

Methods

Chapter 4

"The baseline provides a measure of the status of key indicators for the period immediately preceding Reef Plan 2009."

Photo courtesy of Department of Environment and Resource Management



4.1 Indicators

The baseline provides a measure of the status of key indicators for the period immediately preceding Reef Plan 2009. It is based on historical data and trends and takes into account the influence of a variable climate from year to year. The key indicators outlined in Table 4.1 provide multiple lines of evidence to determine progress towards Reef Plan's goals and targets. It is anticipated that changes in management practices and water quality will be able to be measured in the short term (one to two years) at the paddock and sub-catchment scales. In addition, monitoring and modelling will estimate changes in water quality and ecosystem health at the end-of-catchments and in the Great Barrier Reef lagoon.

Future report cards will show changes from this baseline and, therefore, progress towards Reef Plan's goals and targets.

Table 4.1 – Key indicators and information used in the baseline.

Indicators	Description	Information used
Improved land management	The extent of change in land management practices and effectiveness in terms of water quality improvement.	<ul style="list-style-type: none"> • 2008–2009 management practice adoption data for sugarcane, grazing, grains and horticulture industries. • Review of literature on the effectiveness of management practices in terms of water quality improvement.
Catchment indicators	The extent of landscape attributes that have a significant influence on water quality (wetland and riparian vegetation extent and groundcover).	<ul style="list-style-type: none"> • Wetlands extent data from 2001 to 2005 derived from the Queensland Wetlands Program wetland mapping and the Queensland regional ecosystem mapping. • Riparian extent from 2004 to 2008 derived using remote sensing satellite imagery. • Groundcover determined through remote sensing technologies.
Catchment loads	The loads of key pollutants leaving the catchment and entering the Great Barrier Reef.	<ul style="list-style-type: none"> • Catchment water quality modelling between 1983 and 2009. • Catchment water quality monitoring data sourced from the Department of Environment and Resource Management, Australian Institute for Marine Science and Australian Centre for Freshwater Research for water years (1 October–30 September) between 1972 and 2009.
Great Barrier Reef water quality and ecosystem health	The health of key marine ecosystems such as coral reefs and intertidal seagrasses and the condition of water quality in the inshore Great Barrier Reef lagoon.	<ul style="list-style-type: none"> • Water quality, corals and seagrass data from the Reef Rescue Marine Monitoring program from 2005 to 2009.

4.2 Improved land management—methods

4.2.1 Land use

Land use maps and supporting products are used throughout this report. This information is derived from the Queensland Land Use Mapping Program within the Queensland Department of Environment and Resource Management.

The methodology is accurate, reliable, cost-effective, and makes best use of available databases, satellite imagery and aerial photos. This report uses the latest available land use information for each of the Great Barrier Reef catchments. Depending on the region, this is either from 1999 or 2004. Whilst the data accurately represents the patterns of land uses across catchments, some land use changes may have occurred since the data was collected. Land use data for all Great Barrier Reef catchments up to 2009 is currently being collated and will be used for future reporting.

4.2.2 Effectiveness of improved management practices

For the purpose of this report, the current understanding of the effectiveness of land management practices in relation to improved water quality at the paddock scale was reviewed (Appendix 2). The available information was collated and summarised according to the major pollutants of concern—sediments, nutrients and pesticides. An overview of the economic implications of water quality improvements is also provided where information is available.

4.2.3 Adoption of land management practices

Within the Great Barrier Reef regions, grazing is the dominant extensive land use, and sugarcane and horticulture are the dominant intensive land uses.

Establishing a baseline for management practice adoption for 2008–2009 and measuring change in management practice adoption in subsequent years is a foundation activity within the Paddock to Reef program. ABCD management practice frameworks have been used to establish a baseline of management practices for the sugarcane, grazing, grains and horticulture sectors. The baseline of management practice adoption for 2008–2009 is reported as the percentage of landholders and/or the percentage of land area. Grazing management practice adoption is reported for the Burdekin and Fitzroy regions, which represent the majority of the Great Barrier Reef region's grazing lands. Management practice adoption in the grains sector is reported for the Fitzroy region only.

The baseline of management practice adoption for other industries in the Great Barrier Reef region, including dairy and cotton, will be established and reported along with annual changes in future annual reports.

ABCD land management frameworks

ABCD frameworks have been used for reporting on the relationship between agricultural land management and estimated water quality impacts within the Great Barrier Reef region. ABCD management practice descriptions are widely used within the sugarcane, grains and horticulture industries to represent a continuum of management practice from unacceptable (D) to cutting-edge (A). An ABCD management practice framework has been developed for the grazing industry, based on practices impacting upon land condition.

In addition, ABCD water quality signatures are a representation of the effectiveness (in terms of improving water quality) of different levels of ABCD management practice for a particular soil type or grazing land type in a particular location. Looking forward, the Paddock to Reef program will improve understanding of practice effectiveness for 16 grazing land types and 16 cane soil types in specific locations.

ABCD management practice descriptions

Within each ABCD framework there are management practice descriptions which are a suite of specific management practices that are recommended to maintain and/or improve water quality and land condition outcomes for specific groups of soil types or land types within a specific location (Table 4.2). ABCD management practice descriptions are typically presented as generic word definitions that can be applied to a particular catchment or region. Practical application of the ABCD management practice definitions may result in some local variations in the management practices for soil types,

land types or climatic zones that typically require different management practices (e.g. within a region, wet coastal grazing management practices are usually defined separately from dry rangeland grazing management practices).

ABCD management practice descriptions have been developed to support voluntary adoption of improved management practices and provide a basis for planning and reporting changes in adoption of management practices. Great Barrier Reef-wide ABCD management practice descriptions in this report were developed by Canegrowers (Evans J, 2010), Growcom (Wallace S, 2010), and the Department of Employment, Economic Development and Innovation (DEEDI, 2011) to support the establishment of an industry-wide baseline of management practice adoption. It is important to note that the ABCD management practice descriptions are aimed at improving land and water resource condition and may not represent management practices that would typically be promoted from a pure productivity perspective.

For practical application of the ABCD management practice descriptions, it is important to specify the year of reference. Over time, changes in knowledge, technology, costs and market conditions may see cutting-edge A level practices become B level practices and, if the practices are widely adopted by industry, they may become the common C level practice. To ensure consistency in reporting, the 2008–2009 ABCD management descriptions as defined in this report will be used until 2013. These management practice frameworks will also be periodically reviewed to ensure they are kept up to date with new technologies.

Table 4.2 – Management classes and definitions for ABCD management practice descriptions for sugarcane, horticulture and grains
(Source: Drewy J, et al., 2008).

Class	Description of practice	Farm management plan	Community and industry standard	Effect on resource condition	Effect on profitability
A	Cutting-edge practices that require further validation of environmental, social and economic costs/benefits.	Yes, develops and tests innovative technology.	When validated is an acceptable practice for the long term. (May not be universally endorsed as feasible by industry and community.)	When validated, practice likely to achieve long term resource condition goals if widely adopted.	When validated, improves profitability in the medium to long term. (May reduce profitability during the transition.)
B	Currently promoted practices often referred to as 'Best Management Practices'.	Yes, and utilises common technology.	Acceptable practice for the medium term.	Practice likely to achieve medium term resource condition goals if widely adopted.	Improves profitability in the short to medium term.
C	Common practices. Often referred to as 'Code of Practice'.	Basic.	Acceptable practice today but may not be acceptable in medium term.	Practice unlikely to achieve acceptable resource condition goals if widely adopted.	Decline of profitability in the medium to long term.
D	Practices that are superseded or unacceptable by industry and community standards.	None.	Superseded or unacceptable practice today.	Practice likely to degrade resource condition if widely adopted.	Decline of profitability in the short to medium term.

ABCD Grazing Management Practice Framework

There are some important differences in the framework used to describe management practices for the grazing sector and the frameworks used for sugarcane, horticulture and grains. ABCD land condition indicators (Table 4.3) are widely used in the grazing industry to describe or assess the condition of land. The categories A, B, C and D represent a continuum where land in A condition is at full productive capacity and in a sustainable state, and land in D condition is in a degraded state requiring remediation and more likely to have soil erosion and water quality impacts.

Table 4.3 – Grazing ABCD land condition indicators (Source: Chilcott et al., 2007).

A class grazing land condition	B class grazing land condition
Land condition indicators (all indicators at this level): <ol style="list-style-type: none"> 1. good coverage of perennial, palatable and productive grasses for that land type; little bare ground 2. few weeds and no significant infestations 3. good soil condition; no erosion and good surface condition 4. no sign, or early signs of woodland thickening 5. riparian areas in good condition. 	Land condition indicators (one or more indicators at this level, otherwise similar to A): <ol style="list-style-type: none"> 1. some decline in perennial, palatable and productive grasses for that land type; increase in other species (less favoured grasses, weeds) and/or bare ground 2. some decline in soil condition; some signs of previous erosion and/or current susceptibility to erosion is a concern 3. some thickening in density of woody plants.
C class grazing land condition	D class grazing land condition
Land condition indicators (one or more indicators at this level, otherwise similar to B): <ol style="list-style-type: none"> 1. general decline in perennial, palatable and productive grasses for that land type; large amounts of less favoured species and/or bare ground 2. obvious signs of past erosion and/or susceptibility to erosion currently high 3. general thickening in density of woody plants. 	Land condition indicators (one or more indicators at this level): <ol style="list-style-type: none"> 1. general lack of any perennial grasses or forbs 2. severe erosion or scalding resulting in hostile environment for plant growth 3. thickets of woody plants cover most of the area.

This report presents data on ABCD management practices, as distinct from ABCD land condition. However, these are management practices that impact upon land condition:

- Practices likely to maintain land in very good condition or improve land in lesser condition.
- Practices likely to maintain land in good condition or improve land in lesser condition.
- Practices that may maintain land in fair condition or gradually improve land in poor condition.
- Practices likely to degrade land to poor condition.

The grazing practices framework aligns practices of varying levels of sophistication, control, and impact with eight management principles:

- 1 Objectively determine long term carrying capacity.
- 2 Match stocking rate to forage availability.
- 3 Strategically use fire to achieve management and ecological outcomes.
- 4 Strategically manage weeds and feral animals to achieve productivity and ecological outcomes.
- 5 Strategically use sown pastures to achieve productivity and resource condition outcomes.
- 6 Locate and maintain property roads and firebreaks.
- 7 Prevent and stabilise erosion areas including gullies, stream banks, and hill slopes.
- 8 Manage records.

In using the grazing ABCD framework to assess management practices, the principles above have been weighted to reflect their relative potential impacts upon land condition. For example, practices aligned with principles 1 and 2 around carrying capacity and stocking rate constitute 60 per cent of the total value of the assessment.

It is important to note that the ABCD practice framework for grazing is based on the implicit assumption that A management practices will lead to A land condition. While this is an acceptable generalisation, it will not always be the case. For example, in some instances it is possible for land to be maintained in A or B condition despite quite unsophisticated management (e.g. continuous stocking rate at well below carrying capacity).

Using practice adoption information in catchment water quality modelling

The ABCD management practice and land condition information is critical to measure progress towards Reef Plan's management practice adoption targets. It is also essential information to be used in catchment water quality modelling to estimate the catchment loads at the end of catchments. By improving the accuracy of practice adoption information, pollutant load estimates will also improve. An important step is to distribute the ABCD management practice information in a way that reflects the actual prevalence and location of the practices across the catchment. The pollutant load estimates are influenced by how accurately the management practices are distributed across the catchments. For future reports this will be done using regionally based data and industry experts working closely with catchment water quality modellers. Practice adoption information will also be used, along with better information on the effectiveness of management practices derived from paddock monitoring and modelling, to provide multiple lines of evidence of progress and more accurate pollutant load estimates.

Table 4.4 – Summary of the process followed by Agforce, Canegrowers and Growcom (Source: GHD, 2010a; Wallace S, 2010; DEEDI, 2010; Eames and Collins, 2010).

Industry organisation, leader	ABCD framework	Data	Regional synthesis	GBR-wide synthesis	Conversion of industry reports to GBR-wide report	Confidence in use of data for GBR-wide report
Grazing DEEDI	Great Barrier Reef-wide ABCD grazing management practice framework (DEEDI, 2011)	1 Australian Bureau of Statistics surveys 4651.0 (ABS 2006), 4619.0 (ABS 2009) and 4627.0 (ABS 2009)	Regional expert panels reviewed available data from various sources and provided regional expert opinion.	Management practices for Fitzroy and Burdekin regions were scaled to reflect Great Barrier Reef-wide land use areas and added together.	Management practices for Fitzroy and Burdekin regions were combined.	There are varying levels of suitability for the purpose and confidence in the primary data sources. Multiple lines of evidence and experience of contributing experts means practice assessments are considered to be moderately accurate at the GBR-wide scale.
		2 Dairy cattle survey (Gordon et al., 2005)				
		3 Meat and Livestock Australia Report (Meat and Livestock Australia, 2010)				
		4 Belyando Sutor project (Nelson and Smith, 2005)				
		5 regional expert opinion				
		6 AgForce report (Vitelli M, 2010).				
Sugarcane Canegrowers	GBR-wide ABCD sugarcane management practice (Evans J, 2010)	1 various productivity board surveys	Four GHD reports present results of five regional working group meetings that synthesised regional data and captured regional expert opinion.	Canegrowers Report (GHD, 2010) presents results of an industry-wide work group meeting that synthesised GBR-wide data and captured GBR-wide expert opinion.	Data Aggregation from GHD reports for Wet Tropics, Burdekin, Mackay Whitsunday and Burnett Mary regions were scaled to reflect GBR-wide land use areas and added together. Results for soil, nutrient and herbicide were averaged to get a single ABCD score.	Primary Data Aggregation from GHD reports are considered to be moderately accurate at the GBR-wide scale and are consistent with regional and industry-wide expert opinion.
		2 various mill surveys				
		3 various BSES surveys				
		4 various Canegrowers surveys				
		5 Australian Bureau of Statistics survey				
		6 regional expert opinion				
		7 industry-wide expert opinion.				
Horticulture Growcom	GBR-wide ABCD horticulture management practice framework (Wallace S, 2010)	1 Growcom Farm Management Systems	Not undertaken	Growcom Report (Wallace S, 2010) presents results of an industry-wide work group meeting that synthesised GBR-wide data and captured GBR-wide expert opinion.	Data from Growcom Farm Management Systems for Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy and Burnett Mary regions were scaled to reflect GBR-wide land use areas and added together. Results for soil, nutrient and herbicide were averaged to get a single ABCD score.	Primary Data from Growcom Farm Management Systems are considered to be moderately accurate at the GBR-wide scale and are consistent with various regional surveys and industry-wide expert opinion.
		2 various regional surveys				
		3 Australian Bureau of Statistics survey				
		4 industry-wide expert opinion.				
Grains AgForce DEEDI		1 Grains BMP	Not undertaken	AgForce Report (Eames H and Collins R, 2010) presents results of an industry-wide work group synthesised GBR-wide data and captured GBR-wide expert opinion.	Data from the Grains BMP is presented for the Fitzroy region only. Results for soil, nutrient and herbicide were averaged to get a single ABCD score.	Primary Data from Grains BMP are considered to be moderately accurate at the GBR-wide scale and are consistent with various regional surveys and industry-wide expert opinion.
		2 ABS survey				
		3 industry-wide expert opinion.				

Limitations of the current process and future improvements

How accurately the management practice adoption data derived from different sources reflects the actual level of adoption will always pose a challenge and can be offset by using multiple lines of evidence where available.

The ABCD management practice descriptions for grazing require more work to ensure that the practices described within each class are the best possible representations of key practices affecting land condition. Practice descriptions aligned to each principle, and the weightings of each principle, will be reviewed for future reporting. For example, the assessments of grazing management practice for the Fitzroy and Burdekin regions involved expert panels reviewing the available data for each region and aligning this data with the practices described within the ABCD framework. Some of the principles and practices had relatively comprehensive underpinning data, e.g. information on the ability of graziers in the Burdekin to manage riparian areas was available from a range of surveys. Moderating the various data with local expert opinion provided reasonable confidence in the assessment. On the other hand, the expert panels had very little data to work with regarding other principles and practices such as the use of sown pastures or management of firebreaks. Future iterations of this process will need to include more data and data that is collected for this specific purpose. There is also a need and opportunity to involve more experts in order to increase the spatial resolution of management practice assessments.

The following limitations in the management practice adoption information have been identified:

- there are few cross-regional data sets with a consistent sample methodology for any industry
- there are few cross-regional data sets with a consistent sample density in all regions
- between regions and even within regions, most data sets have inconsistent survey questions, collection method and quality control
- significant gaps in the data sets for all industries mean there is a considerable reliance on expert opinion to extrapolate data from data-rich sub-catchments and regions to data-poor sub-catchments and regions.

The following recommendations are suggested to improve the future process of detecting and quantifying change in management practice adoption:

- agree on a clearly defined process for synthesising regional data sets
- adopt regional expert meetings to synthesise regional data sets for all industries
- identify and standardise the key indicator and survey questions that represent the minimum data set required to detect and quantify change in management practice adoption for each industry
- establish a consistent survey process including collection method and quality control for each industry across all regions

- regionally coordinate and streamline the data capture tables and data collation to enable reporting at sub-catchment, region and cross regional scales.

4.3 Catchment indicators—methods

A range of catchment attributes play a vital role in assessing the link between land management practices and water quality leaving the paddock and ultimately entering the reef. These catchment attributes include riparian (river bank) and wetland areas across the Great Barrier Reef catchments, and groundcover in dry tropical grazing lands.

One approach to improving the water quality of streams, and ultimately that of the Great Barrier Reef, is the rehabilitation of riparian vegetation (Gordon, 2007). Well vegetated riparian areas play a role in stabilising river banks, which helps reduce erosion of sediments and particulate nutrients. Riparian areas also provide important ecological functions for stream ecosystems including nutrient cycling.

Wetlands provide a natural filtration system to protect water quality. Disturbance or destruction of wetlands can result in increased sediment or nutrients flowing into streams and ultimately the Great Barrier Reef lagoon (Department of the Premier and Cabinet, 2009).

Groundcover is a critical attribute of the landscape, affecting soil processes and surface erosion. Low groundcover combined with heavy rainfall, often arising after overgrazing during periods of droughts or low rainfall, have led to catchment degradation in many Australian rangelands (Bastin et al., 2008). Groundcover levels may vary due to anthropogenic management of grazing lands and natural changes due to rainfall.

4.3.1 Riparian vegetation

Geographic information systems and remote sensing provide means for cost-effective and repeatable mapping of vegetation, and can aid in the management of riparian buffer zones (Klemas, 2001; Apan et al., 2002; Goetz, 2006; Yang, 2007).

A methodology was developed to map the extent of woody vegetation (forest) in riparian areas and provide groundcover estimates for the non-forested areas. Estimated changes to the extent of riparian forests during the five years prior to the baseline year have also been prepared. As 2009 data was not available at the time of reporting, available data from 2004 to 2008 has been used. The methodology is summarised below and in Appendix 3.

The first step in the methodology was to generate a spatial layer that represents riparian areas in Great Barrier Reef catchments. The next step was to collate two spatial layers representing the foliage projective cover (Armston et al., 2009) (a measure of forest canopy density), and groundcover (Scarth et al., 2006), both of which were derived from satellite imagery. Foliage projective cover is defined as the percentage of ground area occupied by the vertical projection of foliage. Groundcover refers to vegetative (dead and alive) and non-vegetative surface components (e.g. rock) covering the soil. These layers were then analysed within the riparian areas.

Based on visual interpretation and expert knowledge, a standard buffer of 50 metres was considered a reasonable representation of riparian areas across the 35 catchments for this report. The drainage layer, riverine wetlands and water body layers were all buffered by 50 metre margins and then merged into a single mapping layer to represent the riparian areas of Great Barrier Reef catchments. Estuarine water bodies from the Wetlands Mapping Project were buffered by 100 metres and excluded from the riparian areas as these areas are reported on in the wetlands component of this chapter.

Within the extent of the buffers, the foliage projective cover and groundcover were analysed including the extent of woody vegetation (greater than or equal to 11 per cent foliage projective cover). Where woody vegetation is absent, the groundcover data was analysed and separated into areas of low cover (less than 50 per cent cover) and high cover (greater than or equal to 50 per cent). The groundcover estimates are based on the dry season mean from 1986 to 2009.

Changes in riparian forest extent from 2004 to 2008 were also reported. Forest extent changes can include loss of forests through tree clearing and gains in forest extent through regrowth or new plantings. This report focuses upon the change in riparian forest extent due to tree clearing only, which is likely to be significantly larger than the potential forest gains through regrowth or new plantations.

4.3.2 Wetlands extent

The information used for this baseline report is 2005 wetlands data, the most recently available. This report provides information on the extent of wetlands in 2005 and changes in extent from 2001 to 2005. It does not, however, cover degradation or change in condition of wetlands (Appendix 1). Comparisons with pre-clearing are also made. The pre-clearing extent is simply the extent before clearing, although this term generally equates to the terms 'pre-1750' or 'pre-European times' that are used elsewhere (Neldner et al., 2005).

The information reported in this section is derived from two sources: Queensland Wetlands Program wetland mapping (EPA, 2005) and Queensland regional ecosystem mapping (Neldner et al., 2005). These mapping projects have detailed methodologies (EPA, 2005; Neldner et al., 2005), which are briefly summarised here.

In this report the extent of wetlands is summarised by catchment into three wetland types:

- 1 Vegetated freshwater swamp (palustrine) systems are wetlands with more than 30 per cent emergent vegetation cover and less than eight hectares.
- 2 Lake (lacustrine) systems are wetlands that are over eight hectares with less than 30 per cent emergent vegetation cover (but excluding riverine channels and associated fringing vegetation). Areas of open water of less than eight hectares are classified as lakes if the water is over two metres deep.
- 3 Mangroves and salt flats (estuarine) wetlands are coastal areas that are tidally inundated and dominated by mangrove or salt flat communities.

The results do not include artificial wetlands or wetlands that have been highly modified, such as those converted to cane paddocks or lacustrine wetlands formed by dams across stream channels. However, the mapping of existing wetlands does include less modified wetlands, such as the vegetated freshwater swamps that have had levees or been dammed.

The regional ecosystem mapping is derived by charting the pre-clearing regional ecosystems from stereo aerial photography in conjunction with other information sources including geology and soils mapping, historical survey records and expert ecological knowledge. Remnant vegetation cover is determined from the extent of clearing from recent satellite imagery (Landsat Thematic Mapper 2001 and 2005) which has been processed and supplied by the Statewide Landcover and Trees Study (Department of Environment and Resource Management, 2009a). The remnant cover mapping is updated every two years to determine changes over time. The mapping is validated to a 1:100,000 scale and includes over 8000 wetland sites across Queensland. Regional ecosystem mapping is used to report on the portion of wetlands remaining as a percentage of their pre-clearing extent.

The wetlands mapping methodology is a multi-step process. The extent of water bodies are derived by analysis of satellite images over a 10-year period, which is then combined with topographic and wetland regional ecosystem data to chart wetland extent.

A combination of automated and manual interpretation of imagery is used to delineate change in wetland extent due to clearing of vegetation, destruction of water bodies from draining or earth works, or the creation of new water bodies through dam or weir construction. This method does not include changes in wetland extent due to seasonal wetting and drying. The wetlands mapping is used to report on the extent of wetlands in 2005 and the change in wetland extent between 2001 and 2005. The change in extent is reported as a percentage of the 2001 data to enable comparison between catchments of different sizes.

Limitations and future improvements

The extent of wetlands reported here is based on 1:100,000 to 1:50,000 scale mapping, which delineates features to a minimum size of one hectare. Preliminary accuracy assessments have shown this mapping to have an overall accuracy of between 80 and 98 per cent (Neldner et al., 2005; Knight et al., 2009). The mapping is currently being reviewed and updated where necessary, which will result in improved accuracy over time.

The wetland extent mapping does not discriminate between the condition of wetlands. Therefore wetlands may include areas that have been degraded by grazing, hydrological modification within their catchment, invasion by exotic weed species or other factors that reduce wetland function and value. The Queensland Wetlands Program website (www.derm.qld.gov.au/wetlandinfo) lists methodologies and tools for values or condition assessments. There is no consistent assessment across regions of wetland condition or health, although there are studies across parts of the area (e.g. Veitch and Sawynok, 2005).

Summarising wetlands across whole regions masks variations in wetland loss across parts of the catchment. For example, the results in this report show a 53 per cent loss of vegetated freshwater swamps for the whole Herbert River catchment, while there has been an 83 per cent loss of these wetlands over the lowland parts of the catchment (B. Wilson, unpublished data derived from Queensland Wetlands Program wetland mapping version 1.3). This latter figure is comparable to the 80 per cent loss of freshwater wetlands for this area reported by Johnson et al. (1999). In addition, summarising wetlands into three broad types masks variations within sub-types. For example, in the Burdekin catchment there has been a 30 per cent loss to the pre-clearing extent of salt flats, while the extent of mangroves has slightly increased (Accad et al., 2008) which results in a figure of 100 per cent of mangroves/salt flats remaining.

4.3.3 Groundcover

Remote sensing was used to provide the baseline information for the groundcover target. Remote sensing allows for the long term monitoring of groundcover over large spatial extents. Satellite imagery (derived from Landsat TM and ETM+ technology) has appropriate spatial and spectral resolution to provide reliable estimates of vegetative groundcover in cleared areas or open woodlands (Scarth et al., 2006). Currently, groundcover is monitored annually for these areas across Queensland. Groundcover monitoring is now being enhanced to be more frequent in catchments draining into the Great Barrier Reef. In addition, a method to estimate groundcover in woodlands and open forests has been developed and is being tested.

Satellite imagery and corrections

Satellite imagery from two different data sources was used to determine groundcover:

- Annual dry season Landsat imagery from 1986 until 2009 acquired from Geosciences Australia for the primary purpose of monitoring of tree clearing by the Statewide Landcover and Trees Study (Department of Environment and Resource Management, 2009a).
- All freely available Landsat TM and ETM+ imagery from the United States Geological Survey for Great Barrier Reef catchments. More than 3500 images have been downloaded and incorporated into the Department of Environment and Resource Management archive, providing on average 20 image dates per year from 1999 to 2009.

Defining the extent of the groundcover monitoring area

A traditional definition of dry tropical grazing lands are those grazing areas north of the Tropic of Capricorn but south of the Wet Tropics biogeographic region (Department of Environment and Resource Management, 2009b). However, if this definition was adopted, only certain parts of the Fitzroy catchment would be reported on, as the Tropic of Capricorn bisects the Fitzroy catchment and the Burnett Mary region would be excluded. Although the Herbert catchment is in the Wet Tropics region, it contains significant dry tropical grazing areas. Therefore, the whole Fitzroy, Burdekin and Burnett Mary regions and Herbert catchment were included for reporting purposes. The eastern

Cape York catchments were excluded as they are considered to have low grazing pressure in general, and the tree cover is too high for satellite-based groundcover monitoring. In summary, grazing lands in the Burnett Mary, Burdekin, Fitzroy and Mackay Whitsunday regions, and the Herbert catchment in the Wet Tropics region, have been included in the groundcover baseline.

The grazing lands in the selected catchments were spatially defined based on the most recent version of land use data provided by the Queensland Land Use Mapping Program (Department of Environment and Resource Management, 2008). Within the defined grazing areas, groundcover data was derived for open woodlands, cleared areas or forested areas with foliage projective cover (Specht and Morgan, 1981, Armston et al., 2009) of less than 15 per cent. The current groundcover mapping method is not considered reliable in higher foliage projective cover areas. The foliage projective cover dataset is generated annually by the Statewide Landcover and Trees Study (Department of Environment and Resource Management, 2009a).

Generating a dry season groundcover baseline

A time series of dry season satellite (Landsat) images for 1986–2009 (Statewide Landcover and Trees Study; Department of Environment and Resource Management, 2009a) was used to determine the long term mean groundcover for the selected Great Barrier Reef catchments as a baseline dataset. Measurements of groundcover were available for over 500 field sites within Queensland (Scarth et al., 2006), generally observed in the late dry season.

A groundcover regression model was then used to predict groundcover for each dry season image in Great Barrier Reef catchments from 1986 to 2009. The mean value was calculated for each 25 metre pixel over the 23 years of dry season imagery. This measure has been used to provide a representative baseline, as a single year can be significantly affected by the cover response to seasonal rainfall, and can be misleading (Schmidt et al., 2010). However, 2009 groundcover maps were produced for a single date of late dry season (October–November) imagery as well, so these could be compared to the long term mean.

Seasonal groundcover imagery for the reef catchments

To date, the groundcover monitoring program has reported on percentage of groundcover. However, recent research has resulted in two improved groundcover models. Both models predict the fractions of groundcover in three components: bare ground, green vegetation and dry vegetation. The green vegetation and dry vegetation components can be combined to create the overall groundcover estimate. The method by Scarth et al. (in prep.) is currently being applied to the archive of the United States Geological Survey Landsat imagery for Great Barrier Reef catchments, which will provide seasonal groundcover estimates and is required for sediment generation modelling (Renard et al., 1997).

4.4 Catchment loads—methods

4.4.1 Baseline load estimates

This report provides an estimate of the baseline for catchment loads using the most recent estimates of natural and total loads (Kroon et al., 2010). The total catchment loads were estimated, comprising the anthropogenic (that caused by human activity) and the natural loads. The confidence in the load estimates varies across regions due to variation in availability of historical data and challenges associated with estimating loads in flood events.

In future annual reports, the baseline load estimates will be improved using an updated catchment water quality modelling framework (Source Catchments). Source Catchments will be able to hindcast loads based on historical data and predict future loads based on combinations of climatic and management scenarios. The models will be calibrated and validated using end-of-catchment monitoring data. The model will be able to project long climatic periods to show the variations in loads over time for any particular land use and management practice scenarios.

For this report, loads have been estimated for the key pollutants of concern including:

- total suspended solids
- total nitrogen, dissolved inorganic nitrogen, dissolved organic nitrogen and particulate nitrogen
- total phosphorus, dissolved inorganic phosphorus, dissolved organic phosphorus and particulate phosphorus
- photosynthesis inhibiting (PSII) pesticides (atrazine, ametryn, diuron, hexazinone, simazine, and tebuthiuron).

As shown in Figure 4.1, the total catchment load includes the anthropogenic and the natural load. The catchment loads are derived from current understanding of the land use and management practices from the period immediately preceding Reef Plan 2009. An estimate of the long term average catchment load is made to correct the significant variability in the magnitude of flow events for a given river from year to year.

In future reports, an annual comparison of the anthropogenic catchment loads from the baseline year will be used to measure the load reduction (as required in Reef Plan targets). The load reduction will relate to the anthropogenic load and not the total load that includes a natural load component.

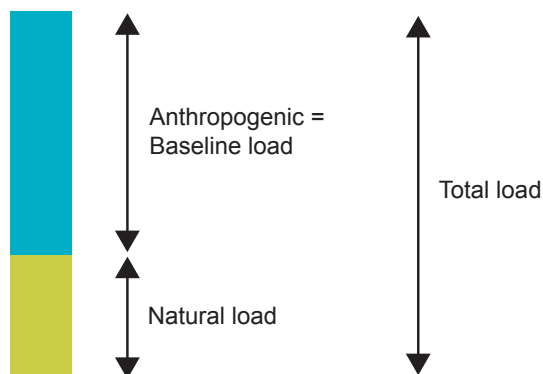


Figure 4.1 – How anthropogenic and natural load combine to form the total catchment load.

The following steps were used to estimate natural, total and anthropogenic catchment loads. Published and available catchment modelling and other information on natural and total catchment loads for each individual basin was collated and reviewed. For catchments with representative data, catchment water quality and flow information was then used to update estimates for total catchment loads and the associated uncertainty (Kuhnert et al., 2009; Wang et al., 2009).

In catchments where monitoring data was either not available or of moderate or indicative quality, the best estimates of total catchment loads were used. In catchments where catchment monitoring data was assessed to be sufficient and of high enough quality, monitoring data was used to update best estimates of total catchment loads.

The anthropogenic (baseline) catchment load for each basin was calculated based on the most recent estimates for natural catchment loads derived from catchment modelling, and total catchment loads derived from a combination of catchment modelling and monitoring, using the following simple formula:

Anthropogenic (baseline) load = total load – natural load.

4.4.2 Catchment modelling information

The main reference used to collate published information on catchment modelling loads was Brodie et al. (2009), with the following main adjustments (Kroon et al., 2010):

- excluding load estimates that did not match the boundaries of the 35 individual catchments
- including total nitrogen and total phosphorus loads for all 35 catchments
- including total load estimates to 24 catchments by disaggregating prior estimates for natural resource management regions into individual basin attributes, using the baseline scenario outputs from the short term modelling project (Cogle et al., 2006)
- disaggregating regional total loads into basin specific loads where possible (e.g. Post et al., 2006; Armour et al., 2009).

Based on this information for each catchment, the most recent estimates of natural and total loads were identified, as these have captured recent improvements in catchment modelling and monitoring data.

4.4.3 Catchment monitoring data

The available catchment monitoring data from the Queensland Department of Environment and Resource Management, the Australian Institute of Marine Science and the Australian Centre for Tropical Freshwater Research at James Cook University was used to update the estimated total catchment loads. The monitoring programs included:

- Surface Water Ambient Network – Department of Environment and Resource Management
- Great Barrier Reef catchment loads monitoring program – Department of Environment and Resource Management
- Queensland-wide sediment monitoring program – Department of Environment and Resource Management
- Australian Institute of Marine Science catchment sampling program
- Australian Centre for Tropical Freshwater Research regional monitoring programs.

Correcting for flow variability from year to year

The loads of pollutants leaving a catchment for any given year are strongly influenced by climate. Years with higher rainfall generally lead to higher runoff and greater flows. This often means the pollutant load is greater. Obtaining a long term loads estimate therefore requires calculating a mean of the pollutant concentration estimates across water years (October to September) for a site and multiplying by the average flow that spanned the monitoring data. The water years used ranged between 1981 and 2009, depending on the catchment.

Suitability assessment

The Department of Environment and Resource Management, Australian Institute of Marine Science and Australian Centre for Tropical Freshwater Research catchment monitoring data was collated by basin, and by sampling location if more than one location was sampled per basin. The suitability of data sets collected for each constituent to be used in the loads regression estimator model was subsequently assessed based on two criteria developed by Joo et al. (in prep):

- the number of samples taken in the top two per cent of flow range
- the ratio between the highest flow rate sampled and the maximum flow rate recorded (both measured in cumecs).

To estimate total catchment loads, only loads that were derived from data sets with excellent representative coverage were used.

Area corrections

Stream gauge sites are generally located upstream of the mouth of the river, above the influence of the tide. In each basin where the total loads (to the coast) were estimated from stream gauge monitoring data, an area correction was applied to account for the additional constituent sources and sinks on the river downstream of the gauge and also from streams flowing directly to the coast within each reporting basin. For example, agriculture occurring in coastal areas which drain below the last gauging station would be a source of additional

pollutants. These load area corrections were made using results from the most recent catchment modelling information.

For each pollutant, the area correction for diffuse sources was calculated as the ratio of the total SedNet/ANNEX (catchment water quality modelling tool) derived load from the basin to the coast, divided by the load at the stream gauge. As such, these ratios are generally above one, reflecting the proportional increase in catchment area between the gauge site and the mouth of the river, and additional contributions from the adjacent coastal streams within each basin boundary. The total loads calculated from stream gauge monitoring data were multiplied by the diffuse load area corrections, and modelled point source loads downstream of the stream gauge were added. The load area corrections were calculated for eight basins with excellent, good or moderate data quality (Kroon et al., 2010).

The area corrections differ from the proportional increase in catchment area where the sources and sinks downstream of the stream gauge differ in nature from those upstream. This includes basins where floodplain deposition outweighs erosion downstream of the gauge site (e.g. total suspended solids, particulate nitrogen and particulate phosphorus in Normanby, Tully, Black, Don and Pioneer), basins with the predominance of intensive land uses on coastal floodplains (e.g. dissolved nutrients in Johnstone, Herbert and Haughton), and basins with point sources (licensed sewage treatment plants or industrial discharges) downstream of the gauge locations (e.g. dissolved organic nitrogen and dissolved organic phosphorus in Barron, Johnstone and Pioneer). In the latter basins, the dissolved organic nitrogen and dissolved organic phosphorus loads from the downstream point sources were added to the gauge loads after applying the diffuse source area corrections.

4.4.4 Estimating mean-annual loads using monitoring data

Catchment monitoring data was used to estimate mean-annual loads which incorporated the area corrections using the process outlined in Kroon et al. (2010).

4.4.5 Confidence in the baseline load estimates

Confidence in the baseline load estimates differs across natural resource management regions due to different levels of comprehensiveness in the data available. For example, confidence in the load estimates for the Cape York basins and region is low, as these estimates are based solely on modelling with limited water quality monitoring data. This lack of monitoring data may explain the apparent large increases in total suspended solids loads in some Cape York catchments that are minimally disturbed and where large increases would not normally be expected. In contrast, confidence in the load estimates for the Wet Tropics region is generally high, as these estimates are based on modelling with comprehensive and long term water quality monitoring. Further information on uncertainty relating to the load estimates is outlined in Appendix 4.

Continuous improvement of catchment modelling capability, in combination with targeted water quality monitoring,

will result in increased confidence in the load estimates, particularly in those basins and regions with no current water quality monitoring. The updated catchment water quality modelling framework (Source Catchments) will provide significant improvements. Current catchment models such as SedNet/ANNEX generate long term average annual sediment and nutrient loads. The transition to Source Catchments will provide a finer resolution time step that will improve load estimates with quantified uncertainties and facilitate the link between catchment and receiving water models.

4.5 Great Barrier Reef water quality and ecosystem health—methods

The Reef Rescue Marine Monitoring Program involves three key programs: inshore water quality monitoring, intertidal seagrass monitoring, and inshore coral reef monitoring (Figure 4.2). In the context of this report, the most significant water quality issues for the Great Barrier Reef mainly affect the inshore waters, and the majority of the assessment and monitoring information relates to this area.

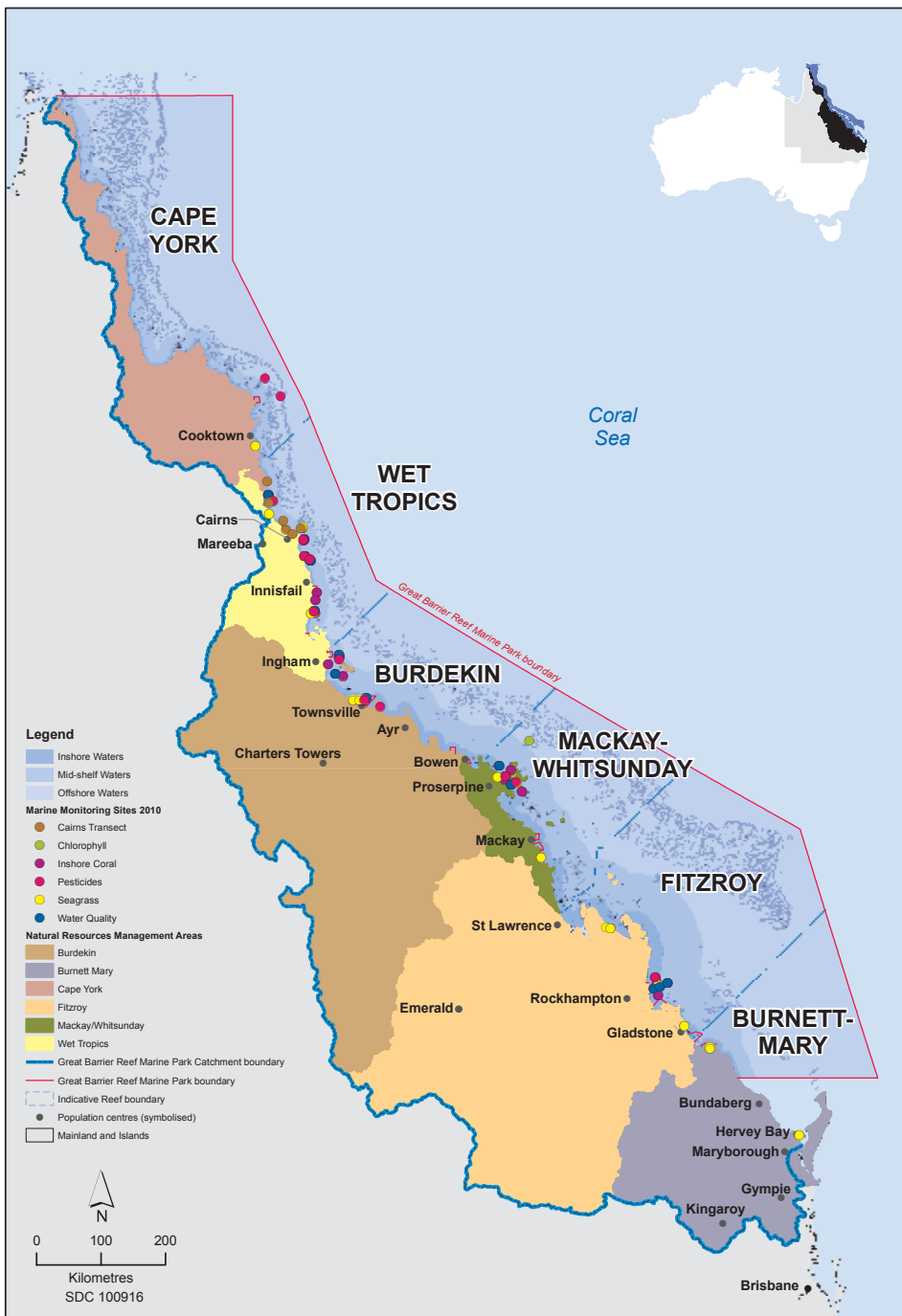


Figure 4.2 – The Great Barrier Reef World Heritage Area and marine monitoring sampling sites.

4.5.1 Great Barrier Reef-wide and regional water quality

Long term monitoring of Great Barrier Reef water quality is essential in understanding the extent of marine water quality improvements as a result of reductions in pollutants from catchments. Of particular importance is the assessment of long term trends in suspended solids, pesticide and nutrient (as chlorophyll *a*) concentrations in the Great Barrier Reef lagoon. Chlorophyll is a measure of algal biomass, which is related to the amount of available nutrients in the water column. In the short term, monitoring change in the concentrations of inshore pollutants such as pesticides will be critical for program assessment as the natural levels of these are zero.

Monitoring includes the measurement of nutrients, water turbidity (suspended sediments) and pesticide concentrations and uses standard water sampling and analysis techniques, as well as remote sensing techniques and *in situ* sensors with long term data logging capacity. Site-specific water quality monitoring is primarily carried out in association with seagrass meadow and coral reef monitoring to allow for correlation with reef ecosystem conditions.

Regional suspended solids, chlorophyll *a* (nutrient) and flood plume extent estimation

Remote sensing techniques are a cost-effective method to monitor spatial and temporal variation in near-surface concentrations of suspended solids, chlorophyll *a* (as a surrogate nutrient measure) and coloured dissolved organic matter (as a measure of freshwater extent) across the Great Barrier Reef region. This is achieved through the analysis of geo-corrected ocean colour imagery and data sets derived from satellite imagery. Data acquisition using remote sensing is most reliable over the dry season (May to October) when there is a higher probability of cloud-free days providing unobstructed satellite views of the Great Barrier Reef region. However, the technique is also often successfully applied during the wet season when cloud cover is more prevalent.

Pesticide concentration estimation

Passive, *in situ* sampling techniques have been developed to monitor pesticides in water (Figure 4.3). Chemicals accumulate within the sampler to concentrations that exceed their concentration in the surrounding environment by orders of magnitude. When deployed for 30 to 60 days, these samplers can accurately predict average water column concentrations of a range of pesticides. Pesticide concentrations are measured in this way at 13 inshore reef sites between Low Isles and North Keppel Island. Samplers are deployed for approximately 30 days during the wet season (November to March), and for two months during the dry season (April to October). Collected samples are analysed for a range of pesticides including chlorpyrifos, diuron, atrazine, hexazinone, endosulphan, simazine and ametryn.

The herbicides most commonly detected in the Great Barrier Reef inhibit the photosynthetic apparatus (PSII) of the target weed and have the capacity to impact on non-target organisms such as corals and seagrass. Herbicide equivalent

concentrations (Herbicide Equivalent Index) have been calculated so that the herbicides that inhibit photosynthesis can be assessed additively.

Flood plume pesticide monitoring data has been collected by a variety of research and monitoring programs since 2004–2005 for marine areas adjacent to the Tully and Murray Rivers, Russell-Mulgrave Rivers, Burdekin and Haughton Rivers, Pioneer and O'Connell Rivers, Fitzroy River and the Mary River. Not all areas were monitored each year.



Figure 4.3 – Passive samplers monitor marine water pesticide concentrations (Image: J. Muller, University of Queensland).

Site-specific water quality

Site-specific water quality monitoring is conducted at inshore coral and seagrass monitoring sites and allows assessment of the impact of local water quality on the health of coral reefs and seagrass meadows. Water quality measurements are undertaken using sensors with long term data logging capacity. Temperature loggers are located at all 32 reef and 28 seagrass monitoring sites (Figure 4.2). Temperature logger data determines the extent to which observed reef or seagrass disturbances might be associated with abnormally high (or low) temperatures. Autonomous water quality loggers (Eco FLNTUSB loggers) are deployed at 14 inshore coral sites (Figure 4.4). These instruments perform simultaneous *in situ* measurements of chlorophyll fluorescence, turbidity and temperature at 10-minute intervals. Instrumental data is

validated by comparison with chlorophyll and suspended solid concentrations obtained by analysis of routine grab water samples collected close to the instruments.

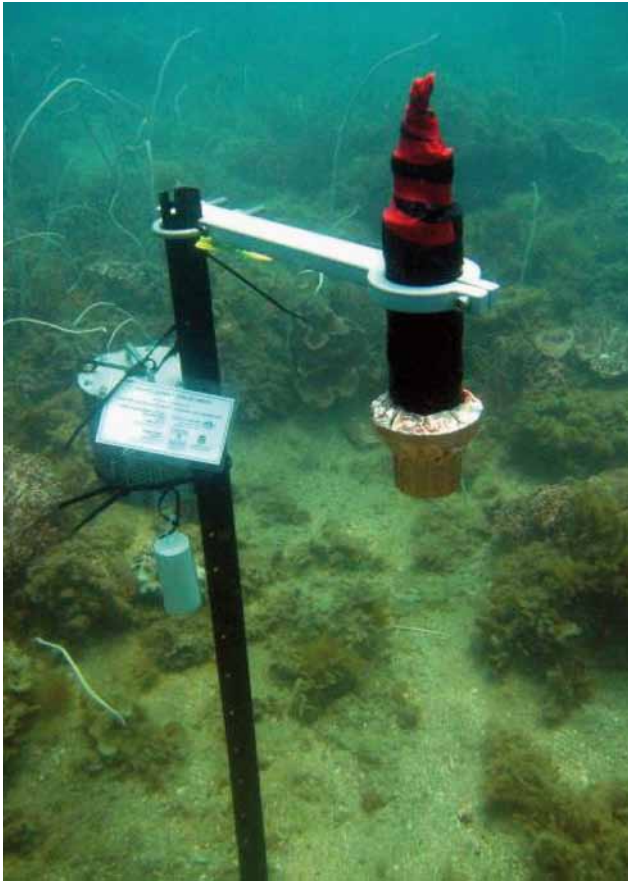


Figure 4.4 – WetLabs fluorometer water quality loggers are used for *in situ* marine water quality monitoring (Image: Australian Institute for Marine Science).

Regional ecosystem health

Runoff carrying pollutants can have significant impacts on the marine ecosystems that make up the Great Barrier Reef Marine Park. Monitoring of coral reefs and seagrass meadows is completed annually to ensure that any change in their status is identified, and as importantly, related to any change in local water quality and environmental conditions.

Intertidal seagrass monitoring

Seagrasses are an important component of the marine ecosystem of the Great Barrier Reef. They are a highly productive habitat and provide nursery grounds for many marine species, including commercially important fish and prawns. There are nearly 6000 square kilometres of seagrasses in shallow waters (under 15 metres) along the Queensland coast. Twenty-eight seagrass meadows are monitored to assess trends in seagrass status, and as a bioindicator of environmental quality associated with changing water quality (Figure 4.2). Sites are monitored twice a year (pre- and post-wet season) at locations between Cooktown and Hervey Bay.

Each site is monitored for its seagrass habitat resource status (percentage of cover and species composition; Figure 4.5) and the presence of indicators of potential nutrient stress (elevated epiphytes and macroalgae). Metrics of nutrient enrichment and light availability to the plant (leaf tissue nutrient ratios) are determined following laboratory analysis of annually collected seagrass samples. The ability for seagrass habitats to recover following disturbance is linked to their reproductive ability, so two measures of seagrass reproductive effort (presence of seeds and the number of reproductive structures on the plant) are also assessed bi-annually as a measure of meadow resilience to changing environmental conditions.



Figure 4.5 – Seagrass is monitored at 28 locations along the Queensland coast (Image: L. McKenzie, DEEDI).

Inshore-shelf coral reef monitoring

A significant number of reefs that make up the larger Great Barrier Reef exist at inshore or nearshore sites, close to the north Queensland coast (Furnas and Brodie, 1996). Thirty-two inshore coral reefs are assessed as part of the Reef Rescue Marine Monitoring Program (Figure 4.6). The reefs are located in the Wet Tropics, Burdekin, Mackay Whitsunday and Fitzroy regions. Of these reefs, 15 are surveyed annually, with an additional 17 reefs surveyed every second year. Monitored

reefs lie along a gradient of exposure to runoff, largely determined as increasing northerly distance from regionally important rivers. Reefs are assessed for hard coral, soft coral and macroalgal densities, as well as species diversity, coral demographics (monitoring of juvenile coral colonies, their sizes and their diversity) and coral larval settlement rates. Comprehensive water quality measurements are also collected at each of the coral reef sites.

The assessment of coral community status and resilience from which the report scores are derived is based on expert understanding of coral reef community dynamics and will evolve as knowledge increases. For each reef, a categorical assessment (three point scale) was made for each of five community attributes: coral cover, rate of increase in hard coral cover, macroalgal cover, density of hard coral juveniles and settlement of coral larvae (available for a subset of reefs). For details on the assessment method, see Thompson et al. (2010).

For hard coral communities, a high cover is usually interpreted as an indication of resilience as the corals are clearly coping with the ambient environmental conditions, and high cover also equates to high broodstock, a necessary link to recruitment. However, high coral cover may simply indicate the absence of disturbance events in the recent past, as these events can drastically reduce coral cover in an otherwise resilient community. For this reason, the coral cover assessment has been considered in two ways—as a static measure of cover where more is better; and using the observed rate of change in cover as a direct measure of recovery potential. The measure of recovery potential is

possible because rates of recovery for inshore reefs on the Great Barrier Reef have been modelled (Thompson and Dolman, 2010), allowing estimation of expected increases in cover for communities of varying composition and levels.



Figure 4.6 – Thirty-two coral reefs are monitored throughout the Great Barrier Reef (Image: Australian Institute of Marine Science).

Table 4.5 – Summary of decision rules for the assessment of coral reef status and resilience.

Community attribute	Assessment category	Decision rule
Combined hard and soft coral cover	+	> 50 per cent
	neutral	between 25 per cent and 50 per cent
	-	< 25 per cent
Rate of increase in hard coral cover	+	above upper confidence interval of model-predicted change
	neutral	within confidence intervals of model-predicted change
	-	below lower confidence interval of model-predicted change
Macroalgae cover	+	< 5 per cent or < 10 per cent and declining from a high cover following disturbance
	neutral	stable between 5–15 per cent or declining between 10–20 per cent
	-	> 15 per cent or increasing
Density of hard coral juveniles	+	> 10.5 juvenile colonies per m ² of available substrate (2 m) > 13 juvenile colonies per m ² of available substrate (5 m)
	neutral	between 7 and 10.5 juvenile colonies per m ² of available substrate (2 m) between 7 and 13 juvenile colonies per m ² of available substrate (5 m)
	-	< 7 juvenile colonies per m ² of available substrate
Settlement of coral spat	+	> 70 recruits per tile
	neutral	between 30 and 70 recruits per tile
	-	< 30 recruits per tile

Explanatory note: + status and resilience is good; neutral denotes status and resilience is moderate; - status and resilience is poor.