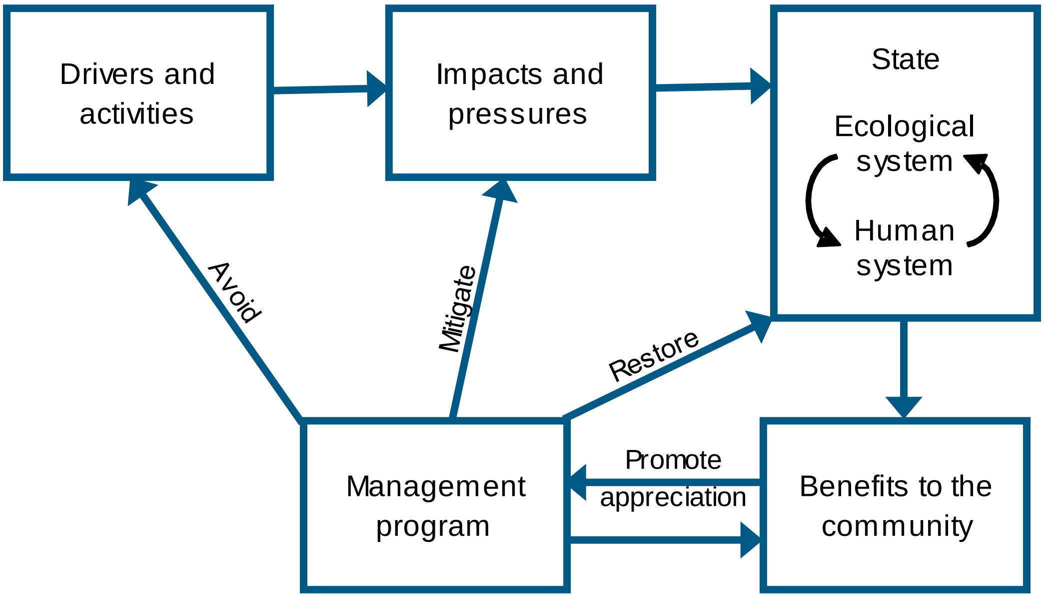


Figure 3.3 Modified DPSIR framework showing pathways of management intervention

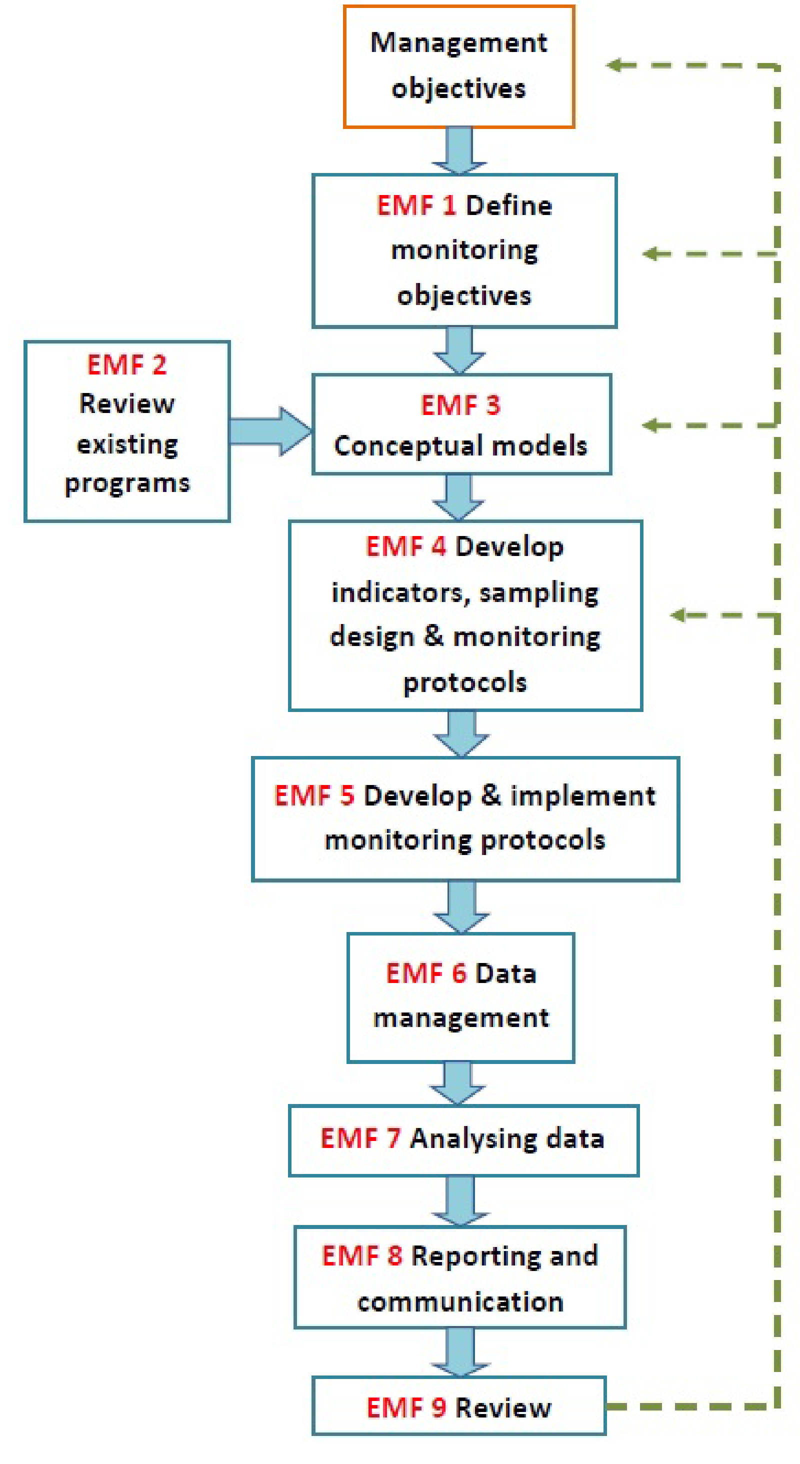
The causal and reactive nature of this DPSIR framework requires the pursuit of three overlapping but distinct goals of understanding, predicting and modifying nature and society. Implied within this framework is a correlation between values of the cause-effect chain, such that indicators of pressures and attributes of ecological and human (cultural, social and economic) systems should occur in a manner that is predictable and relevant to management interventions or responses.

While the DPSIR framework requires a fundamental understanding of the relationships between each of the values in the cause-and-effect chain, it does not provide specific guidance to managers about how to select, interpret, or act upon system indicators to be monitored. Methods to do this that have been used by the GBRMPA in the past include structured lists (Great Barrier Reef Marine Park Authority, 2009a), value-impact matrices (Great Barrier Reef Marine Park Authority, 2009b), conceptual diagrams, influence diagrams (Great Barrier Reef Marine Park Authority, 2009a) and quantitative models (Chaloupka, 2003).

3.2 The Integrated Monitoring Framework

The IMF for the Great Barrier Reef World Heritage Area links monitoring objectives for the property with GBRMPA's management objectives and assesses how current monitoring programs are meeting these needs, including outlining gaps and opportunities (using the prerequisites and essential steps in Table 3.1). A review of existing monitoring programs has identified that most key management needs are currently being addressed by some form of monitoring, but in many cases monitoring is too limited, either spatially or temporally, to adequately meet information needs. Additionally, there is a lack of indicators which address both biophysical and socio-economic values and a need for improved data standardisation, discoverability and accessibility. For easier navigation through Part 3, a diagram of the essential steps from Part 2 indicating how the steps fit together is included in Table 3.1 and used throughout Part 3 of the report.

Table 3.1 Prerequisites and essential steps of the integrated monitoring framework and how the steps fit together for the GBRWHA

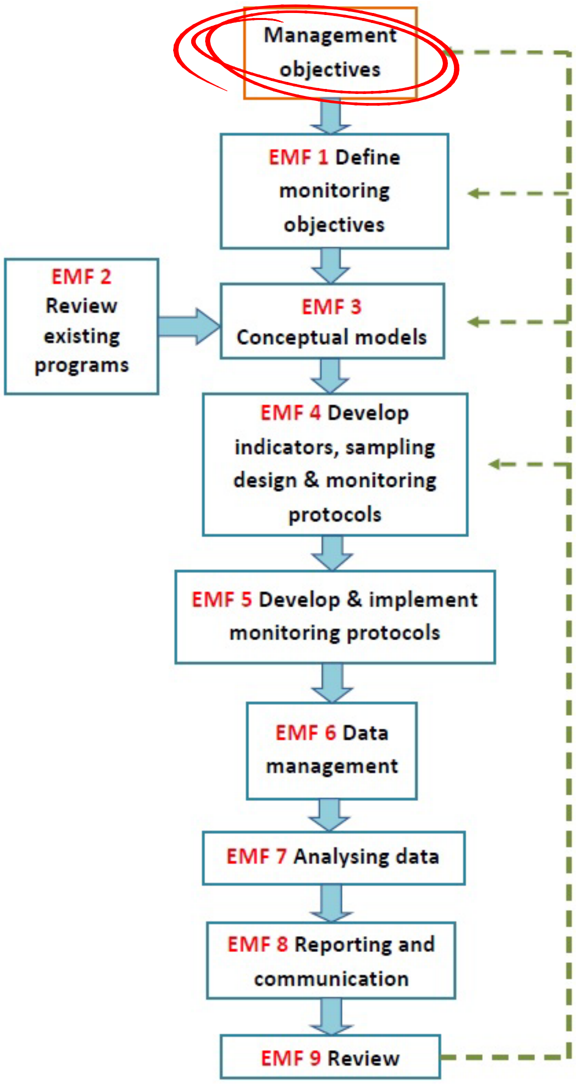
Prerequisites for an Integrated Monitoring Framework	How the steps fit together for the GBRWHA
Management objectives (see Section 3.2.1)	
Governance requirements (see Section 3.2.2)	
Principles of Integrated monitoring (see Section 3.2.2.4)	
Essential monitoring functions	
1. Clearly defining the purpose of the monitoring program and the monitoring objectives	
2. Compiling and analysing relevant information on existing monitoring programs	
3. Developing (and refining) conceptual models	
4. Developing (and refining) overall design for integrated monitoring 4a) Selecting and prioritising indicators 4b) Selecting monitoring programs for integrated monitoring 4c) Developing (and refining) sampling design for integrated monitoring	
5. Developing and refining monitoring protocols	
6. Managing data	
7. Analysing data	
8. Reporting and communication	
9. Reviewing and auditing	

Prerequisites for an Integrated Monitoring Framework

3.2.1 Management objectives for the GBRWHA

Guidance from Part 2:

- Test management objectives to determine if they provide direction at the operational level (i.e. are they realistic, specific and measurable). If they meet the test, organise objectives into a management objectives hierarchy.
- If management objectives do not provide the detail required to provide operational goals this should be noted and management informed with a view to developing more operational objectives.
- Circulate management objectives hierarchy to appropriate governance committees.



3.2.1.1 Methods

The Great Barrier Reef Region Strategic Assessment has identified management outcomes and objectives that address all threats and values of the World Heritage Area, not just those within the GBRMPA's legislative jurisdiction. The IMF has been developed in parallel with the strategic assessment, so the project team has used an evolving set of draft outcomes and objectives as they have become available to guide prioritisation and monitoring objectives for the IMF.

3.2.1.2 Management approach

The Great Barrier Reef Region is a multiple-use area where biodiversity and heritage values are protected as well as the social and economic aspects of the environment while at the same time allowing for a wide range of commercial and recreational activities.

Managing the Region is complex and requires balancing human use with the responsibility to maintain the area's natural and cultural integrity. It is a challenging task because of the size and diversity of the Reef ecosystem, its economic importance, World Heritage status, local, state, national and international interests and jurisdictional, biophysical and social complexities (Day 2011).

The Australian and Queensland Governments work in a close long-term partnership to protect and manage the Region. This cooperative approach was initially formalised by the Emerald Agreement in

1979 and reaffirmed in the Great Barrier Reef Intergovernmental Agreement in July 2009. The Great Barrier Reef Ministerial Forum, consisting of two ministers from each of the Australian and Queensland Governments, facilitates and oversees implementation and achievement of the objectives of the Intergovernmental Agreement.

The Field Management Program undertakes operations and routine day-to-day activities in the Great Barrier Reef Marine Park World Heritage Area. It is a jointly funded, cooperative partnership between the GBRMPA and the Queensland Government.

Many other Queensland and Australian Government agencies have responsibilities within the Region, for example in relation to fisheries, tourism, science, natural resource management and shipping. The fundamental management partnership between the Australian and Queensland Governments to protect the Great Barrier Reef is complemented by partnerships with these other government agencies.

The GBRMPA works in partnership with Traditional Owners on a range of sea country programs to conserve biodiversity and promote sustainable use. Management is also enhanced through partnerships and stewardship arrangements with Great Barrier Reef stakeholders, such as industry associations, scientists, local government and community groups.

Through a network of Reef Advisory Committees, Local Marine Advisory Committees and TUMRAs, the GBRMPA receives technical and community information and advice on a range of issues associated with reef health, use and management.

A comprehensive suite of ecosystem-based management arrangements is aimed at minimising impacts and achieving positive environmental outcomes. Informed by the best available science, the GBRMPA works to balance long-term protection with the needs of the various groups that rely on a healthy Marine Park for their economic, cultural and social wellbeing.

The GBRMPA employs a number of tools to protect and manage the Marine Park, including zoning plans, plans of management, permits, policies and strategies, formal agreements and site management. These are implemented through education, planning, environmental impact assessment, monitoring, stewardship and enforcement.

Within the Marine Park, a number of activities are strictly prohibited (such as mining, oil drilling and spear-fishing on SCUBA) and all other activities (such as fishing, tourism and shipping operations) are carefully managed.

The GBRMPA does not have direct management responsibilities for areas or activities outside the Marine Park, including the port exclusions along the coast. However, it recognises the interconnectedness of the terrestrial and marine natural systems and the significant effects that land-based activities can have on the Great Barrier Reef ecosystem. Consequently, the GBRMPA actively works with those government departments, industries and communities whose actions have the potential to affect the ecosystem.

3.2.1.3 Management objectives

Overarching management objectives for the Great Barrier Reef Marine Park and World Heritage Area are defined in legislation, the Intergovernmental Agreement and the 25-year Strategic Plan. More specific objectives have evolved as issues have been addressed under adaptive management principles and are articulated in the relevant strategies, plans and guidelines listed below:

- Intergovernmental Agreement 2009 (Commonwealth of Australia and State of Queensland, 2009)
- *Great Barrier Reef Marine Park Act 1975* (GBRMP Act)
- Great Barrier Reef World Heritage Listing 1981 (Great Barrier Reef Marine Park Authority 1981)
- 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area 1994–2019 (Great Barrier Reef Marine Park Authority 1994)
- *Environment Protection and Biodiversity Conservation Act 1999*
- threatened species recovery plans (Department of the Environment, various dates)
- Great Barrier Reef Zoning Plan 2003 (Great Barrier Reef Marine Park Authority 2004)
- 2006 Review of the *Great Barrier Reef Marine Park Act 1975*
- Climate Change Action Plan 2009–2012
- Reef Water Quality Protection Plan 2009 (Department of Premier and Cabinet 2009)
- GBRMPA Biodiversity Conservation Strategy 2013 (Great Barrier Reef Marine Park Authority 2013a)
- informing the *Outlook for Great Barrier Reef Coastal Ecosystems 2012* (Great Barrier Reef Marine Park Authority 2012a)

The Intergovernmental Agreement's objective is to ensure an integrated and collaborative approach by the Commonwealth and Queensland to the management of marine and land environments within and adjacent to the GBRWHA so as to:

- provide for the long-term protection and conservation of the environment and biodiversity of the Great Barrier Reef ecosystem, as encompassed by the GBRWHA, and its transmission in good condition to future generations
- allow ecologically sustainable use of the Great Barrier Reef ecosystem subject to the overarching objective of long-term protection and conservation
- provide for meeting Australia's international responsibilities for the GBRWHA under the World Heritage Convention.

To achieve these objectives, the agreement includes each government's ongoing commitment to:

- prohibit activities for the exploration and recovery of minerals or petroleum, and any drilling and mining within the World Heritage Area, including for the purposes of depositing materials
- maintain complementarity of relevant Australian Government and Queensland management arrangements, in particular: marine park legislation and associated regulations; zoning plans and plans of management; planning and development arrangements; environmental assessment and permit requirements; management of fishing activities

- continue an Australian Government–Queensland Ministerial Council to facilitate implementation and achievement of the objectives of the agreement
- continue a joint program of field management, with shared funding on a 50:50 basis, for the Great Barrier Reef Marine Park and Queensland marine and national parks within the World Heritage Area
- continue joint action to halt and reverse the decline in quality of water entering the Reef
- continue joint action to maximise the resilience of the Reef to climate change
- address significant threats to the health and biodiversity of the Reef ecosystem, including pollution from the land and sea, the impacts of climate change, ecologically unsustainable fishing activities and other resource extraction activities
- periodically review the condition of the Reef ecosystem and any need for further action
- ensure that Indigenous traditional cultural practices continue to be recognised in the conservation and management of the Reef.

As part of the Great Barrier Reef Region Strategic Assessment (marine component), the GBRMPA has assessed the projected condition of the Region's values based on the assessments of condition, impacts, resilience, risk and management effectiveness. This process has defined the overarching architecture of values and impacts for the GBRWHA.

Considering the Acts, strategies, plans and agreements listed above, the strategic assessment process has defined desired outcomes for these values and the objectives and targets required to achieve them, focusing on the pressures that are responsible for the greatest predicted risks. At the time of writing this report, these outcomes, objectives and targets were draft and may be refined during completion of the strategic assessment. The draft outcomes, objectives and targets have been assembled into an objectives hierarchy and aligned with draft monitoring objectives as set out in the tables in Appendix 3 and described further in Section 3.2.3.

Recognising that much of what is affecting the condition of the MNES occurs outside the GBRMPA's jurisdiction, a key part of management is working in partnership and encouraging stewardship. To this end, the draft management outcomes and objectives in the strategic assessment address all drivers, threats and values of the World Heritage Area, not just those within the GBRMPA's legislative jurisdiction.

The strategic assessment also assigns targets to the draft outcomes and objectives. This provides a framework for the next 20 years, using an outcomes-based approach to management focused on working with all parties collectively to achieve the outcomes needed to ensure long-term sustainability of the GBRWHA.

The IMF will be used to design an IMP that will facilitate adaptive management and inform future management effectiveness assessments. The monitoring objectives of the proposed IMP will be directly aligned with outcomes, objectives and targets (see Section 3.2.3) to inform management arrangements, as well as, local, state and Australian Government programs and international programs which have a bearing on the health of the World Heritage Area and ramifications for the effectiveness of management arrangements.

3.2.3.4 Other approaches for setting management objectives: Limits of Acceptable Change

During the IMF process, support for 'limits of acceptable change' (LAC) approach was evident. Underlying the LAC concept is that social, cultural and ecological change is a consequence of human use. Applying the LAC approach can help to detect 'unacceptable' change, highlight gaps in understanding and provide direction for future research and monitoring (Oliver 1995). Acceptance of this premise prompts the question "*How much **change** is acceptable*?" rather than a more traditional question of "*How much **use** is acceptable?"* (Stankey et al. 1984). To answer these sorts of questions requires critical reflection and understanding about the past, present and desired future condition of a natural resource.

LAC may establish relationships between drivers of change, pressures, Reef values, processes, ecosystem services and community benefits (Department of the Environment, Water, Heritage and the Arts 2008). While the DPSIR framework requires a fundamental understanding of the relationships between each of the elements in the cause-and-effect chain, it does not provide specific guidance to managers about how to select, interpret, or act upon system indicators. LAC is one approach that can provide the direction needed for effective management.

Figure 3.4 shows how LAC can influence both drivers of change and pressures acting on Reef values. LAC boundaries would be established in partnership with experts, stakeholders, and community members from diverse backgrounds. This collaboration can create opportunities and motivation for the broader community to be actively involved in custodianship and stewardship activities such as restoration of degraded ecosystems, best practice industry standards, and activities that offset impacts from development.

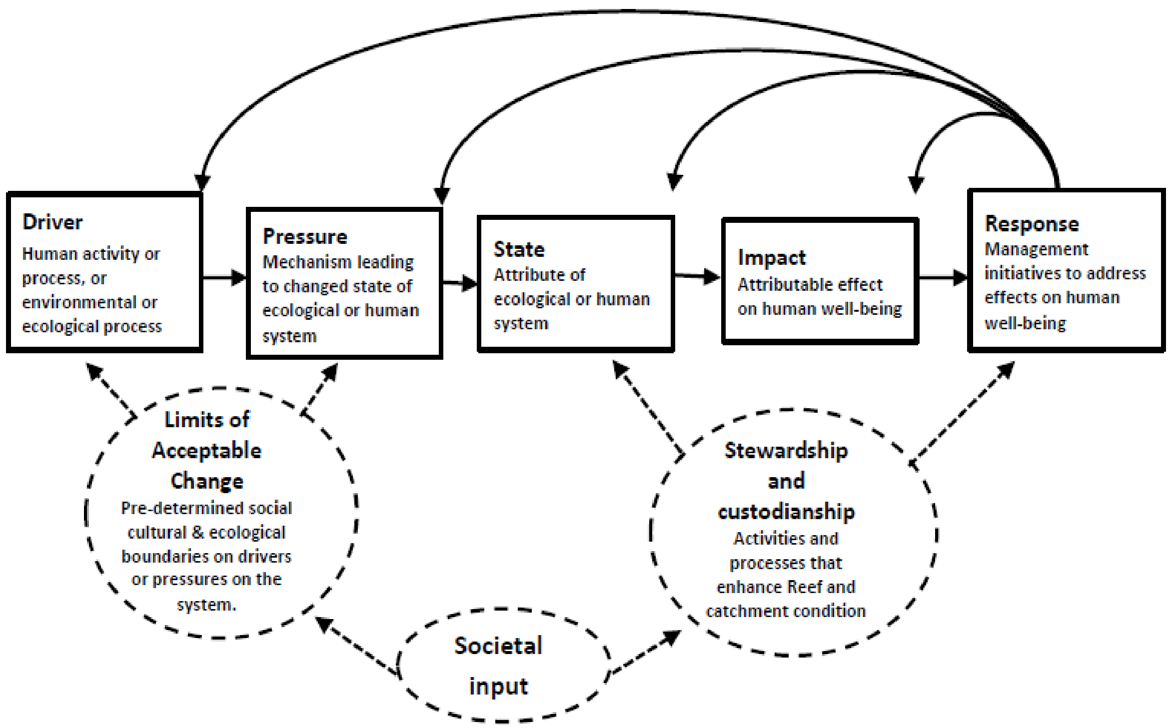


Figure 3.4 How LAC can influence drivers of change and pressures acting on Reef values

If the LAC process were to be applied, the GBRMPA and the Queensland Government could draw upon their extensive stakeholder network comprised of the Reef Guardian Program, Local Marine Advisory Committees (LMACs), Reef Advisory Committees (RACs), and TUMRAs.

Challenges in using the LAC approach include decisions about which indices of change are most appropriate to use and in which context, and to what extent judgements about Reef condition vary according to the perceptions, expertise and memories of the participants in the process.

3.2.1.4 Summary - how the guidance was used

- High-level management objectives for the GBRWHA are articulated in legislation, management and operating plans and strategies.
- More operational management objectives are being developed through the strategic assessment process. These objectives will remain as draft objectives until the strategic assessment report has been approved by the Marine Park Authority, been through public consultation and other prescribed steps and finally approved by the minister.
- Management objectives (Appendix 3) are specific and measurable, but the degree to which this is the case and whether they are realistic will be informed through review and consultation of the strategic assessment reports.

3.2.2 Governance and principles for integrated monitoring

Guidance from Part 2:

Instigate a collaborative process with experts to generate the following outputs:

- a list of key participants in governance
- options for establishing governance arrangements
- preferred governance model for the integrated monitoring, including broad terms of reference for governance, committee structure (e.g. oversight, coordination, provision of expert advice) and key participants (e.g. government, industry, science and community)
- principles for integrated monitoring to guide decision-making about the integrated monitoring.

3.2.2.1 Methods

An initial workshop held in August 2012 included sessions on the philosophy of monitoring and the essential functions of a monitoring framework. Participants contributed to the development of the essential functions underpinning the IMF as described in Part 2 of this report and identified broad objectives for monitoring and areas for improvement in existing monitoring programs.

A second workshop in November 2012 built on the outcomes of the August workshop and participants formulated principles underpinning an IMF in the context of the GBRWHA. These principles were refined by the project team for the purposes of the guidance in Part 2 and are also directly relevant to the GBRHWA IMF (Section 3.2.2.4).

Both workshops included discussion from participants regarding potential governance models. There is currently no overarching governance of monitoring activities in the GBRWHA and each program operates under its own governance structure. The Reef Water Quality and Protection Plan was highlighted as the program which had a supporting governance structure that was most relevant to integrated monitoring, in that it incorporates multiple jurisdictions and has a degree of integration across the monitoring, modelling and reporting framework. Therefore, the project team investigated options to propose a governance structure under the Great Barrier Reef Ministerial Forum that would build on the Reef Plan governance structure where appropriate and minimise the need to create additional entities.

Both the August and November workshops included participants from Queensland and Australian Government management agencies, research and monitoring providers, port and tourism industries, and the collaborating project team (NERP Marine Biodiversity Hub, GBRMPA, AIMS).

3.2.2.2 Proposed governance arrangements

We propose that management of an IMP be included in the current intergovernmental and partnership management arrangements for the Great Barrier Reef, based around the Great Barrier Reef Intergovernmental Agreement and the Great Barrier Reef Ministerial Forum (Figure 3.5). The heads of agencies involved in the IMP would oversee its implementation at a strategic level and report to the Ministerial Forum. An intergovernmental steering committee comprising nominated senior officers from Australian and Queensland Government agencies would be the key decision-making body on operational matters.

Independent science advice and review relating to the program's implementation and outputs would be provided by an independent science panel. A technical advisory group would provide quality control, and strategic direction and guidance to ensure integrated implementation of program.

It is proposed that overall coordination and management of the program would be the responsibility of the Great Barrier Reef Marine Park Authority. The GBRMPA's RACs and LMACs are appropriate forums to obtain cross-sectoral advice from stakeholders and Traditional Owners.

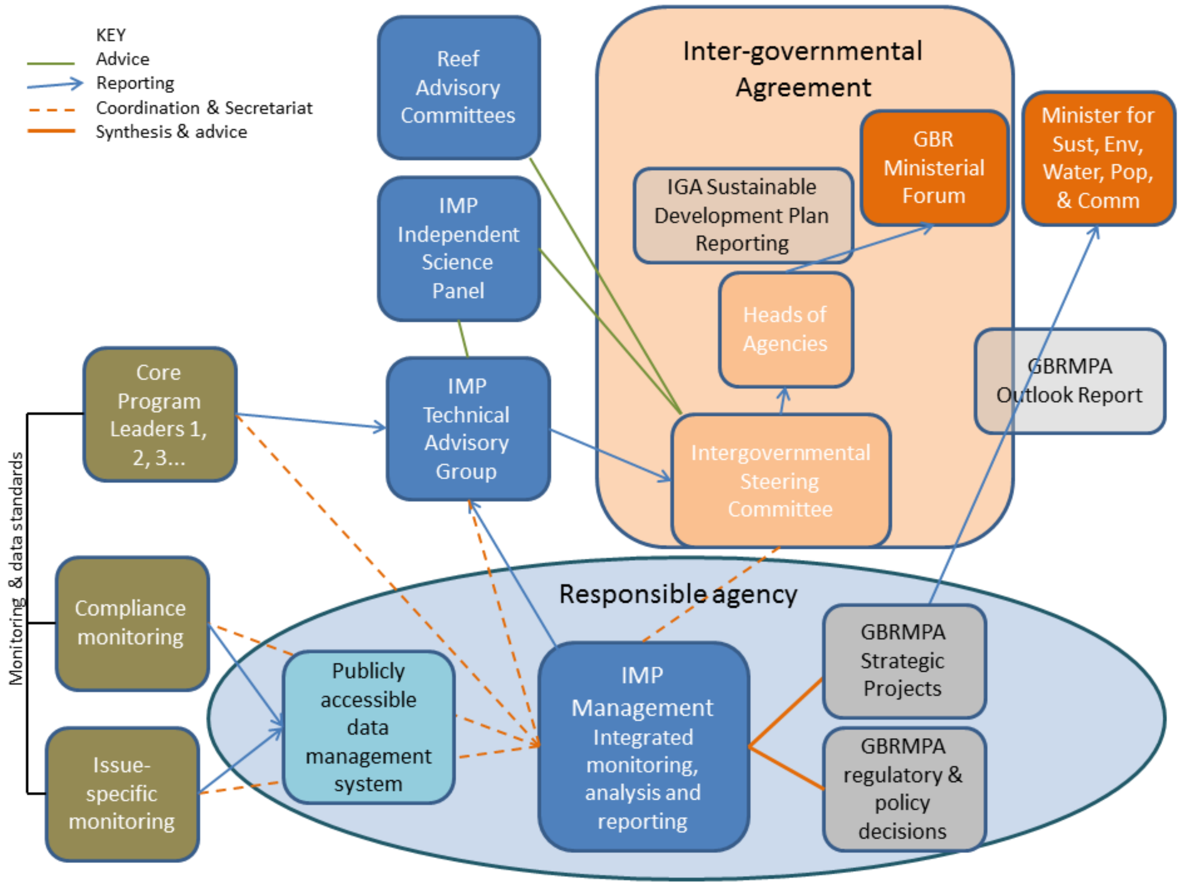


Figure 3.5 A proposed governance framework for core long-term integrated monitoring in the GBRWHA

3.2.2.3 Summary – how the guidance was used

- Governance options and approaches were explored in the first IMF workshop.
- In the GBR there are already established and effective consultative and advisory structures and processes in place, and the process used to derive the governance structure for the Reef Plan provides a useful model for governance arrangements. These existing structures were brought together as the proposed structure for the IMF.

3.2.2.4 Proposed principles for integrated monitoring

Principles are a useful tool to guide the many discussions and decisions that need to be made to establish an IMP. The following proposed principles are based on those presented in Part 2 Box 1 of this report[1]:

a) Adaptive management of matters of national environmental significance is the primary outcome of integrated monitoring.

b) Collaboration between policymakers, park managers, scientists and data managers is essential.

c) A common language and logic is necessary to facilitate collaboration.

d) Explicit links between monitoring, management and scientific understanding are required.

e) Integrated monitoring needs an effective governance structure that is supported by institutions, does not depend on individuals, and provides ongoing access to essential data streams.

f) Prioritisation of objectives, indicators, programs, etc. is essential and needs to be completed in a transparent manner that can be reviewed and updated.

g) It is better to monitor fewer high priorities well than to monitor many interests poorly.

h) Priorities and decisions need to be well documented and readily accessible, including the data supporting those decisions.

i) Integrated monitoring needs to build on existing infrastructure and processes, recognising that not all existing values will become part of the integrated monitoring program.

j) The integrated monitoring program needs to have a lifespan at least as long as the pressures that it is designed to monitor.

k) The integrated monitoring program needs to be supported by research so that it can adapt to changing pressures, environmental conditions and knowledge.

l) The integrated monitoring program needs to be reviewed on a regular basis.

3.2.3 Essential Monitoring Function 1: Clearly defining the purpose of the monitoring program and the monitoring objectives

Guidance from Part 2:

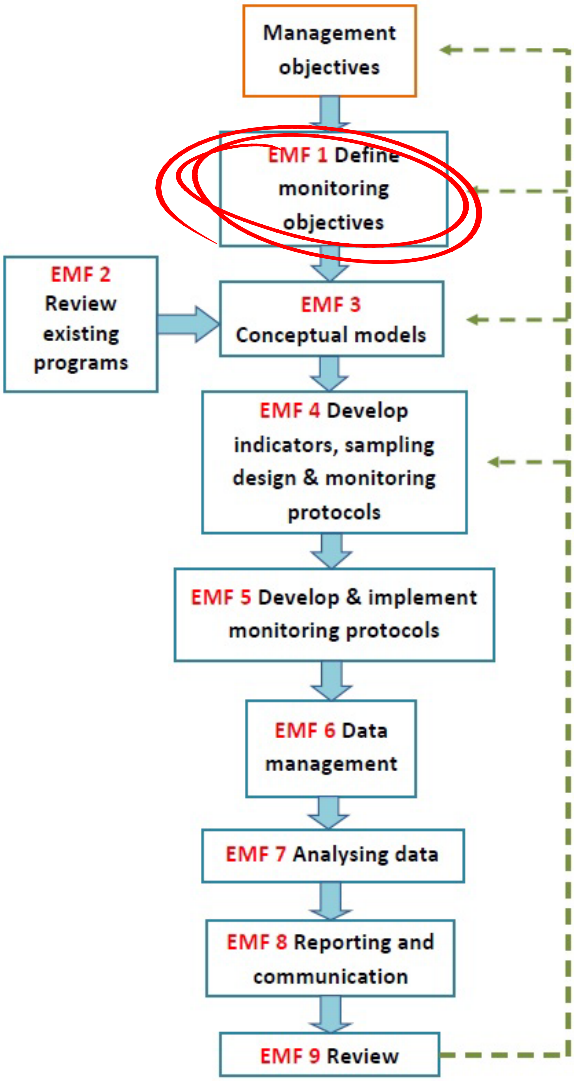
Instigate a collaborative process with experts to generate the following outputs:

- An articulation of the purpose of integrated monitoring
- A list of monitoring objectives identifying relative priorities
- A hierarchy of monitoring objectives and management objectives that identifies the explicit links between each management objective and the monitoring objectives supporting it.

[1] Generated through a workshop held in September 2012 comprising representatives from Australian and Queensland Governments, scientific community and industry.

3.2.3.1 Purpose of the monitoring program

Methods



In the context of the GBRMP Act, the EPBC Act and the strategic assessment process, the project team consulted with relevant management personnel to identify the purpose of the integrated monitoring program. The purpose should be considered along with the Principles of Integrated Monitoring (Section 2.3) during the application of the IMF for the GBRWHA.

Proposed purpose of the integrated monitoring program

The IMF will guide development of an overarching integrated monitoring program that will:

- monitor, evaluate and report on the condition and trends of relevant MNES, including the OUV of the GBRWHA
- monitor, evaluate and report on the impacts of drivers and pressures affecting MNES
- monitor, evaluate and report on local, national and international community benefits derived from the GBRWHA
- monitor, evaluate and report on the impacts of pressures and the effectiveness of management policies, plans and programs to adequately protect MNES
- integrate monitoring, synthesis and reporting with management policies, plans and programs
- improve spatial and temporal compatibility of monitoring data across long-term, short-term and reactive monitoring activities
- improve discoverability and accessibility of government-funded monitoring data for management agencies and the general public
- integrate monitoring, evaluation and reporting across biophysical, social and economic values, pressures and impacts to better understand and address the threats facing the relevant MNES
- provide integrated analyses of data streams that provide the information needed to better assess cumulative impacts
- provide adequate early warning of emerging pressures and threats in order to enable a timely management response.

3.2.3.2 Prioritisation of monitoring needs for management

Methods

Prioritisation of important environmental, economic, cultural and heritage values in the GBRWHA has been an ongoing process. Existing work such as analysis conducted for the *Outlook Report 2009* and other work commissioned since completion of the *Outlook Report* (outlined below) has been used as the basis for prioritising the needs of managers for monitoring information. The first step in the prioritisation process was to assess monitoring needs in light of the draft management objectives hierarchy developed through the strategic assessment process. Given the large spatial extent, historical, cultural and social values, and the wide range of complex ecosystems within the GBRWHA, the project team determined which elements, processes and pressures are the highest priorities for monitoring information.

Specific sets of risk-based criteria were applied to assess the monitoring priority of biophysical values, ecosystem processes and pressures. This was done in an internal GBRMPA workshop and further refined by the project team in consultation with management personnel, particularly the strategic assessment team.

Monitoring of major drivers of change and community benefits derived from Reef values is currently under consideration through a project funded by the NERP Tropical Ecosystems Hub: the Social and Economic Long Term Monitoring Program (SELTMP). Prioritisation to date has been based on work undertaken for the strategic assessment, expert opinion, and management and legislative requirements.

Prioritisation of monitoring needs will need to continue beyond this project in developing an IMP.

Existing work on identifying priority values

Identification of important biophysical, social, economic, cultural and heritage values of the GBRWHA as well as the activities and pressures that act on them, has been an ongoing process since the declaration of the Marine Park in 1975. The most recent synthesis of information about important values, activities and pressures, highlighting where management has most concern, was the *Outlook Report* in 2009 and the statement of scientific information needs that followed it. Further work commissioned since the 2009 *Outlook Report* to address issues highlighted in the report has further refined thinking on priorities. The prioritisation process described here, as part of the IMF, largely draws on this information.

Since publication of the 2009 *Outlook Report* and subsequent science information needs document significant work has generated and synthesised information to address issues of concern highlighted in those documents. This work included assessing inshore biodiversity and coastal ecosystems as well as remaining impacts of fishing through a series of vulnerability assessments for species, groups of species and habitats (work still ongoing). In addition, the strategic assessment process itself includes synthesis of scientific and other management relevant information. The development of the IMF included an update of GBRMPA's science information needs to incorporate further information sources as the basis for identifying management's research and monitoring needs, including:

- *Biodiversity Conservation Strategy 2013* and associated vulnerability assessments (Great Barrier Reef Marine Park Authority 2013a)

- Informing the outlook for Great Barrier Reef coastal ecosystems (Great Barrier Reef Marine Park Authority 2012a)
- Climate Change and the Great Barrier Reef: A Vulnerability Assessment (Johnson and Marshall 2007)
- *Great Barrier Reef Outlook Report 2009* (Great Barrier Reef Marine Park Authority 2009a)
- GBRMPA recreation management strategy (Great Barrier Reef Marine Park Authority 2012b)
- Ecological Risk Assessment of the East coast otter trawl fishery in the Great Barrier Reef Marine Park (Pears et al. 2012)
- Abbot Point Cumulative Impact Assessment (Toki et al. 2012)
- Role, importance and vulnerability of top predators on the Great Barrier Reef (Ceccarelli and Ayling 2010).

From these sources interactions between pressures and values were identified. Each interaction was assigned a high, medium or low score of 'concern to management' based on the following grading statement: management has a high/medium/low level of concern for the interaction due to its current and potential impact on values underpinning MNES. Scores reflect residual impact of interactions (i.e. the effect of current management interventions were taken into account when determining the level of concern to management). The majority of scores were derived from the many vulnerability assessments that underpin the *Biodiversity Conservation Strategy 2013*. The vulnerability assessments were undertaken using a risk-based approach. For further information on methods for these assessments see www.gbrmpa.gov.au/about-the-reef/biodiversity/draft-biodiversity-conservation-strategy.

Due to the numerous many-to-many relationships between pressures and values, a database was built to capture the relationships (database schema – Appendix 4). The database also captures all of relationships between MNES and their underpinning values as well as relationships between pressures and drivers/activities. Further, the database also links current monitoring and management objective information to values and pressures.

Prioritisation criteria for monitoring needs

Criteria for prioritising values, pressures and processes for inclusion in the IMP are listed below. Further prioritisation will be undertaken during design of the IMP taking into consideration the level of understanding of cause-and-effect relationships of driver, activity/pressure, threat and impact on values, as well as sensitivity and information content, to distinguish impacts from multiple pressures (Figure 3.2). This is done through IMF essential functions three and four (Table 3.1). Other practicalities such as cost and feasibility for specific indicators also need to be considered during the IMP design stage (essential function 4).

Criteria for identifying high priority **biophysical values**. Agreement with the statements below results in a score of ‘high’. Values need to be ranked as ‘high’ against five or more statements to be considered a high priority:

1. The value is classified as 'at risk' through the *Biodiversity Conservation Strategy 2013* vulnerability assessments.
2. The value is subject to a high or moderate level of single or cumulative pressures as indicated by vulnerability assessments conducted through the biodiversity strategy and outlook for coastal ecosystems processes as well as the Strategic Assessment, *Outlook Report* and other sources.
3. The value is the subject of specific management actions/strategies. This includes listed threatened and listed migratory species.
4. The value is a Key Ecological Feature[2].
5. Reef stakeholders, visitors and users derive important benefits from the value.
6. The value has recognised iconic status and associated reporting obligations—e.g. World Heritage, Outlook, EPBC Act, Nature Conservation Act.
7. The value is the subject of existing monitoring that is of use to management.

Criteria for identifying high priority **ecosystem processes.** To be considered a high priority an ecosystem process must meet statement one *and* agree with at least three of the other statements:

1. Understanding of the ecosystem process is not sufficiently informed by monitoring priority biophysical values and pressures.
2. The ecosystem process is critical to the functioning of values underpinning MNES.
3. The ecosystem process is critical to the recovery of values assessed to be in poor or very poor condition or declining trend.
4. The ecosystem process is affected by a high or moderate level of individual or cumulative impacts.
5. The ecosystem process is the subject of management actions or strategies and reporting obligations.

Criteria for identifying high priority **pressures.** Agreement with the statements below results in a score of ‘high’. Pressures need to be ranked as ‘high’ against at least three statements to be considered a high priority:

1. The pressure has received a score of high or very high concern through the strategic assessment risk assessment because of impacting multiple values (chronic or acute).
2. The pressure impacts over a broad spatial scale (chronic or acute).
3. The pressure is the subject of specific management actions/strategies.
4. The pressure is the subject of existing monitoring that is of value to management.

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[2] *Key Ecological Features are identified in Marine Bioregional Plans. To be a Key Ecological Feature, a biophysical value must be one or more of:*

- *A species, group of species or a community with a regionally important ecological role (e.g., a predator or prey that affects a large biomass or number of other marine species)*
- *A species, group of species or a community that is nationally or regionally important for biodiversity*
- *An area or habitat that is nationally or regionally important because of high productivity, aggregations of marine life (such as feeding, resting, breeding or nursery areas) or high biodiversity and endemism*
- *A unique sea floor feature with known or presumed ecological properties of regional significance.*

Tables 3.2–3.4 provide an interim list of the scores for biophysical values, ecosystem processes, and pressures that emerged as high priority as a result of applying the above criteria to the identified **biophysical** values, processes and pressures as listed in the strategic assessment 2013. Full details of the prioritisation for all biophysical values, ecosystem processes and pressures are in Appendices 5–7.

Table 3.2 High priority biophysical values

	Prioritisation Criteria						
	1	2	3	4	5	6	7
Priority biophysical values	**'At-risk' Biodiversity Conservation Strategy**	**High or moderate single or cumulative pressure**	**The subject of management actions/strategies**	**A Key Ecological Feature**	**Reef stakeholders, visitors and users derive important benefits**	**Iconic status and reporting obligations**	**The subject of existing monitoring of value to management**
Coral reefs and corals	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Seagrass meadows and seagrasses	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Open waters	HIGH	HIGH	LOW	HIGH	HIGH	LOW	HIGH
Islands	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	LOW
Beaches and coastline	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Mangrove diversity	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Marine turtles	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Seabirds	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Shorebirds	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Dugongs	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Dolphins	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	LOW
Bony fish	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Sharks and rays, including sawfish	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Other invertebrates	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Sea snakes	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	LOW

Further refinement is required to identify the particular species, attributes or variables to be monitored as part of the IMP. For example, the listed values underpinning MNES are not at equivalent taxonomic or ecological levels. While 'dugongs' represents one species, 'bony fish' represents approximately 1625 species. Priority bony fish species should include those considered 'at risk' through the *Biodiversity Conservation Strategy 2013* (e.g. threadfin salmon and grey mackerel; GBRMPA 2013a), those that are of particular interest to the fishing industry (e.g. coral trout and red throat emperor) and those that perform key ecological functions (e.g. herbivorous fish).

Table 3.3 High priority ecosystem processes

		1	2	3	4
Priority Process	**Not informed by monitoring priority biophysical values and pressures**	**Critical to the functioning of values underpinning MNES**	**Critical to the recovery of values assessed to be in poor or very poor condition or declining trend**	**Affected by a high or moderate level impact or cumulative impacts**	**Subject of management actions or strategies and reporting obligations**
Connectivity	HIGH	HIGH	HIGH	HIGH	HIGH
Recruitment	HIGH	HIGH	HIGH	HIGH	HIGH
Primary production (pelagic)	HIGH	HIGH	HIGH	HIGH	HIGH

Table 3.4 High priority pressures

	Prioritisation Criteria				
		1	2	3	4
Priority Pressures	**Trend**	**Impacting multiple values (chronic or acute), high or very high risk under strategic assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**Subject of management actions / strategies**	**Subject of existing monitoring that is of value to management**
Rising sea level	Increasing	HIGH	HIGH	HIGH	LOW
Cyclone activity	Increasing	HIGH	HIGH	LOW	HIGH
Increased sea and air temperature	Increasing	HIGH	HIGH	HIGH	HIGH
Ocean acidification	Increasing	HIGH	HIGH	LOW	HIGH
Altered ocean currents	Increasing	HIGH	HIGH	LOW	HIGH
Outbreaks of disease	Increasing	LOW	HIGH	HIGH	HIGH
Freshwater inflow	Increasing	HIGH	HIGH	HIGH	HIGH
Nutrients from catchment run-off	Decreasing	HIGH	HIGH	HIGH	HIGH
Sediments from catchment run-off	Decreasing	HIGH	HIGH	HIGH	HIGH
Dredging, dumping and resuspension of dredge material	Increasing	HIGH	HIGH	HIGH	LOW
Pesticides from catchment run-off	Decreasing	HIGH	HIGH	HIGH	HIGH
Outbreak of crown-of-thorns starfish	Increasing	HIGH	HIGH	HIGH	HIGH
Clearing or modifying coastal habitats	Increasing	HIGH	HIGH	HIGH	LOW
Coastal reclamation	Increasing	HIGH	LOW	HIGH	LOW
Artificial barriers to flow	Increasing	HIGH	HIGH	HIGH	LOW
Death of discarded species	Stable	HIGH	HIGH	HIGH	HIGH
Marine debris	Increasing	HIGH	HIGH	HIGH	LOW

	Prioritisation Criteria				
		1	2	3	4
Priority Pressures	**Trend**	**Impacting multiple values (chronic or acute), high or very high risk under strategic assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**Subject of management actions / strategies**	**Subject of existing monitoring that is of value to management**
Noise pollution	Increasing	**HIGH**	**HIGH**	**LOW**	**LOW**
Illegal fishing and poaching	Increasing	**HIGH**	**HIGH**	**HIGH**	**LOW**
Extraction of predators	Stable	**HIGH**	**HIGH**	**HIGH**	**HIGH**
Fishing spawning aggregations	Increasing	**HIGH**	**HIGH**	**HIGH**	**LOW**

3.2.3.3 Prioritising drivers and social, cultural, heritage and economic values

Identifying management objectives and effectiveness requires monitoring of the social, cultural and economic drivers and values that influence human attitudes, behaviours and interactions with the Great Barrier Reef. Monitoring of major drivers of change and community benefits derived from Reef values is currently under consideration through a project funded by the NERP Tropical Ecosystems Hub, the Social and Economic Long Term Monitoring Program. This project is working with the IMF to integrate social, cultural and economic with biophysical monitoring. Monitoring social, cultural and economic dimensions of the GBRWHA is only just starting to occur systematically, so developing priorities has been a less rigorous process than the one used in prioritising aspects of biophysical monitoring. Prioritisation to date has been based on work undertaken for the strategic assessment, expert opinion, and management and legislative requirements. Six broad dimensions of community benefits are considered high priority for monitoring:

- Appreciation, enjoyment and aesthetics (based on natural beauty)
- Economic contribution of Reef-dependent industries including income and employment
- Public understanding of the Great Barrier Reef
- Access to Reef resources
- Personal attachment to the Great Barrier Reef
- Health benefits.

Drivers of change most relevant to the Great Barrier Reef Region are climate change, economic growth, population growth, technological developments and societal attitudes (Section 3.1.5). Monitoring drivers of change will be mostly undertaken through analysis of secondary datasets.

The strategic assessment identified a number of heritage (including world, historic and Indigenous heritage) values of high priority to management, including:

- Aesthetics, natural beauty and phenomena (World Heritage criterion vii)
- Ecological and biological processes (World Heritage criterion ix)

- Habitats for conservation of biodiversity (World Heritage criterion x)
- Integrity
- Indigenous sacred sites, sites of particular significance, places important for cultural tradition
- Indigenous stories, song lines, totems and languages
- Indigenous structures, technology, tools and archaeology
- Places of historic significance—light stations
- Places of social significance—iconic sites.

3.2.3.5 Results

Table3.5 lists the full set of proposed priority values, pressures, processes and drivers for long-term core integrated monitoring. Monitoring this set of priorities will allow an understanding of the long-term condition and trend of important values of the GBR ecosystem and well as the pressures that act on those values and how management initiatives/actions are performing.

Table 3.5 Proposed priority values, pressures, processes and drivers for long-term core integrated monitoring

Values underpinning MNES	**Pressures**	**Processes**
• coral reefs and corals • seagrass meadows and seagrasses • open waters • islands • beaches and coastline • mangrove diversity • marine turtles • seabirds • shorebirds • dolphins • dugongs • bony fish • sharks and rays, including sawfish • other invertebrates • sea snakes • income, economic contribution and employment • understanding of the Great Barrier Reef • access to reef resources • appreciation, enjoyment and aesthetics (natural beauty) • personal attachment • health benefits	Climate change • increased sea and air temperature • cyclone activity • ocean acidification • rising sea level • altered ocean currents and smaller scale circulations • increased freshwater flow • outbreaks of disease Water quality and pollution • nutrients from catchment run-off • sediments from catchment run-off • pesticides from catchment run-off • crown-of-thorns starfish • outbreaks of disease • marine debris Coastal habitat degradation • dredging and spoil disposal • clearing and modifying coastal habitats • coastal reclamation • artificial barriers to flow Direct use of the Region • extraction of predators • death of discarded species • illegal fishing and poaching • crown-of-thorns starfish • noise pollution • fishing/spawning aggregations	• connectivity • recruitment • primary production—pelagic **Drivers** • climate change • economic growth • population growth • technological developments • societal attitudes

The anticipated pressures for short to medium-term, issue-specific monitoring include:

- physical damage to benthos (including ship groundings, direct dredging impacts and dumping of dredge spoil)
- oil spill – large
- chemical spill – large

- cyclone activity
- artificial barriers to water flow
- coral bleaching
- crown-of-thorns starfish
- exotic species and diseases
- clearing and modifying coastal habitats (site-specific)
- coastal reclamation (site-specific).

This monitoring could be to test the effectiveness of a specific management action, such as no-anchoring areas, crown-of-thorns starfish eradication, or special management areas; to track crown-of-thorns starfish or disease outbreaks; to monitor recovery from spills and groundings; or to monitor the effects of development activities.

Compliance monitoring is anticipated for those activities where a detailed environmental impact assessment process is undertaken, including developments such as pontoons, jetties, pipelines, dredging and marinas.

Spatial distribution of pressures

Pressures operate at different scales or zones of influence and these overlap to varying degrees both spatially and temporally. Management of these pressures should be based on an understanding of these zones of influence and where the overlaps are. Data from development-specific compliance monitoring, issue-specific monitoring and long-term monitoring should, as far as possible, be standardised to facilitate the synthesis of data across these programs to understand zones of influence of pressures from the GBR-wide through regional to local scales. For further information on the aspects of standardisation across the IMF see Section 3.2.6.

Regional- and local-scale interaction of pressures with values may be as important as GBR-wide scale interactions depending on the element being considered. For instance, for inshore dolphins, pressures at the scale of a single embayment are of high concern to management as populations of these species are small and vulnerable at this scale. The strategic assessment details distribution of impacts from pressures through mapping as part of its cumulative impacts analysis.

Appendices 5-7 list all of the biophysical values underpinning MNES and the pressures affecting them. These pressures can be considered through four broad spatial areas—northern inshore, northern offshore, southern inshore and southern offshore—as well as at the scale of the whole of the GBRWHA. Of the priority pressures listed above, many act across the whole area but others are predominantly inshore (Table 3.6). The southern inshore is clearly the most impacted area of the GBRWHA to date (Table 3.6). However, the northern inshore faces many risks related to future development scenarios. In addition, increased impacts from climate change-driven pressures will affect all regions.

Table 3.6 Distribution of priority pressures for the GBRWHA including potential pressures into the future

Pressure	Southern inshore	Southern offshore	Northern inshore	Northern offshore	Whole of GBR
Rising sea level (future risk)	X	X	X	X	X
Cyclone activity	X	X	X	X	X
Increased sea and air temperature (future risk)	X	X	X	X	X
Ocean acidification (future risk)	X	X	X	X	X
Altered ocean currents (future risk)	X	X	X	X	X
Disease outbreaks	X	X	X	X	X
Freshwater inflow	X		X		
Nutrients from catchment run-off	X				
Sediments from catchment run-off	X		X		
Dredging, dumping and resuspension of dredge material	X				
Dredging, dumping and resuspension of dredge material (increased future risk)			X		
Pesticides from catchment run-off	X				
Outbreaks of crown-of-thorns starfish	X	X		X	
Clearing or modifying coastal habitats	X				
Clearing or modifying coastal habitats (increased future risk)			X		
Coastal reclamation	X				
Coastal reclamation (increased future risk)			X		
Artificial barriers to flow	X				
Death of discarded species	X	X	X	X	X
Marine debris	X	X	X	X	X
Noise pollution	X	X			X
Noise pollution (increased future risk)			X	X	
Illegal fishing and poaching	X	X	X	X	X
Extraction of predators	X	X	X	X	X
Fishing spawning aggregations	X	X	X	X	X

Research needs to support priority monitoring needs

While addressing the monitoring priorities (Table 3.5) will help managing agencies track the most important patterns and trends, research is also required to understand the mechanisms and relationships between drivers, pressures, values and processes and thus, to help guide decision-making (see Section 3.1.5). Table 3.7 indicates where the high priority pressures are acting, or predicted to act in the future, on high priority values. The areas highlighted in red therefore show where research should be focused to understand cause-and-effect relationships between pressures and values and how to best monitor the priority values, pressures and impacts from pressures. In addition, research is required to understand the relationships between drivers and activities and pressures that are causing impacts.

Table 3.7 Direct interactions between priority values and priority pressures

Pressures	Islands	Beaches and coastline	Open waters	Seagrass meadows and seagrasses	Coral reefs (<30m) and corals	Mangrove diversity	Marine turtles	Dugongs	Dolphins	Seabirds	Shorebirds	Other invertebrates	Sea snakes	Bony fish	Sharks and rays	Primary production pelagic	Connectivity	recruitment	Income, economic contribution and	Access to resources and heritage	Appreciation, enjoyment	Personal attachment	Understanding	Health benefits
Rising sea level	■	■		■	■	■	■			■	■						■	■				■	■	■
Cyclone activity	■	■		■	■	■	■			■	■		■	■			■	■	■	■	■	■	■	■
Increased sea and air temperature	■	■	■	■	■		■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
Ocean acidification			■		■							■		■									■	■
Altered ocean currents			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■				■	■
Outbreaks of disease					■		■	■	■					■					■	■	■	■	■	■
Freshwater inflow		■	■	■	■	■						■		■			■	■	■	■	■		■	■
Nutrients from catchment run-off		■	■	■	■	■	■	■	■		■	■		■		■		■	■	■	■	■	■	■
Sediments from catchment run-off		■	■	■	■	■										■		■	■	■	■	■	■	■
Dredging, dumping and resuspension of dredge material		■	■	■	■	■	■					■		■		■			■	■	■	■	■	■
Pesticides from catchment run-off			■	■	■	■						■		■		■		■	■	■	■	■	■	■
Outbreak of crown-of-thorns starfish					■							■						■	■	■	■	■	■	■
Clearing or modifying coastal habitats	■	■		■	■	■	■			■	■	■					■	■	■	■	■	■	■	■
Coastal reclamation	■	■		■		■	■				■						■	■	■	■	■	■	■	■
Artificial barriers to flow											■	■		■	■		■	■					■	■
Death of discarded species							■	■	■			■	■	■	■					■	■	■	■	■
Marine debris		■	■				■	■	■	■	■	■	■	■	■				■	■	■	■	■	■
Noise pollution								■	■												■	■	■	■
Illegal fishing and poaching							■	■	■			■	■	■	■			■	■	■	■	■	■	■
Extraction of predators									■	■				■	■			■	■	■	■	■	■	■
Fishing spawning aggregations														■				■	■	■	■	■	■	■

Using Table 3.7 as a guide, research is needed to:

- understand how pressures interact with values and what thresholds and tipping points might be for those interactions
- develop guidelines and understand where triggers might be for management action
- understand sensitivity and exposure particularly for priority values
- inform qualitative and, where they exist, quantitative DPSIR models of cause-and-effect relationships for the GBR to understand how interactions behave, including cumulatively, and predict future scenarios

- synthesise monitoring data streams and other information to inform ecological and social risk assessments and the development of guidelines for management of pressures
- uncover new biodiversity values and hotspots
- understand the processes that operate in the GBR, particularly those listed in Table 3.3.

3.2.3.6 Monitoring objectives for prioritised values, impacts and drivers

Draft monitoring objectives were developed as part of the IMF for priority values, pressures and drivers through a combination of workshops, incorporation of existing monitoring objectives for management programs, Queensland State and Australian Government recovery plans and strategies, and objectives identified through the vulnerability assessments undertaken as part of the biodiversity conservation strategy for the Great Barrier Reef.

Draft monitoring objectives are listed in Appendix 3. The tables are organised into drivers, pressures and state and table rows indicate which management outcomes, objectives and targets towards which the monitoring objective is intended to contribute.

These objectives contain more details about the monitoring program such as the indicators they address and the protocols used. In doing so, the monitoring objectives explicitly describe the links between monitoring programs and management objectives and outcomes, the expectations placed on monitoring programs, and the data these programs need to produce.

For example, for the management objective *halt and reverse the decline in water quality*, monitoring objectives (what monitoring programs need to provide to help management achieve this objective) include to provide data that:

i. tracks trends in sediment transport from catchments to receiving waters in the GBRWHA

ii. quantifies changes in the extent of land use (clearing and agriculture) in the GBR catchment

iii. monitors trends in concentrations of pesticides in receiving waters and compliance with water quality guidelines

iv. traces the sources of pesticides entering the GBRWHA.

Tables 3.8 and 3.9 present monitoring objectives for two values, coral reefs and seagrass meadows, to illustrate how driver, pressure and state monitoring objectives listed in Appendix 3 inform management outcomes and objectives.

3.2.3.7 Summary – how the guidance was used

- There is a long history and a large body of collaborative synthesis work that identifies priority values for the GBR and associated monitoring priorities. This, as well as recent comprehensive syntheses (e.g. the *Great Barrier Reef Outlook Report 2009*) and vulnerability assessments, was used to prioritise monitoring and articulate the purpose of the IMF.
- Further prioritisation will need to occur in the transition from an IMF to an IMP.

- Some categories of values, such as social and economic values, are being prioritised through separate multi-institutional projects and initiatives such as the Social and Economic Long-term Monitoring Program.

Table 3.8 Linking monitoring objectives to management outcomes and objectives for biophysical values of coral reefs

This table links monitoring to management outcomes and objectives through monitoring objectives for biophysical values coral reefs and corals. The strategic assessment, sets outcomes and targets for values. These outcomes will be achieved through managing pressures (impacts), so objectives and targets have been articulated for these pressures. Full listings of management outcomes and objectives and their associated monitoring objectives organised in a DPSIR format appear in Appendix 3. Note that while several monitoring programs are listed against each monitoring objective, these programs may vary greatly in scope and rigour.

Coral reefs and Corals

Drivers affecting coral reefs and corals: climate change, economic growth, population growth, technological development, societal attitudes (see Appendix 3 for driver monitoring objectives)

Objectives/outcomes hierarchy:

1. GBRMPA Act 1975: the main object of this Act is to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region

2. GBRMPA Strategic Plan 2012–2016:

- **Objective 1. Address the key risks affecting the outlook for the Great Barrier Reef.**
- **Objective 2. Ensure management of the Marine Park supports ecologically sustainable use.**
- **Objective 3. Foster stewardship by engaging, educating and inspiring people through the care and management of the Marine Park.**

3. Biodiversity Conservation Strategy 2013: Build ecosystem resilience in a changing climate by reducing the threats to potentially at-risk elements of biodiversity, especially those found in inshore areas.

4. Draft desired management outcomes (from the strategic assessment) for state of coral reefs and corals including impacts	**5. Draft targets for pressures/impacts required to achieve outcomes (from the strategic assessment). The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.**	**Draft core long-term monitoring objectives**	**Monitoring programs and attributes that have been monitored**
The condition of coral reefs and corals is maintained and enhanced in Northern inshore and offshore areas and the trend in condition is maintained and improved. The condition of Southern inshore and offshore coral reefs and corals is restored to good and the decline in trend of condition is halted and reversed. **Preliminary Targets by 2019** • Trends in coral reef condition and resilience indicators are improved (including herbivory, coral diversity, resistance, disease and recruitment) • Coral mortality resulting from exposure to human activities (including overfishing, sedimentation and physical damage) is reduced • Coral mortality at sites of high ecological and tourism value is reduced, particularly predation by		• Determine trends in coral reef condition, community composition, recruitment and growth rate of inshore, mid-shelf & offshore reefs across the World Heritage Area, including at impacted sites. • Determine trends in coral reef resilience indicators across the World Heritage Area (after McClanahan et al. 2012): resistant coral species, temperature variability, nutrients, sedimentation, coral diversity, herbivore biomass, physical human impacts, coral disease, macro-algae, recruitment, fishing pressure, crustose coralline algae and crown-of-thorns starfish (COTs). • Determine extent, frequency, intensity and recovery of coral reefs to exposure from flood plumes, cyclones and pesticides. • Determine coral larval production, transport and settlement between reefs to identify source & sink reefs and connectivity. • Extent, frequency and intensity of impact effects as well as recovery from exposure of coral reefs to rising sea level flood plumes, cyclones, sediments, nutrients, pesticides, ocean acidification, COTS, clearing & modifying coastal habitat, dredging activities and increased sea and air temperature (see Impacts table for impact specific monitoring objectives).	PROGRAMS: • AIMS Long Term Monitoring Program • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • Eye on the Reef – Reef Health and Impacts surveys • Eye on the Reef weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • GBRMPA-Queensland Parks and Wildlife Service compliance monitoring ATTRIBUTES: % cover of hard & soft corals; coral size classes; larval settlement; taxonomic composition; % coral cover; COTS; counts of juvenile corals; coral disease; *Drupella*; surveys of sessile benthic organisms (~70 categories) using still images visual counts of reef fishes (7 families)

crown-of-thorns starfish • Coral cover is showing an increasing trend towards the Reef-wide and regional levels measured by the AIMS long-term monitoring program at its inception in 1985 Note: The Authority will further examine the development of targets for corals that specify ranges for condition and resilience indicators for regions and subregions			
	Reduce climate change related impacts and build health and resilience of coral reefs and corals. **Targets by 2019** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	Though the agencies responsible for managing the GBRWHA do not have within their mandate responsibility for managing global carbon emissions, it is the role of these agencies to influence global opinion on this. Identifying the impact climate change derived pressures have on GBRWHA values will add to the body of evidence as to why global action needs to be taken. • Measure trends in frequency, intensity and spatial extent of sea and air temperature variability. • Track paths, intensities, spatial extent and system speed of all tropical cyclones in or near the GBRWHA. • Determine rainfall patterns as a result of tropical cyclones and lows. • Determine trend in ocean acidification at the GBR scale. • Determine trend in rising sea level. • Determine trends in oceanic, GBR, regional and local-scale water circulations. • Determine flow rate and volume of fresh water entering the GBR from adjacent catchments. • Determine three-dimensional extent and duration of flood plumes during flood events. • Measure trends in rainfall in the catchment. • Measure trends in incidence of coral disease. • See objectives listed against other pressures for cumulative impacts.	PROGRAMS: • Queensland Integrated Marine Observing System - Great Barrier Reef Ocean Observing System • ReefTemp • AIMS-GBRMPA Sea Temperature Monitoring Program • AIMS Weather Observing System • Bureau of Meteorology ATTRIBUTES: Sea temperature – surface and at depth Air temperature Weather station and satellite data
	Halt and reverse the decline in water quality. **Targets by 2019** • Meet Reef Plan targets for catchment run-off. • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded.	Nutrients • Determine species, concentrations and distribution of nutrients that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine concentrations of chlorophyll a throughout the GBRWHA. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment. Sediments • Measure trends in sediment transport from catchments. • Measure trends in turbidity and light levels for key habitats as a result of sediments against water quality guidelines. • Determine the source and be able to distinguish between sources of sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Distinguish between new sediment entering the GBRWHA and resuspension of sediments. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment. Pesticides • Determine types, concentrations and distribution of pesticides that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of pesticides entering the GBRWHA. • Determine the fate of pesticides entering the GBRWHA.	**Nutrients** PROGRAMS: • Reef Rescue Marine Monitoring Program nutrient monitoring, Ambient water quality • Paddock to Reef Program • Ports ATTRIBUTES Particulate and dissolved nutrient species (N & P) Chlorophyll **Sediments** PROGRAMS • Reef Rescue Marine Monitoring Program ambient water quality • Reef Plan catchment loads • Ambient monitoring associated with ports. ATTRIBUTES: Suspended sediments Turbidity **Pesticides** PROGRAMS: • Reef Rescue Marine Monitoring Program pesticide monitoring, ambient water quality, inshore seagrass • Reef Plan catchment loads

		• Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment.	ATTRIBUTES Pesticide concentrations ambient and in flood waters
	Restore connectivity and improve functioning of coastal and inshore ecosystems. **Targets by 2019** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine changes to inshore fish populations & productivity associated with restoration of coastal ecosystems, such as removal of barriers to flow. • Determine trends in fish health associated with significant coastal developments, especially dredging activity. • Determine types, distribution and fate of marine debris in the GBRWHA. • Determine the source and be able to distinguish between sources of sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Determine the source and be able to distinguish between sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine three-dimensional extent and duration of flood plumes during flood events.	No monitoring
	Reduce the impact of COTS outbreaks and build health and resilience of coral reefs and corals. **Targets by 2019** • Meet Reef Plan targets for catchment run-off. The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Predict COTS outbreak initiation and progression of outbreak wave through early warning monitoring based on COTS numbers, water quality, flood events. • Determine level of COTS and *Drupella* predation on corals throughout the GBR.	PROGRAMS • AIMS LTMP • Integrated Eye on the Reef Health and Impact Surveys (iEotRHIS) ATTRIBUTES: COTS densities
	Ensure direct use of the Region is ecologically sustainable and continues to deliver community benefit. **Targets by 2019** • A reducing trend in the incidence of illegal fishing and poaching through: - Implementation of a remote vessel monitoring system on the commercial fishing fleet by 2015 - The maintenance of an effective field compliance presence in the Region. The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	Fishing • Determine spatial and temporal trends in fishing effort and catch, especially in the Reef Line and Inshore Line and Net Fisheries. • Determine number and mass of fish taken (by species) for all sectors (incl. recreational) analysed by trophic group (i.e. catch). • Determine trends in numbers of registered recreational vessels by Local Government Area and vessel size. • Determine numbers of sharks taken as by-catch in commercial nets and trawl. • Fishery-independent observation program validation of commercial logbook Species of Conservation Interest data (level of mortality and interaction), providing statistically representative coverage of vessel effort from the East Coast Inshore Fin Fish Fishery and East Coast Trawl Fishery (including those vessels operating in remote/less-accessible regions north of Cooktown). Dredging • Determine trends in extent of proposed and actual dredging activities. • Determine movement of sediments from dredging and dumping of dredged spoil. • Determine contribution of dredging activity to sediment resuspension. • Determine impact on sedimentation, turbidity and light levels from sediment plumes derived from dredging activities. • Determine properties of dredged materials including physical properties, nutrients, chemicals and toxins. Anchor damage • Determine extent of anchor damage inside no-anchoring areas compared to outside these areas.	**Fishing** PROGRAMS: • Qld commercial fishery monitoring • Qld trawl vessel monitoring • Qld recreational fishing monitoring VARIABLES: Commercial catch Recreational catch information (limited) Compliance monitoring **Dredging** PROGRAMS • Project specific compliance monitoring programs • Ports ambient monitoring of turbidity and suspended sediments ATTRIBUTES Sedimentation Light Turbidity Research project work done on anchor damage but no long-term monitoring

Table 3.9 Linking monitoring objectives to management outcomes and objectives for biophysical values of seagrass meadows and seagrasses

This table links monitoring to management outcomes and objectives through monitoring objectives for biophysical values seagrass meadows and seagrasses. The strategic assessment has set outcomes and targets for values. These outcomes will be achieved through managing pressures (impacts), so objectives and targets have been articulated for these pressures. Full listings of management outcomes and objectives and their associated monitoring objectives organised in a DPSIR format appear in Appendix 3. Note that while several monitoring programs are listed against each monitoring objective, these programs may vary greatly in scope and rigour.

Seagrass meadows and seagrasses

Drivers effecting seagrass meadows and seagrasses: climate change, economic growth, population growth, technological development, societal attitudes (see Appendix 3 for driver monitoring objectives)

Objectives/outcomes hierarchy:

1. GBRMPA Act 1975: the main object of this Act is to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region.

2. GBRMPA Strategic Plan 2012–2016:

Objective 1. Address the key risks affecting the outlook for the Great Barrier Reef.

Objective 2. Ensure management of the Marine Park supports ecologically sustainable use.

Objective 3. Foster stewardship by engaging, educating and inspiring people through the care and management of the Marine Park.

3. Biodiversity Conservation Strategy 2013: Build ecosystem resilience in a changing climate by reducing the threats to potentially at-risk elements of biodiversity, especially those found in inshore areas.

4. Draft desired management outcomes (from the strategic assessment) for state of value including impacts	**5. Draft targets for pressures/impacts required to achieve outcomes (from the strategic assessment). The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.**	**Draft core long-term monitoring objectives**	**Monitoring programs and attributes that have been monitored**

The condition of seagrass meadows and seagrasses is maintained in Northern inshore and offshore areas and the trend in condition is maintained and improved. The condition of Southern inshore and offshore seagrass meadows and seagrasses is restored to good and the decline in trend of condition is halted and reversed.
Targets by 2019
• Spatial extent and condition of seagrass in each natural resources management region is improved to good condition as defined in the Reef Rescue marine monitoring program12
Note: The Authority will further examine the development of targets for seagrass meadows that specify ranges for distribution, density and condition for regions and subregions
		• Determine extent and condition of seagrass meadows, as well as species composition and community structure at regional and Reef-wide scales including at impacted sites.
		• Measure Extent, frequency and intensity of impact effects as well as recovery from exposure of seagrass beds to rising sea level, flood plumes, cyclones, sediments, nutrients, pesticides, and increased sea and air temperature (see 'Impacts' table for impact specific monitoring objectives).
		• Measure extent of loss of seagrass meadows through dredging activities.
			PROGRAMS:
			• Seagrass-Watch
			• Reef Rescue Marine Monitoring Program Inshore Seagrass Monitoring
			• Ambient Monitoring associated with ports at:
			  • Cairns
			  • Mourilyan
			  • Townsville
			  • Hay Point
			  • Mackay
			  • Abbot Point
			  • Gladstone (Port Curtis Integrated Monitoring Program, Port Curtis & Port Alma Environmental Research and Monitoring Program)
			(None of these programs monitor deep-water seagrass meadows)
			ATTRIBUTES:
			Extent of coverage, species composition, seed banks, epiphytes & macro-algae, meadow edge mapping (late dry season, late monsoon season), reproductive health, seagrass tissue elements (C:N:P) (late dry season), rhizosphere sediment herbicides, in-situ within canopy temperature, in-situ canopy light, dugong trails

	Reduce climate change related impacts and build health and resilience of coral reefs and corals.	• Measure trends in frequency, intensity and spatial extent of sea and air temperature variability. • Track paths, intensities, spatial extent and system speed of all tropical cyclones in or near the GBRWHA. • Determine rainfall patterns as a result of tropical cyclones and lows.	PROGRAMS: • QIMOS - Great Barrier Reef Ocean Observing System

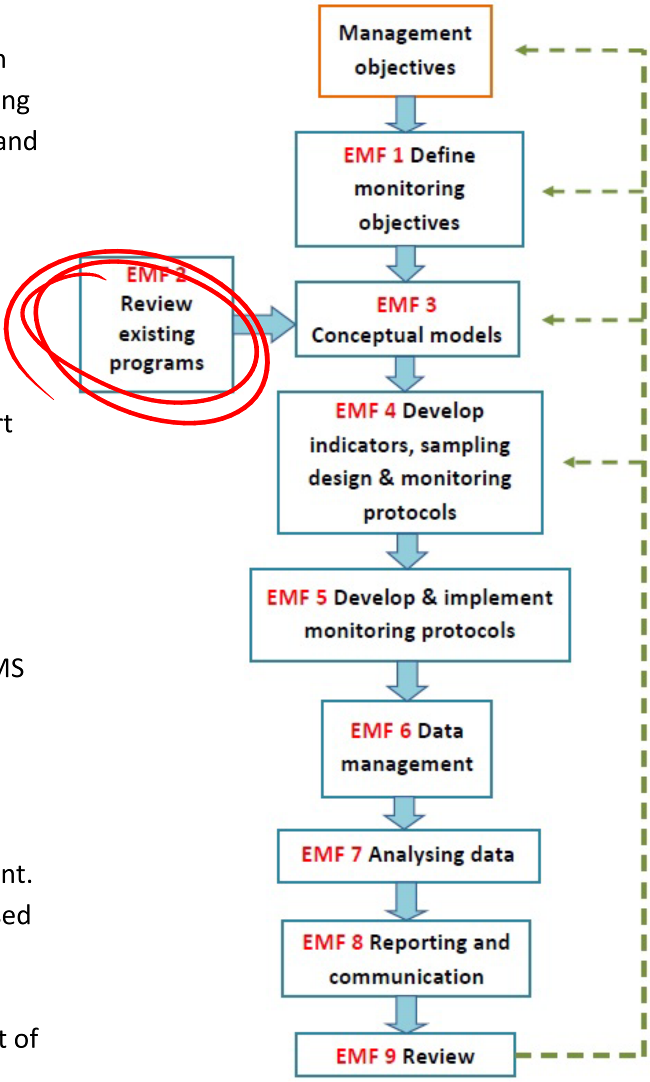
	Targets by 2019 The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine trend in ocean acidification at the GBR scale. • Determine trend in rising sea level. • Determine trends in oceanic, GBR, regional and local-scale water circulations. • Determine flow rate and volume of fresh water entering the GBR from adjacent catchments. • Determine three-dimensional extent and duration of flood plumes during flood events. • Measure trends in rainfall in the catchment. • Measure trends in incidence of coral disease.	• ReefTemp • AIMS-GBRMPA Sea Temperature Monitoring Program • AIMS Weather Observing System • Bureau of Meteorology (BoM) ATTRIBUTES: Sea temperature – surface and at depth Air temperature Weather station and satellite data
	Halt and reverse the decline in water quality. **Targets by 2019** • Meet Reef Plan targets for catchment run-off. • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded.	Nutrients • Determine species, concentrations and distribution of nutrients that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine concentrations of chlorophyll a throughout the GBRWHA. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment. Sediments • Measure trends in sediment transport from catchments. • Measure trends in turbidity and light levels for key habitats as a result of sediments against water quality guidelines. • Determine the source and be able to distinguish between sources of sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Distinguish between new sediment entering the GBRWHA and resuspension of sediments. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment. Pesticides • Determine types, concentrations and distribution of pesticides that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of pesticides entering the GBRWHA. • Determine the fate of pesticides entering the GBRWHA. • Determine extent of proposed and actual land use changes (clearing & agriculture) in the catchment.	**Nutrients** PROGRAMS: • Reef Rescue Marine Monitoring Program nutrient monitoring, ambient water quality • Reef Plan catchment loads • Ports ATTRIBUTES: Particulate and dissolved nutrient species (N & P) Chlorophyll **Sediments** PROGRAMS: • Reef Rescue Marine Monitoring Program ambient water quality • Reef Plan catchment loads • Ambient Monitoring associated with ports ATTRIBUTES: Suspended sediments Turbidity **Pesticides** PROGRAMS: • Reef Rescue Marine Monitoring Program pesticide monitoring, ambient water quality, inshore seagrass • Reef Plan catchment loads ATTRIBUTES: Pesticide concentrations ambient and in flood waters
	Restore connectivity and improve functioning of coastal and inshore ecosystems. **Targets by 2019** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine changes to inshore fish populations & productivity associated with restoration of coastal ecosystems, such as removal of barriers to flow. • Measure trends in fish health associated with significant coastal developments, especially dredging activity. • Determine types, distribution and fate of marine debris in the GBRWHA. • Determine the source and be able to distinguish between sources of sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Determine the source and be able to distinguish between sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine three-dimensional extent and duration of flood plumes during flood events.	No monitoring
	Ensure direct use of the Region is ecologically sustainable and continues to deliver community benefit.	Fishing • Determine spatial and temporal trends in fishing effort and catch, especially in the Reef Line and Inshore Line and Net Fisheries.	**Fishing** PROGRAMS: • Qld commercial fishery monitoring

	Targets by 2019
	• A reducing trend in the incidence of illegal fishing and poaching through:
	- Implementation of a remote vessel monitoring system on the commercial fishing fleet by 2015
	- The maintenance of an effective field compliance presence in the Region.
	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model
		• Determine number and mass of fish taken (by species) for all sectors (incl. recreational) analysed by trophic group (i.e. catch).
		• Determine trends in numbers of registered recreational vessels by Local Government Area and vessel size.
		• Determine numbers of sharks taken as by-catch in commercial nets and trawl.
		• Fishery-independent observation program validation of commercial logbook Species of Conservation Interest data (level of mortality and interaction), providing statistically representative coverage of vessel effort from the East Coast Inshore Fin Fish Fishery and East Coast Trawl Fishery (including those vessels operating in remote/less-accessible regions north of Cooktown).
		
		Dredging and ports
		• Extent of loss of seagrass meadows through dredging activities
		• Determine trends in extent of proposed and actual dredging activities.
		• Determine movement of sediments from dredging and dumping of dredged spoil.
		• Determine contribution of dredging activity to sediment resuspension.
		• Determine impact on sedimentation, turbidity and light levels from sediment plumes derived from dredging activities.
		• Determine properties of dredged materials including physical properties, nutrients, chemicals and toxins.
			• Qld trawl vessel monitoring
			• Qld recreational fishing monitoring
			
			VARIABLES:
			Commercial catch
			Recreational catch information (limited)
			Compliance monitoring
			Dredging
			PROGRAMS:
			• Project specific compliance monitoring programs
			• Ports ambient monitoring of turbidity and suspended sediments
			• Seagrass-Watch
			
			ATTRIBUTES:
			Sedimentation
			Light
			Turbidity
			
			Ports
			
			PROGRAMS:
			• Seagrass-Watch
			• Reef Rescue Marine Monitoring Program Inshore Seagrass Monitoring
			• Ambient Monitoring associated with ports at:
			  • Cairns
			  • Mourilyan
			  • Townsville
			  • Hay Point
			  • Mackay
			  • Abbot Point
			  • Gladstone (Port Curtis Integrated Monitoring Program, Port Curtis & Port Alma Environmental Research and Monitoring Program)
			
			ATTRIBUTES:
			Extent of coverage, species composition, seed banks, epiphytes & macro-algae, meadow edge mapping (late dry season, late monsoon season), reproductive health, seagrass tissue elements (C:N:P) (late dry season), rhizosphere sediment herbicides, in-situ within canopy temperature, in-situ canopy light, dugong trails.

3.2.4 Essential Monitoring Function 2: Compiling and analysing relevant information on existing monitoring programs

Guidance from Part 2

- Produce project outline for compiling, analysing and summarising information on existing monitoring programs defining purpose of review, spatial boundaries and required outputs.
- Seek endorsement of project outline from the appropriate governance committee(s).
- Appoint a suitably qualified analyst(s) to complete project and produce report
- Provide copy of report to appropriate governance committee(s).



3.2.4.1 Methods

In the GBRWHA, several programs (e.g. the AIMS Long-Term Monitoring Program; LTMP) have been established to meaningfully inform management of MNES values. Compiling information on existing programs makes it possible to build on the legacy of this investment. The prioritised monitoring objectives can be used to determine how these programs would contribute to an IMP, and to identify gaps in monitoring information to inform management of the GBRWHA.

A project outline for the review of existing monitoring programs was drawn up and endorsed by the steering committee. In gathering material the review built on two previous surveys of monitoring of the GBR.

There have been several previous surveys of monitoring programs in the GBR Marine Park. Harriott et al. (2002) compiled information on 56 programs in June 2002 and this list was partially revised in 2003 to include 117 programs (Harriott et al. 2003). In 2008 the GBRMPA compiled a list of GBR monitoring programs as an internal document. While this compilation was not intended to be exhaustive, it certainly included the programs that contributed information to the *Outlook Report 2009*. Our review updates these previous lists, and expands them through internet searches for monitoring programs that are relevant to interactions between elements underpinning MNES and impacts, where those interactions have been identified as being of concern to managers through the strategic assessment process. In particular, information was gathered on ambient monitoring programs associated with ports on the GBR coast and on general programs tracking terrestrial activities that potentially affect the GBRWHA, such as land use changes and habitat mapping.

3.2.4.3 Findings

Sixty-five programs were identified in this survey. Table 3.10 presents summary statistics and a full description of each program is given in Appendix 8. Three programs—Coral Reef Watch, Seagrass-Watch and ReefCheck—are part of international programs, five programs are national in scope, 22 are state-wide programs and 35 are specific to the GBRWHA.

Table 3.10 Informal grouping of existing monitoring programs into non-exclusive categories (for instance, biological programs, citizen science programs and management performance programs all monitor biological variables). The right-hand column presents examples of programs in each category rather than an exhaustive list.

Classification	Number of programs	Examples
Physical / Environmental	10	ReefTemp, Queensland Integrated Marine Observing System - Australian baseline sea level monitoring program
Biological	9	Dugong population monitoring, AIMS LTMP
Management performance	10	Effects of rezoning on offshore coral reef systems, Reef Rescue marine monitoring programs
Citizen science	8	ReefCheck, CapReef, Seagrass-Watch, MangroveWatch, Eye on the Reef sightings network, Australian Marine Debris Initiative
Monitoring associated with ports	9	Port Curtis Integrated Monitoring Program, Port Curtis & Port Alma Environmental Research & monitoring Program, Ports North Ecological Health Monitoring Program (Cairns)
Habitat mapping	3	Qld Acid Sulphate Soils Investigation Team, Qld Land Use Monitoring Program, Qld Wetlands Program
Socio-economic	7	International Visitor Survey, National Census of Population and Housing
GBRMP management	7	Compliance—Protecting the Reef (GBRMPA-QPWS), Infrastructure Monitoring on Islands,
Fisheries	3	Qld trawl Vessel Monitoring System

The purpose of this essential function is to identify existing monitoring programs and to indicate how these are aligned with the monitoring priorities identified under Essential Monitoring Function 1 (Table 3.5). This allows due consideration of the legacy of established monitoring programs in designing an IMP for the GBRWHA. Table 3.11 details existing monitoring that concerns the priority drivers of changes in ecosystem condition in the GBRWHA, and the adequacy of those monitoring activities to inform adaptive management of the GBRWHA. Existing monitoring programs that address the high priority pressures on ecosystem condition in the GBRWHA are considered in Table

3.12 with an assessment of their adequacy to inform adaptive management. Existing monitoring programs that are relevant to high priority biophysical values are considered similarly in Table 3.13. Relevant attributes of existing programs are also referred to under the appropriate essential monitoring functions below. A comprehensive compilation of attributes of the individual programs is included in Appendix 8.

Table 3.11 Adequacy of current monitoring to address priority drivers

Driver	Variables currently being monitored	Adequacy of coverage
Climate change: has direct and ongoing effects on the environment, as higher temperatures and changing rainfall regimes in some areas can be expected to have profound and pervasive control over a host of natural processes that underpin the condition and trend of ecosystems. Key pressures influenced by driver: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow	Atmospheric CO_2 concentrations	Adequate global and national monitoring to estimate trends in atmospheric CO_2
Economic growth: will probably include increased demand for energy and other resources, as well as increased waste generation, with all the accompanying environmental implications for resource development, emissions and waste disposal. Alternatively, economic growth may be largely decoupled from increased consumption of resources and increased waste. Improvements in the efficiency of resource use have led to a weakening of the link between economic growth and energy use over recent decades. Key pressures influenced by driver: o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Outbreak of COTS o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	Number and type of new and expanded projects (e.g. coal mines, coal seam gas projects, industry infrastructure including those associated with expanded ports) Extent of agricultural intensification	Partly adequate—specific figures for the GBR catchment are required on a more regular basis than is currently the case

Driver	Variables currently being monitored	Adequacy of coverage
Population growth: population growth is likely to continue to drive the need for expanded suburban development. The size of this impact will depend on how sensitive the planning has been towards local environmental assets and values, and on the effectiveness of policies to improve the energy efficiency of housing and transport. Key pressures influenced by driver: o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Outbreak of COTS o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	Population growth in the catchment, in Queensland, nationally and internationally Percentage of new residents in the catchment Amount and type of coastal and marine infrastructure including ports, marinas, jetties, pontoons, tourist resorts	Partly adequate— specific figures for the GBR catchment are required on a more regular basis than is currently the case
Technological developments: Technological development is the application of scientific knowledge to create tools to solve specific social, economic or environmental problems. Technological advances have brought major changes to the way people communicate, work, learn, travel and spend leisure time. Technology has changed the way we learn about, manage and use the Region and its resources. Key pressures influenced by driver: o Dredging, dumping and resuspension of dredge material o Noise pollution o Illegal fishing and poaching o Extraction of predators	Number and type of new technologies used among Reef users Ways in which new technologies are used to understand and share information about the Reef, enhance visitor experiences, advance research and scientific activities, accelerate catchment and Reef-based extractive activities	Uncertain
Societal attitudes: Societal attitudes operate at international, national and local scales, and are shaped by cultural and social norms, institutional arrangements, economic imperatives and politics. Key pressures influenced by driver: o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	Content and interpretation of mass media messages which are pertinent to the Great Barrier Reef Number, type and intent of local, national and international initiatives which reflect societal attitudes towards the Great Barrier Reef	Uncertain

Table 3.12 Adequacy of current monitoring to address priority pressures

<table>
<tr><th>Pressures/Impacts</th><th>Monitoring programs and variables currently being monitored</th><th>Adequacy</th></tr>
<tr><td>Increased sea & air temperature

Values affected by pressure/impact
o Islands
o Beaches and coastline
o Open waters
o Seagrass meadows and seagrasses
o Coral reefs and corals
o Marine turtles
o Dolphins
o Seabirds
o Shorebirds
o Other invertebrates
o Sea snakes
o Bony fish
o Sharks and rays
o Primary production pelagic
o Connectivity
o Recruitment
o Income, economic contribution and employment
o Appreciation, enjoyment, aesthetics
o Personal attachment
o Understanding</td><td>PROGRAMS:

• Queensland Integrated Marine Observing System
• ReefTemp
• AIMS-GBRMPA Sea Temperature Monitoring Program
• AIMS Weather Observing System
• Bureau of Meteorology weather stations

VARIABLES:
Sea temperature—surface and at depth
Air temperature
Weather station and satellite data</td><td>Adequate: sea surface temperature monitoring has complete spatial coverage through remote sensing backed up with some real-time data and much more logged ground truth data.

Air temperature is monitored by BoM coastal and offshore weather stations and by AIMS weather stations. Coverage is extensive except for the Far Northern Management Area.</td></tr>
<tr><td>Cyclone activity

Values affected by pressure/impact
o Islands
o Beaches and coastline
o Seagrass meadows and seagrasses
o Coral reefs and corals
o Mangrove diversity
o Marine turtles
o Sea snakes
o Bony fish
o Connectivity
o Recruitment
o Income, economic contribution and employment
o Access to resources and heritage
o Appreciation, enjoyment, aesthetics
o Personal attachment
o Understanding</td><td>PROGRAMS:
• QDEHP wave monitoring
• QDEHP Storm Tide
• Bureau of Meteorology

VARIABLES:
Cyclone pressure, direction of movement, extent, wind speeds</td><td>Adequate: Full and continuous coverage of GBRWHA for cyclone tracks via remote sensing and BoM wind speed modelling.

Wave monitoring and storm tide monitoring occurs along the inhabited coast, no coverage of the Far Northern Management Area.</td></tr>
<tr><td>Ocean acidification

Values affected by pressure/impact
o Open waters
o Coral reefs and corals
o Other invertebrates
o Bony fish
o Understanding</td><td>PROGRAMS:
• Queensland Integrated Marine Observing System

VARIABLES:
pH, alkalinity, dissolved CO_2 concentrations</td><td>Adequacy uncertain: A single, continuously recording reference station and more general water sampling can provide precise readings of changes in pCO_2 but sophisticated modelling of hydrodynamics, benthic carbon fluxes, and</td></tr>
</table>

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
		models of cross-shelf and along-shelf water transport are required to link these changes to ocean acidification.
Rising sea level Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Seabirds o Shorebirds o Connectivity o Recruitment o Personal attachment o Understanding	PROGRAMS • Australian baseline sea level monitoring program VARIABLES: Tide height from tidal gauges	Two sea level reference sites within the GBRWHA (probably adequate in combination with oceanographic modelling). Instruments record continuously.
Altered ocean currents and smaller scale circulation Values affected by pressure/impact o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Marine turtles o Dugongs o Dolphins o Seabirds o Shorebirds o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Primary production pelagic o Connectivity o Recruitment o Income, economic contribution and employment o Understanding	PROGRAMS: • Queensland Integrated Marine Observing System VARIABLES Current strength and direction from moorings, gliders, high frequency radar, satellite imagery, hydrodynamic models	Partially adequate: Changes to the East Australian Current were an initial focus for Q-IMOS (extended by hydrodynamic modelling). Finer scale circulation in the GBR waters are subject of modelling under eReefs Project.
Increased freshwater flow Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Other invertebrates o Bony fish o Connectivity o Recruitment o Income, economic contribution and	PROGRAMS: • Qld Surface Water Ambient Network (SWAN) – Water quality • Reef Rescue Marine Monitoring Program ambient water quality, remote sensing, flood monitoring • ReefPlan catchment loads monitoring	Instruments record continuously. Good / adequate coverage on the populated coast, much less information from the Far Northern Management Area.

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Understanding	VARIABLES: Salinity Coloured Dissolved Organic Matter (CDOM) Gauged flow from rivers	
Outbreaks of disease (climate change-driven) Values affected by pressure/impact o Coral reefs and corals o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • AIMS LTMP • Eye on the Reef tourism weekly, Reef Health and Impact Survey, rapid assessment, sightings network • Reef Rescue Marine Monitoring Program inshore coral monitoring • QDEHP wildlife strandings • Qld turtle conservation project VARIABLES: Coral disease—captured through coral monitoring programs Megafauna disease—from strandings database	Adequate coverage on the populated coast, much less in the Far Northern Management Area Coverage of wildlife strandings is uneven; strandings near population centres are more likely to be detected than strandings in remote locations.
Nutrients from catchment run-off Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Dugongs o Dolphins o Shorebirds o Other invertebrates o Bony fish o Primary production pelagic o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • Reef Rescue Marine Monitoring Program nutrient monitoring, ambient water quality • Paddock to Reef catchment loads • Reef Rescue Marine Monitoring Program flood plume monitoring • Ports VARIABLES Particulate and dissolved nutrient species (N & P) Chlorophyll	Adequate coverage on the populated coast, much less in the Far Northern Management Area Sampling focused close to shore, less certainty about changes in offshore regions.
Sediments from catchment run-off Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Primary production pelagic o Recruitment o Income, economic contribution and	PROGRAMS: • Reef Rescue Marine Monitoring Program ambient water quality, flood sampling • Paddock to Reef catchment loads • Ambient monitoring associated with ports at: o Cairns o Mourilyan o Townsville	Good / adequate coverage on the populated coast, none in the Far Northern Management Area Sampling focused close to shore, less certainty about changes in offshore regions.

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	o Hay Point o Mackay o Abbot Point o Gladstone (Port Curtis Integrated Monitoring Program, Port Curtis and Port Alma Environmental Research and Monitoring Program) VARIABLES: Suspended sediments Turbidity	
Pesticides from catchment run-off Values affected by pressure/impact o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Other invertebrates o Bony fish o Primary production pelagic o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • Reef Rescue Marine Monitoring Program pesticide monitoring, ambient water quality, inshore seagrass • Reef Plan catchment loads VARIABLES Pesticide concentrations—ambient and in flood waters	Good / adequate coverage inshore on the populated coast, none offshore nor in the Far Northern Management Area Sampling focused close to shore, less certainty about offshore changes.
Crown-of-thorns starfish Values affected by pressure/impact o Coral reefs and corals o Other invertebrates o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS • AIMS LTMP • Effects of rezoning on offshore coral reef systems • Eye on the Reef – Reef Health and Impact Survey • GBRMPA COTS monitoring (with Association of Marine Park Tourism Operators) VARIABLES: COTS densities	Adequate coverage in Central and Southern GBR, much less in the Far Northern Management Area.
Outbreaks of disease (water quality-related) Values affected by pressure/impact o Coral reefs and corals o Marine turtles o Dugongs o Dolphins o Bony fish o Income, economic contribution and employment o Access to resources and heritage	PROGRAMS: • AIMS LTMP • Effects of rezoning on offshore coral reef systems • Eye on the Reef tourism weekly surveys, Reef Health and Impact Survey, rapid assessment, sightings network • Reef Rescue Marine Monitoring Program inshore coral monitoring • QDEHP wildlife strandings	Adequate coverage in Central and Southern GBR, much less in the Far Northern Management Area.

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	• Qld turtle conservation project VARIABLES: Coral disease—assessed in coral monitoring programs Megafauna disease—through strandings database	
Marine debris Values affected by pressure/impact o Beaches and coastline o Open waters o Mangrove diversity o Marine turtles o Dugongs o Dolphins o Seabirds o Shorebirds o Other invertebrates o Sea snakes o Bony fish o Sharks and Rays o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS • Australian Marine Debris initiative (AMDI) VARIABLES Quantity and source of debris	Partially adequate: AMDI is a community based program working with local groups from Torres Strait to Gladstone. Items of debris are categorised and identified, but emphasis is on community action to reduce marine debris rather than comprehensive data collection. Sampling frequency and data quality are uncertain.
Dredging and spoil disposal Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Other invertebrates o Bony fish o Primary production pelagic o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	Compliance monitoring programs for specific development projects VARIABLES: Sedimentation Light Turbidity Ambient monitoring of turbidity and suspended sediments	Partially adequate: Monitoring associated in space and time with dredging campaigns Long-term effects (years) of dumped dredge spoil on nearby benthic communities is not monitored.
Clearing and modifying coastal habitats Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Seabirds	PROGRAMS • Queensland Land Use Monitoring Program (QLUMP) aerial/satellite surveys • Paddock to Reef integrated monitoring, modelling and reporting program See water quality— nutrients, sediments and pesticides above.	Partially adequate: QLUMP has provided data on change in land use in all GBR catchments in 2009 compared with 1999. Future resurveys are not planned at present.

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
o Shorebirds o Other invertebrates o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding		
Coastal reclamation Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Mangrove diversity o Marine turtles o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS • QLUMP aerial/satellite surveys VARIABLES: Based on satellite imagery, Land use is categorised using the Australian Land Use & Management classification (ALUM)	Partially adequate: QLUMP has provided data on change in land use and extent in all GBR catchments in 2009 compared with 1999. Future resurveys are not planned at present.
Extraction of predators Values affected by pressure/impact o Dolphins o Seabirds o Bony fish o Sharks and rays o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • Qld commercial fishery monitoring • Qld trawl vessel monitoring • Qld recreational fishing monitoring VARIABLES: Commercial catch Recreational catch information (limited) Compliance monitoring	Inadequate: Present data collection limited All data are currently fishery dependent Queensland fishery observer program has been discontinued.
Death of discarded species Values affected by pressure/impact o Marine turtles o Dugongs o Dolphins o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • Qld commercial fishery logbooks • Qld trawl vessel monitoring • Qld recreational fishing surveys • QEHP strandings network VARIABLES: Logbooks	Inadequate: By-catch data now limited QDEHP Strandings network depends on encountering dead animals – more likely near centres of population.

Pressures/Impacts	Monitoring programs and variables currently being monitored	Adequacy
Illegal fishing and poaching Values affected by pressure/impact o Marine turtles o Dugongs o Dolphins o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • GBRMPA-QPWS Compliance monitoring • Integrated Eye on the Reef incident reporting VARIABLES: Infringements of the GBRMP zoning regulations	Extent of program is confidential.
Noise pollution Values affected by o Dugongs o Dolphins o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • Ports monitoring • Abbot Point cumulative impact assessment • Port Curtis & Pt Alma Environmental Research & Monitoring Program VARIABLES: In-water acoustic monitoring around port developments	Partially adequate: Limited to the local effects of port development (mainly construction) Underwater noise could apply to shipping channels and routes, these are not monitored at present.
Artificial barriers to flow Values affected by pressure/impact o Shorebirds o Other invertebrates o Bony fish o Sharks and rays o Connectivity o Recruitment o Understanding	PROGRAMS: • QLUMP Aerial/satellite surveys VARIABLES Based on satellite imagery, Land use is categorised using the Australian Land Use & Management classification (ALUM -160 categories in 6 classes)	Partially adequate: QLUMP has provided data on change in land use and extent in all GBR catchments in 2009 compared with 1999. Future resurveys are not planned at present.
Fishing spawning aggregations Values affected by pressure/impact o Bony fish o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	PROGRAMS: • GBRMPA-QPWS compliance monitoring • Integrated Eye on the Reef Incident reporting VARIABLES: Infringements of the GBRMP zoning regulations	Extent of program is confidential.

Table 3.13 Adequacy of current monitoring to address priority biophysical values

Biophysical values And pressures/impacts affecting them	Monitoring programs and variables that have been monitored	Adequacy
Coral reefs and corals Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Outbreak of COTS o Clearing or modifying coastal habitats	PROGRAMS: • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • Eye on the Reef – Reef Health and Impact Survey • Eye on the Reef - weekly monitoring • ReefCheck • GBRMPA-QPWS compliance monitoring VARIABLES: % cover of hard & soft corals, coral size classes, larval settlement, taxonomic composition, % coral cover, COTS, counts of juvenile corals, coral disease, *Drupella*, surveys of sessile benthic organisms (~70 categories) using still images visual counts of reef fishes (7 families)	Partially adequate: Extensive coverage of coral reefs off the urban coast, and particularly around the tourism centres in the Cairns and Whitsunday region. Little scheduled monitoring in the Far Northern Management Area, though IEotRHIS that are routinely made as part of field management patrols provide some coverage. The GBRWHA includes extensive coral shoals in deeper water. These reefs are not currently monitored nor are they well studied.
Seagrass meadows and seagrasses Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Freshwater inflow o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Clearing or modifying coastal habitats o Coastal reclamation	PROGRAMS: • Seagrass-Watch • Reef Rescue Marine Monitoring Program inshore seagrass monitoring Ambient monitoring associated with ports at: o Cairns o Mourilyan o Townsville o Hay Point o Mackay o Abbot Point o Gladstone (incl. Port Curtis Integrated Monitoring Program, Port Curtis and Port Alma Environmental Research and Monitoring Program) VARIABLES Extent of coverage, species composition, seed banks, epiphytes & macro-algae,	Partially adequate: Extensive surveys of accessible shallow coastal sites along the urban coast, but with limited coverage in the Far Northern Management Area. Importantly, the GBR lagoon includes very extensive areas of seagrass in deeper water (to 30m). These were surveyed in the 1990s but there is no regular assessment of their extent or condition, though this is known to be affected by cyclonic activity.

Biophysical values And pressures/impacts affecting them	**Monitoring programs and variables that have been monitored**	**Adequacy**
	meadow edge mapping (late dry season, late monsoon season), reproductive health, seagrass tissue elements (C:N:P) (late dry season), rhizosphere sediment herbicides, in-situ within canopy temperature, in-situ canopy light, dugong trails	
Mangrove diversity Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Freshwater inflow o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Clearing or modifying coastal habitats o Coastal reclamation	PROGRAMS: • Mangrove watch • QLUMP • Port development monitoring VARIABLES: Extent of mangrove area	Coverage is inadequate. • Mangrove watch activities are very limited in the GBRWHA, but are aiming to expand. • Remote sensing programs such as QLUMP provide estimates of the extent of mangrove habitats but no assessment of habitat quality, species diversity etc.
Islands Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Clearing and modifying coastal habitats o Coastal reclamation o Marine debris	PROGRAMS: • Monitoring island infrastructure • Monitoring fire and weed species • GBRMPA-QPWS Field management patrols • QLUMP VARIABLES: Weeds and pests, infrastructure, *Pisonia* forest scale insects, condition of vegetation (fire monitoring)	Partially adequate: Aside from QLUMP, these programs are focused on immediate management issues of island National Parks
Beaches and coastline Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Freshwater inflow o Nutrients from catchment run-	PROGRAMS: • GBRMPA-QPWS field management patrols • QLUMP • AMDI VARIABLES: remote mapping of coastal habitats, mangroves, saltpans and saline	Partially adequate: QLUMP has provided data on change in land use and extent in all GBR catchments in 2009 compared with 1999. Future resurveys are not planned at present.

Biophysical values And pressures/impacts affecting them	**Monitoring programs and variables that have been monitored**	**Adequacy**
off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Clearing or modifying coastal habitats o Coastal reclamation o Marine debris	grasslands, quantity and source of marine debris	
Open waters Key pressures/impacts affecting value: o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Freshwater inflow o Nutrients from catchment run-off o Sediments from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Marine debris	PROGRAMS: • QDEHP wave monitoring • Queensland Integrated Marine Observing System • Reef Rescue marine monitoring program water quality components, including remote sensing • BoM weather stations VARIABLES: Current movements – large scale and finer scale through modelling, temperature, nutrients, pesticides, turbidity, light, chlorophyll, suspended solids, coloured dissolved organic matter	Partially adequate: Physical variables can be interpolated by modelling. Limited ground truth available for assessing water quality in the GBR lagoon by remote sensing.
Other invertebrates Key pressures/impacts affecting value: o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Freshwater inflow o Nutrients from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Outbreak of COTS o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching	PROGRAMS: • AIMS Long Term Monitoring Program • AIMS Effects of rezoning on offshore coral reef systems • Eye on the Reef – Reef Health and Impact Survey • Eye on the Reef - weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • Qld commercial fishery monitoring • Qld trawl vessel monitoring • QPWS-GBRMPA compliance monitoring VARIABLES: Reefs: surveys & observations of COTS and sessile benthic organisms (~70 categories including corals) Lagoon floor: No ongoing monitoring but comprehensive survey of the seabed biodiversity conducted 2003–2006	Generally inadequate: This is a very large category of values that are monitored very unevenly in terms of data quality, geographic extent and intensity of monitoring

Biophysical values And pressures/impacts affecting them	Monitoring programs and variables that have been monitored	Adequacy
	Commercial prawn and beche-de-mer fishery:: catch statistics Beche-de-mer surveys: stock size, recruitment, growth on 70 reefs but not continuing	
Bony fish Key pressures/impacts affecting value: o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment run-off o Dredging, dumping and resuspension of dredge material o Pesticides from catchment run-off o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	PROGRAMS: • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Inshore zoning effect monitoring • Monitoring spawning aggregations (2 reefs near Cairns) • Qld commercial fishery monitoring • Qld recreational fishing monitoring • Qld trawl vessel monitoring VARIABLES: LTMP: visual counts of reef fishes (7 families) Zoning monitoring: biomass and abundance of coral trout, snapper and others Commercial catch Biological information on targeted species.	Partially inadequate: The AIMS LTMP and effects of rezoning monitoring programs undertake regular surveys of coral reef fishes across the southern GBRWHA but there is no coverage in the Far Northern Management Area. QDAFF surveys are all fishery dependent
Sharks and rays Key pressures/impacts affecting value: o Increased sea and air temperature o Altered ocean currents o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching o Extraction of predators	PROGRAMS: • Qld shark control program (southern inshore) • Qld commercial fishery monitoring • Qld recreational fishing monitoring • Qld trawl vessel monitoring • Reef sharks recorded during AIMS LTMP manta tows VARIABLES: Commercial fishery catch Research done comparing reef shark populations on reefs that are open and closed to fishing Information from shark control program and strandings database Acoustic tagging of sharks for movement and behaviours information	Monitoring sharks and rays is inadequate. Data from the Qld shark control program are collected in very few sites and focused inshore on the urban coast, though the program has a long history AIMS LTMP manta tow surveys only record small numbers of sharks No information from the Far Northern Management Area (where impacts on sharks might be less)

Biophysical values And pressures/impacts affecting them	**Monitoring programs and variables that have been monitored**	**Adequacy**
Marine turtles Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment run-off o Dredging, dumping and resuspension of dredge material o Clearing or modifying coastal habitats o Coastal reclamation o Death of discarded species o Marine debris o Illegal fishing and poaching	PROGRAMS: • QDEHP turtle conservation project • Dugong population monitoring • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld trawl vessel monitoring • Eye on the Reef Sightings network VARIABLES: Nesting populations Populations at known feeding grounds Condition of individuals Eye on the Reef Incidental sightings records	Adequate: Extensive and long-term programs in place.
Seabirds Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Clearing or modifying coastal habitats o Marine debris o Extraction of predators	PROGRAMS: • Coastal bird monitoring (QPWS & GBRMPA) • Birds Australia • Coastal bird monitoring VARIABLES: Census of breeding sites for seabirds and shorebirds	Partially adequate: Subject of a recently revised Coastal Bird Monitoring Strategy (2011) Monitoring principally associated with field management patrols.
Shorebirds Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Nutrients from catchment run-off o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Marine debris	PROGRAMS: • Birds Australia • Coastal bird monitoring (QPWS & GBRMPA) • Port Curtis and Port Alma Environmental Research and Monitoring Program VARIABLES Census of breeding sites for seabirds and shorebirds	Partially adequate: Subject of a recently revised Coastal Bird Monitoring Strategy (2011)

Biophysical values And pressures/impacts affecting them	**Monitoring programs and variables that have been monitored**	**Adequacy**
Dolphins Key pressures/impacts affecting value: o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Nutrients from catchment run-off o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators	PROGRAMS • QDEHP wildlife strandings • Qld commercial fishery monitoring • Eye on the Reef sightings network VARIABLES: Strandings Incidental sightings records (Eye on the Reef) Commercial fishery incidental catch	Inadequate: No formal population monitoring
Dugongs Key pressures/impacts affecting value: o Altered ocean currents o Outbreaks of disease o Nutrients from catchment run-off o Coastal reclamation o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching	PROGRAMS • Dugong monitoring • QDEHP wildlife strandings • Eye on the Reef sightings network • Qld commercial fishery monitoring • Qld trawl vessel monitoring VARIABLES Dugong abundance Strandings Incidental sightings records (iEotR)	Currently adequate: Long time series of carefully designed broad-scale aerial surveys. Program led by Prof Helene Marsh, with uncertain succession plan and no clear institutional support for the longer term.
Connectivity Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Freshwater inflow o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow	See above	Generally adequate: This is a broad process that spans the pelagic larval phase of many marine organisms through movement of juvenile reef fishes from estuaries to mid-shelf reefs to migrations of turtles, humpback whales and shorebirds. It is critical to maintenance of many marine populations and to recovery from disturbance. Some information on particular species (Whales and turtles) is available.
Recruitment Key pressures/impacts affecting value: o Rising sea level o Cyclone activity	See recruitment objectives under habitats and species	Inadequate: This is a very general category of process that are critical to maintenance of all populations and to recovery from disturbance. Some information gathered for particular groups e.g. Reef Rescue Marine

Biophysical values And pressures/impacts affecting them	**Monitoring programs and variables that have been monitored**	**Adequacy**
o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment run-off o Sediments from catchment run-off o Pesticides from catchment run-off o Outbreak of COTS o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations		Monitoring Program and AIMS LTMP survey coral recruits, there is no information on recruitment for the general majority of organisms in the GBRWHA

3.2.4.4 Discussion of review of existing monitoring on the GBR

Are there new technologies/novel approaches that would make programs more efficient or extend their range?

Advances in communications have meant rapid increases in capacity for reporting remote observations in real time (e.g. sensor networks). Developments in robotics have led to much more capable underwater vehicles that can survey deeper regions than can divers. Similarly, researchers from Murdoch University have used unmanned drones in aerial surveys of dugongs and humpback whales. The use of drones avoids the risk of flying observers over great expanses of open water, and drones can fly lower than is recommended for manned aircraft giving a possible observational advantage. These technologies may reduce the size of field teams, but require a substantial initial outlay and may require dedicated technicians.

Many reef monitoring programs survey benthic organisms using photo-transects, either video or still images. These images then have to be viewed for data reduction, which is laborious and slow and delays reporting. Automatic image analysis is a rapidly evolving field and there are a number of initiatives in Australia and overseas that are seeking to automate analysis of such images.

Approximate costs, funding sources and funding stability

Identifying the costs of many programs is difficult because many government programs are embedded in larger management units, or are part of national or state-wide programs. There is also the need for a standardised costing formula concerning on-costs, salaries, in-kind contributions, etc. The recent rearrangement of Queensland Government agencies is also a disrupting factor.

A number of large scale surveys (e.g. dugong population monitoring, humpback whale population monitoring) consist of a sequence of individual surveys, in some cases supported by different funding bodies each time, with no clear future commitment of support (Table 3.14).

Some of the largest monitoring programs are funded under co-investment arrangements between Department of the Environment or GBRMPA and the monitoring agency (e.g. AIMS), but such arrangements mean that important programs are substantially supported by the agency. For instance, the AIMS LTMP costs approximately $2.8M annually, of which co-funding from the NERP Tropical Ecosystems Hub makes up about 15 per cent.

Table 3.14 Sources of funds for monitoring that is relevant to the GBRWHA, with some examples of programs in each category

Source of funding	Number of programs	Examples
Australian Government	9	Great Barrier Reef and Torres Strait Vessel Traffic Service (REEFVTS) (AMSA); Australian baseline sea level monitoring program (Bureau of Meteorology); Reef Rescue Marine Monitoring Program; Integrated Marine Observing System (IMOS)
Australian Government and Queensland Government	8	Qld Wetlands Program, Seagrass-Watch; Paddock to Reef Monitoring, modelling and reporting program
Australian Government and Industry	1	ReefCheck
Queensland Government	19	Marine wildlife strandings; Weeds and pests on islands; QLUMP; State-wide monitoring of commercial fisheries
Queensland Government, Industry, Science and Industry Endowment Fund (SIEF	1	Reef Temp (eReefs)
Queensland Government and GBRMPA	5	Compliance - Protecting the Reef
Industry (Ports)	10	Port Curtis Integrated Monitoring Program; Ports North Ecological Health Monitoring Program (Cairns)
GBRMPA	7	Integrated Eye on the Reef
AIMS	3	AIMS weather stations (co-funded with IMOS); AIMS LTMP and AIMS Effects of rezoning on offshore coral reef systems (co-funded with NERP)
AIMS and GBRMPA	1	Sea temperature monitoring
James Cook University and NERP	1	Coral trout and prey population trends

3.2.4.5 Gaps and opportunities

Tables 3.11–3.13 show that there are clear gaps in the existing monitoring coverage, both in terms of providing information on identified priority MNES (e.g. deep-water seagrass meadows), impacts and drivers, and also in spatial coverage (e.g. lack of any monitoring of many impacts and drivers in the Far Northern Management Area). Table 3.15 indicates simply whether any current monitoring programs address the values or the pressures, or both, that are involved in each interaction. In more than half the cases, the value is not monitored anywhere in the GBRWHA. There would be many more gaps if spatial coverage was also considered.

While the northern GBR is surveyed by remote sensing and aerial survey techniques, in-water and instrumental coverage is very limited for approximately one third of the GBRWHA that lies north of Cooktown. It is possible that the current view that reefs of the northern GBR are in relatively good condition and have shown little net change in recent decades is based on ignorance.

A priority value for monitoring is seagrass meadows and seagrasses, the basic food resource for dugongs and some marine turtles which are themselves also priority subjects for monitoring. While there is relatively extensive sampling of accessible intertidal and shallow-water coastal seagrass meadows (by Seagrass-Watch, Reef Rescue Marine Monitoring Program seagrass monitoring and especially associated with ports), very little is known about the large areas of seagrass in deeper waters of the GBR lagoon.

Strategic assessments have a long-term perspective (25 years or more), but no existing monitoring program has a funding commitment beyond four years. The AIMS LTMP has surveyed coral cover using manta tows across much of the GBRWHA for 28 years, but rising costs have seen the number of reefs surveyed each year fall from more than 100 to less than 40. Reefs in the Far Northern Management Area were surveyed in 2013 for the first time since 2006 using special funding for crown-of-thorns starfish research from the NERP Emerging Priorities program. Funding uncertainty (e.g. for IMOS) leads to staff turn-over and the loss of skilled and experienced personnel.

Another finding from the review of existing programs is a governance issue: there are several long-term data series concerning priority values (e.g. dugongs) that have been driven by individual champions, without long-term institutional commitment. The data series are often a product of a string of individually funded surveys rather than a formal program with a reliable commitment of funds, and there are no apparent succession plans to sustain monitoring of these high priority values. This is incompatible with the long-term focus of strategic assessments.

In terms of opportunities for better coordination of programs, 15 programs monitor the value 'Coral reefs and corals' in the GBR Region, which implies some redundancy. These programs include long-term programs that monitor status and trends (AIMS LTMP), programs that monitor the effects of management actions (Reef Rescue Marine Monitoring Program inshore reef monitoring), citizen science programs (ReefCheck), and monitoring associated with port developments (Port Curtis & Port Alma Environmental Research and Monitoring Program). These programs have a variety of functions and collect a variety of different types of data on coral reefs and corals and report their findings separately and in different ways. The principal opportunity from establishing an IMP is in establishing a mechanism to draw together, evaluate and interpret the relevant results from a wide range of programs to give the most complete assessment of the status and trends in values and pressures and provide the best available information for managing the GBRWHA.

3.2.4.6 Summary – how the guidance was used

- Details of existing 65 programs were collated following the outline that was endorsed by the steering committee (Appendix 8).
- There are gaps in existing monitoring both spatially and in regards to some of the identified monitoring priorities. Many cause-and-effect interactions are not adequately monitored to understand the relationships.
- There are opportunities to integrate monitoring programs that are addressing similar values or pressures so that they are compatible and contribute more efficiently to an overall monitoring program.
- The results of the review of current monitoring are reported here and feed into relevant sections in Part 3 of this report concerning the application of the guidance to establish an IMF to the GBRWHA.

Table 3.15 Extent of existing monitoring of causes and effects of interactions between priority values and priority pressures (see Table 3.7). Some priority values (e.g. islands, beaches, connectivity, recruitment) cover many possible mechanisms of interaction; some of these may be monitored while others are not. For instance the interaction between rising sea level and beaches and coastline is likely to concern changes in extent of habitat which can be mapped by remote sensing, while the interaction between increased sea and air temperature and beaches and coastline is likely to concern the organisms that live in and on beaches which are not currently monitored.

Key:

White	No interaction or not a priority interaction
Grey	No value or pressure monitoring
Yellow	Only pressure monitoring
Blue	Only value monitoring
Light green	Both pressure and value monitored but interaction not inferred
Mid green	Both pressure and value monitored and interaction partially inferred
Dark green	Both pressure and value monitored and interaction fully inferred

Pressures/ impacts	Islands	Beaches and coastline	Open waters	Seagrass meadows and seagrasses	Coral reefs (<30m) and corals	Mangrove diversity	Marine turtles	Dugongs	Dolphins	Seabirds	Shorebirds	Other invertebrates	Sea snakes	Bony fish	Sharks and rays	Primary production pelagic	Connectivity	Recruitment	Income, economic contribution and employment	Access to Reef resources	Appreciation, enjoyment, aesthetics	Personal attachment	Understanding	Health benefits
Rising sea level	Dark green	Dark green	White	Light green	Light green	Yellow	Mid green	White	White	Mid green	Mid green	White	White	White	White	White	Yellow	Yellow	White	White	White	Yellow	Yellow	Yellow
Cyclone activity	Mid green	Mid green	White	Mid green	Dark green	Yellow	Light green	Light green	White	White	White	White	Yellow	Light green	White	White	Yellow	Yellow	Mid green	Yellow	Mid green	Yellow	Yellow	Mid green
Increased sea and air temperature	Light green	Yellow	Yellow	Dark green	Dark green	White	Dark green	White	Light green	Mid green	Mid green	Light green	Yellow	Mid green	Mid green	Light green	Yellow	Yellow	Light green	White	Light green	Yellow	Yellow	Yellow
Ocean acidification	White	White	Yellow	White	Mid green	White	White	White	White	White	White	Light green	White	Light green	White	White	White	White	White	White	White	White	Yellow	Yellow
Altered ocean currents	White	White	Yellow	Light green	Light green	White	Light green	Light green	Light green	Light green	Light green	Light green	Yellow	Light green	Light green	Light green	Yellow	Yellow	Light green	White	White	White	Yellow	Yellow
Outbreaks of disease	White	White	White	White	Dark green	White	Dark green	Mid green	Light green	White	White	White	White	Mid green	White	White	White	White	Light green	Yellow	Light green	Yellow	Yellow	Yellow
Freshwater inflow	White	Yellow	Mid green	Dark green	Dark green	Yellow	White	White	White	White	White	Yellow	White	Yellow	White	White	Yellow	Yellow	Light green	Yellow	Yellow	White	Yellow	Yellow
Nutrients from catchment run-off	White	Yellow	Yellow	Dark green	Dark green	Yellow	Light green	Light green	Light green	White	Yellow	Yellow	White	Yellow	Yellow	White	White	Dark green	Light green	Yellow	Light green	Yellow	Yellow	Yellow
Sediments from catchment run-off	White	Light green	Yellow	Dark green	Dark green	Yellow	White	White	White	White	White	White	White	White	Yellow	White	White	Dark green	Light green	Yellow	Light green	Yellow	Yellow	Yellow

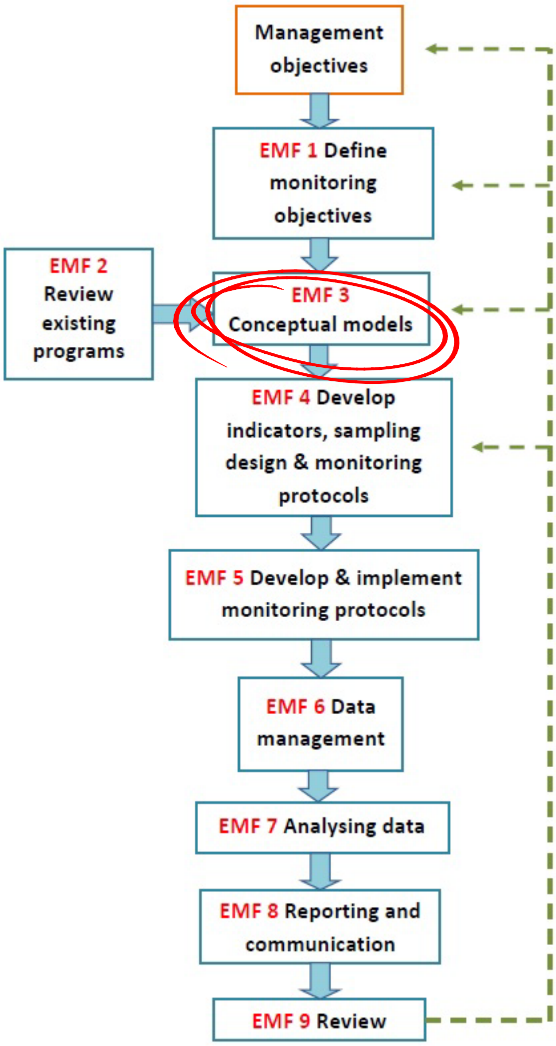
Pressures/ impacts	Islands	Beaches and coastline	Open waters	Seagrass meadows and seagrasses	Coral reefs (<30m) and corals	Mangrove diversity	Marine turtles	Dugongs	Dolphins	Seabirds	Shorebirds	Other invertebrates	Sea snakes	Bony fish	Sharks and rays	Primary production pelagic	Connectivity	Recruitment	Income, economic contribution and employment	Access to Reef resources	Appreciation, enjoyment, aesthetics	Personal attachment	Understanding	Health benefits
Dredging, dumping and resuspension of dredge material																								
Pesticides from catchment run-off																								
Outbreak of COTS																								
Clearing or modifying coastal habitats																								
Coastal reclamation																								
Artificial barriers to flow																								
Death of discarded species																								
Marine debris																								
Noise pollution																								
Illegal fishing and poaching																								
Extraction of predators																								
Fishing spawning aggregations																								

3.2.5 Essential Monitoring Function 3: Developing conceptual models

Guidance from Part 2:

Instigate a collaborative process with experts to generate the following outputs:

- List of conceptual models required to address monitoring priorities identifying existing models and gaps
- Opportunities to fill conceptual model gaps
- Conceptual models to fill gaps (where opportunities exist).



3.2.5.1 Methods

Through the Great Barrier Reef Region Strategic Assessment and an associated research project (A Framework for Understanding Cumulative Impacts and Supporting Environmental Decisions in the Great Barrier Reef World Heritage Area: Anthony et al. 2013), draft qualitative models are being developed to explore the relationships between drivers, activities, pressures and impacts on values for coral reef and seagrass ecosystems and dugong (a dependent species). The models are being developed through workshops with experts in coral reef and seagrass biology and ecology. Although these draft models need further development, they are considered in this report as examples of how a suite of these and other types of model could inform the design of an integrated monitoring program and continue to evolve and improve the program through the adaptive management cycle.

The design stage of the IMP will include details of the underlying conceptual models at varying scales and complexities to explain the rationale of indicator selection, interactions across the DPSIR framework and insights expected to be gained through integration across the monitoring program, where appropriate.

3.2.5.2 Role of models

Modelling plays a critical role in helping managers understand large and complex systems that are subject to cumulative impacts. Their use is fundamental to understanding the multiple cause-and-effect relationships between drivers, activities, impacts and values.

Together with research and monitoring, modelling can assist managers to:

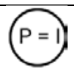
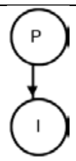
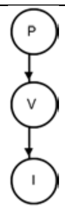
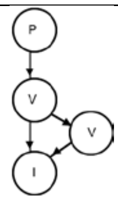
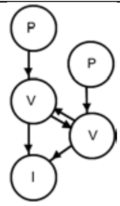
- identify key value and impact indicators for monitoring complex systems

- points for management intervention based on relationships between drivers, pressures, values and impacts
- also identify key areas of uncertainty and can help to tailor future research towards meeting management needs
- compare alternate hypothesis about how a system works
- test various scenarios and make assessments of the relative effectiveness of management interventions (to reduce impacts on values) and monitoring programs.

3.2.5.3 Range of conceptual models

A range of tools, from simple lists to quantitative models, are used to assess the cause-and-effect relationships between impacts and values that underpin MNES. How well each of these 11 tools account for the causal links implied in the DPSIR framework is summarised in Table 3.16.

Table 3.16 Tools to improve understanding of cause-and-effect relationships; adapted from Table 2 of Hayes et al. (2012); reproduced by permission of CSIRO © 2012

	Complexity of cause-effect relationship				
	None[1]	**Simple[2]**	**Directed[3]**	**Diffuse[4]**	**Feedback[5]**
Tools					
1. Unstructured list	✔	✔			
2. Objective-indicator matrix	✔	✔			
3. Structured list		✔	✔		
4. Value-impact matrix		✔	✔		
5. Conceptual diagram or cartoon		✔	✔		
6. Influence diagram		✔	✔	✔	
7. Fuzzy cognitive map		✔	✔	✔	
8. Statistical model		✔	✔	✔	
9. Bayesian network			✔	✔	✔[6]
10. Qualitative process model				✔	✔
11. Quantitative process model				✔	✔

[1]No cause-effect relationship, the pressure is the indicator; methods beyond objective-indicator matrices not needed.

[2]Pressure directly impacts indicator variable; methods beyond statistical models not needed.

[3]Pressure directly impacts a variable that has knock-on effects to indicator variable; methods beyond Bayesian networks not needed.

[4]Pressure indirectly impacts an indicator variable via multiple interaction pathways.

[5]Multiple pressures simultaneously impact complex system with feedbacks between variables.

[6]With difficulty; standard Bayesian networks limited to acyclic graph structures. Dynamic Bayesian networks can account for feedbacks, but are difficult to parameterise and analyse, typically making them impractical for complex systems (but see Box 4 for application with qualitative process models).

P	pressure or impact
V	system variable – an element of the ecological or human system or benefit derived from that system that forms part of the cause-effect relationship but is not measured
I	indicator variable – a measurable indicator (it could be a specific ecosystem element (e.g. seagrass abundance) or benefit derived from the ecosystem (e.g. income) – or a surrogate measure for the health of MNES)

In a complex system such as the Great Barrier Reef, unstructured lists define the scope of the drivers, values or impacts to be considered, but are insufficient on their own as they do not convey any understanding of the interactions between values and impacts.

The use of structured lists (the third tool) that connect the identified impacts to direct drivers and activities is demonstrated in Appendix 2 – Table 4.

Based on an analysis of each impact, value-impact matrices (the fourth tool) are used to comprehensively assess the past and current effect of each impact on each biodiversity, community benefit, Indigenous heritage and historic heritage value (Table 3.7). While these matrices present a comprehensive understanding of the effects of each impact and provide an indication of the severity of the total set of impacts acting on an individual value, they do not allow consideration of complex interactions and cumulative impacts.

Conceptual diagrams, influence diagrams, and fuzzy cognitive maps can be used to map relationships between different impacts, values and processes. These types of diagrams can be employed during the process of building qualitative process models, the tenth tool in the hierarchy.

Qualitative process models provide an initial and general implementation of the full DPSIR framework. They can be used to assess the impact of multiple drivers and activities that act simultaneously on ecological systems (Dambacher et al. 2002, Puccia and Levins 1985) In the examples in Section 3.2.5.5, such models are used to document how key pressures affect MNES associated with coral reefs and seagrass meadows (including dugong). The models were developed in workshops with experts in these fields.

A key advantage of qualitative models is that they provide a relatively rapid and flexible means to understand system dynamics, predict cumulative impacts and consider potential management interventions. Because they can be constructed and analysed relatively quickly, they can be used to compare alternative models of how a system works.

The last tool in the hierarchy, quantitative process model, is useful where management questions require definition of critical thresholds for limits to acceptable change in an MNES. Such models need large amounts of data.

For large complex systems that are subject to cumulative impacts, it is useful to employ the additional tool of Bayesian networks — a type of statistical model that represents system variables and their conditional dependences. Bayesian networks based on qualitative models can carry out four basic analyses to aid integrated adaptive management: *prediction, diagnosis, validation and sensitivity*. Qualitative model predictions, embedded within a Bayesian network, provide an effective means to consider scenarios and to make concurrent assessments of the relative effectiveness of management interventions and monitoring programs.

3.2.5.4 Use of conceptual models to inform the Integrated Monitoring Program

The design of ecological monitoring programs is always based on mental models of how the ecological system functions, even if these are unstated (see Section 2.3.3). However, among the current ecological monitoring programs in the GBRWHA, few are explicitly linked to conceptual models; exceptions include the Seagrass-Watch program and the Reef Rescue Marine Monitoring Program (e.g. Figure 3.6). The SELTMP in development is guided by a simple conceptual model (Figure 3.7).

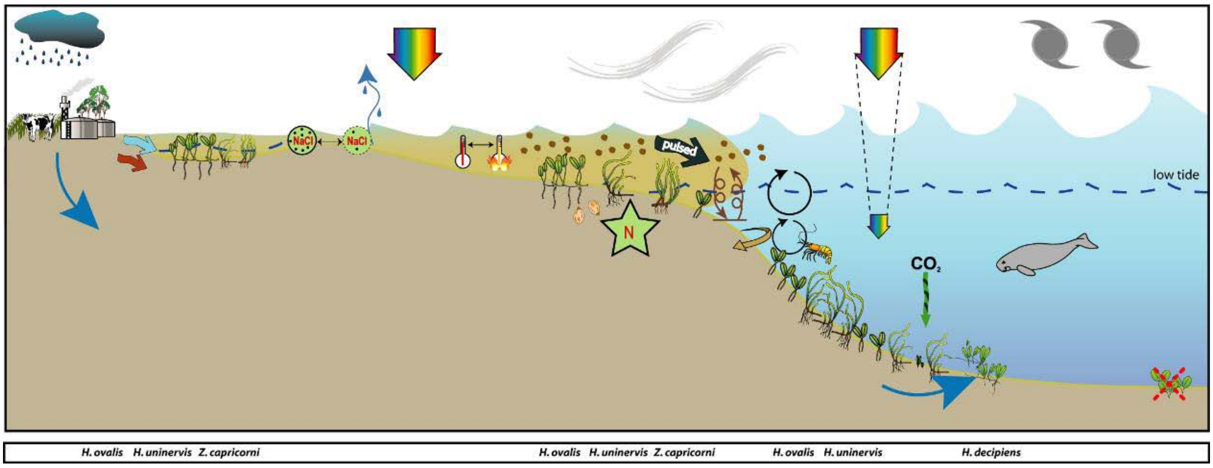


Figure 3.6 Conceptual diagram of coastal habitat in the Burdekin region—major controls are wind and temperature extremes, general habitat, seagrass meadow processes and threats/impacts (see McKenzie et al. 2012 for explanation of icons)

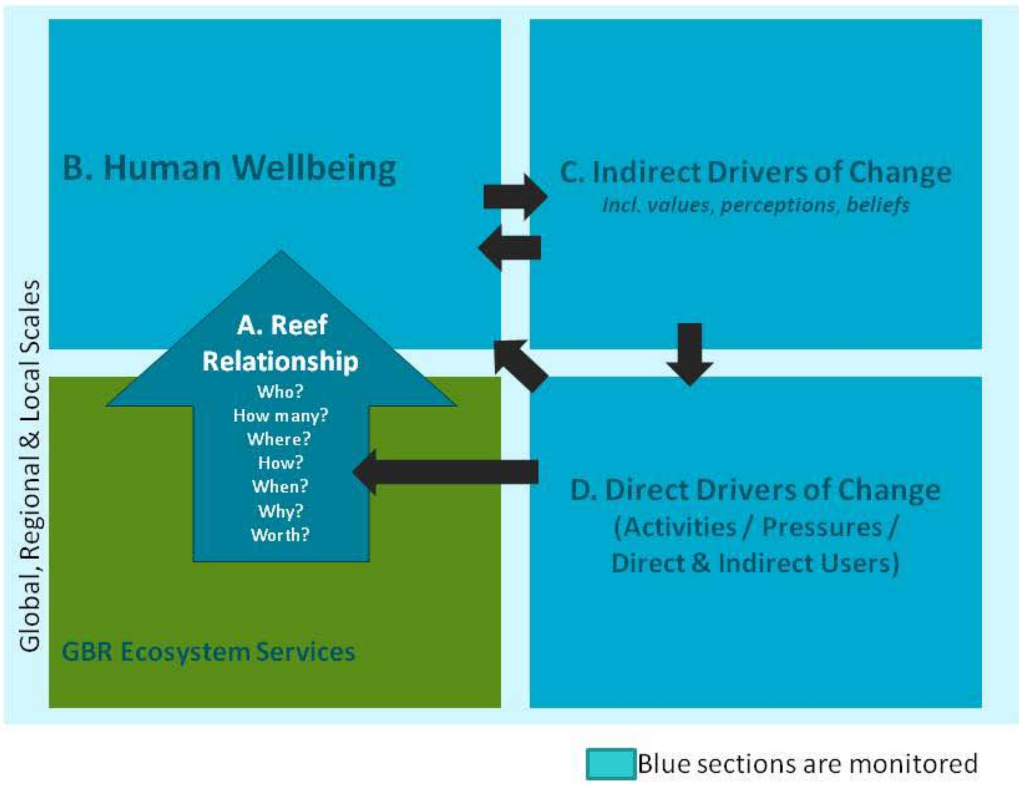


Figure 3.7 Graphic representation of the conceptual model guiding the development of the Socio-Economic Long-Term Monitoring Program

The Great Barrier Reef Marine Park Authority has employed most of the 11 tools in Table 3.16, including structured lists, value-impact matrices (Great Barrier Reef Marine Park Authority 2009b), conceptual diagrams, influence diagrams (Great Barrier Reef Marine Park Authority 2009a) and qualitative and quantitative models, to progressively refine understanding of ecosystems and impacts, and identify those of most concern.

To inform the choice of indicators and overall IMP design we advocate a staged and complementary approach, whereby qualitative process models are used for broader ecosystem understanding and initial assessments of cumulative impacts; and quantitative process models are employed where there are critical management questions and sufficient data, for example related to specific 'at-risk' species or habitats. Knowledge gained from analysis and testing of qualitative models can be used to better focus the application, and inform the construction, of quantitative process models.

An example of this proposed system of related or nested qualitative and quantitative models is Management Strategy Evaluation (MSE). MSE is a multiple objective technique that evaluates the likely level of achievement of the various stakeholder objectives as a result of implementing modelled management strategy options. It is anticipated that with the addition of scenario development and simulation models of varying degrees of sophistication (qualitative to quantitative) managers will be able to project the likely future for key environmental and socio-economic indicators under alternate management regimes, and therefore decide on preferred strategies, set targets, trigger values and acceptable limits of change (see Section 3.2.3).

The design stage of the IMP will articulate this overall system, as well as the details of the underlying conceptual models at varying scales and complexities to explain the rationale of indicator selection, interactions across the DPSIR framework and insights expected to be gained through integration across the monitoring program, where appropriate. Development of models and application to management effectiveness assessments, such as MSE, will take time and continue to be developed over the life of the integrated monitoring program with new information and models being incorporated through the regular review process as detailed in Section 3.2.11

3.2.5.5 Examples of draft qualitative models

Through the GBRWHA strategic assessment and associated resilience decision framework project, qualitative models were developed to examine the relationships of drivers, activities, impacts and values for coral reef and seagrass ecosystems and dugong (a dependent species). The models were developed through workshops with experts in coral reef and seagrass biology and ecology.

The models detail the main variables and effects at a relatively general level of resolution, and exclude minor species groups and weak effects. A number of links are uncertain or contentious; these links provide the basis to consider alternative model structures in subsequent analyses. The models outlined below are preliminary, and will require further refinement and validation before informing the IMP.

A basic feature of qualitative models is the development and analysis of sign directed graphs, or signed digraphs which describe the main interacting variables within a system, linking values and values to their surrounding ecosystem and also to the drivers, activities and impacts of concern. Analysis of the structured lists and value-impact matrices informs assessment of the relative importance of drivers, activities and impacts on MNES, and how they affect the system. While model links are qualitative, such that they represent only the ‘sign’ of the effects (i.e. positive, negative or nil), they nonetheless provide a rigorous means to formally assess a system’s dynamics and its response to disturbances.

The model in Figure 3.8 provides a generalised depiction of the processes that enhance or diminish coral reefs and corals, and the role that coral has in supporting biodiversity. Corals are strongly dependent on successful coral recruitment, compete for space with macro-algae, and provide critical habitat and resource for fishes and invertebrates. Crown-of-thorns starfish can strongly impact corals during outbreaks, and such outbreaks are thought to be enhanced by nutrients. Drivers, activities and impacts on coral reefs do not stand alone, but are intertwined in a complex web of synergistic or cumulative impacts. The figure shows that some cause-and-effect relationships are relatively simple, such as an increase in ocean warming increasing the frequency of coral bleaching events, which then leads to a reduction in coral cover. An increase in the catchment runoff from agriculture, however, leads to increases in three separate impacts (toxins, nutrients, and turbidity and sedimentation) that affect a total of seven ecosystem variables (predatory fish, herbivorous fish, crown-of-thorns starfish, fish and invertebrates, macro-algae, crustose coralline algae and coral recruitment, and coral cover).

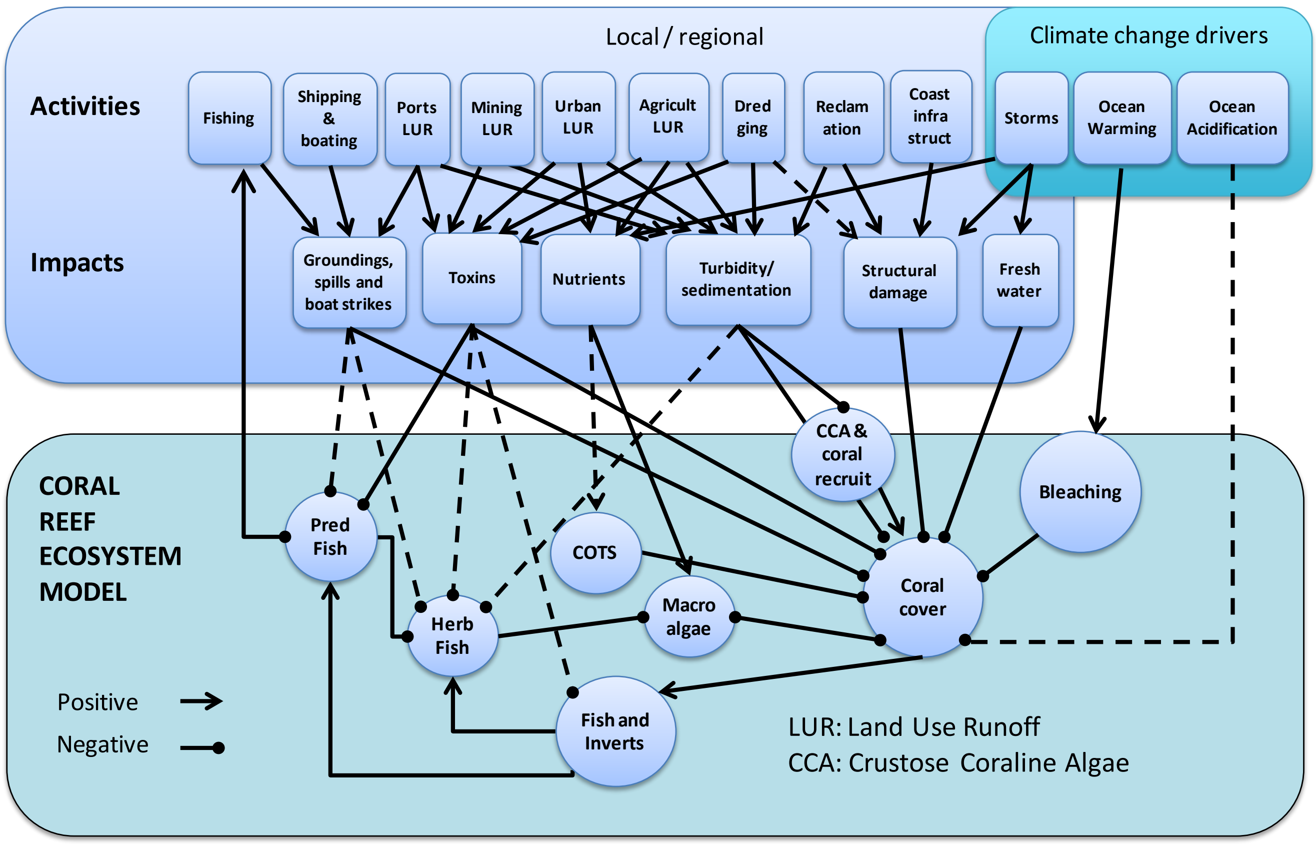


Figure 3.8 Draft qualitative model of how coral reefs are affected by impacts, activities and drivers

The model illustrates how coral reefs are affected by multiple impacts that result from various activities and drivers. It details the main variables and effects at a relatively general (aggregated) level of resolution, and excludes minor species groups and weak effects. Links describe direct positive or negative effects of one node on another. There were a number of links that were uncertain or contentious. These are represented by dashed-line links and provide the basis to consider alternative model structures in subsequent analyses.

The seagrass model (Figure 3.9) represents the dynamics of seagrass communities that can be composed of slow-growing species of seagrass that are favoured by conditions of low disturbance and low levels of grazing ('K' species), or fast growing species that are favoured by frequent disturbances and high grazing pressure ('r' species). A model variable that is a ratio of r : K, represents the relative dominance of these two types of species. In this model dugong populations or storms can act to shift the relative balance between these two types of seagrass species. Other factors that regulate seagrass include epiphytic algae, which grow on the surface of seagrass and can inhibit their growth through shading. Similar to the model for coral reef ecosystems the seagrass meadows model (Figure 3.9) shows that some cause-effect relationships are relatively simple, such as an increase in turbidity and sedimentation suppressing seagrass distribution and abundance, which then leads to a reduction in dugongs. An increase in catchment run-off from agriculture, however, leads to the increase of three separate impacts (pesticides, nutrients and turbidity and sedimentation) that affect a total of five ecosystem variables (scrapers (prawns and fishes), marine turtles, dugongs, epiphytes and seagrass distribution and abundance).

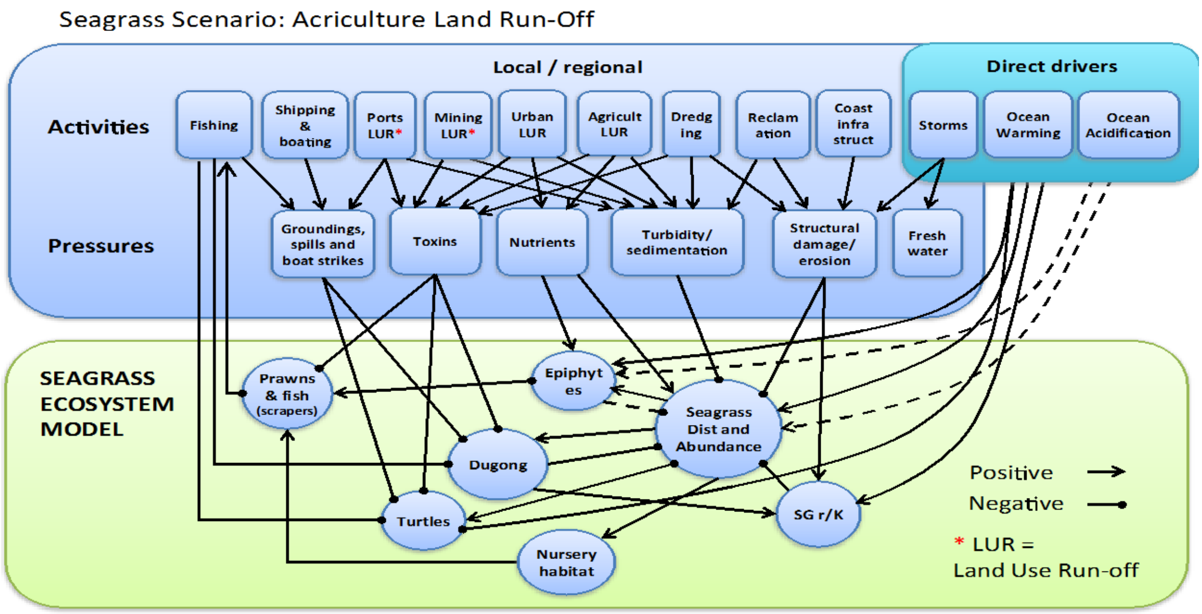


Figure 3.9 Draft qualitative model, or signed digraph, of seagrass affected by multiple impacts

The model illustrates how seagrass meadows are affected by multiple impacts that result from various activities and drivers. It details the main variables and effects at a relatively general (aggregated) level of resolution, and excludes minor species groups and weak effects. Links describe direct positive or negative effects of one node on another. There were a number of links that were uncertain or contentious. These are represented by dashed-line links and provide the basis to consider alternative model structures in subsequent analyses. Some cause-and-effect relationships, again, are more complex. For example, increase in catchment run-off, can have both positive and negative influences on seagrass distribution and abundance.

Further details on conceptual modelling for the GBRWHA are contained in the Regional Sustainability Plan Project 6: *Great Barrier Reef resilience decision framework*.

3.2.5.6 Summary – how the guidance was used

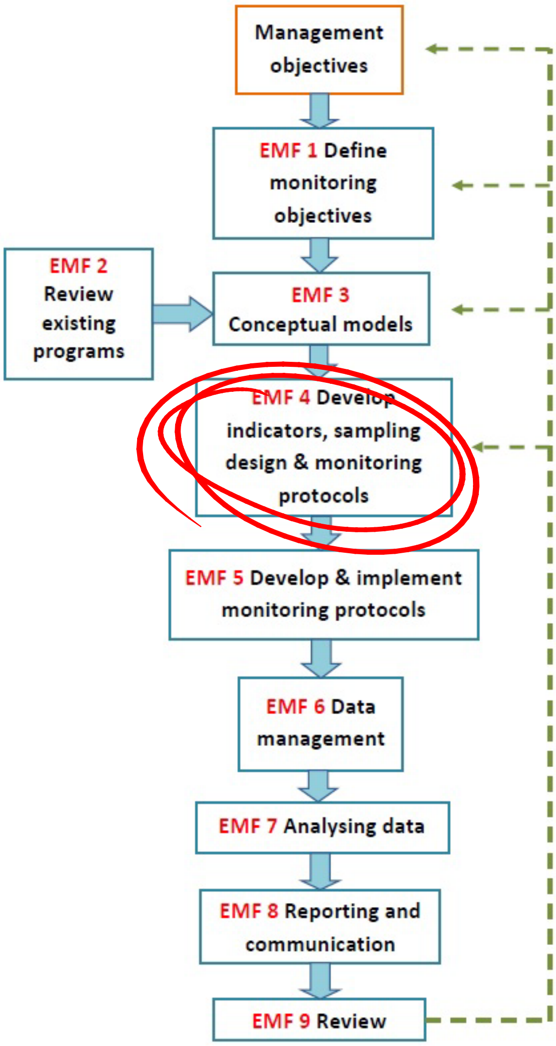
- Among the current ecological monitoring programs in the GBRWHA, few are explicitly linked to conceptual models; exceptions include the Seagrass-Watch and the Reef Rescue Marine Monitoring Program.
- A related research project supporting the strategic assessment and funded under the Sustainable Regional Development program (Great Barrier Reef resilience decision framework) has developed qualitative cumulative impact models for some relevant values in consultation with a wide range of experts.
- This work shows the way forward for describing how the Great Barrier Reef socio-ecological system operates, identifying critical elements, relationships and management 'lever points'; as well as appropriate indicators for monitoring. This work may influence not only the focus of monitoring but also where management is focused.
- Examples of existing conceptual models for coral reefs and seagrasses arising from this research project are provided in this framework. Further work is required to identify or develop similar conceptual models to support monitoring of other values in the World Heritage Area.
- Appendix 8 lists the characteristics of current monitoring programs including conceptual models and/or rationale on which they are based.

3.2.6 Essential Monitoring Function 4: Developing (and refining) overall sampling design for integrated monitoring

4a) Selecting indicators—guidance from Part 2:

Instigate a collaborative process with experts to generate the following outputs:

- a list of selected indicators to support monitoring objectives
- a hierarchy of monitoring objectives, management objectives and selected indicators that identifies the explicit links between each monitoring objective and the selected indicator(s) that support it. There should be a straight line of sight from management objectives to selected indicators.



4b) Selecting monitoring programs for integrated monitoring—guidance from Part 2:

Instigate a collaborative process with experts to produce an outline of the purpose and scope of selected programs to support integrated monitoring. The outline should identify:

- the existing monitoring program options that should be selected to include in integrated monitoring, based on their cost-effectiveness, in particular their capacity to address the high priority monitoring objectives
- the gaps in priority monitoring objectives that are not addressed by step 4a
- options to address gaps in high priority monitoring objective and an analysis of the cost-effectiveness of each option.

4c) Developing (and refining) overall sampling design for integrated monitoring—guidance from Part 2:

Instigate a collaborative process with experts to generate an overview of sampling design requirements for the IMF and an initial assessment of selected monitoring programs that includes:

- statements about the desired level of statistical power and preferred approach to sample site selection for the IMF
- an assessment of selected monitoring programs to determine their capacity to address the needs of strategic assessment. The assessment should consider the level of statistical power,

basis of site selection (i.e. judgemental sampling or probability sampling) and spatial extent of inferences

- identification of opportunities to integrate sampling design across selected monitoring programs to produce cost saving and/or efficiencies for data analysis.

3.2.6.1 Methods

In view of the relatively large number of proposed priority values, pressures, processes and drivers for long-term core integrated monitoring (Table 3.5), the large number of existing monitoring programs (Appendix 8) with different and multiple functions and the strategic assessment which is proceeding in parallel, the project team deferred the process of *selecting* indicators and programs, and *developing* an overall sampling design for the integrated program to the implementation phase of the IMP. Instead this section considers the processes that might be followed to achieve these outcomes in the implementation of the IMP.

3.2.6.2 (4a) Selecting indicators

The existing monitoring programs on the GBR already measure various sets of indicators depending on the objectives of the programs. These indicators were generally selected based on expert opinion. The existing programs provide histories of system dynamics based on those indicators. Qualitative modelling can provide a transparent mechanism for comparing potential indicators, particularly in cases where multiple stressors affect a system. The review of existing monitoring programs in the GBRWHA found that few existing programs used explicit conceptual models. As part of the implementation of an IMP, it will be worth developing the preliminary models shown in Section 3.2.5 further. These models can be used in selection of indicators for any new programs required to address priority monitoring objectives concerning those key ecosystem components that are not addressed by current programs. They can then be used to compare the usefulness of the indicators selected through qualitative modelling with those based on expert opinion that are already in use and that underpin what is known of the dynamics of the ecosystems of the GBRWHA.

3.2.6.3 (4b) Selecting monitoring programs for integrated monitoring

When designing the IMP, existing monitoring programs can be treated in three ways—they can be assimilated directly into the IMP; they can be assimilated in a modified form in terms of sampling methods and sampling design (with attention to comparability with previous methods or design and associated costs of parallel sampling etc.); or they can be omitted from the IMP. Such decisions need to be made in a transparent fashion. Selecting monitoring programs for inclusion in the IMP was considered in two ways during the development of the IMF.

Firstly, participants in Workshop 2 were asked to identify existing monitoring programs that they considered should form the basis of an IMP. The suggestions, which were consistent among break-out groups, are given in Box 8.

Box 8 Existing monitoring programs identified as appropriate for the basis of an integrated monitoring program for the GBRWHA.

This list of programs that were considered fundamental building blocks for a future approach to monitoring the GBRWHA was compiled from break-out groups at Workshop 2 (Townsville, 14–15 November 2012). (in alphabetical order)

- AIMS LTMP – expanded to cover inshore biodiversity and far northern GBR
- Eye on the Reef
- IMOS
- Paddock to Reef (+EReefs)
- Qld fisheries (fishery independent, fishery dependent, by-catch monitoring)
- Seagrass monitoring (expanded to deep water)
- SELTMP + use
- Threatened species monitoring (dugong, turtles, expanded to inshore dolphins)

Secondly, a workshop to develop a process to guide selection of critical monitoring programs (March 2013) identified a number of attributes of monitoring programs that would make them critical (Table 3.17). No differential weighting was ascribed to these attributes, which represent a list of desirable characteristics. Programs with these characteristics will form high value components of an integrated monitoring program.

Table 3.17 Criteria for identifying critical monitoring programs

	Desired attributes	Descriptor
Design aspects	Meets monitoring objectives	The primary consideration. This refers to a program's ability to provide information on indicators relating to high priority monitoring objectives and contribute to adaptive management.
	Accuracy and precision	Program's ability to provide accurate information on status and trends at the spatial and temporal resolution required to meet monitoring objectives.
	Scalability	Ability to use the monitoring results to describe patterns and trends across a range of spatial and temporal scales, and across different levels of resolution (e.g. species to genus, reef to region, months to seasons to decades). Note that strategic assessments take a regional, whole-of-system perspective and consider long (25+yr) timeframes.
	Usefulness to modelling	(Beyond simply reporting status) program results inform modelling and predictions of system status.
	Legacy	Does the program have legacy value that can be built on? (Note that strategic assessments consider long (25+yr) timeframes.)
	Uniqueness vs redundancy	Recognises uniqueness (only program to monitor particular values or impacts).
Operational aspects	Track record	Program's record in delivering on monitoring objectives, sustaining operations and providing information to address management issues.
	QA/QC	Program's systems, processes and track record in ensuring scientific rigour,(e.g. peer review, published SOPs, data used in published literature, scientific and technical oversight of methods, analyses and intepretation, laboratory certification etc.)
	Integration	Program's ability to provide data that can be integrated with other datasets to extend interptretation and useability of data collected; potential for data to be up-scaled to national or internatonal reporting frameworks.
	Cost	Program is cost-effective (i.e. delivers required accuracy and precision at necessary resolution to address monitoring objectives while minimising operational costs).
	Accessiblity to key target audiences	Target audiences can access the program documentation to gain better understanding of the program and resulting data, thus increasing understanding and acceptance of the program; program data and analyses integrate with findings of other monitoring to extend interpretation.
Systems & processes	Data management	Data and knowledge products securely stored in electronic systems, links to data management initiatives (e.g. Australian Ocean Data Network (AODN)).
	Data accessibility	Data easily retrieved and packaged in flexible formats to faciliate use by third parties.
	Data reporting	Data are adequately analysed to provide robust interpretations of patterns and trends; reports produced regularly and are easily accesible; reports tailored to target audiences; program's reports draw on data from other programs.
	Stability and governance	Program has established governance structures that ensure acocuntability, evaluate performance; program has stable funding and is likely to continue into the future; sampling design is stable and is documented, sampling is not constantly changing.

Cost-benefit analysis to prioritise monitoring programs

The costs and benefits of environmental monitoring programs are important factors in selecting monitoring programs for the IMP. Environmental monitoring is essential for managing the GBR Region to inform risk assessment and strategic planning, develop and refine management approaches (i.e. adaptive management), and in improving understanding the GBR system so as to focus management efforts to where they are most needed. Monitoring programs must also fulfil operational requirements and socio-political expectations, and some programs are required by statute. However, monitoring programs require resources and the costs and benefits of monitoring programs need to be balanced.

The review of existing monitoring in the GBRWHA was not able to estimate costs of many programs for several reasons. Many government programs are embedded in larger management units, or are part of national or state-wide programs so itemised figures were not readily available. It is also necessary to standardise costing formulas for on-costs, salaries, in-kind contributions, etc., making this a substantial accountancy task. The recent rearrangement of Queensland Government agencies was also a disrupting factor.

While it was not possible to provide comparable costings for existing Great Barrier Reef monitoring (see Section 3.2.4.4), program costs will clearly vary with the objectives of the program and the level of power required to detect change (Field et al. 2007). In general, monitoring costs increase as the complexity of the system increases, where greater spatial and temporal resolution are required, and with increasing numbers and/or complexity of variables being monitored. Logistical constraints are an important factor, for example, monitoring dissolved inorganic nitrogen levels in deep ocean waters would be very difficult and expensive, whereas tracking the number of tourists arriving at Cairns international airport per year is much easier (and cheaper) to monitor. The GBR's large size, ecological complexity (habitats and biodiversity ranging from rivers and estuaries to deep ocean habitats) and diversity of management issues (local compliance issues to global climate change) place great demands on monitoring programs in the GBR.

Advances in technology such as automated data logging, data analyses, remote sensing and other opportunities such as citizen science have significantly reduced costs of some programs, and these approaches can be employed where appropriate (Newman et al. 2012). Data can now be packaged and shared with real-time or near-real-time reporting, and housed on data servers that can be accessed by dispersed analysts. Technology such as unmanned drones can also decrease costs while increasing monitoring capacity. Monitoring program cost-effectiveness can also be increased by ensuring good program design that optimises sampling design and methods to increase efficiency while maintaining the required level of statistical power and scientific rigour (Field et al. 2007, Lindenmayer and Likens 2010). In Australia these approaches include rotational monitoring designs where sample sites are visited at less frequent intervals (Lindenmayer et al. 2012); indeed these approaches have been used for almost a decade in the Australian Institute of Marine Science's long-term monitoring program for the Great Barrier Reef.

While numerous cost efficiency analyses and cost rationalisation processes can be employed, managers and policymakers must carefully balance the need to maximise efficiency gains with the essential requirement of monitoring programs—providing the outputs needed to fulfil management requirements. Irrespective of cost, the final monitoring design and program implementation must be 'fit-for-purpose', that is, the project must deliver the information and results required to satisfy the stated objectives and desired outcomes of the monitoring program (Lindenmayer et al. 2012). This principle can be extended further when selecting among a suite of potential monitoring programs where it is preferable to have fewer, well designed and robust monitoring programs than many under-developed programs that do not meet end-user requirements (Timko and Innes 2009).

Managers and policymakers must also be aware that complex ecological systems require sustained monitoring efforts over the long term to detect changes arising from impacts or management interventions, and at a spatial and temporal resolution sufficient to detect these trends against background variation (Field et al. 2007). Thus, when resourcing monitoring programs:

> "*the [resourcing] commitment needs to be sufficiently long term to allow a change to be detected over and above the natural temporal fluctuations in the system in question. The time period required will of course vary among study systems, but we would suggest there exist few ecological variables likely to show significant change in less than 5 years, and that 10 years is a sensible minimum target for most ecological monitoring programmes*." (Field et al. 2007).

The slow growth rates of many coral species and the decadal cycles of major disturbances such as outbreaks of the crown-of-thorns starfish mean that 10 years is unrealistically short for assessing long-term trends in some priority values and pressures in the GBRWHA.

One of the most important considerations in enhancing the cost-effectiveness of monitoring lies not in the design of monitoring programs themselves, but in institutional culture and environment surrounding monitoring and the use of monitoring data. Return on investment in monitoring programs is severely diminished if monitoring program outputs are not used by managers. Failure to effectively use and apply monitoring data and/or program outcomes can be due to cultural differences between researchers and managers, different priorities and lack of communication (Field et al. 2007, Lindenmayer et al. 2012). Moreover, the importance and contributions of environmental monitoring need to be better recognised in academic fields, and monitoring professionals should be given the institutional support that facilitates efforts in environmental monitoring (Field et al. 2007, Lindenmayer et al. 2012). Likewise, managers and policymakers must recognise the need to engage effectively with monitoring providers to ensure that monitoring delivers useful outcomes. This requires active collaboration between managers and researchers and investment in institutional arrangements and incentives that help to develop, manage and maintain these connections (Lindenmayer and Likens 2010, Field et al. 2007, Lindenmayer et al. 2012).

The IMF addresses many of these issues and will help maintain monitoring cost-effectiveness by fostering these design principles and technological advances, and will also include other processes to streamline monitoring and maximise gain. For example:

- Clearly linking monitoring programs to management requirements and objectives reduces ambiguity and ensures monitoring is prioritised to the most important needs (Rudd 2011, Lindenmayer and Likens 2010).
- Integrating monitoring data through initiatives such as eReefs ensures that the data collected are used to the maximum extent possible.

- The IMF process provides an important integration step that systematically examines the suite of GBR monitoring programs and identifies links and redundancies among them, thereby increasing overall program efficiency, building synergies among projects and adding value to existing efforts.
- Effective knowledge management reduces the loss of previously collected information and can also enhance data discoverability and access, facilitating further use of existing information (adding value to existing information). This will extend the use and reuse of data, thus maximising value extracted from a monitoring program.
- Establishing a process of regular evaluation and review of the monitoring program and formalising these links and processes with statuary reporting requirements such as the *Great Barrier Reef Outlook Report*.

Monitoring performs essential roles in managing the GBR Region, and the cost and benefits of monitoring should also be kept in perspective with the wider social and economic context. For example, the cost of managing the GBR Marine Park is less than one per cent of the estimated annual economic return generated from the GBR and investment has decreased since 2004 (McCook et al. 2010). While monitoring programs must be efficient and cost-effective, managers and policymakers should consider the cost of GBR monitoring programs within the wider social, cultural and economic context – how much the GBR is worth to Australia and the communities that depend on it? And what is the relative cost of monitoring programs in relation to these values?

3.2.6.4 (4c) Developing an overall sampling design for integrated monitoring

The GBRWHA is unusual in the Australian marine estate in that there are a large number of programs that are currently gathering different types of data on varying spatial scales within the Region. In some cases they have been operating for a considerable time. An integrated monitoring program should build on this legacy wherever there is good alignment with high priority monitoring objectives. The overall sampling design of an IMP for the GBRWHA will describe how, where and how often samples are to be collected. This should be based on identified monitoring priorities, and ultimately on the management priorities. These will determine the spatial extent for inferences and hence inform site selection and considerations of statistical power. A basic function of the IMP will be to ensure that the priority impacts are assessed in such a way that they can be clearly related to changes in indicators of 'ecosystem health' (which has not always been true under the approach to monitoring in the GBRWHA in the past). The need for information to support management decisions within an appropriate time frame will determine the intensity of sampling. For instance, the move to sampling the core AIMS LTMP reefs in alternate years allowed other important information to be gathered, but it hindered the attribution of the causes of change because the longer interval between surveys meant that more disturbances occurred. It is also logical that more frequent surveys are more likely to give early warning of a developing impact. Assessing existing programs and designing the IMP will require one or more expert workshops with participation from statisticians and experts in survey design, as well as field biologists who understand practical constraints.

In regard to sampling design, the guidance strongly favours a probabilistic rather than judgemental approach to selection of survey sites (see Section 2.3.4c), but acknowledges the challenge of integrating existing invaluable monitoring legacy into a fully integrated program. Many existing programs in the GBRWHA do not really conform to either scheme. For instance, the AIMS LTMP survey reefs were chosen to be stratified by latitude and by position on the continental shelf (representing a well-documented gradient of coastal to oceanic influence), but within those strata, survey reefs were selected because of the existence of prior data or for logistical considerations (e.g. good anchorages) rather than through a true randomisation process or because they were judged to be representative on any biological grounds. Many citizen science programs (e.g. ReefCheck, Eye on the Reef Tourism Weekly Monitoring) are constrained by the location of tourism operations (principally on mid-shelf reefs near Cairns and Airlie Beach) because the participants depend on these for access to survey sites. The implications of such sampling allocation will need to be explored early in the design phase of the IMP to ensure compatibility with an overall design before existing programs are incorporated into the IMP.

At a whole-of-GBRWHA scale, spatial distribution of monitoring can be guided by the zones of influence of pressures acting on values. Though some pressures act across the entire GBRWHA many others are confined to the populated urban coast (see Section 3.2.3.8). Inshore areas along the urban coast are known to be the most impacted areas in the GBRWHA (GBRMPA 2009a) where many impact zones of influence overlap resulting in cumulative impacts. Figure 3.10 illustrates a conceptual spatial distribution of monitoring intensity for the GBRWHA. Along the urban coast where catchment run-off as well as impacts form ports and built-up areas overlap to form 'hotspots', sampling would be more dense. Offshore and in the north, sampling would be spatially less intense. Through integration, monitoring activities undertaken by ports and other stakeholders would form nodes of long-term government-funded monitoring.

3.2.6.5 Summary – how the guidance was used

Rather than selecting indicators, monitoring programs and developing an overall sampling plan for the IMP at this stage when the scope and resourcing of the IMP has not been set, this section identified the aspects of these topics that must be considered in the implementation of the IMP for the GBRWHA.

Indicators

- Indicators or attributes currently being monitored against prioritised values are listed and gaps have been identified (Figure 3.15).
- The hierarchy of management and monitoring objectives are presented in two examples: coral reefs and seagrass meadows (Tables 3.8 and 3.9).
- Continued development of conceptual models will validate current indicators and inform selection of new indicators.

Selecting monitoring programs

- Criteria for selecting monitoring programs were developed through an expert workshop.
- The most important attribute of a monitoring program is its relevance to priority monitoring objectives.
- The monitoring program must be fit-for-purpose but be rationalised based on available funds through an analysis of cost-effectiveness. There are strategies to improve cost-

effectiveness of monitoring including technological advances, sharing of resources, use of citizen science programs and partnering with industry.

- The principles of integrated monitoring favour focusing on a few effective programs rather than a larger number of poorly developed programs.
- Strategic assessments take a regional, whole-of-system perspective and consider long (25+yr) timeframes, emphasising the importance of building on previous investment in monitoring.

Sampling design

- The selection of the most appropriate approach to sampling design will depend on the indicators selected and their respective priorities, which in turn, depend on the outcomes of the conceptual modelling work.
- The design of an IMP needs to build effectively on past and present monitoring and existing monitoring.
- Knowledge of available resources is fundamental to determining appropriate sampling design for an IMP.
- While the guidance in Part 2 favours a probabilistic approach to sampling design for monitoring programs existing monitoring in the GBR does not generally conform to this approach.
- This component of the guidance will be dealt with during the design phase of the integrated monitoring program.

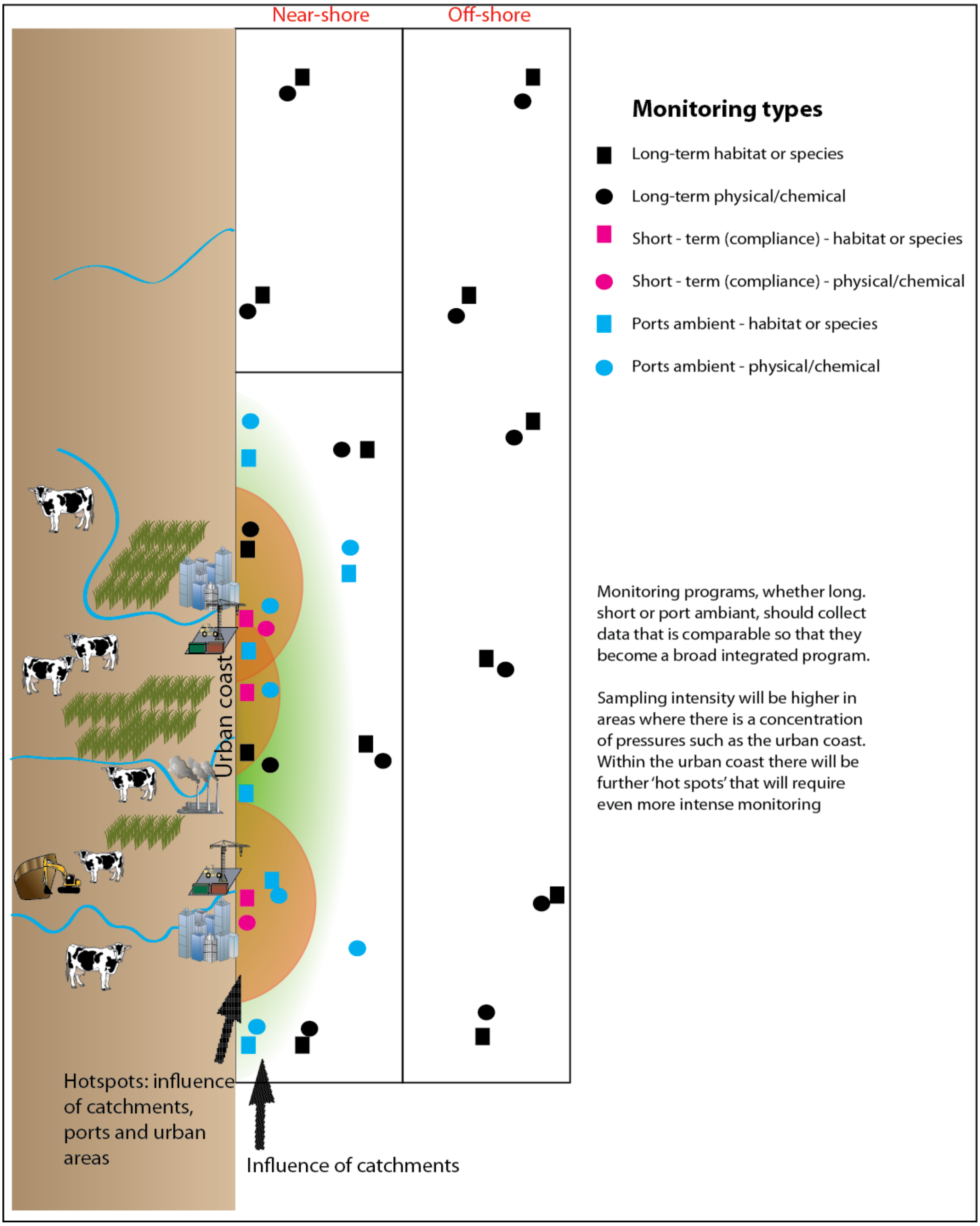
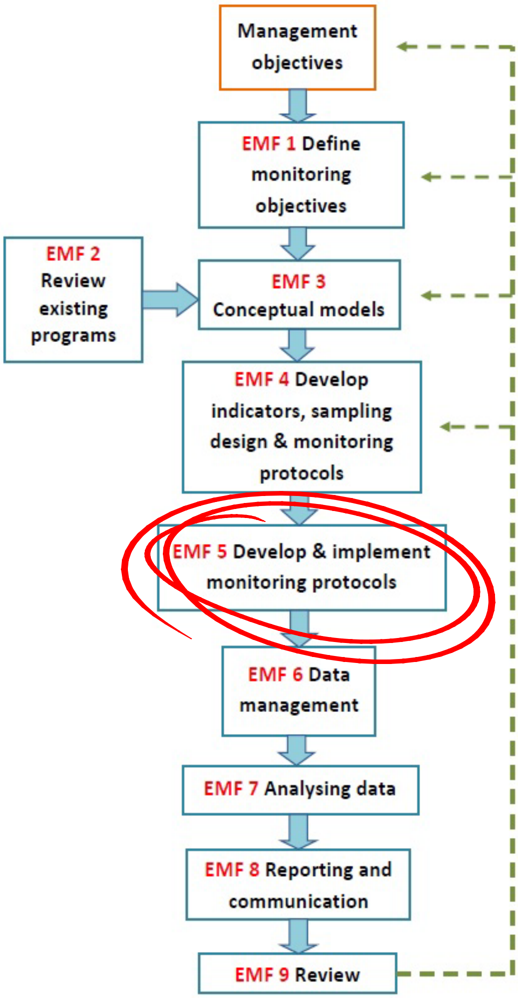


Figure 3.10 Conceptual example of spatial distribution of monitoring and integration of government- and non-government-funded monitoring

3.2.7 Essential Monitoring Function 5: Developing monitoring protocols

Guidance from Part 2:



Instigate a collaborative process with experts to generate an outline of the purpose and scope of monitoring protocols for integrated monitoring. The outline should identify:

- the relationship between monitoring protocols for integrated monitoring and
  - o data collection
  - o data management processes and standards for integrated monitoring (see Section 2.3.6)
  - o data analysis for integrated monitoring (see Section 2.3.7)
  - o reporting and communication for integrated monitoring (see Section 2.3.8).
- existing monitoring protocols that could be used as a basis to develop monitoring protocols for integrated monitoring, in particular their alignment with selected indicators (see Section 2.3.4a) and selected programs (see Section 2.3.4b)
- significant gaps in monitoring protocols for integrated monitoring that would need to be filled and potential opportunities to fill gaps
- preferred monitoring protocol standard for the IMF
- role of governance committee(s) in developing, approving and refining monitoring protocols.

3.2.7.1 Methods

A vital consideration in designing an integrated monitoring program is to ensure that data from different sources are compatible, and that data from a program are collected in the same way over time, in spite of staff changes. In general, designing an integrated program for an area as large and diverse as the GBRWHA and incorporating a variety of existing programs that are currently independent, will require numerous decisions on many aspects of the program that need to be justified on scientific and practical grounds. Having existing protocols to address particular values and pressures, would mean that new programs, for instance short-term programs associated with coastal developments, can adopt these methods and procedures so that their results are immediately compatible with the broader IMP.

Developing monitoring protocols for the IMP will need to occur in parallel with the program's implementation, following finalisation of the steps in 3.2.6. This section discusses the components of a monitoring protocol and seeks to identify which of those components may already exist.

3.2.7.2 Results

Monitoring protocols should encompass the entire monitoring data cycle from collection to reporting (Section 2.3.5). Oakley et al. (2003) recommend that protocols for long-term monitoring programs should include:

- a narrative that gives background information on why a particular component or process of the ecosystem was selected for monitoring, together with an overview of the various components of the monitoring protocol, including the objectives, the sampling design, field methodology, data analysis, data archival and reporting, personnel requirements, training procedures, and operational requirements
- a set of Standard Operating Procedures (SOPs) that provide detailed, step-by-step instructions on how each component of the protocol is to be completed, including instructions for how any of the SOPs are to be amended
- supplementary materials that provide additional guidance and support, and can include items such as reports, photographs, data analysis example, etc.

None of the programs considered by the review (Appendix 8) mentioned such comprehensive documentation, though there are a number of publicly available documents that could be classed as SOPs. For example, the *Survey Manual for Tropical Marine Resources* (English et al. 1997) is a general text on ecological and general biophysical sampling that includes simple advice on data handling. The AIMS LTMP produces and updates SOPs for each type of sampling (www.aims.gov.au/docs/research/monitoring/reef/sops.html). In particular, the citizen science programs (e.g. ReefCheck, Eye on the Reef weekly surveys, Seagrass-Watch) have produced extensive manuals describing their sampling methods and procedures for use in training volunteers. Though workshops and consultation between statisticians and field biologists, these could form a starting point for expert evaluation in the context of developing protocols for the IMP.

These programs all concern the values coral reefs and corals or seagrass meadows and seagrass, leaving most high priority pressures and values unaccounted for. As the IMP is implemented, comprehensive documentation of the methods and procedures will be an early task once critical monitoring programs have been selected.

Documentation of protocols similar to those used by the USNPS (Oakley et al. 2003) will ensure that the chosen methods are carefully described (and frequently reviewed and updated as necessary) but it will also be important to maintain a narrative document (*sensu* Oakley et al. 2003) to ensure that the bases for critical decisions in the development of the integrated monitoring program design and survey methods are well documented (beyond the minutes of advisory committees) and available as foundation for subsequent reviews and refinements.

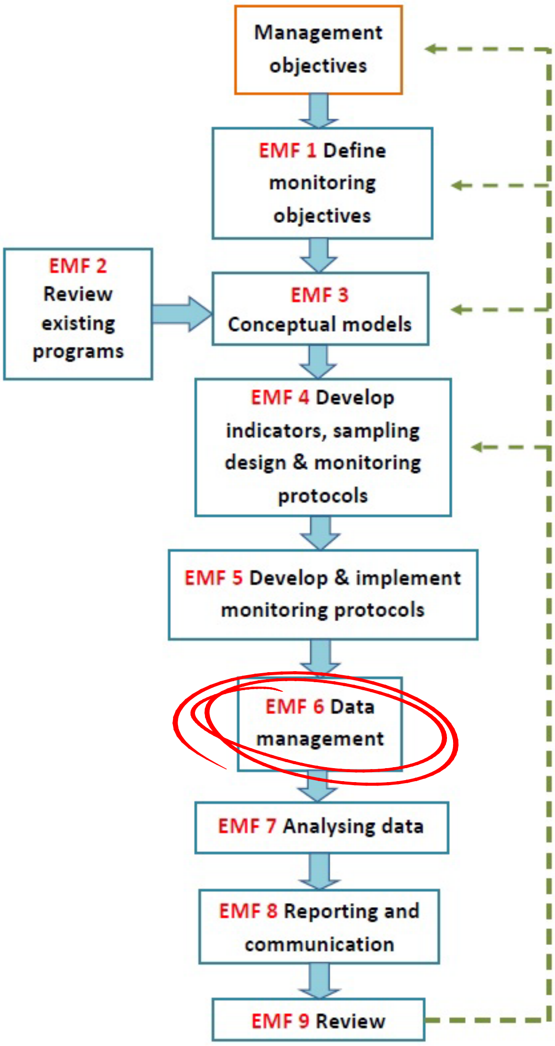
A critical part of the design of an IMP will be to schedule regular and frequent reviews of how well the program serves adaptive management of the GBRWHA, and whether changes in understanding of the ecological system (or in the ecological system itself) necessitate reassessment and redesign of components of the IMP.

3.2.7.3 Summary – how the guidance was used

- Most existing monitoring programs in the GBRWHA do not publish comprehensive descriptions of methods and procedures. Identifying these methods and determining which ones may form the basis of monitoring protocols for the GBRWHA IMP will be an early priority in the implementation phase of the IMP.
- Monitoring protocols should be developed during the design phase of the integrated monitoring program using the information derived from the conceptual modelling, indicators and sampling design processes.
- The selection of monitoring protocols will depend on the indicators and sampling designs selected, which in turn, depend on the outcomes of the conceptual modelling work and sampling design stages.

3.2.8 Essential Monitoring Function 6: Managing data

Guidance from Part 2:



Instigate a collaborative process with experts to generate an outline of the purpose and scope of data management for integrated monitoring. The outline should identify:

- options and preferred data management model for discovery, storage and access to monitoring data
- overview of existing data management infrastructure, processes and standards that would support discovery, storage and access to monitoring data to support the IMF
- significant gaps in data management that would need to be filled and potential opportunities to fill gaps
- the relationship between data management processes and standards and monitoring protocols (see Section 2.3.5)
- the role of governance committee(s) in data management for integrated monitoring.

3.2.8.1 Methods

A workshop was held involving all parties of the project team and representatives from relevant data centres and portal administrators including Integrated Marine Observation System, Australian Ocean Data Network, Australian Institute of Marine Science Data Centre, Great Barrier Reef Marine Park Authority Data Centre, eAtlas, Terrestrial Ecosystem Research Network, Queensland Fisheries, Australian and Queensland Government Paddock to Reef integrated monitoring, modelling and reporting program, and Environmental Resources Information Network (Department of the Environment).

The workshop aimed to identify:

1. the preferred IMP data management approach to support an integrated monitoring program for the GBRWHA
2. important data management characteristics and principles for discovery, storage and access to monitoring data
3. existing data management arrangements for the GBRWHA
4. opportunities for integration and standardisation of data management arrangements to support an integrated monitoring program for the GBRWHA

5. governance requirements and issues for data management to support an integrated monitoring program for the GBRWHA.

3.2.8.2 Results

Monitoring data in the GBRWHA are generated by a wide range of institutions which have their own systems for storing data and making it available. Not all government-funded long-term and shorter-term monitoring data are easily discoverable and/or available by/to government or other interested parties. Data storage arrangements vary from carefully curated government or institutional data systems to management by lead researchers of individual programs. There are a large number of marine data portals that make metadata discoverable, but use of these is currently uneven across programs. Data management is an essential function of any program and it is clearly important that an IMP is supported appropriate data management procedures.

Recently the USA has introduced changes that make data citable. Similar changes are coming in Australia. In effect this means that the citation list for data owners increases each time their data are used by another author. The system promotes value-adding and generates far greater return on investment for research and monitoring but it can only be effective if data are discoverable and accessible.

A broad range of existing data management initiatives is relevant to the GBRWHA (see list below). However, improved discoverability and accessibility under the proposed integrated monitoring program will improve the benefits managers derive from existing data management initiatives. Coordinated collaboration between end-users and existing data management systems is the key to deriving benefits. Data management systems should include tools that directly meet users' needs. Data discovery is clearly an important requirement of a data management system for the GBRWHA IMP but after discovery of the relevant time-series data, continued timely access to that data is imperative.

Following is a list with brief descriptions of the most important data portals and repositories for Great Barrier Reef monitoring data.

GBRMPA Spatial Data Centre

The Centre has a wide range of management relevant GBRWHA spatial data.

eATLAS

The eAtlas makes data available through maps, data, metadata and tools. It houses research data from 38 NERP Tropical Ecosystems research projects, six Reef Rescue Marine Monitoring Projects and the Marine and Tropical Sciences Research Facility. In addition, to give context to research data, reference data are used from the Queensland Government Information Service, Great Barrier Reef Marine Park Authority, Wet Tropical Management Agency, Torres Strait Regional Authority, Geoscience Australia, Landsat, Moderate-resolution Imaging Spectroradiometer (MODIS), and Natural Earth Data.

Australian Ocean Data Network (AODN) and Integrated Marine Observation System (IMOS)

This portal is the primary access point for search, discovery, access and download of data collected by the Australian marine research community. Primary datasets are contributed by the IMOS, an Australian Government Research Infrastructure project, and the six Australian Government agencies with responsibilities in the Australian marine jurisdiction (Australian Antarctic Division, Australian Institute for Marine Science, Bureau of Meteorology, Commonwealth Science and Industrial Research Organisation, Geoscience Australia and the Royal Australian Navy).

Australian Bird and Bat Banding Scheme

The Australian Government's Australian Bird and Bat Banding Scheme manages the collation of information on threatened and migratory bird and bat species. The information provided spans from 1953 to the present, and contains over two million records.

Environmental Resources Information Network (ERIN)

ERIN is a provider of information expertise and services, a broker and facilitator of information and an information hub. It deals with environmental and spatial information through acquisition, analysis and management, delivery through maps, databases, applications and tools, policies, standards and advice, and software management.

Terrestrial Ecosystem Research Network (TERN)

TERN provides national and enduring access to coastal data of national importance. Focus areas include time-series data, video-based data analysis, biological data, and coastal information.

Spatial and Scientific Information for Management of the Reef (SSIMR)—Queensland Government

SSIMR provides the framework, infrastructure and processes to improve information management to support scientific and research activities conducted as part of the Paddock to Reef Program.

Fisheries database—Queensland Government

This will replace the Coastal Habitat Resources Information System (CHRISweb) to house commercial and recreational fishery catch data for Queensland.

Atlas of Living Australia (ALA)

The Atlas of Living Australia contains species information aggregated from a wide range of data providers, including museums, herbaria, community groups, government departments, individuals and universities.

National Plan for Environmental Information (NPEI)

A joint initiative of the Bureau of Meteorology and Department of the Environment established in 2010. The initiative will bring together Australian Government interests in environmental information, to build and maintain environmental information products and services that enable Australia to better manage its natural capital.

Critically, it will establish the Bureau as the central coordinating authority for environmental information to provide an institutional base for addressing the Australian Government's environmental information needs.

In the first phase of the initiative, from 2010 to 2014, the Bureau and the Department will undertake the following activities:

- review the efficiency, effectiveness and appropriateness of existing Australian Government governance of environmental information activity
- introduce legislation to establish the Bureau as the Australian Government central coordinating authority for environmental information
- develop a National Plan for Environmental Information
- establish and implement processes to identify and prioritise requirements for environmental information across the Australian Government, including a targeted review of environmental information requirements
- develop priority national environmental information products and services
- scope the requirements for development of national environmental accounts
- develop environmental information standards to facilitate discovery, access and exchange of environmental information
- commence the development of an environmental information system to support the delivery and discovery of priority environmental information.

AIMS Data Centre

The AIMS Data Centre provides a repository for all data generated by the Australian Institute of Marine Science through infrastructure for metadata, spatial and temporal data services and visualisation and automation for routine collections.

Tropical Data Hub (TDH)

The Tropical Data Hub, based at James Cook University, is an open portal enabling researchers to submit information relating to the tropics in an open and collaborative way. The TDH complements existing data repositories.

Information available through the TDH relates to the physical and natural environment, societies and communities (e.g. linguistic and cultural data), and economics. The use of metadata will ensure that the TDH is readily accessible to governments, researchers and the business sector.

Industry and non-government organisations

Currently there are no standardised requirements for data collection, storage and accessibility of monitoring programs undertaken for the purposes of permit compliance or environmental impacts assessments. This needs to be addressed through the integrated monitoring program.

3.2.8.3 Principles for data management approach

Data must be useable and accessible for over 25 years. This can be achieved by making data self-describable rather than described by the system and by using common standards rather than unique/bespoke standards to maximise the ability to move data to new systems as required. Key principles include:

- development of institutional capacity (as opposed to reliance on individuals)
- clear definition of data community (data generators and users)
- secure funding
- clear definition of roles and responsibilities
- development of clear licensing requirements for data, with a preference for Creative Commons by Attribution
- encourage open access of data (this requires a cultural shift), with an exception for confidentiality if required
- clear articulation of benefits to users
- access to data to inform priorities for adaptive management.

3.2.8.4 Characteristics of data management approach

For monitoring data to be used and useful to management it has to be discoverable, appropriately stored and accessible. Characteristics of data management that improve the efficiency of data use by managers and add value to investments in data generation include:

- intuitive data discovery, including through metadata
- clearly defined data storage options
    - secure
    - distributed and centralised hosting of data
- agreed standards for data community (including version control)
- inclusion of social, economic and environmental data (and cultural data where appropriate)
- an agreed and common vocabulary and key words
- data collection protocols to enable data integration
    - like with like (e.g. linking regional to national)
    - unlike with unlike (e.g. MNES value data with pressure/threat data)
- clear definition of terms and conditions of data use, including rules for acknowledging provenance
- options for entry –flexibility in the level of investment for data providers
- data map –identifying monitoring priorities, critical monitoring programs, institutions (data providers/custodians) and contacts

- regular archiving of data—periodic snapshots of data that are securely stored
- appropriate funding. Investment in data management, analysis and reporting should be approximately 30 per cent of the cost of monitoring programs. Appropriate investment upfront allows for several-fold increases in the value of data over the long term
- a long-term perspective, including management well beyond the life of the data collection period. Datasets appreciate over the long term, increasing in value as data continue to be added. The data management system should to be treated as an asset and include management elements of planning, implementation, maintenance, decommissioning and upgrade.

It is proposed that monitoring information (data) and knowledge products (e.g. maps, reports and models) will be managed though national data nodes and libraries such as eAtlas, the AIMS Data Centre and the libraries of individual institutions. These data centres and libraries will use common metadata standards for managing and archiving information (e.g. ISO 19115) to allow information to be easily discovered and retrieved. Data portals such as the AODN will provide links to individual data nodes and institutions so that end-users can easily locate and retrieve data and information. Interoperability and coordination between data nodes may be enhanced through the implementation of Australia's National Plan for Environmental Information.

It is intended that long-term monitoring data collected by the research institutions, including reports, would be stored in the eAtlas as well as the AODN. Issue-specific and compliance monitoring data would be stored in a purpose-built system due to the sensitive nature of some of this data. The system would allow data to be discovered and accessed by managers, researchers, stakeholders and the general public.

Processes and resources should be in place to synthesise long-term data and reports with issue-specific and compliance data. This synthesised information must be delivered in a digestible and timely manner to feed into policy and regulatory decision processes and reporting.

3.2.8.5 Summary – how the guidance was used

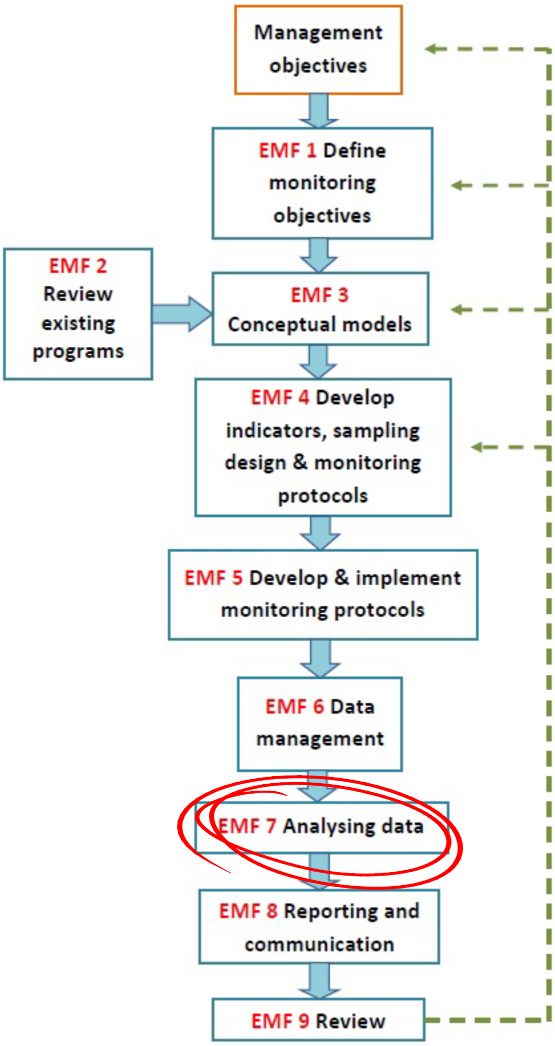
- An expert workshop was convened to discuss how data could and should be managed for an integrated monitoring program for the Great Barrier Reef.
- A clear picture of current data management emerged as well as potential linkages and collaborations that will be explored into the future.
- Principles and characteristics of data management were developed.
- It is proposed that monitoring information (e.g. data) and knowledge products (e.g. maps, reports and models) will be managed though national data nodes and libraries such as the Australian National Data Network, ALA, eAtlas, the AIMS Data Centre and the libraries of individual institutions.

3.2.9 Essential Monitoring Function 7: Analysing data

Guidance from Part 2:

Instigate a collaborative process with experts to generate an outline of the purpose and scope of the integrated data analysis for integrated monitoring. The outline should identify:

- general options and preferences for undertaking and completing an integrated data analysis and role of guidance for the integrated data analysis
- the relationship between integrated data analysis and conceptual models and governance committees
- existing examples of integrated data analysis in the focus area
- significant gaps in integrated data analysis that would need to be filled and potential opportunities to fill gaps.



3.2.9.1 Methods

The project team reviewed existing monitoring programs, including a broad judgement of whether each program was useful to management. The steering committee determined that review of the statistical analysis undertaken by each monitoring program was out of scope of this project.

The IMP design stage will address data analysis. In particular, the development of the program will emphasise improving standardisation of data collection to allow the appropriate integration, analysis and interpretation of data.

3.2.9.2 Results

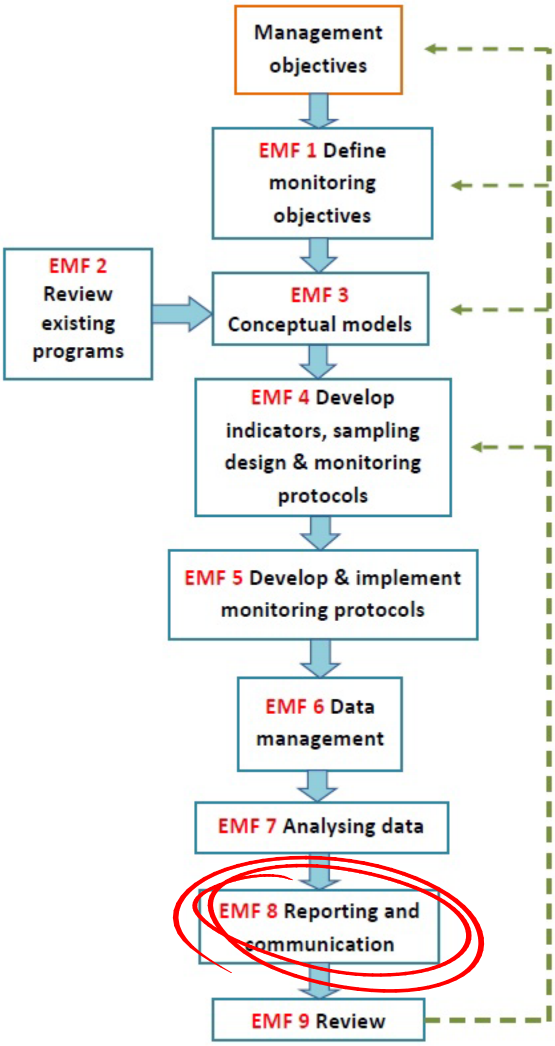
Carefully considered analyses will be very important for extracting value from the monitoring effort and for refining the integrated monitoring program. There are at least two reasons why this essential function will require considerable attention when implementing an IMP. First, as the review of existing monitoring shows, many programs currently report only basic summaries of the data that they gather. Secondly, one primary value of an integrated monitoring program lies in drawing together all available information about drivers, impacts and elements of MNES to assess progress towards management objectives and to ensure that adaptive management of the GBRWHA is based on the best available information. This implies a need for a separate overarching analysis and reporting group or unit that works under the direction of the technical advisory group (see Figure 3.5) and with all the constituent monitoring programs to synthesise their findings into an integrated product, rather than relying on collation of the sets of analyses of their own findings by individual programs (however carefully specified) to achieve this end.

3.2.9.3 Summary – how the guidance was used

- The data management steps (see Section 3.2.8) provided ideas for future structures and processes that could be used to integrate and analyse information obtained from monitoring.
- Integrated monitoring implies the need for an overarching analysis group whose task is to draw together the results from all of the individual monitoring programs to provide the most complete information possible as a basis for adaptive management of the GBRWHA.
- This component will need to be further developed during the design phase of the integrated monitoring program.

3.2.10 Essential Monitoring Function 8: Reporting and communication

Guidance from Part 2:



Instigate a collaborative process with experts to generate an outline of the purpose and scope of reporting and communication for integrated monitoring. The outline should identify:

- key sources of information and target audiences
- general options and preferences for reporting and communications
- existing reporting initiatives and outputs that could support integrated monitoring
- significant gaps in reporting and communication that would need to be filled and potential opportunities to fill gaps
- the relationship between reporting and communication and monitoring protocols
- the role of governance committee(s).

3.2.10.1 Methods

The project team compiled information on reporting and communication mechanisms currently employed by monitoring programs in the GBRWHA (see Appendix 8). In particular, they considered how information was gathered and synthesised for the 2009 *Outlook Report*. It was determined that reporting and communication efforts for the IMP as a whole should build on existing mechanisms to inform the *Outlook Report*. It is anticipated that the integrated nature and coordinated approach proposed for the IMP would directly improve the relevance and timeliness of monitoring information to management for the regular reporting requirements of the Outlook Report.

Monitoring information is needed more frequently than the five-yearly *Outlook Report* cycle for day-to-day management of the GBRWHA and timely communication. The project team determined that the individual reporting timeframes for each component of the integrated monitoring program would be identified during the program design stage. Advice would be sought from relevant experts regarding a suitable reporting schedule depending on the characteristics of the driver, value or impact being monitored. The project team would then consider this in light of management needs and approximate scale of funding to agree an optimal reporting schedule for each component of the Program.

3.2.10.2 Results

Research and monitoring as well as community derived data are captured, synthesised and presented every five years through the *Outlook Report* for the Great Barrier Reef Region. The *Outlook Report* is a statutory reporting responsibility for the GBRMPA that provides a regular and reliable report on the management of the Great Barrier Reef Marine Park, the overall condition of the ecosystem of the Great Barrier Reef Region (including the ecosystem outside that Region to the extent it affects that Region), social, cultural and economic factors, as well as a risk-based assessment of the longer-term outlook for the Great Barrier Reef Region. The report is comprised of seven assessments of the state and condition of values and pressures, risk and resilience as well as an assessment of management effectiveness using the components of the IUCN management cycle framework which guides adaptive management.

There are good examples of monitoring programs that are already tightly integrated into management such as the Reef Rescue Marine Monitoring Program of the Australian and Queensland Government Reef Water Quality Protection Plan, as well as the program monitoring the effectiveness of the 2003 Zoning Plan. These programs report more regularly than the *Outlook Report* cycle and feed directly into assessments of management effectiveness as they were designed with that specific objective. However, for many monitoring programs such a clear link to management is not currently explicitly stated. Through the strategic assessment and the IMF, links to management will be made clearer and the causal relationships among drivers, pressures, impacts and state, will be better understood so that data from monitoring programs can be synthesised with other data in a management context and be readily incorporated into Outlook Reporting and adaptive management assessments.

The 2009 *Outlook Report* highlighted that climate change, continued declining water quality from catchment run-off, loss of coastal habitats from coastal development, remaining impacts from fishing, illegal fishing and poaching as the priority issues reducing the resilience of the Great Barrier Reef particularly inshore, urban coast habitats. In response, managers continued to follow the *Climate Change Action Plan 2007–2012* and developed the *Climate Change Adaptation Strategy and Action Plan 2012–2017*, re-committed to the Australian and Queensland Government Reef Water Quality Protection Plan, developed strategy documents to guide policy for inshore biodiversity and coastal ecosystems and commissioned a trawl ecological risk assessment. In this way, management has adapted and is continuing to adapt, guided by the findings of the *Outlook Report*. *Future Outlook Reports* will include trend information for values and pressures. This will directly facilitate assessments of management performance at this level as value and pressure management objectives and targets are based on trend. Importantly, the 'Outlook' section of the report will provide the information needed to inform adaptive management for predicted future condition. In this way the *Outlook Report* will guide adaptive management and be the primary reporting mechanism of the integrated monitoring program for the GBRWHA.

3.2.10.3 Systems, processes and collaborations to inform reporting

Improved integration and collaboration could be achieved by formalising the responsibilities of Australian Government agencies, including AIMS, CSIRO, Bureau of Meteorology and GBRMPA, as well as Queensland Government departments to contribute to the Commonwealth's World Heritage obligations through an integrated monitoring, analysis and reporting program through the Intergovernmental Agreement.

Under the proposed governance structure the IMP technical advisory group would have responsibility for strategic direction of the program, including identification of components of the program that should be integrated for the purposes of reporting and communication products. This group would also advise on other aspects of integration as described in Section 3.1.4.

The design stage of the integrated monitoring program should include the identification of reporting cycles appropriate to the individual components of the program and aligned with management needs, such as five-yearly Outlook Reports and day-to-day policy, environmental assessment and permit decisions.

Synthesis and integration of reporting and communication across the program will require significant resources and should be incorporated fully in the design and costing stage of the integrated monitoring program. Reporting and communication products, as well as particular collaborations between monitoring providers should be identified specifically by the technical advisory group and a central coordination role (IMP Director Integrated Monitoring, Analysis and Reporting) is necessary to facilitate such activities. Currently most monitoring program budgets do not allow for these important activities and they are considered additional to their core work program.

3.2.10.4 Summary – how the guidance was used

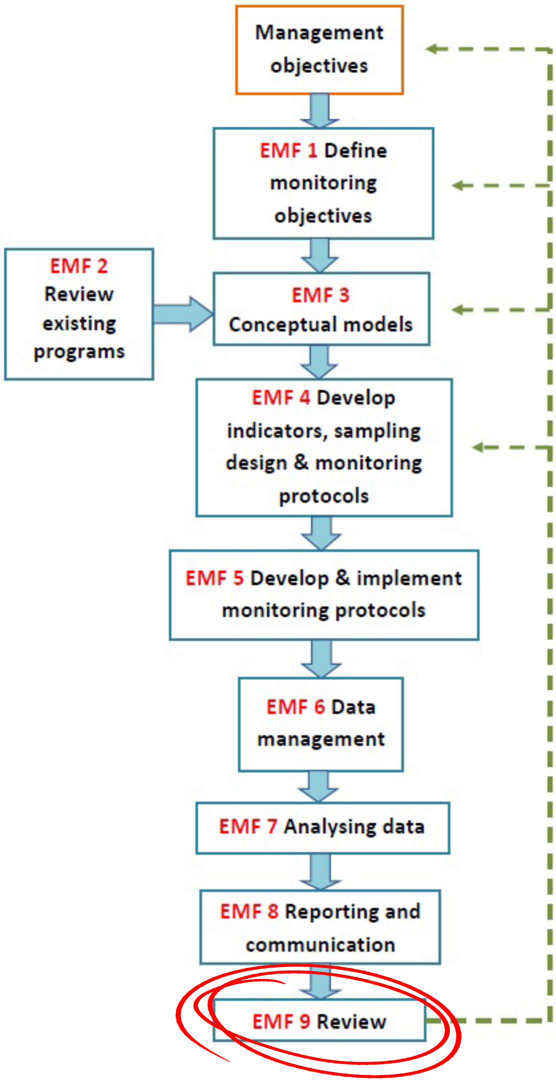
- The *Outlook Report* is the primary and legislated reporting mechanism for management of the Great Barrier Reef and brings together all of the most relevant monitoring and other information for management. This will continue to be the primary reporting mechanism for integrated monitoring.
- The development of the *Outlook Report* followed a process similar to that outlined in the guidance.
- The Great Barrier Reef Marine Park Authority also has an extensive array of established communication and engagement programs that will be used to disseminate the information produced through the integrated monitoring program.

3.2.11 Essential Monitoring Function 9: Reviewing and auditing

Guidance from Part 2:

Instigate a collaborative process with experts to generate an overview of the purpose and scope of review and audit procedures for integrated monitoring. The overview should identify:

- a preferred model for reviewing and auditing, including the nature, timing and level of independence of program reviews and periodic audits of the integrated monitoring program
- the role of governance committee(s) and principles to guide decision-making for integrated monitoring
- the relationship with existing reviews of selected programs.



3.2.11.1 Methods

The project team considered existing review and audit mechanisms for the assessment of management effectiveness rather than for specific monitoring programs. The following proposed review and audit processes are based on the GBRMPA system for assessing management effectiveness and incorporate the review and audit of the proposed governance structure as well as how the integrated program is meeting management needs. Review and audit of specific technical aspects of the monitoring design is addressed under the governance arrangements through the Intergovernmental Operations Committee (Section 3.2.2) and thus also considered during review of those arrangements.

3.2.11.2 Results

Parts two and three of this report detail approaches and processes to address and inform a systematic approach to monitoring with a view to reporting and evaluation in an adaptive management cycle. Figure 3.11 is a map that illustrates how all of the components of this approach work together in informing adaptive management. A demonstration of how this map applies to a value underpinning MNES in the GBRWHA is provided in Figure 3.12. This figure is specific for seagrass habitats and draws on information provided throughout Part 3 of this report to populate the various stages and steps in the figure.

Regular reviews of the effectiveness of individual programs are also a key part of the adaptive monitoring approach (Lindenmayer and Likens 2010). Nearly all sources of funding for monitoring programs require periodic funding applications which include future work plans, and which represent an opportunity for scrutiny of the processes and the value of a program. However, specific relevance to adaptive management of the GBRWHA may not be a major performance criterion in such reviews. Many programs involve co-investment funding, and several of the larger programs on the GBR are largely or substantially funded by research organisations (e.g. AIMS) whose management structures reward scientific publications ahead of extensive reporting to management agencies or large investments in making data available to all.

The GBRMPA has a system for assessing management effectiveness structured around the IUCN management cycle (Hockings et al 2006) where information is gathered and analysed against each of the steps in the cycle. This approach was first taken for the GBR for the 2009 *Outlook Report* and will continue to be done for future Outlook Reports. Through the strategic assessment, 15 broad management topics for the GBRWHA are being assessed for effectiveness (Table 3.18).

Monitoring informs all of the 15 management topics (Table 3.18) but it is intended that monitoring in itself be formally included as a discrete management topic in the regular assessment of management effectiveness. The steps in the IMF map to the IUCN management cycle (Figure 3.13). Information will be gathered against each of the steps in the cycle using the indicators in Table 3.19 as a guide. This approach will provide a five-yearly review and audit of the integrated monitoring program in the context of the *Outlook Report* and overall management effectiveness of the Great Barrier Reef.

3.2.11.3 Summary – how the guidance was used

- The GBRMPA has adopted the IUCN management cycle as its management effectiveness assessment system.
- We recommend that monitoring and reporting be included as a management topic to be assessed for effectiveness under the existing GBRMPA system.

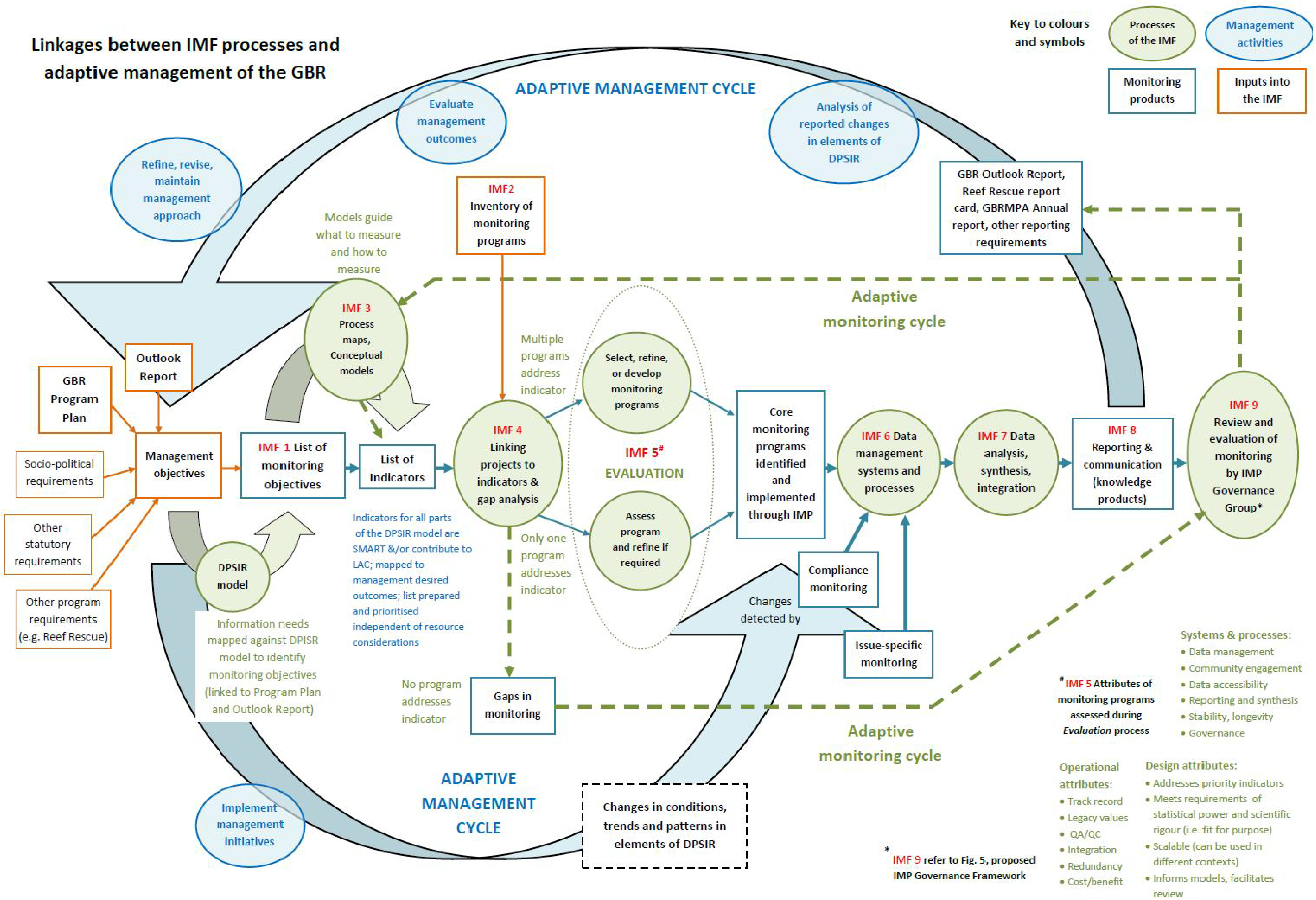


Figure 3.11 Links between IMF and adaptive management of the GBR

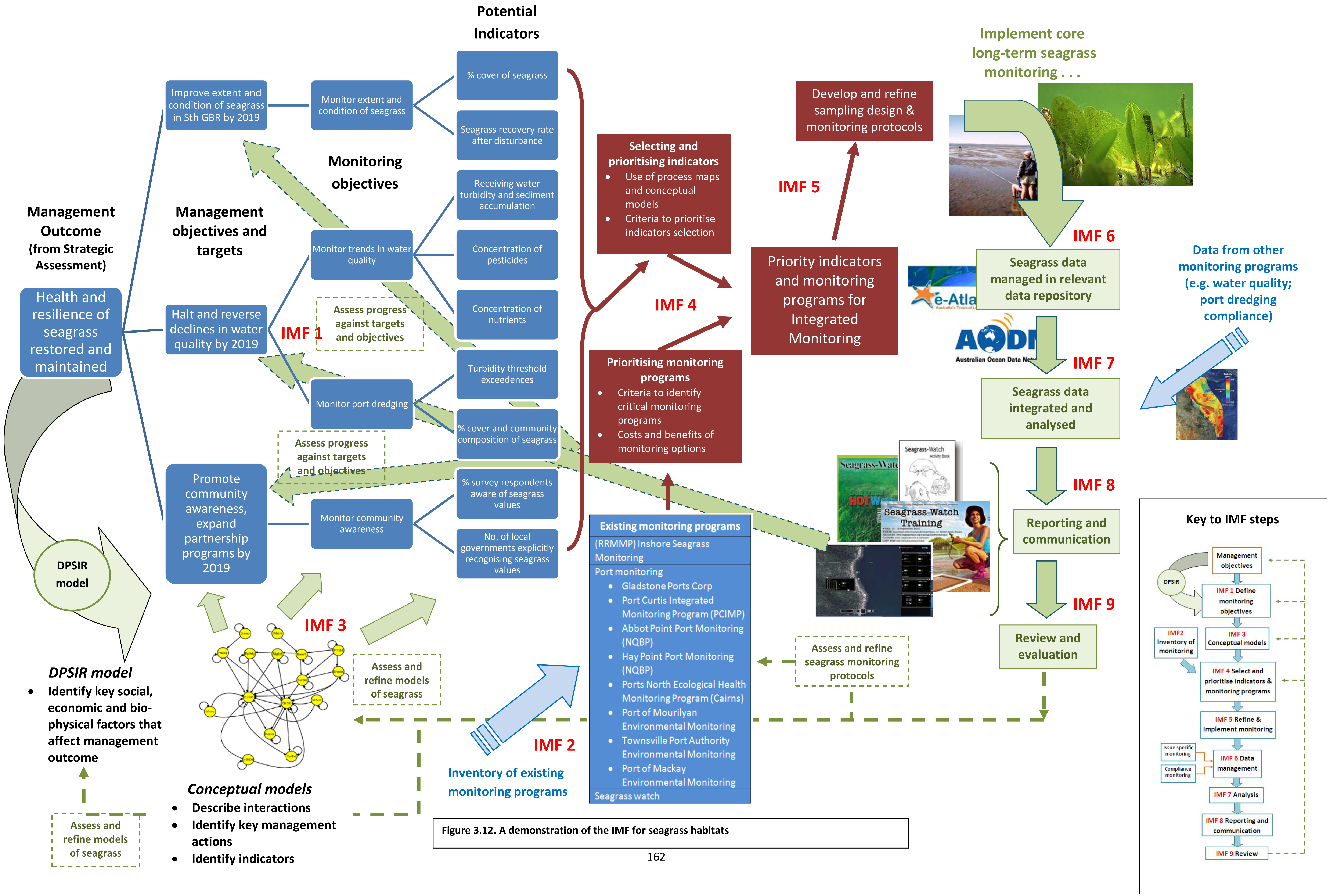


Figure 3.12. A demonstration of the IMF for seagrass habitats

Table 3.18 Management topics by which management effectiveness is assessed through Outlook Reporting

Priority monitoring to inform management topic assessments	Biodiversity protection	Climate change and extreme weather	Coastal development	Defence activities	Commercial fishing	Recreational fishing	Indigenous heritage (including traditional use)	Non-Indigenous heritage	Ports, including dredging and spoil disposal	Recreation	Research activities	Shipping	Social and economic (community) benefits	Tourism, including related facilities	Water quality
Long-term monitoring															
Coral reefs & corals	✓	✓	✓		✓	✓			✓	✓				✓	✓
Seagrass meadows & seagrasses	✓	✓	✓		✓	✓			✓						✓
Marine turtles	✓	✓	✓	✓	✓		✓		✓	✓					✓
Seabirds	✓	✓	✓	✓	✓					✓					
Dolphins	✓	✓	✓	✓	✓				✓	✓					
Dugongs	✓	✓	✓	✓	✓		✓		✓	✓					
Bony fish	✓	✓	✓		✓	✓	✓								✓
Sharks & rays	✓	✓	✓	✓	✓										✓
Primary production – pelagic	✓	✓							✓						✓
Increase in sea and air temperature	✓	✓													
Nutrients from catchment run-off	✓	✓	✓												✓
Ocean acidification	✓	✓													
Sediments from catchment run-off	✓	✓	✓												✓
Extraction of top order predators	✓				✓	✓									
Illegal fishing or collecting/poaching	✓				✓	✓									
Crown-of-thorns starfish	✓	✓			✓										✓
Exotic species and diseases	✓	✓			✓	✓						✓			
Pesticides from catchment run-off	✓	✓	✓												✓
Increased freshwater flow	✓	✓													✓
Clearing/modifying coastal habitat (satellite)	✓		✓						✓						✓
Coastal reclamation (satellite)	✓		✓						✓						✓
Income, economic contribution & employment		✓			✓						✓		✓	✓	
Understanding of the GBR					✓	✓	✓				✓	✓	✓	✓	
Reef access			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Indigenous cultural		✓	✓				✓		✓				✓		
Appreciation/ enjoyment/ aesthetics (natural beauty)		✓	✓			✓	✓		✓	✓		✓	✓	✓	
Marine debris	✓	✓	✓		✓	✓			✓	✓		✓		✓	
Short-term monitoring															
Physical damage to benthos (including ship groundings, direct dredging impacts & dumping of dredge spoil)	✓								✓	✓		✓		✓	✓
Oil spill – large	✓								✓			✓			✓

Priority monitoring to inform management topic assessments	**Biodiversity protection**	**Climate change and extreme weather**	**Coastal development**	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Indigenous heritage (including traditional use)**	**Non-Indigenous heritage**	**Ports, including dredging and spoil disposal**	**Recreation**	**Research activities**	**Shipping**	**Social and economic (community) benefits**	**Tourism, including related facilities**	**Water quality**
Chemical spill – large	✓								✓			✓			✓
Cyclone activity	✓	✓													✓
Artificial barriers to water flow	✓		✓						✓						✓
Crown-of-thorns starfish	✓														
Exotic species and diseases	✓	✓										✓			
Clearing/modifying coastal habitat (site-specific)	✓		✓						✓						✓
Coastal reclamation (site-specific)	✓		✓						✓						✓

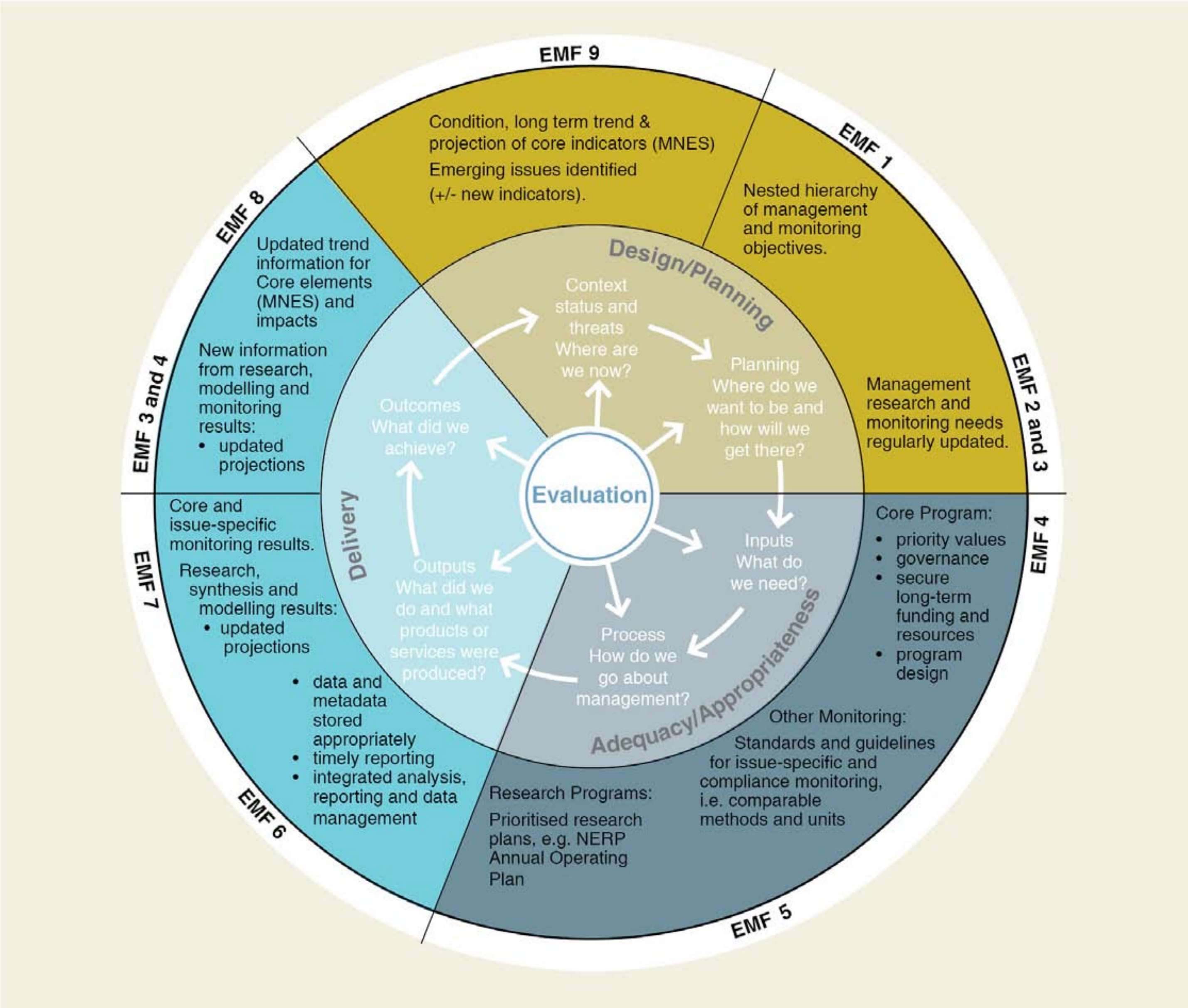


Figure 3.13 Essential monitoring functions of the integrated monitoring framework mapped to the IUCN management cycle.

Table 3.19 Proposed indicators for review and audit to assess effectiveness of monitoring program through the IUCN management cycle structure. This review and audit would be conducted every five years through the *Outlook Report* for the Great Barrier Reef Region
CONTEXT
CO1The values that underpin matters of national environmental significance in the Great Barrier Reef (including Outstanding Universal Value of the GBRWHA) are understood by managers.
CO2 Key drivers, pressures and activities acting on values are understood by managers.
CO3 Consequential and cumulative impacts are understood by managers.
CO4 The current condition, trend and projections for matters of national environmental significance (spatial and non-spatial) is known.
CO5 Emerging issues are identified.
PLANNING
PL1 There is a framework in place to guide the monitoring program.
PL2 Clear, measurable and appropriate objectives for management of values and impacts have been documented.
PL3 Clear, measurable and appropriate objectives for monitoring of values and impacts have been documented.
PL4 The main stakeholders and/or the local community are effectively engaged in planning to address monitoring needs.
PL5 Research and monitoring needs for management of the GBRWHA are regularly updated.
PL6 Appropriate cause-and-effect models for values and impacts exist to guide the identification of research and monitoring needs.
INPUTS
IN2 Current financial resources are adequate and prioritised to meet core monitoring needs.
IN3 Current human resources within the managing organisations are adequate to coordinate the monitoring program.
IN4 The right skill sets and expertise are currently available to perform the required core monitoring.
IN6 Research is focused on informing monitoring and interpreting monitoring results.
IN7 There are additional sources of non-government input (e.g. volunteers) contributing to monitoring.
PROCESSES
PR1 A functioning governance structure exists for the monitoring program.
PR2 Standards and guidelines exist for core long-term, issue-specific and compliance monitoring to ensure compatibility of methods and units where appropriate.
PR4 There is effective performance monitoring to gauge progress towards the objective(s) for individual monitoring programs.
PR5 Appropriate training is available to the monitoring programs to ensure accuracy and consistency in data collection.
PR6 Management of monitoring is consistently implemented across the relevant jurisdictions.
PR8 Direct and indirect impacts of activities associated with monitoring are appropriately considered.
PR13 Relevant standards are identified and being met regarding data storage and accessibility.
PR14 Targets have been established to benchmark management performance.
OUTPUTS
OP1 Monitoring is reporting in timely manner to feed into management reporting and decision-making.
OP2 Data streams are appropriately integrated, analysed and synthesised to inform management.
OP3 Data, metadata and outputs from monitoring programs are stored appropriately and made available publically where possible.
OP4 To date, products or services have been produced in accordance with the stated management objectives for monitoring.
OUTCOMES
OC1 New information from research and monitoring is informing models to update condition, trend and projection information for values and impacts.
OC2 Information from OC1 is incorporated in management reporting including effectiveness of management initiatives, decision-making and updating of management objectives.
OC7 Research and monitoring information is used to update understanding for context above.

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Appendix 1 – Summary of approach to the project: *An integrated monitoring framework for the Great Barrier Reef World Heritage Area*

The project commenced with the appointment of a project steering committee, a project team and development of a project plan. Three work streams were initiated: developing a guide to establish an integrated monitoring framework; reviewing information needs for the Great Barrier Reef World Heritage Area (GBRWHA); and reviewing existing monitoring programs relevant to the GBRWHA. A brief description of each work stream is provided below. All three work streams were progressed concurrently to meet the project timelines.

Workshops were used to build understanding among stakeholders and experts about the objectives, methods and outcomes sought from the project, and to harvest knowledge and insights from stakeholders and experts. A brief description of each workshop is provided below. Numerous meetings and discussions were convened to develop and apply the guidance and produce the project report.

Work stream 1: Developing guidance for integrated monitoring

- The guidance for integrated monitoring was developed by seeking knowledge and insights from individuals with expertise in monitoring and integrated monitoring, and reviewing the scientific literature and relevant reports from marine, terrestrial and freshwater domains.
- The monitoring framework used by the United States National Park Services (Fancy et al. 2009) provided a clearly articulated and useful starting point for development of the guidance.
- Understanding the individual stakeholder expectations of integrated monitoring and developing a common lexicon and logic for integrated monitoring were fundamental to developing the guidance.

Works stream 2: Reviewing information needs for the GBRWHA

The terms of reference for the review were:

- Work with the Great Barrier Reef Strategic Assessment team to clarify single set of values (attributes & elements) and pressures (threats & impacts) to be used for the strategic assessment and Outlook Report 2014.
- Work with the strategic assessment team to identify all existing management objectives and link them to the values, attributes and elements underpinning MNES.
- Update the GBR Science Information Needs tables using the above objectives, values and pressures.
- Review of information needs could be structured using DPSIR framework. Identify existing information on pressure state/impact and response for each element of MNES. These criteria plus identification of spatial distribution of the element would provide a good basis to determine the degree of concern to management and the adequacy of information to make management decisions:
    - Evidence of drivers and pressures, including social and economic information
    - Evidence of State and/or Impact (these may be difficult to separate)
    - Evidence of management response.

Where evidence is not available a gap is clearly identified. Displaying this information in a matrix with supporting evidence will form a basic conceptual model.

Work stream 3: Reviewing existing monitoring programs relevant to the GBRWHA

The terms of reference for the review were:

- Update list of monitoring programs for the GBRWHA. The time taken to scout for additional monitoring programs will be limited and priority will be given to filling the known gaps, particularly relating to ports and coastal development.

For each program:

- Identify the objectives of the program. Are they clearly stated?
- Note whether there is a conceptual model for monitoring specific MNES and provide metadata or link (e.g. URL, reference, etc). Documentation of the rationale for the monitoring program to meet stated objectives may be sufficient.
- Identify monitoring design and protocols—spatial, temporal, MNES attributes monitored, etc.—and provide metadata or link (e.g. URL, reference, etc).
- Note whether analysis of data occurs and provide metadata or link (e.g. URL, reference, etc.).
- Note whether interpretation is relevant to future management needs/actions occurs and provide metadata or link (e.g. URL, reference, etc.).
- Note whether reporting occurs and its frequency, and provide metadata or link ((e.g. URL, reference, etc.).
- Are there new technologies/novel approaches that would make this program more efficient or extend its range to specifically answer MNES questions?
- Does the program get reviewed? At what intervals?
- Note approximate costs and funding source.
- How is data stored? Are data and/or metadata online?

Workshop 1 – Project context and aims and the essential functions of monitoring

A two-day workshop of key stakeholders and experts (approximately 40 participants) was convened to generate shared understanding of:

- what the project would deliver
- the GBRWHA Strategic Assessment work providing inputs to this project
- related work and linkages with other current projects for the GBRWHA
- the various motivations for monitoring and decision contexts
- the essential monitoring functions to be considered in an integrated monitoring framework
- the successes and challenges in monitoring programs
- what is required to connect scientific monitoring with assessment of management effectiveness
- the role of governance in effective monitoring programs.

Workshop 2 – Monitoring priorities and principles for integrated monitoring

A two-day workshop of key stakeholders and experts (approximately 30 participants) was convened to:

- update participants on project work done to date and expectations for project delivery
- demonstrate and seek input on the high level prioritisation of information needs for management
- work through example case studies and develop a shared understanding of how the monitoring framework steps can be used to develop an integrated monitoring program that adequately addresses high priority information needs for management
- establish a set of learnings from the case study work that can be applied in the broader GBR context
- gain insights into options for addressing priority information needs for management.

Workshop 3 – Managing data

A two-day workshop of data generators and data managers relevant to the GBRWHA (approximately 15 participants) was convened to:

- identify preferred IMP data management approach to support an integrated monitoring program for the GBRWHA
- identify important data management characteristics and principles for discovery, storage and access to monitoring data
- understand existing data management arrangements for the GBRWHA
- identify opportunities for integration and standardisation of data management arrangements to support an integrated monitoring program for the GBRWHA
- identify governance requirements and issues for data management to support an integrated monitoring program for the GBRWHA.

Workshop 4 – selecting indictors and monitoring programs

A two-day workshop of GBRWHA managers and experts relevant to the GBRWHA (approximately 15 participants) was convened to:

- identify a process for the selection of monitoring programs for inclusion in the IMF
- identify a process for the selection of indicators for the IMF
- draw on synergies with the thinking and outputs of the concurrent Regional Sustainability Program Project 5: A resilience decision framework for the Great Barrier Reef
- explore the role of an integrated monitoring program to inform modelling and predictions for MNES of the GBRWHA under different management and impact scenarios.

Reference

Fancy SG, Gross JE and Carter S (2009) Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* **151**: 161–174.

Appendix 2 – Values and Pressures

Table 1 Great Barrier Reef Region values — biodiversity

Biodiversity values are matched to the matters of national environmental significance they underpin.

Values that underpin matters of environmental significance	**Matters of national environmental significance**						
	World Heritage properties	**National heritage places**	**Wetlands of international importance**	**Listed threatened species and ecological communities**	**Listed migratory species**	**Commonwealth marine areas**	**Great Barrier Reef Marine Park**
Biodiversity — Great Barrier Reef habitats							
Islands	✓	✓	✓	✓	✓	✓	✓
Beaches and coastlines	✓	✓	✓	✓	✓	✓	✓
Mangrove forests	✓	✓	✓			✓	✓
Seagrass meadows	✓	✓	✓	✓	✓	✓	✓
Coral reefs (<30 m)	✓	✓	✓	✓	✓	✓	✓
Deeper reefs (>30 m)	✓	✓				✓	✓
Lagoon floor	✓	✓				✓	✓
Shoals	✓	✓				✓	✓
Halimeda banks	✓	✓				✓	✓
Continental slope	✓	✓				✓	✓
Open waters	✓	✓	✓	✓	✓	✓	✓
Biodiversity — terrestrial habitats that support the Great Barrier Reef							
Saltmarshes	✓	✓	✓		✓	✓	✓
Freshwater wetlands	✓	✓	✓		✓	✓	✓
Forested floodplain	✓	✓	✓			✓	✓
Heath and shrublands	✓	✓				✓	✓
Grass and sedgelands	✓	✓	✓			✓	✓
Woodlands	✓	✓	✓			✓	✓
Forests	✓	✓	✓			✓	✓
Rainforests	✓	✓		✓		✓	✓
Connecting water bodies	✓	✓	✓	✓	✓	✓	✓
Biodiversity — species							
Mangroves	✓	✓	✓			✓	✓
Seagrasses	✓	✓	✓			✓	✓
Macroalgae	✓	✓				✓	✓
Benthic microalgae	✓	✓				✓	✓
Corals	✓	✓				✓	✓
Other invertebrates	✓	✓	✓			✓	✓
Plankton and microbes	✓	✓				✓	✓
Bony fish	✓	✓	✓			✓	✓

Values that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Sharks and rays	✓	✓		✓	✓	✓	✓
Sea snakes	✓	✓				✓	✓
Marine turtles	✓	✓	✓	✓	✓	✓	✓
Estuarine crocodiles	✓	✓			✓	✓	✓
Seabirds	✓	✓		✓	✓	✓	✓
Shorebirds	✓	✓	✓	✓	✓	✓	✓
Whales	✓	✓		✓	✓	✓	✓
Dolphins	✓	✓			✓	✓	✓
Dugongs	✓	✓	✓		✓	✓	✓

Table 2 Great Barrier Reef Region values — heritage

Biodiversity values are matched to the matters of national environmental significance they underpin.

Values that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Heritage — outstanding universal value							
Criterion VII: Natural phenomena and beauty	✓	✓	The concept of outstanding universal value is specific to World Heritage properties and therefore also national heritage places				
Criterion VIII: Major stages of the Earth's evolutionary history	✓	✓					
Criterion IX: Ecological and biological processes	✓	✓					
Criterion X: Habitats for conservation of biodiversity	✓	✓					
Integrity	✓	✓					
Heritage — Indigenous							
Cultural practices, observances, customs and lore			✓	✓	✓	✓	✓
Sacred sites, sites of particular significance, places important for cultural tradition	✓	✓				✓	✓
Stories, song lines, totems and languages	✓	✓		✓	✓	✓	✓

Values that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Indigenous structures, technology, tools and archaeology	✓	✓	✓			✓	✓
Heritage — historic							
Places of historic significance — historic shipwrecks						✓	✓
Places of historic significance — World War II features and sites						✓	✓
Places of historic significance — light stations						✓	✓
Places of historic significance — other			✓			✓	✓
Places of scientific significance (research stations, expedition sites)						✓	✓
Places of social significance — iconic sites						✓	✓

Table 3 Great Barrier Reef Region values — community benefit

Community benefit values are matched to the matters of national environmental significance they underpin.

Values that underpin matters of environmental significance	Matters of national environmental significance						
	World Heritage properties	National heritage places	Wetlands of international importance	Listed threatened species and ecological communities	Listed migratory species	Commonwealth marine areas	Great Barrier Reef Marine Park
Community benefits of the environment							
Income			✓	✓	✓	✓	✓
Employment			✓	✓	✓	✓	✓
Understanding	✓	✓		✓	✓	✓	✓
Appreciation	✓	✓		✓	✓	✓	✓
Enjoyment	✓	✓	✓	✓	✓	✓	✓
Access to Reef resources			✓	✓	✓	✓	✓
Personal attachment				✓	✓	✓	✓
Health benefits			✓	✓	✓	✓	✓
Aesthetics (see outstanding universal value — criterion vii)	✓	✓	✓			✓	✓

Table 4 maps the relationship between impacts and activities/pressures for the GBRWHA.

Impacts	Direct driver	Activities in the Region									Activities in the catchment			
	Climate change	Tourism	Fishing — commercial	Fishing — recreational	Recreation	Traditional use	Research activities	Defence activities	Shipping	Ports	Agriculture	Aquaculture	Urban development	Industrial development
Acid sulphate soils										X	X	X	X	X
Altered ocean currents	X									X				
Artificial barriers to flow										X	X	X	X	X
Atmospheric pollution									X	X	X		X	X
Boat strikes on wildlife		X	X	X	X	X		X	X	X				
Chemical and oil spills — small		X	X	X	X				X	X			X	X
Chemical spills — large									X	X			X	X
Clearing or modifying coastal habitats		X								X	X	X	X	X
Coastal reclamation		X								X			X	X
Cyclone activity	X													
Death of discarded species			X	X			X							
Disturbance to wildlife		X	X	X	X		X	X	X	X				
Dredging — direct impacts									X	X			X	X
Dumping and resuspension of dredge material									X	X			X	X
Exotic species and diseases			X	X	X				X			X		
Extraction of herbivores				X		X	X							
Extraction of lower order predators			X	X		X	X							
Extraction of lower trophic orders			X	X		X	X							
Extraction of top order predators			X	X		X	X							
Fishing in spawning aggregations			X	X		X								
Freshwater inflow	X										X		X	X
Grounding of large vessels		X	X						X					
Illegal fishing and poaching			X	X										
Increased sea temperature	X													
Light impacts (artificial)		X	X						X	X			X	X
Marine debris		X	X	X	X	X			X	X	X		X	X
Noise pollution		X	X	X	X		X	X	X	X			X	X
Nutrients from catchment run-off											X	X	X	X
Ocean acidification	X													
Oil spill — large									X	X			X	X
Outbreak of crown-of-thorns starfish			X	X							X		X	X
Outbreaks of disease											X		X	X
Outbreaks or blooms of other species									X		X		X	X
Pesticides from catchment run-off											X		X	X
Physical damage to benthos		X	X	X	X	X	X	X	X					
Physical impacts of fishing			X											
Rising sea level	X													
Sediments from catchment run-off										X	X	X	X	X
Urban and industrial discharge		X								X		X	X	X
Wash from vessels		X	X	X	X		X	X	X					
Waste discharge from vessels		X	X	X	X		X	X	X					

Appendix 3 Monitoring objectives: drivers, pressure and state of MNES values

VALUES

Biophysical values and pressures/impacts affecting them	Draft desired management outcomes and targets (from Strategic Assessment/Program Report)	Draft core long-term monitoring objectives	Monitoring programs and variables that have been monitored
Coral reefs and corals Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats	The condition of coral reefs and corals is maintained and enhanced in Northern inshore and offshore areas and the trend in condition is maintained and improved. The condition of Southern inshore and offshore coral reefs and corals is restored to good and the decline in trend of condition is halted and reversed. **Preliminary Targets by 2019** • Trends in coral reef condition and resilience indicators are improved (including herbivory, coral diversity, resistance, disease and recruitment) • Coral mortality resulting from exposure to human activities (including overfishing, sedimentation and physical damage) is reduced • Coral mortality at sites of high ecological and tourism value is reduced, particularly predation by crown-of-thorns starfish • Coral cover is showing an increasing trend towards the Reef-wide and regional levels measured by the AIMS long-term monitoring program at its inception in 1985 Note: The Authority will further examine the development of targets for corals that specify ranges for condition and resilience indicators for regions and subregions	• Determine trends in coral reef condition, community composition, recruitment & growth rate of inshore, midshelf & offshore reefs at higher spatial and temporal coverage than at present including at impacted sites. • Determine trends in coral reef resilience indicators (after McClanahan et al. 2012): resistant coral species, temperature variability, nutrients, sedimentation, coral diversity, herbivore biomass, physical human impacts, coral disease, macroalgae, recruitment, fishing pressure, crustose coralline algae and COTS • Determine coral larval production, transport and settlement between reefs to identify source & sink reefs and connectivity. • Measure extent, frequency and intensity of impact effects as well as recovery from exposure of coral reefs to rising sea level flood plumes, cyclones, sediments, nutrients, pesticides, ocean acidification, COTS, clearing & modifying coastal habitat, dredging activities and increased sea and air temperature (see Pressures table for impact specific monitoring objectives).	PROGRAMS: • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • GBRMPA-QPWS compliance monitoring VARIABLES: % cover of hard & soft corals; Coral size classes; Larval settlement; Taxonomic composition; % coral cover; crown-of-thorns starfish; counts of juvenile corals; coral disease; drupella; surveys of sessile benthic organisms (~70 categories) using still images visual counts of reef fishes (7 families
Seagrass meadows and seagrasses Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Clearing or modifying coastal habitats o Coastal reclamation	The condition of seagrass meadows and seagrasses is maintained in Northern inshore and offshore areas and the trend in condition is maintained and improved. The condition of Southern inshore and offshore seagrass meadows and seagrasses is restored to good and the decline in trend of condition is halted and reversed. **Preliminary Target by 2019** • Spatial extent and condition of seagrass in each natural resources management region is improved to good condition as defined in the Reef Rescue marine monitoring program12 Note: The Authority will further examine the development of targets for seagrass meadows that specify ranges for distribution, density and condition for regions and subregions	• Determine extent and condition of seagrass meadows, as well as species composition and community structure at regional and reef-wide scales including at impacted sites. • Measure extent, frequency and intensity of impact effects as well as recovery from exposure of seagrass beds to rising sea level, flood plumes, cyclones, sediments, nutrients, pesticides, and increased sea and air temperature (see Pressures table for impact specific monitoring objectives). • Determine extent of loss of seagrass meadows through clearing and dredging activities.	PROGRAMS: • Seagrass Watch • (RRMMP) Inshore Seagrass Monitoring Ambient Monitoring associated with ports at: Cairns Mourilyan Townsville Hay Point Mackay Abbot Point Gladstone (PCIMP, PC&PA ERMP) VARIABLES: Extent of coverage; species composition; seed banks; epiphytes & macroalgae; meadow edge mapping (late dry season, late monsoon season) reproductive health; seagrass tissue elements (C:N:P) (late dry season); rizosphere sediment herbicides in-situ within canopy temperature; in-situ canopy light; Dugong trails
Mangrove forests and mangroves Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and	Maintain and enhance the condition for Southern mangroves and maintain for Northern. Trend in condition to be maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine extent and condition of mangroves, as well as species composition and community structure at regional and reef-wide scales including at impacted sites. • Determine extent, frequency and intensity of impact effects as well as recovery from exposure of mangroves to rising sea level, flood plumes, cyclones, sediments, nutrients and pesticides, (see Pressures table for impact specific monitoring objectives). • Determine extent of loss of mangroves through clearing and reclamation activities.	PROGRAMS • Mangrove watch • QLUMP • Port development monitoring VARIABLES: Extent of mangrove area

Biophysical values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from Strategic Assessment/Program Report)**	**Draft core long-term monitoring objectives**	**Monitoring programs and variables that have been monitored**
resuspension of dredge material o Pesticides from catchment runoff o Clearing or modifying coastal habitats o Coastal reclamation			
Islands Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Clearing and modifying coastal habitats o Coastal reclamation o Marine debris	The condition of islands is maintained and enhanced. Halt and reverse declining trend in condition of Southern inshore Islands. Trend in other islands to be maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine condition, trend and dynamics of key ecological attributes and high-value sites on islands, taking into account variation among islands. • Determine availability and suitability of seabird nesting and roosting habitat on islands. • Determine changes to nesting and roosting habitat by human activity (weeds, pests, habitat & vegetation changes), cyclones. rising sea level and geomorphological changes (see 'Impacts' table for impact specific monitoring objectives).	PROGRAMS: • Monitoring island infrastructure • Monitoring fire and weed species • GBRMPA-QPWS Field management patrols • QLUMP VARIABLES: Weeds and Pests; Infrastructure; *Pisonia* forest scale insects; Condition of vegetation (fire monitoring)
Beaches and coastline Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Clearing or modifying coastal habitats o Coastal reclamation o Marine debris	The condition of beaches and coastlines to be maintained for Northern and maintained and enhanced for Southern GBR. Halt and reverse declining trend in condition of Southern beaches and coastlines. Trend in Northern beaches and coastlines to be maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine trends in coastal ecosystem condition and extent and degree of modification. • Determine trends and condition of key in-beach and on-beach communities. • Determine water quality condition and trend for beaches adjacent to urban areas using Reef Plan and Environment Protection (water) Policy 2009 objectives and targets. • Determine extent, frequency and intensity of impact effects as well as recovery from exposure of beaches and coastline to flood plumes, cyclones, sediments, marine debris and increased sea and air temperature (see Pressures table for impact specific monitoring objectives). • Determine availability and suitability of shorebird nesting and roosting habitat, including measures of human disturbance and pest species disturbance.	PROGRAMS: • GBRMPA-QPWS Field management patrols • QLUMP • Australian Marine Debris Initiative VARIABLES: remote mapping of coastal habitats, mangroves, saltpans and saline grasslands, quantity and source of marine debris
Open waters Key pressures/impacts affecting value: o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Marine debris	The condition of Northern inshore and offshore as well as Southern offshore open waters is maintained and enhanced and restored to good in Southern inshore. The trend in condition of Northern inshore and offshore as well as Southern offshore open waters is maintained and improved while the decline in Southern offshore is halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Monitor broad-scale, regional and local-scale water circulations. • Determine trends in concentrations of nutrients, pesticides and sediments in relation to guidelines where they exist (see Pressures table for impact specific monitoring objectives). • Determine trends in sea temperature and acidity (see Pressures table for pressure specific monitoring objectives).	PROGRAMS: • QDEHP wave monitoring • Q-IMOS • Reef Rescue MMP Water Quality components, including remote sensing • BoM weather stations VARIABLES: Current movements – large scale and finer scale through modelling; Temperature; Nutrients; Pesticides; Turbidity; Light; Chlorophyll; Suspended solids; coloured dissolves organic matter
Other invertebrates Key pressures/impacts affecting value: o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Freshwater inflow o Nutrients from catchment runoff	The condition of Northern inshore and offshore as well as Southern offshore other invertebrates is maintained and in Southern inshore condition is maintained and enhanced. The trend in condition of Northern inshore and offshore as well as Southern offshore other invertebrates is maintained and improved while the decline in Southern offshore is halted and reversed. **Targets** The development of targets will be a collaborative process between the	• Determine trends in Beche-de-mer populations including recruitment particularly for black teatfish. • Predict COTS outbreak initiation and progression of outbreak wave through early warning monitoring based on COTS numbers, water quality, flood events.	PROGRAMS: • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • Qld commercial fishery monitoring

Biophysical values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from Strategic Assessment/Program Report)**	**Draft core long-term monitoring objectives**	**Monitoring programs and variables that have been monitored**
o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching	Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.		• Qld trawl vessel monitoring • QPWS-GBRMPA compliance monitoring VARIABLES: REEFS: surveys & observations of COTS and sessile benthic organisms (~70 categories including corals) LAGOON FLOOR: No ongoing monitoring but comprehensive survey of the seabed biodiversity conducted from 2003-2006; COMMERCIAL PRAWN & BECHE-DE-MER FISHERY: catch stats; BECHE-DE-MER SURVEYS: stock size, recruitment, growth on 70 reefs
Bony fish Key pressures/impacts affecting value: o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	The condition of Northern inshore and offshore bony fish is maintained and in Southern inshore and offshore condition is maintained and enhanced. The trend in condition of bony fish is maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine trends in the status and condition (abundance, biomass and size classes) of key species of bony fish populations (based on ecological/economic/social importance). • Determine trends in abundance, biomass and size classes of targeted species (especially on coral reefs) comparing blue, green, yellow & pink zones. • Determine trends in fish larval production and exchange between fished and no-take zones. • Determine trends in ontogenetic migratory patterns for bony fish. • Determine extent of disease outbreaks in bony fish, e.g. Qld grouper mortalities, Gladstone fish populations. • Measure the effect of extreme weather impacts (especially heatwaves, cyclones, floods) on critical bony fish habitat, especially coral reefs, seagrass, mangroves (see objectives listed under these habitats). • Determine changes to inshore fish populations & productivity associated with restoration of coastal ecosystems, such as removal of barriers to flow. • Measure trends in fish health associated with significant coastal developments, especially dredging activity. • Monitor direct effects of key climate change variables (increased temperature, acidification & extreme weather) on bony fish and recovery from these impacts.	PROGRAMS: • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Inshore zoning effect monitoring • Monitoring Spawning aggregations (2 reefs nr Cairns) • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring VARIABLES: LTMP: visual counts of reef fishes (7 families) Zoning monitoring: biomass and abundance of coral trout, snapper & others, Commercial catch Biological information on targeted species.
Sharks and rays Key pressures/impacts affecting value: o Increased sea and air temperature o Altered ocean currents o Clearing or modifying coastal habitats o Artificial barriers to flow o Death of discarded species o Marine debris o Illegal fishing and poaching o Extraction of predators	The condition of Northern offshore and Southern offshore sharks and rays is maintained and enhanced while the condition of Northern inshore and Southern inshore sharks and rays is restored to good. The declining trend in condition of sharks and rays id halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine rends in the status and condition of key species of sharks & rays. Key species include GBRMP Biodiversity Strategy 'At-Risk' sharks & rays, green sawfish, freshwater sawfish, dwarf sawfish, grey nurse shark, whale shark, white shark, speartooth shark, mako shark, estuary stingray, 11 rays identified in the East Coast Otter Trawl Fishery Ecological Risk Assessment. • Determine trends in abundance, biomass and size classes of sharks and rays on coral reefs, comparing blue, green, yellow & pink zones. • Monitor direct effects of key climate change variables (increased temperature, acidification & extreme weather) on sharks and rays and recovery from these impacts. • Monitor effects of extreme weather impacts (especially heatwaves, cyclones, floods) on critical shark and ray habitat, especially coral reefs, seagrass, mangroves (see objectives listed under these habitats).	PROGRAMS • Qld shark control program (southern inshore) • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring • Reef sharks recorded during AIMS LTMP manta tows VARIABLES Commercial fishery catch Research done comparing reef shark populations on reefs that are open and closed to fishing; Information from Shark control program and strandings database Acoustic tagging of sharks for movement and behaviours information
Marine turtles Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents	The condition of Southern inshore and offshore marine turtles is maintained and enhanced while the condition of Northern inshore and offshore marine turtles is restored to good. The trend in condition of Southern inshore and offshore marine turtles is maintained and improved while the declining condition of Northern inshore and offshore marine turtles is halted and reversed. **Preliminary Targets by 2019** • Foraging habitats (seagrass meadows and coral reefs) in the southern two-thirds of the Region are restored as per above targets	• Determine long-term population trends for hawksbill turtles nesting at Milman Island. • Determine long-term population trends for flatback turtles nesting at Peak Island. • Monitor trends in feeding populations at major sites—number, size, condition, breeding condition and related parameters including environmental. • Monitor trends in number of stranded turtles and causes of mortality (necropsies). • Determine incidence of inundation (surface or water table) of nests and	PROGRAMS: • QDEHP turtle conservation project • Dugong population monitoring • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld trawl vessel monitoring • iEotR Sightings network

Biophysical values and pressures/impacts affecting them	Draft desired management outcomes and targets (from Strategic Assessment/Program Report)	Draft core long-term monitoring objectives	Monitoring programs and variables that have been monitored
o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Dredging, dumping and resuspension of dredge material o Clearing or modifying coastal habitats o Coastal reclamation o Death of discarded species o Marine debris o Illegal fishing and poaching	• Foraging habitats (seagrass meadows and coral reefs) in the northern third of the Region are maintained and enhanced as per above targets • Nesting habitats (islands and coastal beaches) are maintained and enhanced • Populations of loggerhead, southern Great Barrier Reef green, and flatback turtle stocks continue to recover • Declines in populations of hawksbill and northern Great Barrier Reef green turtle stocks are halted and reversed	associated egg mortality. • Monitor trends in air and sand temperature at key nesting sites and associated egg mortality. • Determine marine turtle movement/migration & critical habitat use over time to help understand habitat needs/movement patterns and response following extreme events, etc. • Monitor effects of extreme weather impacts (especially heatwaves, cyclones, floods) on critical marine turtle habitat, especially nesting habitat, seagrass and coral reefs, (see objectives listed under these habitats). • Determine trends in incidence of turtle fibro-papilloma disease.	VARIABLES: Nesting populations Populations at known feeding grounds Condition of individuals Incidental sightings records (iEotR)
Seabirds Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Clearing or modifying coastal habitats o Marine debris o Extraction of predators	The condition of Northern inshore and Southern inshore seabirds is maintained and enhanced and in Northern offshore and Southern offshore condition is restored to good. The trend in condition of Northern inshore and Southern inshore seabirds is maintained and improved while the declining trend in Northern offshore and Southern offshore is halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine trends in populations and condition of priority seabird species at priority nesting, foraging, roosting sites as outlined in the Coastal Bird Monitoring and Information Strategy. • Determine trends in offshore and pelagic foraging seabird populations. • Determine availability and suitability of seabird nesting and roosting habitat on islands, this should include human disturbance and pest species disturbance. • Determine trends in seabird prey availability (pelagic & offshore foragers) and El Nino Southern Oscillation cycle (physio-chemical oceanographic). • Monitor trends in availability and suitability of feeding habitat & disturbance by human activity. • Determine effects on seabird populations from increased sea temperature, altered currents, ENSO cycles as well as recovery from these impacts. • Determine availability and suitability of seabird feeding habitat & disturbance by human activity, e.g. shipping.	PROGRAMS: • Birds Australia • Coastal bird monitoring (QPWS & GBRMPA) • PC & PA ERMP VARIABLES Census of breeding sites for seabirds and shorebirds
Shorebirds Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Nutrients from catchment runoff o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Marine debris	The condition of Northern inshore and Southern inshore shorebirds is restored to good. The declining trend in condition of Northern inshore and Southern inshore shorebirds is halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine trends in populations and condition of priority shorebird species at priority nesting, foraging, roosting sites as outlined in the Coastal Bird Monitoring and Information Strategy. • Determine population status and distribution through volunteer observational monitoring—Birds Australia. • Determine availability and suitability of shorebird nesting and roosting habitat, this should include human disturbance and pest species disturbance. • Determine effects on shorebirds from increased sea temperature, disturbance and marine debris as well as recovery from these impacts.	PROGRAMS: • Birds Australia • Coastal bird monitoring (QPWS & GBRMPA) VARIABLES: Census of breeding sites for seabirds and shorebirds
Dolphins Key pressures/impacts affecting value: o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Nutrients from catchment runoff o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators	The condition of Northern inshore and offshore as well as Southern offshore dolphins is maintained and enhanced and in Southern inshore condition is restored to good. The trend in condition of Northern inshore and offshore as well as Southern offshore dolphins is maintained and improved while the declining trend in Southern offshore is halted and reversed **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Monitor trends in distribution, population structure and dispersal patterns (including site fidelity), behavioural ecology, health status and dietary and habitat requirements of inshore dolphins. • Determine condition, extent and extent of habitats suitable for inshore dolphins. • Through an observer program, validate commercial logbook Species of Conservation Interest data (level of mortality and interaction), providing statistically representative coverage of vessel effort from the East Coast Inshore Fin Fish Fishery and East Coast Trawl Fishery (including those vessels operating in remote/less-accessible regions north of Cooktown).Work with Fisheries Qld to develop the independent observer program to a point where it can broadly be considered sufficiently robust. • Monitor trends in number of stranded dolphins and causes of mortality (necropsies). • Monitor trends in water quality, especially inshore areas. • Determine impacts to dolphins from increased sea temperature, altered ocean currents, noise pollution and marine debris as well as recovery from these impacts.	PROGRAMS • QDEHP wildlife strandings • Qld commercial fishery monitoring • iEotR Sightings network VARIABLES: Strandings Incidental sightings records (iEotR) Commercial fishery incidental catch

Biophysical values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from Strategic Assessment/Program Report)**	**Draft core long-term monitoring objectives**	**Monitoring programs and variables that have been monitored**
Dugongs Key pressures/impacts affecting value: o Altered ocean currents o Outbreaks of disease o Nutrients from catchment runoff o Coastal reclamation o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching	The condition of Northern dugongs is maintained and enhanced while the condition of Southern dugongs is restored to good. The trend iin condition of Northern dugongs is maintained and improved while the declining trend in condition of Southern dugongs is halted and reversed. **Preliminary Targets by 2019** • Foraging habitat (seagrass meadows) in the southern two-thirds of the Region is restored and maintained as per above set targets • Foraging habitat (seagrass) in the northern third of the Region is maintained as per above set targets • Southern population: the mortality of dugongs from human-related causes other than traditional use of marine resources is reduced to as close to zero as possible • Northern dugong population surveys continue to demonstrate a stable population	• Monitor trends in status and condition of dugong, including regional, GBR-wide, and neighbouring jurisdictions—dugong numbers, including proportion of mother/calf pairs. • Determine dugong movement/migration & critical habitat use over time to help understand habitat needs/movement patterns and response following extreme events, etc. • Determine condition, extent and extent of habitats suitable for dugongs. • Determine trends in number of stranded dugong and causes of mortality (necropsies). • Determine trends in numbers of dugong take (Traditional Owners, poachers, commercial net bycatch). • Monitor trends and understanding the effects of specific impacts, such as disease. • Determine effects of impacts to dugong populations from noise pollution and marine debris as well as recovery from these impacts.	PROGRAMS • Dugong monitoring - program funding insecure • QDEHP wildlife strandings • iEotR Sightings network • Qld commercial fishery monitoring • Qld trawl vessel monitoring VARIABLES: Dugong abundance Strandings Incidental sightings records (iEotR)
Connectivity Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Freshwater inflow o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow	The condition of Northern inshore and offshore connectivity is maintained while the condition of Southern offshore connectivity is maintained and enhanced. Southern inshore condition of connectivity is restored to good. The trend in condition of Northern inshore and offshore as well as Southern offshore connectivity is maintained and improved while the declining trend in Southern inshore is halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Determine coral larval production, transport and settlement between reefs to identify source & sink reefs and connectivity. • Predict COTS outbreak initiation and progression of outbreak wave through early warning monitoring based on COTS numbers, water quality, flood events. • Monitor trends in fish larval production and exchange between fished and no-take zones. • Determine trends in ontogenetic migratory patterns for bony fish. • Determine changes to inshore fish populations & productivity associated with restoration of coastal ecosystems, such as removal of barriers to flow. • Monitor trends in fish health associated with significant coastal developments, especially dredging activity. • Monitor trends in seabird prey availability (pelagic & offshore foragers) and ENSO cycle (physico-chemical oceanographic). • Determine dugong movement/migration & critical habitat use over time to help understand habitat needs/movement patterns and response following extreme events, etc. • Determine marine turtle movement/migration & critical habitat use over time to help understand habitat needs/movement patterns and response following extreme events, etc. • Determine types, distribution and fate of marine debris in the GBRWHA. • Determine the source and distinguish among sources of pesticides entering the GBRWHA. • Determine the fate of pesticides entering the GBRWHA. • Determine the source and distinguish among sources of sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Determine the source and distinguish among sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine three dimensional extent and duration of flood plumes during flood events.	See above
Recruitment Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Freshwater inflow	The condition of Northern inshore and offshore as well as Southern offshore recruitment is maintained and enhanced while the condition of Southern offshore recruitment is restored to good. The trend in condition of Northern inshore and offshore as well as Southern offshore recruitment is maintained and improved while the declining trend in Southern inshore is halted and reversed. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• See targets for habitats and species	See recruitment objectives under habitats and species.

Biophysical values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from Strategic Assessment/Program Report)**	**Draft core long-term monitoring objectives**	**Monitoring programs and variables that have been monitored**
o Nutrients from catchment runoff o Sediments from catchment runoff o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations			

Community benefit values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from strategic assessment)**	**Draft core long-term monitoring objectives**	**Monitoring programs and attributes that have been monitored**
Income & employment Key pressures/impacts affecting value: o Cyclone activity o Increased sea and air temperature o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Marine debris o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	The condition of income and employment is maintained and enhanced. The trend in condition is maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	Monitor trends in: • Industry-based stewardship, standards and innovations • Education, age and skills within the catchment population and within Reef-dependent and non-Reef-dependent industries • Capacity building opportunities for GBR Traditional Owners through TUMRAs • Economic contributions and employment levels in (a) Reef-dependent and non-Reef-dependent industries that occur in the GBR Region and catchment; and (b) Reef-dependent industries outside of the catchmen. • Marine tourism that occurs outside of the GBRWHA and catchment • Commercial fishing, direct (primary income and employment) and indirect (secondary income and employment) • Percentage of (government and other) funds allocated to different Traditional Owner programs in the GBRWHA • Adaptive capacity of Reef-dependent industries • Percentage spent on Reef-based holidays and how this might be affected by Reef condition.	PROGRAMS • Access economics • ABS census data • International Visitor Survey • National Census of Population and Housing • National Visitor Survey • Regional Tourism Activity Monitor (R-TAM) • Ad hoc social surveys VARIABLES: Economic contribution of Reef-dependent activities Adaptive capacity of Reef-dependent industries Characteristics and travel behaviour of international visitors in Australia Working population profile, community profile, usual residence profile, Indigenous profile and comparable data from previous years Characteristics and travel behaviour of Australian residents Occupancy rates Demographic characteristics of catchment residents and industries
Understanding Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification	The condition of understanding is maintained and enhanced. The trend in condition is maintained and improved. **Preliminary Targets by 2019** • There is local, regional, national and international community awareness of the Great Barrier Reef World Heritage Area; appreciation of its biodiversity and heritage values; and understanding of its issues.	Monitor trends in • Public levels of knowledge about the GBRWHA and issues related to it • Numbers of Reef Guardian cluster projects • Amount and types of information collected and shared via Reef Guardian programs and networking opportunities • How the Reef Guardian program contributes to knowledge and understanding of the GBRWHA and issues associated with it	PROGRAMS Ad hoc social surveys

Community benefit values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from strategic assessment)**	**Draft core long-term monitoring objectives**	**Monitoring programs and attributes that have been monitored**
o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations		• How people develop and use formal and informal networks, social media, mass media and other tools to receive and share information which is used to make decisions about the Reef.	VARIABLES: Public levels of knowledge about the GBRWHA and issues related to it
Access to Reef resources Key pressures/impacts affecting value: o Cyclone activity o Outbreaks of disease o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Death of discarded species o Marine debris o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	The condition of access to reef resources is maintained and enhanced. The trend in condition is maintained and improved. **Targets** The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	Determine trends in • Numbers and types of people who visit/use the Reef • How and when people access the Reef • Proportion of the Marine Park accessed by different users • Perceptions of equity in access to Reef resources • Proportion of the Marine Park accessed by different users • Perceptions of crowdedness at different Reef locations • Costs of access.	PROGRAMS Environmental Management Charge Fisheries monitoring Zoning Plans, POMs Ad hoc social surveys VARIABLES: Numbers and types of people who visit/use the Reef How and when people access the Reef Perceptions of crowdedness at different Reef locations
Appreciation/ enjoyment/ aesthetics: Key pressures/impacts affecting value: o Cyclone activity o Increased sea and air temperature o Outbreaks of disease o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators	The condition of aesthetics is maintained and enhanced. The trend in condition is maintained and improved. **Preliminary Targets by 2019** • There is local, regional, national and international community awareness of the Great Barrier Reef World Heritage Area; appreciation of its biodiversity and heritage values; and understanding of its issues. • Tourism and recreation users of the Region are highly satisfied with their experiences	Determine trends in: • Public enjoyment, appreciation & understanding of the natural, social and cultural dimensions of the GBRWHA • Aesthetic qualities using (a) visual surveys (e.g. manta tows) of habitat types rated according to visual appeal; (b) biophysical monitoring data e.g. water quality (collected in other programs).	PROGRAMS Ad hoc social surveys Visual surveys to ascertain aesthetics National Environmental Research Program Tropical Ecosystems Hub Project 10.2 - Socio-economic system and reef resilience VARIABLES: • Public enjoyment, appreciation & understanding of the natural, social and cultural dimensions of the GBRWHA • Aesthetic qualities

Community benefit values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from strategic assessment)**	**Draft core long-term monitoring objectives**	**Monitoring programs and attributes that have been monitored**
Fishing spawning aggregations			
Personal attachment Key pressures/impacts affecting value: o Cyclone activity o Increased sea and air temperature o Outbreaks of disease o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	The condition of personal connection is maintained. The trend in condition is maintained and improved. **Preliminary Targets by 2019** • Traditional Owners, stakeholders, visitors and local residents maintain their personal connections to the Great Barrier Reef	Monitor trends in: • Number and types of people who visit/use the Reef • Reef Guardian program participation, Local Marine Advisory Committee membership • Occupational identity of Reef-dependent industry employees • Cultural ties, spiritual connections with the Reef • Motivation to visit/be close to the Reef, learn about the Reef.	PROGRAMS Ad hoc social surveys VARIABLES: • Number and types of people who visit/use the Reef • Occupational identity of Reef-dependent industry employees • Motivation to visit/be close to the Reef, learn about the Reef
Health benefits Key pressures/impacts affecting value: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	The condition of health benefits is maintained. The trend in condition is maintained and improved. **Preliminary Targets by 2019** • The Great Barrier Reef continues to provide personal and community health benefits	Monitor trends in • Types of health benefits/products • Types/groups of beneficiaries.	PROGRAMS Ad hoc social surveys VARIABLES: • Psychological benefits of Reef visitation
Heritage values and pressures/impacts affecting them	**Draft desired management outcomes and targets (from strategic assessment)**	**Draft core long-term monitoring objectives**	**Variables that have been monitored or need to be monitored**
Cultural practices, observances, customs and lore	The condition of cultural practices, observances, customs and lore is maintained and enhanced. The trend in condition is maintained and improved. **Preliminary Targets by 2019** • A protocol and knowledge management system for the	To be developed	Monitor trends in: • Processes and mechanisms that contribute to Traditional Owner cultural practices, observances, customs and lore • Public awareness of, understanding and recognition of cultural practices, observances, customs and lore that

Community benefit values and pressures/impacts affecting them	Draft desired management outcomes and targets (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and attributes that have been monitored
	collection, handling and sharing of culturally sensitive information, and its integration in decision making, is developed and implemented • Existing Indigenous heritage information held by the Authority is incorporated into knowledge management systems • An assessment of Indigenous heritage values is completed for 20 per cent of the Region • Cooperative management arrangements are in place with 40 per cent of Great Barrier Reef Traditional Owner groups		relate to the Great Barrier Reef and catchment • Causes of isolation from cultural practices, observances, customs and lore • Integration, acknowledgement or uptake of traditional ecological knowledge by Reef managers • Number of Indigenous heritage values considered in environmental assessments and other management arrangements • Instances that Indigenous heritage values are considered in environmental assessments or other management arrangements or decisions • Number of Indigenous heritage values and concepts used in decision making arrangements for management.
Indigenous sacred sites, sites of particular significance, places important for cultural tradition: Sacred sites and other sites of cultural significance are under pressure in many of the coastal areas in and adjacent to the Region. Pressure is being exerted primarily through coastal habitat degradation, direct use of the Region and climate change. Others are intact and likely to continue to be well managed by Traditional Owners into the future. Relevant MNES: the Great Barrier Reef Marine Park; Commonwealth Marine Area; National Heritage Place, World Heritage	The condition of indigenous sacred sites, sites of particular significance and places important for cultural tradition is restored to good. The declining trend in condition is halted and reversed. **Preliminary Targets by 2019** • A protocol and knowledge management system for the collection, handling and sharing of culturally sensitive information, and its integration in decision making, is developed and implemented • Existing Indigenous heritage information held by the Authority is incorporated into knowledge management systems • An assessment of Indigenous heritage values is completed for 20 per cent of the Region • Cooperative management arrangements are in place with 40 per cent of Great Barrier Reef Traditional Owner groups	• Determine trend in condition of known indigenous heritage sites and activities by developing monitoring frameworks to assist Traditional Owners to readily report on the condition of these sites.	Monitor trends in: • Public awareness of the significance and range of places important for cultural tradition, sacred sites, sites of particular significance • Processes or activities that potentially damage places important for cultural tradition, sacred sites, sites of particular significance • Identification and registration (where appropriate) of sites and activities of Indigenous significance.
Indigenous stories, song lines, totems and languages Direct use of the Region and other drivers can degrade indigenous stories, song lines, totems and languages (for example shipping and clearing of coastal habitats can impact on song lines and totems and the continuation of this heritage). While some languages are still spoken each day some are not, they have been lost or are only ever recollected by elders. Permission to tell these stories can only be given by the custodians of these stories. Relevant MNES: the Great Barrier Reef Marine Park; Commonwealth Marine Area; National Heritage Place; World Heritage.	The condition of indigenous stories, song lines, totems and languages is restored to good. The declining trend in condition is halted and reversed. **Preliminary Targets by 2019** • A protocol and knowledge management system for the collection, handling and sharing of culturally sensitive information, and its integration in decision making, is developed and implemented • Existing Indigenous heritage information held by the Authority is incorporated into knowledge management systems • An assessment of Indigenous heritage values is completed for 20 per cent of the Region • Cooperative management arrangements are in place with 40 per cent of Great Barrier Reef Traditional Owner groups	Determine trends in: • Barriers to the use and transmission of traditional stories, song lines, totems and language • Public interest in, respect, and understanding for traditional stories, song lines, totems and languages that relate to the Great Barrier Reef and catchment.	• To be developed
Indigenous structures,	The condition of indigenous structures, technology, tools and archaeology is restored to good. The declining trend in condition is halted and	Determine trends in: • Traditional Owner access to (or maybe use of?) Indigenous structures,	• To be developed

Community benefit values and pressures/impacts affecting them	Draft desired management outcomes and targets (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and attributes that have been monitored
technology, tools and archaeology Due to the introduction and adoption of new technology, Indigenous people today may live more modern lifestyles than in the past. This is still considered traditional use because it is the cultural practice of activities such as hunting and gathering of resources, the knowledge of where to find them and the preparation, social sharing and consumption of food resources that is important rather than the tools used. The quality and integrity of cultural practices are affected by impacts that diminish the underlying condition of environment (e.g. biodiversity and heritage values). Impacts that diminish water quality, reduce the abundance of target fish species or affect the health and abundance of coral reefs significantly affect this attribute. Relevant MNES: the Great Barrier Reef Marine Park; Commonwealth Marine Area; National Heritage Place, World Heritage	reversed. **Preliminary Targets by 2019** • A protocol and knowledge management system for the collection, handling and sharing of culturally sensitive information, and its integration in decision making, is developed and implemented • Existing Indigenous heritage information held by the Authority is incorporated into knowledge management systems • An assessment of Indigenous heritage values is completed for 20 per cent of the Region • Cooperative management arrangements are in place with 40 per cent of Great Barrier Reef Traditional Owner groups	technology, tools and archaeology • Identification and registration (where appropriate) of Indigenous structures, technology, tools and archaeology • Processes or activities that potentially damage Indigenous structures, technology, tools and archaeology.	
Places of historic significance – light stations: While some light stations are maintained or restored, others are deteriorating. The materials used and construction techniques of some make them vulnerable to deterioration. Increased cyclones and rising sea level are likely to present an increasing risk to these structures. Relevant MNES: the Great Barrier Reef Marine Park; Commonwealth Marine Area; National Heritage Place, World Heritage	The condition of historic light stations is maintained and enhanced. The declining trend in condition is halted and reversed. **Preliminary Targets by 2019** • An historic heritage database for the storage and handling of historic heritage information, and its integration in decision making, is developed and implemented • The number of World War II features and other historic sites with statutory protection is increased • Heritage management plans for Low Isles and North Reef lightstations are completed and heritage management plans for the four Commonwealth heritage listed lightstations implemented	**Historic Indigenous significance** Determine trends in: • Public awareness of, interest in, and respect for places and events of historic Indigenous significance • Processes or activities that potentially damage or compromise places and events of historic Indigenous significance • Number of historic Indigenous heritage values together with the number of times these values are considered in environmental assessments and other management arrangements • Identification and registration (where appropriate) of places and events of historic Indigenous significance **Shared Historic significance** Determine trends in: • Public access to places of historic significance • Public knowledge, understanding and appreciation of historic events and sites Processes or activities that potentially damage or compromise places and events of historic significance • Number of historic heritage values considered in environmental assessments and other management arrangements • Identification and registration (where appropriate) of places and events of historic significance	• To be developed
Places of social significance – iconic sites: The condition of some iconic sites has deteriorated. As many are associated with coral reefs, future risks to that	The condition of iconic sites is maintained and enhanced. The declining trend in condition is halted and reversed. **Targets**	Determine trends in: • Processes or activities that potentially damage or compromise iconic sites (including public access) • Public enjoyment, knowledge, appreciation of and levels of satisfaction with iconic sites	• To be developed.

Community benefit values and pressures/impacts affecting them	Draft desired management outcomes and targets (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and attributes that have been monitored
habitat are likely to also affect their condition. The defined area of such sites makes it more feasible to undertake management intervention to maintain their condition. Relevant MNES: the Great Barrier Reef Marine Park; Commonwealth Marine Area; National Heritage Place, World Heritage	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model.	• Number of iconic sites and events (and their values) considered in environmental assessments and other management arrangements • Number of iconic sites and events (and their values and concepts) incorporated into decision making arrangements for management • Identification, promotion and registration (where appropriate) of iconic sites and events.	

PRESSURES/IMPACTS

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
Increased sea & air temperature Values affected by pressure/impact o Islands o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Marine turtles o Dolphins o Seabirds o Shorebirds o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Primary production pelagic o Connectivity o Recruitment o Income, economic contribution and employment o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Measure trends in frequency, intensity and spatial extent of sea and air temperature variability. • See objectives listed against other pressures for cumulative impacts.	PROGRAMS: • Q-IMOS - Great Barrier Reef Ocean Observing System • ReefTemp • AIMS-GBRMPA Sea Temperature Monitoring Program • AIMS Weather Observing System • BoM VARIABLES: Sea temperature—surface and at depth Air temperature Weather station and satellite data
Cyclone activity Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Sea snakes o Bony fish	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Track paths, intensities, spatial extent and system speed of all tropical cyclones in or near the GBRWHA. • Determine rainfall patterns as a result of tropical cyclones and lows.	PROGRAMS: • QDEHP wave monitoring • QDEHP Storm Tide • BoM VARIABLES: Cyclone pressure, direction of movement, extent, wind speeds

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding			
Ocean acidification Values affected by pressure/impact o Open waters o Coral reefs and corals o Other invertebrates o Bony fish o Understanding	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine trend in ocean acidification at the GBR scale.	PROGRAMS: • Q-IMOS VARIABLES: pH, alkalinity, dissolved CO2 concentrations
Rising sea level Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Seabirds o Shorebirds o Connectivity o Recruitment o Personal attachment o Understanding	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine trend in rising sea level.	PROGRAMS • Australian baseline sea level monitoring program VARIABLES: Tide height from tidal gauges
Altered ocean currents and smaller scale circulation Values affected by pressure/impact o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Marine turtles o Dugongs o Dolphins o Seabirds o Shorebirds o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Primary production pelagic o Connectivity o Recruitment o Income, economic contribution and employment o Understanding	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine trends in oceanic, GBR, regional and local scale water circulations.	PROGRAMS: • Q-IMOS VARIABLES Current strength and direction from moorings, gliders, high frequency radar, satellite imagery, hydrodynamic models Hydrodynamic model outputs
Increased freshwater flow	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader	• Determine flow rate and volume of fresh water entering the GBR from adjacent catchments.	PROGRAMS: • Qld Surface Water Ambient Network

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Other invertebrates o Bony fish o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Understanding	community based on the successful Reef Plan model	• Determine three dimensional extent and duration of flood plumes during flood events. • Measure trends in rainfall in the catchment.	• Reef Rescue Marine Monitoring Program Ambient water quality, Remote sensing, Flood monitoring • BoM riverflow monitoring • Ports VARIABLES: Salinity CDOM Gauged flow from rivers
Outbreaks of disease (climate change driven) Values affected by pressure/impact o Coral reefs and corals o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Measure trends in incidence of coral disease • Measure trends in incidence of turtle fibro-papilloma • Measure trends in incidence of disease outbreaks in bony fish, such as Qld Grouper and Gladstone fish populations.	PROGRAMS: • AIMS LTMP • iEotR tourism weekly, RHIS, rapid assessment, sightings network • Reef Rescue inshore coral monitoring • QDEHP wildlife strandings • Qld turtle conservation project VARIABLES: Coral disease—captured through coral monitoring programs Megafauna disease—through strandings database
Nutrients from catchment runoff Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Dugongs o Dolphins o Shorebirds o Other invertebrates o Bony fish o Primary production pelagic o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Targets by 2019** • Meet Reef Plan targets for catchment runoff • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded	• Determine species, concentrations and distribution of nutrients that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of nutrients entering the GBRWHA. • Determine the fate of nutrient species entering the GBRWHA. • Determine concentrations of chlorophyll a throughout the GBRWHA. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment.	PROGRAMS: • Reef Rescue Marine Monitoring Program nutrient monitoring, Ambient water quality • Reef Plan catchment loads • Reef Rescue Marine Monitoring Program flood plume monitoring • Ports VARIABLES Particulate and dissolved nutrient species (N & P) Chlorophyll
Sediments from catchment runoff	**Preliminary Targets by 2019** • Meet Reef Plan targets for catchment runoff	• Measure trends in sediment transport from catchments. • Measure trends in turbidity and light levels for key habitats as a result of sediments against water quality guidelines. • Determine the source and be able to distinguish between sources of	PROGRAMS: • Reef Rescue Marine Monitoring Program ambient water quality

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Primary production pelagic o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	• Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded	sediments entering the GBRWHA. • Determine the fate of sediments entering the GBRWHA. • Distinguish between new sediment entering the GBRWHA and resuspension of sediments. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment.	• Reef Plan catchment loads • Ambient Monitoring associated with ports at: o Cairns o Mourilyan o Townsville o Hay Point o Mackay o Abbot Point o Gladstone (incl. Port Curtis Integrated Monitoring Program, Port Curtis and Port Alma Environmental Research and Monitoring Program) VARIABLES: Suspended sediments Turbidity
Pesticides from catchment runoff Values affected by pressure/impact o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Other invertebrates o Bony fish o Primary production pelagic o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Targets by 2019** • Meet Reef Plan targets for catchment runoff • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded	• Determine types, concentrations and distribution of pesticides that have entered the GBRWHA for catchments against water quality guidelines. • Determine the source and be able to distinguish between sources of pesticides entering the GBRWHA. • Determine the fate of pesticides entering the GBRWHA. • Measure extent of proposed and actual land use changes (clearing & agriculture) in the catchment.	PROGRAMS: • Reef Rescue Marine Monitoring Program pesticide monitoring, Ambient water quality, inshore seagrass • Reef Plan catchment loads VARIABLES: Pesticide concentrations ambient and in flood waters
Crown-of-thorns starfish Values affected by pressure/impact o Coral reefs and corals o Other invertebrates o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Targets by 2019** • Meet Reef Plan targets for catchment runoff • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Predict COTS outbreak initiation and progression of outbreak wave through early warning monitoring based on COTS numbers, water quality, flood events. • Determine level of COTS & *Drupella* predation on corals throughout the GBR.	PROGRAMS • AIMS LTMP • iEotR RHIS VARIABLES: COTS densities
Outbreaks of disease (water quality related) Values affected by pressure/impact o Coral reefs and corals o Marine turtles o Dugongs	**Preliminary Targets by 2019** • Meet Reef Plan targets for catchment runoff • Ensure Great Barrier Reef Marine Park water quality guidelines are not exceeded	• Measure trends in incidence of coral disease. • Measure trends in incidence of turtle fibro-papilloma. • Measure trends in incidence of disease outbreaks in bony fish, such as Qld grouper and Gladstone fish populations.	PROGRAMS: • AIMS LTMP • iEotR tourism weekly surveys, RHIS surveys, rapid assessment, sightings network • Reef Rescue inshore coral monitoring • QDEHP wildlife strandings • Qld turtle conservation project

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
o Dolphins o Bony fish o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding			VARIABLES: Coral disease—captured through coral monitoring programs Megafauna disease—through strandings database
Marine debris Values affected by pressure/impact o Beaches and coastline o Open waters o Mangrove diversity o Marine turtles o Dugongs o Dolphins o Seabirds o Shorebirds o Other invertebrates o Sea snakes o Bony fish o Sharks and Rays o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Targets by 2019** • The volume of marine debris on the Great Barrier Reef's islands, beaches and coastlines is reduced by 20 per cent • The mortality of species of conservation concern due to ingestion of or entanglement in marine debris is reduced by 20 per cent	• Determine types, distribution and fate of marine debris in the GBRWHA.	PROGRAMS • Australian Marine Debris Initiative (AMDI) VARIABLES • Quantity and source of debris
Dredging and spoil disposal Values affected by pressure/impact o Beaches and coastline o Open waters o Seagrass meadows and seagrasses o Coral reefs and corals o Mangrove diversity o Marine turtles o Other invertebrates o Bony fish o Primary production pelagic o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Measure trends in extent of proposed and actual dredging activities. • Determine movement of sediments from dredging and dumping of dredged spoil. • Determine contribution of dredging activity to sediment resuspension. • Determine impact on sedimentation, turbidity and light levels from sediment plumes derived from dredging activities. • Determine properties of dredged materials including physical properties, nutrients, chemicals and toxins.	Monitoring programs for specific development projects VARIABLES Sedimentation Light Turbidity Ambient monitoring of turbidity and suspended sediments
Clearing and modifying coastal habitats Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Coral reefs and corals	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Measure trends in extent of proposed and actual land use changes (clearing & agriculture) in the catchment to identify seagrass meadows and mangroves subject to new (ongoing) impacts. • Monitor effectiveness of land-based actions to improve water quality of catchment runoff.	PROGRAMS • Queensland Land Use Monitoring Program (QLUMP) Aerial/satellite surveys See water quality – nutrients, sediments and pesticides above.

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
o Mangrove diversity o Marine turtles o Seabirds o Shorebirds o Other invertebrates o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding			
Coastal reclamation Values affected by pressure/impact o Islands o Beaches and coastline o Seagrass meadows and seagrasses o Mangrove diversity o Marine turtles o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine extent of proposed and actual seagrass and mangrove clearing.	PROGRAMS • QLUMP Aerial/satellite surveys
Extraction of predators Values affected by pressure/impact o Dolphins o Seabirds o Bony fish o Sharks and rays o Connectivity o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine spatial and temporal trends in fishing effort and catch, especially the Reef Line, Inshore Line and net fisheries. • Determine number and mass of fish taken (by species) for all sectors (incl. recreational) analysed by trophic group (i.e. catch). • Trends in numbers of registered recreational vessels by Local Government Area and vessel size. • Determine numbers of sharks taken as bycatch in commercial nets and trawl. • Measure trends in grounds subjected to trawling trough VMS data. • Measure trends in fishing impacts, including areas external to WHA that impact migratory species, e.g. long line fishing in the coral sea. • Determine trends in marine debris and catch of seabirds through the long line fishery. • Determine trends in fishing activities that interact with inshore dolphins to verify the level of mortality and interaction, i.e. independent observer program. • Determine trends in extraction of bony fish including targeted and bycatch species, through commercial, recreational and charter fishing activities. • Determine trends in illegal fishing including fish spawning aggregations. • Through an observer program, validate commercial logbook Species of Conservation Interest data (level of mortality and interaction), providing statistically representative coverage of vessel effort from the East Coast Inshore Fin Fish Fishery (ECIFFF) and East Coast Trawl Fishery (including those vessels operating in remote/less-accessible regions north of Cooktown). Work with Fisheries Qld to develop the independent observer program to a point where it can broadly be	PROGRAMS: • Qld commercial fishery monitoring • Qld trawl vessel monitoring • Qld Recreational fishing monitoring VARIABLES: Commercial catch Recreational catch information (limited) Compliance monitoring

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
		considered sufficiently robust.	
Death of discarded species Values affected by pressure/impact o Marine turtles o Dugongs o Dolphins o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Target by 2019** • The incidental catch of species of conservation concern is reduced by 50 per cent	• Determine spatial and temporal trends in fishing effort and catch, especially the Reef Line, Inshore Line and net fishery. • Determine number and mass of fish taken (by species) for all sectors (incl. recreational) analysed by trophic group (i.e. catch). • Determine trends in numbers of sharks taken as bycatch in commercial nets and trawl. • Determine trends in numbers of turtles taken as bycatch in commercial nets and trawls—more relevant, accurate and timely data of where and how often interactions occur between marine turtles and ECIFFF (in particular, set mesh net operations). • Through an observer program, validate commercial logbook Species of Conservation Interest data (level of mortality and interaction), providing statistically representative coverage of vessel effort from the East Coast Inshore Fin Fish Fishery and East Coast Trawl Fishery (including those vessels operating in remote/less-accessible regions north of Cooktown).Work with Fisheries Qld to develop the independent observer program to a point where it can broadly be considered sufficiently robust.	PROGRAMS: • Qld commercial fishery logbooks • Qld trawl vessel monitoring • Qld Recreational fishing surveys • Queensland Department of Environment and Heritage Protection Strandings network VARIABLES: Logbooks
Illegal fishing and poaching Values affected by pressure/impact o Marine turtles o Dugongs o Dolphins o Other invertebrates o Sea snakes o Bony fish o Sharks and rays o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	**Preliminary Target by 2019** • A reducing trend in the incidence of illegal fishing and poaching through: - Implementation of a remote vessel monitoring system on the commercial fishing fleet by 2015 - The maintenance of an effective field compliance presence in the Increase	• Measure trends in numbers of fishers and infringements with regard to zoning Plan (especially green zone infringements). • Measure trends in extent (and details of) illegal fishing. • Measure trends in numbers of turtles and dugong taken by poachers.	PROGRAMS: • GBRMPA-QPWS Compliance monitoring • Integrated Eye on the Reef Incident reporting
Noise pollution Values affected by o Dugongs o Dolphins o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine the potentially serious threat that underwater noise and activity from increased vessel traffic, surveying, construction, dredging and maritime operations pose to inshore dolphins. Work with researchers and other stakeholders to better understand the effects of underwater noise and consider developing a policy framework to inform the management of these impacts.	PROGRAMS: • Ports monitoring VARIABLES: In-water acoustic monitoring around port developments
Artificial barriers to flow Values affected by pressure/impact o Shorebirds o Other invertebrates o Bony fish o Sharks and rays o Connectivity o Recruitment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine trends in ontogenetic migratory patterns for bony fish. • Determine trends in extent of proposed and actual land use changes (clearing & agriculture) in the catchment to identify seagrass meadows subject to new (ongoing) impacts. • Monitor effectiveness of land-based actions to improve water quality of catchment runoff.	PROGRAMS: • QLUMP Aerial/satellite surveys

Pressures/Impacts	Draft management targets required to achieve 'state' outcomes (from strategic assessment)	Draft core long-term monitoring objectives	Monitoring programs and variables currently being monitored
Fishing spawning aggregations Values affected by pressure/impact o Bony fish o Recruitment o Income, economic contribution and employment o Access to resources and heritage o Appreciation, enjoyment, aesthetics o Personal attachment o Understanding	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model	• Determine trends in key species numbers/densities on fish spawning aggregation sites. • Determine trends in incidence of fishing on aggregations site during closures.	• GBRMPA-QPWS Compliance monitoring • Integrated Eye on the Reef Incident reporting
Other impacts	The development of further targets will be a collaborative process between the Australian and Queensland governments, stakeholders and the broader community based on the successful Reef Plan model		

DRIVERS

Driver	Draft understanding required to inform DPSIR framework & modelling	Draft core long-term monitoring objectives	Variables currently being monitored
Climate change has direct and ongoing effects on the environment, as higher temperatures and changing rainfall regimes in some areas can be expected to have profound and pervasive influence over a host of natural processes that underpin the condition and trend of ecosystems. Key pressures influenced by driver: o Rising sea level o Cyclone activity o Increased sea and air temperature o Ocean acidification o Altered ocean currents o Outbreaks of disease o Freshwater inflow	To understand how Reef-dependent industries and local communities are likely to respond to policy and/or legislative requirements in the face of climate change or extreme weather events. To understand how trends in climate change and/or extreme weather events drive factors that affect Reef condition.	Measure trends in: • Global concentration of atmospheric CO2 • Uptake of new technologies to reduce carbon emissions among Reef users and catchment residents • Adaptive capacity of Reef-dependent industries • Public uptake of new information about climate change and its impact on the Great Barrier Reef	Atmospheric CO2 concentrations
Economic growth will probably include increased demand for energy and other resources, as well as increased waste generation, with all the accompanying environmental implications for resource development, emissions and waste disposal. Alternatively, economic growth may be largely decoupled from increased consumption of resources and increased waste. Improvements in the efficiency of resource use have led to a weakening of the link between economic growth and energy use over recent decades. Key pressures influenced by driver: o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff	To understand how trends in economic growth affects Reef-dependent industries, local communities, Reef visitors and Reef condition.	Measure trends in: • New industries/projects in the catchment • Expansion/contraction of global, national and regional economies • Queensland's economic growth rate compared with Australia and OECD economic growth rates • Environmental footprint of marine and catchment industries & coastal and island development	Number and type of new and expanded projects (e.g. Coal mines, coal seam gas projects, industry infrastructure including those associated with expanded ports) Extent of agricultural intensification

Driver	Draft understanding required to inform DPSIR framework & modelling	Draft core long-term monitoring objectives	Variables currently being monitored
o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations			
Population growth is likely to continue to drive the need for expanded suburban development. The size of this impact will depend on how sensitive planning has been towards local environmental assets and values, and on the effectiveness of policies to improve the energy efficiency of housing and transport. Key pressures influenced by driver: o Nutrients from catchment runoff o Sediments from catchment runoff o Dredging, dumping and resuspension of dredge material o Pesticides from catchment runoff o Outbreak of crown-of-thorns starfish o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations	To understand how trends in human population growth affects Reef-dependent industries, local communities, Reef visitors and Reef condition.	Determine trends in population growth in the catchment and how this affects people's relationship with the Great Barrier Reef, and Reef condition. Include trends in: • Population growth in the catchment, in Queensland, nationally and internationally • Percentage of new residents in the catchment • Amount and type of coastal and marine infrastructure including ports, marinas, jetties, pontoons, tourist resorts	Population growth in the catchment, in Queensland, nationally and internationally Percentage of new residents in the catchment Amount and type of coastal and marine infrastructure including ports, marinas, jetties, pontoons, tourist resorts
Technological development Technological development is the application of scientific knowledge to create tools to solve specific social, economic or environmental problems. Technological advances have brought major changes to the way people communicate, work, learn, travel and spend leisure time. Technology has changed the way we learn about, manage and use the Region and its resources. Key pressures influenced by driver: o Dredging, dumping and resuspension of dredge material o Noise pollution o Illegal fishing and poaching o Extraction of predators	To understand how trends in technological development affect the ways in which people understand, learn about, appreciate and enjoy different aspects of the GBRWHA. To understand how trends in technological development affect Reef condition.	• Determine trends in technological developments and their potential effect on people's relationship with the Great Barrier Reef, and Reef condition. • Measure ways in which new technologies are used to understand and share information about the Reef, enhance visitor experiences, advance research and scientific activities, accelerate catchment and Reef-based extractive activities and support Reef-dependent and non-Reef-dependent industries.	Number and type of new technologies used among Reef users Ways in which new technologies are used to understand and share information about the Reef; enhance visitor experiences; advance research and scientific activities; accelerate catchment and Reef-based extractive activities
Societal attitudes Societal attitudes operate at international, national and local scales, and are shaped by cultural and social norms, institutional arrangements, economic imperatives and politics.	To understand how trends in societal attitudes affect the ways in which people relate to the GBRWHA.	• Determine trends in social norms, institutional arrangements, local, national and international agreements and legislation influencing people's relationships with the Reef, and Reef condition. • Determine trends in social and cultural limits around acceptable use of the Reef (past, present, future). • Determine trends in content and interpretation of mass media	Content and interpretation of mass media messages which are pertinent to the Great Barrier Reef Number, type and intent of local, national and international initiatives which reflect societal attitudes towards the Great Barrier Reef

Driver	Draft understanding required to inform DPSIR framework & modelling	Draft core long-term monitoring objectives	Variables currently being monitored
Key pressures influenced by driver: o Clearing or modifying coastal habitats o Coastal reclamation o Artificial barriers to flow o Death of discarded species o Marine debris o Noise pollution o Illegal fishing and poaching o Extraction of predators o Fishing spawning aggregations		messages which are pertinent to the Great Barrier Reef.	

Reference

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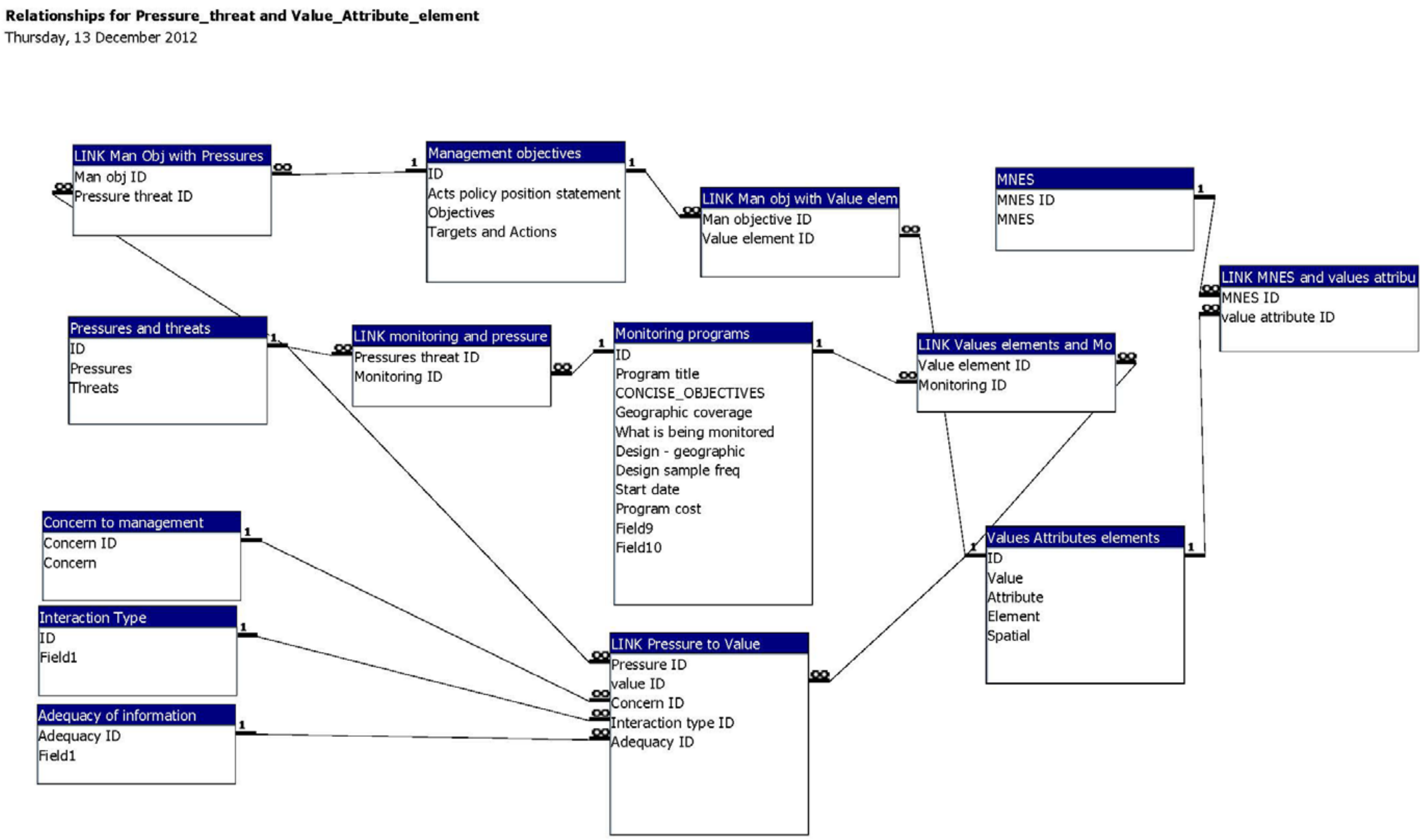
Appendix 4 Database schema



Appendix 5 Prioritisation of MNES values

Understanding the table

Very good	Good	Poor	Very poor
Very good: All major habitats are essentially structurally and functionally intact and able to support all dependent species. Only a few, if any, species populations have deteriorated as a result of human activities or declining environmental conditions.	**Good:** There is some habitat loss, degradation or alteration in some small areas, leading to minimal degradation but no persistent, substantial effects on populations of dependent species. Populations of some species (but no species groups) have deteriorated significantly as a result of human activities or declining environmental conditions.	**Poor:** Habitat loss, degradation or alteration has occurred in a number of areas leading to persistent substantial effects on populations of some dependent species. Populations of many species or some species groups have deteriorated significantly as a result of human activities or declining environmental conditions.	**Very poor:** There is widespread habitat loss, degradation or alteration leading to persistent, substantial effects on many populations of dependent species. Populations of a large number of species have deteriorated significantly.

Area		Trend		Confidence in condition and trend	
N.I.	Northern inshore	↑	Improving	●	Adequate high-quality evidence and high level of consensus
N.O.	Northern offshore	↔	Stable	◐	Limited evidence or limited consensus
S.I.	Southern inshore	↓	Deteriorating	○	Very limited evidence, assessment based on anecdotal information
S.O.	Southern offshore	—	No clear trend		

	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	1							2	3	4	5	6	7
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
	Condition and recent trend												
Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)							
Mangroves	N.I.	↔				◐ ◐	HIGH	HIGH Rising sea level Cyclone activity Increased sea and air temperature Freshwater inflow Sediments from catchment runoff Dredging & dumping of spoil Marine debris Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Nutrients from catchmnet runoff Oil spill - large Pesticides from catchment runoff Wash from vessels	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role -habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals; natural beauty **Social:** supports recreation *e.g. bird-watching; crabbing* stewardship; education **Cultural:** places for teaching TO language and other aspects of culture; source of food for TOs **Economic:** supports commercial fishing, recreation and tourism	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	LOW Mangrove Watch
Mangroves ↔	S.I.		↔			◐ ◐	HIGH	HIGH Rising sea level Cyclone activity Increased sea and air temperature Freshwater inflow Sediments from catchment runoff Dredging & dumping of spoil Marine debris Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Nutrients from catchmnet runoff Oil spill - large Pesticides from catchment runoff Wash from vessels	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role -habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals; natural beauty **Social:** supports recreation *e.g. bird-watching; crabbing* stewardship; education **Cultural:** places for teaching TO language and other aspects of culture; source of food for TOs **Economic**: supports commercial fishing, recreation and tourism	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	LOW Mangrove Watch; Ports ambient monitoring
Seagrasses	N.I.	↔				◐ ◐	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dredging - driect impacts Dumping of dredge material Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role - habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation e.g. *fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing and recreation	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	HIGH • Seagrass Watch • (RRMMP) Inshore Seagrass Monitoring
Seagrasses	N.O.	↔				○ ○	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Cyclone activity Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role -habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation *e.g. fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	LOW None
Seagrasses	S.I.				↓	◐ ◐	HIGH	HIGH Acid sulphate soils Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dredging - driect impacts Dumping of dredge material Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role -habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation e.g. *fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing and recreation	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	HIGH • Seagrass Watch • (RRMMP) Inshore Seagrass Monitoring Ambient Monitoring associated with ports at: • Cairns • Mourilyan • Townsville • Hay Point • Mackay • Abbot Point • Gladstone (PCIMP, PC&PA ERMP)

	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	1							2	3	4	5	6	7
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
	Condition and recent trend												
Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)							
Seagrasses	S.O.			↓		○ ○	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Cyclone activity Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH A group of species with a regionally important ecological role -habitat structure & food source that affects a large biomass and number of other marine species	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation *e.g. fishing* **Cultural:** supports dugong and turtle populations **Economic:** supports commercial fishing and recreation	HIGH Outlook Report Assessment component Biodiversity Strategy 'at risk' habitat	LOW None
Macro algae	N.I., N.O., S.O.	↔				○ ○	LOW	HIGH Cyclone activity Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - GBRMP Zoning plan GBRMPA Act QLD Marine Parks Act Reef Water Quality Protection Plan Climate Change Adaptation Strategy and Action Plan Fisheries Act 1994	LOW	LOW	LOW Outlook Report Assessment component	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral nonitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring)
Macro algae	S.I.		↔			◐ ◐	LOW	HIGH Cyclone activity Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Reef Water Quality Protection Plan Climate Change Adaptation Strategy and Action Plan Fisheries Act 1994	LOW	LOW	LOW Outlook Report Assessment component	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral nonitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring)
Benthic microalgae	N.I., N.O., S.O.	↔				○ ○	LOW	HIGH Cyclone activity Dumping of dredge material Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Reef Water Quality Protection Plan GBRMP Water Quality Guidelines	HIGH A group of species with a regionally important ecological role -food source that affects a large biomass and number of other marine species	LOW	LOW Outlook Report Assessment component	LOW • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program
Benthic microalgae	S.I.		↔			○ ○	LOW	HIGH Cyclone activity Dumping of dredge material Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Reef Water Quality Protection Plan GBRMP Water Quality Guidelines	HIGH A group of species with a regionally important ecological role -food source that affects a large biomass and number of other marine species	LOW	LOW Outlook Report Assessment component	LOW • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program
Corals	N.I., N.O.		⇔			● ●	HIGH	HIGH Altered ocean currents Cyclone activity Dumping of dredge material Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff Clearing and modifying coastal habitat	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH A group of species with a regionally important ecological role - provides habitat structure for a large biomass and number of other marine species; A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH GBRMP Regulations - No specimens to be taken or possessed at any time Biodiversity Strategy 'at risk' habitat Outlook Report Assessment component	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) * Although corals and coral reefs have targeted monitoring programs with valuable long term data sets, species diversity is not currently monitored.
Corals	S.I.				↓	● ●	HIGH	HIGH Altered ocean currents Cyclone activity Dumping of dredge material Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff Clearing and modifying coastal habitat	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH A group of species with a regionally important ecological role - provides habitat structure for a large biomass and number of other marine species; A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH GBRMP Regulations - No specimens to be taken or possessed at any time Biodiversity Strategy 'at risk' habitat Outlook Report Assessment component	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) * Although corals and coral reefs have targeted monitoring programs with valuable long term data sets, species diversity is not currently monitored.
Corals	S.O.			↓		● ●	HIGH	HIGH Altered ocean currents Cyclone activity Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH A group of species with a regionally important ecological role - provides habitat structure for a large biomass and number of other marine species; A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH GBRMP Regulations - No specimens to be taken or possessed at any time Biodiversity Strategy 'at risk' habitat Outlook Report Assessment component	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) * Although corals and coral reefs have targeted monitoring programs with valuable long term data sets, species diversity is not currently monitored.

Value	Area	Condition and recent trend: Very Good	Good	Poor	Very Poor	Confidence (condition, trend)	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high') 1 Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments	2 High or moderate single or cumulative pressures	3 The subject of management actions/strategies	4 A Key Ecological Feature	5 Reef stakeholders, visitors and users derive important benefits	6 Iconic status and reporting obligations	7 The subject of existing monitoring that is of value to management
Other invertebrates	N.I., N.O., S.O	↔				○ ○	HIGH	HIGH Acid sulphate soils Clearing or modifying coastal habitats Cyclone activity Death of discarded species Dredging - direct impacts Dumping of dredge material Extraction of lower trophic orders Increased sea & air temperature Oil spill - large Outbreak of COTS Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of other invertebrates and their habitats Targets – by 2019: • the ecological integrity of other invertebrates is maintained and enhanced APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & Regs QLD Marine Parks Act Fisheries Act 1994 Qld Fisheries Strategy EPBC Act GBRMPA Policy on managing the direct take of Protected species GBRMP Biodiversity Conservation Strategy GBR Climate change adaptation startegy & action plan	HIGH A species, group of species or a community with a regionally important ecological role - a prey that affects a large biomass or number of other marine species.	HIGH **Social:** enhances diving, snorkelling, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports tourism and recreation	HIGH GBRMPA Regs Protected spp: Giant clams Family Tridacnidae (all spp) Helmet shell *Cassis cornuta* Giant triton shell *Charonia tritonis* GBRMP Regs Restricted species: Class Ascidiacea (all species) Class Gastropoda (all spp except Cassis cornuta & Charinia tritonis) Genus *Nautilus* (all spp) Genus *Pinctada* (all spp) Phylum Echinodermata (all spp except those of class Holothuroidea) Phylum Porifera (all spp) Biodiversity Strategy 'at risk': Sea cucumbers Class Holothuroidea Outlook Report Assessment component	LOW • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Other invertebrates	S.I.		↓			○ ○	HIGH	HIGH Altered ocean currents Acid sulphate soils Clearing or modifying coastal habitats Cyclone activity Ocean acidification Death of discarded species Dredging - direct impacts Dumping of dredge material Extraction of lower trophic orders Illegal fishingand poaching Increased sea & air temperature Freshwater inflow Oil spill - large Outbreak of COTS Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Artificial barriers to flow Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of other invertebrates and their habitats Targets – by 2019: • the ecological integrity of other invertebrates is maintained and enhanced APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & Regs QLD Marine Parks Act Fisheries Act 1994 Qld Fisheries Strategy EPBC Act GBRMPA Policy on managing the direct take of Protected species GBRMP Biodiversity Conservation Strategy GBR Climate change adaptation startegy & action plan	HIGH A species, group of species or a community with a regionally important ecological role - a prey that affects a large biomass or number of other marine species.	HIGH **Social:** enhances diving, snorkelling, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty; **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports tourism and recreation	HIGH GBRMPA Regs Protected spp: Giant clams Family Tridacnidae (allspp) Helmet shell *Cassis cornuta* Giant triton shell *Charonia tritonis* GBRMP Regs Restricted species: Class Ascidiacea (all species) Class Gastropoda (all spp except Cassis cornuta & Charinia tritonis) Genus *Nautilus* (all spp) Genus *Pinctada* (all spp) Phylum Echinodermata (all spp except those of class Holothuroidea) Phylum Porifera (all spp) Biodiversity Strategy 'at risk': Sea cucumbers Class Holothuroidea Outlook Report Assessment component	LOW • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Plankton and microbes	N.I., N.O., S.O.	↔				○ ○	LOW	LOW Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBR Climate change adaptation strategy & action plan GBRMP Water Quality Guidelines	LOW	LOW	LOW Outlook Report Assessment component	LOW Reef Rescue Marine Monitoring Program pesticide monitoring, Ambient water quality, Flood monitoring
Plankton and microbes	S.I.		↔			○ ○	LOW	LOW Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment from catchment runoff	BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBR Climate change adaptation strategy & action plan GBRMP Water Quality Guidelines	LOW	LOW	LOW Outlook Report Assessment component	LOW Reef Rescue Marine Monitoring Program pesticide monitoring, Ambient water quality, Flood monitoring
Bony fish	N.I., N.O.	↔				◐ ◐	HIGH	HIGH Acid sulphate soils Altered ocean currents Artificial barriers to flow Clearing or modifying coastal habitats Cyclone activity Ocean acidification Death of discarded species Extraction of lower order predators Extraction of predators Fishing spawning aggregations Grounding of large vessels Illegal fishing & poaching Increased sea & air temperature Dredging and dumping of spoil Outbreak of COTS Outbreak of disease	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of bony fish APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & Regs QLD Marine Parks Act EPBC Act Fisheries Act 1994 Nature Conservation Act GBR Climate change adaptation strategy & action plan Tourism ecocertification & responsible reef practices Coral reef finfish spawning closures Protection of barramundi during its main spawning season Conservation overview and action plan for Australian threatened and otentially threatened marine and estuarine fishes	HIGH A species, group of species or a community that is nationally important for biodiversity; A group of species with a regionally important ecological role - a predator and prey that affects a large biomass and number of other marine species	HIGH **Social:** enhances diving, snorkelling, recreational fishing, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	HIGH Protected under GBRMPA Regs 1983: Seahorses, pipefish, seadragons, Potato rockcod, Qld groper, Humphead Moari Wrasse, Barramundi cod Restricted under GBRMP Regs 1983: over 40 Families listed. Outlook Report - Iconic species: seahorses, pipefish, Maori wrasse Biodiversity Strategy 'at risk': king & blue threadfin salmon, grey mackerel, snapper. Outlook Report Assessment component Fish spawning aggregations are classed by the IUCN as 'wildlife spectacles	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Inshore zoning effect monitoring Program • Spawning aggregations • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring • ReefCheck
Bony fish	S.I., S.O.		↓			◐ ◐	HIGH	HIGH Acid sulphate soils Altered ocean currents Artificial barriers to flow Clearing or modifying coastal habitats Cyclone activity Ocean acidification Death of discarded species Extraction of lower order predators Extraction of predators Fishing spawning aggregations Grounding of large vessels Illegal fishing & poaching Increased sea & air temperature Dredging and dumping of spoil Outbreak of COTS Outbreak of disease	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of bony fish APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & Regs QLD Marine Parks Act EPBC Act Fisheries Act 1994 Nature Conservation Act GBR Climate change adaptation strategy & action plan Tourism ecocertification & responsible reef practices Annual spawning closures Policy on managing activities that include the direct take of protected species from the GBRMP Policy of managing scientific research in the GBRMP Dredging and spoil dispsoal policy Position statement on aquaculture in the GBRMP Conservation overview and action plan for Australian threatened and otentially threatened marine and estuarine fishes	HIGH A species, group of species or a community that is nationally important for biodiversity; A group of species with a regionally important ecological role - a predator and prey that affects a large biomass and number of other marine species	HIGH **Social:** enhances diving, snorkelling, recreational fishing, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	HIGH Protected under GBRMPA Regs 1983: Seahorses, pipefish, seadragons, Potato rockcod, Qld groper, Humphead Moari Wrasse, Barramundi cod Restricted under GBRMP Regs 1983: over 40 Families listed. Outlook Report - Iconic species: e.g. seahorses, pipefish, Maori wrasse, QLD groper Biodiversity Strategy 'at risk': king & blue threadfin salmon, grey mackerel, snapper. Outlook Report Assessment component Fish spawning aggregations are classed by the IUCN as 'wildlife spectacles	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Inshore zoning effect monitoring Program • Spawning aggregations • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring • ReefCheck (southern inshore) • CapReef (southern offshore)
Sharks and rays	N.I., S.I.			↓		◐ ○	HIGH	HIGH Increased sea and air temperature Altered ocean currents Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Cyclone activity Death of discarded species Extraction of predators Illegal fishing & poaching	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of sharks and rays APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Fisheries Act Biodiversity Strategy Recovery Plans for Grey Nurse Shark, Whale Shark, Speartooth Shark, Grren Sawfish, Dwarf Sawfish, Freshwater Swafish	HIGH A species, group of species or a community with a regionally important ecological role - predator that affects a large biomass or number of other marine species; A species, group of species or a community that is nationally or regionally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, recreational fishing, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty; **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	HIGH Threatended marine species: Speartooth shark, Freshwater sawfish, dwarf sawfish, green sawfish, narrow sawfish, white shark, grey nurse shark, whale shark Biodiversity Strategy 'at risk': all species of Sawfish, short-finned mako, long-finned mako, estuary stingray, eastern shovelnose ray, coffin ray, black-spotted whip ray, blue-spotted stingray, speckled maskray, common stingaree, patchwork stingaree, pale tropical skate, skate, Endeavour skate, Asutralian butterfly ray. Outlook Report Assessment component	LOW • Qld shark control program (southern inshore) • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Sharks and rays	N.O., S.O.		↓			◐ ○	HIGH	HIGH Increased sea and air temperature Altered ocean currents Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Cyclone activity Death of discarded species Extraction of predators Illegal fishing & poaching	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain and enhance the condition of sharks and rays APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Fisheries Act Biodiversity Strategy Recovery Plans for Grey Nurse Shark, Whale Shark, Speartooth Shark, Green Sawfish, Dwarf Sawfish, Freshwater Swafish	HIGH A species, group of species or a community with a regionally important ecological role - predator that affects a large biomass or number of other marine species; A species, group of species or a community that is nationally or regionally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, recreational fishing, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	HIGH Threatened marine species: Speartooth shark, Freshwater sawfish, dwarf sawfish, green sawfish, narrow sawfish, white shark, grey nurse shark, whale shark Biodiversity Strategy 'at risk': all species of Sawfish, short-finned mako, long-finned mako, estuary stingray, eastern shovelnose ray, coffin ray, black-spotted whip ray, blue-spotted stingray, speckled maskray, common stingaree, patchwork stingaree, pale tropical skate, skate, Endeavour skate, Asutralian butterfly ray. Outlook Report Assessment component	LOW • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Sea snakes	N.I., N.O., S.I., S.O.		↔			◐ ○	HIGH	HIGH Death of discarded species Illegal fishing & poaching Increasing sea and air temperature Altered ocean currents Clearing or modifying coastal habitats Cyclone activity	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Fisheries Act	LOW	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports tourism and recreation	HIGH Protected under GBRMP Regs 1983: Subfamily Hydrophiinae Outlook Report - Iconic species Outlook Report Assessment component Biodiversity Strategy 'at risk': Sea snakes	LOW • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring

Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)	1	2	3	4	5	6	7
							PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')						
	Condition and recent trend						Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments	High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
Marine turtles	N.I., N.O.,			↓		● ●	HIGH	HIGH Sea level rise Altered ocean currents Boat strike on wildlife Cyclone activity Death of discarded species Disturbance of wildlife Dredging - driect impacts Dumping of dredge material Extraction of lower trophic orders Extraction of lower order predators Illegal fishing & poaching Incresaed sea & air temperature Clearing & monifying coastal habitat Light impacts (artificial) Marine debris Nutrients from catchment runoff Oil spill - large Outbreak of disease Pesticides from catchment runoff Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of marine turtle populations Targets – by 2019: • the trend in marine turtle populations are and showing signs of recovery By 2024 • the long-term trend in marine turtle populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Fisheries Act Nature Conservation Act World Heritage Convention Convention on Biological Diversity International Union for the Conservation of Nature and Natural Resources – Red List of Threatened Species (v. 2010.2) Convention on International Trade of Endangered Species of wildlife fauna and flora Convention on Migratory Species National Recovery Plan for Marine Turtles in Australia, 2003 Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay National Codes of Conduct for turtle & dugong tourism Water Quality guidelines for the GBRMP GBRMPA Climate adaptation strategy & action plan	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatened marine species: Flatback Green, Hawksbill, leatherback, loggerhead, Olive Ridley Biodiversity Strategy 'at risk': Marine turtles Outlook Report Assessment component	HIGH • QDEHP turtle conservation project; • Dugong population monitoring; • QDEHP wildlife strandings; • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Marine turtles	S.I., S.O.		↔			● ●	HIGH	HIGH Sea level rise Altered ocean currents Boat strike on wildlife Cyclone activity Death of discarded species Disturbance of wildlife Dredging - driect impacts Dumping of dredge material Extraction of lower trophic orders Extraction of lower order predators Illegal fishing & poaching Incresaed sea & air temperature Clearing & monifying coastal habitat Light impacts (artificial) Marine debris Nutrients from catchment runoff Oil spill - large Outbreak of disease Pesticides from catchment runoff Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of marine turtle populations Targets – by 2019: • the trend in marine turtle populations are and showing signs of recovery By 2024 • the long-term trend in marine turtle populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act EPBC Act QLD Marine Parks Act Fisheries Act Nature Conservation Act World Heritage Convention Convention on Biological Diversity International Union for the Conservation of Nature and Natural Resources – Red List of Threatened Species (v. 2010.2) Convention on International Trade of Endangered Species of wildlife fauna and flora Convention on Migratory Species National Recovery Plan for Marine Turtles in Australia, 2003 Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay National Codes of Conduct for turtle & dugong tourism Water Quality guidelines for the GBRMP GBRMPA Climate adaptation strategy & action plan	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatened marine species: Flatback Green, Hawksbill, leatherback, loggerhead, Olive Ridley Biodiversity Strategy 'at risk': Marine turtles Outlook Report Assessment component	HIGH • QDEHP turtle conservation project; • Dugong population monitoring; • QDEHP wildlife strandings; • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Estuarine crocodile	N.I., N.O., S.I., S.O.		↑			◐ ◐	LOW	LOW Artificial barriers to flow Incresaed sea & air temperature Increased freshwater inflow Marine debris Oil spill - large	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - GBRMPA Act QLD Marine Parks Act The Salt-water Crocodile Management Program 2007-2017 (Queensland EPA 2007c) The Nature Conservation (Estuarine Crocodile) Conservation Plan 2007 (Queensland EPA 2007)	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatended marine species Outlook Report Assessment component	LOW None
Seabirds	N.I., S.I.		↔			● ◐	HIGH	HIGH Rising sea level Altered ocean currents Clearinh & modifying coastla habitats Chemical & oil spills - small Disturbance of wildlife Incresaed sea & air temperature Marine debris Oil spill - large	BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of seabird populations Targets – by 2019: • the trend in seabird populations are increasing and showing signs of recovery By 2024 • the long-term trend in seabird populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Position Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay Guidelines for Managing Visitation to Seabird Breeding Islands Recovery Plan for Herald Petrel Action Plan for Australian birds 2000 State management plans for island National Parks that have provisions for the protection of birds	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, bird watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatened marine species: Grey-headed albatross, Herald petrel, Little Tern, Northern giant petrel, Red-tailed tropicbird, Sooty albatross, Southern giant petrel, Wandering albatross. Biodiversity Strategy 'at risk': Seabirds Outlook Report Assessment component	HIGH Coastal bird monitoring
Seabirds	N.O., S.O.			↓		● ◐	HIGH	HIGH Rising sea level Altered ocean currents Chemical & oil spills - small Disturbance of wildlife Incresaed sea & air temperature Marine debris Oil spill - large	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of seabird populations Targets – by 2019: • the trend in seabird populations are increasing and showing signs of recovery By 2024 • the long-term trend in seabird populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Biodiversity Strategy Recovery Plans for Herald Petral, Little Tern Position Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay Guidelines for Managing Visitation to Seabird Breeding Islands Action Plan for Australian birds 2000 State management plans for island National Parks that have provisions for the protection of birds	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, bird watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatened marine species: Grey-headed albatross, Herald petrel, Little Tern, Northern giant petrel, Red-tailed tropicbird, Sooty albatross, Southern giant petrel, Wandering albatross. Biodiversity Strategy 'at risk': Seabirds Outlook Report Assessment component	HIGH Coastal bird monitoring
Shorebirds	S.I., N.I.			↓		◐ ◐	HIGH	HIGH Rising sea level Altered ocean currents Clearinh & modifying coastla habitats Chemical & oil spills - small Disturbance of wildlife Incresaed sea & air temperature Marine debris Oil spill - large	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Contribute to the restoration of shorebird populations APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Nature Conservation Act EPBC Act Wildlife Conservation Plan for Migratory Shorebirds Environmental Impact Assessment Policy Qld Coastal Plan Action Plan for Australian birds 2000 State management plans for island National Parks that have provisions for the protection of birds, including shorebirds Back on Track Actions for Biodiversity 2010 RAMSAR wetlands	HIGH A group of species that is nationally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, bird watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Threatened species under the EPBC Act Migratory shorebirds listed under international migratory bird agreements (JAMBA/CAMBA)	HIGH Coastal bird monitoring Qld Wader Study Group Shorebirds 2020 program
Whales	N.I., N.O., S.I., S.O.		↑			● ●	HIGH	LOW Disturbance of wildlife Extraction of lower order predators Marine debris Noise pollution	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & regulations EPBC Act Operational Policy on Whale and Dolphin Conservation in the Great Barrier Reef Marine Park QLD Marine Parks Act Convention on Migratory Species	HIGH a species, group of species or a community that is nationally or regionally important for biodiversity	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Outlook Report - Iconic species Threatened marine species: Blue whale, Fin whale, Humpback whale, Sei Whale, dwarf minke whale. Biodiversity Strategy 'at risk': Humpback whale, dwarf minke whale Outlook Report Assessment component	LOW Humpback whale monitoring - outside GBRMPA; QDEHP wildlife strandings; Dugong monitoring; Sightings network

	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	1							2	3	4	5	6	7
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
	Condition and recent trend												
Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)							
Dolphins	N.I., N.O., S.O.		⬌			◐ ○	HIGH	HIGH Altered ocean currents Death of discarded species Dredging - direct impacts Clearing & modifying coastal habitat Coastal reclamation Illegal fishing & poaching Marine debris Noise pollution Extraction of predators Extraction of lower trophic orders Oil spill - large	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of dolphin populations Targets – by 2019: • the trend in dolphin populations are increasing and showing signs of recovery By 2024 • the long-term trend in dolphin populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & regulations Nature Conservation Act EPBC Act GBRMPA Biodiversity conservation strategy Operational Policy on Whale and Dolphin Conservation in the Great Barrier Reef Marine Park QLD Marine Parks Act Fisheries Act	HIGH A species, group of species or a community that is nationally or regionally important for biodiversity; A species, group of species or a community with a regionally important ecological role - a predator that affects a large biomass or number of other marine species	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Protected under GBRMP Regs 1983: Order cetacia (all spp), incl Australian snubfin dolphin, Indo-pacific humpback dolphins, inshore bottlenose dolphins Outlook Report - Iconic species Biodiversity Strategy 'at risk': Inshore dolphins Outlook Report Assessment component	LOW • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Dolphins	S.I.			↓		◐ ◐	HIGH	HIGH Altered ocean currents Death of discarded species Dredging - direct impacts Clearing & modifying coastal habitat Coastal reclamation Illegal fishing & poaching Marine debris Noise pollution Extraction of predators Extraction of lower trophic orders Oil spill - large	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Restore the condition of dolphin populations Targets – by 2019: • the trend in dolphin populations are increasing and showing signs of recovery By 2024 • the long-term trend in dolphin populations is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act & regulations Nature Conservation Act EPBC Act GBRMPA Biodiversity conservation strategy Operational Policy on Whale and Dolphin Conservation in the Great Barrier Reef Marine Park QLD Marine Parks Act Environmental Impact Assessment Policy FIsheries Act	HIGH A species, group of species or a community that is nationally or regionally important for biodiversity; A species, group of species or a community with a regionally important ecological role - a predator that affects a large biomass or number of other marine species	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Protected under GBRMP Regs 1983: Order cetacia (all spp), incl Australian snubfin dolphin, Indo-pacific humpback dolphins, inshore bottlenose dolphins Outlook Report - Iconic species Biodiversity Strategy 'at risk': Inshore dolphins Outlook Report Assessment component	LOW • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Dugongs	N.I.		⬌			● ●	HIGH	HIGH Boat strike on wildlife Cyclone activity Altered ocean currents Death of discarded species Disturbance of wildlife Dumping of dredge material Clearing & modifying coastal habitat Extraction of lower trophic orders Illegal fishing & poaching Marine debris Noise pollution Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment in catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Reverse the decline and enhance the condition of dugong populations Targets – by 2019: • the trend in dugong populations in the southern two thirds of the Region is increasing and showing signs of recovery • the status of dugongs in the remaining northern third of the Region is maintained and enhanced By 2024 • the long-term trend in dugong populations in the southern two thirds of the Region is increasing APPLICABLE ACTS, PLANS & STRATEGIES - GBRMPA Zoning plan GBRMPA Act & regulations GBRMP Biodiversity conservation Strategy Policy on Managing Activities That Include the Direct Take of a Protected Species From the Great Barrier Reef Marine Park Traditional Use of Marine Resources Agreements Position Statement on the conservation of Dugongs in the GBRMP QLD Marine Parks Act QLD Nature Conservation (Wildlife) Regulation 2006 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Convention on Migratory Species National Codes of Conduct for turtle & dugong tourism	HIGH A species, group of species or a community that is nationally or regionally important for biodiversity; A species, group of species or a community with a regionally important ecological role - a predator that affects a large biomass or number of other marine species	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Dugongs are classified as vulnerable to extinction under the 2009 World Conservation Union (IUCN) Red List of Threatened Species. Dugong are listed under the EPBC Act 1999; the Nature Conservation Act 1992; and is a protected species under the GBRMP Regulations 1983. Biodiversity Strategy 'at risk': Dugong Outlook Report Assessment component	• Dugong monitoring - program funding insecure • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Dugongs	S.I.				↓	● ●	HIGH	HIGH Boat strike on wildlife Cyclone activity Altered ocean currents Death of discarded species Disturbance of wildlife Dumping of dredge material Clearing & modifying coastal habitat Extraction of lower trophic orders Illegal fishing & poaching Marine debris Noise pollution Nutrients from catchment runoff Oil spill - large Pesticides from catchment runoff Sediment in catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Reverse the decline and enhance the condition of dugong populations Targets – by 2019: • the trend in dugong populations in the southern two thirds of the Region is increasing and showing signs of recovery • the status of dugongs in the remaining northern third of the Region is maintained and enhanced By 2024 • the long-term trend in dugong populations in the southern two thirds of the Region is increasing APPLICABLE ACTS, PLANS & STRATEGIES - GBRMPA Zoning plan GBRMPA Act & regulations Policy on Managing Activities That Include the Direct Take of a Protected Species From the Great Barrier Reef Marine Park GBRMP Biodiversity Conservation Strategy Traditional Use of Marine Resources Agreements QLD Marine Parks Act QLD Nature Conservation (Wildlife) Regulation 2006 Convention on International Trade in Endangered Species of Wilde Fauna and Flora (CITES) Convention on Migratory Species National Codes of Conduct for turtle & dugong tourism	HIGH A species, group of species or a community that is nationally or regionally important for biodiversity; A species, group of species or a community with a regionally important ecological role - a predator that affects a large biomass or number of other marine species.	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies; totemic and spiritual significance for some TOs **Economic:** supports tourism and recreation	HIGH Dugongs are classified as vulnerable to extinction under the 2009 World Conservation Union (IUCN) Red List of Threatened Species. Dugong are listed under the EPBC Act 1999; the Nature Conservation Act 1992; and is a protected species under the GBRMP Regulations 1983. Biodiversity Strategy 'at risk': Dugong Outlook Report Assessment component	• Dugong monitoring - program funding insecure • QDEHP wildlife strandings • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring
Islands	N.I., N.O., S.O.		⬌			◐ ◐	HIGH	HIGH Rising sea level Altered ocean currents Chemical & oil spills - small Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Exotic species & diseases	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The condition of islands is maintained and enhanced Targets – by 2019: • the viability of roosting and breeding sites for coastal birds is maintained • the viability of breeding sites for marine turtles is maintained • the ecological integrity of island vegetation is improved • the integrity of Pisonia forests on the Capricornia Cays is improved APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act State management plans for island National Parks Environmental Impact Assessment Policy Position Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay Ecotourism certification - responsible reef practices Threat abatement plans to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 10000 ha.	HIGH A habitat that is regionally important because of aggregations of marine life, including feeding, resting, and nesting. Internationally important for turtles & seabirds	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports tourism and recreation	LOW Outlook Report Assessment component Iconic tourism destinations National and international monitoring and reporting obligations covered by marine turtles, seabirds & shorebirds	LOW Monitoring island infrastructure; GBRMPA-QPWS Field management patrols; QLUMP
Islands	S.I.		↓			◐ ◐	HIGH	HIGH Rising sea level Altered ocean currents Chemical & oil spills - small Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Exotic species & diseases	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The condition of islands is maintained and enhanced Targets – by 2019: • the viability of roosting and breeding sites for coastal birds is maintained • the viability of breeding sites for marine turtles is maintained • the ecological integrity of island vegetation is improved • the integrity of Pisonia forests on the Capricornia Cays is improved APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act State management plans for island National Parks Environmental Impact Assessment Policy Position Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay Ecotourism certification - responsible reef practices Threat abatement plans to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 10000 ha.	HIGH A habitat that is regionally important because of aggregations of marine life, including feeding, resting, and nesting	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports tourism and recreation	LOW Outlook Report Assessment component Iconic tourism destinations National and international monitoring and reporting obligations covered by marine turtles, seabirds & shorebirds	LOW Monitoring island infrastructure; GBRMPA-QPWS Field management patrols; QLUMP;
Beaches and coastlines	N.I.	⬌				◐ ◐	LOW	HIGH Rising sea level Acid sulphate soils Altered ocean currents Artificial barriers to flow Increased sea and air temperature Chemical & oil spills - small Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dumping of dredge material Exotic species & diseases Marine debris Sediments from catchment runoff Nutrients from catchment runoff Wash from vessels	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The condition of beaches and coastlines is enhanced and restored to good condition Targets – by 2019: • the viability of roosting and breeding sites for coastal birds is improved • the viability of breeding sites for marine turtles is improved • the integrity of coastal habitats is improved • the functioning of coastal processes improved • the aquatic connectivity between freshwater and marine environments is improved APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Environmental Impact Assessment Policy Outlook for Coastal Ecosystems EPBC Act Qld State Policy for Coastal Management Environmental Impact Assessment Policy Ecotourism certification - responsible reef practices	HIGH A habitat that is regionally important because of aggregations of marine life, including feeding, resting, and nesting	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	LOW Outlook Report Assessment component: Beaches Iconic tourism destinations National and international monitoring and reporting obligations covered by marine turtles, seabirds & shorebirds	LOW GBRMPA-QPWS Field management patrols; QLUMP

	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	1							2	3	4	5	6	7
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
	Condition and recent trend												
Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)							
Beaches and coastlines	S.I.		↓			◐ ◐	LOW	HIGH Rising sea level Acid sulphate soils Altered ocean currents Artificial barriers to flow Increased sea and air temperature Chemical & oil spills - small Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dumping of dredge material Exotic species & diseases Marine debris Sediments from catchment runoff Nutrients from catchment runoff Wash from vessels	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The condition of beaches and coastlines is enhanced and restored to good condition Targets – by 2019: • the viability of roosting and breeding sites for coastal birds is improved • the viability of breeding sites for marine turtles is improved • the integrity of coastal habitats is improved • the functioning of coastal processes improved • the aquatic connectivity between freshwater and marine environments is improved APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Environmental Impact Assessment Policy Outlook for Coastal Ecosystems EPBC Act Qld State Policy for Coastal Management Environmental Impact Assessment Policy Ecotourism certification - responsible reef practices	HIGH A habitat that is regionally important because of aggregations of marine life, including feeding, resting, and nesting	HIGH **Social:** enhances diving, snorkelling, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing, tourism and recreation	LOW Outlook Report Assessment component: Beaches Iconic tourism destinations National and international monitoring and reporting obligations covered by marine turtles, seabirds & shorebirds	LOW GBRMPA-QPWS Field management patrols; QLUMP
Mangrove Forests	N.I.	↔				◐ ◐	HIGH	HIGH Rising sea level Cyclone activity Increased sea and air temperature Freshwater inflow Sediments from catchment runoff Dredging & dumping of spoil Marine debris Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Nutrients from catchmnet runoff Oil spill - large Pesticides from catchment runoff Wash from vessels	BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Biodiversity Strategy Outlook for Coastal Ecosystems EPBC Act Qld State Policy for Coastal Management Environmental Impact Assessment Policy	HIGH A habitat that is regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding and nursery areas	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals; natural beauty **Social:** supports recreation *e.g. bird-watching; crabbing* stewardship; education **Cultural:** places for teaching TO language and other aspects of culture; source of food for TOs **Economic:** supports commercial fishing, recreation and tourism	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	LOW Mangrove Watch; Qld coastal wetlands mapping; QLUMP
↔ Mangrove Forests	S.I.		↔			● ●	HIGH	HIGH Rising sea level Cyclone activity Increased sea and air temperature Freshwater inflow Sediments from catchment runoff Dredging & dumping of spoil Marine debris Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Nutrients from catchmnet runoff Oil spill - large Pesticides from catchment runoff Wash from vessels	BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act Marine Parks Act Biodiversity Strategy Outlook for Coastal Ecosystems EPBC Act Qld State Policy for Coastal Management Environmental Impact Assessment Policy	HIGH A habitat that is regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding and nursery areas	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals; natural beauty **Social:** supports recreation *e.g. bird-watching; crabbing* stewardship; education **Cultural:** places for teaching TO language and other aspects of culture; source of food for TOs **Economic:** supports commercial fishing, recreation and tourism	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	LOW Mangrove Watch; Qld coastal wetlands mapping; QLUMP; Ports ambient monitoring
Seagrass meadows	N.I.	↔				◐ ◐	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dredging - driect impacts Dumping of dredge material Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH Critically important in primary production and habitat formation for supporting a range of species from dugongs and turtles to fish populations An area or habitat that is nationally or regionally important because of high productivity, aggregations of marine life (such as feeding, resting, breeding or nursery areas) or high biodiversity and endemism A unique sea floor feature with known or presumed ecological properties of regional significance.	HIGH Income and employment Appreciation & enjoyment Understanding Personal attachment Health (personal and community) Historic and Indigenous culture	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	HIGH • Seagrass Watch • (RRMMP) Inshore Seagrass Monitoring
Seagrass meadows	N.O.	↔				○ ○	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Cyclone activity Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH Critically important in primary production and habitat formation for supporting a range of species from dugongs and turtles to fish populations A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding and nursery areas; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation *e.g. fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	LOW None
Seagrass meadows	S.I.				↓	◐ ◐	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Clearing or modifying coastal habitats Coastal reclamation Cyclone activity Dredging - driect impacts Dumping of dredge material Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Reef Water Quality Protection Plan Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH Critically important in primary production and habitat formation for supporting a range of species from dugongs and turtles to fish populations A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding and nursery areas; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation *e.g. fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	HIGH • Seagrass Watch • (RRMMP) Inshore Seagrass Monitoring Ambient Monitoring associated with ports at: • Cairns • Mourilyan • Townsville • Hay Point • Mackay • Abbot Point • Gladstone (PCIMP, PC&PA ERMP)
Seagrass meadows	S.O.			↓↑		○ ○	HIGH	HIGH Altered ocean currents Acid sulphate soils Artificial barriers to flow Cyclone activity Illegal fishing and poaching Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Pesticides from catchment runoff Physical damage to benthos Physical impacts of fishing	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of seagrass meadows is restored to good condition in the southern two thirds of the Region and maintained at very good condition in the northern third of the Region. Targets - by 2019: • the extent and condition of seagrass meadows is improving in the southern two thirds of the Region • the extent and condition of seagrass meadows in the northern third of the Region is maintained APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan MOU between GBRMPA & Ports Dredging & spoil disposal policy Strategic Assessment objectives EPBC Act Qld State Policy for Coastal Management	HIGH Critically important in primary production and habitat formation for supporting a range of species from dugongs and turtles to fish populations A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding and nursery areas; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Natural Heritage:** important breeding and feeding grounds for a variety of fish species, turtles, dugong and other animals **Social:** supports recreation *e.g. fishing* **Cultural:** supports dugong and turtle populations **Economic**: supports commercial fishing	HIGH As a key habitat in the GBRWHA, there are World Heritage obligations to report and National reporting through the Outlook Report	LOW None

	1							2	3	4	5	6	7
	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							**High or moderate single or cumulative pressures**	**The subject of management actions/strategies**	**A Key Ecological Feature**	**Reef stakeholders, visitors and users derive important benefits**	**Iconic status and reporting obligations**	**The subject of existing monitoring that is of value to management**
	Condition and recent trend												
Value	**Area**	**Very Good**	**Good**	**Poor**	**Very Poor**	**Confidence (condition, trend)**							
Coral reefs (<30m)	N.I.		↔			◐ ●	HIGH	HIGH Altered ocean currents Cyclone activity Dumping of dredge material Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff Clearing and modifying coastal habitat	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH Globally important for biodiversity. Regionally important ecological roles A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding or nursery areas; and high biodiversity and endemism; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH A global icon. World heritage obligations to report and National reporting through the Outlook Report	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring)
Coral reefs (<30m)	N.O.		↔			● ●	HIGH	HIGH Altered ocean currents Cyclone activity Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH Globally important for biodiversity. Regionally important ecological roles A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding or nursery areas; and high biodiversity and endemism; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH A global icon. World heritage obligations to report and National reporting through the Outlook Report	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • GBRMPA-QPWS compliance monitoring
Coral reefs (<30m)	S.I.				↓	● ●	HIGH	HIGH Altered ocean currents Cyclone activity Dumping of dredge material Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Increased freshwater flow Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff Clearing and modifying coastal habitat	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH Globally important for biodiversity. Regionally important ecological roles A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding or nursery areas; and high biodiversity and endemism; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH A global icon. World heritage obligations to report and National reporting through the Outlook Report	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • Reef Rescue Marine Monitoring Program inshore coral monitoring • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • GBRMPA-QPWS compliance monitoring
Coral reefs (<30m)	S.O.			↓		● ●	HIGH	HIGH Altered ocean currents Cyclone activity Extraction of lower trophic orders Grounding of large vessels Incresaed sea & air temperature Nutrients from catchment runoff Ocean acidification Oil spill - large Outbreak of COTS Outbreak of disease Pesticides from catchment runoff Physical damage to benthos Sediment from catchment runoff	HIGH BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - The health and resilience of coral reefs is restored to good condition in the southern two thirds of the Region and maintained at good/very good in the northern third of the Region Targets - by 2019: • the trend in coral reef condition, community composition and coral recruitment is increasing • the trend in coral reef resilience indicators is improving By 2024: • the long-term trend in coral cover and condition is increasing APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act GBRMP Water Quality Guidelines Reef Water Quality Protection Plan Biodiversity Strategy Strategic Assessment objectives EPBC Act Fisheries Act High Standard Tourism Operators - Responsible Reef Practices Special Management Areas and Plans of Management Dredging and spoil disposal policy Guidelines on coral transplantation	HIGH Globally important for biodiversity. Regionally important ecological roles A habitat that is nationally and regionally important because of high productivity, aggregations of marine life, including feeding, resting, breeding or nursery areas; and high biodiversity and endemism; A unique sea floor feature with known ecological properties of regional significance.	HIGH **Social:** enhances diving, snorkelling, recreational fishing, reef-walking, wildlife watching, relaxation, spending time with family & friends; education; health; lifestyle; stewardship **Aesthetic:** natural beauty **Natural Heritage:** obligation to have for future generations **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing; tourism and recreation	HIGH A global icon. World heritage obligations to report and National reporting through the Outlook Report	HIGH • AIMS LTMP • AIMS Effects of rezoning on offshore coral reef systems • iEoTR RHIS surveys • iEoTR weekly monitoring • ReefCheck (Coral Reef Health Monitoring) • GBRMPA-QPWS compliance monitoring
Deep water (mesophotic) reefs	N.O.	↔				◐ ◐	LOW	LOW Altered ocean currents Cyclone activity	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW None
Deep water (mesophotic) reefs	S.O.		↔			◐ ◐	LOW	LOW Altered ocean currents Cyclone activity	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW None
Lagoon floor	N.I., N.O., S.I., S.O.		↔			◐ ○	LOW	HIGH Artificial barriers to flow Cyclone activity Dredging - direct impacts Dumping of dredge material Illegal fishing & poaching Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Environmental Impact Assessment Policy Dredging & spoil disposal policy EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW Ports compliance monitoring
Shoals	N.I., N.O., S.I., S.O.		↔			◐ ◐	LOW	LOW Cyclone activity Dredging - direct impacts Dumping of dredge material Illegal fishing & poaching Physical damage to benthos Physical impacts of fishing Sediment from catchment runoff	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain or enhance APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	MEDIUM **Social:** enhances recreational fishing **Cultural:** traditional use of marine resources and ceremonies **Economic:** supports commercial fishing and recreation	LOW Outlook Report Assessment component	LOW None
Halimeda banks	N.O.	↔				◐ ◐	LOW	LOW Cyclone activity	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW None

	PRIORITISATION CRITERIA (Agreement with the statements below results in a score of 'high')												
	1							2	3	4	5	6	7
	Classified as at risk through the 2012 Biodiversity Conservation Strategy vulnerability assessments							High or moderate single or cumulative pressures	The subject of management actions/strategies	A Key Ecological Feature	Reef stakeholders, visitors and users derive important benefits	Iconic status and reporting obligations	The subject of existing monitoring that is of value to management
	Condition and recent trend												
Value	Area	Very Good	Good	Poor	Very Poor	Confidence (condition, trend)							
Continental slope	N.O.	↔				○ ○	LOW	LOW	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW None
Continental slope	S.O.		↔			○ ○	LOW	LOW	LOW BROAD LEVEL SPATIAL AREA OBJECTIVE FOR ELEMENT - Maintain APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act	HIGH A unique sea floor feature with known or presumed ecological properties of regional significance.	LOW	LOW Outlook Report Assessment component	LOW None
Open waters	N.I., N.O., S.O.		↔			● ◐	HIGH	HIGH Ocean acidification Acid sulphate soils Altered ocean currents Clearing or modifying coastal habitats Coastal reclamation Dumping of dredge material Incresaed sea & air temperature Increased freshwater flow Marine debris Noise pollution Nutrients from catchment runoff Sediment from catchment runoff Pesticides from catchment runoff	LOW The condition of open waters is enhanced and restored to good condition Targets – by 2019: • environmental values are restored to good condition and water quality objectives are being met APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Climate change adaptation & action plan	HIGH An area or habitat that is nationally or regionally important because of high productivity, aggregations of marine life (such as feeding, resting, breeding or nursery areas) or high biodiversity and endemism	HIGH	LOW Outlook Report Assessment component	HIGH Reef Rescue Marine Monitoring Program QDEHP wave monitoring; QIMOS BoM
Open waters	S.I.			↓		● ●	HIGH	HIGH Ocean acidification Acid sulphate soils Altered ocean currents Clearing or modifying coastal habitats Coastal reclamation Dumping of dredge material Incresaed sea & air temperature Increased freshwater flow Marine debris Noise pollution Nutrients from catchment runoff Sediment from catchment runoff Pesticides from catchment runoff	LOW The condition of open waters is enhanced and restored to good condition Targets – by 2019: • environmental values are restored to good condition and water quality objectives are being met APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Climate change adaptation & action plan	HIGH An area or habitat that is nationally or regionally important because of high productivity, aggregations of marine life (such as feeding, resting, breeding or nursery areas) or high biodiversity and endemism	LOW	LOW Outlook Report Assessment component	HIGH Reef Rescue Marine Monitoring Program QDEHP wave monitoring; QIMOS BoM

Appendix 6 Prioritisation of pressures affecting MNES values

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Acid sulphate soils	Increasing	LOW Beaches & coastline Mangrove habitats Seagrass Meadows Open Waters Mangroves Seagrasses Other Invertebrates Bony fish Sharks & rays	LOW Local impacts Potential acid sulphate soils are found extensively in the Great Barrier Reef coastal areas and islands.There has been significant historical disturbance and once disturbed if not treated (the most common situation) acidic water and heavy metals continue to be released during rain events over decades. The impacts of acid sulphate soils can affect a range of values such as beaches and coastlines, mangroves, seagrass meadows, invertebrates and fish. The effects are often long-term and difficult to reverse.	HIGH GBRMPA Act QLD Marine Parks Act Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Sustainable Planning Act 2009 EPBC Act	HIGH QASSIT Ports dredging compliance monitoring
Altered ocean currents	Increasing	HIGH Open Waters Coral reefs and corals Seagrass meadows Seabirds Shore birds Marine turtles Dugongs Dolphins Other invertebrades Bony fish Sharks and rays Sea snakes Connectivity Recruitment Income, economic contribution Understanding	HIGH Acts across entire GBRWHA	LOW Climate Change Adaptation and Action Plan	HIGH QIMOS
Artificial barriers to flow	Increasing	HIGH Beaches & coastline Seagrass Meadows Lagoon Floor Mangroves Bony fish Estuarine crocodiles Shorebirds Seabirds Other invertebrades Bony fish Sharks and rays Connectivity Recruitment Understanding	HIGH Barriers to riverine and estuarine flow, such as weirs, dams, gates, levees and ponded pastures are widespread in the catchment.	HIGH QLD Marine Parks Act Environmental Impact Assessment Policy Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Sustainable Planning Act	LOW
Atmospheric pollution	Increasing	LOW Mangroves	LOW Urban and industrial development is relatively minor and localised in the Great Barrier Reef catchment, however future projections suggest an increase in both, which is likely to result in increased atmospheric pollution.	HIGH Environmental Protection Regulation 2008 - National Pollution Inventory	LOW - not accessible Industrial compliance monitoring
Boat strike on wildlife	Increasing	LOW Marine turtles Whales Dolphins Dugongs	LOW DIscrete impacts mainly occuring inshore. The risk of boat strikes may increase where high-speed vessels overlap with key shallow water habitats (e.g. seagrass meadows) or movement corridors for vulnerable animals. The risk also increases in areas adjacent to areas with growing populations visiting the Region and larger volumes of commercial traffic.	HIGH Go slow areas and transit lanes have been declared in some areas where there is high vessel traffic and large populations of marine turtle or dugong, such as near Hinchinbrook Island.	LOW QEHP Wildlife Strandings
Chemical spill - large	Increasing	LOW	LOW Although there has never been a large chemical spill reported in the Region, increasing shipping and industrial development along the Great Barrier Reef coast is increasing its likelihood. While a large chemical spill would not necessarily be visible, it could have widespread and long lasting effects on Great Barrier Reef values. Apart from the physical smothering of plants and animals, a chemical's toxicity and reactions with water could result in persistent effects on the health, growth, reproduction and development of a range of marine plants and animals for several years.	HIGH GBRMP Zoning Plan - Designated Shipping Areas Compulsory pilotage Mandatory vessel reporting Incident response plans	LOW Reactive monitoring Mandatory vessel reporting and monitoring
Chemical & oil spills - small	Increasing	LOW Islands Beaches & coastline Seabirds	LOW localised effects on environmental and social values	LOW	LOW None

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Clearing or modifying coastal habitats	Increasing	HIGH Islands Beaches & coastline Mangrove habitats Seagrass Meadows Coral Reefs (<30m) Bony fish Sharks & rays Estuarine crocodiles Shorebirds Coral reefs and corals Seabirds Marine turtles Sea snakes Dugongs Dolphins Other invertebrades Connectivity Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Mostly southern areas. 70-90% of coastal wetlands have been lost and many vegetation types on the remaining dune systems are now rated 'of concern' or 'endangered'. Extensive areas of coastal habitats have been infilled, modified or cleared.	HIGH QLD Marine Parks Act Environmental Impact Assessment Policy Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Vegetation Management Act 1999 Sustainable Planning Act 2009	LOW Industrial/development compliance and ambient monitoring
Coastal reclamation	Increasing	HIGH Islands Beaches & coastline Mangrove habitats Seagrass Meadows Mangroves Seagrasses Seabirds Shore birds Marine turtles Dolphins Other invertebrades Bony fish Sharks and rays Connectivity Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	LOW Mostly southern areas. About one per cent of the coastline has been directly affected by reclamations, groynes and jetties	HIGH GBRMPA Act QLD Marine Parks Act Environmental Impact Assessment Policy Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Sustainable Planning Act 2009	LOW Industrial/development compliance and ambient monitoring
Cyclone activity	Increasing	HIGH Islands Beaches & coastline Mangrove habitats Seagrass Meadows Coral Reefs (<30m) Deepwater reefs Lagoon Floor Shoals Halimeda Banks Macro algae Benthic Microalgae Corals Bony fish Marine turtles Estuarine crocodiles Dugongs	HIGH It is estimated that cyclones have been responsible for about half of the total coral cover loss since 1985. The extent and severity of cyclone wave damage to corals and other biota (e.g. seagrasses) depends on: the size and duration of cyclone generated waves, exposure of organisms to those waves, and the vulnerability of the organisms to wave action	LOW Climate Change Adaptation and Action Plan	HIGH QDEHP wave monitoring; QDEHP Storm Tide; BoM Reactive monitoring of impact recovery
Death of discarded species	Stable	HIGH Other Invertebrates Bony fish Sharks & rays Sea snakes Marine turtles Dolphins Dugongs Seabirds Shore birds Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH The largest amount of discarded or incidental catch is in the commercial sector and results mainly from trawling activities. The current risks from trawling to target and non-target species and to the broader environmental values and integrity of the World Heritage Area have been assessed as low or intermediate-low, with a few remaining high risks to species of conservation concern - skates, rays and sea snakes Higher risks from the Reef LIne Fisheries	HIGH issues with compliance Zoning plan GBRMPA Act QLD Marine Parks Act EPBC Act Fisheries Act Biodiversity Strategy	HIGH, but issues with data reliability • Qld commercial fishery monitoring • Qld Recreational fishing monitoring • Qld trawl vessel monitoring QDEHP Wildlife Strandings
Disturbance of wildlife	Increasing	LOW Marine turtles Seabirds Shorebirds Whales	LOW Discrete impacts in heavily visited ares	HIGH Zoning plan GBRMPA Act QLD Marine Parks Act Position Statement on Managing access to the Restricted Access Special Management Areas surrounding Raine Island, Moulter Cay and MacLennan Cay Guidelines for Managing Visitation to Seabird Breeding Islands National Codes of Conduct for turtle & dugong tourism	LOW None

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Dredging - direct impacts	Increasing	HIGH Seagrass Meadows Coral Reefs (<30m) Lagoon Floor Shoals Other Invertebrates Marine turtles Dolphins Beaches & coastline Open Waters Mangroves Dugongs Bony fish Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	LOW Southern inshore areas - usually associated with ports, marinas and boat ramps	HIGH GBRMPA Act QLD Marine Parks Act Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Sustainable Planning Act 2009	LOW - issues with accessibility Permit compliance monitoring
Dumping of dredge material	Increasing	HIGH Seagrass Meadows Coral Reefs (<30m) Lagoon Floor Shoals Other Invertebrates Marine turtles Dolphins Beaches & coastline Open Waters Mangroves Dugongs Bony fish Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH fine sediments in most of the Region are continually re-mobilised and re-deposited with re-suspension plumes likely to travel considerably further than previously thought	HIGH GBRMPA Act QLD Marine Parks Act Outlook for Coastal Ecosystems Qld State Policy for Coastal Management - Draft Coastal Protection State Planning Regulatory Provision Sustainable Planning Act 2009	LOW - issues with accessibility Permit compliance monitoring; Ports ambient monitoring
Exotic species and disease	Increasing	LOW Islands Beaches & coastline Other Invertebrates	LOW Introduced marine species have been found in ports along the Great Barrier Reef coastline (e.g. Asian green mussel and Caribbean tubeworm in Cairns port), although none have been recorded beyond these ports. Introduced species on islands, such as rats and dogs, can affect seabird and turtle nesting. Insect invasions have caused serious declines in Pisonia forests which are major nesting sites for several seabird species.Weed species have been introduced to islands within the Region.	HIGH QPWS field management - pest & weed monitoring Biosecurity Qld - National System for the Prevention and Management of Marine Pest Incursions GBRMPA Position Statement on Aquaculture Threat abatement plans for predation by European red fox Threat abatement plans for predation by feral cats Threat abatement plans for predation, habitat degradation, competition and disease transmission by feral pigs Threat abatement plans to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 10000 ha.	HIGH QPWS field management - pest & weed monitoring Biosecurity Qld - National System for the Prevention and Management of Marine Pest Incursions
Extraction of herbivores	Stable	LOW Bony fish Dugong Marine turtles	Currently LOW Potential HIGH Currently the Great Barrier Reef has no dedicated commercial fishery for herbivorous fish. However, a range of factors could lead to significant increases in recreational or commercial fishing pressure on reef herbivores. Further, herbivorous fish populations appear vulnerable to habitat degradation due to turbidity or climate change impacts.	HIGH Fisheries Act GBRMPA Act Zoning Plan	HIGH • Qld commercial fishery monitoring • Qld trawl vessel monitoring LOW • Qld Recreational fishing monitoring
Extraction of lower order predators	Stable	LOW Coral Reefs (<30m) Bony fish Sharks & rays Marine turtles Whales	HIGH Reef-wide Many of these lower order predators are targeted by fisheries and the abundance of some target fishes is lower in fished areas	HIGH Fisheries Act GBRMPA Act Zoning Plan	HIGH • Qld commercial fishery monitoring • Qld trawl vessel monitoring LOW • Qld Recreational fishing monitoring
Extraction of lower trophic orders	Stable	LOW Corals Other Invertebrates Marine turtles Dugongs	HIGH Reef-wide Commercial fisheries extract lower trophic order species. Recreational and traditional fishers also take some lower trophic order species. Particle feeders and scavengers taken in the trawl and pot fisheries made up more than half of the retained commercial catch from the Great Barrier Reef in 2007	HIGH Fisheries Act GBRMPA Act Zoning Plan	HIGH • Qld commercial fishery monitoring • Qld trawl vessel monitoring LOW • Qld Recreational fishing monitoring
Extraction of top order predators	Stable	HIGH Bony fish Sharks & rays Estuarine crocodiles Seabirds Dolphins Bony fish Sharks and rays Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Reef-wide Many top order predator species are extracted during fishing operations in the Region, either as targeted species or as incidental catch.	HIGH Fisheries Act GBRMPA Act Zoning Plan	HIGH • Qld commercial fishery monitoring • Qld trawl vessel monitoring LOW • Qld Recreational fishing monitoring

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Fish spawning aggregations	Increasing	HIGH Bony fish Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Discreet aggregations sites. Potential to impact reef-wide populations	HIGH Coral reef finfish spawning closures and the protection of barramundi during its main spawning season; The protection of representative examples of habitat types in the Great Barrier Reef Marine Park, while not a direct aggregation protection strategy, did include six known fish spawning aggregation sites for coral trout, Spanish mackerel and grunter within no take areas. Fish spawning aggregations are classed by the IUCN as 'wildlife spectacles	LOW GBRMPA-QPWS compliance monitoring; REEFVTS
Grounding of large vessels	Increasing	LOW Coral Reefs (<30m) Corals	LOW Despite over 8000 ship movements within the Great Barrier Reef each year, there have only been a small number of collisions and groundings. A scar from a large grounding, such as Shen Neng, would take decades to recover.	HIGH GBRMP Zoning Plan - Designated Shipping Areas Compulsory pilotage Mandatory vessel reporting Incident response plans	HIGH REEFVTS; GBRMPA-QPWS compliance monitoring Reactive monitoring of site recovery
Illegal fishing and poaching	Increasing	HIGH Bony fish Sharks & rays Sea snakes Marine turtles Dolphins Dugongs Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Reef-wide The wide geographic range of high priority compliance issues and the growing use of surveillance avoidance tactics by commercial and recreational fishers significantly increase the frequency of illegal activity in the Region	HIGH Fisheries Act GBRMPA Act Zoning Plan	LOW GBRMPA-QPWS compliance monitoring
Increased air & sea temperature	Increasing	HIGH Beaches & coastline Open Waters Coral reefs and corals Seagrass meadows Mangroves Seabirds Shore birds Marine turtles Dolphins Other invertebrades Bony fish Sharks and rays Estuarine crocodiles Seabirds Shorebirds Connectivity Recruitment Income, economic contribution Appreciation, enjoyment Personal attachment Understanding	HIGH Acts across entire GBRWHA	HIGH Climate Change Action Plan	HIGH • QIMOS - Great Barrier Reef Ocean Observing System • ReefTemp • AIMS-GBRMPA Sea Temperature Monitoring Program • AIMS Weather Observing System • BoM
Increased freshwater inflow	Increasing	HIGH Seagrass Meadows Coral Reefs (<30m) Open Waters Estuarine crocodiles Mangroves Seabirds Shore birds Other invertebrades Bony fish Sharks and rays Connectivity Recruitment Income, economic contribution Understanding	HIGH Acts on inshore areas along entire length of the GBRWHA. Freshwater input is generally higher in the southern half of the Region, corresponding to the larger catchments.	HIGH Reef Water Quality Protection Plan	HIGH Qld SWAN; Reef Rescue Marine Monitoring Program Ambient water quality, Remote sensing, Flood monitoring; Island infrastructure monitoring BoM riverflow monitoring
Light impacts (artificial)	Increasing	LOW Marine turtles	LOW Restricted to nesting beaches near port, industrial and urban development	LOW Development compliance guidelines?	LOW Some developments monitor light levels e.g. PC&PA ERMP (Gladstone)
Marine debris	Increasing	HIGH Beaches & coastline Open Waters Seagrass Meadows Coral Reefs (<30m) Mangroves Marine turtles Estuarine crocodiles Seabirds Shorebirds Whales Dolphins Dugongs Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Plastic waste including discarded fishing gear (nets, lines and ropes) is one of the most harmful types of debris to marine wildlife through ingestion and entanglement	HIGH A range of marine pollution legislation at the international, national and state level prohibit the dumping of garbage in the Marine Park Threat abatement plan for the impacts of marine debris on vertebrate marine life Volunteer clean-up programmes The Australian Marine Safety Authority conducts intensive enforcement campaigns to ensure compliance with waste discharges and to control poor waste management practices on ships. Reef Pilots receive regular training about marine pollution legislation and reporting. Reef Guardian Schools	LOW Marine pollution legislation & reporting

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Noise pollution	Increasing	HIGH Whales Dolphins Dugongs Appreciation, enjoyment Personal attachment Understanding	HIGH Southern Inshore areas Concerns about the impacts of anthropogenic sound on marine animals has grown over the past four decades and is now considered a significant stressor for marine life worldwide	LOW	LOW Port ambient monitoring: Gladstone & Abbot Point
Nutrients from catchment runoff	Decreasing	HIGH Seagrass Meadows Coral Reefs (<30m) Open Waters Mangroves Seagrasses Macro algae Benthic Microalgae Corals Plankton & microbes Marine turtles Dugongs Dolphins Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Acts on inshore areas along entire length of the GBRWHA	HIGH Reef Water Quality Protection Plan	HIGH Reef Rescue Marine Monitoring Program
Ocean acidification	Increasing	HIGH Coral Reefs (<30m) Deepwater reefs Halimeda Banks Shoals Open Waters Corals Other Invertebrates Plankton & microbes Bony fish Understanding	HIGH Acts across entire GBRWHA	LOW Climate adaptaion strategy & action plan	HIGH Q-IMOS
Oil spill - large	Increasing	LOW Mangroves Seagrasses Macro algae Benthic Microalgae Corals Other Invertebrates Plankton & microbes Marine turtles Estuarine crocodiles Seabirds Shorebirds Dolphins Dugongs	LOW Apart from the physical smothering of plants and animals, oil toxicity and its chemical reactions with water mean a large spill is likely to have persistent effects on the health, growth, reproduction and development of a range of marine plants and animals for several years. A large oil spill is viewed as one of the greatest risks from ships transiting through the Great Barrier Reef. Despite increases in shipping traffic, improvements in shipping safety management have resulted in fewer major shipping incidents in the past 10 years	HIGH GBRMP Zoning Plan - Designated Shipping Areas Compulsory pilotage Mandatory vessel reporting Incident response plans National Contingency Plan	HIGH REEFVTS; GBRMPA-QPWS compliance monitoring Reactive monitoring of site recovery
Outbreak of COTS	Increasing	HIGH Coral reefs and corals Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Outbreaks appear to arise on northern reefs, and gradually progress south over several years	HIGH Reef Plan Climate Adaptation Strategy & Action Plan COTS Control program	HIGH iEotR RHIS; AIMS LTMP AMPTO COTS control program
Outbreak of disease	Increasing	LOW Coral reefs and corals Bony fish Marine turtles Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Potemtial reef-wide Coral disease associated with stress, such as bleaching Southern inshore - fibropapillomas prevalent from turtles in semi-enclosed bays	HIGH Reef Plan Climate Adaptation Strategy & Action Plan	HIGH AIMS LTMP; iEotR tourism weekly, RHIS, rapid assessment, sightings network; Reef Rescue Marine Monitoring Program QDEHP wildlife strandings; Qld turtle conservation project
Outbreak or bloom of other species	Increasing	LOW	LOW Discreet outbreaks *Trichodesmium* is found in nutrient poor tropical waters. Though it occurs naturally, blooms in the central Great Barrier Reef are thought to have increased, possibly due to nutrient in catchment run-off	LOW Reef Water Quality Protection Plan - indirect	HIGH iEotR sightings network; AIMS LTMP; Seagrass Watch; Reef Rescue Marine Monitoring Program inshore seagrass, inshore coral; Ambient ports monitoring; GBRMPA-QPWS compliance monitoring
Pesticides from catchment runoff	Decreasing	HIGH Mangrove habitats Seagrass Meadows Coral Reefs (<30m) Macro algae Benthic Microalgae Other Invertebrates Plankton & microbes Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Acts on inshore areas along entire length of the GBRWHA. Recently, more systematic monitoring of pesticide residues has shown widespread contamination by a range of pesticides in rivers, streams and estuaries draining to the Region, particularly areas south of Port Douglas. The Mackay-Whitsunday Region and waters between Cairns and Cardwell are of the greatest concern for exposure to pesticides. Other nearshore areas are low risk, and further offshore the risk becomes insignificant or zero.	HIGH Reef Water Quality Protection Plan	HIGH Reef Rescue Marine Monitoring Program pesticide monitoring, Ambient water quality, inshore seagrass; Paddock to Reef integrated monitoring, modelling and reporting program

		Prioritisation criteria (Agreement with the statements below results in a score of 'high')			
		1	2	3	4
Pressures that are of concern to management	**Trend**	**Impacting multiple elements (chronic or acute)** **High or very high risk to biodiversity values under Strategic Assessment**	**Impacting over a broad spatial scale (chronic or acute)**	**The subject of management actions/strategies**	**The subject of existing monitoring that is of value to management**
Physical damage to benthos	Increasing	LOW Seagrass Meadows Coral Reefs (<30m) Lagoon Floor Seagrasses Corals Other Invertebrates	LOW Discreet impacts at incident site	HIGH No anchoring areas Special Management Areas Tourism Ecocertification - Responsible Reef Practices	LOW None
Physical impacts of fishing	Stable	LOW Seagrass Meadows Coral Reefs (<30m) Lagoon Floor Shoals Seagrasses Other Invertebrates	LOW Trawling is the fishing activity that causes most of the physical impacts on the Region's marine habitats. Trawling occurs more than once per year in about seven per cent of the Marine Park	HIGH Fisheries Act GBRMPA Zoning Plan GBRMPA Act Qld Marine Parks Act	LOW Inshore Reef Zoning Monitoring
Rising sea level	Increasing	HIGH Islands Beaches & coastline All coastal & shallow water habitats Coral reefs and corals Seagrass meadows Mangroves Seabirds Shore birds Marine turtles Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Acts across entire GBRWHA	HIGH Climate Change Adaptation & Action Plan	LOW AIMS sea level guage Ports ambient monitoring
Sediment in catchment runoff	Decreasing	HIGH Lagoon Floor Shoals Open Waters Macro algae Benthic Microalgae Plankton & microbes Beaches & coastline Open Waters Coral reefs and corals Seagrass meadows Mangroves Marine turtles Dugongs Dolphins Recruitment Income, economic contribution Access to resources Appreciation, enjoyment Personal attachment Understanding	HIGH Acts on inshore areas along entire length of the GBRWHA. Much of the inshore southern area of the Region is now frequently affected by increased suspended solids that often exceed Water Quality Guidelines. Most sediment is confined to the inner shelf and settles out of the water column within five to fifteen kilometres of the coastline, where it may be later resuspended by wind generated waves and currents. However, during flood events, suspended sediment may be carried further offshore	HIGH Reef Water Quality Protection Plan	HIGH Reef Rescue Marine Monitoring Program ambient water quality; Paddock to Reef integrated monitoring, modelling and reporting program Ambient ports monitoring
Urban and industrial discharge	Stable	LOW	LOW Discreet point source pollution subject to strict environmental controls	HIGH Industrial discharge is subject to strict environmental controls	LOW None
Wash from vessels	Increasing	LOW Beaches & coastline Mangrove habitats Mangroves	LOW Discreet point source pollution subject to strict environmental controls	HIGH A range of marine pollution legislation at the international, national and state level prohibit the dumping of garbage in the Marine Park Reef Pilots receive regular training about marine pollution legislation and reporting.	LOW Marine pollution legislation & reporting
Waste discharge from a vessel	Increasing	LOW	LOW Discreet point source pollution subject to strict environmental controls	HIGH A range of marine pollution legislation at the international, national and state level prohibit the dumping of garbage in the Marine Park The Australian Marine Safety Authority conducts intensive enforcement campaigns to ensure compliance with waste discharges and to control poor waste management practices on ships. Reef Pilots receive regular training about marine pollution legislation and reporting.	LOW Marine pollution legislation & reporting

Appendix 7 Prioritisation of ecosystem processes

		Prioritisation Criteria (Agreement with the statements below results in a score of 'high')			
	1	2	3	4	5
Process (from Outlook Report)	**Not informed by monitoring priority bio-physical values and impacts (a process that does not score HIGH for this criterion is not scored for other criteria).**	**critical to the functioning of values underpinning matters of national environmental significance**	**critical to the recovery of values assessed to be in poor or very poor condition or declining trend**	**affected by a high or moderate level impact or cumulative impacts**	**the subject of management actions or strategies and reporting obligations**
Physical Processes					
Ocean currents	LOW sufficiently informed through "Altered ocean currents"				
Cyclones	LOW sufficiently informed through "Cyclone activity"				
Wind	LOW sufficiently informed through "Cyclone activity"				
Sedimentation	LOW sufficiently informed through "Sediments from catchment runoff"				
Sea level	LOW sufficiently informed through "Sea level rise"				
Sea temperature	LOW sufficiently informed through "increase in sea and air temperature"				
light	LOW sufficiently informed through "Sediments from catchment runoff"				
Chemical processes					
Nutrient cycling	MEDIUM sufficiently informed through "Nutrients from catchment runoff"				

		Prioritisation Criteria (Agreement with the statements below results in a score of 'high')			
	1	2	3	4	5
Process (from Outlook Report)	**Not informed by monitoring priority bio-physical values and impacts (a process that does not score HIGH for this criterion is not scored for other criteria).**	**critical to the functioning of values underpinning matters of national environmental significance**	**critical to the recovery of values assessed to be in poor or very poor condition or declining trend**	**affected by a high or moderate level impact or cumulative impacts**	**the subject of management actions or strategies and reporting obligations**
Partical feeding	MEDIUM sufficiently informed through "Corals and coral reefs"				
Primary production - pelagic	**HIGH** Some information may be inferred from water quality monitoring. But specific primary production monitoring of Chl is required.	HIGH With benthic primary production, pelagic primary production forms the base of food web in the GBR.	HIGH High pelagic primary production indicates indicated high nutrient values and poor water quality. Poro water quality is an impediment to the recovery of values assessed as being in poor condition such as coral reefs.	HIGH Nutrients and sediments from catchment runoff as well as resuspended sediments and butrients through dredging activities promotes pelagic primary production.	HIGH - through water quality APPLICABLE ACTS, PLANS & STRATEGIES - GBRMPA Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems EPBC Act Qld State Policy for Coastal Management
Primary production - benthic	**LOW** sufficiently informed through "Corals reefs and corals as well as Seagrass meadows"				
Herbivory	**LOW** sufficiently informed through "Bony fish, dugongs and marine trurtles"				
Predation	**LOW** sufficiently informed through "Bony fish, sharks and rays, and seabirds"				
Symbiosis	**LOW** sufficiently informed through "Coral reefs and corals"				
Reef building	**LOW** sufficiently informed through "Coral reefs and corals"				
Competition	MEDIUM sufficiently informed through "Coral reefs and corals, and bony fish"				

		Prioritisation Criteria (Agreement with the statements below results in a score of 'high')			
	1	2	3	4	5
Process (from Outlook Report)	**Not informed by monitoring priority bio-physical values and impacts (a process that does not score HIGH for this criterion is not scored for other criteria).**	**critical to the functioning of values underpinning matters of national environmental significance**	**critical to the recovery of values assessed to be in poor or very poor condition or declining trend**	**affected by a high or moderate level impact or cumulative impacts**	**the subject of management actions or strategies and reporting obligations**
Connectivity	HIGH Some information from larval studies, fish tagging and migration patterns but a much better understanding is required for management of the GBR.	HIGH Connectivity is important to every aspect of the Reef, including topics as different as nutrient flows, migration, larval dispersal and genetics	HIGH	HIGH The loss and modification of coastal wetlands and the deterioration of connecting waterbodies has reduced or destroyed connectivity between marine and adjacent freshwater habitats	HIGH APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan EPBC Act Qld State Policy for Coastal Management
Recruitment	HIGH Some information available through population studies of corals, seabirds, turtles and bony fish but much more required.	HIGH Recruitment is critical to sustaining populations and communities that make up the GBR	HIGH Recovery of habitats and populations cannot happen without healthy recruitment.	HIGH Recruitment is affected by all impacts listed for the GBR, mamny of them are high and cumulative impacts is very high.	HIGH APPLICABLE ACTS, PLANS & STRATEGIES - Zoning plan GBRMPA Act QLD Marine Parks Act Water Quality Guidelines for the GBRMP Biodiversity Strategy Outlook for Coastal Ecosystems GBR Climate Change Adaptation Strategy & Action Plan EPBC Act Qld State Policy for Coastal Management
Geomorphological processes	MEDIUM sufficiently informed through "beaches and coastline"				

Appendix 8 Characteristics of monitoring programs in the Great Barrier Reef World Heritage Area.

Name of monitoring program	Institution
Coral Reef Watch Satellite SST Monitoring	NOAA
Objectives of the program?	
To identify, in real time, areas around the world where corals are at risk of bleaching	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Rationale: Ambient water temperatures as little as 1 to 2°C above a coral's tolerance level, indicated by summer monthly mean temperatures, can cause coral bleaching (Berkelmans and Willis, 1999; Reaser et al., 2000). Mass coral bleaching has been shown to be caused by prolonged periods of thermal stress. The Degree Heating Weeks (DHW) product accumulates any HotSpots with positive anomalies >1°C over a 12-week window, thus showing how stressful conditions have been for corals in the last three months. It is a cumulative measurement of the intensity and duration of thermal stress, and is expressed in the unit °C-weeks. DHWs over 4°C-weeks have been shown to cause significant coral bleaching; values over 8°C-weeks have caused widespread bleaching and some mortality. [http://coralreefwatch.noaa.gov/satellite/methodology/methodology.html]	
What is monitored?	
Sea surface temperature	
Program documentation	
http://coralreefwatch.noaa.gov/satellite/product_overview.html (& links)	
Relevant MNES elements & activities	
Sea temperature	
Start date	Geographic coverage
1997	Worldwide
Survey Frequency	
Updated twice weekly	
What analysis of data occurs (source)	
Products derived from SST; Long-term mean SST, or climatology; SST Anomaly; Coral bleaching hotspot; Coral bleaching degree heating weeks (DHW); Bleaching alert areas; Coral bleaching Virtual Stations – operational & experimental SST & DHW time series graphs and data for virtual stations;	

Satellite Bleaching Alert; Satellite coral bleaching monitoring source data; CRW products in Google Earth format; Animation products: http://coralreefwatch.noaa.gov/satellite/index.html
Are results interpreted for future management? (source)
Yes, see above http://coralreefwatch.noaa.gov/satellite/index.html
Are results reported? (source). How frequently?
Yes, continuously http://coralreefwatch.noaa.gov/satellite/index.html
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?
Sensor technology and algorithms are evolving continuously

Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security
No cost to Australia

How are data stored?	Are data and/or metadata on-line? (source)
NOAA	Data can be downloaded from: http://coralreefwatch.noaa.gov/satellite/hdf/index.html

Name of monitoring program	Institution
Q-IMOS - Great Barrier Reef Ocean Observing System	IMOS

Objectives of the program?
There are five major areas of research driving the Q-IMOS Node; •Multi-decadal ocean change •Climate variability and weather extremes •Major boundary currents and inter-basin flows •Continental shelf processes •Ecosystem responses
Conceptual model for monitoring specific MNES (and source) or documented rationale
Rationale: Moorings in the northern Great Barrier Reef around Lizard Island are designed to measure

the area of bifurcation where the on-shore South Equatorial Current hits the Reef and splits into two streams, one travelling North and one travelling South. The bifurcation point varies with a range of factors but is normally located around the Cooktown area, so the moorings will detect if this moves north. The moorings off Townsville, as well those around Lizard Island, measure the intrusion of deeper warm water onto and across the Great Barrier Reef shelf. Moorings in the southern Great Barrier Reef are designed to monitor the strength of currents related to upwelling events. The moorings in the Swains region off-shore from Rockhampton will not only measure water moving onto the reef but also the movement of water as it leaves the Great Barrier Reef lagoon in what is known to be a complex process. The mooring pair located around Heron Island in the south, aims to look at water flowing south to form the East Australian Current and to better understand the complex set of eddies and jets that form in this region. http://imos.org.au/661.html
What is monitored?
Basic moorings: Conductivity, Water Temperature, Water Depth, Fluorescence, Dissolved Oxygen, Turbidity, Ocean Currents Plus in reference stations & some other sites: Chl, PAR, Nutrients, plankton, Carbon dioxide, inorganic carbon, alkalinity Variables: Water Pressure: dBar; Water Temp: ^{o}C; Salinity: S/m; Wind speed: km/hr; Air Pressure: hpa; Air Temp: ^{o}C; Hail accumulation: hits.cm^{-2}; Hail duration: s; Hail intensity: hits.cm^{-2}.h^{-1}; Humidity: %; Rain accumulation: mm; Rain duration: s; Rain intensity: mm.hr^{-1}; Wind direction: bearing degrees
Program documentation
http://imos.org.au/httpimosorgauqimossci1ht.html http://imos.org.au/httpimosorgauqimosscihtm.html http://imos.org.au/anmnqld.html
Relevant MNES elements & activities
Ocean currents; sea temperature; light; nutrient cycling; ocean acidity; ocean salinity; pelagic primary production

Start date	Geographic coverage
2007	Four regions: Capricorn Bunker (Heron Is), Swains, Central cross-shelf transect (Orpheus Is - Myrmidon Reef), Lizard Is region

Survey Frequency
Samples every 10 min

What analysis of data occurs (source)	
Data are summarised	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Summary	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
The Q-IMOS Node plan was assessed by the IMOS board against the IMOS 5 year plan in 20009.The plan was reviewed by independent international experts in 2010.	
Approximate costs, funding source, and funding security	
$6M per year, funded by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative.	
How are data stored?	Are data and/or metadata on-line? (source)
AIMS data centre	Data & metadata available at the IMOS data portal: http://imos.aodn.org.au/imos/

Name of monitoring program	Institution
ReefTemp	GBRMPA, CSIRO-CMAR, BoM
Objectives of the program?	Are they clearly stated?
Map bleaching risk on the GBR using AVHRR.	Yes
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Based on bleaching thresholds	
What is monitored?	
Sea surface temperature from remote sensing - The Bureau of Meteorology processes the latest	

NOAA environmental satellite Advanced Very High Resolution Radiometer (AVHRR) thermal imagery for Australia through rigorous algorithms to produce a 15-day composite image of SST (currently from NOAA AVHRR satellites 15, 17, and 18) at a resolution of 0.017995° (~2 km). Data from the resulting Australian Mercator Projection SST Mosaic for the Queensland region is sent to the GBRMPA, along with an age-of-data grid file. In cases where SST cannot be calculated due to cloud cover, the most recent temperature calculated for a grid cell is inserted unless over 15 days old. In ReefTemp, data over 10 days old are not used to estimate bleaching risk.
Program documentation
http://www.cmar.csiro.au/remotesensing/reeftemp/web/ReefTemp_techinfo.htm
Relevant MNES elements & activities
Sea temperature

Start date	Geographic coverage
Long term climatologies based on 1993-2003 dataset.	Australia wide

Survey Frequency
Daily updates for Qld region
What analysis of data occurs (source)
SST data are used to estimate bleaching risk daily
Are results interpreted for future management? (source)
Linked to GBRMPA Bleaching Response Plan
Are results reported? (source). How frequently?
Daily updates at: http://www.cmar.csiro.au/remotesensing/reeftemp/web/ReefTemp_application.htm
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?
Remote sensing platforms and algorithms are continuously improving

Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security

How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Sea Temperature Monitoring Program	AIMS / GBRMPA
Objectives of the program?	
Continuous measurement of sea temperature over a wide area of the GBR as a physical covariate for biological changes, and ground truth for remote sensing	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not applicable	
What is monitored?	
Water temperature on reef flat (1 logger) and reef slope (1 logger) at many reefs. Data loggers instantaneously record sea temperatures every 30 minutes and are exchanged and downloaded approximately every 12 months. Temperature loggers on the reef-flat are generally placed just below Lowest Astronomical Tide level. Reef-slope (or where specified as Upper reef-slope) generally refers to depths 5–9 m while Deep reef-slope refers to depths of ~20 m.	
Program documentation	
http://www.aims.gov.au/docs/research/climate-change/climate-monitoring/sst.html http://data.aims.gov.au/metadataviewer/uuid/4a12a8c0-c573-11dc-b99b-00008a07204e	
Relevant MNES elements & activities	
Sea temperature	
Start date	Geographic coverage
1990, reasonable coverage since 1995	GBR & Torres Strait
Survey Frequency	
Loggers sample every 30 min. Loggers are recovered and downloaded every 1-2 years.	
What analysis of data occurs (source)	
Summary only	

Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
http://data.aims.gov.au/aimsrtds/map.xhtml?parameterType=water+temperature&latitude=-15.623036831528252&longitude=135.966796875&zoom=4&channels=&checked=&from=01-01-1980	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Infrequent internal AIMS science reviews; 4 year funding cycles	
Approximate costs, funding source, and funding security	
~$25K per year; Some GBRMPA funds, mainly AIMS appropriation	
How are data stored?	Are data and/or metadata on-line? (source)
AIMS Data Centre	Metadata on AIMS website; AODN

Name of monitoring program	Institution
AIMS Weather Observing System	AIMS
Objectives of the program?	
To provide near real time weather data for sites across the GBR Ground truth for remotely sensed sea temperatures, and other variables	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
Air pressure, air temperature, humidity, light, wind direction, wind speed. In some sites: rain, sea temperature at one or more depths	

<table>
<tr><td colspan="3">Program documentation</td></tr>
<tr><td colspan="3">http://www.aims.gov.au/docs/data-centre/weatherstations.html

http://data.aims.gov.au/aimsrtds/latestreadings.xhtml</td></tr>
<tr><td colspan="3">Relevant MNES elements & activities</td></tr>
<tr><td colspan="3">Cyclones & wind; sea temperature; light</td></tr>
<tr><td>Start date</td><td colspan="2">Geographic coverage</td></tr>
<tr><td>1990</td><td colspan="2">12 weather stations Torres Strait to S GBR:

Thursday Island, Lizard Island, Agincourt Reef, Myrmidon Reef, Orpheus Island, Rib Reef, Davies Reef , Cleveland Bay, - Cape Bowling Green, Hardy Reef, Square Rocks, Heron Island, One Tree Island</td></tr>
<tr><td colspan="3">Level of training of observers</td></tr>
<tr><td colspan="3">N/A</td></tr>
<tr><td colspan="3">Survey Frequency</td></tr>
<tr><td colspan="3">Updates every 10-30 min</td></tr>
<tr><td colspan="3">What analysis of data occurs (source)</td></tr>
<tr><td colspan="3">Minimal data summary</td></tr>
<tr><td colspan="3">Are results interpreted for future management? (source)</td></tr>
<tr><td colspan="3">Not applicable</td></tr>
<tr><td colspan="3">Are results reported? (source). How frequently?</td></tr>
<tr><td colspan="3">http://data.aims.gov.au/aimsrtds/latestreadings.xhtml

Continuously updated weather data available by selecting station on map: http://maps.aims.gov.au/index.html?intro=false&z=5&ll=136.33984,-23.00000&l0=aims_aims:WeatherStation,g_SATELLITE</td></tr>
<tr><td colspan="3">Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="2">Does the program get reviewed?</td><td>At what intervals?</td></tr>
<tr><td colspan="2"></td><td></td></tr>
</table>

Approximate costs, funding source, and funding security	
$25K Funded by AIMS, funding commitment is fragile	
How are data stored?	Are data and/or metadata on-line? (source)
AIMS data centre	AIMS Data Centre & AODN

Name of monitoring program	Institution
Australian Baseline Sea Level Monitoring Program	Bureau of Meteorology
Objectives of the program?	
The project is designed to monitor sea level around the coastline of Australia. The ultimate goal is to identify long period sea level changes, with particular emphasis on the enhanced greenhouse effect on sea level.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not applicable	
What is monitored?	
SEAFRAME gauges measure sea level by two independent means, and also observe atmospheric pressure, air and water temperatures, wind speed and direction.	
Program documentation	
http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml http://www.bom.gov.au/oceanography/projects/abslmp/reports_yearly.shtml	
Relevant MNES elements & activities	
Sea level; sea temperature; rising sea level	
Start date	Geographic coverage
1991	16 stations Australia-wide; Rosslyn Bay & Cape Ferguson within the GBRWHA
Level of training of observers	
N/A	
Survey Frequency	
Hourly samples	

What analysis of data occurs (source)	
Results included in State of the Climate reports http://www.csiro.au/en/Outcomes/Climate/Understanding/State-of-the-Climate-2012/Oceans.aspx	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
BoM systems	Data at: http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml

Name of monitoring program	Institution
Air Quality Monitoring	QDEHP
Objectives of the program?	
The National Environment Protection Measure for Ambient Air Quality (Air NEPM) (1998) sets national air quality standards for ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, lead and particles as PM10.The desired environmental outcome of the Air NEPM is ambient air quality that provides for the adequate protection of human health and well-being. The Goal of the Air NEPM is to achieve these standards with the allowable exceedences, as assessed in accordance with the monitoring protocol, within 10 years from commencement of reporting.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	

What is monitored?	
Instrumentation differs among sites; includes Ozone, Nitrogen dioxide, Sulphur dioxide, Carbon monoxide, PM10, PM2.5, Lead	
Program documentation	
http://www.ehp.qld.gov.au/air/monitoring/index.html	
Relevant MNES elements & activities	
Atmospheric pollution (urban development & ports); coal dust impacts derived from transportation	
Start date	Geographic coverage
2000	SE Qld, Gladstone, Mackay, Townsville, Mt Isa
Level of training of observers	
N/A (Instrumentation)	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Simple data summaries http://www.ehp.qld.gov.au/air/monitoring/trends.html http://www.ehp.qld.gov.au/air/monitoring/trend-graphs.html	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Data available in near real time: http://www.ehp.qld.gov.au/air/data/search.php	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Funded by QDEHP	

How are data stored?	Are data and/or metadata on-line? (source)
QDEHP systems	http://www.ehp.qld.gov.au/air/data/search.php

<table>
<tr><td colspan="2">Name of monitoring program</td><td>Institution</td></tr>
<tr><td colspan="2">Wave Monitoring</td><td>QDEHP</td></tr>
<tr><td colspan="3">Objectives of the program?</td></tr>
<tr><td colspan="3">Wave information is used in the design and construction of coastal structures and in investigations of natural coastal processes including accretion and erosion.

When a cyclone is approaching the coast, provides advice to the State Counter Disaster Organisation on the potential impact of waves on coastal communities.

Wave data is used at four levels within the meteorological community where the primary aim of collecting and using wave data is for the safety of life and property.

At the regional level, wave data is used as input to forecasts for specific coastal areas and up to 60 nm seaward for periods of many hours in advance. These forecasts are aimed at 'small craft' venturing out on excursions where longer duration planning is required.</td></tr>
<tr><td colspan="3">Conceptual model for monitoring specific MNES (and source) or documented rationale</td></tr>
<tr><td colspan="3">Not Applicable</td></tr>
<tr><td colspan="3">What is monitored?</td></tr>
<tr><td colspan="3">Wave height, wave direction and sea surface temperature</td></tr>
<tr><td colspan="3">Program documentation</td></tr>
<tr><td colspan="3">http://www.ehp.qld.gov.au/coastal/monitoring/waves/index.php</td></tr>
<tr><td colspan="3">Relevant MNES elements & activities</td></tr>
<tr><td colspan="3">Cyclones & wind; climate change-induced altered cyclone activity</td></tr>
<tr><td>Start date</td><td colspan="2">Geographic coverage</td></tr>
<tr><td>From 1978 in some sites</td><td colspan="2">13 sites from Cairns to the NSW border</td></tr>
<tr><td colspan="3">Level of training of observers</td></tr>
<tr><td colspan="3">Not Applicable (instruments)</td></tr>
</table>

Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Basic summaries in the internet : http://www.ehp.qld.gov.au/coastal/monitoring/waves/index.php	
Are results interpreted for future management? (source)	
Intended for coastal & disaster management	
Are results reported? (source). How frequently?	
Recent and current data available in near real time: http://www.ehp.qld.gov.au/coastal/monitoring/waves/index.php	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
QDEHP funding	
How are data stored?	Are data and/or metadata on-line? (source)
QDEHP Systems	http://www.ehp.qld.gov.au/coastal/monitoring/waves/index.php

Name of monitoring program	Institution
Storm tide Monitoring	QDEHP
Objectives of the program?	
To monitor coastal flooding from the sea, usually because of storm surge during tropical cyclones	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Tide height	

Program documentation	
http://www.ehp.qld.gov.au/coastal/monitoring/storm-tides/about_the_network.html	
Relevant MNES elements & activities	
Cyclones & wind; climate change-induced altered cyclone activity	
Start date	Geographic coverage
1975	20 tide gauges along Qld coast
Level of training of observers	
Instruments	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Simple summaries: http://www.ehp.qld.gov.au/coastal/monitoring/storm-tides/about_the_network.html#Location	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
In near real time: http://www.ehp.qld.gov.au/coastal/monitoring/storm-tides/about_the_network.html#Location	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security	
QDEHP	
How are data stored?	Are data and/or metadata on-line? (source)
QDEHP systems	http://www.ehp.qld.gov.au/coastal/monitoring/storm-tides/about_the_network.html#Location

Name of monitoring program	Institution
Dugong Population Monitoring	James Cook Univ.
Objectives of the program?	
Spatial distribution (relative abundance), status & trends in dugong populations on East Coast of Qld	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Dugong abundance (and turtles) by stratified aerial surveys	
Program documentation	
Various scientific publications	
Relevant MNES elements & activities	
Dugongs; cultural practices, observances and customs	
Start date	Geographic coverage
1985	East coast of Qld from NSW border to Torres Strait, including the GBRMP
Survey Frequency	
About every 5 years	
What analysis of data occurs (source)	
Population estimates for the eastern coast of Queensland with uncertainty estimates	
Are results interpreted for future management? (source)	
Yes in publications	

Are results reported? (source). How frequently?	
e-Atlas; scientific journals	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Each survey involves an application for funding with accompanying scrutiny	~ 5 years
Approximate costs, funding source, and funding security	
Estimated cost of each survey about $300K plus salaries for 2 months [funding sources: GBRMPA, Qld Govt; Aust Marine Mammal Centre]	
How are data stored?	Are data and/or metadata on-line? (source)
JCU Tropical Data Hub	incomplete

Name of monitoring program	Institution
Humpback Whale Population Monitoring	Univ of Queensland
Objectives of the program?	
To estimate the numbers of humpback whales migrating along the East coast of Australia	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Systematic sightings of humpback whales passing Point Lookout, N Stradbroke Is, during the annual northward migration. Similar surveys at Cape Byron were discontinued 2005. Surveys in different years are of different duration (estimating total numbers or relative numbers) and may include an aerial survey component too. All observers are volunteers.	
Program documentation	
http://www.uq.edu.au/whale/abundance	

<table>
<tr><td colspan="2">Relevant MNES elements & activities</td></tr>
<tr><td colspan="2">Whales</td></tr>
<tr><td>Start date</td><td>Geographic coverage</td></tr>
<tr><td>1982</td><td>Surveys at narrow points of continental shelf give estimates for the whole coast</td></tr>
<tr><td colspan="2">Survey Frequency</td></tr>
<tr><td colspan="2">Surveys every 1-3 years during annual northward migration period June & July. Most recent survey in 2010, the next is planned for 2014.</td></tr>
<tr><td colspan="2">What analysis of data occurs (source)</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Are results interpreted for future management? (source)</td></tr>
<tr><td colspan="2">Results are reported to and reviewed by the Scientific Committee of the IWC and the Australian Marine Mammal Centre (AMMC)</td></tr>
<tr><td colspan="2">Are results reported? (source). How frequently?</td></tr>
<tr><td colspan="2">Reports to International Whaling Commission [e.g. http://iwc.int/msyrworkshop2], scientific publications</td></tr>
<tr><td colspan="2">Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?</td></tr>
<tr><td colspan="2">Current population estimates are based on sightings. Some previous work using biopsy darts suggest that most of the whales that migrate are males, which may mean that non-breeding females do not migrate and so are not included in the population estimate. A more extensive program involving extensive tissue would give a more accurate measure of the gender and reproductive status of the migrating whales and improve confidence in the population estimate. Another unknown is the location of the important breeding areas within the GBRWHA. To date only ~15 whales have been tagged with satellite tags. A more extensive tagging and tracking program would reveal this information which is fundamental for management</td></tr>
<tr><td>Does the program get reviewed?</td><td>At what intervals?</td></tr>
<tr><td>Each survey requires a separate application for funding, no other review process</td><td></td></tr>
<tr><td colspan="2">Approximate costs, funding source, and funding security</td></tr>
<tr><td colspan="2">A full season survey cost ~$150K (board and lodging for volunteers). Recent surveys have been funded individually through the Australian Marine Mammal Centre (AMMC). No formal commitment for future funding.</td></tr>
</table>

How are data stored?	Are data and/or metadata on-line? (source)
Data stored by project team	Metadata lodged with AMMC (portal under development)

Name of monitoring program	Institution
Coastal Bird Monitoring	GBRMPA, QPWS
Objectives of the program?	
To track population sizes of shorebird and seabird species (selected following the GBRMPA Coastal Bird Monitoring Strategy) based on breeding effort	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Monitoring is guided by the Coastal Bird Monitoring Strategy for the GBRWHA. Seabirds: Herald petrel, wedge-tailed shearwater, red-tailed tropicbird, masked booby, red-footed booby, brown booby, great frigatebird, lesser frigatebird, Australian pelican, eastern reef egret, silver gull, Caspian tern, crested tern, lesser crested tern, roseate tern, black-naped tern, little tern, sooty tern, bridled tern, common noddy, black noddy Shorebirds: beach stone-curlew, pied oystercatcher, sooty oystercatcher, red-capped plover.	
Program documentation	
Coastal Bird Monitoring Strategy for the GBRWHA http://www.gbrmpa.gov.au/__data/assets/pdf_file/0003/4818/gbrmpa_coastalbirdmonitoringstrategy.pdf	
Relevant MNES elements & activities	
Seabirds; shorebirds	
Start date	Geographic coverage
GBRMPA-QPWS coastal bird monitoring began ~1985	GBRWHA
Survey Frequency	
Most breeding sites are censused once or twice per year depending on whether winter or summer	

breeders use the site. Michaelmas Cay surveyed every 2 mo.	
What analysis of data occurs (source)	
Analysis to date has been opportunistic	
Are results interpreted for future management? (source)	
The program is run by the management organisation	
Are results reported? (source). How frequently?	
Not routinely reported publicly	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
The Qld coastal bird monitoring strategy is currently being reviewed	
Approximate costs, funding source, and funding security	
The program is part of the GBRMPA-QPWS Field management program	
How are data stored?	Are data and/or metadata on-line? (source)
The Coastal Bird Atlas database is included in Qld Govt's (formerly DERM) WetlandInfo system	Presence/absence data is available through Qld Govt's WildNet

Name of monitoring program	Institution
Qld Turtle Conservation Project	QDEHP
Objectives of the program?	
Monitor populations of turtles on East Coast of Queensland: a) assess breeding on nesting beaches, b) survey feeding areas (and assess condition of individuals)	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	

What is monitored?	
1. Recording, measuring and tagging nesting populations of marine turtles at index beaches within each genetic stock for each species in Queensland 2. Recording population size, condition, reproductive condition and breeding history of individuals at marine turtle feeding grounds along the Queensland coast	
Program documentation	
Relevant MNES elements & activities	
Marine turtles	
Start date	Geographic coverage
1975	Eastern Qld coast to Torres Strait
Survey Frequency	
Surveys are made annually	
What analysis of data occurs (source)	
Specific to publications	
Are results interpreted for future management? (source)	
The program is run by one of the management organisation	
Are results reported? (source). How frequently?	
Results are not published on the internet. The program has produced a large number of peer-reviewed publications and grey literature reports, e.g. http://www.ehp.qld.gov.au/wildlife/watching/turtles/publications.html	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Program has had external reviews in 1986 and 1995	irregular
Approximate costs, funding source, and funding security	
Estimate: $500K + parts of 4 salaries	

How are data stored?	Are data and/or metadata on-line? (source)
QDEHP Queensland turtle database	No

Name of monitoring program	Institution
Coral reef fish spawning aggregation site long term monitoring program	GBRMPA
Objectives of the program?	
1. Determine temporal trends in the condition of primary spawning aggregation sites and the formation of coral trout spawning aggregations. 2. Determine temporal trends in the numbers and sizes of coral trout aggregating to spawn at these sites.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Assessment of the primary coral trout (*Plectropomus* spp.) spawning aggregation on each reef by underwater visual census following a standard protocol at permanent sites. Surveys are made around the new moon in October, which is the most important spawning period for coral trout on the GBR. The surveys also involve assessment of the spawning site, including habitat type, general abundance of other target and prey species.	
Program documentation	
Relevant MNES elements & activities	
Bony fish	
Start date	Geographic coverage
1990	Sites on two mid-shelf reefs(Scott Reef & Elford Reef) near Cairns
Survey Frequency	
Annual	
What analysis of data occurs (source)	
Not publicly available	

Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
~$10K p.a.; funded by GBRMPA; funding uncertain	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA	No

Name of monitoring program	Institution
Long-term Monitoring Program	AIMS
Objectives of the program?	
Monitor the status and trends in condition of coral reefs of the GBR	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
No explicit conceptual model	
What is monitored?	
1. Manta tow surveys for crown-of-thorns starfish (COTS), reef-wide coral cover, number of coral trout, number of sharks (broadscale surveys) 2. (In standard habitat) surveys of sessile benthic organisms (~70 categories) using still images; visual counts of reef fishes (7 families) & length estimates of all serranids, lutjanids and lethrinids. 3. Counts of juvenile corals 4. Agents of coral mortality (disease, *Drupella*, CoTS)	
Program documentation	
http://www.aims.gov.au/docs/research/monitoring/reef/reef-monitoring.html	

http://www.aims.gov.au/docs/research/monitoring/reef/sampling-methods.html http://www.aims.gov.au/docs/research/monitoring/reef/sops.html http://www.aims.gov.au/docs/research/monitoring/reef/status-reports.html	
Relevant MNES elements & activities	
Coral reefs (<30m); macroalgae; benthic microalgae;corals; other invertebrates; bony fish; sharks and rays	
Start date	Geographic coverage
Manta tow surveys – 1982 Intensive surveys – 1992	Intensive surveys of sites on 47 Inshore, mid-shelf, and outer shelf reefs between Lizard Is region (14.6 S) and Lady Musgrave Is (23.8 S). Historically, manta tow surveys, of about 100 mainly of mid-shelf and outer shelf reefs, from Cape York (11 S) to Lady Musgrave. Very limited surveys north of Lizard Is since 2008.
Level of training of observers	
Full-time graduate employees who are trained in data collection and cross-calibrated. Observers are also responsible for data checking and data reduction. They also actively participate in reporting and scientific publications from the results of surveys.	
Survey Frequency	
Study reefs were surveyed annually until 2005, then in odd-numbered years (alternating with program: Effects of rezoning on offshore coral reef systems)	
What analysis of data occurs (source)	
Most analysis is associated with scientific publications	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Results from manta tow and SCUBA search surveys are reported directly to principal stakeholders within a month of collection. http://www.aims.gov.au/docs/research/monitoring/reef/latest-surveys.html Annual summaries of data for each survey reef are available on the internet. http://data.aims.gov.au/monmap3/cruisereport.jsp?cruise=all or http://data.aims.gov.au/reefpage2/allreefs.jsp Many other findings concerning reef status and reef ecology are reported in scientific publications	

and at conferences.	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Monitoring of benthic communities is primarily based on photo-transects, so processing the images and data reduction are laborious and slow. Several projects are investigating ways to automate this.	
Does the program get reviewed?	At what intervals?
Yes, as part of AIMS' science review process [NB this is not a review of relevance to management]	Irregularly, last review 2008
Approximate costs and funding source	
$2.484M per survey year; $375K from NERP; otherwise AIMS appropriation.	
How is data stored?	Are data and/or metadata on-line? (source)
Data are lodged in the AIMS Data Centre	Metadata: http://www.aims.gov.au/docs/data/data.html; AODN

Name of monitoring program	Institution
Effects of rezoning on offshore coral reef systems	AIMS
Objectives of the program?	
To track the development of effects of rezoning the GBRMP in 2004	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not explicit	
What is monitored?	
1. Manta tow surveys for crown-of-thorns starfish (COTS), reef-wide coral cover, number of coral trout, number of sharks (broadscale surveys) 2. (In standard habitat) surveys of sessile benthic organisms (~70 categories) using still images; visual counts of reef fishes (7 families) & length estimates of all serranids, lutjanids and lethrinids. 3. Counts of juvenile corals 4. Agents of coral mortality (disease, *Drupella*, COTS)	
Program documentation	
http://www.aims.gov.au/documents/.../05734196-b5f0-4d49-8900-6ea1ffa6835f http://www.nerptropical.edu.au/project/monitoring-ecological-effects-great-barrier-reef-zoning-	

plan http://www.nerptropical.edu.au/publication/project-81-factsheet-monitoring-ecological-effects-gbr-zoning-plan-mid-and-outer-shelf	
Relevant MNES elements & activities	
Coral reefs (<30m); corals; bony fish; other invertebrates; sharks and rays; macroalgae; benthic microalgae	
Start date	Geographic coverage
2005	Five sets of reefs between Cooktown and the Capricorn-Bunker Is
Level of training of observers	
Full-time graduate employees who are trained in data collection and cross-calibrated. Observers are also responsible for data checking and data reduction. They also actively participate in reporting and scientific publications from the results of surveys.	
Survey Frequency	
Alternate years	
What analysis of data occurs (source)	
Data are analysed for diverging trends in fish and coral communities on reefs that are open and closed to fishing	
Are results interpreted for future management? (source)	
This is principally a study of management effectiveness	
Are results reported? (source). How frequently?	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Monitoring of benthic communities is primarily based on photo-transects, so processing the images and data reduction are laborious and slow. Several projects are investigating ways to automate this.	
Does the program get reviewed?	At what intervals?
Yes, as part of AIMS' science review process [NB this is not a review of relevance to management]	Irregularly, last review 2008
Approximate costs, funding source, and funding security	
$2.819M per survey year; $375K from NERP; otherwise AIMS appropriation.	

How are data stored?	Are data and/or metadata on-line? (source)
Data are stored in the AIMS Data Centre	Metadata: http://www.aims.gov.au/docs/data/data.html; AODN

Name of monitoring program	Institution
Coral Trout and Coral Trout Prey Population Trends	James Cook University
Objectives of the program?	
To study the effects of rezoning the GBRMP in 2004 on abundance and biomass of coral trout and other species of fish including prey species on inshore reefs	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None evident	
What is monitored?	
Underwater visual census - Although 150 species of reef fish are surveyed, the analysis has focused on coral trout (*Plectropomus* spp.), fishes that are coral trout prey, and fishes of particular interest such as stripey sea perch (*Lutjanus carponotatus*). The biological characteristics of the coral reef communities and incidence of coral disease are also recorded.	
Program documentation	
http://www.nerptropical.edu.au/project/marine-reserves-contribute-biodiversity-and-fishery-sustainability http://www.nerptropical.edu.au/publication/project-82-factsheet-assessing-effects-management-zoning-inshore-reefs-great-barrier	
Relevant MNES elements & activities	
Bony fish; corals; coral reefs (<30 m)	

Start date	Geographic coverage
1999, extended 2004	Inshore reefs in the Palm, Whitsunday and Keppel Island groups
Survey Frequency	
Annual surveys	
What analysis of data occurs (source)	
The abundances of exploited and other fish species in areas that are open to fishing are compared with those in areas where fishing is prohibited – scientific publications	

Are results interpreted for future management? (source)	
This program monitors the effects of management	
Are results reported? (source). How frequently?	
Scientific publications; NERP conferences;	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Not explicitly, but subject to frequent research proposals for funding renewal	
Approximate costs, funding source, and funding security	
funded by NERP Tropical Ecosystems until 2014; no long term funding commitment	
How are data stored?	Are data and/or metadata on-line? (source)
Data stored by project team	No

Name of monitoring program	Institution
Eye on the Reef - Tourism Weekly Monitoring Surveys	GBRMPA
Objectives of the program?	
• To provide status information and early warning on water quality, the presence of protected and iconic species, and the health of the Reef. • To provide vital reef health trend information to inform the Early Warning System and Incident Response components of GBRMPA's Reef Health Incident Response System, as well as triggers for management actions.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Water temp; Secchi depth; macroalgae (5 types); herbivorous fishes (Scarids / Acanthurids; number & average size); corals (soft + 7 life forms); coral bleaching; bleached clams; COTS; *Drupella*; coral disease (3 types); coral spawning; fish spawning; turtles (3 spp); sea-snakes; iconic bony fishes (12 categories); sharks & rays (5 categories); invertebrates(cuttlefish, sea cucumbers, triton shell);	

jellyfish (irukanji, boxjelly, *Physalia*); *Trichodesmuim*; based on 30 min swim	
Program documentation	
http://www.gbrmpa.gov.au/our-partners/tourism-industry/eye-on-the-reef/tourism-weekly-monitoring-surveys	
Relevant MNES elements & activities	
Sea temperature; coral reefs (<30m); macroalgae; benthic microalgae; corals; sea snakes; marine turtles; other invertebrates; bony fishes, sharks & rays	
Start date	Geographic coverage
1997	Tourism sites generally near Cairns and in Whitsundays, but also Osprey Reef
Level of training of observers	
Participants attend quarterly training workshops, including at least one in-water training day run by the GBRMPA and QPWS	
Survey Frequency	
Participants undertake to survey the same site in 40 weeks per year	
What analysis of data occurs (source)	
Eye on the Reef database not yet public	
Are results interpreted for future management? (source)	
Eye on the Reef database not yet public	
Are results reported? (source). How frequently?	
Eye on the Reef database not yet public	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Overall cost of all components of EotR program (less in kind) ~$170K p.a.	

How are data stored?	Are data and/or metadata on-line? (source)
The GBRMPA have custom-designed data system	To be available this calendar year

Name of monitoring program		Institution
Eye on the Reef - Reef Health Impacts Surveys		GBRMPA
Objectives of the program?		
Reef Health and Impact Survey (RHIS) is a quick and efficient way to provide a snapshot of reef health at any time on any reef		
Conceptual model for monitoring specific MNES (and source) or documented rationale		
Not explicit		
What is monitored?		
• Macroalgal cover (5 growth forms) • Coral cover (7 growth forms + soft coral) • Coral bleaching (coral type affected) • Incidence of coral disease (3 + other); coral predation (COTS, *Drupella* by coral type); recent coral damage. • Presence of garbage		
Program documentation		
http://www.gbrmpa.gov.au/our-partners/tourism-industry/eye-on-the-reef/reef-health-and-impact-survey		
Relevant MNES elements & activities		
Coral reefs <30m; corals; macroalgae; benthic microalgae; other invertebrates; marine debris		
Start date	Geographic coverage	
2009	GBRWHA wide as part of Field Management patrols	
Level of training of observers		
≥2 hr online tutorial, plus 1 day field training		
Survey Frequency		
Opportunistic / responsive to disturbance events		

What analysis of data occurs (source)	
Data system provides basic summaries	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Web presentation system in advanced development	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
No regular reviews	
Approximate costs, funding source, and funding security	
Overall cost of all components of EotR program (less in kind) ~$170K p.a.	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA systems	Web presentation system in advanced development

Name of monitoring program	Institution
Eye on the Reef - Rapid monitoring	GBRMPA
Objectives of the program?	
To allow collection of information on protected and iconic species distribution, after Reef health incidents, or to give early warning of Reef health impacts under GBRMPA's Reef Health Incident Response System. To promote stewardship: using simple science to introduce reef users to the main threats that are affecting the Great Barrier Reef.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	

What is monitored?	
Records the presence or absence of: • Macroalgae (5 growth forms) • Corals (7 growth forms + soft coral) • Coral bleaching (coral type affected) • Occurrence of coral disease (3 + other); coral predation (COTS, *Drupella* by coral type); recent coral damage • Garbage	
Program documentation	
Eye on the Reef database not yet public	
Relevant MNES elements & activities	
Coral reefs <30m; corals; macroalgae; nenthic microalgae; other invertebrates; marine debris	
Start date	Geographic coverage
	Opportunistic
Level of training of observers	
Intended for observers with minimal training	
Survey Frequency	
Opportunistic / response to incidents	
What analysis of data occurs (source)	
Are results interpreted for future management? (source)	
Eye on the Reef database not yet public	
Are results reported? (source). How frequently?	
Eye on the Reef database not yet public	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security	
Overall cost of all components of EotR program (less in kind) ~$170K p.a.	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA system	Web presentation system in advanced development

Name of monitoring program		Institution
Eye on the Reef – Sightings network		GBRMPA
Objectives of the program?		
To build knowledge about species diversity, abundance, habitat and range.		
Conceptual model for monitoring specific MNES (and source) or documented rationale		
Not explicit		
What is monitored?		
Reef visitors are encouraged to record sightings and submit photos of interesting animals (whales, COTS, etc.)		
Program documentation		
http://www.gbrmpa.gov.au/our-partners/tourism-industry/eye-on-the-reef/sightings-network		
Relevant MNES elements & activities		
Whales; dolphins; dugong; other invertebrates		
Start date	Geographic coverage	
2007	GBR & adjacent areas (Coral Sea, Gulf of Carpentaria, SE Qld etc)	
Level of training of observers		
None		
Survey Frequency		
Opportunistic / responsive to disturbance events		
What analysis of data occurs (source)		
Data system provides basic summaries		

Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Web presentation system using Google Earth	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
No	
Does the program get reviewed?	At what intervals?
No schedule of reviews	
Approximate costs, funding source, and funding security	
Overall cost of all components of EotR program (less in kind) ~$170K p.a.	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA systems	(http://www.gbrmpa.gov.au/sn/)

Name of monitoring program	Institution
Queensland Shark Control Program	Qld DAFF
Objectives of the program?	
To reduce populations of large sharks to minimise the threat of shark attack on humans in particular locations.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Records of sharks caught (and bycatch)	
Program documentation	
http://www.daff.qld.gov.au/28_15736.htm http://www.daff.qld.gov.au/28_21847.htm	

<table>
<tr><td colspan="3">Relevant MNES elements & activities</td></tr>
<tr><td colspan="3">Sharks & rays; extraction of top order predators (e.g. sharks); entanglement of bycatch</td></tr>
<tr><td>Start date</td><td colspan="2">Geographic coverage</td></tr>
<tr><td>1962-1983 at different locations</td><td colspan="2">Lines and/or nets set near Cairns, Townsville, Mackay, Yeppoon/ Emu Park, Tannum Sands, Bundaberg</td></tr>
<tr><td colspan="3">Level of training of observers</td></tr>
<tr><td colspan="3">Mainly contractors</td></tr>
<tr><td colspan="3">Survey Frequency</td></tr>
<tr><td colspan="3">Nets checked every 2 days</td></tr>
<tr><td colspan="3">What analysis of data occurs (source)</td></tr>
<tr><td colspan="3">Summaries of sharks caught at each location</td></tr>
<tr><td colspan="3">Are results interpreted for future management? (source)</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Are results reported? (source). How frequently?</td></tr>
<tr><td colspan="3">http://www.daff.qld.gov.au/28_21844.htm</td></tr>
<tr><td colspan="3">Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="2">Does the program get reviewed?</td><td>At what intervals?</td></tr>
<tr><td colspan="2">QDAFF conducts ongoing assessment of the SCP's performance to ensure it is meeting its aims</td><td>ongoing</td></tr>
<tr><td colspan="3">Approximate costs, funding source, and funding security</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="2">How are data stored?</td><td>Are data and/or metadata on-line? (source)</td></tr>
<tr><td colspan="2">QDAFF systems</td><td>http://www.daff.qld.gov.au/28_21844.htm</td></tr>
</table>

Name of monitoring program	Institution
Marine wildlife stranding & mortality	QDEHP
Objectives of the program?	
The primary goal of this database is to record information on where sick, injured, dying and dead marine animals have been found in Queensland and assess causes of injury and death where possible. Incidental information on sharks, rays, seabirds and other marine animals is also recorded	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
Animals that are stranded on Qld shores are recorded and examined and sometimes autopsied	
Program documentation	
http://www.ehp.qld.gov.au/wildlife/caring-for-wildlife/frequently-asked-questions.html	
Relevant MNES elements & activities	
Marine turtles; whales; dolphins; dugongs; vessel strike	
Start date	Geographic coverage
Since 1982 for a few locations, State-wide since 1996	Ad hoc State-wide
Level of training of observers	
Variable	
Survey Frequency	
Ad hoc	
What analysis of data occurs (source)	
Frequent summaries	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Approx. annual reports available on the internet: http://www.ehp.qld.gov.au/wildlife/caring-for-wildlife/strandnet-reports.html#dugong	

Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Funded by QDEHP	
How are data stored?	Are data and/or metadata on-line? (source)
QDEHP Strandnet	

Name of monitoring program	Institution
Reef Rescue Marine Monitoring Program Inshore Seagrass monitoring program	JCU
Objectives of the program?	
To detect change in inshore seagrass meadows in response to improvements in water quality associated with improving land use practices in coastal catchments and with disturbance events.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Reports from this program provide conceptual diagrams for different types of seagrass communities encountered along the Queensland coast.(http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report)	
What is monitored?	
• seagrass % cover & species composition • seed banks • epiphytes & macro-algae • meadow edge mapping (late dry Season, late monsoon Season) • reproductive health • seagrass tissue elements (C:N:P) (late dry Season) • rhizosphere sediment herbicide concentration • in-situ within canopy temperature • in-situ canopy light	
Program documentation	
http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/our-monitoring-and-assessment-programs/reef-rescue-marine-monitoring-program	

http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report http://e-atlas.org.au/rrmmp/gbr-deedi-interdial-seagrass
Relevant MNES elements & activities
Seagrass meadows; seagrass; light

Start date	Geographic coverage
2005	63 accessible inshore sites between Cooktown & Great Sandy Strait

Level of training of observers
Core surveys by trained and qualified scientists, supplementary surveys by volunteers who attend a training course and are supervised by full-time Fisheries Qld / JCU staff
Survey Frequency
Two surveys annually focussed on late dry season and late wet season to assess the status of seagrass prior to and post wet season, when most runoff enters the GBR.
What analysis of data occurs (source)
Summary data, limited analysis of trends
Are results interpreted for future management? (source)
The Marine Monitoring Program is designed to detect change in inshore seagrass meadows in response to improvements in water quality associated with improving land use practices in coastal catchments.
Are results reported? (source). How frequently?
Annual survey reports: http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?
See entry under Seagrass-Watch

Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security
Approx. $440K in 2012.

How are data stored?	Are data and/or metadata on-line? (source)
Data stored in JCU	No

Name of monitoring program		Institution
Reef Rescue Marine Monitoring Program Inshore Coral Reef monitoring program		Australian Institute of Marine Science
Objectives of the program?		
To detect change in inshore coral reef communities in response to improvements in water quality associated with improving land use practices in coastal catchments and with disturbance events		
Conceptual model for monitoring specific MNES (and source) or documented rationale		
Reference to Fabricius KE (2011) Factors determining the resilience of coral reefs to eutrophication: A review and conceptual model. In Dubinsky Z. and Stambler N. (eds) Coral Reefs: An Ecosystem in Transition. Springer Science and Business Media B.V.		
What is monitored?		
• benthic cover (algae, hard and soft corals), • taxonomic composition (mainly to species) • coral demographics (the size classes of corals), • coral settlement rates on terracotta tiles Note reefs surveys match spatially with other aspects of the RRMMP notably water quality sampling		
Program documentation		
http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/our-monitoring-and-assessment-programs/reef-rescue-marine-monitoring-program http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report http://e-atlas.org.au/rrmmp/gbr-aims-inshore-coral-reef-monitoring		
Relevant MNES elements & activities		
Coral reefs; corals; macroalgae; benthic microalgae; recruitment		
Start date	Geographic coverage	
2005	14 core sites and 35 sites in total between Snapper Island & the Keppels,	

Level of training of observers
Highly trained full-time staff
Survey Frequency
Annual surveys of core sites, others generally surveyed in alternate years
What analysis of data occurs (source)
Analysis of trends
Are results interpreted for future management? (source)
The Marine Monitoring Program is designed to detect change in inshore coral reefs in response to improvements in water quality associated with improving land use practices in coastal catchments.
Are results reported? (source). How frequently?
Annual reports to GBRMPA : http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?

Does the program get reviewed?	At what intervals?

Approximate costs, funding source, and funding security
Total cost in 2012 $863K, AIMS co-investment = $711K; Funding source: AG

How are data stored?	Are data and/or metadata on-line? (source)
AIMS Data Centre,	AIMS metadata; AODN : http://catalogue.aodn.org.au/geonetwork/srv/eng/metadata.show?uuid=c30cfb2d-46be-4837-9733-9bb60489b65b

<table>
<tr><td>Name of monitoring program</td><td>Institution</td></tr>
<tr><td>Reef Rescue Marine Monitoring Program Inshore Water Quality Monitoring – Ambient Pesticide Sampling</td><td>Entox / Univ of Queensland</td></tr>
<tr><td colspan="2">Objectives of the program?</td></tr>
<tr><td colspan="2">To determine time integrated baseline concentrations of specific organic chemicals in water, with the aim to evaluate long term trends in pesticide concentrations in response to improvements in water quality associated with improving land use practices in coastal catchments.</td></tr>
<tr><td colspan="2">Conceptual model for monitoring specific MNES (and source) or documented rationale</td></tr>
<tr><td colspan="2">None explicit</td></tr>
<tr><td colspan="2">What is monitored?</td></tr>
<tr><td colspan="2">An index of overall PSII inhibition & spectrum of herbicides based on samples from:
• Empore Disk (ED) samplers deployed at all 15 sample sites during the wet and the dry seasons.
• Polydimethylsiloxane (PDMS) samplers deployed at 9 sites in the wet season & at 3 of those sites in dry season.
• Semi-permeable membrane devices (SPMD) deployed at 3 of the sites (wet & dry season).</td></tr>
<tr><td colspan="2">Program documentation</td></tr>
<tr><td colspan="2">http://e-atlas.org.au/rrmmp/gbr-entox-uq-inshore-pesticide-monitoring</td></tr>
<tr><td colspan="2">Relevant MNES elements & activities</td></tr>
<tr><td colspan="2">Pesticides (incl. herbicides) from catchment runoff</td></tr>
<tr><td>Start date</td><td>Geographic coverage</td></tr>
<tr><td>2005</td><td>15 inshore sites between Low Isles and the Keppels</td></tr>
<tr><td colspan="2">Level of training of observers</td></tr>
<tr><td colspan="2">Instruments – passive samplers</td></tr>
<tr><td colspan="2">Survey Frequency</td></tr>
<tr><td colspan="2">Wet and Dry Season samples in each year</td></tr>
<tr><td colspan="2">What analysis of data occurs (source)</td></tr>
<tr><td colspan="2">Summary data only e.g.
http://www.gbrmpa.gov.au/__data/assets/pdf_file/0003/7680/EnTox_pesticide_monitoring_report_2009_10.pdf</td></tr>
</table>

Are results interpreted for future management? (source)	
The Marine Monitoring Program is designed to detect change in inshore pesticide levels in response to improvements in water quality associated with improving land use practices in coastal catchments.	
Are results reported? (source). How frequently?	
Annual reports to GBRMPA available on the internet: http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
$250K without including in-kind	
How are data stored?	Are data and/or metadata on-line? (source)
UQ systems	Metadata: http://e-atlas.org.au/sites/default/files/article/238/gbr-rrmmp-entox-uq-inshore-pesticides-meta-data.pdf

Name of monitoring program	Institution
Reef Rescue Marine Monitoring Program Inshore Water Quality Monitoring – Ambient Water Quality Sampling	AIMS
Objectives of the program?	
To determine the status of marine water quality in coastal and inshore regions of the GBR lagoon and assess long-term trends in water quality on the Great Barrier Reef.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Sampling and analyses of a comprehensive suite of dissolved and particulate nutrients and carbon, suspended solids, chlorophyll a and salinity using grab sampling, as well as state of the art sensors with long-term data logging capacity.	

• ammonium= NH_4 • nitrite= NO_2 • nitrate= NO_3 • phosphate /filterable reactive phosphorus=PO_4 • silicate/filterable reactive silicon= $Si(OH)_4$ • dissolved organic nitrogen=DON • dissolved organic phosphorus= DOP • dissolved organic carbon= DOC • particulate organic nitrogen= PN • particulate phosphorus = PP • particulate organic carbon= PO • suspended solids (SS) • chlorophyll a In situ loggers record chlorophyll fluorescence, turbidity and temperature.	
Program documentation	
http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/our-monitoring-and-assessment-programs/reef-rescue-marine-monitoring-program http://e-atlas.org.au/content/rrmmp.	
Relevant MNES elements & activities	
Sediment in catchment runoff; nutrients from catchment runoff	
Start date	Geographic coverage
2005	14 inshore sites between Cape Tribulation & the Keppel Is (in conjunction with RRMMP inshore reef monitoring)
Level of training of observers	
Trained scientists	
Survey Frequency	
Twice annually – wet season, dry season	

What analysis of data occurs (source)	
http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report	
Are results interpreted for future management? (source)	
The Marine Monitoring Program is designed to detect change in inshore water quality in response to improving land use practices in coastal catchments.	
Are results reported? (source). How frequently?	
http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Total cost in 2012 $1.263M, AIMS co-investment = $724K; Reef Rescue / GBRMPA / AIMS	
How are data stored?	Are data and/or metadata on-line? (source)
AIMS Data Centre	Metadata via AIMS & AODN http://catalogue.aodn.org.au/geonetwork/srv/eng/metadata.show?uuid=a5a02dc8-16b4-4b50-abad-af4a1c1e9c49

Name of monitoring program	Institution
Reef Rescue Marine Monitoring Program Inshore Water Quality Monitoring – Flood Sampling	Centre for Tropical Water and Aquatic Ecosystem Research – James Cook University
Objectives of the program?	
To better understand how extreme weather events affect water quality conditions in the GBR.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not explicit	

What is monitored?	
Surface water grab samples in flood waters resulting from flood events recording: • Total Suspended sediment (TSS), • Chlorophyll-a (Chl-a), • Coloured Dissolved Organic Matter (CDOM), • dissolved and particulate nutrients (nitrogen and phosphorus), • salinity, • temperature • PSII herbicides.	
Program documentation	
http://e-atlas.org.au/rrmmp/gbr-actrf-jcu-terrestrial-run-off	
Relevant MNES elements & activities	
Sediment in catchment runoff; nutrients from catchment runoff	
Start date	Geographic coverage
2005	Mainly central & southern the GBRWHA
Level of training of observers	
Trained scientists	
Survey Frequency	
Opportunistic when floods occur	
What analysis of data occurs (source)	
The program maps the extent of flood plumes and calculates a "Water Quality Index" based on normalised values of 8 water quality variables to allow comparison of exposure to pollutants among sites and times. (http://www.gbrmpa.gov.au/__data/assets/pdf_file/0004/28255/MMP-Flood-monitoring-Report-2010-11.pdf)	
Are results interpreted for future management? (source)	
The Marine Monitoring Program is designed to detect change in characteristics of flood waters in response to improvements in water quality associated with improving land use practices in coastal catchments.	
Are results reported? (source). How frequently?	
Annual reports to GBRMPA (http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report)	

Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
$187K + in kind Source: AG	
How are data stored?	Are data and/or metadata on-line? (source)
James Cook University Share Drive as MS-Access database	http://e-atlas.org.au/sites/default/files/article/241/gbr-rrmmp-actrf-jcu-terrestrial-run-meta-data.pdf

Name of monitoring program	Institution
Reef Rescue Marine Monitoring Program - using Remote Sensing for GBR wide water quality	Environmental Earth Observation Programme, CSIRO Land & Water
Objectives of the program?	
To develop and apply techniques for large-scale monitoring of coastal water quality; to estimate the extent of flood plumes	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
MODIS Aqua ocean colour imagery used to derive spatial and temporal information on near-surface concentrations of suspended solids (as non-algal particulate matter), turbidity (as vertical attenuation of light coefficients Kd), chlorophyll a, and coloured dissolved organic matter (CDOM)	
Program documentation	
http://e-atlas.org.au/rrmmp/gbr-csiro-remote-sensing-wq	
Relevant MNES elements & activities	
Sedimentation; nutrient cycling; primary productivity - pelagic	

Start date	Geographic coverage
2005	GBR - wide
Level of training of observers	
n/a	
Survey Frequency	
Images available daily (cloud permitting)	
What analysis of data occurs (source)	
Program produces regional maps of freshwater plume extent in wet season, maps of median Chl-a and Total Suspended Solids in wet and dry seasons, plus regional assessment of marine water quality index and exceedance of water quality guidelines.	
Are results interpreted for future management? (source)	
The Marine Monitoring Program is designed to detect change in regional water quality in the GBR lagoon in response to improving land use practices in coastal catchments.	
Are results reported? (source). How frequently?	
Annual reports to GBRMPA (http://www.gbrmpa.gov.au/resources-and-publications/publications/annual-reef-rescue-marine-monitoring-science-report)	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
$146K + in kind Source: AG	
How are data stored?	Are data and/or metadata on-line? (source)
CSIRO systems	Not yet

<table>
<tr><td>Name of monitoring program</td><td>Institution</td></tr>
<tr><td>Paddock to Reef Catchment loads monitoring program</td><td>Qld DSITIA</td></tr>
<tr><td colspan="2">Objectives of the program?</td></tr>
<tr><td colspan="2">To measure and report on progress towards Reef Water Quality Protection Plan 2009 goals and targets</td></tr>
<tr><td colspan="2">Conceptual model for monitoring specific MNES (and source) or documented rationale</td></tr>
<tr><td colspan="2">None explicit</td></tr>
<tr><td colspan="2">What is monitored?</td></tr>
<tr><td colspan="2">Water quality indicators (at paddock, sub-catchment and basin scales):

Discharge
Total nitrogen (TN)
Total dissolved nitrogen (TDN)
Oxidised nitrogen (NOx)
Ammonia (NH3)
Dissolved organic nitrogen (DON)
Total phosphorus (TP)
Total dissolved phosphorus (TDP)
Dissolved phosphorus (DOP)
Filterable reactive phosphorus (FRP)
Total suspended solids (TSS)
Particle size analysis (at select sites)
Pesticides and herbicides (at select sites)

Dissolved and particulate components sampled by grab sampling; some passive samplers deployed in parallel</td></tr>
<tr><td colspan="2">Program documentation</td></tr>
<tr><td colspan="2">http://wetlandinfo.derm.qld.gov.au/wetlands/SupportTools/MonitoringExtentAndCondition/current-and-future-monitoring/paddock-reef-program.html

http://www.nrm.qld.gov.au/water/monitoring/how_monitored.html</td></tr>
<tr><td colspan="2">Relevant MNES elements & activities</td></tr>
<tr><td colspan="2">Freshwater inflow; sediment in catchment runoff; altered salinity; nutrients from catchment runoff; pesticides (incl. herbicides) from catchment runoff</td></tr>
</table>

Start date	Geographic coverage
Sediment& nutrients 2005; full program 2009	25 sites in 11 catchments between the Normanby River (Cape York) and the Burnett River
Level of training of observers	
DNRM staff	
Survey Frequency	
Some instruments sample continuously, grab sampling dependent on flow and access	
What analysis of data occurs (source)	
Summery statistics (in printed reports)	
Are results interpreted for future management? (source)	
The program is designed to detect change in stream water quality in response improving land use practices in coastal catchments.	
Are results reported? (source). How frequently?	
Publications and reports	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Qld Govt Water database	http://watermonitoring.derm.qld.gov.au/host.htm

Name of monitoring program	Institution
Qld surface water ambient water quality & quantity monitoring program (SWAN)	DSITIA

Objectives of the program?
The program aims to: - collect ambient water quality data (both high and low flows) at a selection of Department of Environment and Resource Management gauging stations - assess and report on the condition and trend of Queensland's freshwater aquatic ecosystem health.
Conceptual model for monitoring specific MNES (and source) or documented rationale
None explicit
What is monitored?
Manual sampling at all sites: General parameters – major Ions Unfiltered nutrient samples – total nutrients (total phosphorus and total nitrogen) Filtered nutrient samples – speciated nutrients (orthophosphate, oxidised nitrogen, ammonium) In-situ (on-site) sampling at all sites: Dissolved oxygen Electrical conductivity at 25 °C pH at 25 °C Turbidity (Nephelometric Turbidity Units) Total alkalinity Continuous time series measurements at a subset of sites: Electrical conductivity at 25 °C pH at 25 °C Turbidity Temperature
Program documentation
http://wetlandinfo.derm.qld.gov.au/wetlands/SupportTools/MonitoringExtentAndCondition/current-and-future-monitoring/surface-water-ambient-network.html

Relevant MNES elements & activities	
Freshwater inflow; sediment in catchment runoff; altered salinity; nutrients from catchment runoff	
Start date	Geographic coverage
1960	196 sites Qld-wide
Level of training of observers	
DNRM staff	
Survey Frequency	
Samples collected at 1, 3 or 4 month intervals depending on the site	
What analysis of data occurs (source)	
Summary statistics and trends, http://www.nrm.qld.gov.au/water/monitoring/qld_ambient_program/qld-ambient-reports.html	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
http://www.nrm.qld.gov.au/water/monitoring/qld_ambient_program/qld-ambient-reports.html	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Review of many aspects of program begun 2009, due for implementation June 2010	Irregular
Approximate costs, funding source, and funding security	
Qld Govt	
How are data stored?	Are data and/or metadata on-line? (source)
Qld DNRM systems	Data available through the Water Monitoring Data Portal: http://watermonitoring.derm.qld.gov.au/host.htm

<table>
<tr><td colspan="2">Name of monitoring program</td><td>Institution</td></tr>
<tr><td colspan="2">Capricorn Reef Monitoring Program (CapReef)</td><td>(Community)</td></tr>
<tr><td colspan="3">Objectives of the program?</td></tr>
<tr><td colspan="3">CAP Reef is a community group concerned with issues around recreational fishing in the southern GBR and coastal waters. Their current project has two aims:

1. To support increased understanding of long-term trends in recreational fishing in Gladstone Harbour, the Narrows and adjacent waterways through sourcing additional data for the CapReef database.
2. To promote sustainable fishing practices in Gladstone Harbour, the Narrows and adjacent waterways.</td></tr>
<tr><td colspan="3">Conceptual model for monitoring specific MNES (and source) or documented rationale</td></tr>
<tr><td colspan="3">None explicit</td></tr>
<tr><td colspan="3">What is monitored?</td></tr>
<tr><td colspan="3">Recreational fishing behaviour

Data being collected for this project includes:

• Historical information from boat ramp survey, boat registrations, fishing club records, tagging and Barramundi recruitment surveys
• Boat ramp surveys to capture details of all fish caught on fishing trips (forms are available)
• Trailer counts
• Fisher survey
• Fish tagging
• Barramundi recruitment surveys
• River flows and weather data</td></tr>
<tr><td colspan="3">Program documentation</td></tr>
<tr><td colspan="3">http://info-fish.net/capreef/about-capreef/

http://info-fish.net/capreef/gladstone-harbour-monitoring/</td></tr>
<tr><td colspan="3">Relevant MNES elements & activities</td></tr>
<tr><td colspan="3">bony fish; sharks and rays</td></tr>
<tr><td>Start date</td><td colspan="2">Geographic coverage</td></tr>
<tr><td>2005</td><td colspan="2">Gladstone Harbour, inshore Southern GBR waters</td></tr>
<tr><td colspan="3">Survey Frequency</td></tr>
<tr><td colspan="3">Daily / weekly</td></tr>
</table>

What analysis of data occurs (source)	
Report to be produced at the end of the project	
Are results interpreted for future management? (source)	
Report to be produced at the end of the project	
Are results reported? (source). How frequently?	
Past reports are available: http://info-fish.net/suntag/forms/capreef.html	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Project funded by Gladstone Ports Corp	
How are data stored?	Are data and/or metadata on-line? (source)
	No

Name of monitoring program	Institution
Reefcheck (Coral Reef Health Monitoring)	Reefcheck Australia
Objectives of the program?	
To protect and help to rehabilitate Australia's valuable coral reefs through: 1) community education, to raise awareness of the key issues 2) scientific research, to collect data that contributes to solutions.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Coral cover, algae, target organisms	

Program documentation	
http://www.reefcheckaustralia.org/ http://www.reefcheckaustralia.org/files/documents/420/rca_methods_2012.pdf	
Relevant MNES elements	
Coral reefs <30m; macroalgae; benthic microalgae; corals; other invertebrates; bony fish	
Start date	Geographic coverage
2001	Opportunistic surveys at tourism sites from Osprey Reef in the north down to sites in SE Qld
Level of training of observers	
The program has a well-documented protocol and observers are required to take field courses before collecting data	
Survey Frequency	
Opportunistic (many sites not resurveyed)	
What analysis of data occurs (source)	
Basic summaries for each site presented on Internet.	
Are results interpreted for future management? (source)	
Analysis and interpretation is minimal.	
Are results reported? (source). How frequently?	
Data are summarised on the Internet shortly after surveys are completed. Reports prepared every 1-2 years. http://www.reefcheckaustralia.org/public-reports.html	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
No mention of reviews	--
Approximate costs, funding source, and funding security	
Course fees, donations, some Caring for our Country funding.	

How are data stored?	Are data and/or metadata on-line? (source)
	http://www.reefcheckaustralia.org/public-reports.html

Name of monitoring program	Institution
Seagrass-Watch	James Cook University
Objectives of the program?	
- To educate the wider community on the importance of seagrass resources. - To raise awareness of coastal management issues. - To build the capacity of local stakeholders in the use of standardised scientific methodologies. - To conduct long-term monitoring of seagrass & coastal habitat condition. - To provide an early warning system of coastal environment changes for management. - To support conservation measures which ensure the long-term resilience of seagrass ecosystems	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Multiple conceptual model diagrams for different habitats and locations on the Program's website; for examples see: http://seagrasswatch.org/cairns.html	
What is monitored?	
Extent of coverage, species composition, estimates of abundance, presence of epiphytes and macro-algae, presence of dugong feeding trails. Additional data is collected on canopy temperature and local water quality, sediment indicators, and light loggers.	
Program documentation	
http://seagrasswatch.org/home.html http://www.seagrasswatch.org/Methods/Manuals/SeagrassWatch_monitoring_guidelines_2ndEdition.pdf	
Relevant MNES elements & activities	
Seagrass meadows; seagrass	
Start date	Geographic coverage
1998	Torres Strait, Cooktown to Moreton Bay

Level of training of observers	
Survey Frequency	
Varies locally, 1-3 surveys annually	
What analysis of data occurs (source)	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Website gives biomass, species composition and trends for each survey site, with brief interpretation	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
This program monitors many accessible coastal sites in the GBRWHA, but there are large areas of seagrass meadows in the GBR lagoon at ~30m depth. These represent a food source for dugong and green turtles, but are not monitored and would not be easily monitored by divers. The increasing availability of towed video units, ROVs and AUVs provide ways to gather images of these habitats over large areas.	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Funding has fluctuated and is currently very low (~$15K from the GBRMPA)	
How are data stored?	Are data and/or metadata on-line? (source)
Formerly stored on Qld DPI&F servers, now JCU	

Name of monitoring program	Institution
Mangrove Watch	NGO
Objectives of the program?	
To assist communities to monitor the status of mangroves in local areas; to promote stewardship	

Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Physical condition of the shoreline habitat and human influence is assessed from video	
Program documentation	
http://www.mangrovewatch.org.au/	
Relevant MNES elements & activities	
Beaches & coastlines; mangroves	
Start date	Geographic coverage
	Some nr Pt Douglas; Hinchinbrook; SE Qld
Level of training of observers	
Volunteers	
Survey Frequency	
Opportunistic	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Some funding from Caring for our Country	

How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Australian Marine Debris Initiative	Tangaroa Blue Foundation
Objectives of the program?	Are they clearly stated?
The program aims to: • raise public awareness about marine debris and its impact on the marine environment • clean up beaches, coastline and islands • collect detailed data and information on the amount and types of marine debris being found • collate the marine debris data and distribute to all parties with an interest in the ocean and coast, highlighting areas that can be worked on to reduce marine debris in our local waters.	Yes
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None stated	
What is monitored?	
Items of marine debris are removed by community groups and catalogued following an identification manual into a national database	
Program documentation	
http://www.tangaroablue.org/amdi/amdi-program.html http://www.tangaroablue.org/amdi/database-overview.html	
Relevant MNES elements	
Beaches and coastline; open waters; marine turtles; dugongs; dolphins; seabirds; shorebirds; bony fish; income, economic contribution and employment; access to resources and heritage; appreciation, enjoyment, aesthetics; personal attachment; understanding	
Start date	Geographic coverage
2004 in WA; 2007 in N Qld	Australia-wide , including GBR coast, Cape York & Torres Strait

Level of training of observers	
Manual for debris identification on line: http://www.tangaroablue.org/resources/id-manual.html	
Survey Frequency	
Variable among local community groups; some groups in N Qld have clean ups monthly	
What analysis of data occurs (source)	
Quantities of debris items summarised into standard categories	
Are results interpreted for future management? (source)	
Are results reported? (source) How frequently?	
On-line reporting in development	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
No mention	
Approximate costs, funding source, and funding security	
The program receives about $350K from Caring for our Country	
How are data stored?	Are data and/or metadata on-line? (source)
The foundation's computers	Web site in development

Name of monitoring program	Institution
Port Curtis & Port Alma Environmental Research & Monitoring Program	Multi -institutions
Objectives of the program?	
To acquire a detailed ecological understanding of the marine environment of Port Curtis and Port Alma that can be used to monitor, manage and/or improve the regional marine environment and to offset potential impacts from the [Western Basin development] project on listed threatened and migratory species and values of the Great Barrier Reef World Heritage Area and National Heritage	

Place.
Conceptual model for monitoring specific MNES (and source) or documented rationale
None explicit
What is monitored?
• Shorebirds / Shorebird prey /Shorebird habitat • Turtle nesting / light impacts • Turtle foraging • Inshore dolphin populations & activity, genetics & heavy metal content • Dugong populations & activity, genetics • Acoustic tagging / satellite tagging megafauna for population & movement studies – dugong, dolphins, turtles • Megafauna strandings - pathology, genetics & heavy metals analysis • Seagrass, population dynamics, seed banks, recovery potential, nutritional quality • Mangroves & tidal wetlands – extent & condition • Coral monitoring distribution & abundance of corals and other associated benthos
Program documentation
http://www.westernbasinportdevelopment.com.au/ermp/section/environmental http://www.westernbasinportdevelopment.com.au/media/pdf/ERMP%20Approval.pdf
Relevant MNES elements & activities
Beaches and coastlines; mangroves; seagrass meadows; coral Reefs <30m; saltmarshes; seagrasses; corals; marine turtles; shorebirds; dolphins; dugongs; light impacts; noise pollution; sedimentation

Start date	Geographic coverage
2011	Port Alma & Port Curtis and adjacent habitat

Level of training of observers
Trained scientists and consultants
Survey Frequency
This varies among the sub-programs – Surveys during two periods for migratory shore birds (passing northwards and later southwards, less frequent for mangroves and coastline.
What analysis of data occurs (source)
No reporting of monitoring results yet.
Are results interpreted for future management? (source)
No reporting of monitoring results yet.

Are results reported? (source). How frequently?	
Initial reports: http://www.westernbasinportdevelopment.com.au/ermp-environmental-reports	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
The developers are required to commit $\geq$ \$7M over 10 years, funding from Gladstone Ports Corporation and other developers	
How are data stored?	Are data and/or metadata on-line? (source)
	Not yet

Name of monitoring program	Institution
Port Curtis Integrated Monitoring Program (PCIMP)	Multiple
Objectives of the program?	
To foster coordination of monitoring activities among stakeholders of Port Curtis and to share and disseminate information to improve our capacity to manage our natural resources in a sustainable and balanced way for the prosperity of our communities and the health of our natural environment.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Water Quality: Turbidity, Dissolved oxygen, pH, Salinity / Conductivity, Temperature, Light (PAR), Nutrients, Chlorophyll A, Metals; Sediments - metals in 165 sites across the harbour sampled in 2 month cycles. Intertidal and Coastal Monitoring: Seagrass mapped in 2003, mangroves mapped 2004; both updated regularly since. Assessment of intertidal communities in 2006/07 examined mangrove health and associations between sediment contaminants and intertidal invertebrate communities at 62 sites across the harbour. Expanded in 2009 to include broad scale mapping of the entire intertidal and coastal habitat (mangroves and seagrasses) using remote sensing, plus surveys of sediment	

contaminants and intertidal invertebrate communities at 78 sites across Port Curtis.	
Program documentation	
http://www.pcimp.com.au/	
Relevant MNES elements & activities	
Seagrass meadows; coral reefs <30m; saltmarshes; seagrasses; macroalgae; corals; sedimentation; nutrient cycling	
Start date	Geographic coverage
2003	Port Curtis & adjacent waterways
Level of training of observers	
Trained scientists & consultants	
Survey Frequency	
Survey frequency varies among program components	
What analysis of data occurs (source)	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Report card produced every 3 yr, major reports every 3 yr. http://www.pcimp.com.au/report_card.html	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Cost > $600K per year - Program funded by a large consortium of Gladstone Industry & Govt organisations	

How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Abbot Point Port Monitoring	North Qld Bulk Ports
Objectives of the program?	Are they clearly stated?
To assess the overall state of the port environment or to detect any changes occurring	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Seagrass communities Coral communities Benthic macro-invertebrates Algae Turtles Marine mammals Fisheries Marine water quality Marine sediment quality Noise & vibration	
Program documentation	
http://www.nqbp.com.au/abbot-point/	
Relevant MNES elements & activities	
Seagrass meadows; coral reefs <30m; seagrasses; macroalgae; corals; other invertebrates; bony fish; whales; dolphins; dugongs; sedimentation; atmospheric pollution; dredge spoil disposal; dredging – resuspension of dredge spoil; nutrients from catchment runoff; noise pollution; coal dust impacts	

from transportation	
Start date	Geographic coverage
	Abbot Point and surrounds
Level of training of observers	
Trained scientific consultants	
Survey Frequency	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Mainly with consultants	No

Name of monitoring program	Institution
Hay Point Port Monitoring	North Qld Bulk Ports
Objectives of the program?	
To assess the overall state of the port environment or to detect any changes occurring	

Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Seagrass (since 2004) Coral Benthic macro-invertebrates Algae Turtles Marine mammals Fisheries Marine water quality Marine sediment quality Noise & vibration	
Program documentation	
Not publicly available	
Relevant MNES elements & activities	
Seagrass meadows; coral reefs <30m; seagrasses; macroalgae; corals; other invertebrates; marine turtles; whales; dolphins; dugongs; sedimentation; atmospheric pollution; nutrients from catchment runoff; noise pollution; coal dust impacts from transportation	
Start date	Geographic coverage
2004	Hay Pt & environs
Level of training of observers	
Scientific consultants	
Survey Frequency	
Not publicly available	
What analysis of data occurs (source)	
Not publicly available	

Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Ecological Health Monitoring Program (Cairns)	Ports North
Objectives of the program?	
A series of monitoring programs to measure and track impacts associated with port operations have been implemented at each of our ports to: • Aid the management of conservation areas • Inform day to day management and assist long term planning • Monitor trends in condition of port ecosystems and surrounding waters • Facilitate environmentally sensitive development • Assist in identifying and managing potential environmental impacts, • Gather data to assist in justifying environmental terms of future development applications and subsequent conditions	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Water quality - hydrocarbons, heavy metals, tri-butyl tin, phosphorous, and nitrogen	

Sediment - Standard sediment analyses? Metals? Seagrass - At each survey site, habitat characteristics including seagrass presence, species composition, above-ground biomass, percent algal cover, depth below mean sea level (dbMSL; for sub tidal meadows), sediment type, time and position fixes (GPS; ±5m) were recorded.	
Program documentation	
http://www.portsnorth.com.au/content/portsnorth-standard2.asp?name=Environment_Management	
Relevant MNES elements & activities	
Seagrass meadows; seagrasses; sedimentation; nutrients from catchment runoff	
Start date	Geographic coverage
Water quality sampling since 1995, seagrass since 2001	Trinity Inlet
Level of training of observers	
Consultants with scientific training	
Survey Frequency	
Annual surveys	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Not publicly available	
Approximate costs, funding source, and funding security	
Not publicly available	

How are data stored?	Are data and/or metadata on-line? (source)
On consultants' systems	No

Name of monitoring program	Institution
Port of Mourilyan Environmental Monitoring	Ports North
Objectives of the program?	
To assess the overall state of the port environment or to detect any changes occurring.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
The following environmental initiatives have been undertaken at the Port of Mourilyan: • water quality monitoring • seagrass monitoring • environmental resource mapping • port baseline survey for marine pests	
Program documentation	
http://www.portsnorth.com.au/content/portsnorth-standard2.asp?name=Port_Mourilyan	
Relevant MNES elements & activities	
Seagrass meadows; seagrasses; sedimentation; nutrients from catchment runoff	
Start date	Geographic coverage
1993	Port & estuary
Level of training of observers	
Consultants with scientific training	
Survey Frequency	
Annual surveys	
What analysis of data occurs (source)	
Only seagrass report is available publicly, basic data summary.	

Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Annual seagrass monitoring reports: http://www.portsnorth.com.au/files/pdf/Mourilyan%20Seagrass%20Monitoring%202011.pdf	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Not publicly available	
Approximate costs, funding source, and funding security	
Not publicly available	
How are data stored?	Are data and/or metadata on-line? (source)
Consultants' systems	No

Name of monitoring program	Institution
Townsville Port Authority Environmental Monitoring	Townsville Port Authority
Objectives of the program?	
To assess the overall state of the port environment or to detect any changes occurring	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Water Quality: pH, DO, SS, N, P, Metals in River / Creek, Port & Channel Sediment in Ross River, Ross Creek, Port & Channel Intertidal & shallow water Seagrass density & biomass in S Cleveland Bay and S Magnetic Is Introduced species in the port	

Program documentation	
http://www.townsville-port.com.au/about-the-port/environment	
Relevant MNES elements & activities	
Seagrass meadows; seagrasses; sedimentation; atmospheric pollution; nutrients from catchment runoff	
Start date	Geographic coverage
2004	Port & estuary & S Cleveland Bay
Level of training of observers	
Consultants with scientific training	
Survey Frequency	
Water quality & Sediment - monthly in wet season; bi-monthly in dry; Seagrass annually with full Cleveland Bay coverage every 5-6 years (last 2007)	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Not publicly available	
Approximate costs, funding source, and funding security	
Not publicly available	
How are data stored?	Are data and/or metadata on-line? (source)
TPA systems	No

Name of monitoring program	Institution
Port of Mackay Environmental Monitoring	Queensland Bulk Ports
Objectives of the program?	
To assess the overall state of the port environment or to detect any changes occurring	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Coral [near dredge spoil disposal] Benthic macro-invertebrates Algae Turtles Marine mammals Fisheries Marine water quality Marine sediment quality Noise & vibration	
Program documentation	
Not publicly available	
Relevant MNES elements & activities	
Seagrass meadows; Coral Reefs <30m; seagrasses; corals; bony fish; marine turtles; whales; dolphins; dugongs; sedimentation; atmospheric pollution; nutrients from catchment runoff; noise pollution; coal dust impacts from transportation	
Start date	Geographic coverage
	Port of Mackay & environs
Level of training of observers	
Consultants with scientific training	

Survey Frequency	
Not publicly available	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Not publicly available	
Approximate costs, funding source, and funding security	
Not publicly available	
How are data stored?	Are data and/or metadata on-line? (source)
Consultants' systems	No

Name of monitoring program	Institution
Qld Acid Sulphate Soils Investigation Team (QASSIT)	Qld DNRM
Objectives of the program?	
To identify the extent, location, and risk level of acid sulphate soils (ASS) in Queensland	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
Mapping of ASS, so far focussed in SE Qld and in sugar growing areas Gladstone to Yeppoon, Mackay, and Wet Tropics	

Program documentation	
http://www.nrm.qld.gov.au/land/ass/qassit.html	
Relevant MNES elements & activities	
Acid sulphate soils exposed	
Start date	Geographic coverage
1995	State-wide
Level of training of observers	
QDNRM staff	
Survey Frequency	
What analysis of data occurs (source)	
Mapping	
Are results interpreted for future management? (source)	
Used for guidance on land use and development	
Are results reported? (source). How frequently?	
Maps available from the Department library	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
N/A, Qld Govt	
How are data stored?	Are data and/or metadata on-line? (source)
QDNRM systems	

Name of monitoring program	Institution
Queensland Wetlands Program	Qld Govt, the Department of the Environment & the GBRMPA
Objectives of the program?	
To support projects that will result in long-term benefits to the sustainable use, management, conservation and protection of Queensland wetlands. Includes a wetlands inventory database which integrates existing and new inventory information from field surveys to form the basis of a wetlands information system for the storage, maintenance and delivery of wetland data.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Developing conceptual models of the functioning of different types of wetlands was an early priority http://wetlandinfo.derm.qld.gov.au/wetlands/ScienceAndResearch/ConceptualModels.html	
What is monitored?	
Program documentation	
http://wetlandinfo.derm.qld.gov.au/wetlands/PPL/QldWetlandProgramme.html	
Relevant MNES elements & activities	
Mangroves; saltmarshes; freshwater wetlands	
Start date	Geographic coverage
2003	State-wide, but with early focus on GBR catchments
Level of training of observers	
The program provides tools for use by Govt departments and NRM bodies etc for assessing wetlands	
Survey Frequency	
Variable	
What analysis of data occurs (source)	
This varies among the projects	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Inventory:	

http://wetlandinfo.derm.qld.gov.au/wetlands/MappingFandD/WetlandMapsAndData/SummaryInfo.jsp	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
In 2009, the program was evaluated by Halcrow Pacific and Institute of Sustainable Futures, University of Technology Sydney	
Approximate costs, funding source, and funding security	
Funded by Caring for our Country Reef Rescue initiative and Q2 Coasts and Country Program.	
How are data stored?	Are data and/or metadata on-line? (source)
Qld Govt systems	

Name of monitoring program	Institution
Qld Land Use Monitoring Program (QLUMP)	Qld DSITIA
Objectives of the program?	
QLUMP maps and assesses patterns of land use and land use change across the State	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
QLUMP maps and assesses patterns of land use and land use change across the State in accordance with the Australian Land Use and Management (ALUM) classification from remote sensed images. Land use in GBR catchments was mapped for 1999 and 2009 (funded by Reef Plan).	
Program documentation	
http://www.nrm.qld.gov.au/science/lump/	
Relevant MNES elements & activities	
Islands; coastal infrastructure incl. island resorts and marinas; clearing or modifying coastal habitats - mangroves, wetlands; marine reclamation; artificial barriers to water and estuarine flow; ponded	

pastures	
Start date	Geographic coverage
1999?	State wide
Level of training of observers	
Not applicable – remote sensing	
Survey Frequency	
Depends on needs and resources	
What analysis of data occurs (source)	
Mapping of land use using ALUM classification	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Land use datasets are available State-wide 1999 for all catchments in Queensland, and also for selected catchments in 2004, 2006 and 2009. The nominal scale for mapping years is 1:50,000 in the coastal zone and high intensity land use areas, and 1:100,000 in the pastoral zone and low intensity land use areas.	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Qld Govt funds	
How are data stored?	Are data and/or metadata on-line? (source)
Qld DSITIA systems	

Name of monitoring program	Institution
Socio-Economic Long-term Monitoring Program (SELTMP)	CSIRO
Objectives of the program?	
Develop a long-term social and economic monitoring program using the advice of a user-based steering committee and science advisory committee that provides sufficient social and economic data to assist the GBRMPA and industry bodies to understand changes that are occurring within the region and to make plans for the future. Collect three longitudinal data points a year apart for each of the seven stakeholder groups.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
A simple conceptual diagram provided	
What is monitored?	
A. Reef-User/Reef Relationship Social Relationship with the Environment 1. Place based factors 2. Identity based factors 3. Social capital factors 4. Human capital factors Economic Relationship with the Environment 5. Business approach: lifestyle versus production 6. Financial approach 7. Financial investment in industry 8. Diversity of household income Use of the Environment: Where, When, How, How Much, and Why 9. Environmental footprint 10. Spatial and temporal patterns of use 11. Level of specialization 12. Environmental perceptions, knowledge, stewardship and awareness B. Wellbeing	

To be developed C. Indirect drivers of social and economic change 1. Economic 2. Social and cultural 3. Demographic 4. Politics and GBR management 5. Communication and media 6. Science and technology 7. Perceived reef condition D. Direct drivers of social and economic change 1. Climate change 2. Primary resource industry activities 3. Coastal development	
Program documentation	
http://www.nerptropical.edu.au/project/seltmp http://e-atlas.org.au/nerp-te/gbr-jcu-social-economic-monitoring-10-1	
Relevant MNES elements & activities	
SELTMP gathers data on heritage & community benefit values	
Start date	Geographic coverage
2012	GBRWHA & hinterland
Level of training of observers	
Trained social scientists	
Survey Frequency	
Annual	
What analysis of data occurs (source)	
Project in initial stages	

Are results interpreted for future management? (source)	
Project in initial stage	
Are results reported? (source). How frequently?	
Project in initial stage	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Project in initial stage	
Approximate costs, funding source, and funding security	
Funded by NERP Tropical Ecosystems Hub (with co-investment) til Dec 2014	
How are data stored?	Are data and/or metadata on-line? (source)
CSIRO systems	

Name of monitoring program	Institution
International Visitor Survey	Tourism Australia - Department of Resources, Energy and Tourism
Objectives of the program?	
To provide statistics, research and analysis to support industry development, policy development and marketing for the Australian tourism industry	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	

What is monitored?	
About 40,000 visitors are interviewed each year at 8 major airports. Interviews concern characteristics, travel behaviour, and estimated expenditure of international visitors in Australia, categorised by: • Usual place of residence • Repeat visitation • Group tours • Travel party • Sources of information about Australia • Purpose of visit and places visited • Transportation and accommodation • Activities • Expenditure • Demographics.	
Program documentation	
http://www.ret.gov.au/tourism/research/tra/Pages/default.aspx	
Relevant MNES elements & activities	
Diving & snorkelling activity	
Start date	Geographic coverage
1999	Australia-wide
Level of training of observers	
N/A	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Reports provide simple summaries and trends in many variables	
Are results interpreted for future management? (source)	
Indirect relevance via tourism industry	
Are results reported? (source). How frequently?	
Data are summarised in quarterly reports http://www.ret.gov.au/tourism/research/tra/Pages/default.aspx	

Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	**At what intervals?**
Approximate costs, funding source, and funding security	
The International Visitor Survey & the National Visitor Survey together cost $5M per yr in total	
How are data stored?	Are data and/or metadata on-line? (source)
DRET systems	No

Name of monitoring program	Institution
National Visitor Survey	Tourism Australia - Department of Resources, Energy and Tourism
Objectives of the program?	
To provide statistics, research and analysis to support industry development, policy development and marketing for the Australian tourism industry	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not applicable	
What is monitored?	
Characteristics and travel behaviour of Australian residents based on annual surveys of ~120,000 Australians over 15 yr old. Random dialling telephone survey contains over 70 questions regarding: - Destination - Purpose - Transportation - Travel package - Sources of information about the trip - Activities - Expenditure - Accommodation - Travel party - Demographics.	
Program documentation	
http://www.ret.gov.au/Department/archive/tourism-	

review/tra/domestic/national/Pages/default.aspx	
Relevant MNES elements & activities s	
Diving & snorkelling activity	
Start date	Geographic coverage
1998 (replacing Domestic Tourism Monitor)	Australia-wide
Level of training of observers	
N/A	
Survey Frequency	
continuous	
What analysis of data occurs (source)	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Data summarised into quarterly reports: http://www.ret.gov.au/Department/archive/tourism-review/tra/domestic/national/Pages/default.aspx	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
No	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
The International Visitor Survey & the National Visitor Survey together cost $5M per yr in total	
How are data stored?	Are data and/or metadata on-line? (source)
DRET systems	No

Name of monitoring program		Institution
National Census of Population and Housing		Australian Bureau of Statistics
Objectives of the program?		Are they clearly stated?
To accurately measure the number and key characteristics of people who are in Australia on Census Night, and of the dwellings in which they live.		Yes
Conceptual model for monitoring specific MNES (and source) or documented rationale		
N/A		
What is monitored?		
working population profile, community profile, usual residence profile, Indigenous profile and comparable data from previous years		
Program documentation		
http://www.abs.gov.au/websitedbs/censushome.nsf/home/about?opendocument&navpos=100		
Relevant MNES elements		
Community benefits		
Start date	Geographic coverage	
1901	Australia-wide	
Level of training of observers		
N/A		
Survey Frequency		
5 years		
What analysis of data occurs (source)		
http://www.abs.gov.au/websitedbs/censushome.nsf/home/data?opendocument&navpos=200		
Are results interpreted for future management? (source)		
Not directly		
Are results reported? (source). How frequently?		
http://www.abs.gov.au/websitedbs/censushome.nsf/home/data?opendocument&navpos=200		

Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Australian Bureau of Statistics systems	http://www.abs.gov.au/websitedbs/censushome.nsf/home/data?opendocument&navpos=200

Name of monitoring program	Institution
Recreational Vessel Registration	Queensland Transport and Main Roads
Objectives of the program?	Are they clearly stated?
Registration statistics for recreational craft	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
No and size of vessels registered	
Program documentation	
http://www.msq.qld.gov.au/Registration/Recreational-ships.aspx	
Relevant MNES elements & activities	

Start date	Geographic coverage
2001	State-wide
Level of training of observers	
N/A	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Simple summary	
Are results interpreted for future management? (source)	
No	
Are results reported? (source). How frequently?	
Vessel registration by postcode: http://www.tmr.qld.gov.au/About-us/Corporate-information/Open-data-datasets.aspx	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Funded by Qld Govt	Limited: http://www.tmr.qld.gov.au/About-us/Corporate-information/Open-data-datasets.aspx

Name of monitoring program	Institution
Great Barrier Reef & Torres Strait Vessel Traffic Service (REEFVTS)	Australian Maritime Safety Authority
Objectives of the program?	Are they clearly stated?
Avoidance of impact from shipping activities on the ecosystems of the GBRWHA	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Identity & positional information on: - All ships >50 m overall length - All oil tankers, liquefied gas carriers, chemical tankers or ships coming within the INF Code, regardless of length - Ships engaged in towing or pushing where the towing or pushing ship or the towed or pushed ship is a ship prescribed within the categories shown above or where the length of the tow, measured from the stern of the towing ship to the after end of the tow, exceeds 150 metres.	
Program documentation	
http://www.amsa.gov.au/shipping_safety/REEFVTS/AboutREEFVTS.asp	
Relevant MNES elements & activities	
Start date	Geographic coverage
2004	GBRWHA - wide
Level of training of observers	
N/A	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	

Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
AMSA systems	No

Name of monitoring program	Institution
GBR Environmental Management Charge data	GBRMPA
Objectives of the program?	
To assess the numbers of visitors to the GBR via commercial operations	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Information on the number of tourists visiting the Great Barrier Reef Marine Park compiled from logbook data that tourism operators are required to provide when submitting their Environmental Management Charge (EMC) returns as required by their operating permits. QPWS-GBRMPA Compliance monitoring program verifies submissions.	
Program documentation	
http://www.gbrmpa.gov.au/zoning-permits-and-plans/environmental-management-charge	
Relevant MNES elements & activities	

Start date	Geographic coverage
1993	Potentially all GBRWHA
Level of training of observers	
N/A	
Survey Frequency	
Continuous data collection compiled quarterly	
What analysis of data occurs (source)	
Basic statistics on visitation	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Available internally to GBRMPA	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA permits, compliance and management system (PCaMS)	Available internally

Name of monitoring program	Institution
GBRMPA-QPWS Compliance monitoring – Protecting the Reef	GBRMPA -QPWS
Objectives of the program?	
Ensuring compliance with the GBR Marine Park Act, State Marine Parks Act, Nature Conservation Act and subordinate regulations related to net, line and trawl fisheries, dugong protection, zoning plan, and emerging compliance issues to prevent serious environmental harm.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	

• Permit Compliance
  - Tourism activities
  - Research
• Zoning compliance
  - illegal fishing (Rec & commercial)
• Compliance with TUMRAs
• Hunting - Wildlife / vulnerable species
• Mooring use
• Shipping issues
• Implementation of Environmental Management Charge	

Program documentation	
http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/field-management-of-the-great-barrier-reef-marine-park/Compliance-management	
Relevant MNES elements & activities	
Fishing in unprotected fish spawning aggregations; illegal fishing or collecting; poaching and illegal harvest	
Start date	Geographic coverage
	All of GBRWHA
Level of training of observers	

Survey Frequency	
Variable	
What analysis of data occurs (source)	
Internal confidential	
Are results interpreted for future management? (source)	
Internal confidential	
Are results reported? (source). How frequently?	
Internal confidential	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA systems	No

Name of monitoring program		Institution
Eye on the Reef (EotR) Eyes and Ears Incident Reporting Network		GBRMPA
Objectives of the program?		
Reef users report activity that is not allowed in the Marine Park. Extends compliance monitoring.		
Conceptual model for monitoring specific MNES (and source) or documented rationale		
Not applicable		
What is monitored?		
Reef users report activity that is not allowed in the Marine Park.		
Program documentation		
http://www.gbrmpa.gov.au/our-partners/tourism-industry/eyes-and-earsreporting		
Relevant MNES elements & activities		
Fishing in unprotected fish spawning aggregations; illegal fishing or collecting; poaching and illegal harvest		
Start date	Geographic coverage	
?	Reef wide	
Level of training of observers		
None		
Survey Frequency		
Continuous		
What analysis of data occurs (source)		
Data feeds into GBRMPA compliance monitoring		
Are results interpreted for future management? (source)		
Not applicable		
Are results reported? (source). How frequently?		
Results are not reported publicly		
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?		

Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
GBRMPA systems	Information is confidential

Name of monitoring program	Institution
QPWS Fire Monitoring	QPWS
Objectives of the program?	
To identify and assess condition of vegetation for ecological burning, and for fuel reduction burning for protection of life and property.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
What is monitored?	
Condition of vegetation / build-up of fuel on GBR islands	
Program documentation	
Relevant MNES elements	
Islands; fire-altered regime	
Start date	Geographic coverage
	State-wide
Level of training of observers	
QPWS field management staff	

Survey Frequency	
Annually	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
QPWS Weeds & Pest Animal Monitoring	QPWS
Objectives of the program?	
To identify and assess weed and pest infestations to aid priority setting for management action.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
What is monitored?	
Surveys of weeds and pest animals on GBR islands	

Program documentation	
Relevant MNES elements & activities	
Islands	
Start date	Geographic coverage
	GBR-wide
Level of training of observers	
QPWS field management staff	
Survey Frequency	
Annual	
What analysis of data occurs (source)	
Not publicly available	
Are results interpreted for future management? (source)	
Not publicly available	
Are results reported? (source). How frequently?	
Not publicly available	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Scale insect Population Monitoring in the *Pisonia* forests	QPWS
Objectives of the program?	
Early detection of outbreaks of scale insects that can kill *Pisonia* forests, which have important role in ecology of sand cays through stabilising the cays with their roots and providing shelter and breeding sites for many bird species	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
Not explicit	
What is monitored?	
Pisonia trees, scale insects (a species causing major defoliation of *Pisonia*), and parasite and predator species of the scale insects.	
Program documentation	
http://www.nprsr.qld.gov.au/parks/capricornia-cays/pdf/scale-insect.pdf	
Relevant MNES elements & activities	
Islands	
Start date	Geographic coverage
1993	Capricornia Cays (and Coral Sea Cays)
Level of training of observers	
GBRMPA-QPWS Field Management staff	
Survey Frequency	
Part of, and dependent on, Field Management surveys	
What analysis of data occurs (source)	
Not reported publicly	

Are results interpreted for future management? (source)	
Not reported publicly	
Are results reported? (source) How frequently?	
Not reported publicly	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)

Name of monitoring program	Institution
Infrastructure Monitoring on Islands (SAMS)	GBRMPA-QPWS
Objectives of the program?	Are they clearly stated?
Monitoring aims to identify and assess condition of assets to aid priority-setting for maintenance and replacement.	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
N/A	
What is monitored?	
Condition monitoring of built structures in water and on islands of the GBRWHA, including public moorings and reef protection markers, and visitor facilities on islands such as camping areas, walking tracks, lookouts, picnic areas, boardwalks, signs and interpretation assets. Monitoring of islands and	

mooring and reef-protection systems of the GBRWHA is part of a State-wide system.	
Program documentation	
None	
Relevant MNES elements & activities	
Start date	Geographic coverage
2000	GBRMP - wide
Level of training of observers	
QPWS-GBRMPA field management staff	
Survey Frequency	
Annual	
What analysis of data occurs (source)	
N/A	
Are results interpreted for future management? (source)	
Results are important for local protection of coral reef and island ecosystems of the GBRWHA and to provide opportunities for the public to experience the GBRWHA in safety	
Are results reported? (source). How frequently?	
Internal	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
Funded by QPWS - GBRMPA	
How are data stored?	Are data and/or metadata on-line? (source)
QPWS - systems	No

Name of monitoring program	Institution
Qld long-term monitoring of commercial fisheries	QDAFF
Objectives of the program?	Are they clearly stated?
Monitor harvest and population dynamics of selected species	Yes
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
All fishery-dependent surveys based on log books (catch & effort data), plus biological information (e.g. length, sex and age of fish being harvested) from fishers, wholesalers, retailers. Species monitored within the GBRWHA are Spanish mackerel, spotted mackerel, grey mackerel, plus 'coral reef fin fish'	
Program documentation	
http://www.daff.qld.gov.au/28_10737.htm http://www.daff.qld.gov.au/28_10715.htm	
Relevant MNES elements	
Bony fish; income; employment; access to reef resources?	
Start date	Geographic coverage
Systematic data collection on most spp began after 2000, but irregular data exists from 1970s onwards	State-wide
Level of training of observers	
Based primarily on fishers' logbooks	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Summary	
Are results interpreted for future management? (source)	
Feed directly into fishery management	

Are results reported? (source). How frequently?	
CHRIS web based interactive mapping and	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Qld Govt data systems	Only to 2005; replacement for CHRIS web portal due to be implemented in second half of 2013

Name of monitoring program	Institution
Trawl Fishery Vessel Monitoring System	QDAFF
Objectives of the program?	
To track the position of trawl vessels on a continuous basis in order to track activities of vessels and to monitor quota (defined as days at sea)	
Conceptual model for monitoring specific MNES (and source) or documented rationale	
None explicit	
What is monitored?	
Position (and speed) of vessels on an hourly basis. Gives estimate of fishing effort (in conjunction with log-book). Fishery quotas are determined by days at sea, defined as days moving more than 250m at <5kts in fishing zones. Position information can indicate non-compliance with Marine Park Zoning	
Program documentation	
http://www.dpi.qld.gov.au/28_16340.htm	

Relevant MNES elements & activities	
Lagoon floor habitat; extraction of filter feeders; income, employment, access to reef resources?	
Start date	Geographic coverage
2001	Qld East coast
Level of training of observers	
N/A	
Survey Frequency	
Continuous	
What analysis of data occurs (source)	
Fishing effort	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Contributes to annual status reports: http://www.daff.qld.gov.au/documents/Fisheries_SustainableFishing/ASR_ECOTF2011.pdf	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
no	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
Queensland Govt systems	Only to 2005; replacement for CHRIS web portal due to be implemented in second half of 2013

Name of monitoring program	Institution
Qld State-wide monitoring of recreational fishing	QDAFF

Objectives of the program?
1) to improve the understanding of recreational fishing in Queensland 2) to contribute to the sustainable management of our fisheries resources Questions such as: • What proportion of Queenslanders go fishing? • How often do they go? • What are they catching? • How much do they catch?
Conceptual model for monitoring specific MNES (and source) or documented rationale
Not applicable
What is monitored?
State-wide recreational fishing survey 2010-11: 12 mo. telephone diary collection data: - State-wide and regional annual catch (harvest and release), effort and catch per unit effort for species commonly caught by recreational fishers - fishing participation rates of Queenslanders among various subgroups (e.g. age, gender, area of residence) - other recreational fishing industry-related data (e.g. boat ownership, fishing club membership) - fishers' awareness and opinions on fisheries-related issues. Programs for important species collect data at boat ramps.
Program documentation
http://www.daff.qld.gov.au/28_18273.htm
Relevant MNES elements & activities
Bony fish; sharks & rays; enjoyment

Start date	Geographic coverage
1996	All population centres (but skewed to SE Qld)

Level of training of observers
Telephone survey
Survey Frequency
Random telephone surveys were conducted in 1996, 1998, 2001 and 2004 to obtain fishing participation information and also to recruit around 5000 volunteers to participate in the diary

programs. Diary programs were completed in 1997, 1999, 2002 and 2005.	
What analysis of data occurs (source)	
http://www.daff.qld.gov.au/documents/Fisheries_RecreationalFishing/2010-SWRFS-final-V4.pdf	
Are results interpreted for future management? (source)	
Are results reported? (source). How frequently?	
Results of 2010 survey available: http://www.daff.qld.gov.au/documents/Fisheries_RecreationalFishing/2010-SWRFS-final-V4.pdf	
Are there new technologies/novel approaches that would make this program more efficient or extend its range to answer MNES questions?	
Does the program get reviewed?	At what intervals?
Approximate costs, funding source, and funding security	
How are data stored?	Are data and/or metadata on-line? (source)
QDAFF systems	Not currently