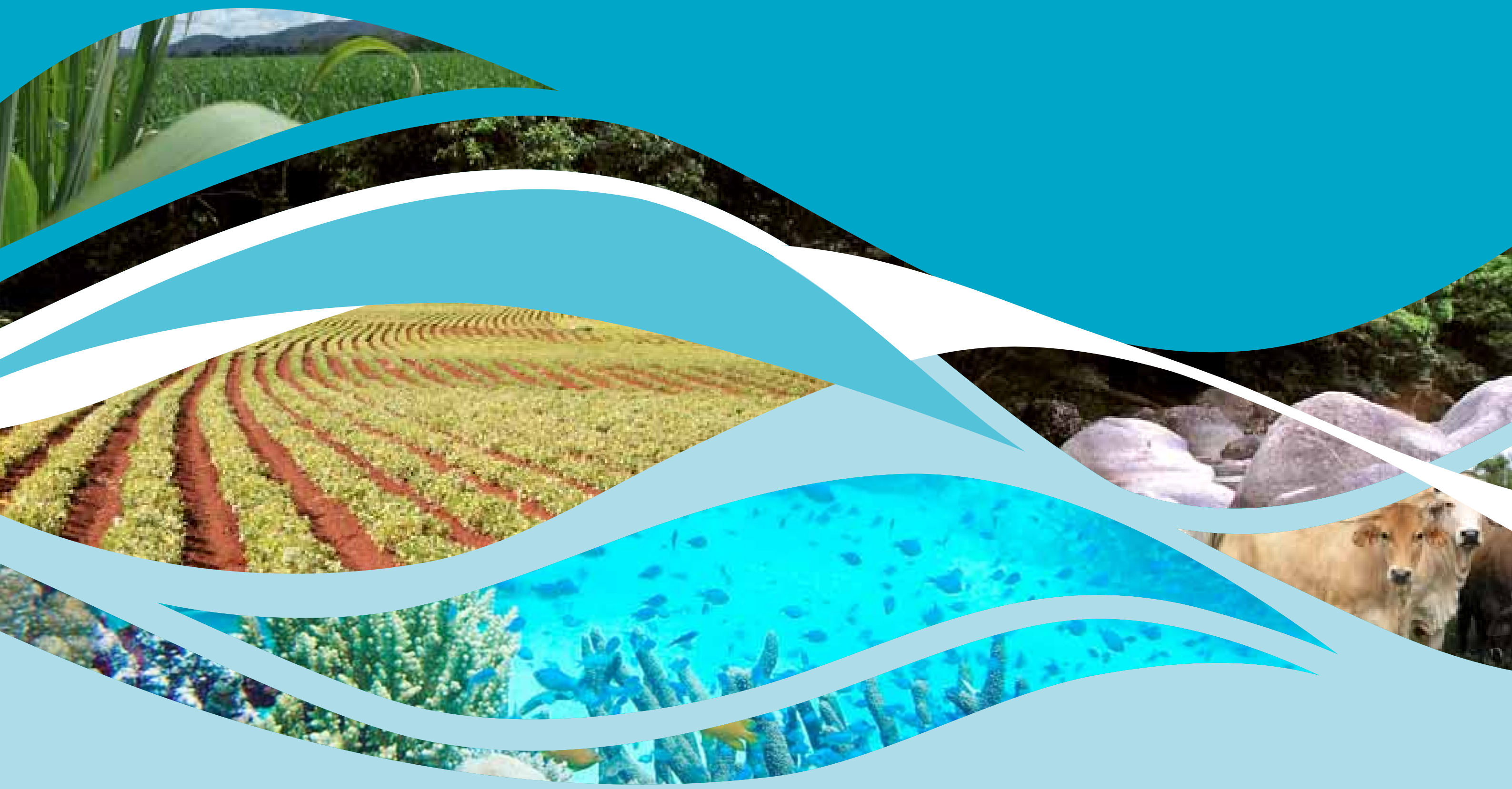
Reef Water Quality Protection Plan

First Report
2009 Baseline



Australian Government

Queensland Government

A broad range of organisations and individuals are acknowledged for their contribution to this report.

Copies of this publication can be obtained by contacting (07) 3225 8050 or at www.reefplan.qld.gov.au

Foreword

The Great Barrier Reef is one of our most precious resources and its protection is our collective responsibility. Through the Reef Water Quality Protection Plan, the Australian and Queensland Governments are working collaboratively with the natural resource management, industry and conservation sectors, scientists and communities to improve the health of the reef for current and future generations. Together we will promote changes to the way in which farms are managed throughout the reef's catchments. These changes will generate economic benefits for land managers and importantly, improve the quality of water entering the Great Barrier Reef and build its capacity to respond to the impacts of a changing climate. This report represents the fundamental first step in measuring our progress towards achieving the objectives of the Reef Water Quality Protection Plan 2009 (Reef Plan).

When developing Reef Plan, our governments agreed that it was critical to develop ambitious and quantitative targets. At the time, we recognised it would take commitment and collaboration to achieve these targets and a significant program of monitoring, modelling and reporting would be required. We are pleased to see such positive progress to date, both in terms of on-ground changes being made as well as the implementation of such a significant monitoring program.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program was established as a joint initiative to measure progress and is a world-leading example of what can occur when our governments work together in collaboration with industry, regional bodies and scientific research organisations to ensure monitoring and modelling is integrated and focused. It will allow us to answer some of the key questions surrounding reef health.

We commend all those involved in preparing this First Report and thank them for their ongoing commitment to Reef Plan and the future protection of the reef.

Anna Bligh MP
Premier of Queensland

Tony Burke MP
Minister for Sustainability, Environment, Water, Population and Communities

1 Executive summary

The Great Barrier Reef World Heritage Area is renowned internationally for its ecological importance and beauty. However, despite it being one of the best managed coral reefs in the world (Great Barrier Reef Outlook Report 2009) there is a very real risk of damage to the reef from climate change. One of the best ways to protect the reef from this threat is to reduce other stresses on its delicate ecosystem.

Poor water quality from catchment runoff affects the health of the Great Barrier Reef, causing degradation of inshore reefs and contributing to crown of thorns outbreaks. This decreases the reef's ability to withstand and recover from other impacts caused by climate change, such as coral bleaching and damage from increased storm intensity.

The Reef Water Quality Protection Plan (Reef Plan) is the Australian and Queensland Governments' commitment to halt and reverse the decline in water quality flowing to the reef. Originally introduced in 2003, the plan was updated in 2009 to promote accelerated action and includes ambitious quantitative targets around practice change and reductions in catchment pollutant loads.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) is a world-leading program founded on collaboration between governments, industry, regional natural resource management bodies and research organisations. It integrates information from the paddock, to the catchment, to the marine system providing the linkage between management actions and water quality outcomes for the Great Barrier Reef.

The First Report provides an estimate of the status of key indicators for the period immediately preceding Reef Plan 2009. It therefore does not include the effects of Cyclone Yasi and the more recent flood events which will be presented in subsequent reports. It will serve as a baseline that will be used as a point of comparison to measure progress towards Reef Plan goals and targets. This report also describes some historical trends to provide context, better understand the influence of a variable climate from year to year, and help interpret changes over time.

This First Report is based on the best available data and information and uses multiple lines of evidence to measure progress. Confidence in the estimates varies for each of the indicators. However, the program is based on a philosophy of continuous improvement which will help improve data confidence over time.

Snapshot of the results

The results highlight that there are areas of concern that justify the need for accelerated action to improve water quality and build resilience of the Great Barrier Reef. These include five to nine times the natural loads of pollutants, significant loss of some freshwater wetlands, decline of seagrasses in some areas and the exceedance of Great Barrier Reef Marine Park Water Quality Guidelines for total suspended solids and chlorophyll *a* in marine areas. However, despite some poor indicators, the reef remains in moderate condition overall.

High rainfall in the Great Barrier Reef catchment (particularly in the Burdekin and Fitzroy regions between 2008 and 2009) has resulted in large flood plumes reaching marine waters. This rainfall, as well as the significant flood events of 2011, will continue to strongly influence the quality of water entering the reef, particularly in inshore areas (within 20 kilometres). While these waters only represent around eight per cent of the Great Barrier Reef Marine Park, they support significant ecosystems and are the primary focus for most recreation, commercial tourism and fisheries activities.

Improved land management

- Cutting-edge (A) or best management (B) practices are used by 36 per cent of sugarcane growers for nutrients, seven per cent for herbicides and 19 per cent for soil.
- Practices considered unacceptable by industry or community standards (D) are used by 34 per cent of sugarcane growers for nutrients, eight per cent for herbicides and 45 per cent for soil.
- Cutting-edge (A) or best management (B) practices are used by 39 per cent of horticulture producers for nutrients, 78 per cent for herbicides and 70 per cent for soil.
- Practices considered unacceptable by industry or community standards (D) are used by 24 per cent of horticulture producers for nutrients, six per cent for herbicides and 11 per cent for soil.
- Fifty per cent of graziers across the Burdekin and Fitzroy regions are using (A or B) management practices that are likely to maintain land in good to very good condition or improve land in lesser condition. Twelve per cent of graziers in the Burdekin and Fitzroy regions are using (D) management practices that are likely to degrade land to poor condition.
- Cutting-edge or best management (A or B) practices have been adopted by 85 per cent of grain growers in the Fitzroy region. Code of practice or unacceptable (C or D) practices are being used by 15 per cent of grain growers.

Catchment indicators

- The total riparian area (area within 50 metres of the stream) in the Great Barrier Reef region is six million hectares. There has been a loss of 30,000 hectares (0.49 per cent) of riparian vegetation between 2004 and 2008.
- Of all wetland types, vegetated freshwater swamps have had the greatest loss since pre-European times (25 per cent). Loss of all types of wetlands between 2001 and 2005 was 883 hectares.
- The 2009 mean dry season groundcover for the grazing lands of the Great Barrier Reef region was 84 per cent, which is above the Reef Plan target of 50 per cent. This is due to higher than the historical average rainfall across many grazing areas.

Catchment loads

- Total catchment loads are five to nine times the natural loads for suspended solids, nitrogen and phosphorous.
- Annual total suspended solid loads are 17 million tonnes, of which 14 million tonnes are from human activity. The largest contribution of total suspended sediment load is from the Burdekin and the Fitzroy regions (4.7 and 4.1 million tonnes respectively), mainly derived from grazing lands.
- Agricultural fertiliser use is a key source of dissolved nitrogen and phosphorus runoff; annual loads of dissolved nitrogen are 31,000 tonnes.
- All pesticides are from human activities. The total annual pesticide loads are approximately 28,000 kilograms and the highest loads are from the Mackay Whitsunday and Wet Tropics regions (approximately 10,000 kilograms each per year).

Great Barrier Reef water quality and ecosystem health

- The Great Barrier Reef is in moderate condition overall, however, this varies regionally.
- Inshore waters often contain elevated concentrations of total suspended solids and chlorophyll *a*.
- Monitoring during flood events over the past five years has detected pesticide concentrations above the Great Barrier Reef Marine Park Water Quality Guidelines at least 25 kilometres from the mouth of the Pioneer and O'Connell Rivers. Concentrations that may have short term effects on the health of marine plants have also been detected up to 50 kilometres from the coast.
- Inshore seagrasses are in moderate condition. Seagrass abundance is moderate and has declined over the past five to 10 years, associated with excess nutrients. The number of reproductive structures is poor or very poor in four of the six regions, indicating limited resilience to disturbance.
- Most inshore reefs are in good or moderate condition and have either high or increasing coral cover. However, corals in the Burdekin region are mostly in poor condition and have shown little recovery in the past four years.

The Paddock to Reef program will continue to review and update the monitoring, modelling and reporting techniques used to ensure that the accuracy of the information reported is constantly improved over time. The program will inform research, development and innovation initiatives established under Reef Plan 2009 and will be used to better target new initiatives and investments in reef water quality improvement.

Table of contents

List of figures

List of tables

Introduction

Chapter 2

"Improvement of Great Barrier Reef water quality will increase the likelihood that these tropical marine ecosystems will survive."

Photo courtesy of Great Barrier Reef Marine Park Authority

2.1 The Great Barrier Reef

The Great Barrier Reef is renowned internationally for its ecological importance and beauty. It is the largest and best known coral reef ecosystem in the world, extending over 2300 kilometres along the Queensland coast and covering an area of 350,000 square kilometres (Figure 2.1). It includes over 2900 reefs as well as extensive seagrass meadows, mangrove forests and soft bottom habitats. The biodiversity of the region is important for the continued survival of many species. It is a World Heritage Area, and is protected within the Great Barrier Reef Marine Park in recognition of its diverse, unique and universal values. The reef is also critical for the prosperity of Australia, annually contributing over $6 billion to the Australian economy (GBRMPA, 2009).

The Great Barrier Reef is home to thousands of species, including coral and other invertebrates, bony fish, sharks, rays, marine mammals, marine turtles, sea snakes and seabirds, as well as a wide variety of other animals, algae and other marine plants (GBRMPA, 2009). It provides an important habitat for species of conservation concern such as dugongs, whales, dolphins, sharks and marine turtles. It is this biodiversity that builds such a remarkable ecosystem and supports human use (such as tourism and commercial and recreational fisheries) of the Great Barrier Reef.

The Great Barrier Reef remains one of the most healthy and well managed coral reef ecosystems in the world (GBRMPA, 2009). However, there is no room for complacency as the future health and resilience of the reef remains under threat from a range of factors including climate change, catchment pollutants and coastal development. As with coral reefs worldwide, the Great Barrier Reef is threatened by increasing seawater temperatures and altered water chemistry caused by global climate change. Maintenance, and where necessary, improvement of Great Barrier Reef water quality will increase the likelihood that these tropical marine ecosystems will survive the additional stresses imposed by a changing climate, including elevated seawater temperatures, increasing seawater acidity and increased tropical monsoonal storm activity and flood runoff.

2.2 Threats from land management

Although the Great Barrier Reef region is relatively sparsely populated, extensive land modification (such as clearing) has occurred over the past 200 years since European settlement (Furnas, 2003; Hutchings and Haynes, 2005). The Great Barrier Reef receives runoff from 35 major catchments which drain 424,000 square kilometres of coastal Queensland. These catchments are spread from the Cape York region in the north, to the Burnett Mary region in the south. Climate and soil characteristics vary across the catchments. Grazing is the dominant agricultural land use. Sugarcane and horticultural crops dominate in the high rainfall and coastal irrigation areas. Large sections of summer and winter rain-fed grain crops and irrigated cotton are prevalent in the inland areas of the Fitzroy region.

The quality of water flowing into the reef lagoon from the land has deteriorated dramatically over the past 150 years (Furnas, 2003). Flood events in the wet season deliver pollutants from the adjacent catchments onto the Great Barrier Reef well in excess of natural levels. This has contributed to reduced resilience and has made the Great Barrier Reef more vulnerable to other pressures such as climate change.

In response to this threat, in 2003, the Queensland and Australian Governments established the Reef Water Quality Protection Plan (Reef Plan), to halt and reverse the decline in water quality. Reef Plan is focused on the significant threat of diffuse source pollution from agriculture in catchments adjacent to the reef. This is considered the single biggest manageable threat to the reef in terms of water quality. Neither Reef Plan nor this report address point sources of pollution such as sewage treatment plants or mines, or urban diffuse pollution such as stormwater runoff. They are managed through different mechanisms.

Recent science has further highlighted the links between expanding catchment development, intensification of agricultural production and declining water quality in the Great Barrier Reef lagoon. Long term monitoring and modelling have demonstrated that concentrations of nutrients are much higher in northern Queensland rivers adjacent to intensive agriculture than the relatively pristine rivers in Cape York (Mitchell et al., 2001); that sediment and nutrient exports have increased to the Great Barrier Reef over the last 200 years (Furnas, 2003); and that flood events are critical in transporting these pollutants to the marine environment (Devlin et al., 2001). Monitoring has also shown that pesticides are being transported into river systems and the Great Barrier Reef at harmful concentrations during flood events (GBRMPA, 2009; Lewis et al., 2009).

The significant number of reef, seagrass and mangrove ecosystems that exist in coastal or nearshore locations are directly exposed to catchment water pollution influences (Furnas and Brodie, 1996; Furnas, 2003). The highest risk area for degraded water quality, the inshore waters, make up approximately eight per cent of the Great Barrier Reef Marine Park and are near the coast (up to 20 kilometres offshore). This area not only has significant ecological communities, as described above, it is also the area of the Great Barrier Reef most used by recreational visitors and commercial tourism operations and it has significant commercial fisheries resources. Degradation of inshore reefs between Port Douglas and the Whitsundays has been associated with increased terrestrial runoff of pollutants in the region (Udy et al., 1999; van Woesik et al., 1999; Fabricius and De'ath, 2004; Fabricius et al., 2005; Devantier et al., 2006). Damage to both inshore and outer-shelf reefs of the central Great Barrier Reef from crown-of-thorns starfish outbreaks has been attributed to increased nutrient concentrations in inshore waters from terrestrial runoff (Brodie et al., 2005).

Based on the latest scientific consensus, the Australian and Queensland Governments reaffirmed their commitment in 2009 to an updated Reef Water Quality Protection Plan (Reef Plan 2009), which is designed to accelerate actions to improve the quality of water flowing from paddocks to the reef.

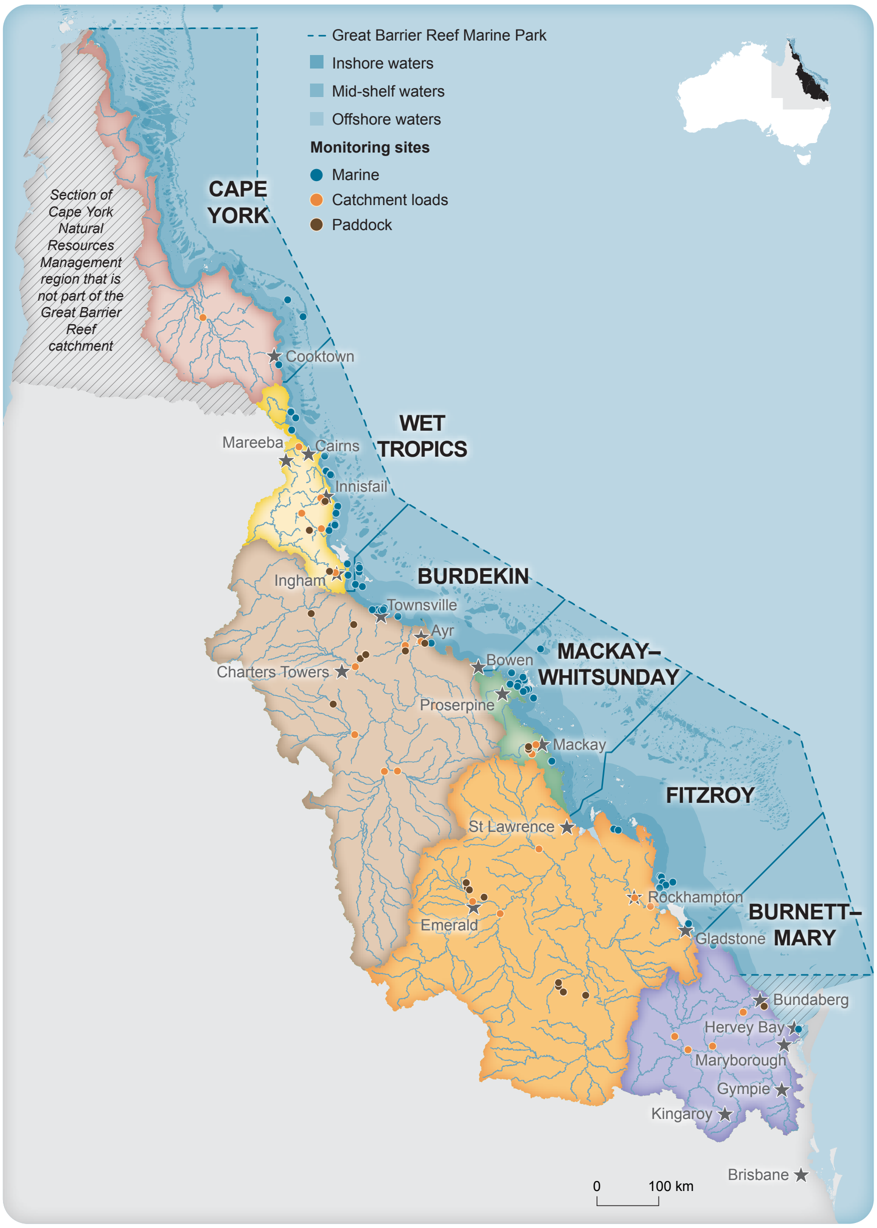


Figure 2.1 – The Great Barrier Reef showing regions, Paddock to Reef program monitoring sites and marine park.

2.3 About this report

This report provides a measure of the status of key indicators for the Great Barrier Reef and its adjacent catchments for the period immediately preceding Reef Plan 2009. It therefore does not include the effects of Cyclone Yasi and the more recent flood events which will be presented in subsequent reports. It is based on historical data and trends and takes into account the influence of a variable annual climate. Figure 2.2 outlines the report structure.

This report presents the current understanding of 2008–2009 conditions. This is the baseline from which the progress towards Reef Plan goals and targets will be measured. The intention of the Paddock to Reef program, however, is to continuously improve the accuracy and precision of monitoring and modelling.

Appendix 1 describes the approaches to the continuous improvement of the Paddock to Reef program. Consequently, this will also lead to an improved estimate of the baseline in future years. For example, current load estimates rely heavily on the currently available catchment water quality model, Sednet/ANNEX. While this model provides a relatively robust estimate of catchment loads, there is significant scope for improvement. A more sophisticated model, Source Catchments, will be used for subsequent reports. Rather than compare two different models, the new Source Catchments model will be hindcast to recalibrate the baseline based on the improved model. This will allow for annual comparison and a more accurate baseline.

Figure 2.2 – Structure of the report.

2.3.1 How are the results presented?

This document provides context to the baseline estimates by explaining historical trends to demonstrate the connection between the paddock and the reef (Figure 2.3). These trends are important as they demonstrate variability over time, and are integral in the assessment and interpretation of how paddock to reef indicators change.

Description of indicators

Management practice adoption

This report presents the management practice adoption information as at 2008–2009 for the sugarcane, grazing, horticulture and grains agricultural industry sectors using an ABCD management practices framework. This information is derived from a range of datasets of varying comprehensiveness.

Under this framework, the management practices for sugarcane, horticulture and grains are defined as:

A – Cutting-edge practices that require further validation of environmental, social and economic costs and benefits

B – Currently promoted practices often referred to as best management practice

C – Common practices often referred to as code of practice

D – Practices that are superseded or unacceptable by industry and community standards.

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

A – Practices likely to maintain land in very good condition or improve land in lesser condition

B – Practices likely to maintain land in good condition or improve land in lesser condition

C – Practices that may maintain land in fair condition or gradually improve land in poor condition

D – Practices likely to degrade land to poor condition.

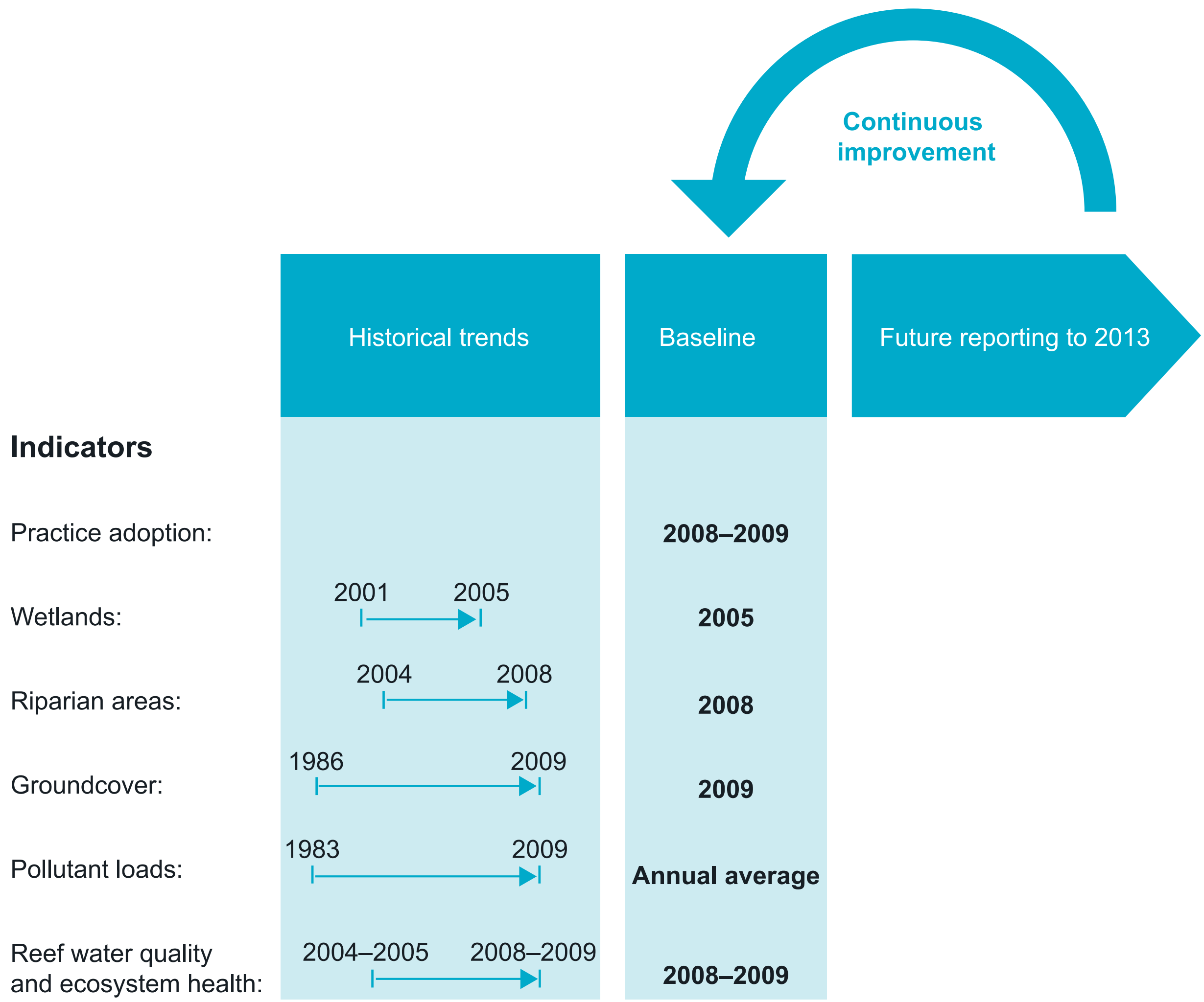


Figure 2.3 – How the baseline results are presented for each indicator.

Catchment indicators

This report presents information on catchment attributes that play a role in water quality leaving the paddock and entering the reef such as wetlands, riparian areas and groundcover.

The wetlands baseline information identifies the extent of vegetated freshwater swamps (palustrine wetlands) and mangroves/salt flats (estuarine wetlands) as at 2005 and indicates the loss of these wetlands historically and between 2001 and 2005. Extent information for the 2009 baseline year is still being prepared and will be made available in subsequent reports. New techniques are currently being tested to further report on wetland condition and extent.

The riparian baseline information reports the extent of riparian areas in a condition susceptible to erosion (non-forested with low groundcover) as at 2008 and the loss of riparian vegetation between 2004 and 2008. Extent information for the 2009 baseline is still being prepared and will be made available in subsequent reports.

This baseline information for groundcover presents the average late dry season groundcover as at 2009 and the historical average for the 1986 to 2009 period. The area with groundcover below the target of 50 per cent and below 30 per cent is also presented.

Catchment loads

Catchment loads are presented as the annual average total load at the end of the catchment for key pollutants calculated from monitoring and modelling data between 1983 and 2009. The total load includes the natural load and the anthropogenic load (the load due to human activity). The key pollutants presented graphically are total suspended solids, total nitrogen, dissolved nitrogen, total phosphorus, dissolved phosphorus and photosystem inhibiting (PSII) pesticides.

Great Barrier Reef water quality and ecosystem health

This report presents information on water quality, seagrass and corals for the Great Barrier Reef. Water quality includes suspended sediments, chlorophyll *a* (a surrogate measure for nutrients) and pesticides. Seagrass health includes an assessment of abundance, reproduction, nutrient status and light availability. Coral health includes an assessment of hard coral and macroalgae cover and trends in cover, juvenile density and recruitment.

Management overview

Chapter 3

"Achieving Reef Plan goals relies on building strong partnerships between all levels of government, industry, natural resource management agencies and individual landholders."

Photo courtesy of Queensland Government

3.1 Taking action

The Reef Water Quality Protection Plan was first endorsed by the Australian and Queensland Governments in 2003 with the aim of halting and reversing the decline in water quality from broad scale agriculture. In 2009, both governments reaffirmed this commitment by endorsing an updated Reef Water Quality Protection Plan (Reef Plan 2009) which is designed to accelerate actions that will improve the quality of water flowing from paddocks to the reef and build resilience in the reef in the face of climate change.

3.2 Commitment

Reef Plan 2009 is a joint initiative of the Australian and Queensland Governments and is being achieved in close partnership with landholders and community groups. Reef Plan 2009 outlines 11 key actions that must be implemented to ensure key targets are met. These actions include financial incentives to landholders to improve practices, implementation of regulations and policies that improve land practices and conserve key areas, more effective education and extension and creating a better understanding of the problem through research and monitoring.

The Australian and Queensland Governments have committed significant funding and resources to initiatives which contribute to improved reef water quality through Reef Plan. The Australian Government has committed $200 million over five years to the Caring for our Country Reef Rescue program. The Queensland Government has committed $175 million over five years, which includes a $50 million package to support the new Reef Protection package (legislation, research, extension and support).

3.3 Reef Plan, Reef Rescue and Reef Protection initiatives

Reef Plan 2009 is the overarching strategy that identifies the collective actions required to address the decline in reef water quality. It encompasses a range of major initiatives such as the Australian Government's Reef Rescue initiative and the Queensland Government's Reef Protection package. It was developed collaboratively by the Australian and Queensland Governments, industry, regional bodies and conservation groups.

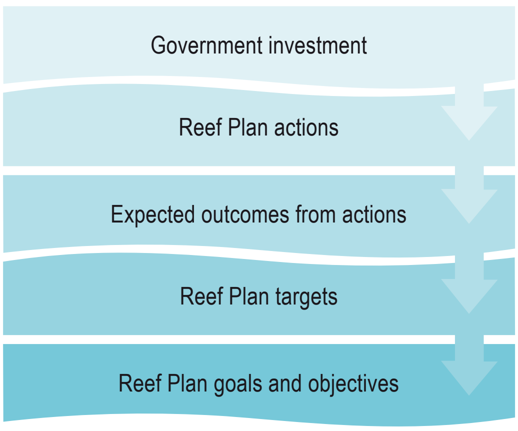


Figure 3.1 – How investment drives action and progress towards Reef Plan goals and objectives.

3.4 Working together

Reducing the impacts of land use on reef water quality is not solely the responsibility of governments. Achieving Reef Plan goals relies on building strong partnerships between all levels of government, industry, natural resource management agencies and individual landholders. Governments are working with landholders through extension staff, regional bodies, industry groups and Reef Plan committee members to ensure a coordinated and cohesive approach to improving reef water quality. The Paddock to Reef integrated monitoring, modelling and reporting program relies upon the cooperation between all partners to ensure that monitoring data is integrated and effective and can demonstrate the effectiveness of management changes.

3.5 Goals and targets

The success of Reef Plan actions must be measured to ensure that the investment provided by all the partners has achieved the desired outcomes. To provide a meaningful measure of success, it is imperative to set targets. These targets provide all investors, including the Australian public, with a common understanding of the expected outcomes.

Goals and targets have been identified for the short term (2013) and the medium term (2020).

Reef Plan goals

Immediate goal – To halt and reverse the decline in water quality entering the reef by 2013.

Long term goal – To ensure that by 2020 the quality of water entering the reef from adjacent catchments has no detrimental impact on the health and resilience of the Great Barrier Reef.

Achievement of Reef Plan's goals will be assessed against the following quantitative targets established for land management and water quality outcomes.

Reef Plan targets

By 2013 there will be a minimum:

- 50 per cent reduction in nitrogen and phosphorus loads at the end-of-catchments
- 50 per cent reduction in pesticides at the end-of-catchments
- 50 per cent late dry season groundcover on dry tropical grazing land.

By 2020 there will be a minimum:

- 20 per cent reduction in sediment load at the end-of-catchments.

Note: The pollutant reductions relate to the load contributed by human activities (called the anthropogenic load) and do not include the naturally occurring load in river systems.

By 2013:

- 80 per cent of landholders in agricultural enterprises (sugarcane, horticulture, dairy, cotton and grains) will have adopted improved soil, nutrient and chemical management practices
- 50 per cent of landholders in the grazing sector will have adopted improved pasture and riparian management practices
- there will have been no net loss or degradation of natural wetlands
- the condition and extent of riparian areas will have improved.

Reef Plan water quality targets are a sum of the targets of the Australian and Queensland Government targets. The specific five-year outcomes, due for completion in 2013, for the Reef Rescue initiative are to reduce the discharge of:

- dissolved nutrients and chemicals from agricultural lands to the Great Barrier Reef lagoon by 25 per cent
- sediment and particulate nutrients from agricultural lands to the Great Barrier Reef lagoon by 10 per cent.

This First Report and subsequent reports will track progress towards all Reef Plan targets.

3.6 Progress on Reef Plan Actions

Since the release of Reef Plan 2009, significant progress has been made, demonstrating the effectiveness of reaffirming the government's commitment to the plan. Figure 3.2 summarises progress to July 2010.

Action	Deliverable	Completed / on target	Satisfactory progress	Delayed / limited progress	Not due
Develop, implement and maintain a Research, Development and Innovation Strategy for agreed reef water quality priorities.	• A three-year Research Development and Investment Strategy for agreed reef water quality priorities by September 2009.	✓			
	• An updated Research Development and Investment Plan by July each year.		✓		
Coordinate and integrate agreed research and development priorities into programs of work.	• An evaluation report outlining the extent of uptake of research and development priorities by research providers by July each year.				✓
Prioritise and align investments for reef water quality based on catchment scale and reef-wide risk assessments of key pollutants and source areas.	• Reef Rescue investment for 2009–2010 and onwards is delivered based on a multi-criteria analysis.	✓			
	• The Queensland Integrated Waterway Monitoring Risk Assessment is used to inform cooperative agreements and other water quality monitoring activities for 2009–2010.	✓			
	• A prioritisation process to guide investment in future water quality initiatives (other than Caring for our Country) is agreed by September 2009 for funding 2009–2010 and beyond.	✓			
	• A Reef Plan Investment Strategy is developed and implemented by September 2009 to coordinate investments across programs, while acknowledging the different objectives of the various programs.	✓			
Identify improved land management practices to maximise reef water quality improvements.	• Improved land management practices for high-risk catchments are identified based on best available knowledge by September 2009.	✓			
	• Improved land management practices are revised based on new information and made available to all land managers by June 2010.		✓		
	• Evaluate the actual costs and benefits of adopting improved land practices that have been identified and promoted to landholders by June 2011 and June 2013.				✓
Implement improved land management practices that maximise reef water quality improvements as part of property level management systems.	• Landholders implement improved land management practices.		✓		
	• Report annually by industry sector on uptake of improved land management practices as part of industry-led property level management systems.		✓		
	• Develop and implement a strategy to coordinate improvement of water quality management on public land in reef catchments by December 2009.	✓			
Provide coordinated education and extension services to landholders to assist with uptake of land management practices that maximise reef water quality improvement.	• Undertake education and extension services targeting water quality improvement on an ongoing basis.	✓			
	• Review extension and education services with recommendations for improvement and resourcing by December 2009.	✓			
	• Review recommendations and implement appropriate changes to the extension and education program by June 2010.	✓			
	• Develop an education and extension strategy for coordination of activities across different programs and agencies by December 2009.	✓			

Action	Deliverable	Completed / on target	Satisfactory progress	Delayed / limited progress	Not due
Review existing, and develop and implement new regulations and policies for improving reef water quality and the conservation and protection of wetland and riparian areas with emphasis on property level planning and action.	• Implement the following new or amended regulations:				
	- reef regulatory package to be developed by mid-2009 and implemented by 2010	✓			
	- wetlands regulation implemented in priority areas by December 2009.	✓			
	• Implementation of Land Management Agreements commences by September 2009 in high priority reef catchments where leases trigger the Delbessie Agreement requirements.	✓			
	• Annually report on the implementation of conservation agreements and covenants in high priority reef catchments.	✓			
	• Reef Plan objectives incorporated into existing statutory regional plans, planning policies and Coastal and Water Resource Management Plans by June 2010 and into new plans as they are developed.		✓		
Develop, review and implement non-regulatory policies and incentives for improving reef water quality and the conservation and protection of wetland and riparian areas.	• Reef Rescue investment strategies are updated annually.	✓			
	• Reef Rescue outcomes and targets met by June 2013 with annual reporting on progress.	✓			
	• New cooperative agreement and NRM program for 2009–2013 agreed by September 2009.	✓			
Develop and implement a Reef Plan Monitoring and Evaluation Strategy to measure the efficiency and effectiveness of the Reef Plan.	• A Reef Plan Monitoring and Evaluation Strategy is endorsed by September 2009.	✓			
	• Reef Plan targets are monitored, reported and reviewed annually.	✓			
	• Reef Water Quality Report prepared to report annually on implementation of Reef Plan and water quality and associated ecosystem health.		✓		
	• Independent audit and evaluation report undertaken by June 2010.		✓		
	• Undertake further independent audits prior to June 2013 as necessary.				✓
Develop and implement an integrated and coordinated paddock to Reef monitoring (modelling) and reporting program as part of the Reef Plan Monitoring and Evaluation Strategy.	• Integrated paddock to reef monitoring and reporting program designed and implemented by September 2009 including the following components:	✓			
	- monitoring of uptake of improved management practices		✓		
	- paddock scale water quality monitoring and modelling to measure effectiveness of management practices	✓			
	- catchment and sub-catchment water quality and land condition monitoring and modelling program	✓			
	- wetland mapping	✓			
	- marine water quality and ecosystem health monitoring and modelling.	✓			
Improve data and information management to support data sharing, assessment and reporting.	• A scoping document on information management needs and a review of existing systems by September 2009.	✓			
	• Improved information management system implemented by December 2009.		✓		

Figure 3.2 – Progress towards Reef Plan actions as at July 2010.

3.7 Paddock to Reef program

The Paddock to Reef program (Figure 3.3) has been established to measure progress towards Reef Plan's goals and targets. The program is an ambitious initiative that integrates multiple lines of evidence to directly link management practice change to water quality and ecosystem health. This program builds upon similar approaches around the world which have linked management practices to water quality improvement (e.g. Garbrecht and Starks, 2009; Cullum et al.,2006).

The Paddock to Reef program will detect changes in management practices and water quality at the end-of-catchment over short time frames (i.e. a few years). Detecting changes further downstream requires the ability to deal with lag times associated with the movement of pollutants from the paddock to the reef. It also requires the ability to deal with the high variability in the climate, both spatially across vast catchments, over time and between seasons. These challenges are currently addressed through a range of modelling and monitoring approaches.

Figure 3.3 – Conceptual model of the Paddock to Reef program showing the processes for monitoring, modelling and reporting on Reef Plan goals.

Linking management actions and water quality and ecosystem health can be achieved by modelling (supported by monitoring management practices and water quality) the pollutants from paddocks, transported downstream by rivers, delivered to estuaries and ultimately to coral reefs further offshore. This approach requires the ability to link the monitoring and modelling outputs at each scale and then across these scales. A range of modelling and monitoring tools and techniques have been identified and work programs developed for each of the following key components of the design:

- Management practice adoption—collecting management practice information over time for each main agricultural industry within each region will determine the extent of change in land management practices.
- Paddock monitoring and modelling—paddock monitoring, modelling and rainfall simulation monitoring will assess the water quality improvements from the adoption of management practices.
- Catchment indicators—a range of landscape attributes including groundcover, wetland and riparian areas have a significant influence on water quality. Remote sensing technologies are being used to measure status and change of these key catchment indicators.
- Catchment water quality—catchment monitoring and modelling activities will improve the ability to measure the change in water quality loads at sub-catchment and end-of-catchment scales.
- Marine—assessing the health of key marine ecosystems (inshore coral reefs and intertidal seagrasses) and the condition of water quality in the inshore Great Barrier Reef lagoon.

The key monitoring sites for the Paddock to Reef program are shown in Figure 2.1.

At the heart of the Paddock to Reef program is the philosophy of continuous improvement. To achieve this, the monitoring data that is collected will be used to continually improve the models. Similarly, research, development and innovation initiatives will be aligned to improve the methods and results of the program over time (Appendix 1).

3.8 Who is involved?

The Paddock to Reef program is a $35 million program over four years funded by the Australian and Queensland Governments. Implementation of the program is a collaborative effort between governments, key industry partners, research organisations, regional natural resource management bodies and individuals.

Key Partners:

Queensland Department of the Premier and Cabinet

Queensland Department of Environment and Resource Management

Queensland Department of Employment, Economic Development and Innovation

Great Barrier Reef Marine Park Authority

Australian Department of Sustainability, Environment, Water, Population and Communities

Contributors:

AgForce Queensland

Australian Centre for Tropical Freshwater Research

Australian Department of Agriculture, Fisheries and Forestry

Australian Institute of Marine Science

Bureau of Sugar Experiment Stations

Burnett Mary Regional Group

Canegrowers

Cape York Sustainable Futures

CSIRO

Fitzroy Basin Association

Growcom

Meat and Livestock Australia

NQ Dry Tropics

Queensland Farmers Federation

Reef and Rainforest Research Centre

Reef Catchments Natural Resource Management

Terrain Natural Resource Management

University of Maryland, United States of America

The University of Queensland

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.	• 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).	• 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.	• 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.	• 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): **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):** **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): **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):** **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:

A. Practices likely to maintain land in very good condition or improve land in lesser condition.
B. Practices likely to maintain land in good condition or improve land in lesser condition.
C. Practices that may maintain land in fair condition or gradually improve land in poor condition.
D. 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) 2 Dalrymple survey (Gordon et al., 2005) 3 Meat and Livestock Australia Report (Meat and Livestock Australia, 2010) 4 Belyando Suttor project (Nelson and Smith, 2005) 5 regional expert opinion 6 AgForce report (Vitelli M, 2010).	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.
Sugarcane Canegrowers	GBR-wide ABCD sugarcane management practice (Evans J, 2010)	1 various productivity board surveys 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.	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.
Horticulture Growcom	GBR-wide ABCD horticulture management practice framework (Wallace S, 2010)	1 Growcom Farm Management Systems 2 various regional surveys 3 Australian Bureau of Statistics survey 4 industry-wide expert opinion.	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.
Grains AgForce DEEDI		1 Grains BMP 2 ABS survey 3 industry-wide expert opinion.	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.

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 sythesise 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.

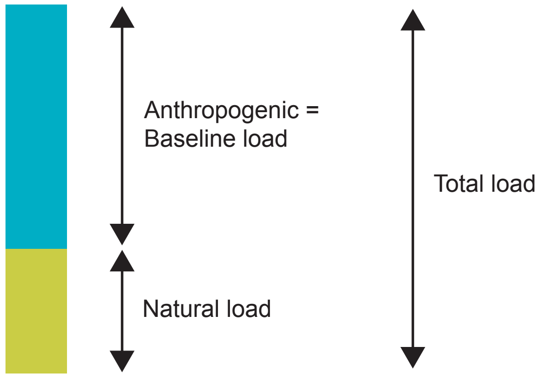


Figure 4.1 – How anthropogenic and natural load combine to form the total catchment load.

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.

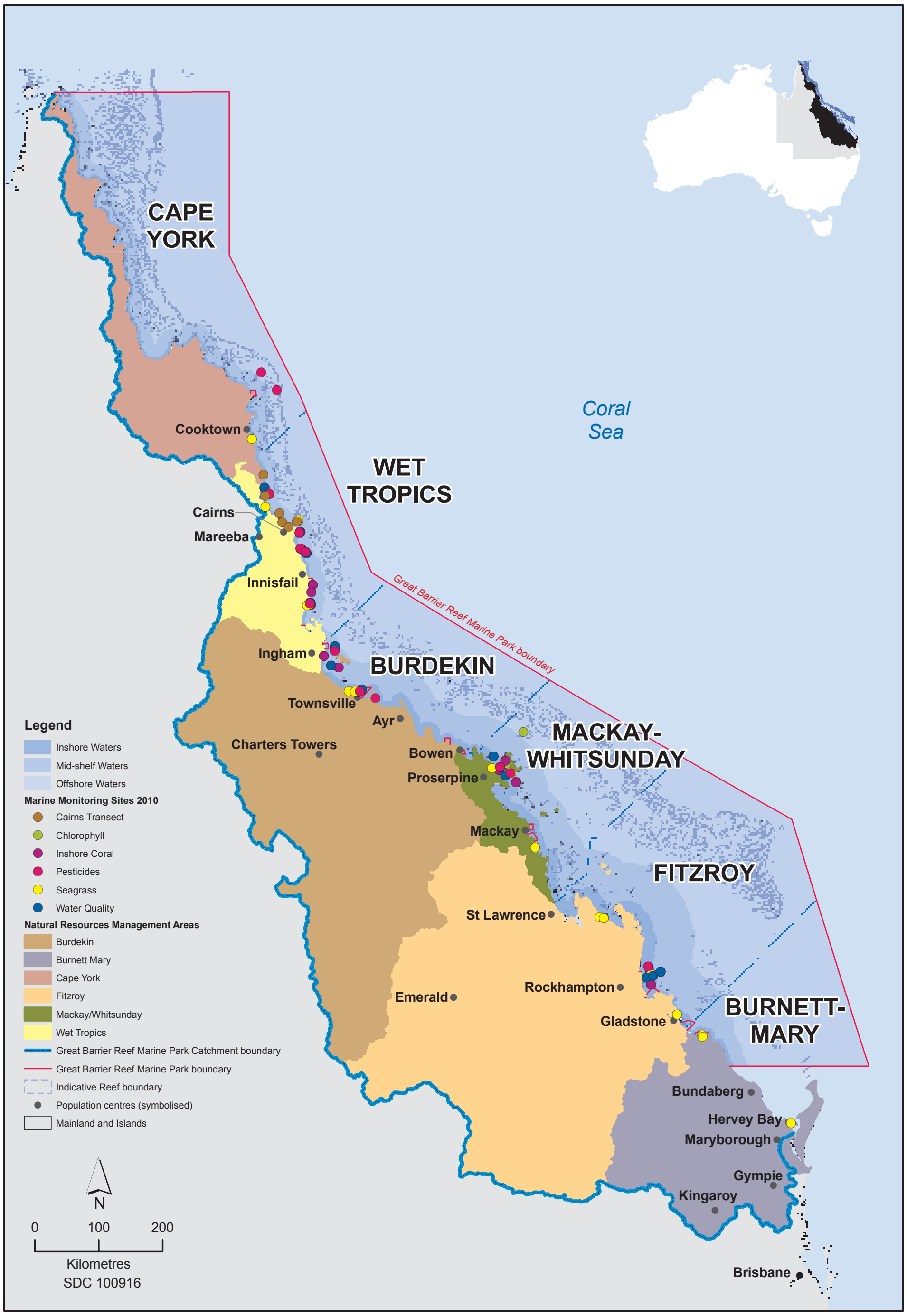


Figure 4.2 – The Great Barrier Reef World Heritage Area and marine monitoring sampling sites.

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.

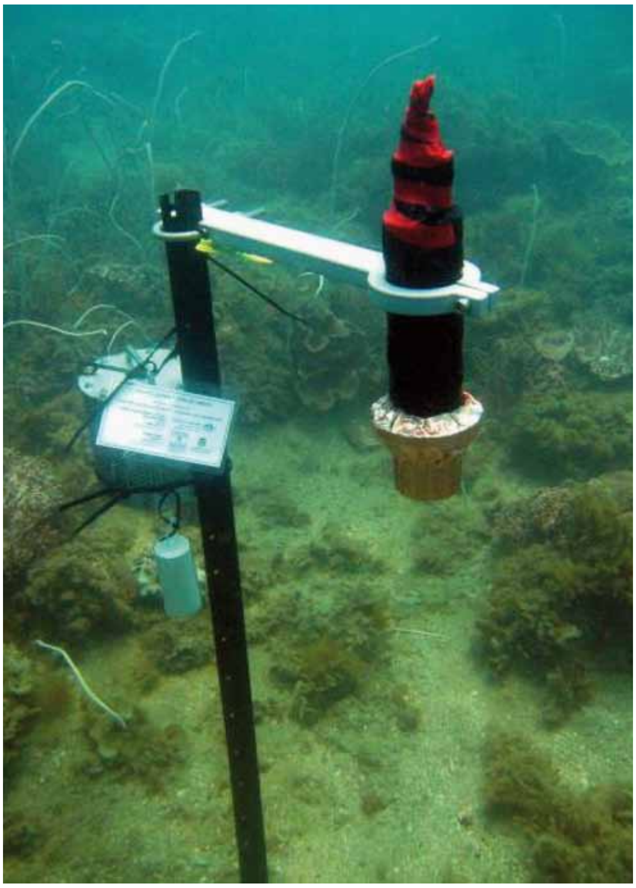


Figure 4.4 – WetLabs fluorometer water quality loggers are used for *in situ* marine water quality monitoring (Image: Australian Institute for Marine Science).

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.

Great Barrier Reef region

Chapter 5

"Scientific consensus is that the declining quality of water entering the Great Barrier Reef is a major threat to the inshore ecosystems."

Photo courtesy of Great Barrier Reef Marine Park Authority

5.1 Profile

There are 35 major creek or river catchments adjacent to the Great Barrier Reef, ranging from small tidal creeks to the largest river basins on Australia's east coast—the Fitzroy and Burdekin (Furnas, 2003). These catchments are spread across six natural resource management regions from Cape York in the north to the Burnett Mary region in the south.

Climate and soil characteristics vary across the catchments, and the interactions of soil types, topography and land use lead to substantial differences in the water quality discharged from wet catchment and dry catchment rivers (EPA, 2008). Major land uses in the Great Barrier Reef region are shown in Figure 5.1. Grazing is the dominant agricultural land use. Sugarcane and horticultural crops dominate in the high rainfall and coastal irrigation areas. Large sections of summer and winter rain-fed grain crops and irrigated cotton are prevalent in the inland areas of the Fitzroy region.

Although the coastal catchments adjacent to the Great Barrier Reef region are relatively sparsely populated and remote, extensive land modification has occurred over the past 200 years since European settlement (Furnas, 2003; Hutchings and Haynes, 2005). Recent science has highlighted the connection between expanding catchment activity in these adjacent catchments and declining water quality in the inshore waters of the Great Barrier Reef lagoon. Long term

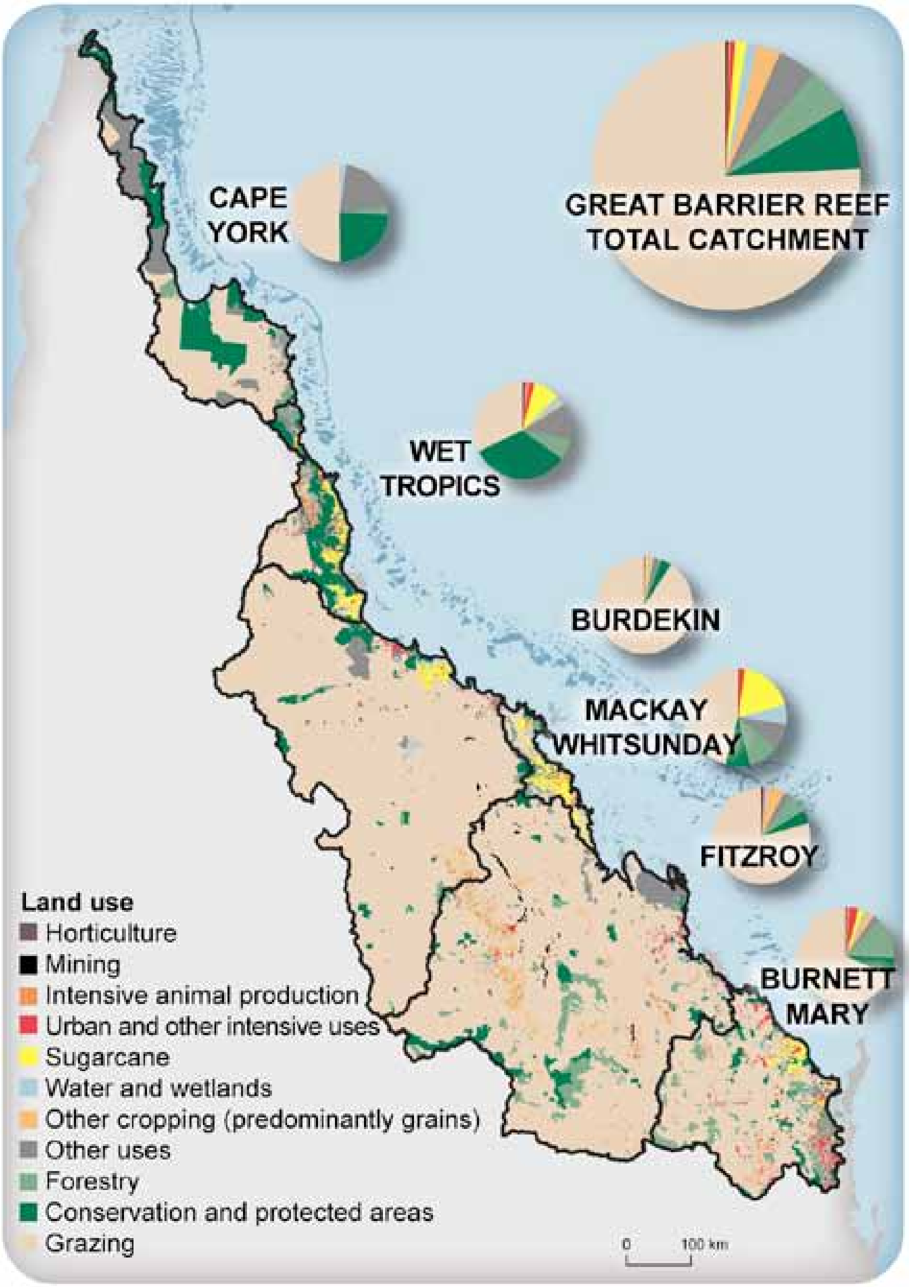
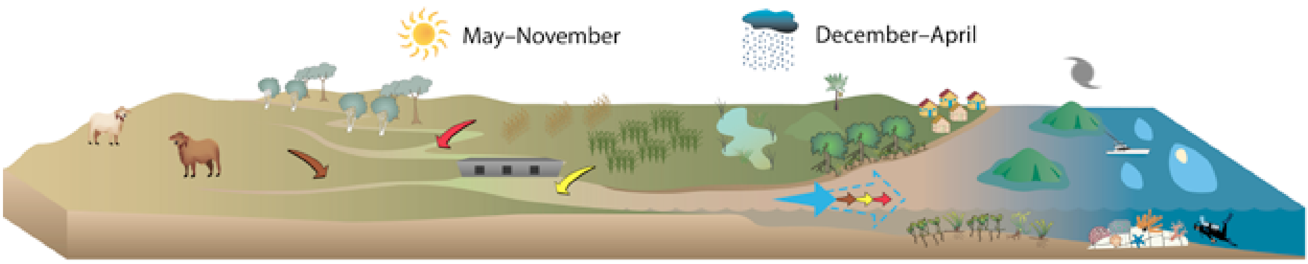


Figure 5.1 – Land use map of the Great Barrier Reef catchment.

monitoring and modelling has demonstrated that concentrations of nutrients are much higher in northern Queensland rivers adjacent to intensive agriculture than the relatively pristine rivers in Cape York (Mitchell et al., 2001); that sediment and nutrient exports to the Great Barrier Reef have increased significantly over the past 200 years (Furnas, 2003); and that flood events are critical in transporting these pollutants to the marine environment (Devlin et al., 2001). Monitoring has also shown that pesticides are being transported into river systems and the Great Barrier Reef at harmful concentrations during flood events (GBRMPA, 2009; Lewis et al., 2009). Inshore waters cover approximately eight per cent of the areas of the Great Barrier Reef Marine Park.

Scientific consensus is that the declining quality of water entering the Great Barrier Reef is a major threat to the inshore ecosystems (Department of the Premier and Cabinet, 2008). Figure 5.2 shows the key processes influencing water quality and ecosystem health in the Great Barrier Reef region. Flood events in the wet season deliver a large proportion of pollutants on to the Great Barrier Reef. Concentrations of dissolved inorganic nitrogen, dissolved inorganic phosphorus and suspended sediment are all many times higher during flood events than at other times and are well above natural loads.



The Great Barrier Reef catchments are largely rural and dominated by summer monsoonal rains and occasional cyclones delivering sediments, nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows, which can be affected by water reservoirs and dams. Grazing is the largest single land use, and sugarcane, horticulture and other cropping make up other agricultural land uses. Small urban centres are located on the coastal strip. Habitats include wetlands, reef, seagrass and mangrove habitats, and continental and coral islands are present. Reef-based tourism, as well as commercial and recreational fisheries, is an important part of the regional economy.

Figure 5.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Great Barrier Reef region.

5.2 Adoption of improved management practices

5.2.1 Results

- **Overall, cutting-edge (A) or best management (B) practices are used by 20 per cent of sugarcane growers, with 50 per cent using common (C) practices and 30 per cent using unacceptable (D) practices.**
- **Practices considered unacceptable by industry or community standards (D) are used by 34 per cent of sugarcane growers for nutrients.**
- **Fifty per cent of graziers across the Burdekin and Fitzroy regions are using (A or B) management practices that are likely to maintain land in good to very good condition or improve land in lesser condition.**
- **Twelve per cent of graziers in the Burdekin and Fitzroy regions are using (D) management practices that are likely to degrade land to poor condition.**
- **Overall, cutting-edge (A) or best management (B) practices for horticulture are used by 62 per cent of producers on 68 per cent of the land area.**
- **Practices considered unacceptable by industry or community standards (D) are used by 24 per cent of horticulture producers for nutrients, six per cent for herbicides and 11 per cent for soil.**

The adoption of improved management practices for sugarcane, horticulture and grains is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

5.2.2 Sugarcane

As at 2008–2009, there are 4252 landholders growing sugarcane on 5653 square kilometers of land within the Great Barrier Reef region. The overall management practices (including nutrient, herbicide and soil) are shown in Figure 5.3 and Table 5.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 20 per cent of sugarcane growers on 22 per cent of the land area. Code of practice or common practices (C) are used by 50 per cent of sugarcane growers. Practices considered unacceptable by industry and community standards (D) are used by 30 per cent of growers.

Cutting-edge (A) or best management (B) practices are used by 36 per cent of sugarcane growers for nutrients and 19 per cent for soil.

Practices considered unacceptable by industry or community standards (D) are used by 34 per cent of sugarcane growers for nutrients and 45 per cent for soil.

Cutting-edge (A) or best management (B) practices are used by only seven per cent of sugarcane growers for herbicides. The vast majority (85 per cent) are using practices for herbicides which are common practice or equivalent to code of practice (C). Practices considered unacceptable by industry or community standards (D) are used by only eight per cent of sugarcane growers for herbicides.

Table 5.1 – ABCD sugarcane management practices for the Great Barrier Reef region. (Source: modified from GHD, 2010a).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of cane growers	87	781	2145	1239
% of cane growers	2%	18%	50%	30%
Area (km²)	94	1149	2845	1564
% of area	2%	20%	50%	28%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	84	1427	1279	1462
% of cane growers	2%	34%	30%	34%
Area (km²)	113	2091	1583	1865
% of area	2%	37%	28%	33%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	51	252	3625	324
% of cane growers	1%	6%	85%	8%
Area (km²)	57	339	4805	452
% of area	1%	6%	85%	8%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	127	665	1530	1930
% of cane growers	3%	16%	36%	45%
Area (km²)	113	1017	2148	2374
% of area	2%	18%	38%	42%

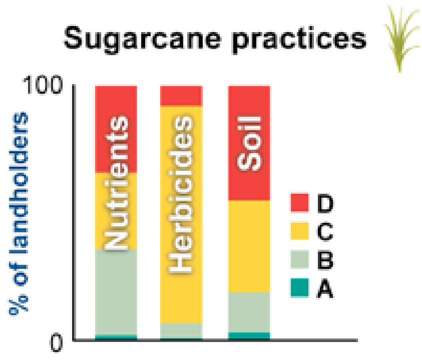


Figure 5.3 – Adoption of improved sugarcane management practices using the ABCD management framework for the Great Barrier Reef region.

5.2.3 Grazing

Within the combined Burdekin and Fitzroy regions there are an estimated 4418 landholders grazing cattle on 251,000 square kilometres of land.

Fifty per cent of graziers across the Burdekin and Fitzroy regions are using A or B management practices that are likely to maintain land in good to very good condition or improve land in lesser condition. Thirty-eight per cent of graziers in the combined regions are using (C) management practices that may maintain land in fair condition or gradually improve land in poor condition. Twelve per cent of graziers in the Burdekin and Fitzroy regions are using (D) management practices that are likely to degrade land to poor condition.

The Fitzroy region has 14 per cent of graziers using A practices compared to six per cent of graziers in the Burdekin region. A higher proportion of graziers in the Burdekin region are using C practices (49 per cent), compared to the Fitzroy region (35 per cent).

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

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

Table 5.2 – ABCD grazing management practices for the combined Burdekin and Fitzroy regions.

Combined Burdekin and Fitzroy regions	A practices	B practices	C practices	D practices
Number of graziers	542	1656	1672	548
% of graziers	12%	38%	38%	12%
Area (km²)	24,186	89,489	106,398	31,407

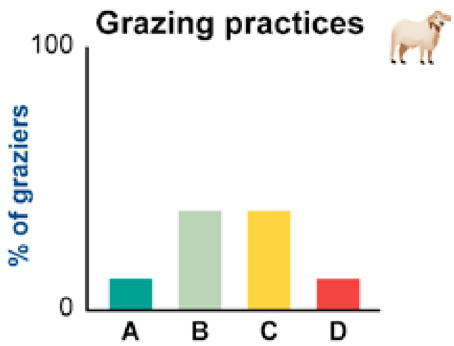


Figure 5.4 – Adoption of improved grazing management practices using the ABCD management framework for the Burdekin and Fitzroy regions.

5.2.4 Horticulture

There are approximately 970 producers growing horticultural crops on 668 square kilometres of land within the Great Barrier Reef region as at 2008–2009. The horticultural crops vary between regions, with major crops including bananas, paw paws, tomatoes, lychees, citrus, subtropical fruits and vegetables.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 5.3. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 62 per cent of producers. Code of practice or common (C) practices are used by 24 per cent of producers. Practices considered unacceptable by industry or community standards (D) are used by 14 per cent of producers.

Cutting-edge (A) or best management (B) practices are used by 39 per cent of horticulture producers for nutrients, 78 per cent for herbicides and 70 per cent for soil.

Practices considered unacceptable by industry or community standards (D) are used by 24 per cent of horticulture producers for nutrients, six per cent for herbicides and 11 per cent for soil.

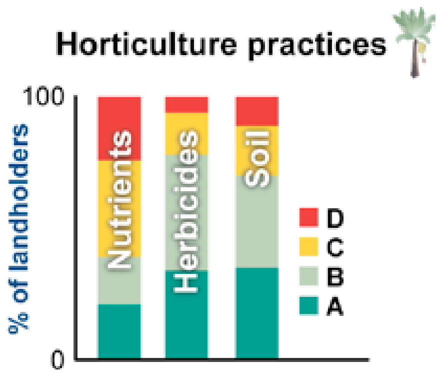


Figure 5.5 – Adoption of improved management practices for horticulture using the ABCD management framework for the Great Barrier Reef region.

The high adoption of A and B management practices in horticulture is most likely due to several factors. First, the Growcom Farm Management Systems database was the primary source of data used. This program is based on voluntary recruitment of horticultural growers, which possibly skews the results more toward A and B management. In addition, horticultural crops usually require precise management of nutrients and herbicides to achieve a profitable (i.e. marketable) crop. Also, achieving A and B soil management within horticultural tree crops, which by their nature are long term crops on permanent beds, is relatively easy to achieve.

Table 5.3 – ABCD horticulture management practices the Great Barrier Reef region. (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	292	314	233	131
% of horticulture producers	30%	32%	24%	14%
Area (km²)	227	228	141	72
% of area	34%	34%	21%	11%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	204	176	361	229
% of horticulture producers	21%	18%	37%	24%
Area (km²)	177	146	230	115
% of area	27%	22%	34%	17%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	323	428	157	62
% of horticulture producers	34%	44%	16%	6%
Area (km²)	276	283	77	32
% of area	41%	42%	12%	5%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture growers	347	338	181	104
% of horticulture producers	35%	35%	19%	11%
Area (km²)	228	256	116	68
% of area	35%	38%	17%	10%

5.3 Catchment indicators

5.3.1 Results

- **The total riparian area (area within 50 metres of the stream) in the Great Barrier Reef region as at 2008 is six million hectares, of which an estimated 100,000 hectares is likely to be susceptible to erosion (non-forested and low groundcover).**
- **There has been a loss of 30,000 hectares (0.49 per cent) of riparian vegetation between 2004 and 2008.**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangrove/salt flats) across the Great Barrier Reef region as at 2005 is 720,000 hectares. Wetland loss since pre-European times is 14 per cent.**
- **Wetland loss from 2001 to 2005 was 883 hectares with up to eight per cent loss of vegetated freshwater swamps in some catchments.**
- **Many smaller coastal catchments with extensive lowlands have undergone widespread loss of vegetated freshwater swamps with less than 20 per cent of these original wetlands remaining in some catchments.**
- **The 2009 mean dry season groundcover for the grazing lands of the Great Barrier Reef region is 84 per cent, which is above the Reef Plan target of 50 per cent. This is due to higher than the historical average rainfall across many grazing areas.**

5.3.2 Riparian vegetation

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.

There are six million hectares of riparian areas across the Great Barrier Reef catchments. There are high proportions of forest and groundcover over most of the catchments' riparian areas. As at 2008, 4.7 million hectares (77.6 per cent) of riparian areas are forested, 1.2 million hectares (19.8 per cent) are non-forested but have high groundcover and 100,000 hectares (1.7 per cent) were non-forested and have low groundcover. The non-forested and low groundcover areas are likely to be susceptible to erosion and therefore sediment loss to streams. The Burdekin and Fitzroy regions have a higher proportion of areas of low riparian groundcover compared with other regions with 2.8 per cent and 2 per cent respectively.

Generally, clearing of forested riparian areas has been low overall (less than one per cent). From 2004 to 2008, 30,000 hectares (0.49 per cent) of forested riparian areas were cleared in the Great Barrier Reef catchments. The greatest proportion of clearing of forested riparian areas between 2004 and 2008 occurred in the Burnett Mary (1 per cent), followed by the Fitzroy (0.7 per cent) and Mackay Whitsunday (0.6 per cent) regions. The Cape York region (0.03 per cent) followed by the Wet Tropics (0.17 per cent) sustained the least amount of clearing of forested riparian areas between 2004 and 2008.

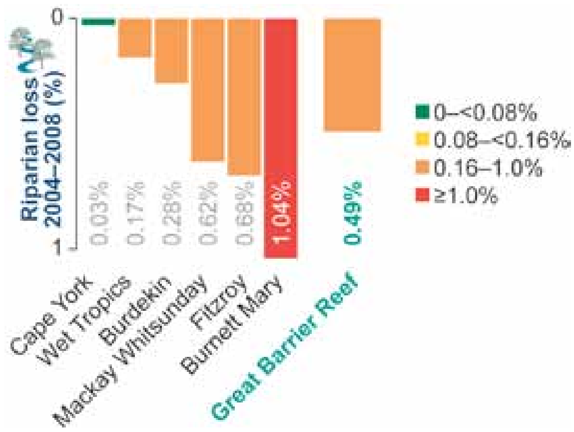


Figure 5.6 – Loss of forested riparian areas between 2004 and 2008 across the Great Barrier Reef regions.

Table 5.4 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (below 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Region	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Cape York	585,519	560,421	95.71	18,886	3.23	2083	0.34	0.71	198	0.03
Wet Tropics	469,606	426,772	90.88	36,361	7.74	1916	0.4	0.97	788	0.17
Burdekin	2,063,747	1,592,363	77.16	400,013	19.38	57,814	2.8	0.66	5834	0.28
Mackay Whitsunday	132,706	100,852	76.00	27,004	20.35	646	0.48	3.17	824	0.62
Fitzroy	1,881,612	1,331,269	70.75	496,123	26.37	38,237	2.03	0.85	12,702	0.68
Burnett Mary	879,403	651,410	74.07	210,841	23.98	3800	0.43	1.52	9185	1.04
Total Great Barrier Reef	**6,012,594**	**4,663,086**	**77.56**	**1,189,228**	**19.78**	**104,498**	**1.74**	**0.93**	**29,532**	**0.49**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

5.3.3 Wetlands

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

Wetland types

As at 2005, there are approximately 720,000 hectares of wetlands mapped, which is approximately 1.7 per cent of the total area of the Great Barrier Reef catchments. Of these wetland areas:

- 250,000 hectares are vegetated freshwater swamps (palustrine wetlands). These areas occur with the greatest density in the small coastal catchments with extensive lowlands such as the Jeannie, Proserpine, Shoalwater, Burrum and the Mulgrave to Murray catchments in the Wet Tropics.
- 23,000 hectares are lakes (lacustrine wetlands).
- 446,000 hectares are mangroves/salt flats (estuarine wetlands). These wetlands occur in the greatest density in catchments such as the Jeannie, Johnstone, Haughton, O'Connell and Styx.

Extent of wetlands compared to pre-European times

Overall, 86 per cent of the total pre-European extent of wetlands remain across the Great Barrier Reef region. In terms of specific wetland types, 75 per cent of the pre-European extent of vegetated freshwater swamps remain across the Great Barrier Reef catchments. Loss of these vegetated freshwater swamps since pre-European times has been high in the Wet Tropics and Mackay Whitsunday regions, with 51 per cent and 47 per cent lost respectively. Many smaller coastal catchments with extensive lowlands have undergone widespread loss of freshwater swamps with greater than 80 per cent lost in catchments such as the Kolan, Pioneer, Calliope and Barron. This loss of wetlands has mainly occurred due to drainage, clearing and levelling of lowlands and parts of catchments associated with intensive agriculture. Over 90 per cent of pre-European mangroves and salt flats remain in most catchments, with the exception of the Burnett (78 per cent), Barron (71 per cent) and Pioneer (80 per cent). The Cape York (nil) and Burdekin (nine per cent) regions have had the least amount of wetlands lost since pre-European times.

Generally, there has been no great reduction in lakes compared to their pre-European extent while there has been a slight increase in lakes extent over the 2001–2005 period.

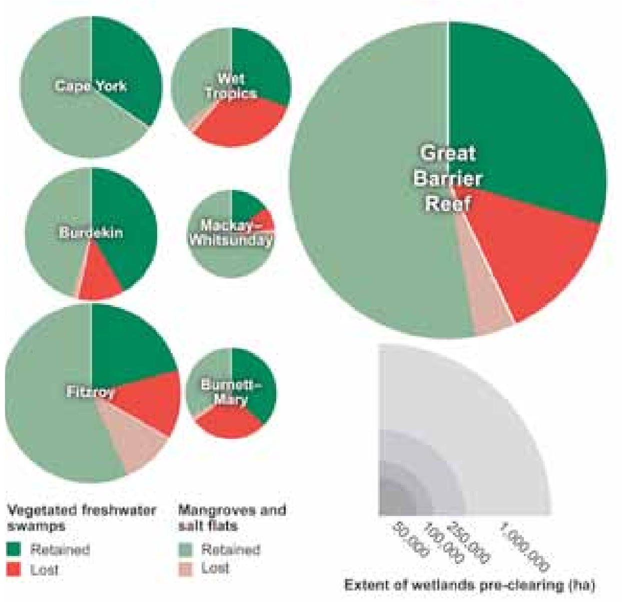


Figure 5.7 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent.

Wetlands loss from 2001 to 2005

The combined loss of vegetated freshwater swamps and mangroves/salt flats between 2001 and 2005 was 0.12 per cent (over 800 hectares) across the Great Barrier Reef catchments. The loss of vegetated freshwater swamps between 2001 and 2005 was 0.27 per cent (approximately 640 hectares). There was a loss of vegetated freshwater swamps of greater than one per cent in the Kolan, Mossman, Mary and Murray catchments between 2001 and 2005. There was little reduction in the extent of mangroves and salt flats between 2001 and 2005.

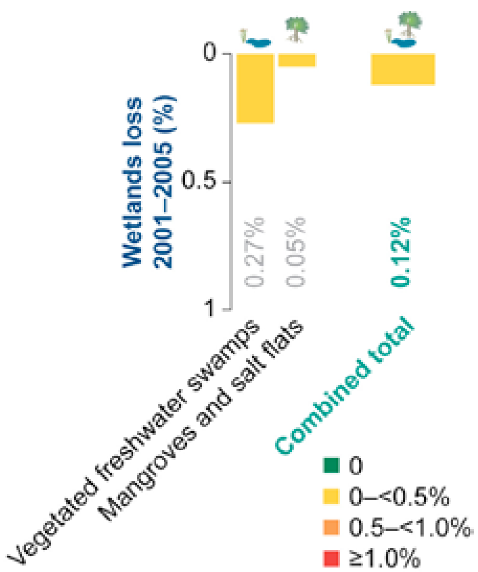


Figure 5.8 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Great Barrier Reef region.

Table 5.5 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Great Barrier Reef catchments for lakes, vegetated freshwater swamps and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Region	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Cape York	59,135	100	0	6420	98	0	110,940	100	0	176,495	100	0
Wet Tropics	36,735	49	0.63	770	100	0	43,325	93	0.08	80,830	66	0.33
Burdekin	61,875	80	0.13	8180	99	0	66,855	98	0.03	136,910	91	0.07
Mackay Whitsunday	9695	53	0.05	205	100	0	47,780	96	0.02	57,680	88	0.03
Fitzroy	57,280	78	0.23	6965	88	-0.17	154,010	85	0.09	218,255	83	0.12
Burnett Mary	26,210	58	0.69	360	73	-7.04	23,385	95	0.05	49,955	70	0.36
Total Great Barrier Reef	**250,930**	**75**	**0.27**	**22,898**	**96**	**-0.1**	**446,295**	**93**	**0.05**	**720,125**	**86**	**0.12**

Note: The figures reported here pre-date the cessation of broad scale clearing of vegetation under the *Vegetation Management Act 1999* that occurred in December 2006 and the introduction of a State Planning Policy in 2010 to control earth works in wetlands of the region.

5.3.4 Groundcover in grazing lands

Groundcover was assessed in the grazing lands of the following areas:

- Burnett Mary
- Burdekin
- Fitzroy
- Herbert Catchment (in the Wet Tropics)
- Mackay Whitsunday.

Groundcover estimates can only be calculated for grazing lands with a foliage projective cover of less than 15 per cent. Foliage projective cover is defined as the percentage of ground area occupied by the vertical projection of foliage. This corresponds to 63 per cent of the grazing lands of the Great Barrier Reef catchments.

Late dry season groundcover

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. Groundcover is influenced by a combination of factors including land use, land type, management practices and changes in climate.

The long term mean dry season groundcover for the grazing lands of the Great Barrier Reef catchments over the 1986–2009 period was 79 per cent, which is above the Reef Plan target of 50 per cent. The average groundcover in 2009 was higher than the historical average, increasing to 84 per cent. It is believed that this is a result of a number of recent wet years that have contributed to improved groundcover. However, the proportion of the grazing area with groundcover of 50 per cent or greater in 2009 was similar to the long term mean (95 per cent).

Despite the generally higher cover, it appears that areas with low cover (less than 30 per cent) have increased in 2009, with 1.6 per cent coverage compared to the long term mean of one per cent. This is accompanied by a reduction in areas with medium groundcover (over 30 per cent and below 50 per cent) in 2009 with three per cent compared to the long term mean of 3.7 per cent. The Burdekin region had the greatest area below the 50 per cent groundcover target in 2009, with 6.3 per cent of the area below 50 per cent, including 2.3 per cent of the area below 30 per cent groundcover. A reduction in the area with groundcover over 30 per cent and below 50 per cent occurred in 2009 with three per cent compared to the long term mean of 3.7 per cent for grazing lands across the Great Barrier Reef. This may be the result of locally increased grazing activities but could also be related to flood-induced reduction in groundcover.

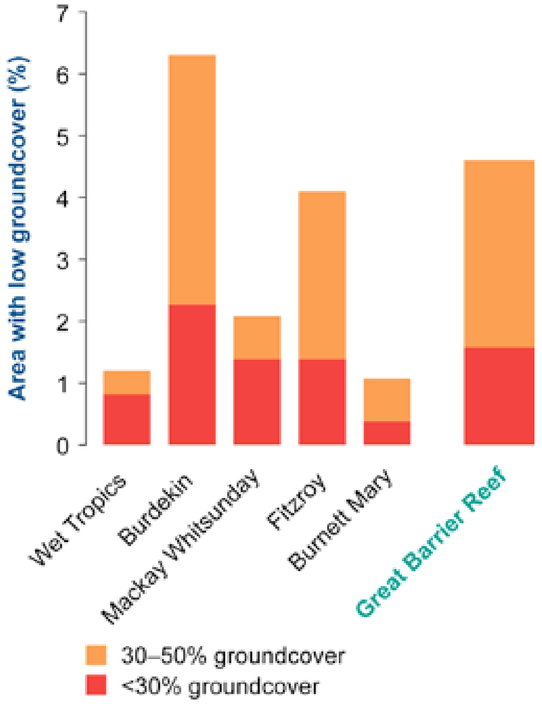


Figure 5.9 – Area with low groundcover (below 30 per cent and between 30 per cent and 50 per cent) for the Great Barrier Reef region and each dryland grazing area as at 2009.

Table 5.6 – Long term mean late dry season groundcover and 2009 groundcover showing the percentage of area below 30 per cent, 30 per cent to 50 per cent, and above 50 per cent for the regions and catchments.

Region	Total catchment area (km²)	Foliage projective cover < 15% (% of catchment)	Grazing (% of catchment)	Foliage projective cover < 15% grazing (% of grazing)	Long term mean groundcover index (%)	2009 groundcover index	Long term mean groundcover index (%)			Groundcover index 2009 (%)		
							Area < 30%	Area ≥ 30% < 50%	Area ≥ 50%	Area < 30%	Area ≥ 30% < 50%	Area ≥ 50%
Wet Tropics (Herbert catchment only)	9844	15.9	57.4	10.4	93.4	95.1	0.3	0.2	99.5	0.8	0.4	98.9
Burdekin	140,671	43.5	90.7	48.6	74.7	82.8	1.7	5.4	92.9	2.3	4.0	93.7
Mackay Whitsunday	8990	35.6	45.8	29.6	89.9	93.2	0.4	0.7	98.9	1.4	0.7	97.9
Fitzroy	155,741	50.6	79.1	55.0	79.4	82.5	0.7	3.0	96.3	1.4	2.7	95.9
Burnett Mary	53,024	34.2	69.4	41.3	87.5	92.3	0.1	0.6	99.3	0.4	0.7	98.9
Total Great Barrier Reef	**368,270**	**49.9**	**80.8**	**49.4**	**78.6**	**84.0**	**1.0**	**3.7**	**95.3**	**1.6**	**3.0**	**95.4**

5.4 Catchment loads

The baseline loads of total suspended solids, nitrogen, phosphorus and pesticides at the end of the catchment are estimated for individual regions and totalled for the Great Barrier Reef region, using monitoring and modelling data (Kroon et al., 2010). The load estimates are derived from an understanding of the land use and management practices from the period preceding Reef Plan 2009. The loads are presented as long term averages to account for the significant variability in the magnitude of flow events for a given river from year to year.

In future annual reports the baseline load estimates will be refined by using the latest 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 future climatic and management scenarios.

5.4.1 Results

- **Although natural catchment loads occur, most of the loads to the Great Barrier Reef are from human activities.**
- **Annual total suspended solid loads are 17 million tonnes, of which 14 million tonnes are from human activity.**
- **The largest contribution of total suspended sediment load is from the Burdekin and the Fitzroy regions (4.7 and 4.1 million tonnes respectively), mainly derived from grazing lands.**
- **Agricultural fertiliser use is a key source of dissolved nitrogen and phosphorus runoff; annual loads of dissolved nitrogen are 31,000 tonnes of which 17,500 tonnes are from human activity.**
- **The highest total load of dissolved nitrogen is from the Wet Tropics region with 11,000 tonnes per year, of which 6300 tonnes are from human activity.**
- **All pesticides are from human activities. The total annual pesticide loads are approximately 28,000 kilograms and the highest loads are from the Mackay Whitsunday and Wet Tropics regions (approximately 10,000 kilograms each per year).**

5.4.2 Baseline catchment loads

The total loads leaving the catchments are significantly higher than in pre-European times (natural loads) (Kroon et al. 2010). The increase in loads due to human activity (anthropogenic loads) differs significantly across the load indicators and regions, reflecting local and regional differences in catchment land use and management, as well as local and regional topography, soil characteristics and rainfall.

The estimated total suspended solids load leaving the Great Barrier Reef catchments is 17 million tonnes per year, of which 14 million tonnes are from human activity. Most sediment originates from the extensive grazing lands of the dry (Burdekin and Fitzroy) catchments. The regions with the highest total suspended solids load are the Burdekin (4.7 million tonnes per year) and the Fitzroy (4.1 million tonnes per year). The regions with the highest proportional increase compared to natural loads are the Burnett Mary (12 times the natural loads) and Burdekin (eight times the natural loads).

The estimated total nitrogen load leaving the Great Barrier Reef catchments is 80,000 tonnes per year, of which 66,000 tonnes are from human activity. The total nitrogen loads are similar across all regions apart from the Mackay Whitsunday region, which is lower. The regions with the highest proportional increase compared to natural loads are the Burnett Mary, Fitzroy and Mackay Whitsunday (all with approximately nine times the natural loads).

The estimated total phosphorus load leaving the Great Barrier Reef catchments is 16,000 tonnes per year, of which 14,000 tonnes are from human activity. The regions with the highest total phosphorus load are the Fitzroy (4100 tonnes per year) and the Burnett Mary regions (3100 tonnes per year). The regions with the highest proportional increase compared to natural loads are the Fitzroy (21 times the natural loads), Burnett Mary (15 times the natural loads), and Mackay Whitsunday (15 times the natural loads).

The estimated load of dissolved nitrogen leaving the Great Barrier Reef catchments is 31,000 tonnes per year, of which 17,000 tonnes are from human activity. The highest total load of dissolved nitrogen comes from the Wet Tropics region with 11,000 tonnes per year, of which 6300 tonnes are from human activity. The region with the highest proportional increase compared to natural loads is the Mackay Whitsunday region (four times the natural loads).

The estimated load of dissolved phosphorus leaving the Great Barrier Reef catchments is 2100 tonnes per year, of which 1300 tonnes per year are from human activity. The highest loads of dissolved phosphorus comes from the Wet Tropics region with 530 tonnes per year, of which 225 tonnes are from human activity. The region with the highest proportional increase compared to natural loads is the Mackay Whitsunday region (six times the natural loads).

The total photosystem inhibiting (PSII) pesticide load leaving the Great Barrier Reef catchments is an estimated 28,000 kilograms per year. Pesticides do not occur naturally in the environment, therefore this load is entirely from human activity. The highest estimated pesticide load is in the Wet Tropics and Mackay Whitsunday regions, each with 10,000 kilograms per year leaving the catchment. Of the pesticide residues most commonly found in surface waters in the Great Barrier Reef region, diuron, atrazine, ametryn and hexazinone derive largely from areas of sugarcane cultivation, while tebuthiuron is derived from rangeland beef grazing areas (Lewis et al., 2009). It is important to note that this estimate does not include several land uses known to leak photosystem inhibiting (PSII) pesticides (e.g. grazing, forestry, cotton, urban) and non-photosystem inhibiting (PSII) pesticides, indicating that the total pesticide pollutant load to the Great Barrier Reef is likely to be higher.

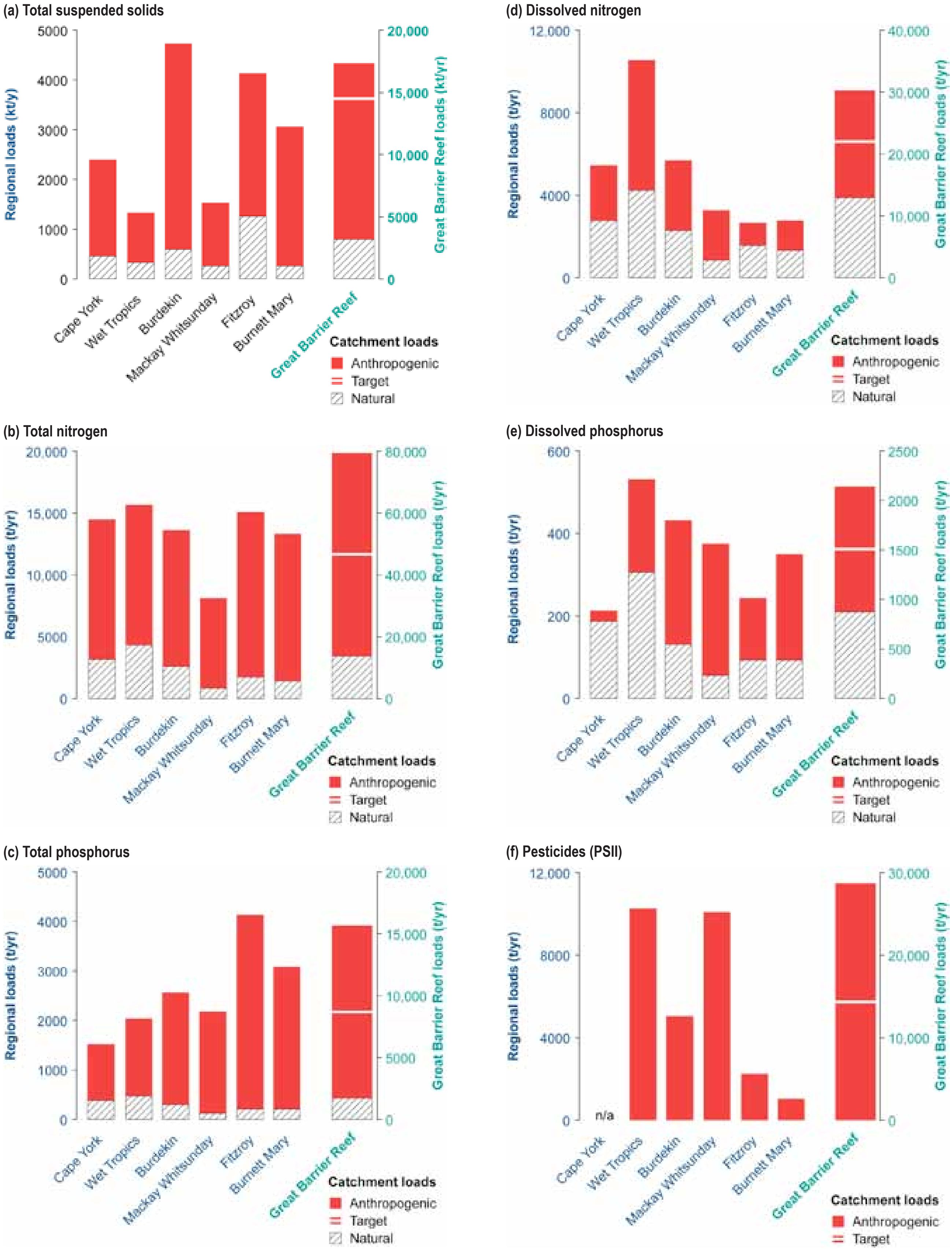
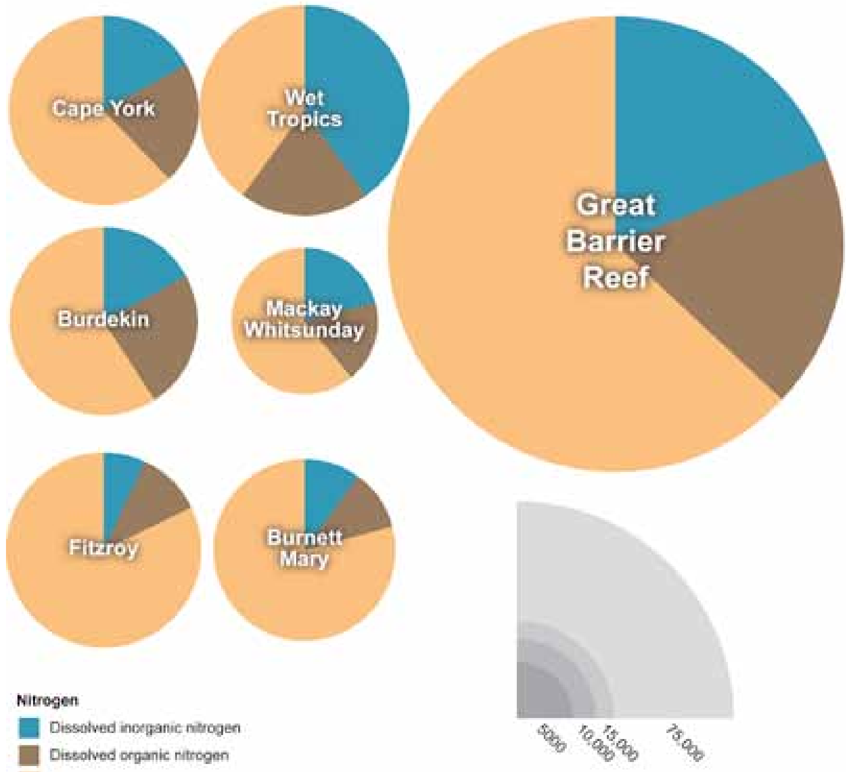


Figure 5.10 – Total and anthropogenic (caused by human activity) pollutant load estimates for the Great Barrier Reef and regions for (a) total suspended solids, (b) total nitrogen, (c) total phosphorus, (d) dissolved nitrogen, (e) dissolved phosphorus and (f) pesticides.



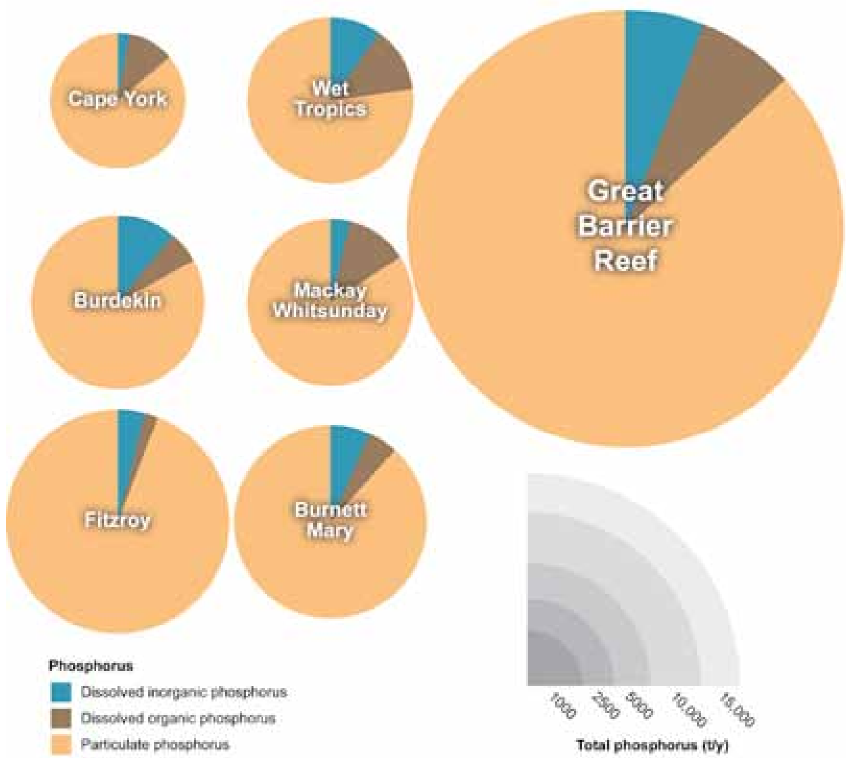


Figure 5.11 – The proportion of dissolved inorganic, dissolved organic and particulate forms of nitrogen and phosphorus leaving the Great Barrier Reef catchments.

Table 5.7 – Total and anthropogenic (caused by human activity) pollutant load estimates for the Great Barrier Reef and regions.

Catchment loads		Region						Total Great Barrier Reef
		Cape York	Wet Tropics	Burdekin	Mackay Whitsunday	Fitzroy	Burnett Mary	
TSS (kilotonnes/yr)	Natural	444	302	596	248	1259	263	**3112**
	Anthropogenic	1944	1058	4142	1294	2850	2813	**14,101**
	Total	2388	1360	4738	1542	4109	3076	**17,213**
TN (tonnes/yr)	Natural	2998	4400	2446	912	1672	1463	**13,891**
	Anthropogenic	11,340	11,176	11,139	7180	13,454	11,700	**65,989**
	Total	14,338	15,576	13,585	8092	15,126	13,163	**79,880**
DIN (tonnes/yr)	Natural	1281	1109	1096	387	770	660	**5303**
	Anthropogenic	1135	5972	1235	1359	337	699	**10,737**
	Total	2416	7081	2331	1746	1107	1359	**16,040**
DON (tonnes/yr)	Natural	1539	3138	1155	477	800	720	**7829**
	Anthropogenic	1518	350	2263	1093	785	729	**6738**
	Total	3057	3488	3418	1570	1585	1449	**14,567**
PN (tonnes/yr)	Natural	178	153	195	48	102	83	**759**
	Anthropogenic	8687	6872	8129	5164	12,332	10,272	**51,456**
	Total	8865	7025	8324	5212	12,434	10,355	**52,215**
DIN + DON (tonnes/yr)	Natural	2820	4247	2251	864	1570	1380	**13,132**
	Anthropogenic	2653	6322	3498	2452	1122	1428	**17,475**
	Total	5473	10,569	5749	3316	2692	2808	**30,607**
TP (tonnes/yr)	Natural	380	499	319	150	197	203	**1748**
	Anthropogenic	1136	1538	2236	2022	3945	2889	**13,766**
	Total	1516	2037	2555	2172	4142	3092	**15,514**
DIP (tonnes/yr)	Natural	48	88	20	14	13	23	**206**
	Anthropogenic	6	136	262	70	146	186	**806**
	Total	54	224	282	84	159	209	**1012**
DOP (tonnes/yr)	Natural	142	221	113	44	78	69	**667**
	Anthropogenic	19	89	38	244	8	72	**470**
	Total	161	310	151	288	86	141	**1137**
PP (tonnes/yr)	Natural	190	190	186	92	106	111	**875**
	Anthropogenic	1111	1573	1882	1841	3791	2631	**12,829**
	Total	1301	1763	2068	1933	3897	2742	**13,704**
DIP + DOP (tonnes/yr)	Natural	190	309	133	58	91	92	**873**
	Anthropogenic	25	225	300	314	154	258	**1276**
	Total	215	534	433	372	245	350	**2149**
PSII (kg/yr)	Natural	0	0	0	0	0	0	**0**
	Anthropogenic	ND	10,054	4911	10,019	2269	990*	**28,243**
	Total	ND	10,054	4911	10,019	2269	990*	**28,243**

TSS – total suspended solids, TN – total nitrogen, DIN – dissolved inorganic nitrogen, DON – dissolved organic nitrogen, PN – particulate nitrogen, TP – total phosphorus, DIP – dissolved inorganic phosphorus, DOP – dissolved organic phosphorus, PP – particulate phosphorus, PSII – photosystem (PSII) inhibiting herbicides.

ND – denotes lower than detectable.
*Note: this load is based upon previous pesticide estimates compared to the other regions which use 2009 estimates.

5.5 Great Barrier Reef water quality and ecosystem health

Waters within 20 kilometres of the shore are at highest risk of degraded water quality. These waters are only approximately eight per cent of the Great Barrier Reef Marine Park, but support significant ecosystems as well as recreation, tourism and fisheries.

5.5.1 Results

- **Significant rainfall events occurred between 2007 and 2009, which affected salinity levels, leading to localised coral bleaching and coral death on shallow, inshore reefs between Cairns and Townsville. Water temperatures were elevated for short periods but not long enough to sustain any widespread bleaching episodes.**
- **Inshore water quality is moderate overall. Concentrations of total suspended solids range from poor (Burdekin and Mackay Whitsunday regions) to very good (Burnett Mary region).**
- **Pesticides have been detected at all 13 inshore Great Barrier Reef monitoring sites over the past five years of monitoring. Overall concentrations were lowest in the Fitzroy region and highest in the Wet Tropics region.**
- **Monitoring during flood events over the past five years has detected pesticide concentrations above the guidelines at least 25 kilometres from the mouth of the Pioneer and O'Connell Rivers. Concentrations that may have short term effects on the health of marine plants have also been detected up to 50 kilometres from the coast.**
- **Inshore seagrasses are in moderate condition overall. Seagrass abundance is moderate and has declined over the past five to 10 years, associated with excess nutrients. The number of reproductive structures is poor or very poor in four of the six regions, indicating limited resilience to disturbance.**
- **Most inshore reefs are in good or moderate condition based on coral cover, macroalgal abundance, settlement of local corals and numbers of juvenile corals. Most inshore reefs have either high or increasing coral cover. However, corals in the Burdekin region are mostly in poor condition and have shown little recovery in the past four years.**

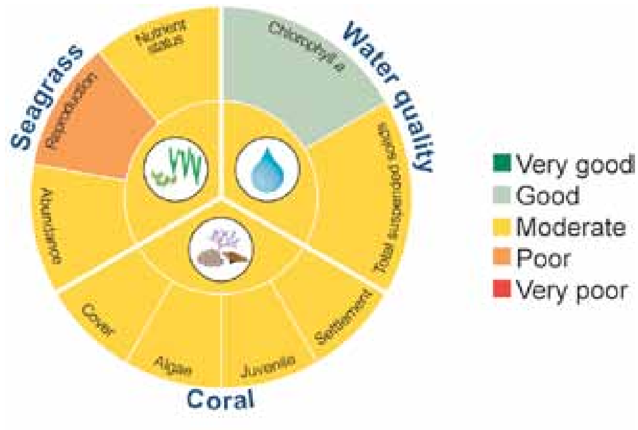


Figure 5.12 – Water quality and ecosystem health of the Great Barrier Reef showing the status of water quality, seagrass and corals.

5.5.2 Water quality

Water quality: river flow and flood extent

The 2007–2009 period was unusual with regards to river flows in the Great Barrier Reef catchments. In 2007–2008, both the Burdekin and Fitzroy Rivers experienced extensive flooding, and the Burdekin River flooded again over the 2008–2009 wet season. In contrast, during the same two-year period, rivers of the Wet Tropics and Mackay Whitsunday regions (with the exception of the Herbert River) only experienced slightly above-average flow conditions without significant flooding occurring (Table 5.8). Freshwater discharge from the Great Barrier Reef catchments in 2008–2009 was two times the annual median flow, with the flow in the Burdekin River more than five times the annual median flow. The Herbert River was more than three times the annual median flow. Flow peaked in all Great Barrier Reef rivers between mid-February and mid-March 2009.

Flood plume movement across Great Barrier Reef marine waters is a consequence of the volume and duration of river (flood) flows, wind direction and velocity, as well as local marine current and tidal dynamics. Over the 2008–2009 wet season, flood plumes extended across inshore waters of the southern and northern Great Barrier Reef, but had a more limited influence on far northern Great Barrier Reef waters. Flood plumes lowered local water salinity and were associated with severe stress and localised coral bleaching and death on shallow, inshore reefs between Cairns and Townsville. While these impacts are serious for affected reefs, damage from floodwaters was relatively minor on a reef-wide scale.

Tropical Cyclone Hamish, a category five system, tracked down the reef between 5 and 11 March 2009. Tropical Cyclone Hamish resulted in highly destructive winds over extensive offshore areas in the central to southern Great Barrier Reef. Although damage was reported reef-wide, the most severe damage occurred south of the Whitsunday group of islands. Most reef damage was sustained within 30 kilometres of the cyclone eye track. Within this area, damage was often severe on several sides of the reef, although most damage occurred on exposed windward sides of affected reefs. However, even on severely damaged reefs, pockets of untouched reef often remained. Scouring (tissue stripped off coral), coral breakage and macroalgal blooms were the most common type of impact caused by the cyclone.

Water quality: water temperature

Extreme sea surface temperatures occurred in Great Barrier Reef waters during November and December 2008; however, prolonged monsoonal conditions from January 2009 onwards to the end of the wet season reduced temperature stress across most of the reef, keeping water temperatures below coral bleaching thresholds. As a result, mass coral bleaching did not occur over the 2008–2009 wet season, and only localised, minor temperature-induced bleaching was observed on reefs in the northern half of the Great Barrier Reef Marine Park.

Table 5.8 – Annual freshwater discharge (in megalitres) for major Great Barrier Reef catchment rivers in 2008–2009. The median and mean annual flow is estimated from available long term time series for each river. Data was supplied by the Department of Environment and Resource Management. Long term medians were estimated from annual total flows (October to September).

Region	River	Long term river discharge median (ML)	Long term river discharge mean (ML)	Total year discharge 2008–2009 (ML)	Difference between 2008–2009 flow and long term median (ML)	Relative magnitude between 2008–2009 flow and long term median
Cape York	Normanby	3,550,421	3,707,007	2,338,784	-1,211,637	0.66
Wet Tropics	Barron	692,447	795,275	779,456	87,009	1.13
	Mulgrave	719,625	743,399	688,515	-31,110	0.96
	Russell	1,049,894	1,051,743	1,212,230	162,337	1.16
	North Johnstone	1,845,338	1,797,648	1,986,776	141,438	1.08
	South Johnstone	810,025	801,454	1,043,893	233,868	1.29
	Tully	3,128,458	3,175,298	3,759,051	630,593	1.20
	Herbert	3,122,768	3,492,135	9,606,409	6,483,641	3.08
Burdekin	Burdekin	5,957,450	9,575,660	30,110,062	24,152,612	5.05
Mackay Whitsunday	Proserpine	35,736	70,568	63,263	27,527	1.77
	O'Connell	148,376	201,478	167,586	19,211	1.13
	Pioneer	731,441	648,238	931,808	200,367	1.27
	Plane	112,790	154,092	188,195	75,405	1.67
Fitzroy	Fitzroy	2,708,440	4,461,132	2,193,040	-515,400	0.81
Burnett	Burnett	147,814	217,511	12,079	-135,735	0.08
Total		**24,761,023**	**30,892,638**	**55,081,147**	**30,320,124**	**2.22**

Water quality: chlorophyll *a* and suspended solids

Chlorophyll *a* is used as an indicator of nutrient loads in the marine system. Data analysed from satellite imagery showed that inshore waters in the Wet Tropics and Burdekin regions had elevated concentrations of chlorophyll *a* over the monitoring period (Table 5.9).

The satellite data also showed that highest concentrations of suspended solids were recorded at inshore areas of the Cape York, Burdekin and Mackay Whitsunday regions. High concentrations of suspended solids were also recorded in midshelf and offshore waters in the Mackay Whitsunday region. It should be noted that the Cape York remote sensed water quality data requires further validation.

Table 5.9 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter as a measure of suspended solids using remote sensing data (retrieved from MODIS AQUA) for the inshore, midshelf and offshore waterbodies (1 May 2008–30 April 2009).

	Chlorophyll *a*: relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			Suspended solids: relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Region	Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
Cape York	41	2	0	55	39	13
Wet Tropics	57	9	0	41	13	12
Burdekin	54	1	0	65	5	3
Mackay Whitsunday	24	3	0	74	42	50
Fitzroy	35	2	0	35	2	0
Burnett Mary	27	2	0	13	2	3

Water quality: pesticides

Over the past five years of monitoring, time-integrated passive samplers have detected pesticides at all 13 inshore Great Barrier Reef monitoring sites. There are often clear differences in the types of pesticides detected between regions, which are often related to the type of agriculture practised (and types of pesticide applied) in adjacent catchments. Pesticides typically detected at inshore reef sites along the north Queensland coast include diuron, atrazine and hexazinone (Figure 5.13). Other chemicals detected regularly include simazine and tebuthiuron. Diuron is usually detected at the highest concentrations at most monitored sites, and concentrations of detectable pesticides are typically one to two orders of magnitude higher in the wet season compared with samples collected in the dry season. Pesticide monitoring in 2008–2009 detected average concentrations of pesticides below the guidelines at all monitored inshore reef sites, with clear differences between regions. Overall, average water concentrations of pesticides were lowest in the Fitzroy region (typically below two nanograms per litre) and highest in the Wet Tropics region, where the maximum average water concentrations of individual pesticides ranged from 2 to 15 nanograms per litre.

Although time-integrated passive samplers generally detect pesticide concentrations below ecosystem protection guidelines, spot sampling during flood events has detected concentrations above guidelines and above known effect concentrations (sublethal photosystem inhibition) for some organisms.
The following case study discusses the results for flood plume monitoring conducted in the Mackay Whitsunday region (Lewis et al., 2009).

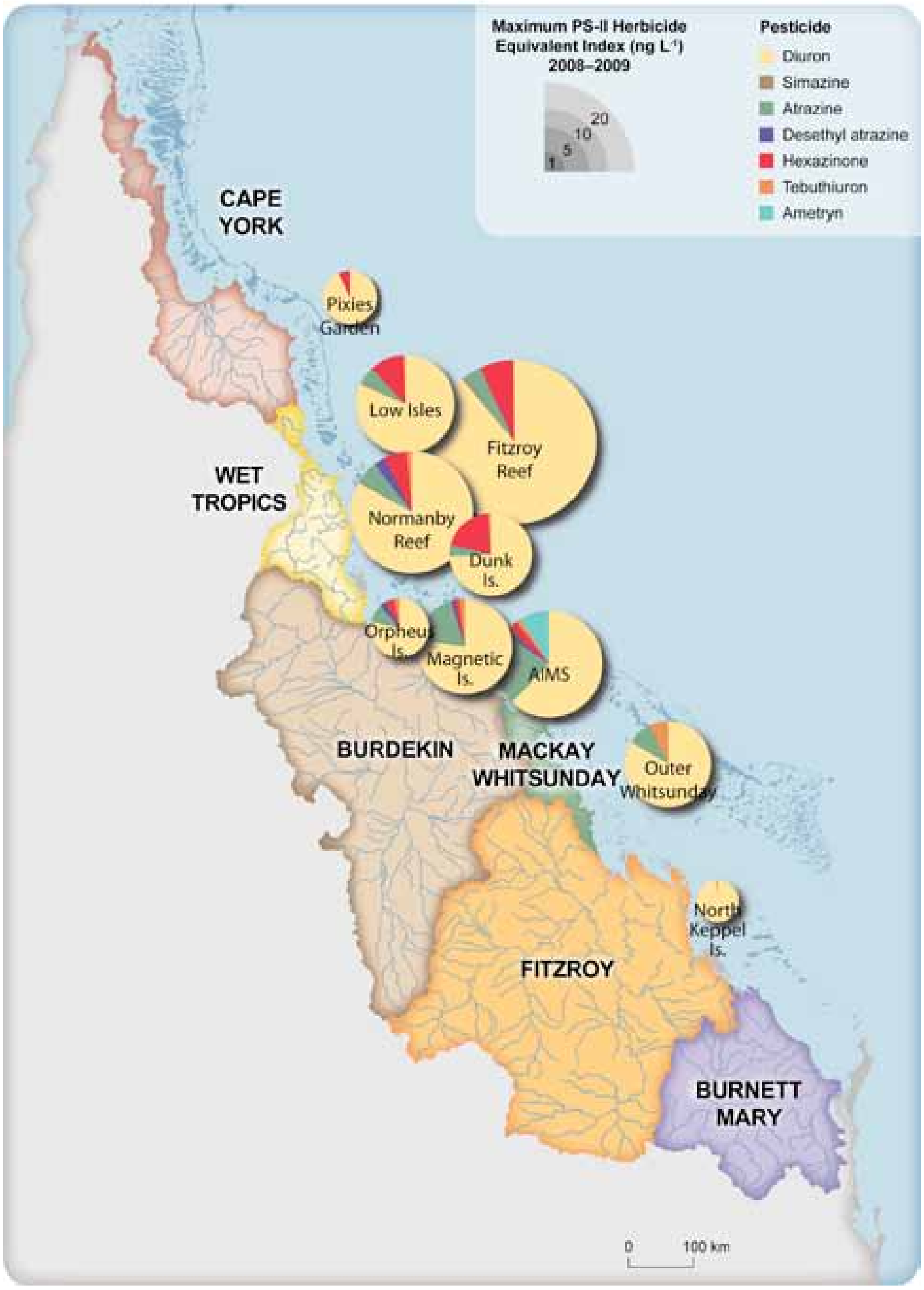


Figure 5.13 – Summary of maximum herbicide Diuron Equivalents (HEq), Great Barrier Reef, 2008–2009 from passive samplers (Source: Entox, UQ).

Case Study: Pesticides in flood plumes in the Mackay Whitsunday region

Over 95 per cent of sediments, nutrients and pesticides are exported to the Great Barrier Reef during high river flow events that typically occur during the wet season months (January to March). The resulting flood plumes in the Great Barrier Reef lagoon carry the highest amounts of these terrestrial materials and hence have the most potential to directly impact marine ecosystems (Devlin and Brodie, 2005). Monitoring of flood plumes has been ongoing in the Great Barrier Reef for well over a decade, although the measurement of pesticide concentrations has only occurred in the past eight years. Flood plume pesticide monitoring data collected by a variety of research and monitoring programs (including Great Barrier Reef Marine Monitoring Program partners) is available 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. Pesticide monitoring during this time has revealed that several pesticides are regularly above levels of analytical detection. Some pesticide residues (diuron, atrazine and tebuthiuron) exceed concentrations that cause negative effects on marine plants or are above guideline values for the protection of the Great Barrier Reef Marine Park (Lewis et al., 2009). The highest herbicide concentrations are found at river mouths before they become diluted progressively offshore as the river waters mix with seawater. The pesticides 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. Herbicide equivalent concentrations (PSII Herbicide Equivalent Index) have been calculated so that the herbicides that inhibit photosynthesis can be assessed additively.

Flood plume monitoring in the Mackay Whitsunday region has been conducted since 2005 by the Reef Rescue Marine Monitoring Program, Reef Catchments and Marine and Tropical Sciences Research Facility. The results of flood plume monitoring conducted in the Mackay Whitsunday region for the years 2005, 2007 and 2009 are shown in Figure 5.14. The herbicide equivalent concentration in at least one flood plume has exceeded ecosystem protection guidelines (over 900 nanograms per litre) at a distance at least 25 kilometres from the mouth of the Pioneer River (as shown in red in Figure 5.14). In addition, herbicide equivalent concentrations exceed known sublethal photosystem inhibition effect levels for either seagrass (Haynes et al., 2000: 100 nanograms per litre) or microalgae (Bengston-Nash, 2005: 50 nanograms per litre) in all monitored flood plumes, some for up to 50 kilometres from the mouths of both the Pioneer and O'Connell Rivers (as shown in yellow in Figure 5.14). This shows that herbicide residues in parts of inshore waters of the Great Barrier Reef lagoon are, at times, at concentrations known to have negative effects on marine plants.

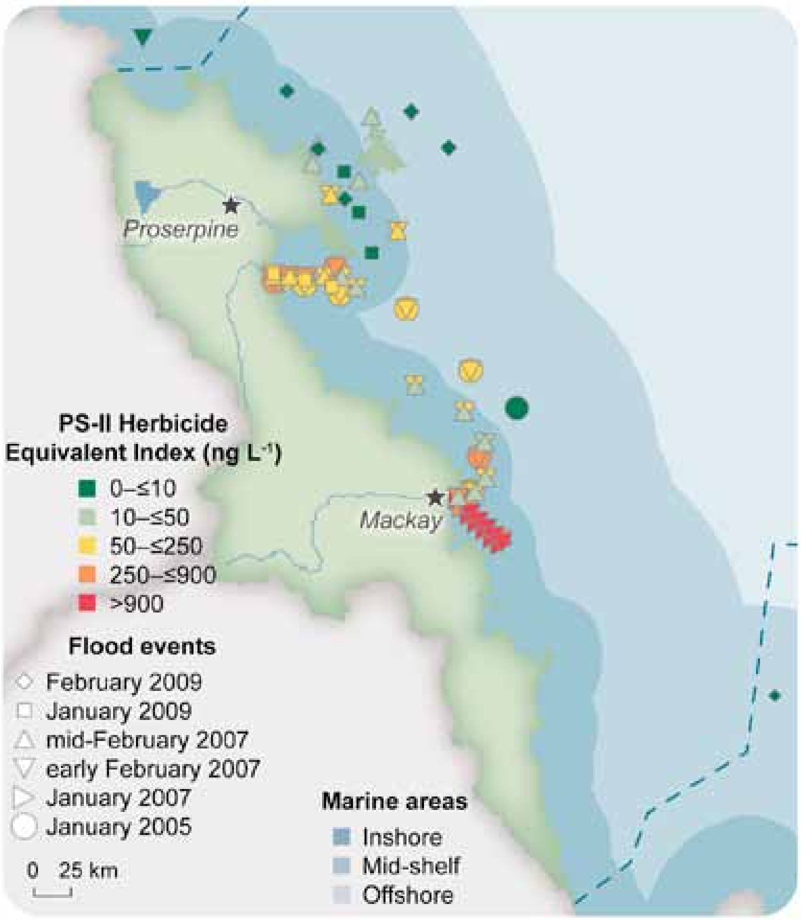


Figure 5.14 – Pesticides in flood plumes in the Mackay Whitsunday region.

5.5.3 Seagrass status

The types of seagrass species present in the Great Barrier Reef region vary between locations and habitats. Seagrass meadows located in inshore reef habitats tend to have more species than meadows at coastal or estuarine locations. Seagrass meadow cover (as a percentage of the substrate covered by plant material) also varies considerably between sites and locations at intertidal monitoring sites. At a Great Barrier Reef-wide scale, there is no evidence of long term sustained loss or gain in seagrass cover where monitoring has occurred, although considerable variation in cover exists between years and monitoring sites. This variation is natural inter-habitat variability and is also often a result of severe weather related impacts. Seagrass cover at some sites south of the Wet Tropics region is, however, considerably lower than the long term average for the Great Barrier Reef. Intertidal seagrass meadows in the Great Barrier Reef region also often have low or variable numbers of reproductive structures (Table 5.10). This suggests that many of these meadows may have reduced resilience to recover from future adverse environmental conditions such as flooding or mass sediment movements created by cyclonic conditions.

As bio-indicators of the environmental status of the inshore Great Barrier Reef, seagrass monitoring at intertidal sites indicates that there is a general trend of nutrient enrichment with plants growing in reducing light levels. Importantly, seagrass monitoring data from the Wet Tropics and the Burdekin regions suggests that many of these sites are showing increasing signs of nutrient saturated conditions, as seagrass tissue nitrogen levels in coastal habitats of these regions have consistently increased over the past 15 years.

5.5.4 Coral status

Coral reef communities are also highly variable along the length of the Great Barrier Reef. Monitoring of inshore reef communities over the past five years has provided valuable information about their condition (Figure 5.15).

Coral reef communities from the Daintree and Johnstone-Russell/Mulgrave sub-regions of the Wet Tropics have generally high coral cover (above 50 per cent) that has increased during periods without acute disturbance from cyclones and coral bleaching events. They have low macroalgae cover and relatively high densities of juvenile coral colonies.

In contrast, reefs in the Burdekin region have relatively high cover of macroalgae and moderate to low coral cover, with no clear evidence of increase in coral cover over the past five years. The limited recovery of coral cover in the Herbert Tully sub-region since Cyclone Larry in 2006 may be a consequence of riverine influence from regular flood events in the region.

The lack of recovery in the Burdekin region is concerning as there have been no obvious disturbances since coral bleaching impacted reefs in 2002, and the settlement of coral larvae in the region is low.

In the Mackay Whitsunday region, average coral cover is relatively high but has not increased despite a lack of acute disturbances in the region over the last five years. The cover of macroalgae is low and the relative density of juvenile colonies and settlement of spat is moderate relative to other monitoring regions.

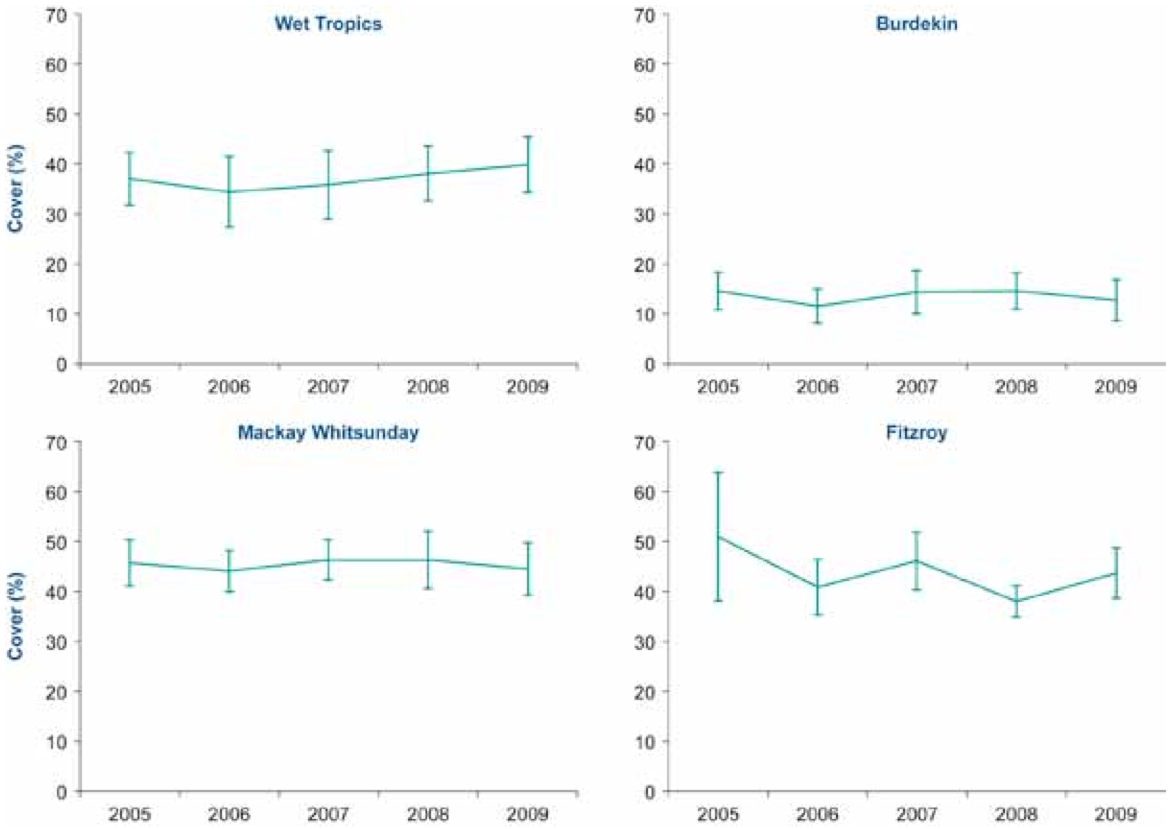
Corals in the Fitzroy region have been repeatedly affected by bleaching, causing substantial declines in coral cover in 1998, 2002 and 2006, but reefs have rapidly recovered from these past disturbances. Monitoring has found that reefs in the Fitzroy region have high cover (relative to other regions) and high (but variable) larvae settlement. However, these southern reefs also have high macroalgae cover and low juvenile coral colony densities. Recovery from disturbance in this region was usually by re-growth from fragments and not recruitment. It is currently unclear how resilient the Fitzroy region reefs would be to a disturbance that would cause widespread mortality.

Table 5.10 – Intertidal Great Barrier Reef seagrass abundance, reproductive health and nutrient status (2008–2009).

Region	Seagrass abundance	Reproductive status	Nutrient Status (C:P and N:P ratios*)	Overall status
Cape York	Moderate	Good	Good	Moderate
Wet Tropics	Moderate	Poor	Poor	Poor
Burdekin	Good	Poor	Moderate	Moderate
Mackay Whitsunday	Moderate	Very poor	Poor	Poor
Fitzroy	Good	Poor	Moderate	Moderate
Burnett Mary	Moderate	Very good	Moderate	Good

*C:P is the ratio of carbon to phosphorus; N:P is the ratio of nitrogen to phosphorus.

a) Coral cover



b) Macroalgal cover

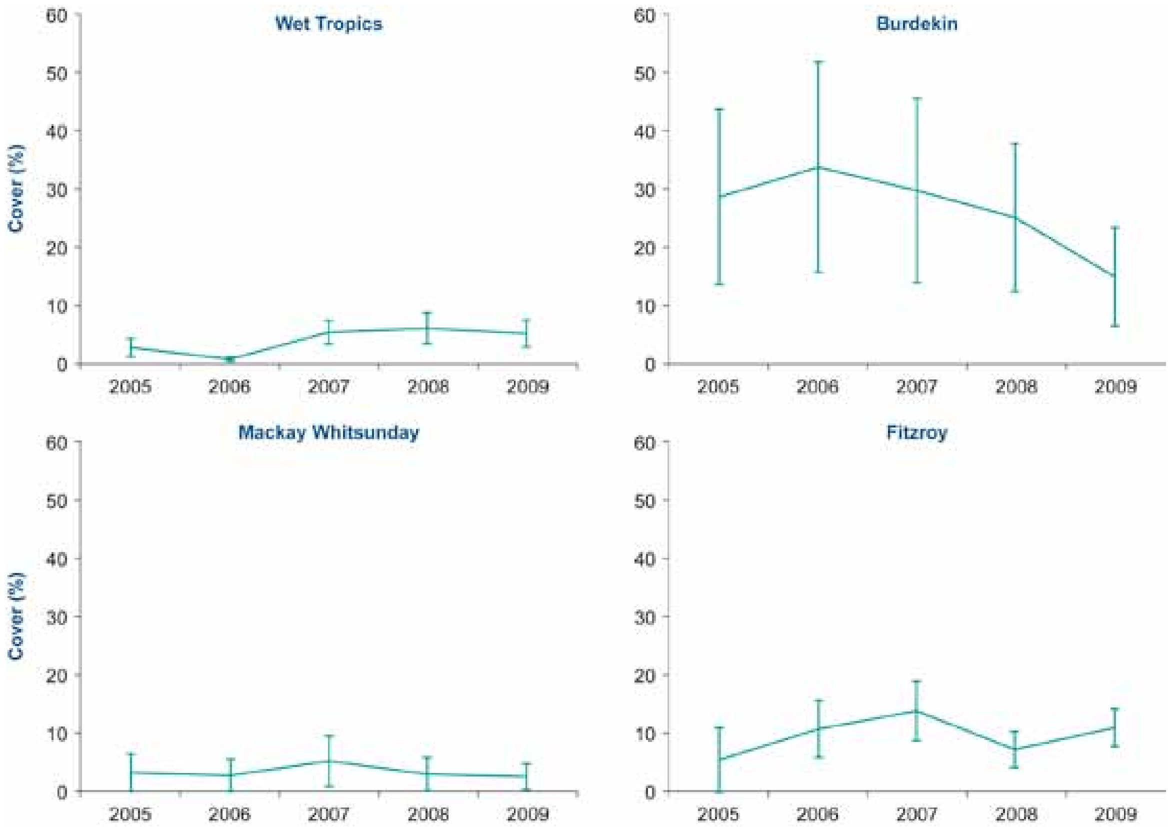


Figure 5.15 – Long term (2005–2009) trends in average (+/- standard error) hard coral (a) and macroalgal cover (b) for each natural resource management region (Source: Australian Institute for Marine Science). For each region, only reefs sampled in all years are included to ensure consistency among annual averages.

Cape York region

Chapter 6

"The region contains some exceptional conservation assets, including relatively intact and extensive coastal dune-fields, wetlands, rainforest, heathlands and river systems that support high levels of biodiversity found nowhere else in Australia."

Photo courtesy of Cape York Sustainable Futures

6.1 Profile

The Cape York region includes 43,000 square kilometres of catchments that drain eastwards into the Great Barrier Reef. The region contains some exceptional conservation assets including relatively intact and extensive coastal dune-fields, wetlands, rainforest, heathlands and river systems that support high levels of biodiversity found nowhere else in Australia. This region has a larger area of coral reefs than any other region and these are considered to be in good condition. A sizeable proportion of land in Cape York is under Aboriginal ownership or management. Traditional use of marine resources is very high, particularly in inshore areas adjacent to Indigenous communities.

The eastern catchments of the Cape York region have a population of 18,700 (2007). The weather is generally divided into the wet and dry seasons. From December to March, the area can be deluged by heavy monsoonal rain depressions with associated cyclonic influences.

Major catchments of the region include Jacky Jacky Creek, the Olive–Pascoe, Lockhart, Stewart, Normanby, Jeannie and Endeavour Rivers. The region is noted for its biodiversity and relative naturalness. Its dune-fields and deltaic fan deposits are amongst the best developed in the world.

The regional economy is based on resources and primary industries. Its economic base is dominated by the mining sector. The dominant land use in terms of area is cattle grazing (57 per cent). The Cape York cattle industry remains only marginally productive as stocking rates are as low as one head per 60 hectares and, as a consequence, property sizes are very large. The conversion of land to National Parks and to Aboriginal and Islander use has reduced pastoral leases. Aboriginal people now oversee almost 20 per cent of the total area of Cape York, and National Parks manage around 10 per cent. Fire management is also important for water quality on Cape York. Approximately 57 per cent (7.5 million hectares) of Cape York was affected by fire in 2009.

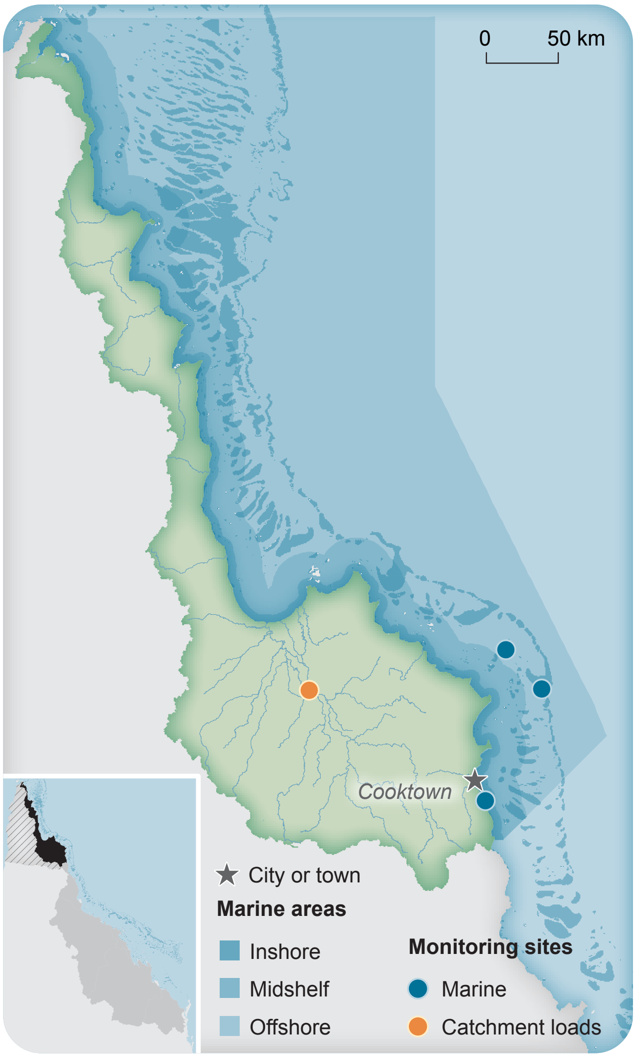
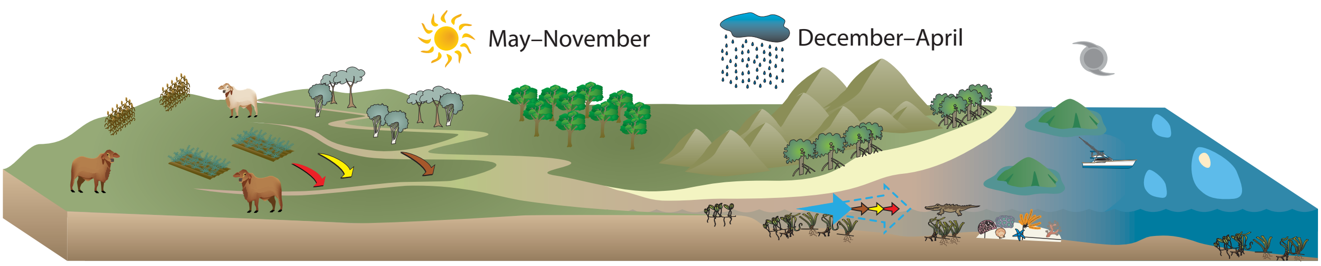


Figure 6.1 – Map of the eastern catchments of Cape York and Great Barrier Reef Marine Park showing the catchment and marine monitoring sites.



The Cape York region has occasional cyclones and summer-dominated rainfall that delivers sediments , nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows . There is extensive grazing year-round, with some horticulture and other cropping . A large proportion of the land is used for conservation purposes, e.g., national parks. The outer reef is located very close to the shoreline and there are many continental islands and coral cays . Habitats include fringing and offshore reefs , intertidal, subtidal and deep-water seagrass and mangroves . Reef-based tourism , as well as commercial and recreational fisheries , are an important part of the regional economy.

Figure 6.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Cape York region.

6.2 Adoption of improved management practices

6.2.1 Results

- **Management practice adoption data for grazing (the predominant agricultural industry) is not available at this time.**
- **Overall, cutting-edge (A) or best management (B) practices are used by 73 per cent of producers on 70 per cent of the horticultural land area, while eight per cent use practices considered unacceptable by industry and community standards (D).**
- **In terms of nutrient management, 53 per cent of horticulture producers are using cutting-edge (A) or best management (B) practices, while 20 per cent use practices considered unacceptable by industry and community standards (D).**

Land use: 43,032 square kilometres

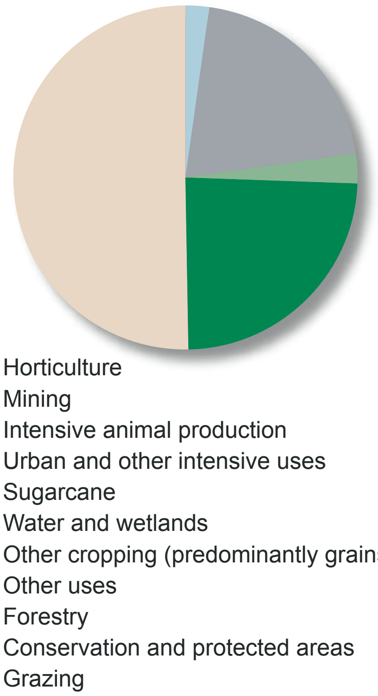


Figure 6.3 – Cape York region land use.

6.2.2 Horticulture

The adoption of improved management practices for horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

There are 30 landholders growing horticultural crops on 30 square kilometres of land within the Cape York region as at 2008–2009. The major horticultural crops include bananas and other tropical fruits.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 6.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 73 per cent of producers on 70 per cent of the horticultural land area. Code of practice or common (C) practices are used by 19 per cent of producers. Practices considered unacceptable by industry or community standards (D) are used by eight per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 53 per cent of producers. Nutrient management practices considered unacceptable by industry and community standards (D) are used by 20 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 89 per cent of producers, while four per cent of producers are using unacceptable (D) nutrient management practices.

Cutting-edge (A) or best management (B) practices for soils are used by 76 per cent of producers, with 24 per cent of producers using common (C) soil management practices.

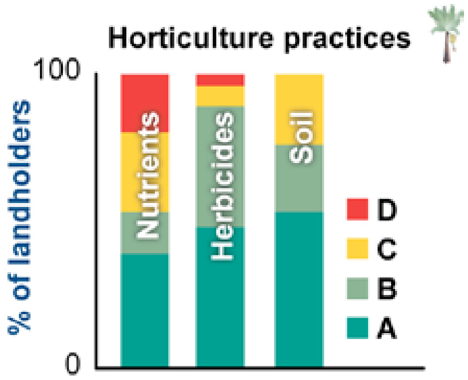


Figure 6.4 – Adoption of improved management practices for horticulture using the ABCD management framework for the Cape York region.

Table 6.1 – ABCD horticulture management practices for the Cape York region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	14	8	6	2
% of horticulture producers	47%	26%	19%	8%
Area (km^2)	11	10	6	3
% of area	37%	33%	20%	10%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	12	4	8	6
% of horticulture producers	39%	14%	27%	20%
Area (km^2)	13	1	11	5
% of area	44%	2%	36%	18%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	15	12	2	1
% of horticulture producers	48%	41%	7%	4%
Area (km^2)	10	16	1	3
% of area	34%	54%	2%	11%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	16	7	7	0
% of horticulture producers	53%	23%	24%	0%
Area (km^2)	10	13	7	0
% of area	34%	44%	22%	0%

6.3 Catchment indicators

6.3.1 Results

- **The Cape York region has the highest proportion of forested and/or high groundcover riparian areas with 579,000 hectares.**
- **The loss of riparian vegetation between 2004 and 2008 was 199 hectares (0.03 per cent).**
- **As at 2005, 100 per cent of the total pre-European extent of wetlands remains.**

6.3.2 Riparian vegetation

The Cape York region has the highest proportion of forested riparian areas, with 560,420 hectares (95.71 per cent). A total of 2084 hectares (0.34 per cent) is non-forested and has low groundcover. The non-forested and low groundcover areas are likely to be susceptible to erosion and, therefore, sediment loss to streams. The Jacky Jacky catchment has the highest area of low riparian groundcover with 1.78 per cent.

The greatest proportion of clearing of forested riparian areas between 2004 and 2008 was on the Endeavour catchment (1.78 per cent).

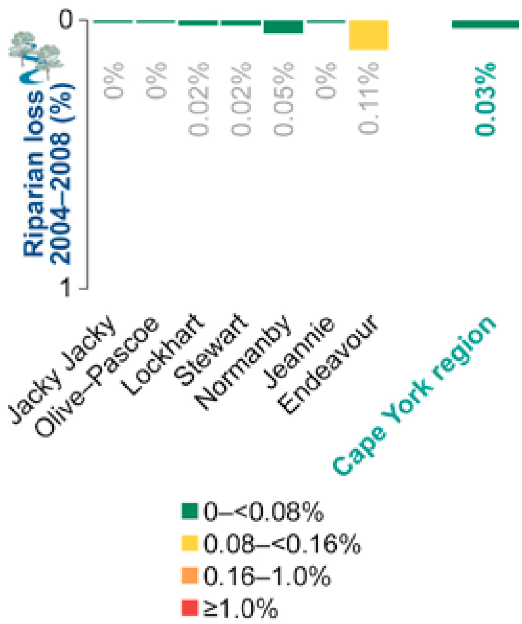


Figure 6.5 – Loss of riparian vegetation between 2004 and 2008 in the Cape York region.

Table 6.2 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Jacky Jacky	47,165	45,705	96.90	362	0.77	840	1.78	0.55	0	0.00
Olive–Pascoe	88,091	87,113	98.89	482	0.55	226	0.26	0.31	4	0.00
Lockhart	71,925	71,495	99.40	272	0.38	72	0.10	0.12	17	0.02
Stewart	64,553	63,263	98.00	957	1.48	149	0.23	0.29	16	0.02
Normanby	148,596	130,224	87.64	15,007	10.10	445	0.30	1.97	70	0.05
Jeannie	85,511	83,734	97.92	1153	1.35	288	0.34	0.39	3	0.00
Endeavour	79,678	78,886	99.01	655	0.82	64	0.08	0.09	89	0.11
Cape York region	**585,519**	**560,420**	**95.71**	**18,888**	**3.23**	**2084**	**0.34**	**0.71**	**199**	**0.03**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

6.3.3 Wetlands

As at the 2005 baseline, there are approximately 176,000 hectares of wetlands in the Cape York region. Of these wetland areas there are:

- 59,000 hectares of vegetated freshwater swamps (palustrine wetlands). The greatest area of vegetated freshwater swamps is in the Normanby and Jacky Jacky catchments
- 6400 hectares of lakes (lacustrine wetlands)
- 111,000 hectares of mangroves/salt flats (estuarine wetlands). These wetlands occur in the greatest density in the Normanby and Jacky Jacky catchments.

One hundred per cent of the total wetlands remain from pre-European times. There was no loss of wetlands between 2001 and 2005.

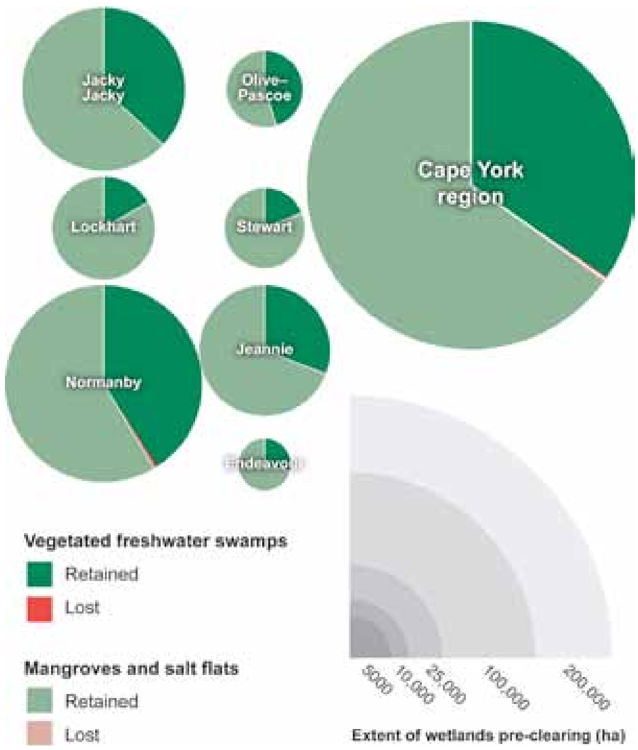


Figure 6.6 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Cape York region.

Table 6.3 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Cape York region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Endeavour	1210	98	0	15	100	0	2955	98	0	4180	98	0
Jacky Jacky Creek	15,550	100	0	2775	100	0	26,450	100	0	44,775	100	0
Jeannie	8285	99	0	1660	98	0	18,645	100	0	28,590	100	0
Lockhart	2800	100	0	80	100	0	13,900	100	0	16,780	100	0
Normanby	25,250	99	0	260	79	0	35,880	100	0	61,390	99	0
Olive Pascoe	4120	100	0	1630	100	0	5035	100	0	10,785	100	0
Stewart	1920	100	0	ND	ND	ND	8075	99	0	9995	99	0
Cape York region	**59,135**	**100**	**0**	**6420**	**98**	**0**	**110,940**	**100**	**0**	**176,495**	**100**	**0**

ND – denotes no data.

6.4 Catchment loads

The total suspended solids load leaving the Cape York region is an estimated 2.4 million tonnes per year, of which 1.9 million tonnes are from human activity (Kroon et al., 2010). Such apparent large increases in loads over natural loads are not expected for most Cape York catchments, which are relatively undisturbed compared to other Great Barrier Reef regions.

The estimated total nitrogen load leaving the Cape York region is 14,000 tonnes per year, of which 11,000 tonnes are from human activity. A large proportion of this is in the form of particulate nitrogen with 8900 tonnes per year (of which 8700 tonnes are from human activity).

The total phosphorus load leaving the Cape York region is 1500 tonnes per year, of which 1100 tonnes are from human activity.

The dissolved nitrogen load is 5500 tonnes per year, of which 2700 tonnes are from human activity. The dissolved phosphorus load is approximately 215 tonnes per year, of which 25 tonnes are from human activity.

The pesticide loads are not estimated for the Cape York region due to a lack of adequate monitoring or modelling data.

Note: The confidence in the baseline load estimates differs across regions due to different levels of data comprehensiveness. The confidence in the baseline load estimates for the Cape York catchments and region is low, as these estimates are based solely on modelling, with limited water quality monitoring data.

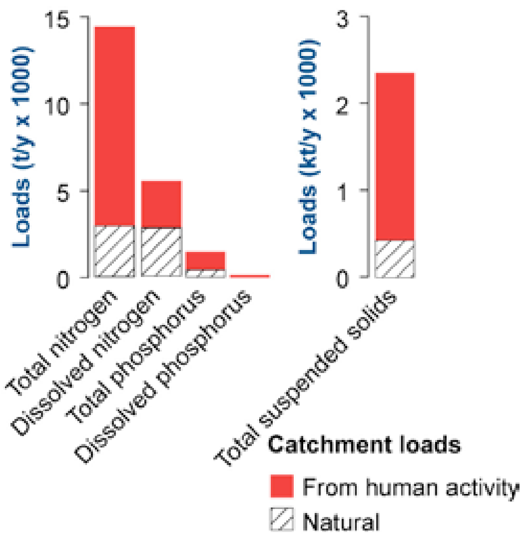


Figure 6.7 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen and dissolved phosphorus.

6.5 Great Barrier Reef water quality and ecosystem health

6.5.1 Results

- **At present, the development pressures and impacts on water quality in the Cape York region are considered to be low in comparison to other areas adjacent to the Great Barrier Reef.**
- **Water quality results are moderate for both chlorophyll *a* and total suspended solids.**
- **At the one station monitored in the region, seagrass reproduction and nutrient status are good. However, the moderate abundance resulted in overall moderate condition.**

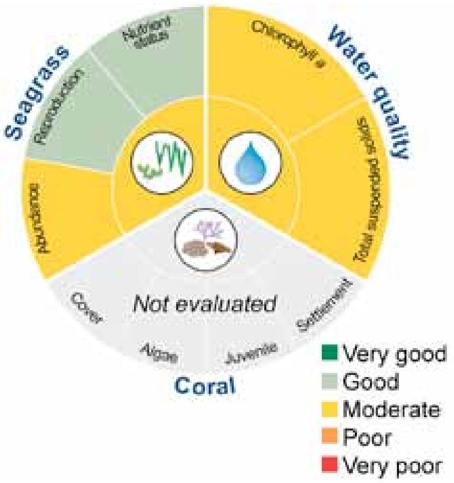


Figure 6.8 – Water quality and ecosystem health of the Cape York region showing the status of water quality and seagrass (grey = no coral data).

6.5.2 Water quality

At present, the development pressures and impacts on water quality in the Cape York region are considered to be low in comparison to other areas of the Great Barrier Reef. Therefore, it is seen as a low priority for intensive monitoring efforts. No coral monitoring occurs in the Cape York region in the Marine Monitoring Program, though some sites are monitored in the southern section as part of the Long Term (Reef) Monitoring Program undertaken by the Australian Institute of Marine Science.

Water quality data has been used to derive the Great Barrier Reef Marine Park Water Quality Guidelines; however, there are no ongoing water quality monitoring sampling sites in this region.

Table 6.4 presents the exceedance of mean annual chlorophyll *a* and suspended solids for the inshore, midshelf and offshore waterbodies of the Cape York region. Further work is required to validate the remote sensing data in Cape York. As such, Cape York water quality data was not used in the assessment of overall Great Barrier Reef water quality status.

Monitoring of water column pesticides at two locations in the southern section of the region detected diuron and hexazinone in the water column, although their concentrations were relatively low and did not exceed the Great Barrier Reef Marine Park Water Quality Guidelines (GBRMPA, 2009).

Table 6.4 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Cape York region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
41	2	0	55	39	13

6.5.3 Seagrass status

Archer Point, in the southern section of this remote region, is the only seagrass location currently monitored. For this meadow, seagrass species composition has varied since 2003 but has stabilised over the past 12 months. The nutrient ratios suggest the habitat has low light availability sufficient for growth, is nutrient poor, and the plants are possibly replete or nitrogen limited. Seagrass cover, although seasonal, has remained stable and appears to have recovered from previous declines.

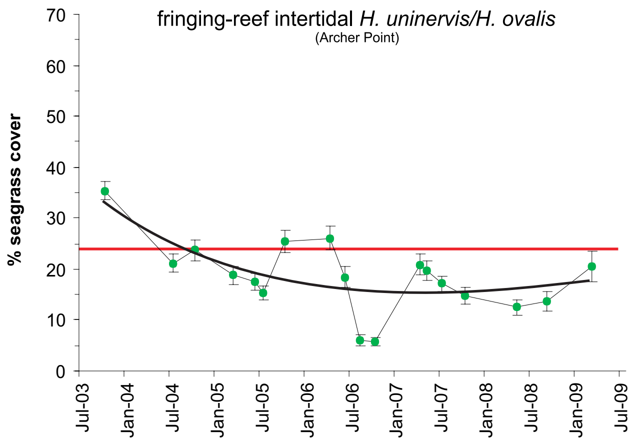


Figure 6.9 – Long term seagrass cover, Archer Point (reef) Cape York region compared with long term Great Barrier Reef average (red line) (Source: DEEDI).

Wet Tropics region

Chapter 7

"The proximity of vulnerable coral reef ecosystems to the coast, the frequency and intensity of rainfall events and the presence of intensive agriculture on the coast floodplain amplifies the risk of pollutants entering the Great Barrier Reef lagoon."

Photo by K Sorensen, Terrain NRM

7.1 Profile

The Wet Tropics region extends from the Bloomfield River in the north, to Crystal Creek in the south, and west to include the Atherton Tablelands. The region, some 22,000 square kilometres in extent, includes most of the Queensland Wet Tropics World Heritage Area and parts of the Great Barrier Reef World Heritage Area. With these two significant areas, the region is one of the most biodiverse places in the world. The deeply incised landscape incorporates seven catchments: Daintree–Mossman, Barron, Mulgrave, Russell, Johnstone, Tully–Murray and Herbert. The tropical climate results in cyclones and 60 to 70 per cent of the rainfall (1500 to 4000 millimetres) occurs in summer.

The region is the most populous of northern Australia and is growing rapidly. Cane farming is the major land use, while dairying, grazing, cropping, tropical horticulture and mining are also present. With its World Heritage properties, the region is a destination for millions of visitors each year, making nature-based tourism such as reef visitation, recreational fishing and boating a major contributor to the economy.

The proximity of vulnerable coral reef ecosystems to the coast, the frequency and intensity of rainfall events and the presence of intensive agriculture on the coast floodplain with significant use of fertilisers and pesticides amplifies the risk of pollutants entering the Great Barrier Reef lagoon. Increased fragmentation of remnant vegetation, overgrazing and exotic weeds have led to a decline in riparian areas.

The regional natural resource management body, Terrain Natural Resource Management works with landholders to adopt improved management practices that reduce nutrient, pesticide and sediment runoff. The focus has been on sugarcane (the largest intensive agricultural use in the region and a major source of nitrogen and photosystem inhibiting (PSII) chemicals), bananas, pawpaws, mixed cropping in the Tablelands, and grazing in both wet and dry country.

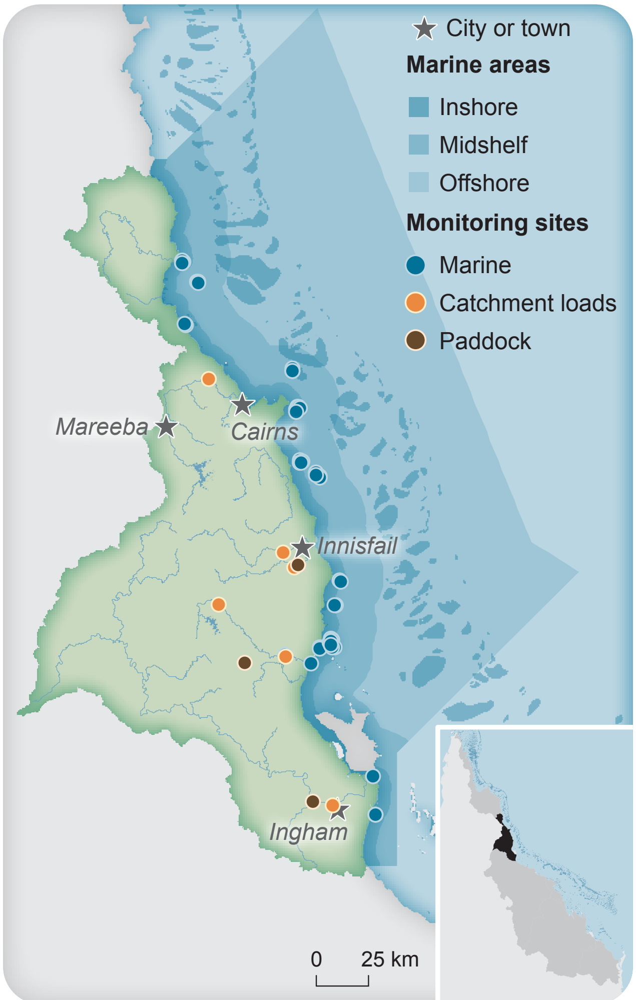
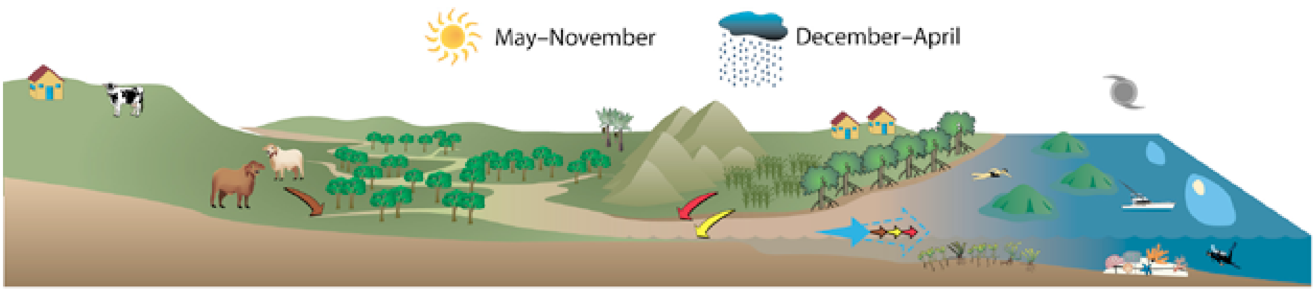


Figure 7.1 – Map of the Wet Tropics region and Great Barrier Reef Marine Park showing the paddock, catchment and marine monitoring sites.



The Wet Tropics region has occasional cyclones and highly variable rainfall predominantly in summer that delivers sediments nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows . Coastal ranges separate the western areas and floodplain. The Wet Tropics World Heritage area covers nearly half the landscape. The dominant land uses include grazing to the west , sugarcane on the narrow coastal floodplain, and some horticulture across the region. Cairns is the major urban centre with many smaller towns on the coastal strip and Atherton Tablelands. The proximity of the outer reef supports strong tourism and recreational and commercial fisheries . Habitats include fringing and offshore reefs , shallow-water seagrass and extensive coastal mangroves . There is a mix of continental islands and coral cays .

Figure 7.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Wet Tropics region.

7.2 Adoption of improved management practices

7.2.1 Results

- **Overall, cutting-edge (A) or best management (B) practices are used by 10 per cent of sugarcane growers. Practices considered unacceptable by industry or community standards (D) are used by 46 per cent of sugarcane growers.**
- **In terms of nutrient management, cutting-edge (A) or best management (B) practices are used by 20 per cent of sugarcane growers. Practices considered unacceptable by industry or community standards (D) are used by 72 per cent of sugarcane growers.**
- **In terms of soil management, cutting-edge (A) or best management (B) practices are used by seven per cent of sugarcane growers with 56 per cent using unacceptable (D) soil management practices.**
- **Overall, cutting-edge (A) or best management (B) practices are used by 67 per cent of horticulture producers. Practices considered unacceptable by industry or community standards (D) are used by 13 per cent of horticulture producers.**
- **In terms of nutrient management, cutting-edge (A) or best management (B) practices are used by 43 per cent of horticulture producers. Practices considered unacceptable by industry or community standards (D) are used by 28 per cent of horticulture producers.**
- **Management practice adoption data for the grazing industry is not available at this time.**

The adoption of improved management practices for sugarcane and horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

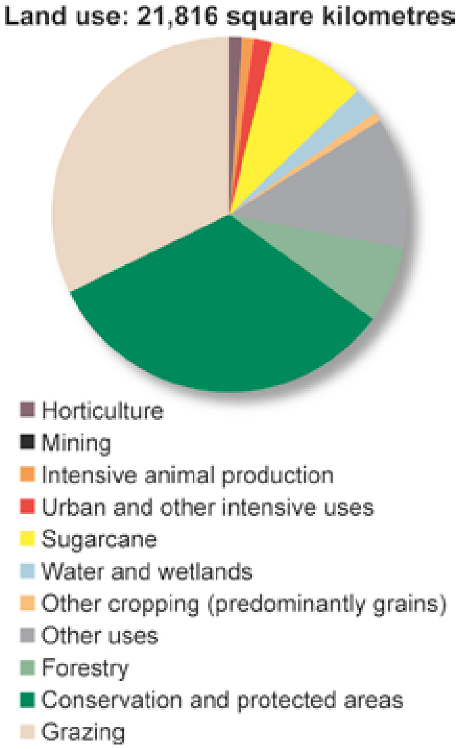


Figure 7.3 – Wet Tropics region land use.

7.2.2 Sugarcane

There are 1527 landholders growing sugarcane on 1947 square kilometres of land within the Wet Tropics region as at 2008–2009. The overall management practices (including nutrient, herbicide and soil) are shown in Table 7.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 10 per cent of sugarcane growers on 10 per cent of the land area. Code of practice or common (C) practices are used by 44 per cent of growers. Practices considered unacceptable by industry and community standards (D) are used by 46 per cent of growers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 20 per cent of sugarcane growers. Nutrient management practices considered unacceptable (D) are used by 72 per cent of growers.

Cutting-edge (A) or best management (B) practices for herbicides are used by only four per cent of growers. The vast majority of growers (87 per cent) are using herbicide management practices which are common practice or equivalent to code of practice (C). Only nine per cent of growers are using herbicide management practices considered unacceptable (D).

Cutting-edge (A) or best management (B) practices for soil are used by only seven per cent of sugarcane growers. Soil management practices considered unacceptable (D) are used by 56 per cent of growers.

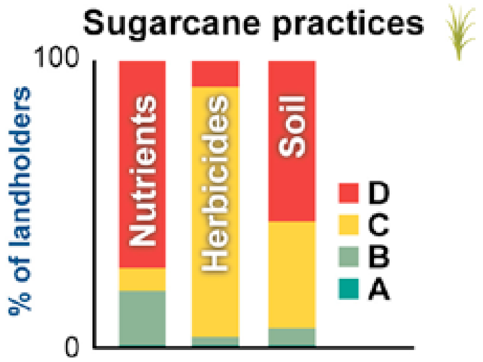


Figure 7.4 – Adoption of improved sugarcane management practices using the ABCD management framework for the Wet Tropics region.

Table 7.1 – ABCD sugarcane management practices for the Wet Tropics region (Source: modified from GHD, 2010b).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of cane growers	15	143	672	697
% of cane growers	1%	9%	44%	46%
Area (km²)	19	182	857	889
% of area	1%	9%	44%	46%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	15	290	122	1100
% of cane growers	1%	19%	8%	72%
Area (km²)	19	370	156	1402
% of area	1%	19%	8%	72%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	15	46	1328	138
% of cane growers	1%	3%	87%	9%
Area (km²)	19	58	1694	176
% of area	1%	3%	87%	9%
Soil Management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	15	92	565	855
% of cane growers	1%	6%	37%	56%
Area (km²)	19	117	720	1091
% of area	1%	6%	37%	56%

7.2.3 Horticulture

As at 2008–2009, there are 330 landholders growing horticultural crops on 251 square kilometres of land within the Wet Tropics region. The main horticultural crops include bananas, pawpaws and potatoes.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 7.2. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 67 per cent of producers on 74 per cent of the horticultural land area. Code of practice or common (C) practices are used by 20 per cent of producers. Practices considered unacceptable by industry or community standards (D) are used by 13 per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 43 per cent of producers. Nutrient management practices considered unacceptable (D) are used by 28 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 88 per cent of producers, while one per cent of producers are using unacceptable (D) class nutrient management practices.

Cutting-edge (A) or best management (B) practices for soil are used by 72 per cent of producers, while nine per cent are using unacceptable (D) class soil management practices.

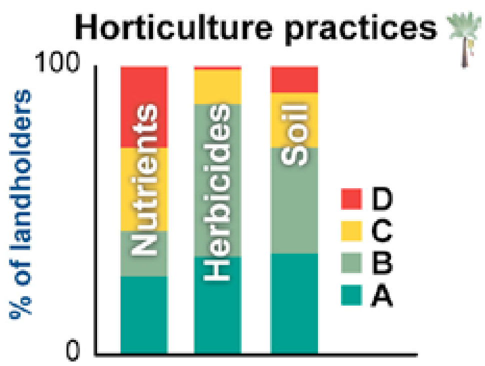


Figure 7.5 – Adoption of improved management practices for horticulture using the ABCD management framework for the Wet Tropics region.

Table 7.2 – ABCD horticulture management practices for the Wet Tropics region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	106	117	65	42
% of horticulture producers	31%	36%	20%	13%
Area (km²)	93	94	36	28
% of area	37%	37%	15%	11%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	90	53	95	92
% of horticulture producers	27%	16%	29%	28%
Area (km²)	90	48	52	61
% of area	36%	19%	21%	24%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	112	176	38	4
% of horticulture producers	35%	53%	11%	1%
Area (km²)	107	123	20	2
% of area	42%	49%	8%	1%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	115	124	61	30
% of horticulture producers	35%	37%	19%	9%
Area (km²)	83	110	36	22
% of area	33%	44%	14%	9%

7.3 Catchment indicators

7.3.1 Results

- **The total riparian area in the Wet Tropics region is 470,000 hectares, of which an estimated 1900 hectares are likely to be susceptible to erosion (non-forested and low groundcover).**
- **The loss of riparian vegetation between 2004 and 2008 was 787 hectares (0.17 per cent).**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangroves) across the Wet Tropics region is 81,000 hectares.**
- **The loss of vegetated freshwater swamps since pre-European times has been high (51 per cent) in the Wet Tropics region. The Barron catchment has lost 81 per cent of vegetated freshwater swamps.**
- **The loss of vegetated freshwater swamps over the 2001–2005 period was 233 hectares (0.63 per cent) with the Mossman catchment losing 17 hectares (8.33 per cent) of vegetated freshwater swamps during this period.**
- **The 2009 mean dry season groundcover for the grazing lands of the Herbert catchment is 95 per cent, which is above the Reef Plan target of 50 per cent.**

7.3.2 Riparian vegetation

The Wet Tropics region has a total of 427,000 hectares or 91 per cent of riparian areas forested, 36,000 hectares (7.74 per cent) of non-forested areas with high groundcover and 1900 hectares (0.4 per cent) non-forested with low groundcover. The non-forested and low groundcover areas are likely to be susceptible to erosion and, therefore, sediment loss to streams. The loss of riparian vegetation between 2004 and 2008 was 787 hectares (0.17 per cent). The Murray catchment had the highest clearing of riparian vegetation between 2004 and 2008 with 254 hectares (1.6 per cent) cleared.

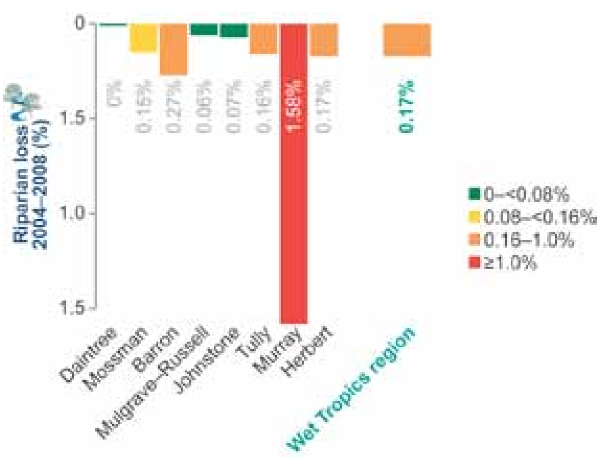


Figure 7.6 – Loss of riparian vegetation between 2004 and 2008 in the Wet Tropics region.

Table 7.3 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Daintree	120,673	119,372	98.92	1162	0.96	39	0.03	0.08	5	0.00
Mossman	16,368	14,830	90.60	1400	8.55	34	0.21	0.63	24	0.15
Barron	44,189	40,242	91.07	3396	7.69	178	0.40	0.84	121	0.27
Mulgrave Russell	29,203	24,676	84.50	3947	13.52	169	0.58	1.41	17	0.06
Johnstone	37,903	30,532	80.55	6331	16.70	171	0.45	2.29	26	0.07
Herbert	178,008	160,049	89.91	15,074	8.47	1127	0.63	0.99	296	0.17
Tully	27,195	23,562	86.64	2933	10.79	133	0.49	2.09	44	0.16
Murray	16,065	13,509	84.09	2118	13.18	66	0.41	2.32	254	1.58
Wet Tropics region	**469,606**	**426,772**	**90.88**	**36,361**	**7.74**	**1917**	**0.40**	**0.97**	**787**	**0.17**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

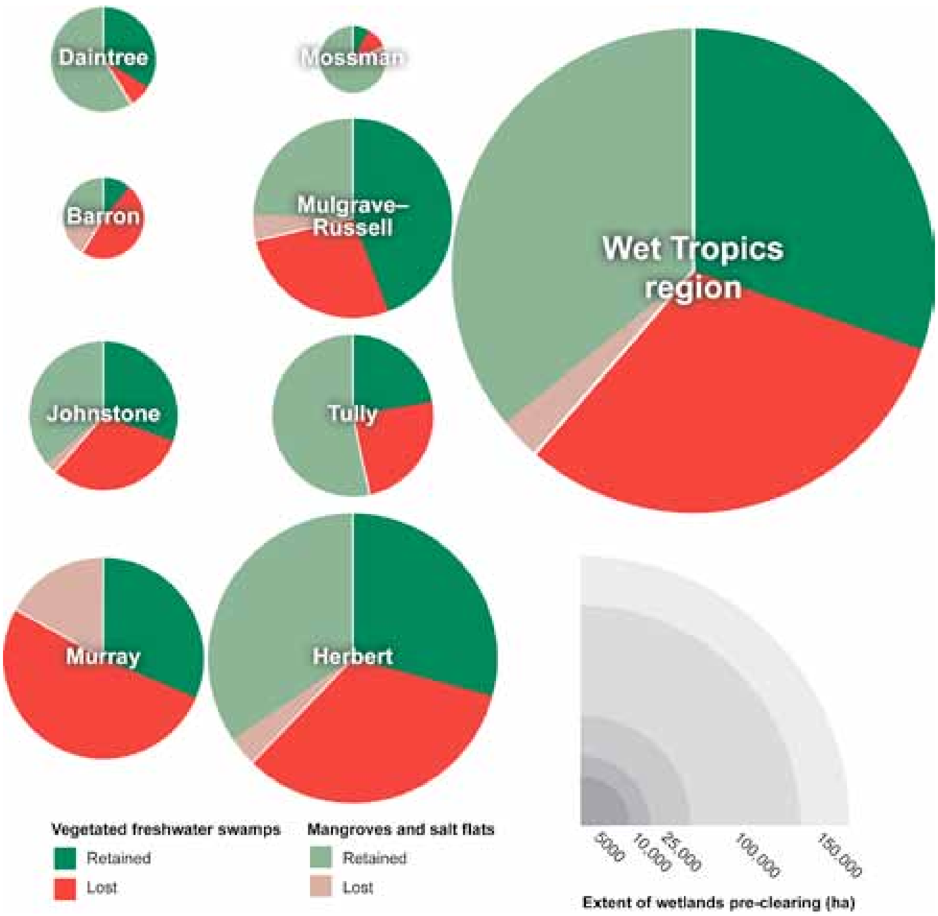


Figure 7.7 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Wet Tropics region.

7.3.3 Wetlands

Wetland types

As at 2005, there are approximately 81,000 hectares of wetlands in the Wet Tropics region. Of these wetland areas there are:

- 37,000 hectares of vegetated freshwater swamps (palustrine wetlands). The greatest area of vegetated freshwater swamps is in the Herbert and Mulgrave Russell catchments.
- 770 hectares of lakes (lacustrine wetlands).
- 43,000 hectares of mangroves/salt flats (estuarine wetlands). These wetlands occur in the greatest density in the Herbert and Murray catchments.

Across the Great Barrier Reef catchments, the greatest loss of wetlands has occurred in the Wet Tropics, with 34 per cent of the total wetlands lost since pre-European times. Fifty-one per cent of vegetated freshwater swamps have been lost across the region since pre-European times. The Barron catchment has had significant loss (81 per cent) of vegetated freshwater swamps leaving only 19 per cent remaining. Ninety-three per cent of mangroves and salt flats remain for the region.

The overall loss of all wetlands in the Wet Tropics region between 2001 and 2005 was 266 hectares (0.33 per cent).

The loss of vegetated freshwater swamps over the 2001–2005 period was 233 hectares (0.63 per cent). The greatest loss of vegetated freshwater swamps during this period was in the Mossman catchment with 8.33 per cent. There was a small reduction in the extent of mangroves/salt flats over the 2001–2005 period, ranging from nil to 0.33 per cent.

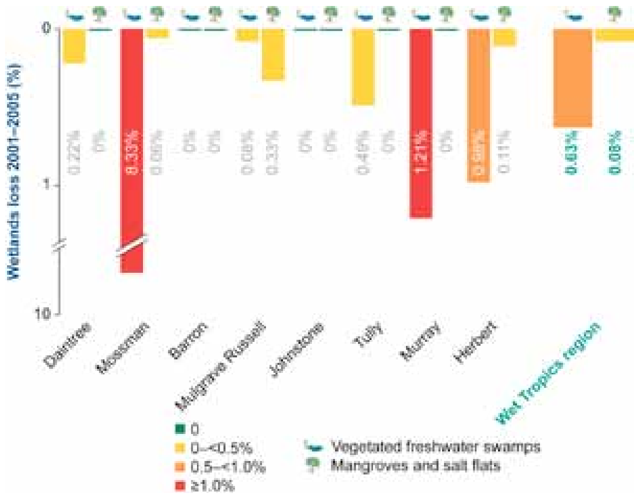


Figure 7.8 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Wet Tropics region.

Table 7.4 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Wet Tropics region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Barron	380	19	0	100	100	0	980	71	0	1460	47	0
Daintree	1930	83	0.22	ND	ND	ND	3295	98	0	5225	92	0.08
Herbert	12,675	47	0.98	520	99	0	14,870	91	0.11	28,065	63	0.5
Johnstone	3510	50	0	5	100	0	4100	93	0	7615	67	0
Mossman	190	43	8.33	10	100	0	1675	91	0.06	1875	80	0.97
Mulgrave Russell	9110	62	0.08	120	100	0	5015	86	0.33	14,245	70	0.17
Murray	4680	48	1.21	5	100	0	11,140	100	0	15,825	77	0.36
Tully	4260	38	0.49	10	100	0	2250	99	0	6520	49	0.32
Wet Tropics region	**36,735**	**49**	**0.63**	**770**	**100**	**0**	**43,325**	**93**	**0.08**	**80,830**	**66**	**0.33**

ND – denotes no data.

7.3.4 Groundcover in grazing lands in the Herbert catchment

Groundcover is influenced by a combination of factors including the land type, climate and management practices. The Herbert is the only catchment in the Wet Tropics with a significant area of grazing land (Table 5.6). The long term mean dry season groundcover for the grazing lands of the Herbert catchment over the 1986–2009 period is 93 per cent, which is above the Reef Plan target of 50 per cent. Similar to other regions, the average groundcover in 2009 is higher than the historical average, increasing to 95 per cent. The proportion of the grazing area with groundcover of 50 per cent or greater in 2009 is very high (99 per cent). Only 1.2 per cent of the area was below the 50 per cent groundcover target with 0.8 per cent of the area below 30 per cent.

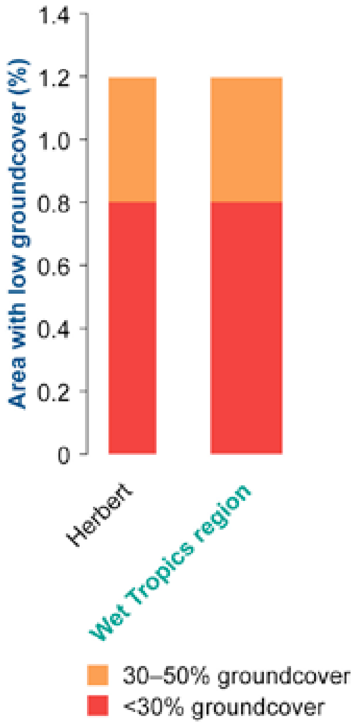


Figure 7.9 – Area with low groundcover (area less than 30 per cent and between 30 per cent and 50 per cent) as at 2009 for the Herbert catchment.

7.4 Catchment loads

The total suspended solids load leaving the catchments of the Wet Tropics region is an estimated 1.4 million tonnes per year, of which 1.1 million tonnes are from human activity (Kroon et al., 2010).

The fertilised agricultural areas of the coastal Wet Tropics are one of the key areas for nutrients (mainly nitrogen) that pose the greatest risk to the Great Barrier Reef (Brodie, 2007).

The estimated total nitrogen load leaving the catchments of the Wet Tropics is 16,000 tonnes per year, of which 11,000 tonnes are from human activity.

The dissolved nitrogen load is 11,000 tonnes per year, of which 6300 tonnes are from human activity, significantly higher than other regions. It is estimated that the main source of this load in the Wet Tropics region is fertiliser loss from sugarcane areas (Brodie et al., 2009).

The estimated total phosphorus load leaving the catchments of the Wet Tropics is 2000 tonnes per year, of which 1500 tonnes are from human activity.

The dissolved phosphorus load is 530 tonnes per year, of which 230 tonnes are from human activity.

The total photosystem inhibiting (PSII) pesticide load leaving the catchments of the Wet Tropics region is an estimated 10,000 kilograms per year. Along with the Mackay Whitsunday region, this is significantly higher than other regions. The pesticide residues most commonly found in surface waters from areas of sugarcane cultivation are diuron, atrazine, ametryn and hexazinone (Lewis et al., 2009). It is important to note that this estimate does not include several land uses known to leak PSII pesticides (e.g. grazing, forestry, cotton, urban) and non-PSII pesticides, indicating that the total pesticide pollutant load to the Great Barrier Reef is likely to be higher.

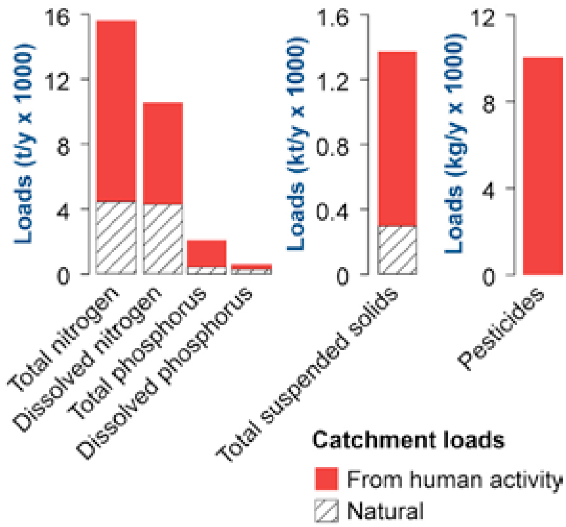


Figure 7.10 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen, dissolved phosphorus and pesticides.

7.5 Great Barrier Reef water quality and ecosystem health

7.5.1 Results

- **Inshore waters in the Wet Tropics region have concentrations of chlorophyll *a* and suspended solids above Great Barrier Reef Marine Park Water Quality Guidelines. A range of pesticides including diuron, atrazine, hexazinone, simazine and tebuthiuron are detectable in inshore waters of the region.**
- **Seagrass abundance is variable within the region. Seagrass meadows in the southern portion of the region have lower cover due to losses from cyclones prior to 2009, and many meadows have low numbers of reproductive structures, indicating reduced resilience to disturbance.**
- **The overall status of inshore reefs in the Wet Tropics region is good. Reefs in the northern part of the region have high coral cover, low cover of macroalgae, and moderate to high densities of juvenile colonies relative to other regions. However, reefs in more southern parts are in poor condition and have low coral cover, higher abundance of algae and have not yet shown recovery following disturbance.**

Figure 7.11 – Water quality and ecosystem health of the Wet Tropics region showing the status of water quality, seagrass and corals.

7.5.2 Water quality

Freshwater flows in the Barron, Russell, Johnstone and Tully rivers for 2008–2009 were slightly above (1.08 to 1.29 times) median flows for these major regional rivers. In contrast, freshwater discharge from the Herbert River was much higher, being more than three times the annual median flow in 2008–2009.

Great Barrier Reef Marine Park Water Quality Guideline exceedances for chlorophyll *a* and suspended solids concentrations were calculated for the May 2008 to April 2009 period from satellite imagery. The mean chlorophyll *a* and suspended sediment concentrations exceeded the Great Barrier Reef Marine Park Water Quality Guidelines values (GBRMPA, 2009) in some inshore areas of the Wet Tropics region (Table 7.5).

Table 7.5 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Wet Tropics region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
57	9	0	41	13	12

A range of pesticides were detected in time-integrated passive samplers deployed in inshore marine waters in the Wet Tropics region over the 12-month monitoring period (Figure 5.13). Detected pesticides included diuron, atrazine, hexazinone, simazine and tebuthiuron. Concentrations of detected pesticides were typically higher during the wet season, and the maximum water concentrations of individual herbicides ranged from 2 to 15 nanograms per litre.

In high river flow conditions, a similar range of pesticides were detected off the Tully and Murray Rivers in 2008 but not above Great Barrier Reef Marine Park Water Quality Guidelines. However, concentrations of diuron did exceed 100 nanograms per litre (Lewis et al., 2009), which is above the effects level for photosynthesis inhibition in a number of marine plants.

7.5.3 Seagrass status

Seagrass meadows are monitored at reef and coastal sites at four locations in the Wet Tropics region. Seagrass cover, although seasonal, has generally increased or stabilised over the past 12 months and is naturally lower at coastal locations compared to reef locations (Figure 7.12). The Lugger Bay and Dunk Island sites were impacted by the passage of Cyclone Larry across the Queensland coast in 2006. Seagrass cover at the Dunk Island site has recovered since the cyclone. Monitoring suggests that seagrass meadows throughout the region are receiving reduced light levels (from elevated epiphytes and high turbidity) and are nutrient rich. Nitrogen levels are high and increasing at coastal locations in the region.

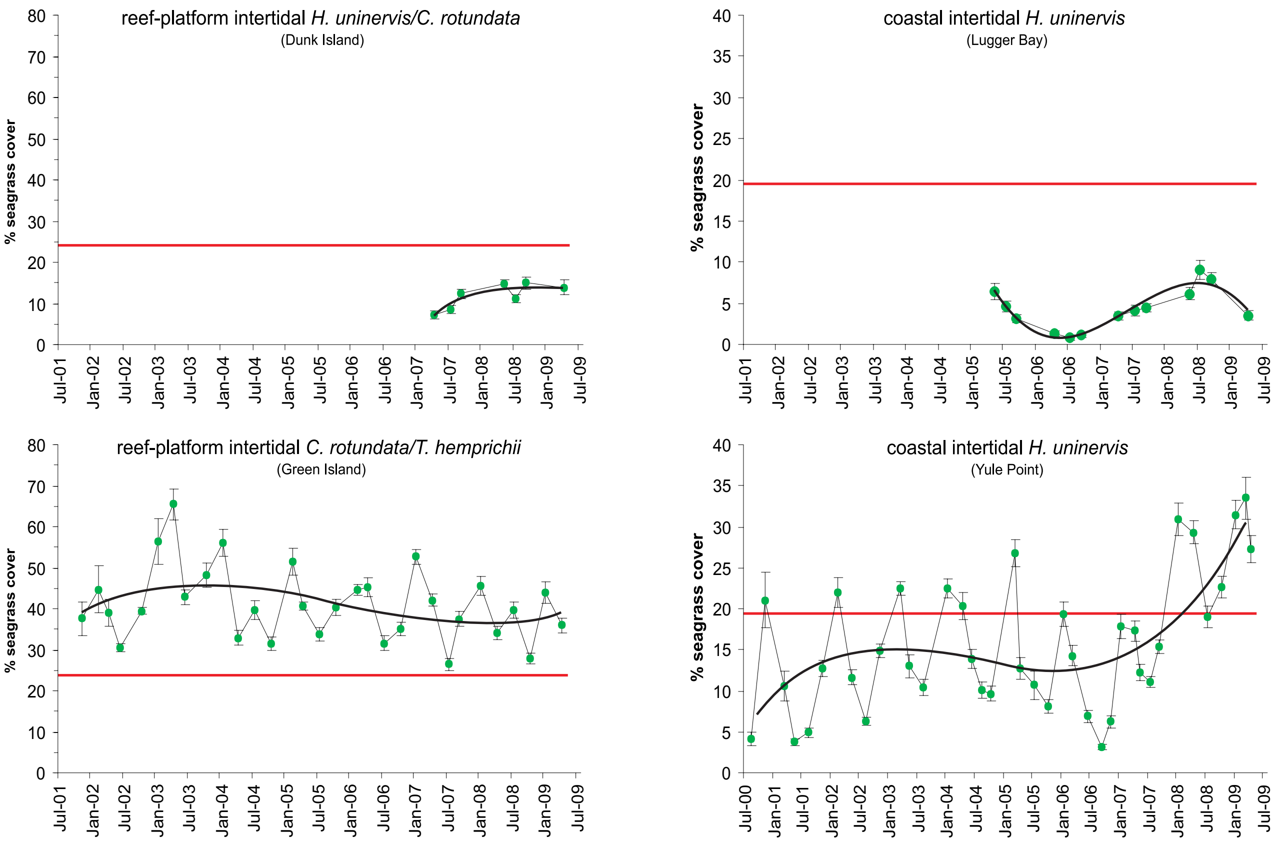


Figure 7.12 – Long term seagrass cover, Yule Point (coastal), Green Island (reef), Lugger Bay (coastal) and Dunk Island (reef), Wet Tropics region, compared with long term Great Barrier Reef average (red line) (Source: DEEDI).

7.5.4 Coral status

Twelve inshore reefs are monitored in the Wet Tropics region, and the overall status of these inshore reefs is good. Reefs in the northern Wet Tropics region, including those at Snapper Island and in the Fitzroy/Frankland Island Groups, are in good condition. They have high coral cover which increased during periods without disturbance, variable to high numbers of juvenile corals and low density of macroalgae. Importantly, these reefs have demonstrated potential to recover from environmental disturbances such as cyclones, bleaching, floods and outbreaks of crown-of-thorns starfish. In contrast, surveyed reefs in the southern section of the Wet Tropics region in the vicinity of the Herbert and Tully Rivers have lower coral cover, lower numbers of juvenile corals at some locations, higher levels of macroalgae, and have shown no clear pattern of increasing coral cover following disturbances.

Table 7.6 – Summary of coral community status of monitored reefs in the Wet Tropics region, 2008–2009.

Reef	Depth (m)	Overall status	Coral cover	Change in hard coral cover	Macroalgae cover	Juvenile density	Settlement
Snapper Island North	2	+	+	neutral	neutral	neutral	N/A
	5	++	+	neutral	+	neutral	N/A
Snapper Island South	2	+++	neutral	+	+	+	N/A
	5	+	+	neutral	+	-	N/A
Fitzroy Island East	2	+++	neutral	neutral	+	+	+
	5	+++++	+	+	+	+	+
Frankland Group East	2	+	neutral	neutral	+	neutral	neutral
	5	++++	neutral	+	+	+	+
Frankland Group West	2	-	neutral	neutral	+	-	-
	5	-	+	-	neutral	neutral	-
Fitzroy Island West	2	+++++	+	+	+	+	+
	5	+++++	+	+	+	+	+
High Island East	2	++	+	neutral	+	neutral	neutral
	5	+++	+	neutral	+	neutral	+
High Island West	2	+	+	-	+	neutral	neutral
	5	+	neutral	neutral	+	neutral	neutral
North Barnard Group	2	-	-	neutral	-	+	N/A
	5	-	-	neutral	-	+	N/A
Dunk Island North	2	-	-	neutral	-	+	N/A
	5	neutral	-	neutral	neutral	+	N/A
King Reef	2	- - - -	-	-	-	-	N/A
	5	- -	-	-	-	+	N/A
Dunk Island South	2	- -	-	neutral	-	neutral	N/A
	5	neutral	neutral	neutral	neutral	neutral	N/A

Explanatory note: + status and resilience is good; neutral denotes status and resilience is moderate; - status and resilience is poor. Overall status is estimated by summing the individual status scores.

Burdekin region

Chapter 8

"The Burdekin catchments drain a great diversity of tropical landscapes: semi-arid drylands, wooded grasslands, mountainous tropical rainforests, coastal plains and wetlands."

Photo courtesy of NQ Dry Tropics

8.1 Profile

The Burdekin region, which covers a land area of approximately 141,000 square kilometres, is largely drained by a single river system, the Burdekin. Regional land use is dominated by extensive grazing on natural pastures. The major threat from this land use is sediment and associated particulate nutrients from soil erosion, while some herbicide residues have also been detected in river runoff.

Other smaller coastal rivers drain around six per cent of the region. Intensive, irrigated agriculture along the coastal floodplain is dominated by sugar and horticulture. Runoff from these industries drains into the Great Barrier Reef through several smaller rivers, creeks and groundwater. Dissolved nutrients from fertiliser use and pesticides are the major threat to water quality entering the Great Barrier Reef from sugar and horticulture cropping areas.

The regional climate is characterised by strong seasonality, with pronounced wet and dry seasons, and high inter-annual variability. Discharge from rivers and creeks in the Burdekin region is characterised by high-magnitude pulses of water of short duration that are associated with wet season rains.

The Burdekin catchments drain a great diversity of tropical landscapes: semi-arid drylands, wooded grasslands, mountainous tropical rainforests, coastal plains and wetlands. The biodiversity assets of the Burdekin region are equally diverse and of both national and international significance. Many wetlands are listed in the National Directory of Important Wetlands in Australia.

The regional natural resource management body, NQ Dry Tropics, partners with industry groups to deliver training, extension support and financial incentives to landholders to accelerate best practice adoption of land management in the sugar, horticulture and grazing industries. Programs specifically target nutrient, pesticide and sediment reduction from these agricultural activities.

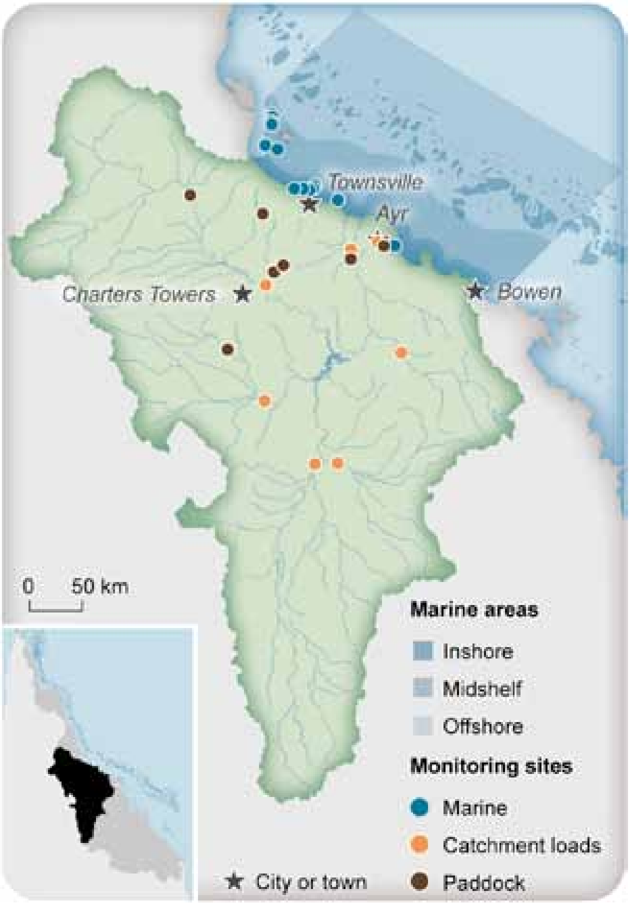
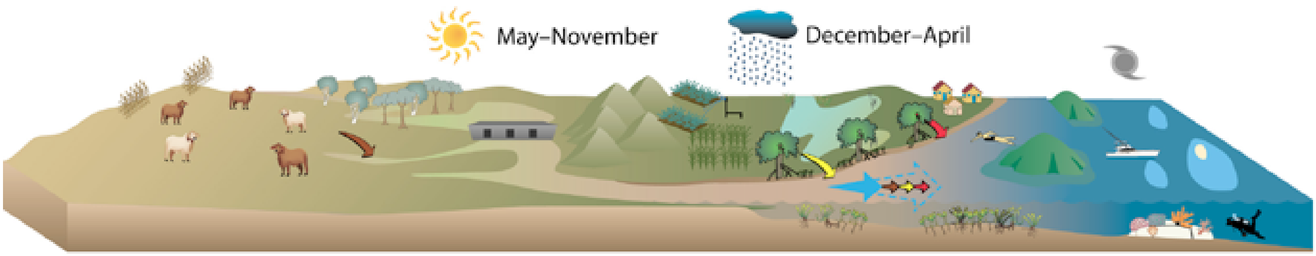


Figure 8.1 – Map of the Burdekin region and Great Barrier Reef Marine Park showing the paddock, catchment and marine monitoring sites.



The Burdekin region has occasional cyclones and highly variable rainfall predominantly in summer that falls mostly along the coastal areas and delivers sediments , nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows , which can be affected by reservoirs and dams. The large region is mostly drained by the Burdekin River. Grazing is the dominant land use and sugarcane , horticulture and other cropping are important irrigated land uses. The Burdekin dam and groundwater are important for irrigation. Urban centres such as Townsville and the smaller towns of Ayr and Bowen are located on the coastal strip. Habitats include fringing and offshore reefs , shallow-water seagrass , mangroves and freshwater swamp wetlands . There are continental islands (such as Magnetic Island) along the coast. Reef-based tourism , as well as commercial and recreational fisheries , are an important part of the regional economy.

Figure 8.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Burdekin region.

8.2 Adoption of improved management practices

8.2.1 Results

- **Thirty-nine per cent of graziers are using (A or B) practices likely to maintain land in good to very good condition or improve land in lesser condition.**
- **Practices (D) considered likely to degrade land to poor condition are used by 12 per cent of graziers.**
- **Overall, cutting-edge (A) or best management (B) practices are used by 33 per cent of sugarcane growers.**
- **In terms of nutrient management, 45 per cent of sugarcane growers use best management (B) practices.**
- **In terms of herbicide and soil management, practices considered unacceptable by industry or community standards (D) are used by 25 per cent and 23 per cent of sugarcane growers respectively.**
- **Overall, cutting-edge (A) or best management (B) practices are used by 63 per cent of horticulture producers.**
- **In terms of nutrient management, cutting-edge (A) or best management (B) practices are used by 35 per cent of horticulture producers.**

The adoption of improved management practices for sugarcane and horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

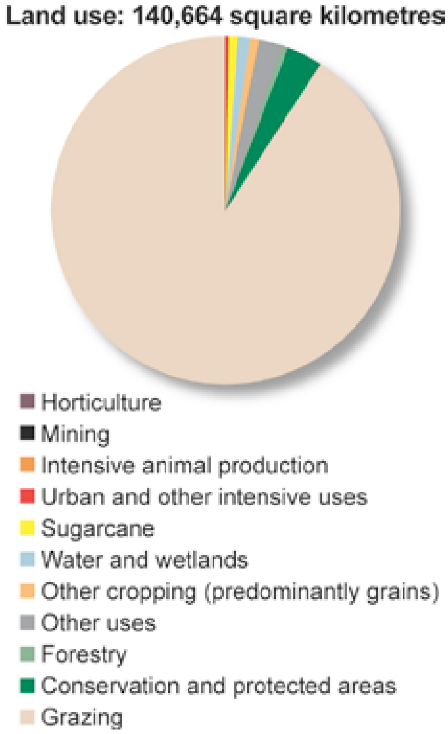


Figure 8.3 – Burdekin region land use.

8.2.2 Sugarcane

As at 2008–2009, there are 657 landholders growing sugarcane on 1061 square kilometres of land within the Burdekin region. The overall management practices (including nutrient, herbicide and soil) are shown in Table 8.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 33 per cent of sugarcane growers on 54 per cent of the land area. Code of practice or common (C) practices are used by 49 per cent of sugarcane growers. Practices considered unacceptable by industry and community standards (D) are used by 18 per cent of growers.

Best management (B) practices for nutrients are used by 45 per cent of sugarcane growers while six per cent of growers are using unacceptable (D) nutrient management practices.

Best management (B) practices for herbicides are used by 22 per cent of growers. Twenty-five per cent of growers are using herbicide practices considered unacceptable (D).

Cutting-edge (A) or best management (B) practices for soil are used by 32 per cent of growers with 23 per cent using unacceptable (D) soil management practices.

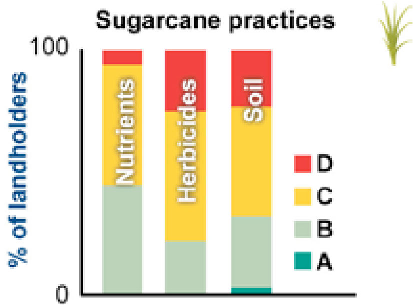


Figure 8.4 – Adoption of improved sugarcane management practices using the ABCD management framework for the Burdekin region.

Table 8.1 – ABCD sugarcane management practices for the Burdekin region (Source: modified from GHD, 2010c).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of cane growers	7	210	322	118
% of cane growers	1%	32%	49%	18%
Area (km²)	18	555	364	124
% of area	2%	52%	34%	12%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	0	296	322	39
% of cane growers	0%	45%	49%	6%
Area (km²)	0	668	371	21
% of area	0%	63%	35%	2%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	0	145	348	164
% of cane growers	0%	22%	53%	25%
Area (km²)	0	552	318	191
% of area	0%	52%	30%	18%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	20	191	296	150
% of cane growers	3%	29%	45%	23%
Area (km²)	53	446	403	159
% of area	5%	42%	38%	15%

8.2.3 Grazing

There are an estimated 827 landholders grazing cattle on 128,000 square kilometres of land in the Burdekin region. Thirty-nine per cent of graziers are using (A or B) practices that are likely to maintain land in good to very good condition or improve land in lesser condition. Forty-nine per cent of graziers are using (C) management practices that may maintain land in fair condition or gradually improve land in poor condition. Practices (D) considered likely to degrade land to poor condition are being used by 12 per cent of graziers.

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

A – Practices likely to maintain land in very good condition or improve land in lesser condition.

B – Practices likely to maintain land in good condition or improve land in lesser condition.

C – Practices that may maintain land in fair condition or gradually improve land in poor condition.

D – Practices likely to degrade land to poor condition.

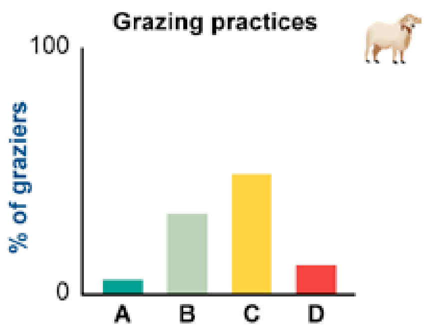


Figure 8.5 – Adoption of improved grazing management practices using the ABCD management framework for the Burdekin region.

Table 8.2 – ABCD grazing management practices for the Burdekin region.

Burdekin	A practices	B practices	C practices	D practices
Number of graziers	46	271	406	104
% of graziers	6%	33%	49%	12%
Area (km²)	7200	42,048	63,040	16,192

8.2.4 Horticulture

As at 2008–2009, there are 192 landholders growing horticultural crops on 156 square kilometres of land within the Burdekin region. The main horticultural crops include tomatoes, mangoes and vegetables.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 8.3. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 63 per cent of producers. Code of practice or common (C) practices are used by 25 per cent of producers. Practices considered unacceptable by industry and community standards (D) are used by 12 per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 35 per cent of producers. Code of practice or common (C) nutrient management practices are used by 51 per cent of producers. Nutrient management practices considered unacceptable (D) are used by 14 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 81 per cent of producers while 10 per cent of growers use unacceptable (D) nutrient management practices.

Cutting-edge (A) or best management (B) practices for soil are used by 75 per cent of producers, with 11 per cent using unacceptable (D) soil management practices.

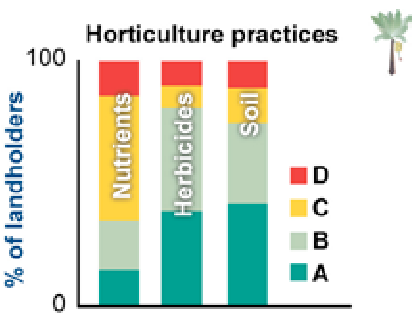


Figure 8.6 – Adoption of improved management practices for horticulture using the ABCD management framework for the Burdekin region.

Table 8.3 – ABCD horticulture management practices for the Burdekin region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	60	61	48	23
% of horticulture producers	31%	32%	25%	12%
Area (km²)	54	53	37	12
% of area	34%	34%	24%	8%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	29	38	98	27
% of horticulture producers	15%	20%	51%	14%
Area (km²)	21	47	78	10
% of area	13%	30%	50%	7%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	73	81	18	20
% of horticulture producers	39%	42%	9%	10%
Area (km²)	78	58	10	10
% of area	50%	38%	6%	6%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	79	64	27	22
% of horticulture producers	42%	33%	14%	11%
Area (km²)	63	53	23	17
% of area	40%	34%	15%	11%

8.3 Catchment indicators

8.3.1 Results

- **The total riparian area in the Burdekin region is 2.1 million hectares, of which an estimated 58,000 hectares are likely to be susceptible to erosion (non-forested and low groundcover) and, therefore, sediment loss to streams.**
- **The loss of riparian vegetation between 2004 and 2008 was 5834 hectares (0.28 per cent).**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangroves/salt flats) across the Burdekin region as at 2005 is 137,000 hectares.**
- **As at 2005, the loss of vegetated freshwater swamps since pre-European times was 20 per cent; however, 49 per cent and 37 per cent were lost in the Don and Haughton catchments respectively.**
- **The loss of vegetated freshwater swamps over the 2001–2005 period was 124 hectares (0.2 per cent) across the Burdekin region, with almost three per cent loss in the Ross catchment.**
- **The 2009 mean dry season groundcover for the grazing lands of the Burdekin region is 83 per cent, which is above the Reef Plan target of 50 per cent.**
- **Despite the generally higher cover, areas with low cover (under 30 per cent) have increased in 2009.**

8.3.2 Riparian vegetation

The Burdekin region has 1.6 million hectares (77 per cent) of riparian areas forested and 400,000 hectares (19 per cent) of non-forested riparian areas with high groundcover. Fifty-eight thousand hectares (2.8 per cent) of riparian areas were non-forested areas with low groundcover. The Burdekin and Don catchments have the highest percentage of area with low riparian forest and groundcover, with 2.9 per cent and 2.6 per cent respectively. These areas are likely to be susceptible to erosion and, therefore, sediment loss to streams.

The Ross catchment had the highest proportion of clearing between 2004 and 2008, with 415 hectares (one per cent).

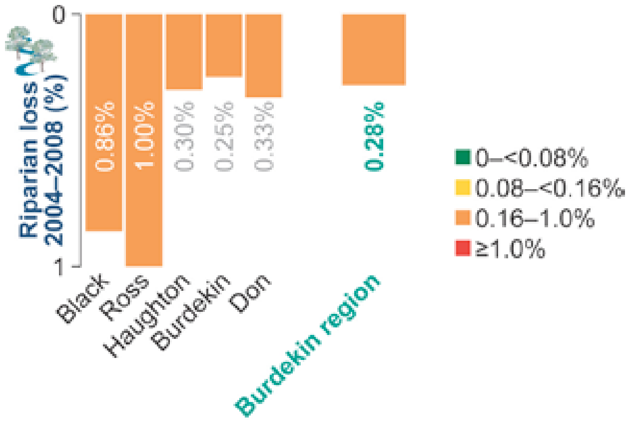


Figure 8.7 – Loss of riparian vegetation between 2004 and 2008 in the Burdekin region.

Table 8.4 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008, and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Burdekin	1,832,515	1,415,482	77.24	353,586	19.30	53,921	2.94	0.52	4652	0.25
Black	32,604	30,303	92.94	1786	5.48	235	0.72	0.86	280	0.86
Ross	41,391	32,222	77.85	7926	19.15	667	1.61	1.39	415	1.00
Haughton	91,974	65,164	70.85	23,469	25.52	1297	1.41	2.22	272	0.30
Don	65,264	49,192	75.37	13,246	20.30	1694	2.60	1.73	215	0.33
Burdekin region	2,063,748	1,592,363	77.16	400,013	19.38	57,814	2.80	0.66	5834	0.28

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

8.3.3 Wetlands

As at 2005, there are approximately 137,000 hectares of wetlands in the Burdekin region. Of these wetland areas there are:

- 62,000 hectares of vegetated freshwater swamps (palustrine wetlands). The greatest area of vegetated freshwater swamps is in the Burdekin catchment.
- 8200 hectares of lakes (lacustrine wetlands).
- 67,000 hectares of mangroves/salt flats (estuarine wetlands). These wetlands occur in the greatest density in the Don, Haughton and Ross catchments.

Ninety-one percent of wetlands remain from pre-European times. There has been a 20 per cent loss of vegetated freshwater swamps since pre-European times across the region; however, 49 per cent and 37 per cent have been lost in the Don and Haughton catchments respectively. More than 98 per cent of mangroves and salt flats remain in all catchments.

The overall loss of wetlands in the Burdekin region between 2001 and 2005 was 144 hectares (0.11 per cent). The loss of vegetated freshwater swamps over the 2001–2005 period was 124 hectares (0.2 per cent) across the Burdekin region, with almost three per cent loss in the Ross catchment. There was little reduction in the extent of mangroves/salt flats over the 2001–2005 period, ranging from nil to 0.43 per cent.

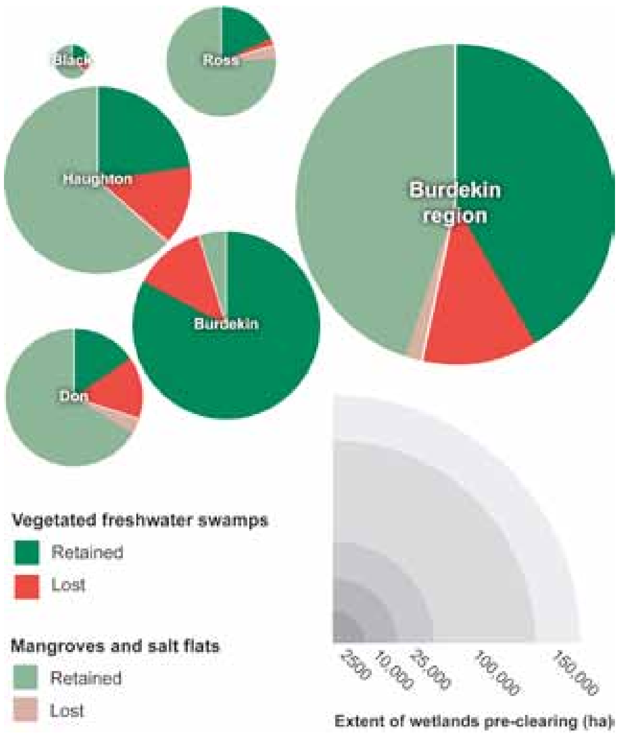


Figure 8.8 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Burdekin region.

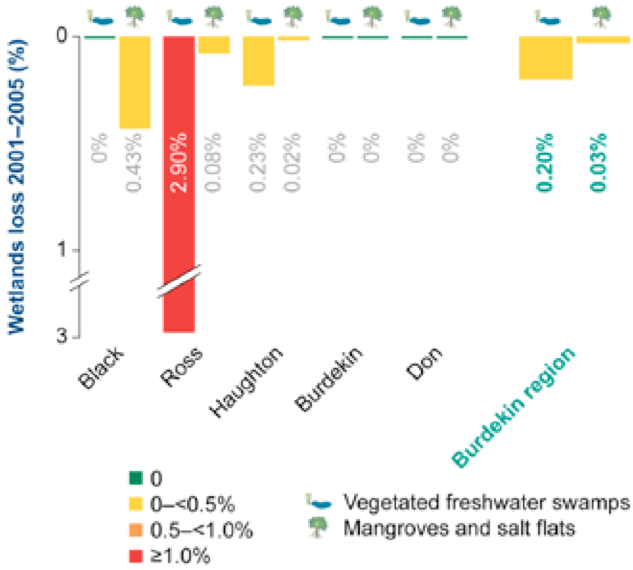


Figure 8.9 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Burdekin region.

Table 8.5 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Burdekin region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Black	430	75	0	NP	NP	NP	1080	97	0.43	1510	91	0.31
Burdekin	42,390	87	0	8015	100	0	2425	100	0	52,830	93	0
Don	4225	51	0	10	100	0	18,205	95	0	22,440	85	0
Haughton	11,650	63	0.23	155	80	0	31,955	99	0.02	43,760	88	0.07
Ross	3180	90	2.9	0	100	0	13,190	95	0.08	16,370	94	0.22
Burdekin region	61,875	80	0.20	8180	99	0	66,855	98	0.03	136,910	91	0.11

NP – wetland type was not present.

8.3.4 Groundcover in grazing lands

The majority of the region's grazing lands are in the Burdekin catchment. The long term mean dry season groundcover for the grazing lands of the Burdekin region over the 1986–2009 period is 75 per cent, which is above the Reef Plan target of 50 per cent (Table 5.6). The average groundcover in 2009 is higher than the historical average, increasing to 83 per cent. Despite the generally higher cover, it appears areas with low cover (under 30 per cent) have increased in 2009, with 2.3 per cent coverage compared to the long term mean of 1.7 per cent. This is accompanied by a reduction in areas with groundcover (greater than or equal to 30 per cent up to 50 per cent) in 2009 with four per cent compared to the long term mean of 5.4 per cent.

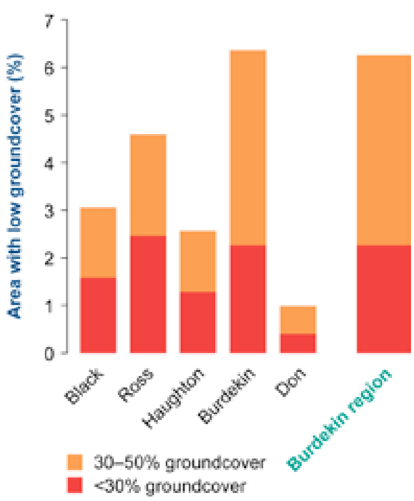


Figure 8.10 – Area with low groundcover (area under 30 per cent and between 30 per cent and 50 per cent) as at 2009 for the Burdekin region.

8.4 Catchment loads

The total suspended solids load leaving the catchments of the Burdekin region is an estimated 4.7 million tonnes per year, of which 4.1 million tonnes are from human activity. These high suspended sediment concentrations in streams are associated with rangeland grazing and locally specific catchment characteristics.

The total nitrogen load leaving the catchments of the Burdekin region is 14,000 tonnes per year, of which 11,000 tonnes are from human activity.

The total phosphorus load leaving the catchment of the Burdekin region is 2600 tonnes per year, of which 2200 tonnes are from human activity.

The dissolved nitrogen load is 5700 tonnes per year, of which 3500 tonnes are from human activity. It is estimated that the main source of this load is fertiliser loss from sugarcane areas (Brodie et al., 2009). The dissolved phosphorus load is 430 tonnes per year, of which 300 tonnes are from human activity.

The total photosystem inhibiting (PSII) pesticide load leaving the catchments of the Burdekin region is estimated at 4900 kilograms per year. The pesticide residues most commonly found in surface waters from areas of sugarcane cultivation are diuron, atrazine, ametryn and hexazinone (Lewis et al., 2009). It is important to note that this estimate does not include several land uses known to leak PSII herbicides (e.g. grazing, forestry, cotton, urban) and non-PSII pesticides, indicating that the total pesticide pollutant load to the Great Barrier Reef is likely to be higher.

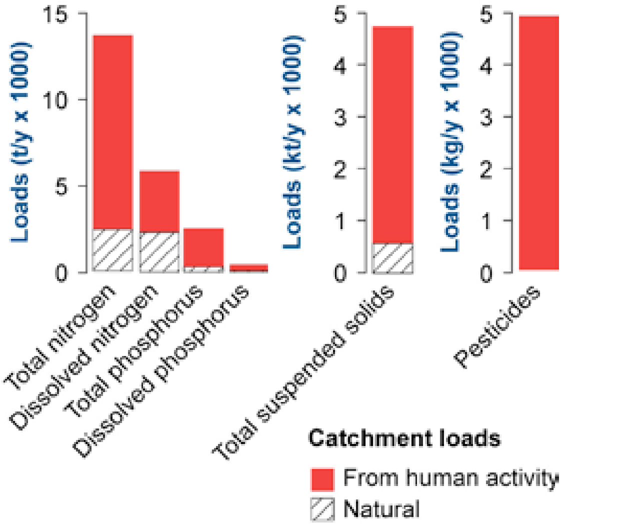


Figure 8.11 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen, dissolved phosphorus and pesticides.

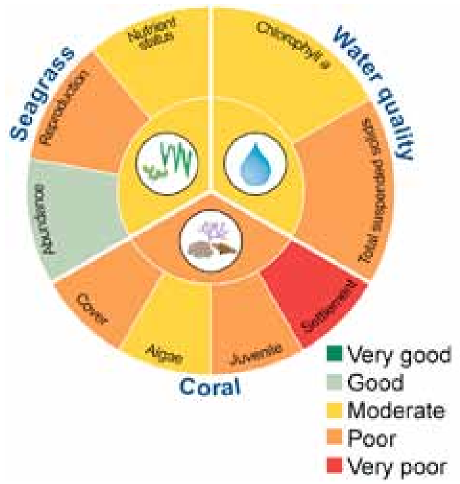


Figure 8.12 – Great Barrier Reef water quality and ecosystem health of the Burdekin region showing the status of water quality, seagrass and corals.

8.5 Great Barrier Reef water quality and ecosystem health

8.5.1 Results

- **Inshore waters in the Burdekin region have concentrations of chlorophyll *a* and total suspended solids above Great Barrier Reef Marine Park Water Quality Guidelines. A range of pesticides including diuron, atrazine, hexazinone, simazine, ametryn and tebuthiuron are detectable in inshore waters of the region.**
- **Seagrass abundance in the region is good, but has declined at coastal locations and is variable at reef locations. There are low numbers of reproductive structures indicating reduced resilience to disturbance.**
- **Inshore reefs in the Burdekin region are in poor condition. The lack of recovery of these reefs is of concern as there have been no obvious natural disturbances since they were impacted by coral bleaching in 2002. Settlement of coral larvae is very poor and numbers of juvenile corals are poor, which may be due to low coral cover limiting the availability of coral larvae.**

8.5.2 Water quality

Fresh water discharged from the Burdekin River in 2008–2009 was more than five times the annual median regional flow. Great Barrier Reef Marine Park Water Quality Guideline exceedances for chlorophyll *a* and suspended solids concentrations were calculated for the May 2008–April 2009 period from satellite imagery (Table 8.6). The mean chlorophyll *a* and suspended sediment concentrations exceeded the Great Barrier Reef Marine Park Water Quality Guideline values (GBRMPA, 2009) for the inshore area of the Burdekin region.

Table 8.6 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Burdekin region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
54	1	0	65	5	3

A range of pesticides were detected in passive samplers deployed in inshore marine environments in the Burdekin region over the monitoring period (Figure 5.13). Detected pesticides included diuron, atrazine, hexazinone, simazine, ametryn and tebuthiuron. Concentrations of pesticides were typically (but not always) higher during the wet season. The maximum water concentrations of individual pesticides in the region ranged from 0.25 to 10 nanograms per litre.

Pesticides detected in high river discharge conditions had concentrations exceeding Great Barrier Reef Marine Park Water Quality Guidelines for diuron at several inshore sites (Lewis et al., 2009).

8.5.3 Seagrass status

Seagrass meadows are monitored at reef and coastal sites at four locations in the Burdekin region. In 2008–2009 seagrass abundance declined at coastal locations and was variable at reef locations (Figure 8.13). Seagrass tissue nutrient concentrations indicate that all sites are light limited and nutrient rich. In coastal locations in Townsville, nitrogen levels are elevated and increasing. Monitoring has shown that regional meadow light regimes are influenced primarily by climatic factors such as day length, rainfall, wind speed and tidal height.

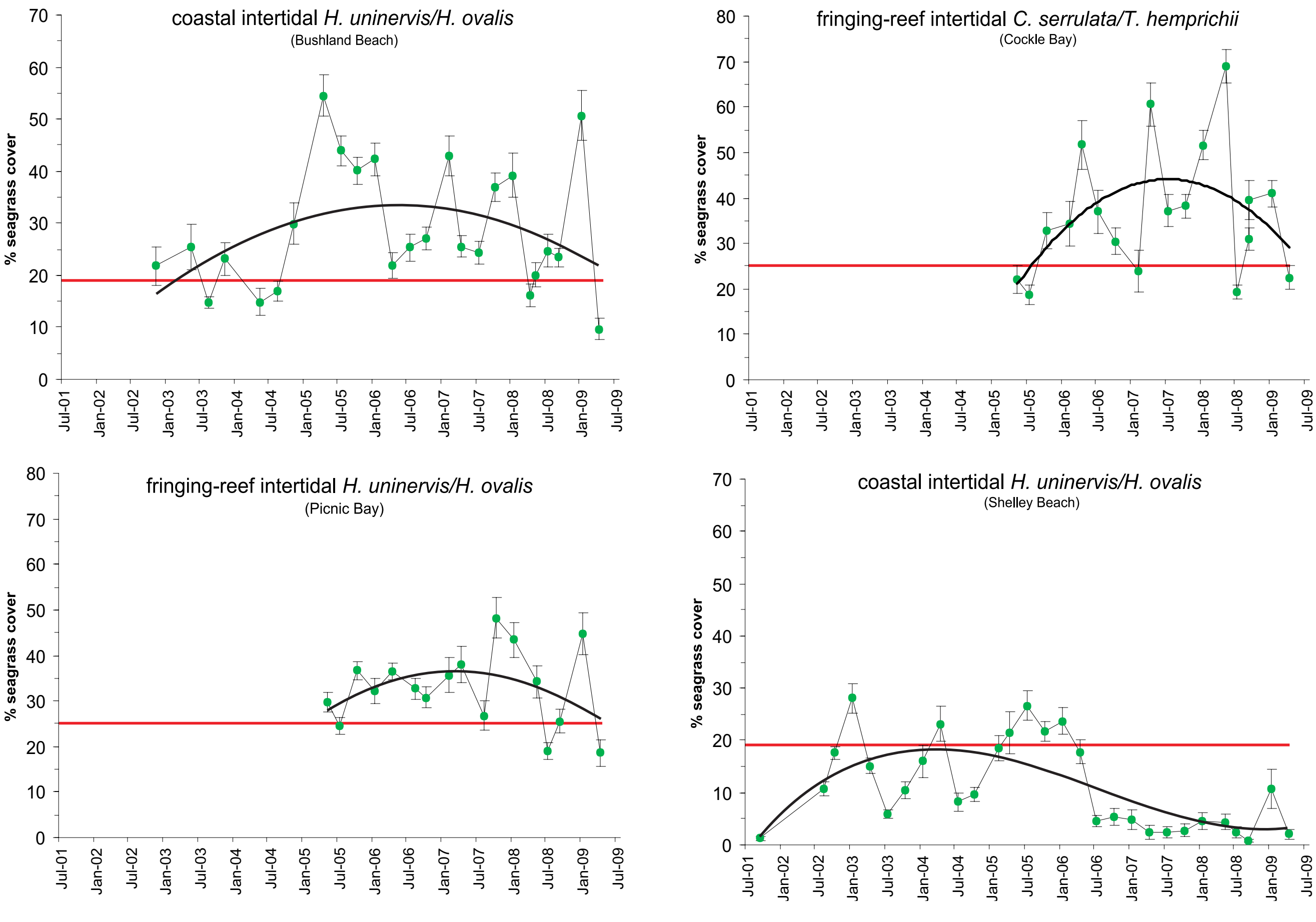


Figure 8.13 – Long term seagrass cover, Bushland Beach (coastal), Shelley Beach (coastal), Cockle Bay (reef) and Picnic Bay (reef), Burdekin region, compared with long term Great Barrier Reef average (red line) (Source: DEEDI).

8.5.4 Coral status

Seven inshore reefs are monitored in the Burdekin region. These reefs have all been exposed to severe disturbances from elevated seawater temperatures, cyclones or both, with crown-of-thorns starfish outbreaks also impacting some reefs. Most of the Burdekin region reefs have failed to recover from these disturbances over the past five years of monitoring, and remain in a poor state with low coral cover and high macroalgal cover. Critically for reef resilience and recovery, levels of coral recruitment in the region have remained consistently low over the five year monitoring period. The regionally low coral cover may be limiting the availability of coral larvae, which may explain the regionally low density of juvenile colonies.

Table 8.7 – Summary of coral community status of monitored reefs in the Burdekin region, 2008–2009.

Reef	Depth (m)	Overall status	Coral cover	Change in hard coral cover	Macroalgae cover	Juvenile density	Settlement
Orpheus Island East	2	neutral	neutral	neutral	+	-	N/A
	5	+	neutral	+	+	-	N/A
Pelorus Island and Orpheus Island West	2	++	neutral	neutral	+	+	N/A
	5	-	neutral	-	+	neutral	-
Havannah Island	2	-	-	neutral	+	-	N/A
	5	- - - -	-	-	-	-	N/A
Pandora Reef	2	- -	-	+	-	-	N/A
	5	- - -	-	+	-	-	-
Lady Elliot Reef	2	neutral	neutral	neutral	-	+	N/A
	5	+	neutral	N/A	neutral	+	N/A
Middle Reef		++	neutral	neutral	+	+	N/A
Geoffrey Bay	2	- - -	-	neutral	-	-	N/A
	5	- - - -	-	-	-	neutral	-

Explanatory note: + status and resilience is good; neutral denotes status and resilience is moderate; - status and resilience is poor. Overall status is estimated by summing the individual status scores.

Mackay Whitsunday region

Chapter 9

"The region supports a diverse range of ecosystems from hard and soft coral communities and extensive mangrove, seagrass and fish habitats to the nationally recognised Goorganga wetland complex."

Photo by J Turner

9.1 Profile

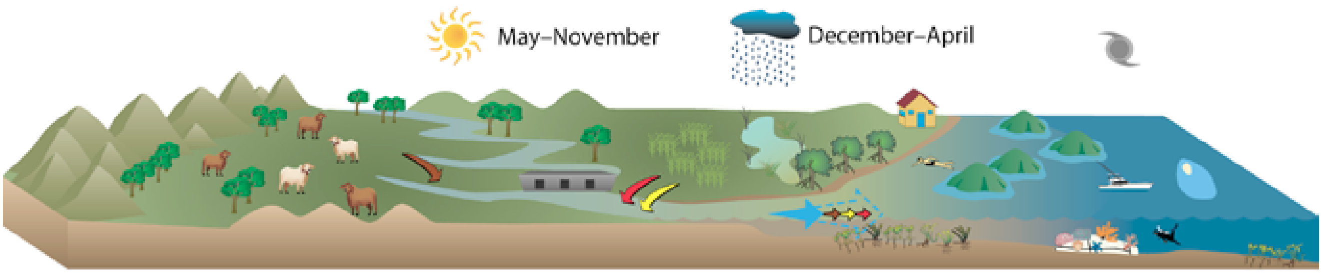
The Mackay Whitsunday region covers an area of 9000 square kilometres and includes the catchments of the Pioneer, O'Connell and Proserpine River systems, which drain directly into the Great Barrier Reef lagoon. There are significant biodiversity assets throughout the region, mainly in national parks and state lands, including marine parks. The region includes 250 kilometres of coast with numerous beaches, coastal lagoons, reefs and 74 offshore islands.

The dominant land use in the region is sugarcane production, with grazing, tourism and aquaculture also significant regional industries. The subtropical to tropical climate is characterised by a distinct wet season with 50 to 60 per cent of the average annual rainfall (1300 to 2000 millimetres) falling between January and March.

The region supports a diverse range of ecosystems from hard and soft coral communities and extensive mangrove, seagrass and fish habitats to the nationally recognised Goorganga wetland complex (Ball, 2008).

There is significant agriculture production in the region, including grazing, horticulture and the largest area of sugarcane production in Australia. Consequently, the sugarcane industry is the main diffuse source of nutrients and herbicide pollutants. In response, the region's agricultural industries are taking an active role in implementing improved farming practices in order to lower catchment loads and remove the associated threats to the Great Barrier Reef. The Mackay Whitsunday regional body, Reef Catchments, supports the region's agricultural industries in adopting improved farming practices.

Figure 9.1 – Map of the Mackay Whitsunday region and Great Barrier Reef Marine Park showing the paddock, catchment and marine monitoring sites.



The Mackay Whitsunday region has a number of small, steep catchments. The landscape is largely rural, has occasional cyclones and is dominated by summer monsoonal rains delivering sediments , nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows , which can be affected by reservoirs and dams . Grazing is the largest single land use, followed by sugarcane and natural areas . Urban centres such as Mackay and Proserpine are located on the coastal strip. Habitats include wetlands , fringing and offshore reefs , intertidal, subtidal and deep water seagrass and mangroves . The continental islands (Whitsunday group) are important for tourism and the region also supports important commercial and recreational fisheries .

Figure 9.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Mackay Whitsunday region.

9.2 Adoption of improved management practices

9.2.1 Results

- **Overall, cutting-edge (A) or best management (B) practices for nutrients are used by 40 per cent of sugarcane growers, while 11 per cent of growers are using practices considered unacceptable by industry or community standards (D).**
- **In terms of herbicide management, the vast majority of sugarcane growers (97 per cent) are using common practice or equivalent to code of practice (C) management practices.**
- **In terms of soil management, best management (B) practices are used by 24 per cent of sugarcane growers, with 44 per cent using unacceptable (D) soil management practices.**
- **Cutting-edge (A) or best management (B) practices for nutrients are used by 22 per cent of horticulture producers. Code of practice or common (C) nutrient management practices are used by 50 per cent of growers.**
- **In terms of nutrient management, 28 per cent of horticulture producers are using practices considered unacceptable (D).**
- **Management practice adoption data for the grazing industry is not available at this time.**

The adoption of improved management practices for sugarcane and horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

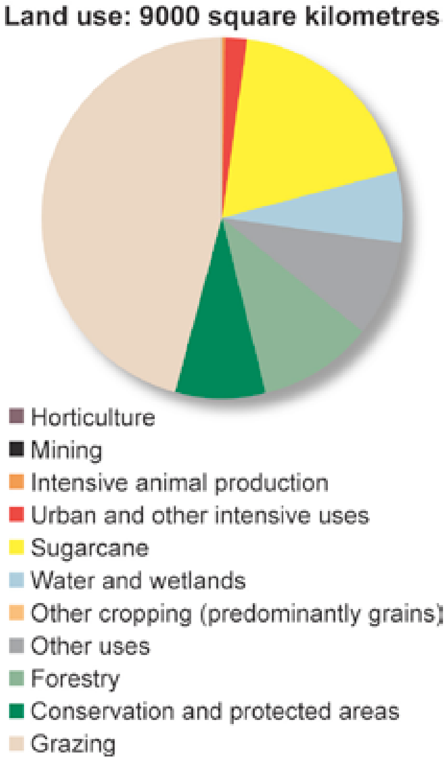


Figure 9.3 – Mackay Whitsunday region land use.

9.2.2 Sugarcane

As at 2008–2009, there are approximately 1320 landholders growing sugarcane on 1674 square kilometres of land within the Mackay Whitsunday region. The overall management practices (including nutrient, herbicide and soil) are shown in Table 9.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 23 per cent of sugarcane growers, while 59 per cent of sugarcane growers are using common or code of practice (C) management practices. Practices considered unacceptable by industry or community standards are used by 18 per cent of growers.

Cutting-edge (A) or best management (B) practices for nutrient are used by 40 per cent of sugarcane growers. Nutrient management practices considered unacceptable (D) are used by 11 per cent of growers.

Cutting-edge (A) or best management (B) practices for herbicides are used by only three per cent of growers. The rest of the growers (97 per cent) are using common practice or equivalent to code of practice (C) herbicide management practices. Results indicate that no growers are using herbicide management practices considered unacceptable (D).

Cutting-edge (A) or best management (B) practices for soil are used by 24 per cent of growers. Soil management practices considered unacceptable (D) are used by 44 per cent of growers.

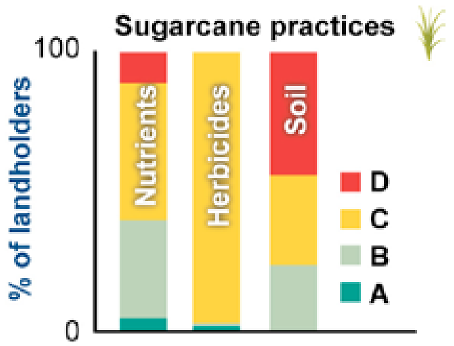


Figure 9.4 – Adoption of improved sugarcane management practices using the ABCD management framework for the Mackay Whitsunday region.

Table 9.1 – ABCD sugarcane management practices for the Mackay Whitsunday region (Source: modified from GHD, 2010d).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of cane growers	31	264	783	242
% of cane growers	3%	20%	59%	18%
Area (km²)	39	335	993	307
% of area	3%	20%	59%	18%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	66	462	647	145
% of cane growers	5%	35%	49%	11%
Area (km²)	84	586	820	184
% of area	5%	35%	49%	11%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	26	13	1281	0
% of cane growers	2%	1%	97%	0%
Area (km²)	33	17	1624	0
% of area	2%	1%	97%	0%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of cane growers	0	317	422	581
% of cane growers	0%	24%	32%	44%
Area (km²)	0	402	535	737
% of area	0%	24%	32%	44%

9.2.3 Horticulture

As at 2008–2009, there are 32 landholders growing horticultural crops on 12 square kilometres of land within the Mackay Whitsunday region. The main horticultural crops include lychees, mangoes and vegetables.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 9.2. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 53 per cent of producers. Code of practice or common (C) practices are used by 34 per cent of producers. Practices considered unacceptable by industry and community standards (D) are used by 13 per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 22 per cent of producers. Code of practice or common (C) nutrient management practices are used by 50 per cent of producers. Nutrient management practices considered unacceptable (D) are used by 28 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 62 per cent of producers, while 2 per cent of producers are using unacceptable (D) nutrient management practices.

Cutting-edge (A) or best management (B) practices for soil are used by 76 per cent of producers, with 7 per cent using unacceptable (D) soil management practices.

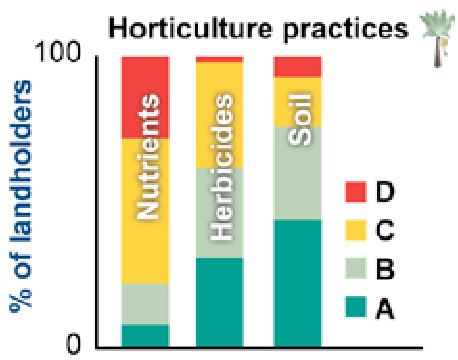


Figure 9.5 – Adoption of improved management practices for horticulture using the ABCD management framework for the Mackay Whitsunday region.

Table 9.2 – ABCD horticulture management practices for the Mackay Whitsunday region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	9	8	11	4
% of horticulture producers	28%	25%	34%	13%
Area (km²)	2.8	2.9	5.1	1.3
% of area	23%	24%	43%	10%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	2	4	16	10
% of horticulture producers	8%	14%	50%	28%
Area (km²)	0.3	1.8	7.6	2.4
% of area	3%	15%	62%	20%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	10	10	11	1
% of horticulture producers	31%	31%	36%	2%
Area (km²)	4.4	3.2	4.2	0.1
% of area	37%	27%	35%	1%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	15	10	5	2
% of horticulture producers	44%	32%	17%	7%
Area (km²)	3.5	3.8	3.4	1.3
% of area	29%	31%	29%	11%

9.3 Catchment indicators

9.3.1 Results

- **The total riparian area in the Mackay Whitsunday region is 130,000 hectares, of which 650 hectares are likely to be susceptible to erosion (non-forested and low groundcover).**
- **The O’Connell catchment had the highest riparian clearing rate between 2004 and 2008, with 389 hectares (1.16 per cent) cleared.**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangroves/salt flats) across the Mackay Whitsunday region as at 2005 is 58,000 hectares. This represents 88 per cent of wetlands remaining from pre-European times.**
- **Forty-seven per cent of vegetated freshwater swamps have been lost since pre-European times.**
- **The Pioneer and O’Connell catchments have had significant loss of wetlands since pre-European times with 84 per cent and 62 per cent of vegetated freshwater swamps lost respectively.**
- **The 2009 mean dry season groundcover for the grazing lands of the Mackay Whitsunday region is 93 per cent, which is above the Reef Plan target of 50 per cent.**

9.3.2 Riparian vegetation

The Mackay Whitsunday region had a total of 100,000 hectares (76 per cent) of riparian areas forested, and 27,000 hectares (20 per cent) of non-forested riparian areas with high groundcover areas. Only 650 hectares (0.48 per cent) were non-forested with low groundcover making these areas likely to be susceptible to erosion and, therefore, sediment loss to streams. From 2004 to 2008, 825 hectares (0.62 per cent) of forested riparian areas were cleared. Within the region, the O’Connell catchment had the highest clearing rate between 2004 and 2008, with 389 hectares (1.16 per cent) cleared.

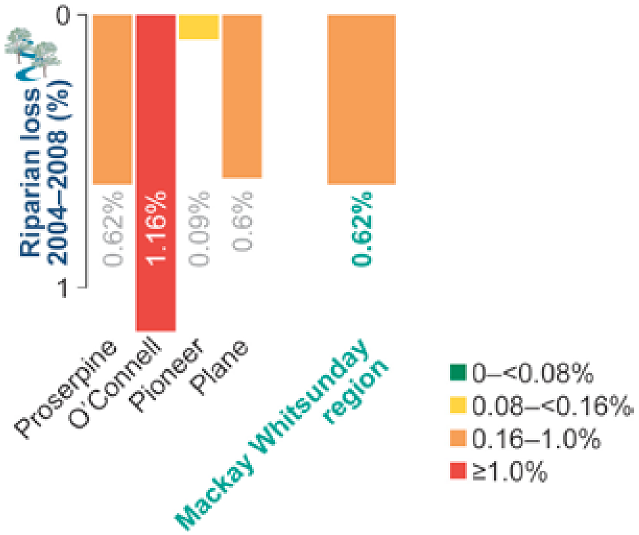


Figure 9.6 – Loss of riparian vegetation between 2004 and 2008 in the Mackay Whitsunday region.

Table 9.3 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Proserpine	32,094	26,466	82.46	5153	16.06	134	0.42	1.06	200	0.62
O'Connell	33,553	26,271	78.30	6605	19.69	149	0.44	1.57	389	1.16
Pioneer	32,684	24,158	73.91	6656	20.36	296	0.91	4.82	29	0.09
Plane	34,377	23,957	69.69	8590	24.99	68	0.20	5.12	207	0.60
Mackay Whitsunday region	**132,708**	**100,852**	**76.00**	**27,004**	**20.35**	**647**	**0.49**	**3.17**	**825**	**0.62**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

9.3.3 Wetlands

Wetland types

As at 2005, there are approximately 58,000 hectares of wetlands in the Mackay Whitsunday region. Of these wetland areas, there are:

- 9700 hectares of vegetated freshwater swamps (palustrine wetlands). The Proserpine catchment has the greatest areas of vegetated freshwater swamps.
- 200 hectares of lakes (lacustrine wetlands).
- 48,000 hectares of mangroves/salt flats (estuarine wetlands).

Compared with pre-European times, 88 per cent of the total extent of wetlands remain. Forty-seven per cent of vegetated freshwater swamps in the region have been lost since pre-European times. The Pioneer and O'Connell catchments have had significant loss of wetlands since pre-European times, with 84 per cent and 62 per cent of vegetated freshwater swamps lost respectively. Of mangroves and salt flats, 96 per cent remains for the region.

Wetland loss in the Mackay Whitsunday region between 2001 and 2005 was 15 hectares (0.03 per cent). The loss of vegetated freshwater swamps over the 2001–2005 period was four hectares (0.05 per cent), with the greatest loss in the O'Connell catchment (0.28 per cent). There was minimal loss of mangroves/salt flats over the 2001–2005 period, ranging from nil to 0.04 per cent.

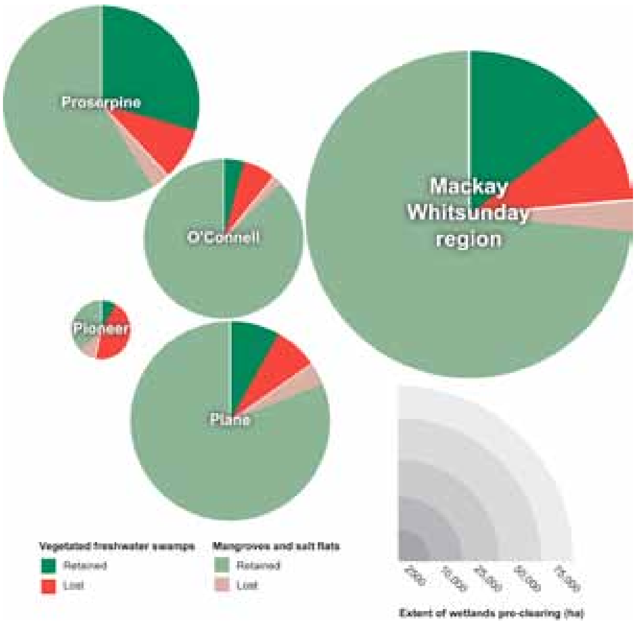


Figure 9.7 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Mackay Whitsunday region.

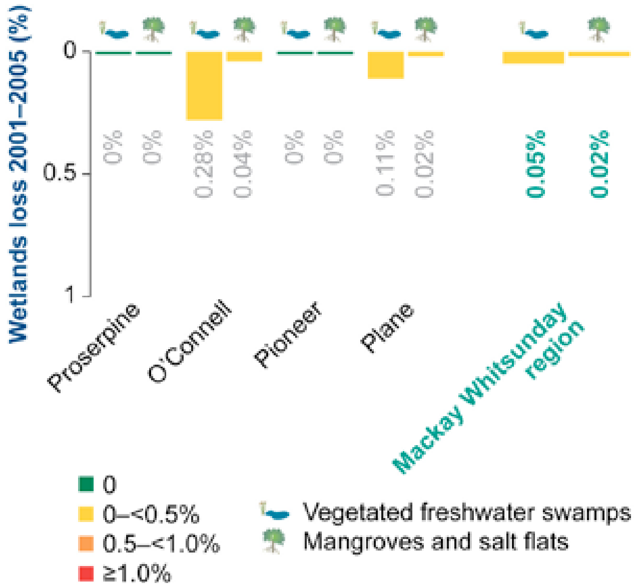


Figure 9.8 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Mackay Whitsunday region.

Table 9.4 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Mackay Whitsunday region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
O'Connell	650	38	0.28	15	100	0	13,555	98	0.04	14,220	91	0.05
Pioneer	180	16	0	NP	NP	NP	780	80	0	960	40	0.03
Plane	1955	52	0.11	NP	NP	NP	19,685	96	0.02	21,640	89	0.03
Proserpine	6910	77	0	190	100	0	13,760	95	0	20,860	92	0
Mackay Whitsunday region	**9695**	**53**	**0.05**	**205**	**100**	**0**	**47,780**	**96**	**0.02**	**57,680**	**88**	**0.03**

NP – wetland type was not present.

9.3.4 Groundcover in grazing lands

Groundcover is influenced by a combination of factors including the land type, climate and management practices. The majority of the Mackay Whitsunday region's grazing lands are in the upper lands of the region's catchments. The long term mean dry season groundcover for the grazing lands of the Mackay Whitsunday region (Table 5.6) over the 1986–2009 period is 90 per cent, which is above the Reef Plan target of 50 per cent. Similar to other regions, the average groundcover in 2009 is higher than the historical average, increasing to 93 per cent. The proportion of the grazing area with groundcover of 50 per cent or greater in 2009 is high (97.9 per cent). Only 2.1 per cent of the area was below the 50 per cent groundcover target, with 1.4 per cent of the area below 30 per cent.

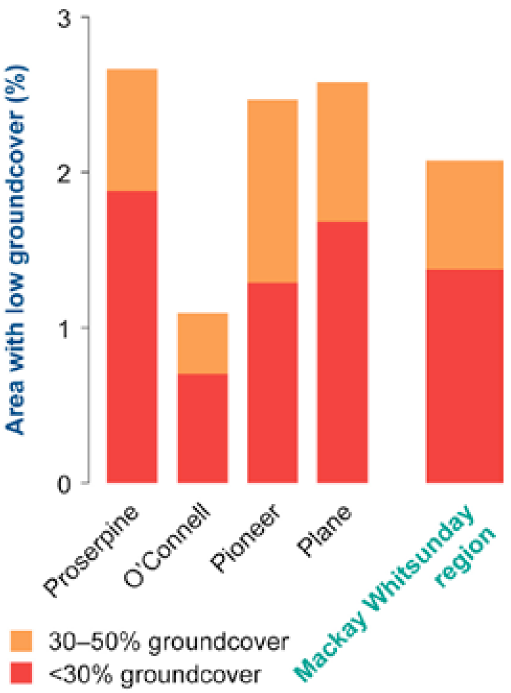


Figure 9.9 – Area with low groundcover (area under 30 per cent and between 30 per cent and 50 per cent) as at 2009 for the Mackay Whitsunday region.

9.4 Catchment loads

The total suspended solids load leaving the catchments of the Mackay Whitsunday region is an estimated 1.5 million tonnes per year. Of this, 1.3 million tonnes are from human activity (Kroon et al., 2010).

The total nitrogen load leaving the catchments of the Mackay Whitsunday region is 8100 tonnes per year, of which 7200 tonnes are from human activity.

The total phosphorus load leaving the catchments of the Mackay Whitsunday region is 2200 tonnes per year, of which 2000 tonnes are from human activity.

The dissolved nitrogen load is 3300 tonnes per year, of which 2500 tonnes are from human activity. The dissolved phosphorus load is 370 tonnes per year, of which 310 tonnes are from human activity.

The total photosystem inhibiting (PSII) pesticide load leaving the catchments of the Mackay Whitsunday region is an estimated 10,000 kilograms per year. Along with the Wet Tropics region, this was significantly higher than other regions. The pesticide residues most commonly found in surface waters from areas of sugarcane cultivation are diuron, atrazine, ametryn and hexazinone (Lewis et al., 2009). It is important to note that this estimate does not include several land uses known to leak PSII pesticides (e.g. grazing, forestry, cotton, urban) and non-PSII pesticides, indicating that the total pesticide pollutant load to the Great Barrier Reef is likely to be higher.

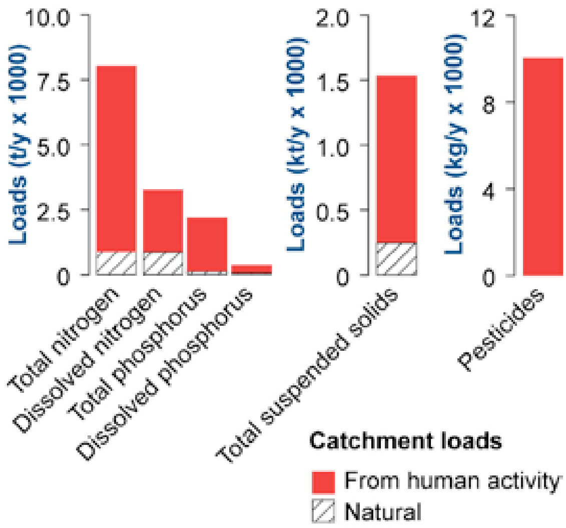


Figure 9.10 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen, dissolved phosphorus and pesticides.

9.5 Great Barrier Reef water quality and ecosystem health

9.5.1 Results

- **Inshore waters in the Mackay Whitsunday region have concentrations of suspended solids above Great Barrier Reef Marine Park Water Quality Guidelines. A range of pesticides including diuron, atrazine and tebuthiuron are detectable in inshore waters of the region.**
- **Seagrass abundance is moderate but is declining at many sites. Seagrass reproductive capacity is declining raising concerns about resilience to disturbance.**
- **Inshore reefs in the Mackay Whitsunday region are in moderate condition. Coral cover is stable but has not increased in recent years despite the lack of disturbances, leading to a poor rating overall. The cover of macroalgae is low and the number of juvenile colonies is good, but has declined in recent years.**

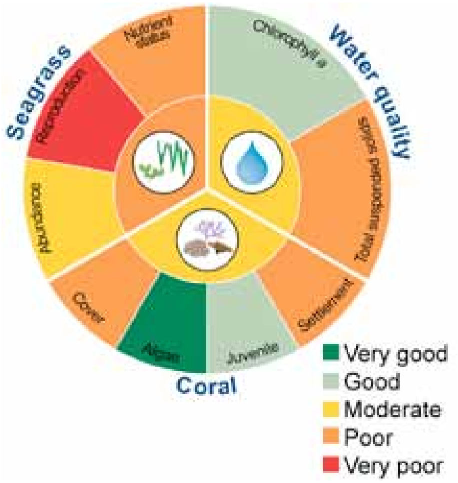


Figure 9.11 – Great Barrier Reef water quality and ecosystem health of the Mackay Whitsunday region showing the status of water quality, seagrass and corals.

9.5.2 Water quality

Over the period 2008–2009, freshwater discharges from the Proserpine, O'Connell and Pioneer Rivers and Plane Creek were above median flows, with the Proserpine River and Plane Creek having flows 1.8 and 1.7 times greater than the median flow respectively. Great Barrier Reef Water Quality Guideline (GBRMPA, 2009) exceedances for chlorophyll *a* and suspended solids concentrations were calculated for the May 2008–April 2009 period from satellite imagery (Table 9.5). The mean values of suspended solids concentrations in the region exceeded the Great Barrier Reef Marine Park Water Quality Guideline values for the inshore, midshelf and offshore areas.

Table 9.5 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Mackay Whitsunday region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
24	3	0	74	42	50

A range of pesticides were detected in passive samplers deployed in inshore marine environments in the Mackay Whitsunday region over the monitoring period (Figure 5.13). Detected pesticides included diuron, atrazine, and tebuthiuron. In contrast to other regions, atrazine was the pesticide detected in highest concentrations. Concentrations of detected pesticides were typically (but not always) higher during the wet season. The maximum water concentrations of individual pesticides ranged from 0.15 to 4.1 nanograms per litre.

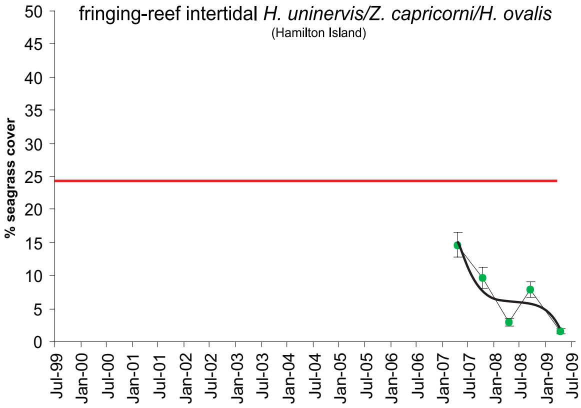
In high river flow conditions, diuron was detected at concentrations above Great Barrier Reef Marine Park Water Quality Guidelines off the Pioneer River in 2007, and tebuthiuron was detected above Great Barrier Reef Marine Park Water Quality Guidelines off the O'Connell River in 2005 and 2007 (Lewis et al., 2009). Refer to the case study: Pesticides in flood plumes in the Mackay Whitsunday region (Section 5.5.2).

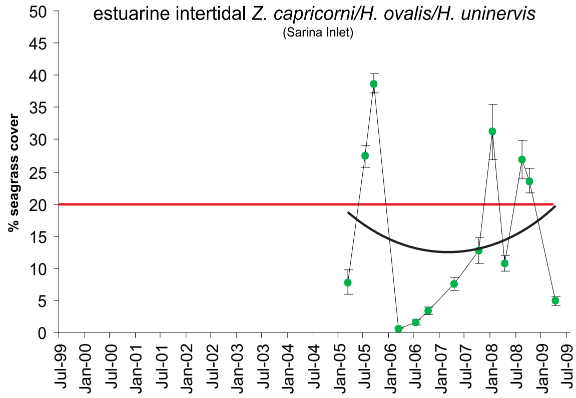
9.5.3 Seagrass status

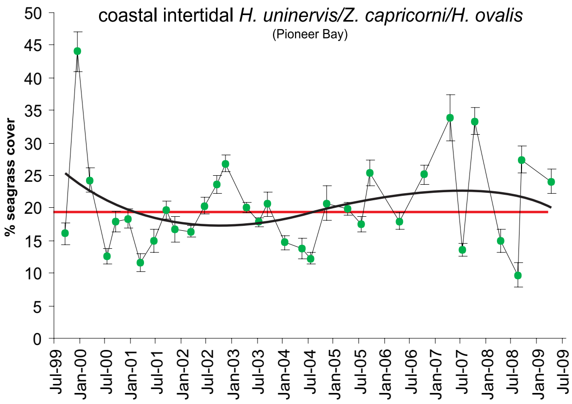
Seagrass meadows are monitored at reef, coastal and estuarine sites at three locations in the Mackay Whitsunday region. Similar to other regions, seagrass cover is variable between habitat types. Cover at the coastal site is currently higher than the long term Great Barrier Reef average, whereas cover at the estuarine and reef sites is lower (Figure 9.12). Seagrass cover at the reef site has declined since 2007.

Seagrass reproductive capacity in the region is in decline, raising concerns about the ability of regional meadows to recover from significant future disturbance events such as cyclones and floods. Seagrass meadows in the region are also subjected to reduced light availability.

Figure 9.12 below – Long term seagrass cover, Pioneer Bay (coastal), Sarina Inlet (estuarine) and Hamilton Island (reef), Mackay Whitsunday region, compared with long term Great Barrier Reef average (red line) (Source: DEEDI).







9.5.4 Coral status

Seven coral reefs are monitored in the Mackay Whitsunday region. Coral status in the region is moderate overall, with monitored reefs having high coral cover and low cover of macroalgae. Despite the lack of disturbances such as cyclones and bleaching events in the region over the past four years, coral cover is stable and has not increased. However, this is generally expected from resilient reefs. The density of juvenile corals has declined over the past four years to low levels, despite high densities of coral larvae settling on reefs in the region. The sediment at these reefs has a high proportion of fine (silt and clay) particles, which increased after repeated flood events in recent years.

Table 9.6 – Summary of coral community status of monitored reefs in the Mackay Whitsunday region, 2008–2009.

Reef	Depth (m)	Overall status	Coral cover	Change in hard coral cover	Macroalgae cover	Juvenile density	Settlement
Double Cone Island	2	neutral	+	-	+	neutral	-
	5	+	+	-	+	neutral	neutral
Daydream Island	2	-	neutral	-	+	neutral	-
	5	+	neutral	-	+	+	neutral
Hook Island	2	++	+	neutral	+	neutral	N/A
	5	+	+	-	+	neutral	N/A
Dent Island	2	++	+	-	+	+	N/A
	5	neutral	neutral	-	+	neutral	N/A
Shute Island and Tancred Island	2	+++	+	neutral	+	+	N/A
	5	+	neutral	-	+	+	N/A
Pine Island	2	- -	neutral	-	neutral	neutral	-
	5	+	neutral	-	+	+	neutral
Seaforth Island	2	neutral	neutral	-	neutral	+	N/A
	5	neutral	-	-	+	+	N/A

Explanatory note: + status and resilience is good; neutral denotes status and resilience is moderate; - status and resilience is poor. Overall status is estimated by summing the individual status scores.

Fitzroy region

Chapter 10

"The Fitzroy is the largest of all catchments draining into the Great Barrier Reef lagoon… Much of the inland parts of the region contain open woodlands that include important areas of remnant Brigalow, as well as threatened native grasslands."

Photo courtesy of Fitzroy Basin Association Inc.

10.1 Profile

The Fitzroy region includes the Fitzroy, Boyne, Calliope, Waterpark, Shoalwater and Styx/Herbert catchments, and covers 156,000 square kilometres. The Fitzroy is the largest of all catchments draining into the Great Barrier Reef lagoon. The region experiences highly variable rainfall, high evaporation rates and prolonged dry periods, which are often followed by floods. Much of the inland parts of the region contain open woodlands that include important areas of remnant Brigalow, as well as threatened native grasslands.

Grazing is the predominant land use but there are also significant areas of cultivation including large expanses of irrigated and dryland cropping. Low groundcover is the main pressure resulting in excess sediments, nutrient and chemicals delivered to the Great Barrier Reef. Management focuses on activities to increase cover and reduce fertiliser and chemical application.

The Fitzroy Basin Association has been working with landholders in priority areas to reduce sediment and nutrients delivered to the reef by 1 per cent every year for the past five years. Landholders managing more than 22 per cent of the region have implemented projects to date. These activities support Reef Plan targets to reduce sediment loads delivered to the Great Barrier Reef.

Best available science helps prioritise investment in grazing land management. Through the Grains Best Management Practices program, growers benchmark their practices. A network of sub-regional groups, AgForce, Growcom and the Department of Employment, Economic Development and Innovation all work with the Fitzroy Basin Association to deliver best management practice knowledge and skills to landholders.

Figure 10.1 – Map of the Fitzroy region and Great Barrier Reef Marine Park showing the paddock, catchment and marine monitoring sites.

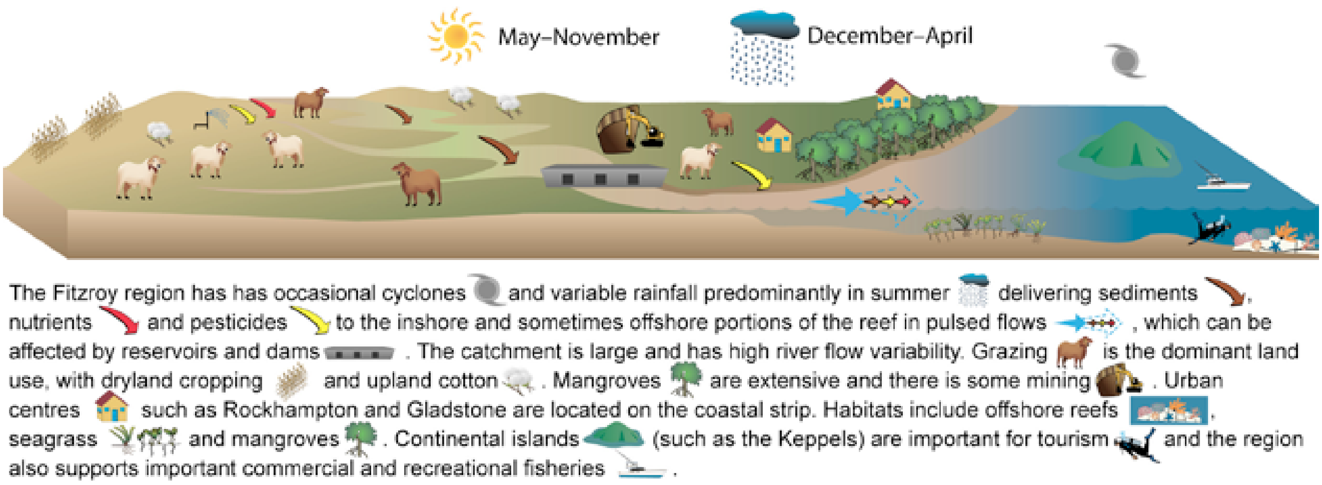


Figure 10.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Fitzroy region.

10.2 Adoption of improved management practices

10.2.1 Results

- **Fifty-three per cent of graziers are using (A or B) practices that are likely to maintain land in good to very good condition or improve land in lesser condition.**
- **Practices (D) likely to degrade land to poor condition are used by 12 per cent of graziers.**
- **Cutting-edge (A) or best management (B) practices for nutrients are used by 39 per cent of horticulture producers.**
- **Nutrient management practices considered unacceptable by industry and community standards (D) are used by 26 per cent of horticulture producers.**
- **In terms of herbicide management, cutting-edge or best management (A or B) practices are used by 64 per cent of producers, while 4 per cent of horticulture producers are using unacceptable (D) herbicide management practices.**
- **Cutting-edge (A) or best management (B) practices are used by 85 per cent of grain growers on 90 per cent of the land area. Code of practice (C) or practices considered unacceptable by industry and community standards (D) are used by 15 per cent of grain growers.**

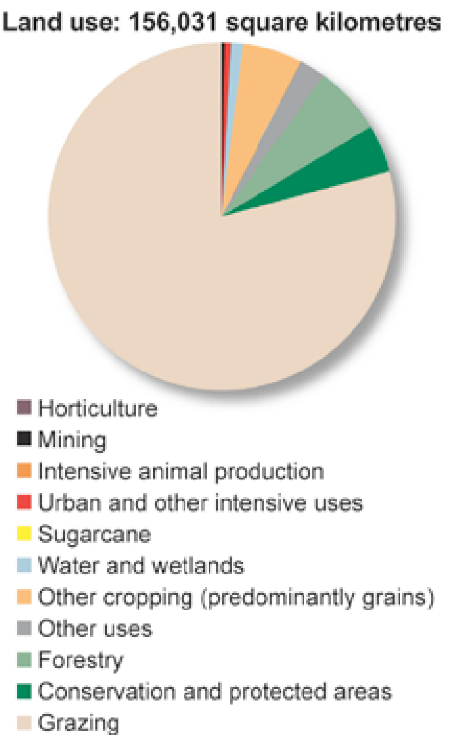


Figure 10.3 – Fitzroy region land use.

10.2.2 Grazing

There are an 3591 landholders grazing cattle on 123,000 square kilometres of land in the Fitzroy region. Fifty-three per cent of graziers are using (A or B) practices that are likely to maintain land in good to very good condition, or improve land in lesser condition. Thirty-five per cent of graziers are using (C) management practices which may maintain land in fair condition or gradually improve land in poor condition. Practices (D) considered likely to degrade land to poor condition are used by 12 per cent of graziers.

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

A – Practices likely to maintain land in very good condition or improve land in lesser condition

B – Practices likely to maintain land in good condition or improve land in lesser condition

C – Practices that may maintain land in fair condition or gradually improve land in poor condition

D – Practices likely to degrade land to poor condition.

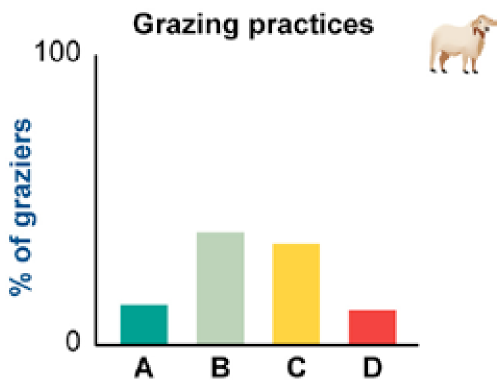


Figure 10.4 – Adoption of improved grazing management practices using the ABCD management framework for the Fitzroy region.

Table 10.1 – ABCD grazing management practices for the Fitzroy region.

Fitzroy	A practices	B practices	C practices	D practices
Number of graziers	496	1385	1266	444
% of graziers	14%	39%	35%	12%
Area (km²)	16,986	47,441	43,358	15,215

10.2.3 Horticulture

The adoption of improved management practices for horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices that are considered unacceptable by industry or community standards.

As at 2008–2009, there are 106 landholders growing horticultural crops on 58 square kilometres of land within the Fitzroy region. The main horticultural crops include citrus and subtropical fruit trees.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 10.2. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 54 per cent of producers. Code of practice or common practices (C) are being used by 33 per cent of producers. Practices considered unacceptable by industry or community standards (D) are used by 13 per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 39 per cent of producers. Code of practice or common (C) nutrient management practices are used by 35 per cent of producers. Nutrient management practices considered unacceptable (D) are used by 26 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 64 per cent of producers, while 4 per cent of producers are using unacceptable (D) nutrient management practices.

Cutting-edge (A) or best management (B) practices for soil are used by 60 per cent of producers with 32 per cent using code of practice (C) soil management practices.

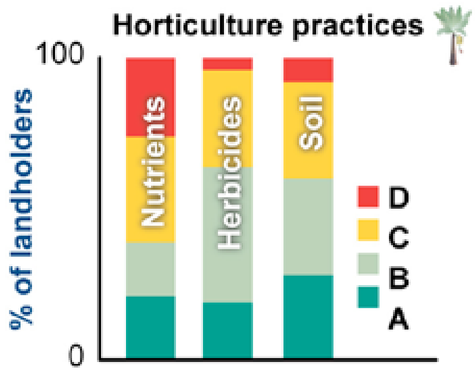


Figure 10.5 – Adoption of improved management practices for horticulture using the ABCD management framework for the Fitzroy region.

Table 10.2 – ABCD horticulture management practices for the Fitzroy region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture growers	24	33	35	14
% of horticulture growers	23%	31%	33%	13%
Area (km²)	16	17	18	7
% of area	27%	29%	32%	12%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture growers	22	19	38	27
% of horticulture growers	21%	18%	35%	26%
Area (km²)	15	12	18	13
% of area	26%	20%	32%	22%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture growers	20	48	33	4
% of horticulture growers	19%	45%	32%	4%
Area (km²)	17	23	17	1
% of area	30%	39%	30%	1%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture growers	31	33	33	9
% of horticulture growers	28%	32%	32%	8%
Area (km²)	15	16	20	7
% of area	26%	28%	34%	12%

10.2.4 Grains

The overall grain management practices (including nutrient, herbicide and soil) are shown in Table 10.3. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 85 per cent of growers. Code of practice (C) or practices considered unacceptable by industry or community standards (D) are used by 15 per cent of grain growers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 87 per cent of growers. Code of practice (C) or unacceptable (D) nutrient management practices are used by 13 per cent of grain growers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 83 per cent of growers. Code of practice (C) or unacceptable (D) nutrient management practices are used by 17 per cent of grain growers.

Cutting-edge (A) or best management (B) practices for soil management are used by 86 per cent of growers. Code of practice (C) or unacceptable (D) nutrient management practices are used by 14 per cent of grain growers.

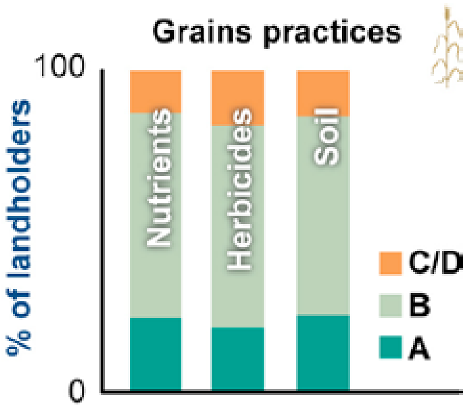


Figure 10.6 – Adoption of improved management practices for grains using the ABCD management framework for the Fitzroy region.

Table 10.3 – ABCD grain management practices for the Fitzroy region (Source: modified from Eames H. et al., 2010).

Combined management	A cutting-edge	B best practice	C code or D unacceptable practice
% grain growers	22	63	15
Area (km²)	2621	5302	913
% of area	30	60	10
Nutrient management	**A cutting-edge**	**B best practice**	**C code or D unacceptable practice**
% grain growers	23	64	13
Area (km²)	2651	5389	796
% of area	30	61	9
Herbicide management	**A cutting-edge**	**B best practice**	**C code or D unacceptable practice**
% grain growers	20	63	17
Area (km²)	2386	5301	1149
% of area	27	60	13
Soil management	**A cutting-edge**	**B best practice**	**C code or D unacceptable practice**
% grain growers	24	62	14
Area (km²)	2827	5213	796
% of area	32	59	9

10.3 Catchment indicators

10.3.1 Results

- **The total riparian area in the Fitzroy region is 1.9 million hectares, of which an estimated 38,000 hectares are likely to be susceptible to erosion (non-forested and low groundcover).**
- **The Fitzroy region has the lowest proportion of forested riparian areas compared to other regions with 1.3 million hectares (71 per cent).**
- **The loss of riparian vegetation between 2004 and 2008 was 12,702 hectares (0.68 per cent).**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangroves/saltwater flats) across the Fitzroy region as at 2005 is 220,000 hectares. This represents 83 per cent of wetlands remaining from pre-European times.**
- **The Calliope, Fitzroy and Boyne catchments have had significant loss of vegetated freshwater swamps since pre-European times, with between 57 and 90 per cent lost.**
- **The 2009 mean dry season groundcover for the grazing lands of the Fitzroy region is 83 per cent, which is above the Reef Plan target of 50 per cent.**
- **As at 2009, four per cent of the grazing land area is below the 50 per cent groundcover target, with 1.4 per cent of the area below 30 per cent.**

10.3.2 Riparian vegetation

The Fitzroy region had the lowest proportion of forested riparian areas within the Great Barrier Reef region, with 1.3 million hectares (71 per cent). There were 500,000 hectares (26 per cent) of non-forested areas with high groundcover. 38,000 hectares (2.03 per cent) were non-forested with low groundcover, making these areas likely to be susceptible to erosion and, therefore, sediment loss to streams. From 2004 to 2008, 12,702 hectares (0.68 per cent) of forested riparian areas were cleared. The Waterpark and Styx catchments had the highest proportion of clearing between 2004 and 2008, with 564 hectares (1.7 per cent) and 725 hectares (1.6 per cent) respectively.

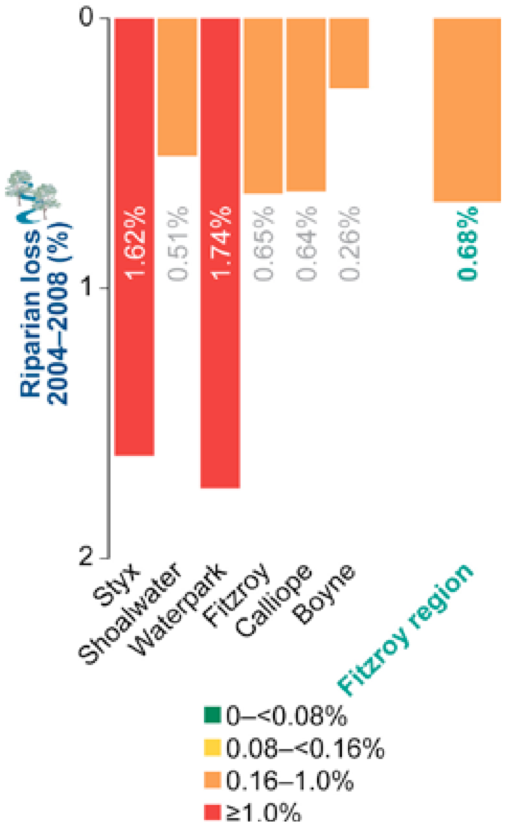


Figure 10.7 – Loss of riparian vegetation between 2004 and 2008 in the Fitzroy region.

Table 10.4 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Fitzroy	1,660,113	1,149,092	69.22	459,014	27.65	37,092	2.23	0.90	10,744	0.65
Styx	44,759	31,946	71.37	12,095	27.02	560	1.25	0.35	725	1.62
Shoalwater	68,923	58,257	84.52	10,242	14.86	248	0.36	0.25	349	0.51
Waterpark	32,513	31,335	96.38	911	2.80	55	0.17	0.65	564	1.74
Calliope	32,164	22,585	70.22	9105	28.31	195	0.61	0.87	206	0.64
Boyne	43,141	38,055	88.21	4758	11.03	87	0.20	0.56	114	0.26
Fitzroy region	**1,881,613**	**1,331,270**	**70.75**	**496,125**	**26.37**	**38,237**	**2.03**	**0.85**	**12,702**	**0.68**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

10.3.3 Wetlands

Wetland types

As at 2005, there are approximately 218,000 hectares of wetlands in the Fitzroy region. Of these wetland areas there are:

- 57,000 hectares of vegetated freshwater swamps (palustrine wetlands). The greatest area of vegetated freshwater swamps is in the Fitzroy catchment.
- 6900 hectares of lakes (lacustrine wetlands).
- 150,000 hectares of mangroves/salt flats (estuarine wetlands).

Of the region's total wetlands, 83 per cent remains from pre-European times, while 78 per cent of vegetated freshwater swamps remain. The Calliope, Fitzroy and Boyne catchments have had significant loss of wetlands since pre-European times, with between 57 and 90 per cent lost. The extent of vegetated freshwater swamps in the Styx and Shoalwater catchments has increased. This is due to the conversion of estuarine plains to freshwater wetlands by damming of ponded pastures, which is a common practice in many coastal catchments. Of the mangroves and salt flats, 85 per cent remains for the region.

The overall loss of wetlands in the Fitzroy region between 2001 and 2005 was 278 hectares (0.13 per cent). The loss of vegetated freshwater swamps over the 2001–2005 period was 146 hectares (0.25 per cent), with this loss derived entirely from the Fitzroy and the Styx catchments. There was a moderate loss of mangroves/salt flats over the 2001–2005 period, ranging from nil to 0.36 per cent.

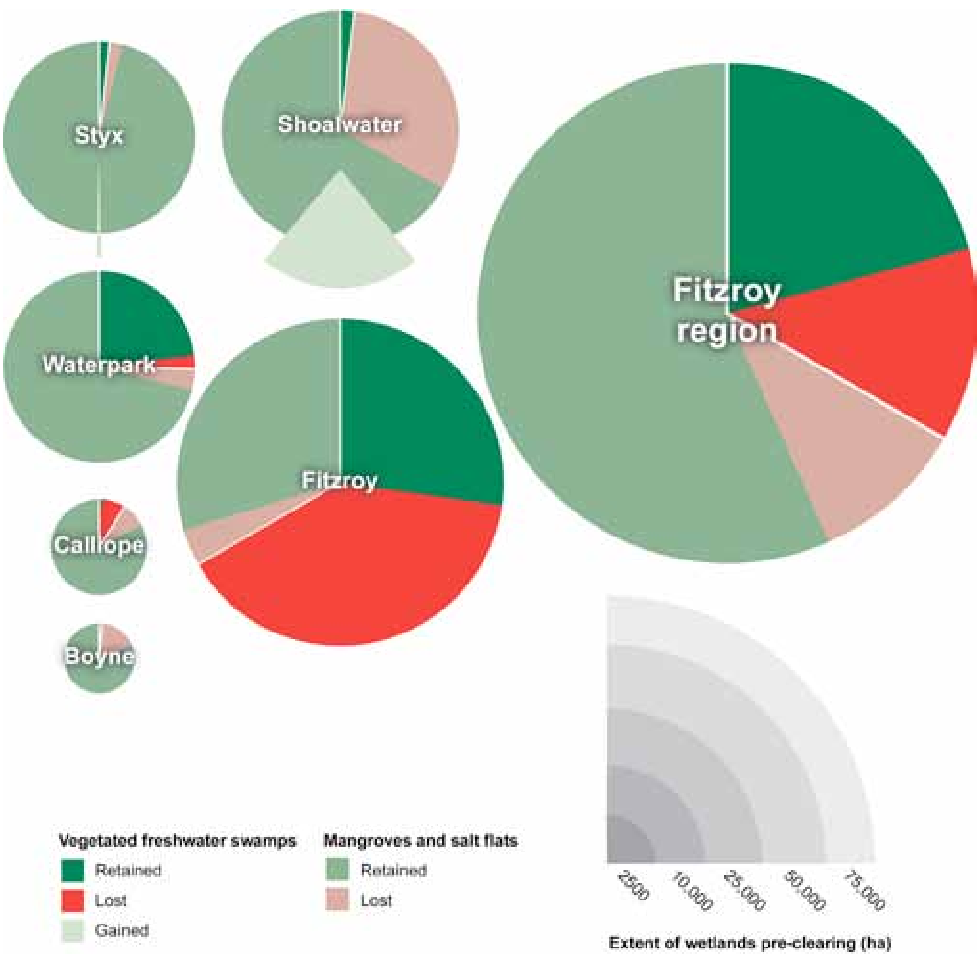


Figure 10.8 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Fitzroy region.

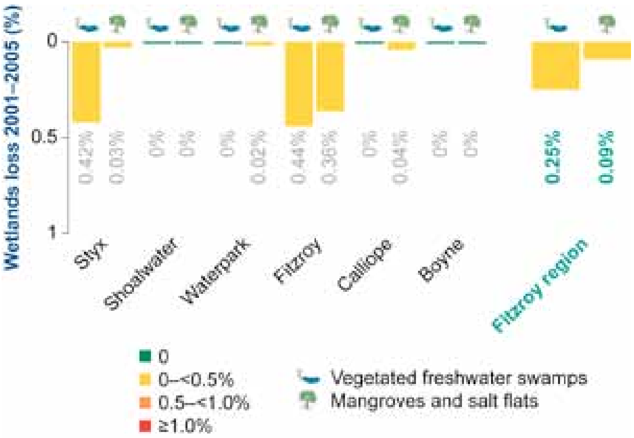


Figure 10.9 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Fitzroy region.

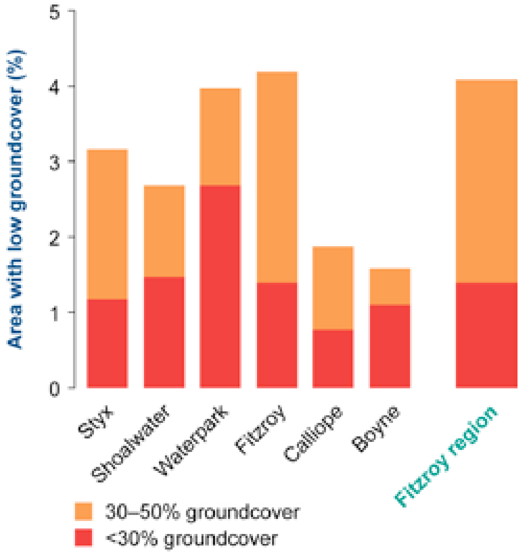


Figure 10.10 – Area with low groundcover (area under 30 per cent and between 30 per cent and 50 per cent) as at 2009 for the Fitzroy region.

Table 10.5 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Fitzroy region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Boyne	35	43	0	10	100	0	4305	82	0	4350	80	0.00
Calliope	90	10	0	20	100	0	8210	91	0.04	8320	90	0.04
Fitzroy	31,775	41	0.44	6870	88	-0.17	34,405	89	0.36	73,050	65	0.34
Shoalwater	14,820	1114	0	40	100	0	40,630	68	0	55,490	81	0
Styx	1310	169	0.42	20	100	0	38,335	98	0.03	39,665	99	0.04
Waterpark Creek	9250	92	0	5	100	0	28,125	95	0.02	37,380	94	0.02
Fitzroy region	**57,280**	**78**	**0.25**	**6965**	**88**	**-0.17**	**154,010**	**85**	**0.09**	**218,255**	**83**	**0.13**

10.3.4 Groundcover in grazing lands

Groundcover is influenced by a combination of factors including the land type, climate and management practices. The majority of the region's grazing lands are in the largest catchment, the Fitzroy. The long term mean dry season groundcover for the grazing lands of the Fitzroy region over the 1986–2009 period is 79 per cent (Table 5.7), which is above the Reef Plan target of 50 per cent. Similar to other regions, the average groundcover in 2009 is higher than the historical average, increasing to 83 per cent. The proportion of the grazing area with groundcover of 50 per cent or greater in 2009 is high (96 per cent). Only 4.1 per cent of the area was below the 50 per cent groundcover target, with 1.4 per cent of the area below 30 per cent.

10.4 Catchment loads

The total suspended solids load leaving the catchments of the Fitzroy region is an estimated 4.1 million tonnes per year. Of this, 2.9 million tonnes are from human activity. This is the second highest of the Great Barrier Reef regions (second only to the Burdekin region). These high suspended sediment loads in streams are associated with extensive grazing areas (Packett et al., 2009).

The total nitrogen load leaving the catchments of the Fitzroy region is 15,000 tonnes per year, of which 13,000 tonnes are from human activity. A large proportion of this is in the form of particulate nitrogen, with a total load of 12,000 tonnes per year, which is almost entirely due to human activity.

The total phosphorus load leaving the catchments of the Fitzroy region is 4100 tonnes per year, of which 3900 tonnes are from human activity.

The dissolved nitrogen load is 2700 tonnes per year of which 1100 tonnes per year are from human activity. The dissolved phosphorus load is 245 tonnes per year, of which 154 tonnes are from human activity.

The total photosystem inhibiting (PSII) pesticide load leaving the catchments of the Fitzroy region is an estimated 2300 kilograms per year. It is important to note that this estimate does not include several land uses known to leak PSII pesticides (e.g. grazing, forestry, cotton, urban) and non-PSII pesticides, indicating that the total pesticide pollutant load to the Great Barrier Reef is likely to be higher.

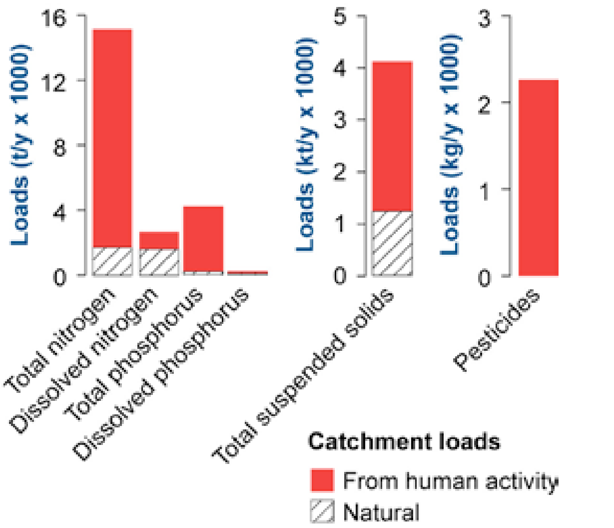


Figure 10.11 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen, dissolved phosphorus and pesticides.

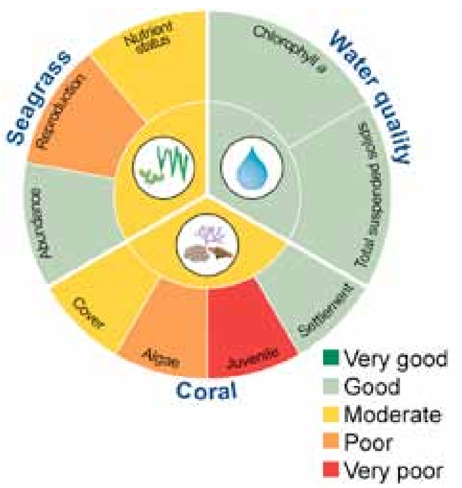


Figure 10.12 – Great Barrier Reef water quality and ecosystem health of the Fitzroy region showing the status of water quality, seagrass and corals.

10.5 Great Barrier Reef water quality and ecosystem health

10.5.1 Results

- **Water quality in the Fitzroy region is good overall, but concentrations of chlorophyll *a* and suspended solids are above Great Barrier Reef Marine Park Water Quality Guidelines in the inshore area. The pesticides diuron and tebuthiuron are detectable in inshore waters of the region.**
- **Seagrass abundance in the region has increased or is variable at coastal and estuarine locations, but has declined in reef locations. There are low numbers of reproductive structures, indicating reduced resilience to disturbance. The Shoalwater Bay site contains the most healthy and least impacted coastal seagrass meadows along the urban coast of the Great Barrier Reef.**
- **Reefs in the Fitzroy region are in moderate condition overall, with moderate coral cover and good settlement of juvenile corals, but very poor juvenile diversity and high cover of macroalgae. The reefs have been subject to significant disturbances over the past 10 years and have recovered, but mainly by re-growth from fragments and not recruitment. As a result, their long term resilience to future disturbance is uncertain.**

10.5.2 Water quality

Freshwater discharge from the Fitzroy River during 2008–2009 was less than the river's long term median. Great Barrier Reef Marine Park Water Quality Guideline (GBRMPA, 2009) exceedances for chlorophyll *a* and suspended solids concentrations were calculated for the May 2008–April 2009 period from satellite imagery (Table 10.6). The mean chlorophyll *a* and suspended sediment concentrations exceeded the Great Barrier Reef Marine Park Water Quality Guideline value for the region's inshore area.

Table 10.6 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Fitzroy region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
35	2	0	35	2	0

Diuron and tebuthiuron were the two pesticides detected in passive samplers deployed in the Fitzroy region at North Keppel Island (Figure 5.13). Diuron was found at the highest concentration and maximum water concentrations of individual pesticides ranged from 0.18 to 1.1 nanograms per litre over the sampling period.

10.5.3 Seagrass status

Seagrass meadows are monitored at reef, estuarine and coastal sites at three locations in the Fitzroy region. Seagrass meadow cover has increased over the past seven years at coastal and estuarine sites in the region. Average seagrass cover at the coastal location has been consistently higher than the long term Great Barrier Reef average (Figure 10.13). In contrast, seagrass cover at the reef location is much lower than the long term Great Barrier Reef average. Biomonitoring suggests that more southern meadows at Great Keppel Island and Gladstone receive low light levels and are subject to nutrient rich conditions. In contrast, the more remote northern Shoalwater Bay site had lower nutrient conditions and was less turbid. Monitoring sites at Shoalwater Bay contain the most healthy and least impacted coastal seagrass meadows along the urban coast of the Great Barrier Reef.

10.5.4 Coral status

Six coral reefs are monitored in the Fitzroy region. These reefs have been exposed to several disturbances over the past 10 years including floods and coral bleaching events. However, the reefs in the region have high average coral cover and high settlement of larval spat. They also often have low coral diversity, low numbers of coral recruits and high densities of macroalgae. This combination of factors is of concern as coral reef recovery in the past has been a consequence of coral regrowth from surviving fragments rather than recruitment. As a result, the reefs are likely to be vulnerable to a major disturbance event in the future that could cause extensive mortality of whole coral colonies, which in turn would preclude recovery through regrowth of surviving fragments.

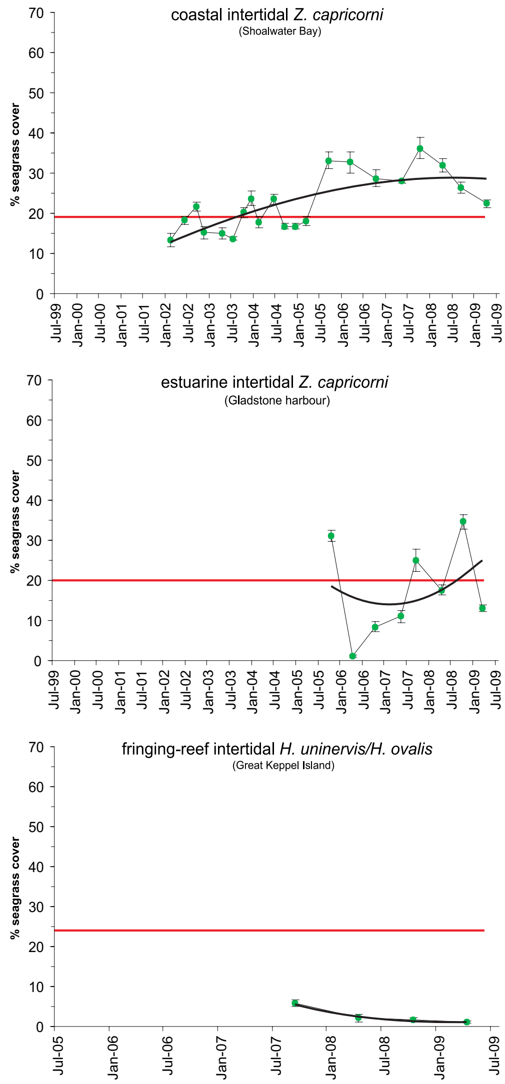


Figure 10.13 – Long term seagrass cover, Shoalwater Bay (coastal), Gladstone Harbour (estuarine) and Great Keppel Island (reef), Fitzroy region, compared with long term Great Barrier Reef average (red line) (Source: DEEDI).

Table 10.7 – Summary of coral community status of monitored reefs in the Fitzroy region, 2008–2009.

Reef	Depth (m)	Overall status	Coral cover	Change in hard coral cover	Macroalgae cover	Juvenile density	Settlement
Barren Island	2	-	neutral	neutral	+	-	-
	5	+	+	+	neutral	neutral	-
North Keppel Island	2	- - - -	-	-	-	-	N/A
	5	- - - -	-	-	-	-	N/A
Humpy Island and Halfway Island	2	+	+	neutral	neutral	-	+
	5	- -	neutral	-	-	-	+
Middle Island	2	- -	neutral	N/A	-	-	N/A
	5	+	+	N/A	neutral	neutral	N/A
Pelican Island	2	+++	+	+	neutral	neutral	+
	5	+	neutral	+	neutral	-	+
Peak Island	2	- -	-	+	-	-	N/A
	5	- - -	neutral	-	-	-	N/A

Explanatory note: + status and resilience is good; neutral denotes status and resilience is moderate; - status and resilience is poor. Overall status is estimated by summing the individual status scores.

Burnett Mary region

Chapter 11

"The region contains a diversity of ecosystems including rainforest, eucalypt woodlands and forest as well as sandy heaths, coastal dune formations, mangroves and salt marsh."

Photo courtesy of Burnett Mary Regional Group

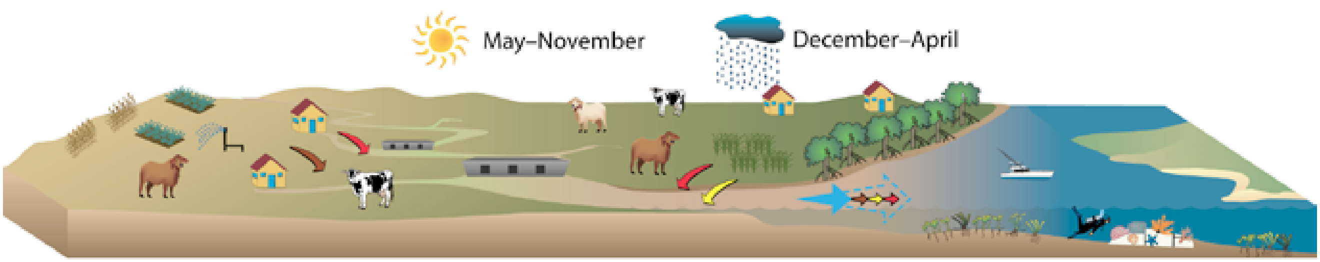
11.1 Profile

The Burnett Mary region, approximately 53,000 square kilometres, covers all lands drained by the Mary, Kolan, Burnett, Auburn, Boyne, Elliot, Gregory, Isis and Burrum Rivers and their tributaries. It encompasses the World Heritage-listed Great Sandy Straits, which includes Fraser Island, the largest sand island in the world. The southern tip of the Great Barrier Reef Marine Park is also included within the region's boundaries. The region contains a diversity of ecosystems including rainforest, eucalypt woodlands and forest as well as sandy heaths, coastal dune formations, mangroves and salt marsh. Regional industries include dairying, grazing, forestry, irrigated cropping, fisheries and tourism.

The region has a moderate, subtropical climate, with mean annual rainfall of about 1000 millimetres around the coastal regions. This region is judged to be high in recreation value due to the size of the population.

The Burnett Mary Regional Group is working with industry and land holders to improve land management practices for improved water quality outcomes. Land management practice improvement as a result of capacity building activities and incentives will reduce sediment, nutrients and pesticides entering waterways. This improved water quality will reduce the degrading impacts upon coastal habitats, including estuaries, seagrass and coral found in the Great Barrier Reef.

Figure 11.1 – Map of the Burnett Mary region and Great Barrier Reef Marine Park showing the paddock, catchment and marine monitoring sites.



The Burnett Mary region has a subtropical climate, with more rain in the summer and in the coastal areas that delivers sediments, nutrients and pesticides to the inshore and sometimes offshore portions of the reef in pulsed flows which can be affected by water reservoirs and dams. The landscape has mixed land use, including grazing, dairy, horticulture, sugarcane and other cropping. Surface and groundwater are important for irrigation. Urban centres such as Bundaberg, Hervey Bay and Maryborough are located on the coastal strip, with other towns such as Gympie and Kingaroy located inland. The region includes the Great Sandy Biosphere, and the Fraser Island World Heritage Area is located offshore. Habitats include offshore reefs, intertidal and deep-water seagrass and mangroves. Reef-based tourism, as well as commercial and recreational fisheries, is an important part of the regional economy.

Figure 11.2 – Conceptual model showing the key processes influencing water quality and reef ecosystem health in the Burnett Mary region.

11.2 Adoption of improved management practices

11.2.1 Results

- **In terms of nutrient management, cutting-edge (A) or best management (B) practices are used by 52 per cent of sugarcane growers, while 25 per cent of growers are using practices considered unacceptable by industry or community standards (D).**
- **In terms of herbicide management, the vast majority of sugarcane growers (89 per cent) are using common practice or equivalent to code of practice (C) management practices.**
- **Soil management practices considered unacceptable by industry and community standards (D) are used by 46 per cent of sugarcane growers.**
- **In terms of nutrient management, cutting-edge (A) or best management (B) practices are used by 42 per cent of horticulture producers.**
- **Cutting-edge (A) or best management (B) practices for soil management are used by 65 per cent of horticulture producers with 15 per cent using unacceptable (D) soil management practices.**
- **Management practice adoption data for the grazing and grain industries is not available at this time.**

The adoption of improved management practices for sugarcane and horticulture is presented using the ABCD management practice framework, a suite of management practices that are recommended to maintain and/or improve water quality:

A – Cutting-edge practice

B – Best practice

C – Common or code of practice

D – Practices considered unacceptable by industry or community standards.

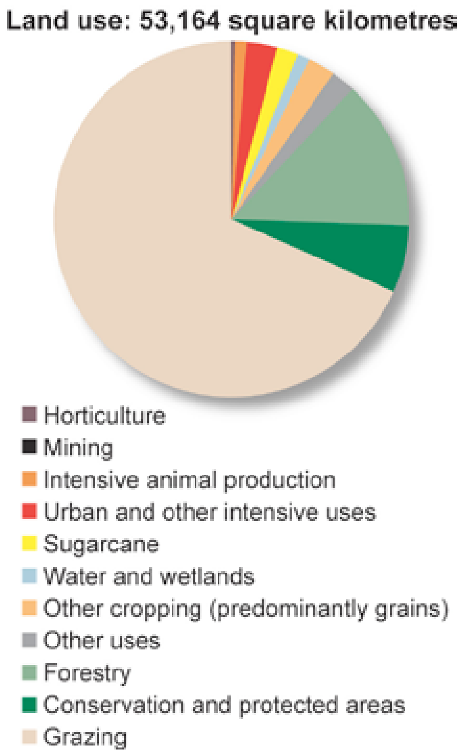


Figure 11.3 – Burnett Mary region land use.

11.2.2 Sugarcane

As at 2008–2009, there are 747 landholders growing sugarcane on 968 square kilometres of land within the Burnett Mary region. The overall management practices (including nutrient, herbicide and soil) are shown in Table 11.1. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 27 per cent of sugarcane growers. Common or code of practice (C) management is used by 48 per cent of sugarcane growers. Practices considered unacceptable by industry and community standards (D) are used by 25 per cent of growers.

Cutting-edge (A) or best management (B) practices for nutrient management are used by 52 per cent of sugarcane growers. Nutrient management practices considered unacceptable (D) are used by 25 per cent of growers.

Cutting-edge (A) or best management (B) practices for herbicides are used by only eight per cent of growers. The vast majority of growers (89 per cent) are using common or equivalent to code of practice (C) management practices. Only three per cent of growers are using herbicide management practices considered unacceptable (D).

Cutting-edge (A) or best management (B) practices for soil are used by 21 per cent of growers. Soil management practices considered unacceptable by industry and community standards (D) are used by 46 per cent of growers.

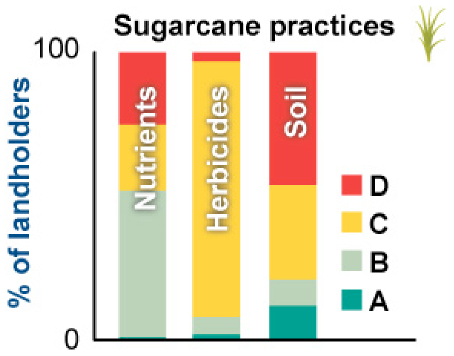


Figure 11.4 – Adoption of improved sugarcane management practices using the ABCD management framework for the Burnett Mary region.

Table 11.1 – ABCD sugarcane management practices for the Burnett Mary region (Source: modified from GHD, 2010e).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of canegrowers	37	164	362	184
% of canegrowers	5%	22%	48%	25%
Area (km²)	39	235	474	219
% of area	4%	24%	49%	23%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of canegrowers	7	381	172	187
% of canegrowers	1%	51%	23%	25%
Area (km²)	10	494	222	241
% of area	1%	51%	23%	25%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of canegrowers	15	45	665	22
% of canegrowers	2%	6%	89%	3%
Area (km²)	29	58	861	19
% of area	3%	6%	89%	2%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of canegrowers	90	67	247	343
% of canegrowers	12%	9%	33%	46%
Area (km²)	77	155	339	396
% of area	8%	16%	35%	41%

11.2.3 Horticulture

As at 2008–2009, there are 280 landholders growing horticultural crops on 191 square kilometres of land within the Burnett Mary region. The main horticultural crops include macadamias, citrus and vegetables.

The overall management practices (including nutrient, herbicide and soil) are shown in Table 11.2. Adoption of specific nutrient, herbicide and soil management practices are also reported.

Cutting-edge (A) or best management (B) practices are used by 59 per cent of producers. Code of practice or common practices (C) are used by 27 per cent of producers. Practices considered unacceptable by industry and community standards (D) are used by 14 per cent of producers.

Cutting-edge (A) or best management (B) practices for nutrients are used by 42 per cent of producers. Code of practice or common nutrient management practices (C) are used by 36 per cent of producers. Nutrient management practices considered unacceptable (D) are used by 22 per cent of producers.

Cutting-edge (A) or best management (B) practices for herbicides are used by 70 per cent of producers, while 5 per cent of producers are using unacceptable (D) nutrient management practices.

Cutting-edge (A) or best management (B) practices for soil are used by 65 per cent of producers, with 20 per cent using code of practice or common practices (C). Soil management practices considered unacceptable (D) are used by 15 per cent of producers.

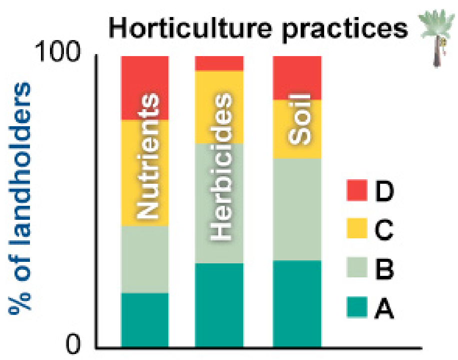


Figure 11.5 – Adoption of improved management practices for horticulture using the ABCD management framework for the Burnett Mary region.

Table 11.2 – ABCD horticulture management practices for the Burnett Mary region (Source: modified from Wallace S, 2010).

Combined management	A cutting-edge	B best practice	C code practice	D unacceptable practice
Number of horticulture producers	72	93	75	40
% of horticulture producers	26%	33%	27%	14%
Area (km^2)	60	64	42	25
% of area	32%	34%	22%	12%
Nutrient management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	53	66	100	61
% of horticulture producers	19%	23%	36%	22%
Area (km^2)	57	40	55	39
% of area	30%	21%	29%	20%
Herbicide management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	81	115	71	13
% of horticulture producers	29%	41%	25%	5%
Area (km^2)	66	78	39	8
% of area	34%	41%	20%	5%
Soil management	**A cutting-edge**	**B best practice**	**C code practice**	**D unacceptable practice**
Number of horticulture producers	83	96	55	46
% of horticulture producers	30%	35%	20%	15%
Area (km^2)	58	75	31	27
% of area	30%	39%	16%	14%

11.3 Catchment indicators

11.3.1 Results

- **The total riparian area in the Burnett Mary region is 880,000 hectares, of which an estimated 3800 hectares are likely to be susceptible to erosion (non-forested and low groundcover).**
- **The loss of riparian vegetation between 2004 and 2008 was 9185 hectares (1.04 per cent), the highest proportion among the Great Barrier Reef regions.**
- **The Burrum catchment had the highest proportion of riparian clearing between 2004 and 2008, with 791 hectares (1.84 per cent).**
- **The extent of wetlands (including vegetated freshwater swamps, lakes and mangroves/salt flats) across the Burnett Mary region as at 2005 is 50,000 hectares. This represents 70 per cent of wetlands remaining from pre-European times.**
- **The loss of vegetated freshwater swamps since pre-European times is 42 per cent.**
- **The Kolan, Burnett and Mary catchments have had significant loss of wetlands, with between 62 and 86 per cent of vegetated freshwater swamps lost since pre-European times.**
- **The 2009 mean dry season groundcover for the grazing lands of the Burnett Mary region was 92 per cent, which is above the Reef Plan target of 50 per cent. The Burrum catchment had the highest proportion of area below 50 per cent (4.9 per cent) and 3.5 per cent of the area below 30 per cent groundcover.**

11.3.2 Riparian areas

The Burnett Mary region has a total of 650,000 hectares (74 per cent) of riparian areas forested, and 210,000 hectares (24 per cent) non-forested with high groundcover. Only 3800 hectares (0.43 per cent) of riparian areas are non-forested with low groundcover making these areas likely to be susceptible to erosion and, therefore, sediment loss to streams.

The loss of riparian vegetation between 2004 and 2008 was 9185 hectares (1.04 per cent). This was the highest proportion of all the Great Barrier Reef regions. The Burrum catchment had the highest proportion of clearing between 2004 and 2008, with 791 hectares (1.84 per cent).

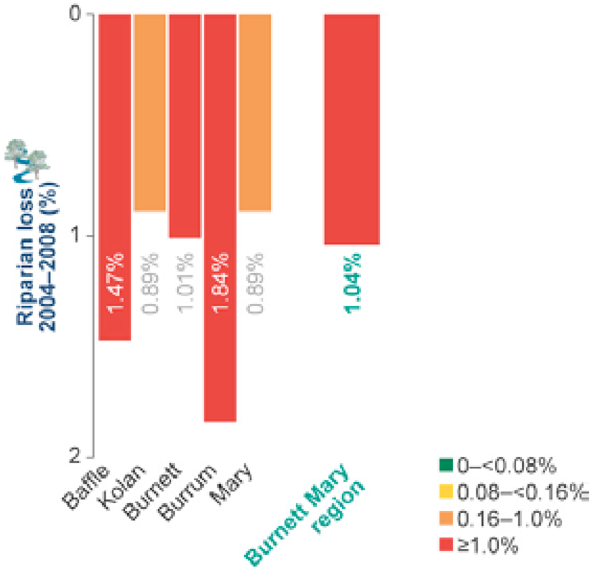


Figure 11.6 – Loss of riparian vegetation between 2004 and 2008 in the Burnett Mary region.

11.3.3 Wetlands

As at 2005 there are approximately 50,000 hectares of wetlands in the Burnett Mary region. Of these wetland areas, there are:

- 26,000 hectares of vegetated freshwater swamps (palustrine wetlands). The greatest area of vegetated freshwater swamps is in the Baffle, Burrum and Mary catchments.
- 360 hectares of lakes (lacustrine wetlands).
- 23,000 hectares of mangroves/salt flats (estuarine wetlands). These wetlands occur in the greatest extent in the Baffle catchment.

In total, 70 per cent of the total wetlands remain since pre-European settlement, with only 58 per cent of freshwater swamps remaining. The Kolan, Burnett and Mary catchments have had significant wetlands loss, with between 62 per cent and 86 per cent of vegetated freshwater swamps lost. This loss is particularly prevalent in the lowlands of these catchments. Overall 95 per cent of mangroves and salt flats remain for the region.

The overall loss of the Burnett Mary region's wetlands between 2001 and 2005 was 180 hectares (0.36 per cent). The loss of vegetated freshwater swamps over the 2001–2005 period was 181 hectares (0.69 per cent), with the greatest loss in the Kolan (2.53 per cent) and Mary (1.21 per cent) catchments. There was a moderate reduction in the extent of mangroves/salt flats over the 2001–2005 period, ranging from nil to 0.28 per cent.

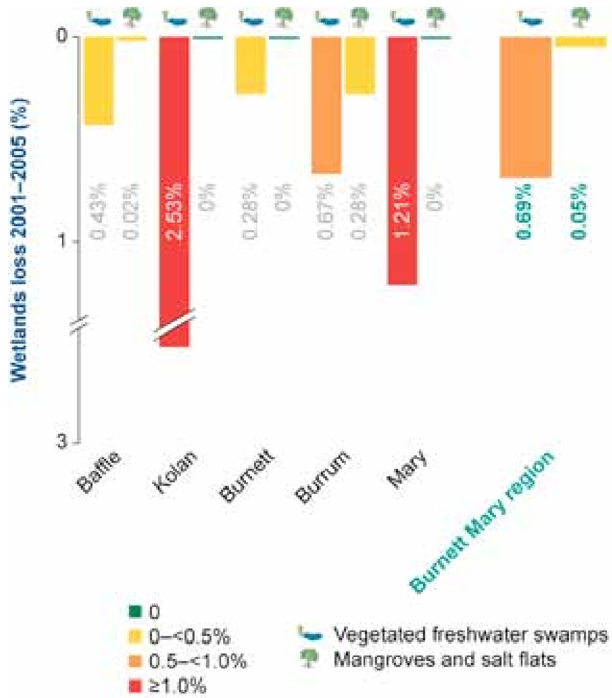


Figure 11.7 – Loss of vegetated freshwater swamps and mangroves/salt flats (between 2001 and 2005) for the Burnett Mary region.

Table 11.3 – Areas forested within the riparian buffer, non-forested with high groundcover (above or equal to 50 per cent), non-forested with low groundcover (less than 50 per cent) for 2008 and the area cleared from 2004 to 2008.

Catchment	Total riparian buffer area	Forested		Non-forested high groundcover		Non-forested low groundcover		Missing data*	2004–2008 riparian clearing	
	(ha)	Area (ha)	%	Area (ha)	%	Area (ha)	%	%	Area (ha)	%
Baffle	55,305	48,018	86.82	6623	11.98	111	0.20	1.00	813	1.47
Burnett	503,891	347,557	68.97	147,785	29.33	2846	0.56	1.13	5114	1.01
Kolan	46,340	37,804	81.58	7624	16.45	88	0.19	1.78	414	0.89
Burrum	42,892	39,018	90.97	2940	6.85	189	0.44	1.74	791	1.84
Mary	230,974	179,012	77.50	45,870	19.86	565	0.24	2.39	2053	0.89
Burnett Mary region	**879,402**	**651,409**	**74.07**	**210,842**	**23.98**	**3799**	**0.43**	**1.52**	**9185**	**1.04**

*Missing data refers to areas affected by cloud, cloud shadow, topographic shadow or areas of water within the riparian buffer.

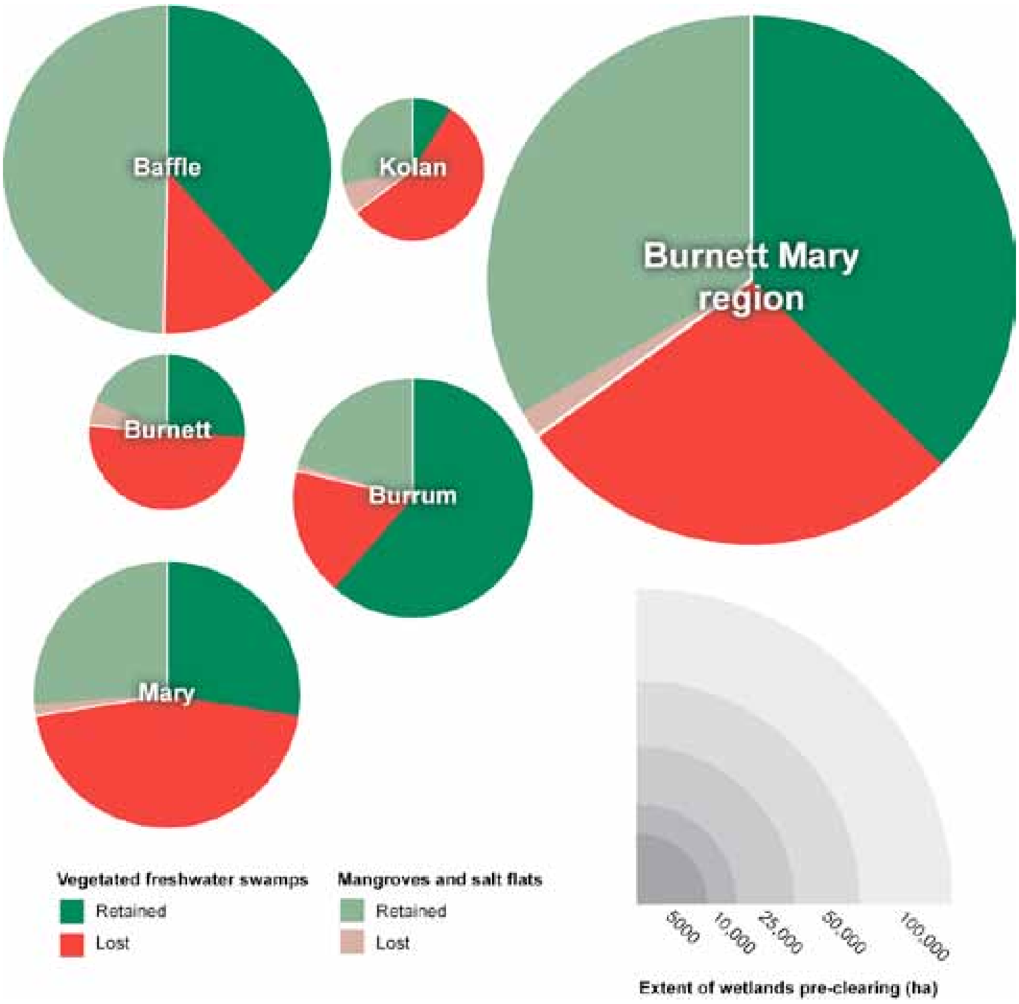


Figure 11.8 – Extent (hectares) and proportion of vegetated freshwater swamps and mangroves/salt flats remaining from pre-European extent in the Burnett Mary region.

Table 11.4 – The extent of wetlands in 2005 and change between 2001 and 2005 across the Burnett Mary region for vegetated freshwater swamps, lakes and mangrove/salt flat wetlands.

	Vegetated freshwater swamps			Lakes			Mangroves and salt flats			All wetlands		
Catchment	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)	Extent 2005 (ha)	Extent (% pre-European)	Loss 2001–2005 (% of 2001)
Baffle Creek	10,430	77	0.43	180	100	-7.04	13,275	99	0.02	23,885	87	0.15
Burnett	1580	34	0.28	15	100	0	1115	78	0	2710	48	0.17
Burrum	8840	78	0.67	160	100	0	2935	96	0.28	11,935	82	0.57
Kolan	460	14	2.53	NP	NP	NP	1425	80	0	1885	38	0.63
Mary	4900	38	1.21	5	100	0	4635	95	0	9540	51	0.63
Burnett Mary region	**26,210**	**58**	**0.69**	**360**	**73**	**-7.04**	**23,385**	**95**	**0.05**	**49,955**	**70**	**0.36**

NP – wetland type was not present.

11.3.4 Groundcover in grazing lands

Groundcover is influenced by a combination of factors, including the land type, climate and management practices. The majority of the region's grazing lands are in the Burnett catchment. The long term mean dry season groundcover for the grazing lands of the Burnett Mary region over the 1986 to 2009 period is 88 per cent (Table 5.6), which is above the Reef Plan target of 50 per cent. Similar to other regions, the average groundcover in 2009 is higher than the historical average, increasing to 92 per cent. The proportion of the grazing area with groundcover of 50 per cent or greater in 2009 is high (99 per cent). Only 1.1 per cent of the area was below the 50 per cent groundcover target, with 0.4 per cent of the area below 30 per cent. The Burrum catchment had the highest proportion of area below 50 per cent (4.9 per cent), with 3.5 per cent of the area below 30 per cent groundcover.

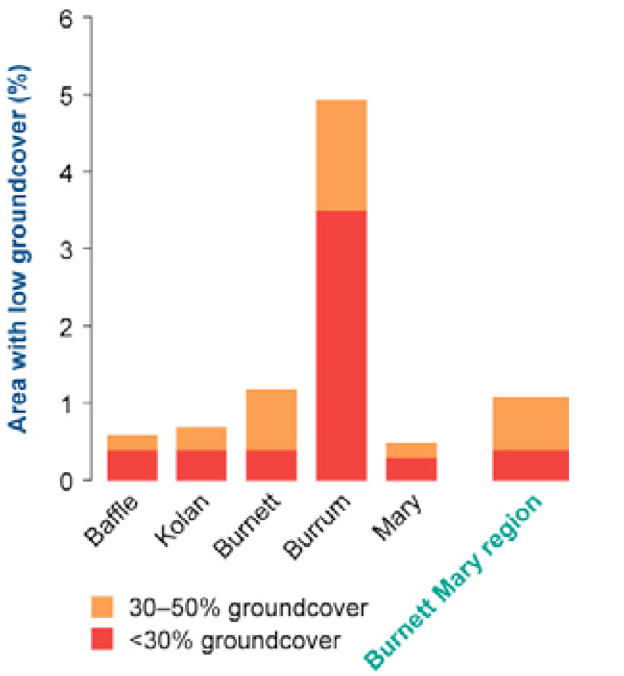


Figure 11.9 – Area with low groundcover (under 30 per cent and between 30 per cent and 50 per cent) as at 2009 for the Burnett Mary region.

11.4 Catchment loads

The total suspended solids load leaving the catchments of the Burnett Mary region is an estimated 3.1 million tonnes per year, of which 2.8 million tonnes are from human activity. Most of this sediment originates from the extensive grazing lands within the region.

The estimated total nitrogen load leaving the catchments of the Burnett Mary region is 13,000 tonnes per year, of which 12,000 tonnes are from human activity. A large proportion of this total load is in particulate nitrogen (10,000 tonnes per year).

The total phosphorus load leaving the catchment of the Burnett Mary region is 3100 tonnes per year, of which 2900 tonnes are from human activity. Similar to total nitrogen, a large proportion of the total phosphorus load is in particulate form (2700 tonnes per year).

The dissolved nitrogen load is 2800 tonnes per year, of which 1400 tonnes are from human activity. The dissolved phosphorus load is 350 tonnes per year, of which 258 tonnes are from human activity.

The total photosystem inhibiting (PSII) pesticide load leaving the catchments of the Burnett Mary region is an estimated 990 kilograms per year.

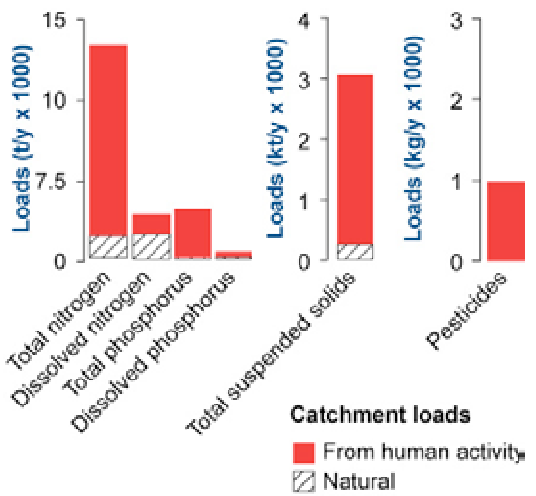


Figure 11.10 – Total and anthropogenic (caused by human activity) pollutant load estimates for total suspended solids, total nitrogen, total phosphorus, dissolved nitrogen, dissolved phosphorus and pesticides.

11.5 Great Barrier Reef water quality and ecosystem health

11.5.1 Results

- **Inshore waters within the Great Barrier Reef Marine Park portion of the Burnett Mary region are in very good condition.**
- **Seagrass meadows in the region, although in good condition overall, are in decline or have failed to recover from the effects of flooding in 2006. The presence of many reproductive structures suggests recovery may be possible.**

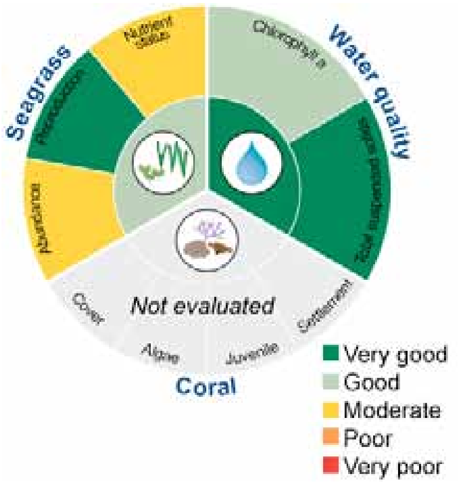


Figure 11.11 – Great Barrier Reef water quality and ecosystem health of the Burnett Mary region showing the status of water quality and seagrass (grey = no coral data).

11.5.2 Water quality

Freshwater discharge from regional rivers was well below the long term annual median flow for the region during 2008–2009. Great Barrier Reef Marine Park Water Quality Guideline exceedances for chlorophyll *a* and suspended solids concentrations were calculated for the May 2008 to April 2009 period from satellite imagery (Table 11.5). Chlorophyll *a* and suspended solids concentrations for the Great Barrier Reef Marine Park portion of the Burnett Mary region were generally better than other regions. It should be noted that the water quality data presented here has been validated only for the area of the Great Barrier Reef Marine Park that falls within the Burnett Mary region and this summary is not necessarily representative of the full region's marine waters.

Table 11.5 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter (as a measure of suspended solids) for the Burnett Mary region (1 May 2008–30 April 2009).

Chlorophyll *a*: Relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			**Suspended solids:** Relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
27	2	0	13	2	3

11.5.3 Seagrass status

Seagrasses are monitored at two estuarine locations in the north and south of the Burnett Mary region respectively. These meadows are in decline or have failed to recover from the effects of flooding in 2006 (Figure 11.12). Meadows in Rodds Bay are in good reproductive condition; however, meadows in Hervey Bay are in poor reproductive condition, raising concerns about the ability of seagrass meadows in Hervey Bay to recover from significant disturbance events such as cyclones and floods. The region's seagrasses have nutrient rich tissues, and those at Urangan are subject to low light regimes.

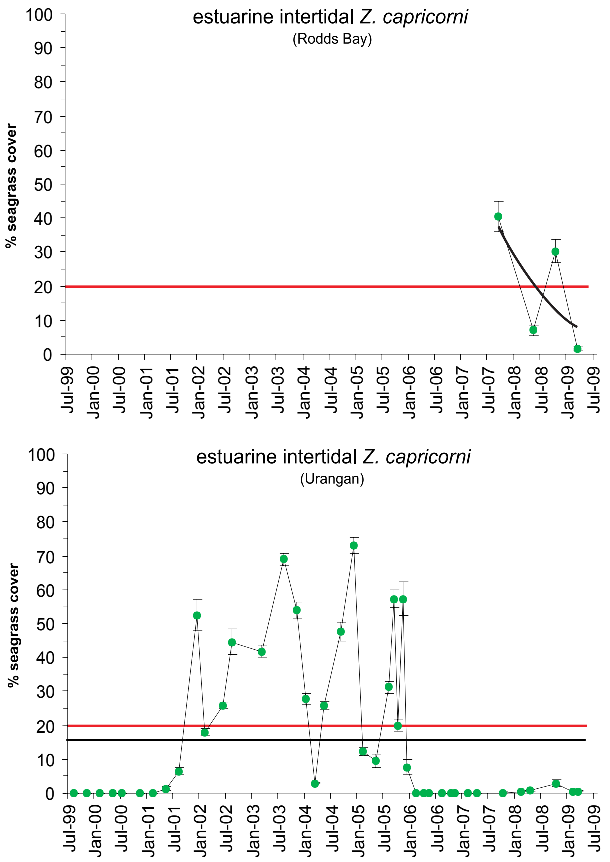


Figure 11.12 – Long term seagrass cover, Urangan (estuarine) and Rodd's Harbour (estuarine), Burnett Mary region, compared with long term Great Barrier Reef average (red line) (Source: DEEDI).

Conclusion

Chapter 12

"The results highlight that there are significant areas of concern that justify the need for accelerated action to improve water quality and build resilience of the Great Barrier Reef."

Photo by K Rohde

The Australian and Queensland Governments have committed to ensuring that by 2020 the quality of water entering the reef from adjacent catchments has no detrimental impact on the health and resilience of the reef. Achievement of these goals will be assessed against a set of quantitative targets for land management and water quality outcomes outlined in the Reef Water Quality Protection Plan 2009 (Reef Plan).

This first report will be used as the point of comparison to measure progress towards Reef Plan's goals and targets. This report card presents results up to 2009 and, therefore, does not include the effects of Cyclone Yasi and the more recent flood events which will be presented in subsequent reports.

The results highlight that there are significant areas of concern that justify the need for accelerated action to improve water quality and build resilience of the Great Barrier Reef.

High rainfall in the Great Barrier Reef catchment (particularly in the Burdekin and Fitzroy regions) between 2007 and 2009 resulted in large flood plumes to marine waters. This rainfall, as well as the significant flood events of 2011, will continue to strongly influence the quality of water entering the reef, particularly in inshore areas (within 20 kilometres). While these waters only represent around 8 per cent of the Great Barrier Reef Marine Park, they support significant ecosystems and are the primary focus for most recreation, commercial tourism and fisheries activities.

The water quality and ecosystem health of the Great Barrier Reef is in moderate condition overall, while regionally variable results (e.g. the Wet Tropics and Mackay Whitsunday regions having poor seagrass and the Burdekin region having poor coral status) identify specific areas for management attention.

Most inshore reefs are in good or moderate condition, based on coral cover, macroalgal abundance, settlement of larval corals and numbers of juvenile corals. Most inshore reefs have either high or increasing coral cover. However, corals in the Burdekin region are mostly in poor condition. Seagrass abundance in intertidal regions is highly variable and has declined over the past five to 10 years, which is associated with excess nutrients. Many seagrass meadows had low or variable numbers of reproductive structures limiting their resilience to disturbance.

Inshore waters often contain concentrations of chlorophyll *a* and total suspended solids above Great Barrier Reef Marine Park Water Quality Guidelines, with the highest concentrations evident in the Wet Tropics, Burdekin and Mackay Whitsunday regions. Monitoring during flood events has measured pesticide concentrations above Great Barrier Reef Marine Park Water Quality Guidelines at least 25 kilometres from a river mouth and also concentrations that may have short term effects on the health of marine plants up to 50 kilometres from the coast.

Total catchment loads are five to nine times the natural loads for suspended solids, nitrogen and phosphorous. Annual total suspended solid loads are 17 million tonnes, of which 14 million tonnes are from human activity. The largest contribution of total suspended sediment load is from the Burdekin and the Fitzroy regions (4.7 and 4.1 million tonnes respectively), mainly derived from grazing lands. Agricultural fertiliser use is a key source of dissolved nitrogen and phosphorus runoff; annual loads of dissolved nitrogen are 31,000 tonnes.

All pesticides are from human activities. The total annual pesticide loads are approximately 28,000 kilograms and the highest loads are from the Mackay Whitsunday and Wet Tropics regions (approximately 10,000 kilograms each per year).

The total riparian area (area within 50 metres of the stream) in the Great Barrier Reef region is six million hectares; however, there was a loss of 30,000 hectares (0.5 per cent) between 2004 and 2008. Wetland loss since pre-European times has been significant, with greater than 80 per cent of vegetated freshwater swamps lost in some lowland areas. Some areas are less impacted, with Cape York still having 100 per cent of wetlands remaining and no loss of riparian areas between 2004 and 2008.

The 2009 mean dry season groundcover for the grazing lands of the Great Barrier Reef region was 84 per cent, which is above the Reef Plan target of 50 per cent. This is due to higher than the historical average rainfall across many grazing areas.

Cutting-edge (A) or best management (B) practices for nutrients are used by 39 per cent of horticulture producers and 36 per cent of sugarcane growers. Practices considered unacceptable by industry and community standards (D) are used by 24 per cent of horticulture producers and 34 per cent of sugarcane growers.

Fifty per cent of graziers across the Burdekin and Fitzroy region are using (A or B) practices likely to maintain land in good to very good condition, or improve land in lesser condition. Practices (D) considered likely to degrade land to poor condition are used by 12 per cent of graziers in the Burdekin and Fitzroy regions. The Fitzroy region has 14 per cent of graziers using (A) practices likely to maintain land in very good condition or improve land in lesser condition 9compared to 6 per cent of graziers in the Burdekin.

The Paddock to Reef program will continue to review and update the monitoring, modelling and reporting techniques to ensure the accuracy of the information is continuously improved over time. The program will inform research, development and innovation initiatives established under Reef Plan 2009 and will better target new initiatives and investments in reef water quality improvement.

Appendices

Chapter 13

"The Paddock to Reef program will inform research, development and innovation initiatives established under Reef Plan 2009."

Photo courtesy of Great Barrier Reef Marine Park Authority

Appendix 1 Continuous improvement

The Paddock to Reef program will inform research, development and innovation initiatives established under Reef Plan 2009, including the Reef Plan Research, Development and Innovation Strategy, Annual Research, Development and Innovation Plan and the Research and Development component of Caring for our Country Reef Rescue.

The Paddock to Reef Program also links to broader research and development initiatives such as the National Environmental Research Program Tropical Ecosystems hub. It is recognised that some knowledge gaps exist within the Paddock to Reef program. These include:

- effectiveness of management practices in improving water quality
- the contribution of gullies to transported sediments
- techniques to monitor riparian and wetland condition
- improved pollutant load estimates through catchment water quality modelling
- receiving water quality modelling to improve understanding of the impact of pollutants on the health of Great Barrier Reef ecosystems.

Further information on these knowledge gaps and approaches to address these are outlined in the following sections.

Improving our understanding of practice effectiveness

Paddock scale monitoring and modelling is a key component of the Paddock to Reef program. It provides information on the water quality changes related to specific management practices on specific land types and climatic regions. Paddock models are used to corroborate this information. The program consists of three monitoring and modelling activities:

1. Paddock monitoring—collecting runoff during actual rainfall events from a uniform portion of a paddock. Over time, the paddock monitoring provides temporal data to capture variability in rainfall and other climatic factors, changes in management and changes in system responses.
2. Rainfall simulation—collecting runoff from a simulated rainfall event from a plot within a paddock. Over time, the rainfall simulation work progressively extends the spatial coverage by capturing the variation in response at sites with different soil or land type characteristics.
3. Paddock modelling—over time, the paddock modelling progressively develops spatial coverage across soil and land types with improved estimations from using paddock monitoring and rainfall simulation information.

Paddock monitoring is undertaken on sets of rows (cane and horticulture), contour bays (grains), hillslopes (grazing) and multi-farm catchments up to 30,000 hectares (cane, grain and grazing). Monitored parameters include runoff and leachate volumes, total suspended solids, electrical conductivity, total nitrogen, total phosphorus, nutrient species (i.e. dissolved and particulate forms) and pesticides (where used) from rainfall and irrigation. Field equipment and laboratory methods have been standardised. Runoff is collected as discrete or composite samples through time, using automated refrigerated pumping samplers, to provide event mean concentrations. Leachate is measured using suction lysimeters or solute samplers.

Samples for nutrient and pesticides are collected from soils and trash. Soils at each site are characterised (morphology, chemical and physical properties). Farm operations that affect water quality (including tillage, nutrient and pesticide applications) and agronomic data are recorded. This allows paddock sites to be modelled using soil water balance and water quality models that can then be applied to other time periods and conditions. Data generated is used to calibrate and verify the paddock scale models used in the Paddock to Reef program.

Figure 13.1 – Automated sampler in the Burdekin (Image: Zoe Bainbridge, Australian Centre for Tropical Freshwater Research).

Sugarcane

Management systems include current farming practice (single cane row on 1.5 metre-wide beds and uncontrolled traffic) and the new farming system (dual row cane on approximately 1.8 metre beds, controlled traffic and legume crop rotation). Nutrient management includes practices such as following general recommended application rates, the Six Easy Steps program and the nitrogen replacement approach. Pesticide management focuses on decreasing the reliance on residual herbicides (e.g. atrazine, diuron) and greater use of low persistence knockdown herbicides, integrated weed management planning and precision application (i.e. shielded sprayers).

In the Mackay Whitsunday region, a multi-block monitoring site is installed at North Eton (area approximately 54 hectares) with 100 per cent sugarcane. A multi-farm site (approximately 2965 and approximately 95 per cent sugarcane) is also being monitored. Improved management practices are being implemented within a large proportion of these areas and the level of implementation of these practices will also be monitored.

Figure 13.2 – Flume at paddock monitoring site, Mackay Whitsunday (Image: Ken Rohde).

Grazing

Paddock scale monitoring for grazing land use compares practices that manage hillslope (sheet and rill) erosion in pastures, riparian areas (off-stream watering and fencing) and gully rehabilitation. Existing pasture monitoring sites in the Fitzroy and Burdekin regions will continue to investigate runoff impacts of grazing pressures (percentage of use/stocking rate), spelling, patchiness and fire management. Limited pesticide monitoring will be conducted. Monitoring will continue at the sub-catchment scale near Bauhinia Downs, with three sites (4000, 6000 and 27,000 hectares) in Muddy and Spottswood Creeks where grazing is the dominant land use (approximately 95 per cent of catchment). Similarly, monitoring will continue in the Gordonstone nested catchments (see Grains section) with a 300 hectare grazing catchment (Neilsen et al., 2010). Other sites in the Fitzroy region have been established to assess the use of off-stream watering in an attempt to reduce cattle pressure on riparian zones and river bank frontage.

Sediment yields from gully rehabilitation practices is monitored in the Burdekin region. Sites are located in the Upper Burdekin and Bowen/Bogie catchments, which contain the areas identified in the Burdekin Water Quality Improvement Plan (Dight, 2009) and Reef Rescue Program as high-priority sediment source areas. Gully erosion rates under different practices are compared using a range of techniques including vegetation monitoring, erosion pins and catchment sediment yields. This data is linked to mapping of gully extent over time using historic air photos and remote sensing (where available) to determine the gully behaviour relative to the whole property and surrounding landscapes. Sediment loads from the sub-catchments containing gully monitoring sites are also monitored.

Figure 13.3 – Grazing in a creek bed, Fitzroy catchment (Image: Mark Silburn, DERM).

Grains

Dryland grains cropping is monitored in the Gordonstone Creek catchment, Capella. At the paddock scale, there are three contour bays (approximately 10 to 45 hectares), while at the sub-catchment scale there are five monitoring sites at increasing scales (approximately 300, 500, 5000, 8000 and 30,000 hectares). Monitoring at the paddock scale focus is on zero till controlled traffic farming within single, double or triple spaced contour bays (i.e. cutting-edge (A) or best management (B) practice). A site using common practices (C), such as conventional/reduced tillage with controlled traffic, is used for rainfall simulation experiments. Data for practices considered unacceptable by industry and community standards (D) will be generated through analysis and modelling of historical data from Capella (Carroll et al., 1997).

Horticulture

Horticulture management practices are monitored at the paddock scale in the Wet Tropics and Burnett Mary regions. The Wet Tropics site focuses on a comparison of nutrient management and inter-row management (bare versus vegetated inter-rows) strategies in bananas. The Burnett Mary site assesses both horticulture (vegetables under plastic mulch) and sugarcane cultivation in rotation, where monitoring is focused on soil and nutrient management and comparing nutrient and pesticide management when returning to cane.

Monitoring wetland (lakes and swamps) condition in the Great Barrier Reef

Wetlands filter out nutrients, sediments and pesticides from waterways. In addition, wetlands are high in biodiversity, have important recreational values and play a vital role in Queensland's primary industries, especially grazing and fisheries. Wetlands can also mitigate the effects of extreme climate events such as storm surges and floods.

The highly variable nature of wetlands, makes them difficult to monitor as the natural variability in the system needs to be separated from those changes caused by human effects.

The Queensland Wetlands Program has developed and implemented several projects to increase the capacity to monitor the wetland extent, risk and condition of Queensland's lakes and vegetated fresh water swamps. In the Great Barrier Reef catchments, coastal wetlands of one hectare or more, and those above five hectares further inland, have been identified, and mapping updates have provided an effective mechanism for reporting on wetland extent changes over time.

In addition to the mapping, wetlands have been classified into different wetland habitat types and conceptual models describing scientific understanding of their components and processes have been developed.

Methods for monitoring the condition of and risk to different wetland types and wetland regions are being developed and tested. An assessment and reporting framework has also been developed, together with a software tool that enables integrated assessment of all wetlands within an area (e.g. catchment) or an individual wetland.

Improved catchment water quality modelling

Using catchment water quality models to report on pollutant load reductions

Reef Plan 2009 has set water quality catchment load targets, with a combination of monitoring and modelling to inform progress on achieving these targets by 2013. Catchment modelling will be used to report catchment pollutant loads for each catchment in the Great Barrier Reef for a revised baseline (2008–2009) and changes relative to the baseline for 2010 to 2013.

The overall approach involves monitoring and modelling a range of attributes including management practices at paddock scale and upscaling to sub-catchment and basin scales.

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 facilitate the link between catchment and receiving water models. The project will establish a 2008–2009 baseline, with the impact on current investments assessed against human loads for subsequent report cards.

Source Catchments modelling framework

Source Catchments is a water quality and quantity modelling framework that supports decision-making and a whole-of-catchment management approach. It allows modelling on the amounts of water and contaminants flowing through an unregulated catchment and into major rivers, wetlands, lakes, or estuaries. Source Catchments is the software evolution of the E2 Modelling Framework, which was released in 2005 through the eWater Toolkit.

Source Catchments can be used to predict the flow and load of constituents at any location in the catchment over time, usually at daily time steps, and can produce reports at varying temporal scales (from daily to annual) and spatial scales (from a single sub-catchment to whole-of-catchment). Scenarios can include actual or planned changes in land use, land management, climate variability and climate change.

This software gives access to a collection of models, data and knowledge that simulate the effects of climatic characteristics (such as rainfall and evaporation) and catchment characteristics (such as land use or vegetation cover) on runoff and contaminant loads from unregulated catchments.

The Source Catchments modelling framework was designed to allow modellers and researchers to construct models by selecting and linking component models from a range of available choices. The model structure and algorithms are not fixed but can be defined by the user who can choose from a suite of available options. As a result, Source Catchments enables a flexible modelling approach, allowing the attributes and detail of the model to vary in accordance with modelling objectives.

Receiving water quality models

A receiving water quality modelling framework is a critical link between catchment models (which describe how management impacts on the delivery of nutrients and sediments to the ends of catchments) and the fate and impacts of these pollutants as they pass through estuaries and into the Great Barrier Reef lagoon.

Receiving water quality model

The marine receiving water model inputs catchment loads of fresh water, sediments, nutrients and pesticides derived from catchment modelling or from measurement, and simulates the transport and transformation of these substances in the receiving waters, including their impact on primary production. The foundation model for the development of materials transport is a Great Barrier Reef-wide hydrodynamic model, capable of simulating currents and mixing that are important for transporting contaminants, as well as water temperature and salinity.

Current work

A Marine and Tropical Science Research Facility and Great Barrier Reef Marine Park Authority funded project undertaken by the Australian Institute for Marine Science and the CSIRO has developed a hydrodynamic model of the entire Great Barrier Reef that includes all the important factors affecting currents, mixing, temperature and salinity within the lagoon and exchanges with the adjacent Coral Sea. A pilot four-kilometre resolution regional model has been established, including river inflows for a number of real-time gauged rivers, and is running in near real-time. Comparisons between observed and predicted tidal sea levels, which drive the general circulation, are a powerful verification of a model's performance. The general agreement of both magnitude and phasing of tidal water level fluctuations at coastal stations throughout the Great Barrier Reef gives confidence in the accuracy of the model's simulation of a dominant hydrodynamic process. Qualitative assessment of a pilot 2009 wet season hindcast of this model indicates general agreement in extent and timing of the predicted surface fresh water plume and the remotely sensed plume distribution. Predicted and observed sub-surface salinities also show good agreement. In addition, a pilot one-kilometre resolution model is undergoing preliminary evaluation.

Appendix 2 Evidence of the effectiveness of improved management practices

This section summarises knowledge of the effectiveness of management practices in providing improved water quality in surface runoff at the paddock scale. Information is presented according to the major pollutants of concern: sediments, nutrients and pesticides. An overview of the economic implications of water quality improvements is also provided.

Results are organised according to management practices that are designed to reduce the runoff of:

- sediment
- nutrients
- pesticides.

Sediments

Most soil conservation practices necessary to reduce erosion and sediment loss from agricultural lands are widely understood (Freebairn et al., 1996) by landholders. General principles include:

- controlling runoff to avoid concentrated flow (e.g. contour banks and waterways in cropping, road management in grazing and forestry)
- maintaining groundcover (stubble in grains, trash in sugarcane, pasture in grazing)
- minimising tillage and maintain soil strength (resistance to erosion)
- use of land within its capabilities (e.g. avoiding steep slopes)
- maximising infiltration but also maximising use of this water by plants (e.g. opportunity cropping in grains)
- controlled machinery traffic to reduce soil compaction
- prevention and repair of gully erosion
- maintaining vegetative cover in riparian areas and flow pathways (e.g. sediment trapping).

These practices aim to maximise water use for plant production, minimise the amount of runoff, slow and spread that runoff and protect the soil surface from raindrops and flowing water. These principles are well supported by field studies. Other practices such as sediment traps (Connolly et al., 1999, 2002), vegetative filters and buffers (USDA-NRCS 2000), grassed headlands, constructed wetlands (reviewed by McJannet, 2007) and riparian management (Lovett and Price, 2001) aim to remove sediment from runoff water after it leaves the paddock. These off-paddock practices are not a substitute for careful paddock management but are tools to further improve water quality.

Data from studies in sugarcane indicate rates of soil erosion are highest under burnt cane, intensive tillage practices (Prove et al., 1995; Sallaway et al., 1979, 1980). Green cane trash blanketing and minimum tillage reduced sediment movement off paddocks by up to 90 per cent (Prove et al., 1995; Rayment, 2002) in steeper, particularly high rainfall areas. Avoiding tillage has a major impact on soil erosion as it reduces rill erosion in the inter-rows (Prove et al., 1995). On low slopes (e.g. less than 1 per cent), rill erosion does not occur and the inter-rows become a site for sediment deposition. In these cases, groundcover is very effective in reducing soil erosion (Waters, 2001; Silburn and Glanville, 2002; Masters et al., 2008). In sugarcane (with trash blankets retained on the soil surface) and bananas, fallows and plant crops (as opposed to ratoon crops) are susceptible to erosion and require management.

These general principles are supported by studies in grains and anecdotal evidence from horticulture cropping areas. Maintenance of groundcover is crucial for managing water quality (Figures 13.4, 13.5, 13.6 and 13.7). A 12-year study of grain cropping on Vertosol (black clay) at Capella found a significant reduction in erosion with greater than 30 per cent surface cover (Carroll et al., 1997). Opportunity cropping using zero tillage was the most effective cropping system for producing consistently high groundcover and reduced runoff and soil loss. These findings are supported by a review of studies in Queensland grain growing areas over the past 40 years (Thomas et al., 2007), which showed that no-till/reduced till and conservation farming dramatically reduces soil loss. Controlled traffic farming has been shown to be effective in enhancing infiltration and reducing runoff and thereby reducing soil loss, especially when combined with maintenance of groundcover (Tullberg et al., 2001, 2007; Li et al., 2001; Silburn and Glanville, 2002; Rohde and Yule, 2003; Masters et al., 2008).

Figure 13.4 – Green cane trash blanket provides good control of soil erosion, Mackay, Queensland (Image: Bronwyn Masters, DERM).

Figure 13.5 – Mulch crop sown in the interspaces in horticulture to prevent erosion (Image: Neil Halpin, DEEDI).

Figure 13.6 – Surface cover and sediment concentrations at Gregory Highway site, Gordonstone, for two similar rainstorm events (100 millimetres and 127 millimetres) with contrasting levels of cover (low cover shown in red; high cover shown in green).

Figure 13.7 – Annual average soil loss from hillslope plots with different pasture cover, in semi-arid Central Queensland (means of seven years data) (Source: Silburn et al., in press) (Image: David Waters, DERM).

High erosion rates have been measured in bananas grown on steeper slopes with little groundcover when rainfall intensity was high (McKergow et al., 2004). Sediment, total nitrogen and total phosphorus losses from banana fields to streams were reduced by 25 to 65 per cent by grass buffer strips, but only where runoff did not become concentrated (McKergow et al., 2004). In horticulture, planting of cover crops in the interspaces between vegetable beds covered with plastic mulch is seen as a way of minimising sediment losses. The water quality benefits of management practices such as bio-mulches in horticultural crops have not been quantified in Queensland.

Groundcover has a strong effect on hillslope runoff and sediment losses in extensively grazed pastures in Queensland (Miles, 1993; McIvor et al., 1995; Scanlan et al., 1996; Connolly et al., 1997; Carroll et al., 2000; Waters, 2004; Bartley, et al., 2006; Silburn et al., in press).

Groundcover depends on pasture growth and grazing utilisation. However, climatic events outside management control may affect cover and soil erosion. For example, during drought, cover can degrade even in the absence of commercial grazing though not as quickly as with grazing (Pressland and Graham, 1989).

Gully erosion is a significant source of sediment in grazing lands (Cogle et al., 2006). Management can influence gully sediment yield via four mechanisms:

- Reducing the amount of runoff water from the hillslope draining into the gully. There are too many gullies to treat individually and improving cover levels is the most common management practice change that will potentially affect gully erosion rates.
- Increasing vegetation cover on the gully walls to reduce local erosion (rain-splash, sheet-wash and rill processes).
- Reducing sediment transport capacity of the gully channel (e.g. more roughness).
- Fencing to exclude disturbance to the fringes of the gully and gully edges by cattle.

Little data exists on the net contribution of gullies to transported sediments. For example, sediment sourced at the top of the gully may be deposited within the gully channel. The Paddock to Reef program seeks to provide data of this nature in Great Barrier Reef catchments. In particular, natural chemical tracers can assist in differentiating hillslope from gully and riverbank sediments.

Nutrients

The main approaches for nutrient management in reef catchments focus on nitrogen and phosphorus. Higham et al., (2009) provide rankings of the relative effectiveness of practices in the ABCD framework in managing nutrient losses. Common principles to reduce nutrients in runoff and deep drainage are:

- minimising the rate of nutrient inputs
- accounting for all nutrient sources (e.g. from legumes, mill mud and irrigation water, etc)
- matching application rates and timing with soil nutrient levels and yield goals
- managing soil water to reduce nitrate losses below the root zone
- reducing the amount of runoff by various soil management practices
- reducing sediment movement to reduce phosphorus and some nitrogen in runoff.

Potential nutrient losses in runoff and drainage will be related to the amount of the nutrient in the soil, which is a result of the rate of application, placement and rates of removal (e.g. crop use, losses). This emphasises the importance of minimising excess inputs of fertiliser.

In sugarcane, research and industry consultation resulted in the Six Easy Steps nutrient management program, which is considered best practice across the industry (Schroeder et al., 2005, 2010). Crop, water and nitrogen balances in sugarcane in the Burdekin (Thorburn et al., 2009) were used to calibrate the APSIM crop model and then predict losses for different management practice classes (Figure 13.8). The results provide increased confidence that A and B class nitrogen management practices identified in the ABCD framework will improve water quality over current (C) and dated (D) management practices.

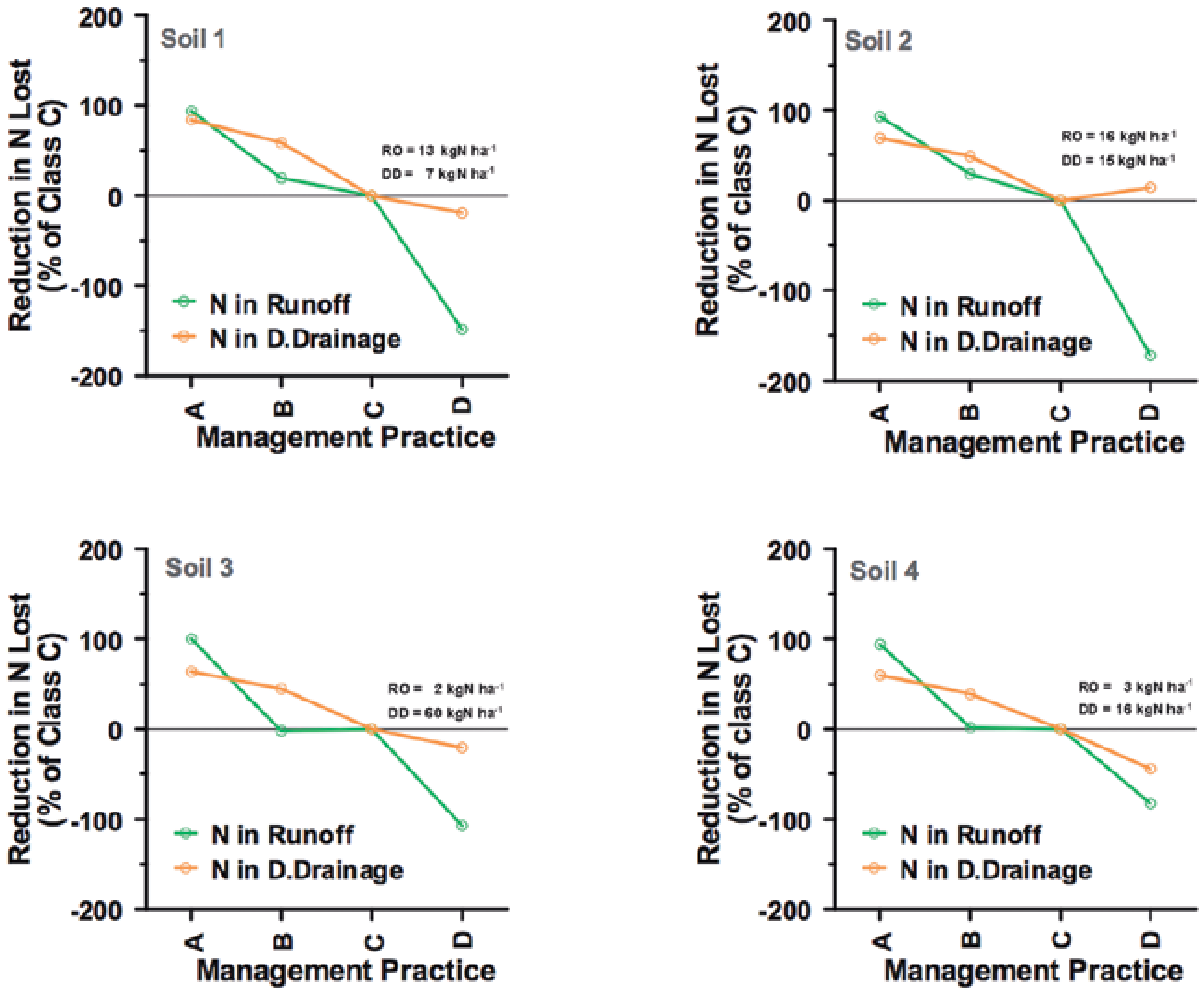


Figure 13.8 – Improving water quality associated with decreasing nitrogen application rates on four Burdekin soils, relative to C management class (Source: Thorburn et al., 2009).

In recent years, use of legume crops in sugarcane rotations has increased. While legume crops improve soil health, reduce sediment loss and provide organic fertiliser (Garside and Bell, 2001; Reghenzani and Armour, 2000), little is known of their potential impacts on water quality. However, it is possible that inputs of nitrogen from the legume may be greater than crop uptake and so leak to the environment over subsequent crops. Other management practices, for example fertiliser placement, are more likely to change the nitrogen loss pathways than the amount that is lost (Prove et al., 1997, Masters et al., 2008, Thorburn et al., 2010). Reducing nitrogen lost by one loss pathway such as runoff, may be countered by an increase in the loss through another pathway, such as deep drainage and to the atmosphere, reinforcing the need for a holistic approach to managing the overall nitrogen surplus. The elevated soil phosphorus status of most sugarcane soils, particularly those receiving mill by-products, such as mill mud (Rayment and Bloesch, 2006) suggests that the environmental significance of dissolved inorganic phosphorus in both drainage and runoff needs to be tested.

In bananas, Armour and Daniells (2001) showed that nitrogen fertiliser rates could be reduced by more than 50 per cent, from 520 kilograms of nitrogen per hectare per year to 150 and 225 kilograms per hectare per year for plant and ratoon crops respectively. This was based on matching application rates to crop demand with fortnightly applications under favourable weather conditions. Application rates of nitrogen in the Queensland banana industry have already been reduced by as much as 40 per cent over the past 12 years. The contribution made by excess nutrient addition to nutrient loads entering runoff or groundwater from banana and other horticultural crops is unclear and there have been few detailed studies. However, Mitchell et al., (2007) found clear relationships between the proportion of land in tropical catchments where fertilisers were used (cane and bananas) and the average nitrate nitrogen (NO_3-N) concentration in runoff.

The main nutrient runoff losses from low input, extensive grazing lands are those attached to sediment (particulate nitrogen and phosphorus) (O'Reagain et al., 2005; Cogle et al., 2006). Managing erosion should limit nutrient losses attached to sediment. However, there is little data available on nutrient losses from grazing lands and their management, particularly for dissolved nutrients. Data from Mount Mort shows that cover had a large effect in reducing runoff, sediment and total nitrogen and total phosphorus loads (Finlayson and Silburn, 1996).

Pesticides

The main pesticides of interest are herbicides, in particular residual herbicides that inhibit photosynthesis, referred to as PSII herbicides (e.g. atrazine, diuron). Pesticide transport off-field and off-farm in runoff can be controlled by:

- minimising the rate of pesticide applications
- improving application efficiency (spray nozzle technology, banded spraying, controlled traffic farming)
- carefully selecting pesticides with particular properties (e.g. pesticides that dissipate more rapidly [shorter half-life] and are more sorbed to soil)
- timing applications to avoid periods with higher risk of large rainfall events
- adhering to labelling (appropriate use, storage and disposal of chemicals)
- reducing the amount of runoff by various soil management practices
- management of off-paddock water through collection drains and sumps.

Minimising pesticide movement in runoff is primarily achieved by reducing pesticide inputs (getting the best control with lowest application rates) (Simpson, 2007; Silburn and Kennedy, 2007). The ultimate way to reduce runoff of residual herbicides is to not use them at all (A or B practice) or to use them much less, for example for plant cane only.

There is a clear relationship between the concentration of pesticides in runoff and that in the soil (Leonard et al., 1979; Silburn, 2003; Silburn and Kennedy, 2007; Rattray et al., 2007) and some evidence that pesticide runoff is proportional to the concentration in trash (Masters et al., 2008). Thus, any practices that reduce these surface stores of pesticide should reduce losses in runoff. Time of application through the year has a large effect on potential for pesticide runoff, with a more than 10-fold difference between the wettest and driest months (Rattray et al., 2004; Simpson, 2007).

The properties (half-life, solubility, soil sorption, volatility etc.) of pesticides are a useful guide to their behaviour in the environment. These properties will influence how quickly the pesticides break down in the soil and how likely they are to be transported off-site in runoff water or attached to eroding sediments (Simpson, 2007; Silburn and Kennedy, 2007).

The rainfall simulation work of Masters et al. (2008) provides some of the only paddock scale data comparing pesticide dissipation and runoff for older-conventional and new farming system sugarcane farming practices (i.e. C versus B class). This work found significant reductions in herbicide losses under new farming system practices (controlled traffic, banded pesticide application) compared to conventional broadcast application (100 per cent coverage). These results have broad relevance to much of the sugar industry, particularly for areas totally reliant on rainfall. Soil management practices have also been shown to be effective in reducing pesticide runoff indirectly by reducing water and sediment movement (e.g. Silburn et al., 2002; Masters et al., 2008).

For pesticides used in grazing lands, such as tebuthiuron (Graslan), there is poor understanding of use and how the pelletised product behaves in the environment. However, tebuthiuron is regularly detected in Great Barrier Reef streams (Lewis et al., 2009; Packett et al., 2009).

Mackay Whitsunday rainfall simulator—sediment, nutrient and herbicide in runoff from cane farming practices (Masters et al., 2008).

Key results from the rainfall simulation study were:

Soil management—Control traffic farming had significantly less runoff (43 per cent) and sediment loss (44 per cent) than current practice under storm rainfall.

Nutrient management—Total nitrogen loss from surface applications of Dunder fertiliser and sub-surface applications of granular fertiliser were similar, as both were applied at the same rate (160 kilograms of nitrogen per hectare). Nitrate losses were greater from granular applications than from Dunder, with losses being reduced on Control Traffic Farming compared to current practice. However, Dunder had greater amounts of ammonia in runoff compared with granular treatments.

Herbicide management—Reducing applied amounts by 50 to 60 per cent reduced event mean concentrations in runoff for all herbicides (ametryn, atrazine, diuron, and hexazinone) by more than 50 per cent, when rainfall was one day after application. Further reductions in runoff loads were made on Control Traffic Farming compared with current practice. There were strong relationships between herbicide concentration on the trash, event mean concentration in runoff and time after application, for all herbicides.

Recommended best practice for management of water quality in cane is no-till green harvested control traffic farming, with fertilisers and herbicides applied as early as possible before the onset of the wet season. Residual herbicides should be banded on centres of beds and fertilisers applied sub-surface.

Economics of best management practices

The potential economic benefits of adoption of management practices that lead to improved water quality outcomes have been demonstrated in sugarcane (Van Grieken et al., 2010), grains (Strahan and Hoffman, 2009) and grazing systems. Strahan and Hoffman (2009) modelled adoption of the Grains Best Management Program in the Fitzroy Basin and concluded that:

"By comparing the results achieved for the farm management practices assessed it is evident that very significant dollar per hectare benefits may be achieved from the adoption of more sustainable farm management practices. Improved management practices are cost effective, improve the efficiency of production and increase farm viability. Furthermore, improved management practices that also increase crop yields and/or cropping frequency will improve farm viability substantially."

In grazing lands it is clear there are situations where investments in improved management are worthwhile for the landholders and others that provide mainly a public benefit in terms of minimising sediment loss.

Analysis of the direct costs and benefits related to changing cane management practices according to the ABCD framework (Van Grieken et al., 2010a) in multiple regions shows that cost reductions are substantial and yield responses are marginal (Van Grieken et al., 2010b,c). This suggests there are good opportunities for landholders to improve financial viability at the same time as reducing pollutant export to the Great Barrier Reef.

Appendix 3 Description of the methods for estimating the extent of riparian vegetation

Creating a spatial layer to represent riparian areas

There is a great diversity of river types within the Great Barrier Reef catchments from small, first order streams in upland areas to large coastal rivers. Riparian areas may range in size from small pockets between the streambed and the upper stream bank to lower parts of the river system that include extensive floodplains. A standardised approach was used to define riparian watercourse boundaries or stream centre lines and then buffer these by 50 metres on each side to create the riparian areas spatial layer extent. This spatial extent is likely to cover most riparian areas. In the case of some smaller streams, this layer is likely to include some adjacent land.

For this report, a standard buffer of 50 metres was considered a reasonable representation of riparian areas across the 35 catchments, based on visual interpretation and expert knowledge.

Several datasets were used to define riparian watercourse boundaries and stream mid-lines. The primary data set was the 1:100,000 Geoscience Australia drainage layer (2009). A 50 metre buffer margin around the linear features in this layer includes the streambed but also proportions of, or all of, the adjacent riparian areas. This, however, inadequately represents large streams where a defined buffer may not extend outside the water body due to the size of the river itself. To resolve this, the riverine water body and lacustrine water body data from the Wetlands Mapping Project (EPA, 2005) was used to define the width of large rivers. The riverine wetlands class from this project was, therefore, included to better define the riparian width.

The drainage layer, riverine wetlands and water body layers were all buffered by 50 metre margins and then merged into a single geographic information system 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.

Riparian forest extent mapping and groundcover for the baseline

The National Forest Inventory has defined the minimum crown cover for forests as 20 per cent (Montreal Process Implementation Group for Australia, 2008). Scarth et al. (2008) showed that foliage projective cover of 11 per cent is equivalent to 20 per cent crown cover. Therefore, areas with foliage projective cover of at least 11 per cent are considered forested in this study. Foliage projective cover data was generated using satellite imagery from 1986 to 2009 using the method described by Armston et al. (2009). Groundcover estimates were generated from satellite imagery for 2009 based on the method described by Scarth et al. (2006). With the current methodology, reliable groundcover estimates can only be produced for both cleared areas and open woodlands.

Within the extent of the buffers, the foliage projective cover and groundcover were analysed. The foliage projective cover analysis included statistics on 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.

Monitoring forest extent change from 2004 to 2008

Changes in forest extent from 2004 to 2008 were also reported. Forest extent changes include loss of forests through tree clearing and gains in forest extent through regrowth or new plantings. The monitoring of forest extent for this project, however, is restricted to tree clearing only. It is expected that the reduction in forest extent as a result of tree clearing is significantly larger than the potential forest gains through regrowth or new plantations.

In Queensland, landcover change mapping has been in progress since 1995, as part of the Statewide Landcover and Trees Study (SLATS; www.nrw.qld.gov.au/slats). The primary objective for this program is to detect and map changes in woody vegetation as a result of tree clearing. Statewide Landcover and Trees Study data from 2004 to 2008 was analysed within the riparian areas and statistics generated for Great Barrier Reef catchments and sub-catchments. At the time of publication, the change detection from 2008 to 2009 has not been completed.

Limitations

Several limitations need to be considered when using this data. Initially, the area statements on the extent of forests within riparian areas were based on foliage projective cover estimates derived from satellite imagery with a pixel size of 30 metres (re-sampled to 25 metres). Higher quality (SPOT 5) imagery for 2009 will be available for the majority of the Great Barrier Reef catchments for future reports. Following geometric and radiometric corrections of this imagery, foliage projective cover estimates will be generated at higher spatial resolution (10 metres). It is likely the baseline information will be updated to reflect the new estimates. Field data will also be collected to validate these foliage projective cover estimates and the derived forest extent mapping.

Monitoring of tree clearing within riparian areas can be conducted using Statewide Landcover and Trees Study data. It is likely, however, that some regrowth has since occurred. It was not possible to reliably map regrowth using existing imagery for the short period of 2004 to 2008. Further research is required before detection of regrowth can be undertaken within riparian areas.

Other limitations include the accuracy of the drainage layer and the Wetlands Mapping Project. These data sets have been mapped at a scale of 1:100,000. The satellite imagery used (Landsat) is only suitable for producing maps at a scale of 1:100,000 or coarser. However, the overall accuracy of the riparian buffer areas will be restricted by the drainage layer and Wetlands Mapping Project.

Missing data in the summary statistics is mostly due to cloud and cloud shadow cover in the groundcover data. However, it may also be due to topographic shading and water areas within the buffered riparian extents. It is not possible to map tree or groundcover using remote sensing in these areas.

The riparian results in this report were limited to two indicators of riparian vegetation: forest extent and groundcover. For example, forest extent may include woody weed infestations. Although woody weeds species have a lower ecological value than native vegetation, they can provide higher bank stability compared to banks with no vegetation at all. Groundcover may give an indication of stream bank stability in non-forested areas, but groundcover is difficult to assess under forest canopies. Other indicators could be developed in the future to assess the ecological function of riparian zones, including connectivity of riparian vegetation.

Appendix 4 Description of the method to estimate catchment loads

The following information is from Kroon et al. (2010).

Use of different methods to estimate catchment loads

To estimate natural and total catchment loads in the Great Barrier Reef, generally two different methods are used:

- A (deterministic) process-based model (e.g. SedNet, Source Catchments) that incorporates mapped information about different sources of pollutants, and takes into account the hydrology and contaminant transport characteristics of the system (Wilkinson et al., 2004). This information is used to route the pollutants through a river network and to estimate a load.
- A statistical modelling framework (e.g. Load Regression Estimator methodology), which makes use of monitoring data collected at a site within a catchment over a specified time frame (e.g. this report, also Kuhnert et al., 2009; Wang et al., 2009).

The choice between using a (deterministic) process-based model or a statistical modelling framework to estimate catchment pollutant loads depends on the resolution and representativeness of the monitoring data captured, and how well the process model is believed to mimic the underlying hydrological processes and variability of the system. Where the monitoring data is representative of the river system, statistical approaches tend to be applied. When monitoring data is sparse or unavailable, process-based models are typically used. In addition, some parameters in process based models are calibrated using the same monitoring data that is used as a means for calculating loads, ignoring uncertainty in the model structure as well as on the data that is used for calibration purposes.

Effect on total pollutant load estimates

The results show that the total load estimates of total suspended solids, dissolved inorganic nitrogen, dissolved organic nitrogen, dissolved inorganic phosphorus and dissolved organic phosphorus for individual basins derived from the two methods are in general agreement. For basins where long term monitoring records provided good temporal coverage, this is to be expected as SedNet model runs have been adjusted with validated sediment rating curves (total suspended solids) and are driven by stream concentration monitoring data (dissolved inorganic nitrogen, dissolved organic nitrogen, dissolved inorganic phosphorus and dissolved organic phosphorus). Differences between the two methods can arise from the fact that the mean-annual Load Regression Estimator loads are valid for the monitoring periods, which may cover on average a wetter or drier period than the long term average.

The SedNet total particulate phosphorus and particulate nitrogen loads, and consequently total phosphorus and total nitrogen loads, were greater than the 80 per cent confidence interval for the Load Regression Estimator load estimates in several basins (Barron, Herbert and Pioneer) and not smaller than the 80 per cent confidence interval in any basins. In the Pioneer, this mismatch is consistent with that for total suspended solids on which SedNet particulate nutrient load estimates are based. Over-estimation of particulate nutrient loads in SedNet modelling has been previously identified, and estimates have been halved in some previous reporting to match monitoring-derived load estimates (Cogle et al., 2006). In the Barron and Herbert basins, over-estimating particulate nutrient loads in SedNet is likely due to the soil nutrient concentration data used in SedNet modelling being an over-estimate of the concentrations of material delivered to streams, or the predicted mix of hillslope and sub-surface erosion was biased towards hillslope erosion.

Effect on baseline pollutant load estimates

The baseline pollutant load for each basin was calculated based on the most recent estimates for natural catchment pollutant loads derived from catchment modelling, and total pollutants loads derived from a combination of catchment modelling and monitoring. For some basins, results from different catchment model runs were used as the most recent available estimates for natural and total catchment loads, as not all studies modelled natural and total catchment loads, or modelled total catchment loads for all constituents. This has resulted, in a few cases, in the following discrepancies in baseline load estimates:

- Total nitrogen and total phosphorus baseline loads do not always correspond with the sum of baseline loads of all nitrogen and phosphorus constituents, respectively (e.g. Wet Tropics, Burdekin and Mackay Whitsundays Natural Resource Management regions, and Great Barrier Reef region).
- Out of the 350 baseline load estimates for the individual basins, 13 had negative values:
  - Four of these are attributed to pollutant trapping and processing within reservoirs that outweighs the load increases associated with land use changes from natural.
  - Five of the remaining nine were derived from subtracting modelled natural loads from modelled total loads. Most of these can be attributed to the higher dissolved organic nitrogen and dissolved organic phosphorus concentrations assigned to rainforest in natural pollutant load estimates (e.g. McKergow et al., 2005b) compared with those in more recent total pollutant load estimates (e.g. Cogle et al., 2006; Armour et al., 2009; Post et al., 2006)[1].
  - The final four were derived from subtracting modelled natural loads from monitored total loads. The Tully dissolved organic nitrogen and dissolved organic phosphorus total load estimates were not smaller than the most recent modelled estimates, which were themselves based on lower rainforest concentrations of dissolved organic nitrogen and dissolved organic phosphorus than those used to estimate natural loads. Similarly, the negative baseline dissolved organic nitrogen load for the

[1] The higher dissolved organic nitrogen and dissolved organic phosphorus concentrations assigned to rainforest affects the natural loads from all basins with significant rainforest to varying degrees (all basins in Cape York and Wet Tropics regions, Black, Proserpine, O'Connell, Pioneer), and the total loads from the Cape York basins (excluding Normanby).

Johnstone may be due to higher rainforest concentrations in the modelled natural loads (McKergow et al., 2005b). The total dissolved inorganic nitrogen load for the Barron is similar to previous estimates (e.g. Furnas, 2003; McKergow et al., 2005b), but 10 times lower than the best modelled estimate (Cogle et al., 2006).

To ensure that future estimates of catchment loads to the Great Barrier Reef are beyond reproach, it is recommended that:

- Improvements in the quality of model inputs be made in future catchment modelling, including terrain slope, gully extent and activity, hydrographic gauging[2], riverbank height and the network extent over which bank erosion is represented, reservoir sediment trapping, c-factor associated with closed/rainforest (e.g. Armour et al., 2009)[3], and the nutrient concentrations of soil and dissolved runoff.
- The natural pollutant load estimates for all basins be revised in parallel with revision of total catchment loads, ensuring consistency in data inputs and modelling methods (Source Catchments), and improving the robustness of the baseline load estimates to the Great Barrier Reef, and all sources of uncertainty (parameter, model and data) associated with load estimates are propagated through the catchment models, resulting in transparent, objective and repeatable estimates of end-of-catchment loads.

[2] Floodplain hydrodymanic modelling can also be used to reduce uncertainties by explicitly representing flow velocity across a floodplain.

[3] SedNet estimates for total suspended solids (and PN and PP) from basins that contain significant closed/rainforest are most likely overestimates, as total suspended solids monitoring data indicates that lower USLE cover factors should be applied in rainforest areas. This will have resulted in SedNet over-estimating total suspended solids loads in basins with closed/rainforest (natural loads: all basins in Cape York and Wet Tropics regions, Black, Proserpine, O'Connell, Pioneer; total loads: Lockhart, Russell-Mulgrave, Murray, O'Connell (possibly), Plane Creek basin (possibly), and Mary (possibly)).

References

Accad A, Neldner VJ, Wilson BA and Niehus RE (2008). *Remnant Vegetation in Queensland*. Analysis of remnant vegetation for the years 1997, 1999–2001, 2003 and 2005, including regional ecosystem information. Brisbane: Queensland Herbarium, Environmental Protection Agency.

Apan AA, Raine SR and Paterson MS (2002). Mapping and analysis of changes in the riparian landscape structure of the Lockyer Valley catchment, Queensland, Australia. *Landscape and Urban Planning*, 59:43–57.

Armour JD and Daniells JW (2001). *Banana nutrition in north Queensland*. Final Report FR95013 to Horticulture Australia Ltd.

Armour J, Hateley L and Pitt G (2009). Catchment modelling of sediment, nitrogen and phosphorus nutrient loads with SedNet/ANNEX in the Tully–Murray basin. *Marine and Freshwater Research*, 60:1091–1096.

Armston JD, Denham RJ, Danaher TJ, Scarth PF and Moffiet T (2009). Prediction and validation of foliage projective cover from Landsat-5 TM and Landsat-7 ETM+ imagery. *Journal of Applied Remote Sensing*, 3:033540.

Australian Bureau of Statistics (2006). 4651.0 Land Management: Fitzroy and Livingstone Shires, Queensland, 2004-05. Commonwealth of Australia.

Australian Bureau of Statistics (2009). 4619.0 Land Management Practices in the Great Barrier Reef Catchments, Preliminary, 2008–09. Commonwealth of Australia.

Australian Bureau of Statistics (2009). 4627.0 Land Management and Farming in Australia, 2007–2008. Commonwealth of Australia.

Ball D (2008). Mackay Whitsunday Biodiversity, Coast and Marine—State of the Region Series.

Bartley R, Roth CH, Ludwig J, McJanne D, Liedloff A, Corfield J, Hawdon A and Abbott B (2006). Runoff and erosion from Australia's tropical semi-arid rangelands: influence of groundcover for differing space and time scales. *Hydrological Processes*, 20:3317–3333.

Bastin G and ACRIS Management Committee (2008), Rangelands 2008—Taking the Pulse. Canberra: published on behalf of the ACRIS Management Committee by the National Land and Water Resources Audit.

Brodie J. (comp.) (2007). Nutrient Management Zones in the Great Barrier Reef Catchment: A Decision System for Zone Selection. Department of Environment and Heritage, Canberra.

Brodie J, Fabricius K, De'ath G and Okaji K (2005). Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. *Marine Pollution Bulletin* 51:266–278. Townsville, Australia.

Brodie J, Mitchell A and Waterhouse J (2009). Regional assessment of the relative risk of the impacts of broadscale agriculture on the Great Barrier Reef and priorities for investment under the Reef Protection Package. Stage 2 Report.

Carroll C, Halpin M, Burger P, Bell K, Sallaway MM and Yule DF (1997). The effect of crop type, crop rotation, and tillage practice on runoff and soil loss on a Vertisol in central Queensland. *Australian Journal of Soil Research*, 35:925–939. doi: 10.1071/S96017.

Carroll, C, Merton, L, Burger, P (2000). Impact of vegetative cover and slope on runoff, erosion and water quality for field plots on a range of soil and spoil materials on central Queensland coal mines. *Australian Journal of Soil Research*, 38:3131–327.

Chilcott C, Sandral C, Whish G and Paton C (2007). Meat and Livestock Australia (MLA) Grazing Land Management—Mackay Whitsunday Version. Workshop notes. Meat and Livestock Australia Ltd, Brisbane, Australia.

Cogle AL, Carroll C and Sherman BS (eds) (2006). The use of SedNet and ANNEX models to guide Great Barrier Reef catchment sediment and nutrient target setting. Supplement. Queensland Department of Natural Resources Mines and Water.

Connolly RD, Carroll C, Frances J, Silburn DM, Simpson B and Freebairn DM (1999). A simulation study of erosion in the Emerald Irrigation Area. Australian Journal of Soil Research 37, 479–494.

Connolly RD, Ciesiolka CAA, Silburn DM and Carroll C (1997). Distributed hydrology model (ANSWERS) applied to a range of catchment scales using rainfall simulator data. IV. Evaluating pasture catchment hydrology. *Journal of Hydrology*, 201:311–328.

Connolly RD, Silburn DM and Freebairn DM (2002). Transport of sediment and pesticides in surface water. In: '2002 Environmental Protection and Risk Assessment of Organic Contaminants'. (Eds: R Kookana, R Sadler, N Sethunathan and R Naidu). pp.147–171. Science Publishers, Inc.: Enfield, New Hampshire, USA.

Cullum RF, Knight SS, Cooper CM and Smith S (2006). Combined effects of best management practices on water quality in oxbow lakes from agricultural watersheds. *Soil and Tillage Research* 90, 212–221.

De Vantier LM, De'ath G, Turak E, Done TJ and Fabricius, KE (2006). Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef coral reefs. *Coral Reefs* 25, 329–340.

Department of Employment, Economic Development and Innovation (2011) Grazing management practices framework. Brisbane, Australia.

Department of Environment and Resource Management, Remote Sensing Centre, Division of Environment and Resource Sciences, (2009a). Land cover change in Queensland 2007–2008: A Statewide Landcover and Trees Study (SLATS) Report, viewed 16 May 2010, <www.derm.qld.gov.au/slats/report.html>.

Department of Environment and Resource Management, Regional natural resource management bodies, (2009b), viewed 11 June 2010, <www.regionalnrm.qld.gov.au/my_region/index.html>.

Department of Environment and Resource Management, Remote Sensing Centre, Division of Environment and Resource Sciences (2008), Queensland Land Use Mapping Program, viewed 16 May 2010, <www.derm.qld.gov.au/science/lump/index.html>.

Department of the Premier and Cabinet (2008). Scientific consensus statement on water quality in the Great Barrier Reef. Brisbane, Australia.

Department of the Premier and Cabinet (2009). Reef Water Quality Protection Plan 2009. Reef Water Quality Protection Plan Secretariat, Brisbane, Australia. <www.reefplan.qld.gov.au/library/pdf/reef-plan-2009.pdf>.

Devlin M. and Brodie J (2005). Terrestrial discharge into the Great Barrier Reef Lagoon: Nutrient behaviour in coastal waters. *Marine Pollution Bulletin* 51(1–4):9–22.

Devlin M, Waterhouse J, Taylor J, Brodie J (2001). *Flood plumes in the Great Barrier Reef: spatial and temporal patterns in composition and distribution*. Great Barrier Reef Marine Park Authority Research Publication No 68. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Dight I (2009). Draft Burdekin Water Quality Improvement Plan: better water for the Burdekin, NQ Dry Tropics. Burdekin Solutions Ltd., Townsville, Australia.

Eames H and Collins R (2010). Industry Report (Great Barrier Reef Catchment)—Grains Best Management Practices 2008–2009, Department of Employment, Economic Development and Innovation, Rockhampton, Australia.

Environmental Protection Agency (2008). 2007 Water Quality Report. Great Barrier Reef catchments and inshore ecosystems. Brisbane, Australia.

Environmental Protection Agency (EPA) (2005). *Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping Classification for Wetlands in Queensland*. Version 1.2, Queensland Government, Brisbane, Australia. (<www.epa.qld.gov.au/wetlandinfo/resources/static/pdf/MappingMethod/p01769aa.pdf>)

Evans J (2010). Great Barrier Reef-wide sugarcane ABCD management practice descriptions 2008–2009. Great Barrier Reef-wide Sugar Working Group Meeting. Canegrowers Ltd, Brisbane, Australia.

Fabricius KE and De'ath G (2004). Identifying ecological change and its causes: a case study on coral reefs. *Ecological Applications*. 14:1448–1465.

Fabricius K, De'ath G, McCook L, Turak E and Williams DM (2005). Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef. *Marine Pollution Bulletin*, 51:384–398.

Finlayson B and Silburn DM (1996). Soil, nutrient and pesticide movements from different land use practices and subsequent transport by rivers and streams. pp.129–140. In: 'Downstream Effects of Land Use', (HM Hunter, AG Eyles, GE Rayment, eds), Department of Natural Resources, Queensland, Australia.

Freebairn DM, Loch RJ and Silburn DM (1996). Soil erosion and soil conservation for vertisols. *Developments in Soil Science*, 24:303–362.

Furnas, M and Brodie, J (1996). *Current status of nutrient levels and other water quality parameters in the Great Barrier Reef*. In: Hunter, HM et al. (eds). Proceedings of the Conference on the Downstream Effects of Land Use, 26–28 April, 1995, Rockhampton, Australia. pp.9–21.

Furnas M (2003). *Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef*. Australian Institute of Marine Science, Townsville, Australia.

Garbrecht JD and Starks PJ (2009). Watershed sediment yield reduction through soil conservation in a West-Central Oklahoma watershed. *Ecohydrology* 2:313–320. DOI: 10.1002/eco.55.

Garside AL and Bell MJ (2001). Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugarcane cropping system. In: Proceedings from the Australian Society of Sugarcane Technologists Conference, May 2001, Mackay, Queensland.

GHD (2010a). Canegrowers Report for Sugar Cane Land Management Practices Baseline Study Great Barrier Reef-wide report. GHD, Brisbane, Australia.

GHD (2010b). Canegrowers Report for Sugar Cane Land Management Practices Baseline Study Northern region. GHD, Brisbane, Australia.

GHD (2010c). Canegrowers Report for Sugar Cane Land Management Practices Baseline Study Burdekin region. GHD, Brisbane, Australia.

GHD (2010d). Canegrowers Report for Sugar Cane Land Management Practices Baseline Study Central region. GHD, Brisbane, Australia.

GHD (2010e). Canegrowers Report for Sugar Cane Land Management Practices Baseline Study Great Barrier Reef Southern region. GHD, Brisbane, Australia.

Great Barrier Reef Marine Park Authority (2009). *Great Barrier Reef Outlook Report 2009*. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Geoscience Australia (2009). Queensland Drainage 100K, Department of Environment and Resource Management SIRQRY database, <www.ga.gov.au/topographic-mapping/>.

Goetz SJ, Wright RK, Smith AJ, Zinecker E and Schaub E (2003). IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analysis in the mid-Atlantic region. *Remote Sensing of the Environment*, 88:195–208.

Gordon A, Reid A, Shepherd RN, Vitelli M (2005). A survey of Dalrymple Shire graziers grazing land management practices 1994 to 2004. Dalrymple Landcare Committee Inc. Queensland, Australia.

Gordon IJ (2007). Linking land to ocean: feedbacks in the management of socio-ecological systems in the Great Barrier Reef catchments. *Hydrobiologia*, 591:25–33.

Great Barrier Reef Marine Park Authority (2009). Water Quality Guidelines for the Great Barrier Reef Marine Park. Townsville, Queensland.

Higham W, Eberhard R, Waterhouse J, Mitchell C, Freebairn D and Hamilton G (2009). Paddock scale monitoring and modelling for Reef Rescue Plan. Reef Catchments, Mackay, Australia.

Hutchings P and Haynes D (2005). Marine Pollution Bulletin Special Edition Editorial. *Marine Pollution Bulletin*, 51:1–2.

Johnson AKL, Ebert SP and Murray AE (1999). Distribution of coastal freshwater wetlands and riparian forests in the Herbert River Catchment and implications for management of catchments adjacent to the Great Barrier Reef Marine Park. Environmental Conservation, 26 (3):229–253.

Joo M, Raymond M and Huggins R (In prep). Assessment of sediment and nutrient concentrations under different flow conditions for the Great Barrier Reef catchments. Department of Environment and Resource Management, Brisbane, Australia.

Keating BA, Carberry PS, Hammer GL, Probert ME, Robertson MJ, Holzworth D, Huth NI, Hargreaves JNG, Meinke H, Hochman Z, McLean G, Verburg K, Snow V, Dimes JP, Silburn M, Wang E, Brown S, Bristow KL, Asseng S, Chapman S, McCown RL, Freebairn DM and Smith CJ (2003). An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy* 18:267–288.

Klemas VV (2001). Remote Sensing of Landscape-Level Coastal Environmental Indicators. *Environmental Management*, 27:47–57.

Knight AW, Tindall, DR and Wilson, BA (2009). A multi-temporal multiple density slice method for wetland mapping across the state of Queensland, Australia. *International Journal of Remote Sensing*, 30(13). pp.3365–3392.

Kroon F, Kuhnert K, Henderson B, Henderson A, Turner R, Huggins R, Wilkinson S, Abbott B, Brodie J and Joo M (2010). Baseline Pollutant loads to the Great Barrier Reef. CSIRO: Water for a Healthy Country Flagship Report series. Australia.

Kuhnert PM, Wang Y-G, Henderson B, Stewart L and Wilkinson S. (2009). Statistical methods for the estimation of pollutant loads from monitoring data, Final Project Report for the Marine and Tropical Science Research Facility (MTSRF) Project 3.7.7. <www.rrrc.org.au/publications/downloads/377-CSIRO-Kuhnert-P-et-al-2009-Statistical-methods-for-estimating-pollutant-loads.pdf>.

Leonard RA, Langdale GW, Fleming WG (1979). Herbicide runoff from upland piedmont watersheds—data implications for modeling pesticide transport. *Journal of Environmental Quality* 8:223– 229.

Lewis SE, Brodie JE, Bainbridge ZT, Rohde KW, Davis AM, Masters BL, Maughan M, Devlin MJ, Mueller JF, Schaffelke B (2009). Herbicides: A new threat to the Great Barrier Reef. *Environmental Pollution*, 157:2470–2484.

Li Y, Tullberg JN and Freebairn DM (2001). Traffic and residue cover effects on infiltration. *Australian Journal of Soil Research*, 39:239–247.

Lovett S and Price P (2001). Managing Riparian Lands in the Sugar Industry: A Guide to Principles and Practices, Sugar Research and Development Corporation/Land and Water Australia. Brisbane, Australia.

Masters B, Rohde K, Gurner N, Higham W and Drewry J (2008). Sediment, nutrient and herbicide run-off from cane farming practices in the Mackay Whitsunday region: field based rainfall simulation study of management practices. Queensland Department of Natural Resources and Water for the Mackay Whitsunday Natural Resource Management Group, Mackay, Queensland.

McIvor JG, Williams J and Gardener CJ (1995). Pasture management influences runoff and soil movement in the semi-arid tropics. *Australian Journal of Experimental Agriculture* 35(1):55–65.

McJannet DL (2007). Towards an understanding of the filter function of tropical wetlands: Lessons from temperate locations, development of a conceptual model and design of a field monitoring strategy. CSIRO: Water for a Healthy Country National Research Flagship.

McKergow LA, Prosser IP, Grayson RB and Heiner D (2004). Performance of grass and rainfall riparian buffers in the wet tropics, Far North Queensland 2. Water Quality. *Australian Journal Soil Research*, 42:485–498.

McKergow LA, Prosser IP, Hughes AO and Brodie J (2005b). Regional scale nutrient modelling: exports to the Great Barrier Reef World Heritage Area. *Marine Pollution Bulletin*, 51:186–199.

Meat and Livestock Australia (2010). Environmental practices amongst beef and sheep producers within the reef catchments of Queensland. Report prepared by Solutions Marketing & Research Pty Ltd, Neutral Bay, NSW.

Miles RL (1993). Soil degradation processes in a semi arid woodland. PhD thesis, Griffith University, Australia.

Mitchell A, Reghenzani J, Furnas M, Brodie J and Lewis S (2007). Nutrients and suspended sediments in the Tully River: Spatial and temporal trends. Australian Centre for Tropical Freshwater Research Report. No. 06/10. James Cook University, Townsville, Australia. 115pp.

Mitchell A, Reghenzani J and Furnas M (2001). Nitrogen levels in the Tully River—a long term view. *Water Science and Technology*, 43:99–105.

Montreal Process Implementation Group for Australia (2008). Australia's State of the Forests Report Five-yearly report, 2008.

Neilsen S, Dougall C, Stevens S, Burger P and Carroll C (2010). Draft Focus Neighbourhood Catchment Technical Report—Part A. A comparison of runoff and constituent generation under grazing and differing zero-till farming methods on two soil types in the Fitzroy Basin. Department of Environment and Resource Management, Queensland, Australia.

Neldner VJ, Wilson BA, Thompson EJ and Dillewaard, HA (2005). *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland*. Version 3.1. Brisbane, Queensland Herbarium, Environmental Protection Agency: p.128.

Nelson B and Smith D (2005). Belyando Suttor grazing land management pilot project: NHT Extension BD IFA03: property level rangeland grazing targets for the northern Brigalow Belt bioregion within the Burdekin catchment. Queensland Department of Primary Industries and Burdekin Dry Tropics Board.

O'Reagain PJ, Brodie J, Fraser G, Bushell JJ, Holloway CH, Faithful JW and Haynes D (2005). Nutrient loss and water quality under extensive grazing in the upper Burdekin River catchment, North Queensland. *Marine Pollution Bulletin* 51:37–50.

Packett R, Dougall C, Rohde K and Noble R (2009). Agricultural lands are hot-spots for annual runoff polluting the southern Great Barrier Reef lagoon. *Marine Pollution Bulletin*, 58, 976–986.

Post D, Bartley R, Corfield J, Nelson B, Kinsey-Henderson A, Hawdon A, Gordon I, Abbott, B, Berthelsen S, Hodgen M, Keen R, Kemei J, Vleeshouwer J, MacLeod N and Webb M (2006). *Sustainable grazing for a healthy Burdekin catchment*. CSIRO Land and Water Science Report. Sydney, Australia.

Pressland AJ and Graham TWG (1989). Approaches to the restoration of rangelands—the Queensland experience. *Australian Rangeland Journal*, 11(2):101–109.

Proceedings of the Australian Society of Sugarcane Technologists, 23:230–235.

Prove BG, Doogan VJ and Truong PNV (1995). Nature and magnitude of soil erosion in sugarcane and on the wet tropical coast of north-eastern Queensland. *Australian Journal of Experimental Agriculture*, 35:641–649.

Prove BG, Moody PW and Reghenzani JR (1997). Nutrient balances and transport from agricultural and rainforest lands: a case study in the Johnstone River Catchment. Final Project Report, Project No. DAQ3S. LWRRDC Final Report (SRC1). Queensland Department of Natural Resources, Brisbane, Australia. (Sugar Research and Development Corporation/LWRRDC).

Rattray DJ, Silburn DM, Freebairn DM and McClymont D (2004). Modelling soil and management effects on herbicide runoff from dryland agriculture. Paper 692. In: ISCO 2004 'Conserving Soil and Water for Society: Sharing Solutions', 13th International Soil Conservation Organisation Conference, Brisbane, July 2004. (Eds: SR Raine, AJW Biggs, NW Menzies, DM Freebairn, PE Tolmie) (ASSSI/IECA: Brisbane).

Rattray DJ, Standley J, Silburn DM, Freebairn DM and Spann KP (2007). Where does atrazine go when applied to a black Vertosol? *Australian Journal Soil Research* 45(8):598–606.

Rayment G (2002). Water quality pressures and status in sugar catchments (Exposure Draft). Cooperative Research Centre for Sustainable Sugar Production, Sugar CRC/natural resource management, Indooroopilly, Australia.

Rayment GE and Bloesch PM (2006). Phosphorus fertility assessment of intensively farmed areas of catchments draining to the Great Barrier Reef World Heritage Area; 1: soil phosphorus status. *Communications in Soil Science and Plant Analysis* 37:2249–2264.

Reghenzani JR and Armour JD (2000). Management to minimize nutrient export from canelands. In: 'Environmental short course for sustainable sugar production.' (Eds. Bruce C, Johnston M and Rayment GE). CRC for Sustainable Sugar Production, James Cook University, Townsville, Australia. pp.117–122.

Renard K, Foster G, Weesies G, McCool D and Yoder D (1997). Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook. No. 703. U.S. Department of Agriculture.

Rohde K and Yule D (2003). Soil compaction and Controlled Traffic. International Soil Tillage Research Organisation (ISTRO) 16th Triennial Conference, Brisbane, Australia, 13–18 July 2003. pp.1020–1027. University of Queensland, Brisbane, Australia.

Scanlan JC, Pressland AJ and Myles DJ (1996). Run off and soil movement on mid-slopes in north-east Queensland grazed woodlands. *Rangeland Journal*, 18:33–46.

Scarth PF, Gillingham S and Muir J (2008). *Assimilation of spectral information and temporal history into a statewide woody cover change classification*. In: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference, Darwin, Australia, October 2008.

Scarth P, Byrne M, Danaher T, Henry B, Hassett R, Carter J and Timmers P (2006). *State of the paddock: monitoring condition and trend in groundcover across Queensland*. In: Proceedings of the 13th Australasian Remote Sensing Conference, November 2006, Canberra, Australia.

Schmidt M, Tindall D, Speller K, Scarth P and Dougall C (2010) 'Groundcover monitoring with satellite imagery in agricultural areas and improved pastures' 2010. DERM Report on behalf Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

Schroeder BL, Wood AW, Moody PW, Bell MJ and Garside AL (2005). Nitrogen fertiliser guidelines in perspective. *Proceedings of the Australian Society of Sugarcane Technologists*, 27:291–304.

Schroeder BL, Wood AW, Sefton M, Hurney AP, Skocaj DM, Stainlay T and Moody, PW (2010). District yield potential: An appropriate basis for nitrogen guidelines for sugarcane production. *Proceedings of the Australian Society of Sugarcane Technologists*, 32:193–209.

Sherman BS, Brodie JE, Cogle, AL and Carroll C. (2007). Appropriate use of catchment models for water quality target setting and land-use management. In: *Water quality and Sediment Behaviour of the Future: Predictions for the 21st Century*. IAHS Publication 314, IAHS Press.

Silburn DM (2003). Characterising Pesticide Runoff from Soil on Cotton Farms using a Rainfall Simulator. Unpublished Ph.D, Faculty of Agriculture, Food and Natural Resources, University of Sydney, Australia.

Silburn DM and Glanville SF (2002). Management practices for control of runoff losses from cotton furrows under storm rainfall. I. Runoff and sediment on black Vertosol. *Australian Journal of Soil Research*, 40(1): 1–20.

Silburn DM and Kennedy IR (2007). Rain simulation to estimate pesticide transport in runoff. pp.120–135. In: Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring and Remedial Action. ACS Symposium Series No. 966. (Eds: IR Kennedy, KR Soloman, SJ Gee, AN Crossan, S Wang and F Sanchez-Bayo). Washington, DC, United States of America.

Silburn DM, Carroll C, Ciesiolka CAA, deVoil RC and Burger P (in press). Hillslope runoff and erosion on duplex soils in grazing lands in semi-arid Central Queensland I. Influences of cover, slope and soil. Accepted by *Australian Journal of Soil Research*.

Silburn DM, Simpson BW and Hargreaves PA (2002). Management practices for control of runoff losses from cotton furrows under storm rainfall. II. Transport of pesticides in runoff. *Australian Journal of Soil Research*, 40(1):21–44.

Simpson BW (2007). Lessons for achieving effective management from field research on agrochemicals. pp.338–359. In: Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring and Remedial Action. ACS Symposium Series No. 966. (Eds: IR Kennedy, KR Soloman, SJ Gee, AN Crossan, S Wang and F Sanchez-Bayo). Washington, DC, United States of America.

Specht RL and Morgan DG (1981). The balance between the foliage projective covers of overstorey and understorey strata in Australian vegetation. *Australian Journal of Ecology*, 6:193–202.

Strahan R and Hoffman A (2009). Estimating the economic implications for broad acre cropping farms in the Fitzroy Basin catchments of adoption of best management practices. Department of Employment, Economic Development and Innovation, Queensland, Australia.

Thomas GA, Titmarsh GW, Freebairn DM and Radford BJ (2007). No-tillage and conservation farming practices in grain growing areas of Queensland—a review of 40 years of development. *Aus J Exp Ag*, 47:887–898.

Thompson A, Davidson J, Schaffelke B and Sweatman, H (2010). *Final report of AIMS Activities 2009–2010 Inshore coral reef monitoring*. AIMS, Townsville, Australia. 95pp.

Thompson A and Dolman A (2010). Coral Bleaching: one disturbance too many for near-shore reefs of the Great Barrier Reef. Coral Reefs.

Thorburn P, Attard S, Anderson T, Davis M, Kemei J, Shannon E, Milla R, van Greiken M, Davis A and Brodie J (2009). Adopting systems approaches to water and nutrient management for future cane production in the Burdekin. Final Report for the Sugar Research and Development Corporation, Research Project CSE012. CSIRO Sustainable Ecosystems, Brisbane, Australia.

Thorburn PJ, Biggs JS, Collins K, Probert ME (2010). Using the APSIM model to estimate nitrous oxide emissions from diverse Australian sugarcane production systems. Agriculture, Ecosystems and Environment 136 (2010) 343–350.

Tullberg JN, Yule DF and McGarry D (2007). Controlled traffic farming—From research to adoption in Australia. *Soil and Tillage Research*, 97:272–281.

Tullberg JN, Ziebarth PJ and Li Yuxia (2001). Tillage and traffic effects on runoff. *Australian Journal of Soil Research*, 39:249–257.

Udy JW, Dennison W, Lee Long W and McKenzie L (1999). Responses of seagrasses to nutrients in the Great Barrier Reef, Australia. *Marine Ecological Progress Series*, 185:257–271.

USDA-NRCS (2000). Conservation Buffers to Reduce Pesticide Losses United States. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) National Water and Climate Center and the United States Environmental Protection Agency (USEPA) Office of Pesticide Programs.

Van Grieken ME, East M, Poggio M and Page J (2010c). Economic modelling of cane farming systems in the Wet Tropics, Mackay Whitsunday and Burdekin catchments. Reef Rescue Monitoring and Evaluation Paddock to Reef program. A Report to Reef Catchments natural resource management. CSIRO: Water for a Healthy Country National Research Flagship.

Van Grieken ME, Webster AJ, Coggan A, Thorburn P and Biggs J (2010a). Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. A report to the Marine and Tropical Science Research Facility. CSIRO: Water for a Healthy Country National Research Flagship.

Van Grieken ME, Webster AJ, Poggio M, Thorburn P, Biggs J, Stokes C and McDonald C (2010b). Implementation costs of Agricultural Management Practices for Water Quality Improvement in the Great Barrier Reef Catchments. A report to the Marine and Tropical Science Research Facility. CSIRO: Water for a Healthy Country National Research Flagship.

Van Woesik R, Tomascik T and Blake T (1999). Coral assemblages and the physico-chemical characteristics of the Whitsunday Islands: evidence of recent community changes. *Marine and Freshwater Research*, 50:427–440.

Veitch V and Sawynok B (2005). Freshwater Wetlands and Fish: Importance of Freshwater Wetlands to Marine Fisheries Resources in the Great Barrier Reef, Sunfish, Queensland, Australia.

Vitelli M (2010). Grazing industry benchmarking report for catchments draining into the Great Barrier Reef Lagoon. AgForce Queensland, Brisbane, Queensland.

Wallace S (2010). Reef Rescue Horticulture Great Barrier Reef Catchment Baseline Data 2008–2009. Growcom Australia, Brisbane, Queensland.

Wang Y-G, Kuhnert PM, Henderson B and Stewart L (2009). Reporting credible estimates of river loads with uncertainties in Great Barrier Reef catchments. In: Anderssen, RS, RD Braddock and LTH Newham (eds), 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, July 2009, pp.4262–4268. <www.mssanz.org.au/modsim09/I4/wang_y-g.pdf>.

Waters D (2001). Best Management Practices to Minimise Pollutant Transport from Cotton Production Systems. Final report to Cotton Research and Development Corporation. Department of Natural Resources and Mines, Brisbane, Australia.

Waters DK (2004). Grazing management implications on runoff and erosion processes in semi-arid Central Queensland. In: 'Conserving Soil and Water for Society: Sharing Solutions. Proceedings 13th International Soil Conservation Organisation Conference'. Brisbane, 2004. (Eds: SR Raine, AJW Biggs, NW Menzies, DM Freebairn and PE Tolmie), Paper 427. (ASSSI/IECA: Brisbane).

Wilkinson SN, Henderson A, Chen Y and Sherman, BS (2004). SedNet: User Guide Version 2.0.0 (Client Report for the Cooperative Research Centre for Catchment Hydrology). Canberra: CSIRO.

Yang, X (2007). Integrated use of remote sensing and geographic information systems in riparian vegetation delineation and mapping. *International Journal of Remote Sensing*, 28:353–370.

Partners

Queensland Government

Caring for our Country

Australian Government
Great Barrier Reef Marine Park Authority

National Research FLAGSHIPS
Water for a Healthy Country
CSIRO

Burnett Mary Regional Group

James Cook University Australia

Reef Catchments Mackay Whitsunday Inc

entox
national research centre for environmental toxicology

University of Maryland Center for Environmental Science

NQ Dry Tropics
Land & Water Solutions

Cape York Sustainable Futures

Australian Government
Australian Institute of Marine Science

terrain
Natural Resource Management

fba
Fitzroy Basin Association

Australian Government

www.reefplan.qld.gov.au

Queensland Government