Australian Government

Great Barrier Reef
Marine Park Authority

GREAT BARRIER REEF
WATER QUALITY PROTECTION PLAN (REEF PLAN)

First Annual Marine Monitoring Programme Report September 2005

Great Barrier Reef Water Quality Protection Plan (Reef Plan)

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Marine Monitoring Programme Report

September 2005

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Australian Government

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CONTENTS

EXECUTIVE SUMMARY

A variety of evidence now clearly indicates that exports of sediment and nutrients from the catchments adjacent to the Great Barrier Reef (Australia) have increased substantially over the last 150 years. There is also well-documented evidence that benthic communities on nearshore Great Barrier Reef coral reefs vary along measured or presumed gradients of water quality or terrestrial influence. Observed benthic community changes include variations in the cover, composition and relative abundance of macroalgae, encrusting algae, hard corals and soft corals, the recruitment of young hard corals and the abundance of coral bio-eroders.

Based on a review of this type of scientific data, the Australian and Queensland Governments have agreed that there is an overwhelming case for halting and reversing the decline in water quality in the waterways entering the Great Barrier Reef (the Reef). The value of the Great Barrier Reef and the sustainable development of its catchment are of sufficient importance that early action is justified to address deleterious ecosystem changes. The primary framework through which this is to be addressed is outlined in the *Reef Water Quality Protection Plan* (Reef Plan) that was released by the Australian and Queensland Governments in December 2003. Most of the Reef Plan is focused on land-based actions to improve land use practices within the Great Barrier Reef Catchment and thereby reduce the amount of nutrients and sediment entering river systems flowing into the Great Barrier Reef.

The goal of the Reef Plan is to "halt and reverse the decline in water quality entering the Reef within 10 years". A key component of the Reef Plan is the implementation of a long-term water quality and ecosystem-monitoring programme for the Reef lagoon (the Marine Monitoring Programme). The primary objective of the Marine Monitoring Programme is to *assess the long-term effectiveness of the Reef Plan in reversing the decline in water quality of runoff originating from Great Barrier Reef Catchments*. To meet this primary objective, five monitoring sub-programmes have been designed. These include: river mouth water quality monitoring, nearshore marine water quality monitoring, marine biological monitoring, pollutant bioaccumulation monitoring and monitoring of social and economic indicators. The development of each component was guided by a panel of independent scientists with specific expertise relevant to the particular monitoring task. The broad objectives of each sub programme include:

- Assessment of trends and delivery of pollutants to the Reef, and consequently, the effectiveness of implementation of pollutant-reducing initiatives in the Great Barrier Reef Catchment
- Measurement of trends (spatial and temporal) in the concentrations of pollutants in the inshore marine environment, and consequently, the extent of improvements as a consequence of any reductions in pollutant delivery (at river mouths)
- Assessment of trends in the status of inshore coral reef and seagrass ecosystems related to pollutant delivery
- Measurement of inshore pollutant concentrations in mud crabs as an indicator of inshore pollutant concentrations in inshore Great Barrier Reef environments
- Assessment of the contribution that a healthy Great Barrier Reef ecosystem makes to the welfare of Queensland's regional communities and Australia at large.

A significant component of the Marine Monitoring Programme will include involvement of local community members in the sampling programmes, and the integration of the programme with the Queensland Government and Regional Natural Resource Management bodies water quality monitoring programmes in the Great Barrier Reef Catchment. The Marine Monitoring Programme will build upon outcomes from a number of previous and current long-term research and monitoring projects within the Great Barrier Reef that support the objectives of the Reef Plan. These activities provide essential baseline information on the status of water quality in reef and regional river waters and on the status of important regional ecosystems.

The Marine Monitoring Programme is funded through the Natural Heritage Trust, (which is administered by the Department of the Environment and Heritage), until 2008. The Great Barrier Reef Marine Authority (GBRMPA) has been allocated $6.063 million over the three years from 2004-2005 to implement and manage the programme. The GBRMPA, through a competitive tender process, has contracted a Consortium of monitoring providers led by the Cooperative Research Centre for the Reef Ltd (CRC Reef) to undertake the Marine Monitoring Programme. Consortium members include the Australian Institute of Marine Science, University of Queensland, CSIRO, Queensland EPA, Queensland Department of Primary Industry and Fisheries and Queensland Department of Natural Resources and Mines.

An Expert Advisory Panel has been established to review project progress and final reports and to provide advice to the GBRMPA on the design of the Marine Monitoring Programme in the future.

Considerable progress has been made to implement the Marine Monitoring Programme in the Great Barrier Reef to date. This has included establishment of passive sampler water quality monitoring sites, river mouth sampling, as well as marine biological monitoring and bioaccumulation surveys. Socio-economic data relevant to the Great Barrier Reef has also begun to be collected on a regular basis. Work is ongoing to refine information reported against the three key social and economic indicators into a framework of criteria and indicators against which to assess and report the social and economic dimensions of the Great Barrier Reef, and human interactions with the environment.

While there is a growing body of information on distributions of key water quality parameters and affected biological communities within the Reef region, and of trends in a number of these parameters and communities over time, there is still limited information on the biological and physical processes by which water quality drives the performance of Reef communities. There is a need for ongoing, targeted research to determine or clarify the links between water quality and the health of regional ecosystems.

This report provides an overview of the development of the Marine Monitoring Programme, a description of each component of the programme, an overview of the current status of the components of the programme and an outline of the implementation of the programme as at June 2005. This report is GBRMPA's inaugural report for the Marine Monitoring Programme. The structure of this report will form the basis of Annual Reports from the GBRMPA for the life of the Reef Water Quality Protection Plan Marine Monitoring Programme.

PART 1: BACKGROUND

The Great Barrier Reef World Heritage Area

The Great Barrier Reef (the Reef) extends over 2 300km parallel to the Queensland (Australian) coast between latitude 9° and 24°S and covers an area of approximately 350 000km^2 (Figure 1). It consists of an archipelagic complex of over 2 900 reefs and was proclaimed a Marine Park in 1975. The Great Barrier Reef is the largest reef system in the world. A majority of the reefs are situated on the mid- and outer-continental shelf and are located 20 to 150 km from the mainland. The main reef does not form a continuous barrier, but consists of individual reefs separated by inter-reefal waters. A significant number of reefs (*ca* 750) also exist at 'inshore' or 'nearshore' sites, close to the coast, within the Great Barrier Reef Lagoon (Furnas and Brodie 1996). The Great Barrier Reef was listed on the World Heritage Register in 1981 in recognition of its outstanding universal value (Anon 1981), and is the largest of the world's 788 World Heritage Areas.

Sources of pollutants to the Great Barrier Reef

Protection of the ecological systems of the Great Barrier Reef World Heritage Area (GBRWHA) from water sourced pollutants is recognised as one the major challenges facing the GBRMPA in managing the World Heritage Area (Haynes *et al.* 2001). Evidence derived from modelling and sampling in relatively undisturbed catchments of northern Queensland and in southern catchments modified by European settlement since the 1850's indicate that the export of sediments and nutrients from disturbed catchments has risen dramatically over the last 150 years (Furnas 2003; Table 1). There is also increasing evidence concerning the modern widespread contamination of coastal ecosystems with a range of pesticide residues (Haynes et al. 2000a; Mitchell *et al.* 2005; Müller and Shaw 2005).

Management of Great Barrier Reef water quality is typically difficult, as many water quality problems are a consequence of poor land management practices carried out in the Great Barrier Reef Catchment (Figure 1), an area not under the direct control of the GBRMPA (Haynes and Michalek-Wagner 2000).

Table 1. Estimates of change in pollutant inputs to the Great Barrier Reef (Furnas 2003).

	Pre-1850s annual pollutant flux estimate	Current annual pollutant flux estimate
Sediment	1-5 Million tonnes per year	14 million tonnes per year
Phosphorus	2 400 tonnes per year	7 000 tonnes per year
Nitrogen	23 000 tonnes per year	43 000 tonnes per year

Figure 1. The Great Barrier Reef World Heritage Area coast and its associated Catchment, Queensland, Australia.

Great Barrier Reef water quality deterioration

Water quality deterioration and its associated impacts on the ecosystems of the Great Barrier Reef was a focus of study for the GBRMPA in the 1990s. Between 1996 and 2000, scientific staff within the GBRMPA (in association with a number of other scientific institutions) carried out significant monitoring programmes connected with the investigation of:

- Spatial variability of flood plume pollutant concentrations within the Great Barrier Reef (Devlin *et al*. 2001)
- Inshore Great Barrier Reef coral recruitment dynamics and water quality (Smith *et al*. 2005)
- Temporal and spatial variation in Great Barrier Reef chlorophyll *a* (nutrient) concentrations (Brodie *et al.* 2005)
- Spatial variability in pesticide concentrations within the Great Barrier Reef (Haynes *et al.* 2000a)
- Herbicide impacts on local seagrass species (Haynes *et al*. 2000b)
- Pollutant bioaccumulation in Great Barrier Reef dugong and marine mammals (McLaughlin *et al.* 2001; Vetter *et al.* 2001; Haynes *et al.* 2005).

The results of these programmes identified Great Barrier Reef water quality as a major management issue for Government and precipitated the production of the *Great Barrier Reef Catchment Water Quality Action Plan* in September 2001 (Brodie *et al.* 2001).

Further reading/information

- *The State of the Great Barrier Reef*, GBRMPA
  http://www.gbrmpa.gov.au/corp_site/info_services/publications/sotr/
- *GBR Water Quality: Current Issues,* GBRMPA
  http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/current_issues/
- *State of the Environment Queensland 2003*
  http://www.epa.qld.gov.au/environmental_management/state_of_the_environment/state_of_the_environment_2003/
- *Australia State of the Environment 2001 Report*
  http://www.deh.gov.au/soe/2001/
- *Sources, Fates and Consequences of Pollutants in the Great Barrier Reef. Marine Pollution Bulletin* Vol 41, (2000). Ed P. Hutchings and D. Haynes.
- *Catchment to Reef: Water Quality Issues in the Great Barrier Reef Region Marine Pollution Bulletin* Vol 51 (2005). Ed P. Hutchings and D. Haynes.
- Furnas, M. (2003). *Catchments and Corals: Terrestrial runoff to the Great Barrier Reef*. Australian Institute of Marine Science, Townsville. 334
- Shaw, M. and Müller, J. (2005). Preliminary evaluation of the occurance of herbicides and PAHs in the Wet Tropics region of the Great Barrier Reef, Australia, using passive samplers. *Marine Pollution Bulletin* (in press).

Findings of the Queensland Scientific Review Panel

Following the release of the *Great Barrier Reef Catchment Water Quality Action Plan* (Brodie *et al.* 2001), the Queensland Government commissioned an independent panel of experts to review the scientific evidence linking land use, water quality and Reef degradation. In their final report, *A Report on the Study of Land Sourced Pollutants and their impacts on Water Quality in and adjacent to the Great Barrier Reef (2003)*, the Science Panel found the following:

- There are clear indications that major land use practices in the Great Barrier Reef Catchment have led to accelerated erosion and greatly increased the delivery of sediment and nutrients to the Great Barrier Reef over pre-1850 levels

- Causes of this increase include grazing practices in the drier catchments and overgrazing in general, urban development, agricultural production, water use practices, extensive vegetation clearing, wetland drainage on coastal plains, and development on acid sulphate soils
- There is clear evidence of adverse impacts on some rivers, estuaries and inshore areas
- Coral reefs at a number of inshore locations along the coast (that is up to 20 km from shore) have been disturbed and have remained in a disturbed state
- Overseas experience shows that by the time widespread effects are obvious, the system would be almost irreparably damaged.

The Australian and Queensland Governments agree that there is an overwhelming case for halting and reversing the decline in water quality in the waterways entering the Great Barrier Reef. The value of the Great Barrier Reef and the sustainable development of its catchment are of sufficient importance that early action is justified to reduce these risks. In August 2002, the Australian and Queensland Governments entered into a Memorandum of Understanding to jointly develop the Reef Plan as the primary framework under which this issue is to be addressed. The Australian Government also commissioned the Productivity Commission to report back to Government on the values of the major industries in the Reef and its Catchment. The Productivity Commission released a report in February 2003 titled *Industries, Land Use and Water Quality in the Great Barrier Reef Catchment,* which identified the increasing economic importance of industries reliant on the health of the Reef. The report also concluded that no single solution will control diffuse pollution entering the Reef and that various combinations of measures will be necessary.

The Reef Plan was subsequently developed by the Australian and Queensland Governments and released in December 2003.

The Reef Water Quality Protection Plan (Reef Plan)

The *Reef Water Quality Protection Plan* (Reef Plan) is a joint initiative of the Australian and Queensland Governments. The goal of the Reef Plan is to "halt and reverse the decline in water quality entering the Reef within 10 years". Through the Reef Plan, Governments are acting on the potential risk to the Great Barrier Reef from the progressive decline in water quality in waterways entering the Reef, with a focus on diffuse sources of pollutants entering waterways in the Great Barrier Reef Catchment. The Reef Plan identifies nine strategies and 65 actions to address degraded water quality entering the Great Barrier Reef across several areas of interest including self management, education, economic incentives, planning, regulatory frameworks, research, partnerships, priorities and targets and monitoring.

The Reef Plan builds upon the existing participation and support of stakeholders in identifying and implementing solutions to the challenge, and facilitates sustainable natural resource management and the long-term security of industries reliant on the resources of the Great Barrier Reef and its catchment. While some money has been allocated specifically for Reef Plan implementation, the Governments recognised that protection of the Great Barrier Reef is core government business. Therefore Governments decided to focus funds from their major natural resource management programmes, the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust to address the issue Reef water quality issue. As such, implementation of the Reef Plan will occur through the coordination of many existing Queensland and Australian Government legislative and regulatory processes, and through the development and maintenance of partnerships between Regional Natural Resource Management bodies, industry sectors and the general community. Educational and research institutions will be critical to achieving the desired goal. The Reef Plan also recognises the desire of Indigenous people to protect and heal country and culture for future generations. Successful implementation of the Reef Plan and other strategies will help to ensure the long-term sustainability of the Great Barrier Reef and the ecosystems, species and industries it supports.

Further reading/information

- *Great Barrier Reef Catchment Water Quality Action Plan: A Report To Ministerial Council on targets for pollutant loads* http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/action_plan/
- Industries, Land use and Water Quality in the Great Barrier Reef Catchment http://www.pc.gov.au/study/gbr/index.html
- *Memorandum of understanding between the Commonwealth Government and the government of the State of Queensland on cooperation to protect the Great Barrier Reef from land-sourced pollutants* http://www.deh.gov.au/coasts/pollution/reef/mou/index.html
- *Reef Water Quality Protection Plan* http://www.deh.gov.au/coasts/pollution/reef/
- Queensland Scientific Panel Report http://www.deh.gov.au/coasts/pollution/reef/science/pubs/full-science.pdf
- Williams, D. (2001). *Review of Impacts of Terrestrial Run-off on the Great Barrier Reef World Heritage Area.* http://www.reef.crc.org.au/discover/threats/waterqualityreview.html

The Reef Plan Water Quality and Ecosystem Monitoring Programme

A key component of the Reef Plan is the implementation of long-term water quality, ecosystem and socio-economic monitoring programmes in the Great Barrier Reef lagoon. The GBRMPA has specific responsibility for implementation of the marine monitoring component of the Reef Plan in the Great Barrier Reef lagoon. The Reef Plan specifies that the programme is to be in place by June 2005, and the data collected by the monitoring programme is to be reported annually to Government.

The Reef Plan Water Quality and Ecosystem Monitoring Programme (the Marine Monitoring Programme) is funded through the Natural Heritage Trust, administered by the Department of the Environment and Heritage, until 2008. The GBRMPA is to receive $6.063 million over three years from 2004-2005 to implement and manage the programme. The GBRMPA has out-sourced the Marine Monitoring Programme through a competitive tender process (see Management of the Marine Monitoring Programme this section).

Design of the Marine Monitoring Programme

A key attribute of the Marine Monitoring Programme is the balance between research, management and monitoring. This balance will ensure well-informed, reef water quality management decisions, which are based on an integrated monitoring programme supported by a targeted, scientific research programme.

The primary objective of the Marine Monitoring Programme is *to assess the long-term effectiveness of the Reef Plan in reversing the decline in water quality of runoff originating from Great Barrier Reef Catchments.* To meet this objective, the Marine Monitoring Programme is comprised of five sub-programmes: River mouth water quality monitoring, inshore marine water quality monitoring, marine biological monitoring, bioaccumulation monitoring and socio-economic monitoring.

The Australian National Water Quality Management Strategy has developed guidelines for the design of water quality monitoring programmes (ANZECC, 2000). The guidelines emphasise the need for a formal process in designing monitoring programmes through the initial steps of:

- Defining the issue
- Compiling available information
- Developing a conceptual model
- Setting objectives

These steps were followed in the design of the current programme. Definition of the issue of declining water quality in the Reef was the impetus for the development of the Reef Plan, and is summarised in Part 1 of this report. A comprehensive summary of available information is also outlined in Haynes *et al.* 2001, Williams 2001 and Brodie, 2002.

The development of each specific monitoring sub-programme was guided by panels of independent scientists with specific expertise relevant to the particular monitoring task. These scientific panels set the objectives for each component of the

Marine Monitoring Programme that were in line with the overall objectives of the Australian and Queensland Governments in the Reef Plan.

An Expert Advisory Panel has been established to review project progress and final reports and to provide advice to the GBRMPA on the design of the monitoring programme in the future. The membership of the Expert Advisory Panel and its Terms of Reference are included in Appendix 2.

A brief outline and the objective of each of the components of the Marine Monitoring Programme are provided below.

a. River mouth water quality monitoring

Objective: Assessment of trends in delivery of loads of pollutants to the Reef, and consequently, the effectiveness of implementation of pollutant-reducing initiatives in the Great Barrier Reef catchment.

River mouth water quality monitoring assesses change over time in concentrations and loads of the major land sourced pollutants (including sediments, nutrients and pesticides) discharged to the marine environment that have the potential to adversely affect coral reef and seagrass ecosystems. River mouth water quality monitoring is an essential component of the Marine Monitoring Programme as it provides the primary indicator of the change in delivery of pollutants to the waters of the Great Barrier Reef, and consequently of the effectiveness of measures aimed at reducing the transfer of pollutants to the Great Barrier Reef.

b. Inshore marine water quality monitoring

Objective: Measurement of trends (spatial and temporal) in the concentrations of pollutants in the inshore marine environment, and consequently, the extent of improvements as a consequence of any reductions in pollutant delivery (at river mouths).

Water quality monitoring is also carried out in the inshore waters (that is, within ten kilometres of the coast) of the Great Barrier Reef to assess changes over time in concentrations of key water quality indicators. Monitoring of marine water quality is required to establish the extent of improvements in lagoon waters as a consequence of any reductions in pollutant delivery (at river mouths). This monitoring includes the measurement of nutrients, as well as the measurement of water turbidity and pesticide concentrations at key inshore reef sites. Traditional water quality sampling techniques are also used along inshore sampling transects during the wet and dry seasons. There is also a long-term programme investigating the use of state-of-the-art water quality sensors with long-term data logging capacity to minimise fieldwork in the marine environment.

c. Marine biological monitoring

Objective: Assessment of the impacts of land-sourced pollutants on inshore coral reef and seagrass ecosystems, and assessment of trends in the status of inshore coral reef and seagrass ecosystems related to pollutant delivery.

Monitoring of the major marine ecosystem types most at risk from land-based sources of pollutants (intertidal seagrass beds and inshore coral reefs) is carried out to ensure that any change in their status is identified. Monitoring sites are associated with the inshore marine water quality monitoring programme to enable correlation with concurrently collected water quality information. Marine biological monitoring includes the use of traditional video-transect monitoring, as well as the assessment of coral recruitment and community composition, and the assessment of intertidal seagrass status.

d. Bioaccumulation monitoring

Objective: Measurement of inshore pollutant concentrations in mud crabs as a potential long-term indicator of temporal and spatial variation in inshore pollutants concentrations in inshore Great Barrier Reef environments.

Organisms exposed to pollutants often develop subtle cellular differences and may accumulate certain water quality toxicants. Measurement of these cellular changes and the assessment of body burdens of pollutants in key ecosystem indicator organisms can provide a sensitive, early warning of the presence of pollutants before conventional monitoring techniques detect them in the water column or bottom sediments. Surveys of inshore crab pollutant concentrations have demonstrated this type organism as a useful monitoring vehicle to assess pesticide concentrations in inshore marine biota. The utility of mud crabs will be trialled in this sub-programme.

The marine components of the Marine Monitoring Programme are summarised in Table 2. The programme will be implemented across the Great Barrier Reef with a focus on ten river mouths that were selected based on their relative importance in the long-term transport of sediments and nutrients to the Great Barrier Reef. Indicative locations for each of the components of the programme are included in Table 2.

e. Monitoring of social and economic indicators

Objective: To assess the contribution that a healthy Great Barrier Reef ecosystem makes to the welfare of Queensland's regional communities and Australia at large.

The Great Barrier Reef Marine Park is managed as a multi-use marine park, with reef-based industries and activities contributing from the Great Barrier Reef's natural capital, an estimated Gross Value of Product (GVP) per annum of $4.2billion (Productivity Commission 2003). In 2003, more than 1.8 million people visited the Great Barrier Reef with commercial operators (GBRMPA Environmental Management Charge data). The flow-on effect of these industries, which rely on the continued health of the Reef system for long-term economic sustainability, underpins a significant and growing proportion of Queensland's regional economy. Declining water quality directly threatens maintenance of the Great Barrier Reef's natural capital and therefore the ongoing prosperity of the industries and the communities that rely upon them. The social and economic components of the Marine Monitoring Programme will report on three key indicators:

- Market values of Great Barrier Reef industries and their inputs to regional economies
- Patterns of human use of the Great Barrier Reef – non-commercial recreational activities; tourism and commercial fishing
- Community and visitor perceptions of and satisfaction with Great Barrier Reef health.

Conceptual model refinement

These indicators can be used to assess the contribution that a healthy Great Barrier Reef ecosystem makes to the welfare of Queensland's regional communities and Australia at large. Further work is required to refine and complete an appropriate conceptual model(s) for the Marine Monitoring Programme. The components of the model will include:

- Pollutant sources
- Pollutant transport
- Pollutant fate
- Pollutant impact: - Nutrient impact on corals and seagrass
  - Sediment impacts on corals and seagrass
  - Pesticide impacts on corals and seagrass
- External socio-economic influences.

The GBRMPA will work with the Consultant, with advice from the Expert Advisory Panel, to further develop this model over the next 12 months.

Further reading/information

- Reef Plan Marine Monitoring Programme – Call for Expressions of Interest http://www.gbrmpa.gov.au/corp_site/about_gbrmpa/documents/rwqpp_eoi.pdf
- Brodie, J. (2002). *Great Barrier Reef World Heritage Area Water Quality Monitoring Programme.* Australian Centre for Tropical Freshwater Research Report No. 02/01.
- ANZECC (2000). *Australian Guidelines for Water Quality Monitoring and Reporting,* Australian and New Zealand Environment and Conservation Council, Canberra.

Table 2. Summary of the sub-components of the Marine Monitoring Programme.

Programme	Cape York	Wet Tropics	Burdiken	Mackay-Whitsunday	Fitzroy	Burnett-Mary
River Mouth WQ Monitoring Nutrient, sediment and pesticide flux assessment, including community-based river monitoring assessment	Normanby	Barron Johnstone Tully Herbert	Burdekin	Pioneer O'Connell	Fitzroy	Burnett
Inshore chlorophyll monitoring Community-based chlorophyll assessment	Cooktown	Palm Cove Fitzroy Is Clump Point Cardwell	Magnetic Is	Airlie Beach Mackay	Gladstone Rosslyn Bay	Agnes Waters Bagaral Hervey Bay
Inshore passive samplers Tourism Industry-based deployment of pesticide samplers	Lizard Is	Low Isles Fitzroy Is Normanby Is Bedarra Is	Orpheus Is Magnetic Is	Long Is	Nth. Keppel Is	Lady Elliot Is
Seagrass Community-based Seagrass Watch monitoring programme	Cooktown	Green Is Cairns Mission Beach	Pallarenda Cockle Bay	Airlie Beach Mackay	Shoalwater Bay Gladstone	Hervey Bay
Inshore coral reef video and demography assessment Assessment of adult coral cover & subadult survival & growth		Snapper Is Daintree reefs Fitzroy Is High Is Russell Is Normanby Is Dunk Is King Reef S Barnard Is	Magnetic Is Pandora Reef Havana Is Orpheus Is Lady Elliot Reef Middle Reef	Pine Is Shute Is Daydream Is Double Cone Is Lindeman Is Dent Is Hook Is Seaforth Is Tancreed Is	Peak Is Pelican Is Humpy Is Halfway Is Middle Is Nth Keppel Is Barren Is	
Inshore marine water quality monitoring Chlorophyll, turbidity, temperature, pesticides and nutrients Inshore reef larval supply Settlement plate deployment to assess coral larvae supply rates		High Is Fitzroy Is Normanby Is		Pine Is Double Cone Is Daydream Is		
Inshore bio-accumulation (Mud crab pollutant assessment)	Normanby	Barron Johnstone Tully Herbert	Burdekin Gordon Ck	Pioneer O'Connell	Fitzroy	Burnett

Links with Australian and Queensland water quality indicators

Biophysical indicators, such as the indicators outlined in Part 2 of this report are parameters that provide a measure of water quality or ecosystem condition. Many Australian environmental reporting systems are based on environmental indicators. A useful definition of an indicator is a "*direct or indirect measure of environmental quality that can be used to assess status and trends in the environment's ability to support human and ecological health.*" (National Air and Radiation Indicators Project (http://www.pepps.fsu.edu/NARIP/)). Essentially, the Marine Monitoring Programme assesses water quality through measurement of physical, chemical and biological indicators. Where possible, these water quality indicators are aligned with Queensland and Australian Government indicators to maximise the usefulness of the collected data (Table 3).

Table 3. Comparison of Reef Plan monitoring programme and State and Australian Government indicators.

Indicator	Reef Plan Marine Monitoring Programme (2005-ongoing)	Draft Queensland Water Quality Guidelines (2004)	ANZECC guidelines (2000)	Australian State of the Environment Indicators (2001)
River Indicator				
River Turbidity	Y	Y	Y	
River Total N	Y	Y	Y	Y
River Oxidised N	Y	Y	Y	
River NH3-N	Y	Y	Y	
River Total P	Y	Y	Y	Y
River FRP	Y	Y	Y	
River Chlorophyll *a*	Y	Y	Y	
River Pesticides	Y		Y	Y
Marine Indicator				
Marine Turbidity	Y	Y	Y	Y
Marine Total N	Y	Y	Y	Y
Marine Oxidised N	Y	Y	Y	
Marine NH3-N	Y	Y	Y	
Marine Total P	Y	Y	Y	
Marine FRP	Y	Y	Y	
Marine Chlorophyll	Y	Y	Y	
Marine water temp.	Y			Y
Marine Pesticides	Y		Y	
Biological Indicator				
Seagrass area	Y			
Coral area	Y			Y
Mangrove area	*			Y

* Being completed through a joint EPA/DEH Wetland Mapping and Classification project under Reef Plan

Complementary Queensland and Australian indicator-based monitoring programmes include:

- The National State of the Environment (SoE) Reports provide information about environmental and heritage condition, trends and pressures for the Australian continent, surrounding seas and Australia's external territories. The reports are based on data and information gathered and interpreted against environmental indicators
- The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), specify biological, water and sediment quality guidelines for protection of a range of aquatic ecosystems
- The Queensland Water Quality Guidelines (QWQG, 2005) are technical guidelines for the protection of Queensland aquatic ecosystems that complement the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, (ANZECC, 2000). The guidelines include locally and regionally relevant water quality data for fresh, estuarine and marine waters.

Links with the Queensland catchment monitoring programmes

There are two additional interrelated monitoring programmes being carried out as part of the Reef Plan which compliment the marine monitoring programme:

1. The Queensland Government's Stream and Estuary Assessment Programme, which is a coordinated water quality monitoring programme in high-risk catchments to track long-term trends in water quality entering the Great Barrier Reef lagoon (Reef Plan Strategy I5).
2. As part of the coordinated water quality monitoring programme, the Regional Natural Resource Management Boards will be encouraged to support and improve community and industry based water quality information collection programmes in high-risk Reef Catchments (Reef Plan Strategy I6).

1. Reef Plan catchment monitoring programme (Department of Natural Resources and Mines & Energy and Environmental Protection Agency)

The Queensland Department of Natural Resources and Mines (DNRM) and the Queensland Environment Protection Authority (EPA) are developing a *Stream and Estuary Assessment Programme* to upgrade their state-wide water quality monitoring activities. This will provide enhanced understanding and assessment of the condition of water quality and ecosystem health across Queensland and of changes in its condition with time.

The programme has a focus on monitoring of suspended sediment, nutrient and (in certain situations) pesticide loads in waterways and includes the following components (Figure 2):

- 'End-of-catchment' monitoring of sediment, nutrient and pesticides to determine change over time in loads entering the marine (that is, Great Barrier Reef) environment
- Ongoing monitoring of major sub-catchments for sediment and nutrient loads to determine sub-catchment loads and to track changes. This data will also be used to help determine cause and effect relationships, and for model calibration
- Short-term monitoring in high risk catchments to aid model parameterisation and process understanding, including the determination of the generation rates of sediment and nutrients from specific land uses and specific land management practices
- Remote sensing of land condition, use and management to inform modelling activities and monitor the progress of management actions.

The primary focus of the Queensland Government catchment monitoring programme is on monitoring of major runoff events to quantify sediment and nutrient loads. There will also be some less intensive monitoring over the range of flow conditions at least for several years, to quantify loads and evaluate the significance of low-medium flows in overall sediment and nutrient budgets. The end-of-catchment monitoring component carried out as part of the Marine Monitoring Programme is critical to the Queensland Government's overall monitoring programme. The Queensland Government's programme will concentrate its efforts on the same catchments that are being monitored by the GBRMPA in the river water quality monitoring programme.

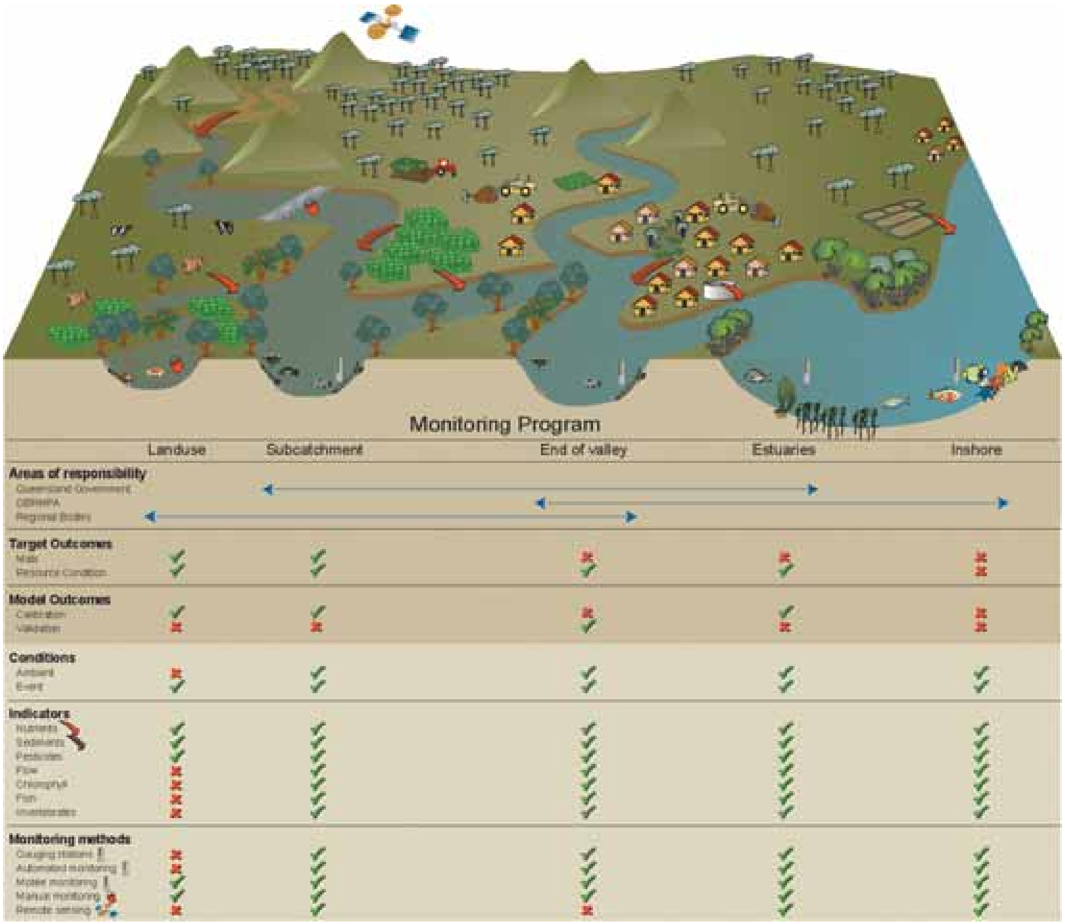

Figure 2. Integration of Great Barrier Reef, Queensland and regional monitoring programmes *(Qld EPA).*

Regional Natural Resource Management (NRM) Board monitoring

Six regions have been identified across the Great Barrier Reef Catchment for the purposes of determining natural resource management and sustainable agriculture priorities. Each region has formed a Natural Resource Management (NRM) Board to direct the management and protection of their region's natural resources. Funding of natural resource management in each region is based on Regional NRM Plans. These Plans specify targets for the maintenance and improvement of the natural resources within local catchments, particularly in relation to salinity, water quality and biodiversity. The Plans are required to identify targets for a set of indicators, including those for water quality, for assessing resource condition. Indicators for water quality include:

- Nutrients (nitrogen and phosphorus)
- Salinity
- Turbidity and suspended sediments
- River condition, including biological indicators (when established).

For example, the Mackay Whitsunday NRM group has developed an Integrated Monitoring Programme which aims to determine the fate of terrestrial materials in the marine environment, determine loads of pollutants to the Great Barrier Reef lagoon and identify potential impacts of terrestrial materials. The programme includes ambient and event monitoring of water quality parameters including nutrients, salinity, suspended sediments, chlorophyll *a* and pesticides in high risk catchments.

The Regional monitoring programmes will complement the Queensland Government monitoring programmes and provide opportunities for the GBRMPA to engage the community in marine water quality monitoring activities.

Further reading/information

- *Draft Queensland Water Quality Guidelines*
  http://www.epa.qld.gov.au/publications/p01414aa.pdf/Draft_Queensland_water_quality_guidelines_2004.pdf
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)* - Paper No. 4
  http://www.deh.gov.au/water/quality/nwqms/#monitor
- *State of the Environment (Australia) reporting*
  http://www.deh.gov.au/soe/2001/coasts/indicators.html

Management of the Marine Monitoring Programme

Following a call for Expressions of Interest in September 2004, the GBRMPA appointed the Cooperative Research Centre for the Reef Ltd (CRC Reef), as the leader of a consortium of providers (the Consortium), to undertake the Marine Monitoring Programme until August 2006. The CRC Reef has sub-contracted seven monitoring providers with a long-term track record of monitoring and research in the relevant areas (Figure 3a). The Consortium includes:

- The Australian Institute of Marine Science (AIMS)
- The University of Queensland- National Research Centre for Environmental Toxicology (NTOX)
- The Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- The Queensland Department of Primary Industry and Fisheries (DPI&F)
- The Queensland Department of Natural Resources and Mines (QNRM)
- The Queensland Environment Protection Agency (EPA)
- Sea Research Pty Ltd.

The largest subcontract is with AIMS, which also has a major role in integrating monitoring outcomes from the other monitoring providers that are contracted to deliver components of the Marine Monitoring Programme (Figure 3b).

Management of the monitoring programme is carried out jointly by the GBRMPA and the CRC Reef. A Project Management Steering Committee and a Project Committee have been established to manage the progress of the Marine Monitoring Programme with representatives from the GBRMPA, CRC Reef and AIMS on each committee. Task leaders from each component of the Marine Monitoring Programme are also invited to attend the Project Committee meetings.

Reporting

The annual reporting framework for the Marine Monitoring Programme is outlined in Figures 3a and 3b. Reporting products include progress reports, monitoring summaries and final reports from the Consortium to the GBRMPA. These reports are independently reviewed and will be submitted to the Australian and Queensland Governments on a regular basis. The GBRMPA is also required to prepare progress reports under NHT contractual arrangements, and contribute to the Reef Plan Annual Report. The GBRMPA will also prepare an array of communication products on the progress of the Marine Monitoring Programme.

Quality Assurance

The Marine Monitoring Programme will include an appropriate quality assurance programme to cover all monitoring activities. Due to the high dependency of data from the Queensland and regional monitoring programmes to report the overall Great Barrier Reef Catchment and lagoon condition, it will be critical to ensure that datasets are compatible and produced to a common quality standard.

There are a number of areas where incompatibility between monitoring programmes may lead to difficulties in data comparison. The GBRMPA is (through the Expert Advisory Panel), convening a working group with representatives from each of the monitoring programmes and experts in quality assurance procedures and management. Issues that will be addressed by December 2005 include:

- Methods used are to be fit for purpose and suited to a range of conditions
- A common set of methods for all field and laboratory procedures are adhered to
- Participation of laboratories in appropriate accreditation processes or adherence to set protocols
- Open and transparent participation in inter-laboratory performance testing trials
- Regular exchange of replicate samples between laboratories
- Rigorous procedures to ensure 'chain of custody' and tracking of samples
- Appropriate standards and procedures for data management and reporting.

Review of the Marine Monitoring Programme

Monitoring incorporated into the Marine Monitoring Programme is often innovative and in many instances, comprises cutting-edge science (for example, new generation passive samplers and data loggers, bioaccumulation monitoring, remote sensing). Concurrent research to support the Marine Monitoring Programme is an essential component of an evolving monitoring programme. The Marine Monitoring Programme will be reviewed regularly, and new techniques incorporated when they can either save money, or increase efficiencies or data quality. In particular, new techniques derived from research programmes being carried out within the CRC Reef, James Cook University and the University of Queensland as well as within Marine Monitoring Programme will be progressively incorporated into the long-term monitoring programme as they are assessed and become available.

An Expert Advisory Panel will provide advice to GBRMPA on technical, scientific and communication aspects related to the monitoring and assessment tasks associated with the marine monitoring sub programmes and the overall Marine Monitoring Programme, and will also contribute to the overall review of the programme beyond the current contract period (January 2005 to June 2006).

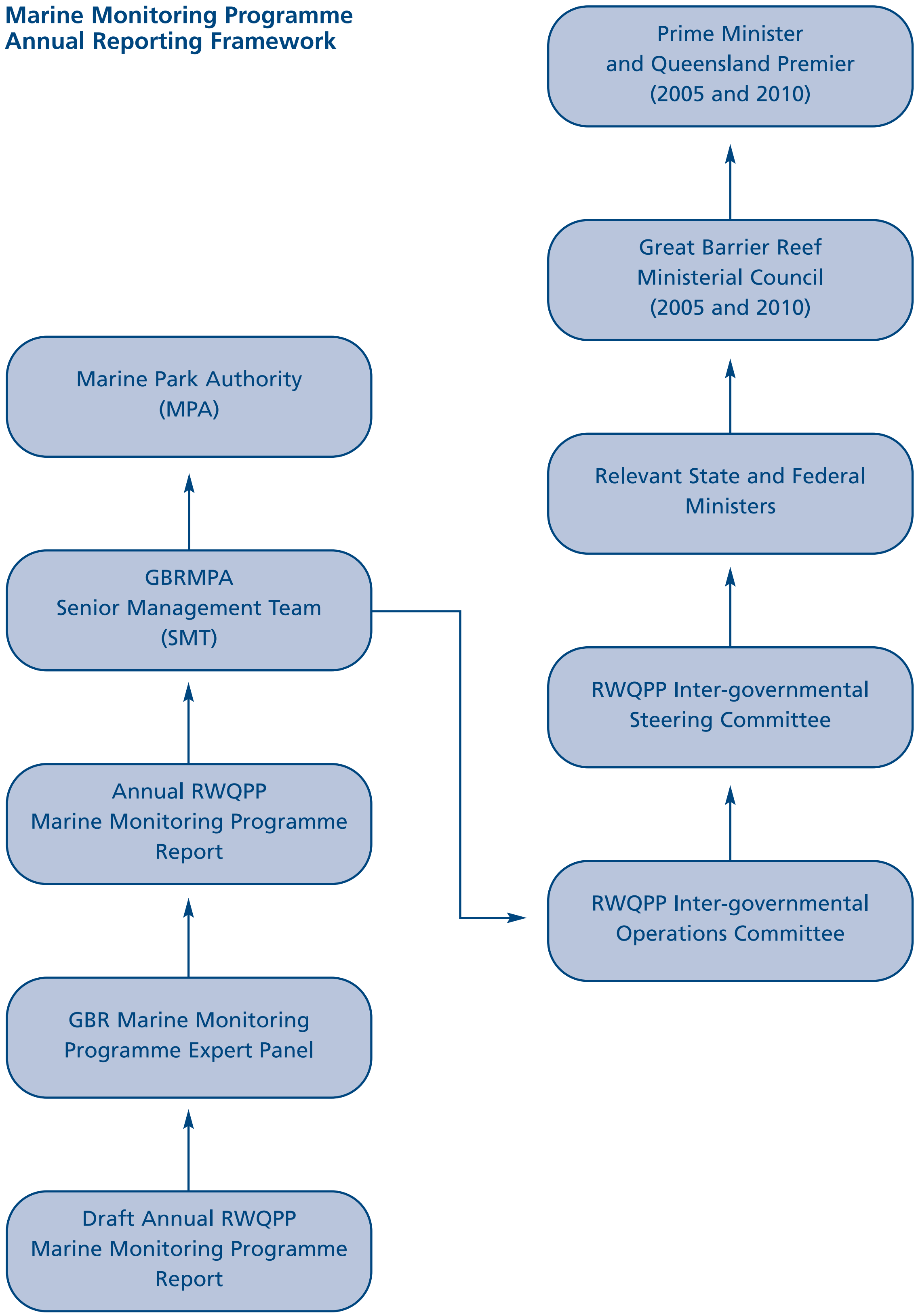

Figure 3a. Marine Monitoring Programme reporting framework.

Marine Monitoring Programme
Contractor Reporting Relationships

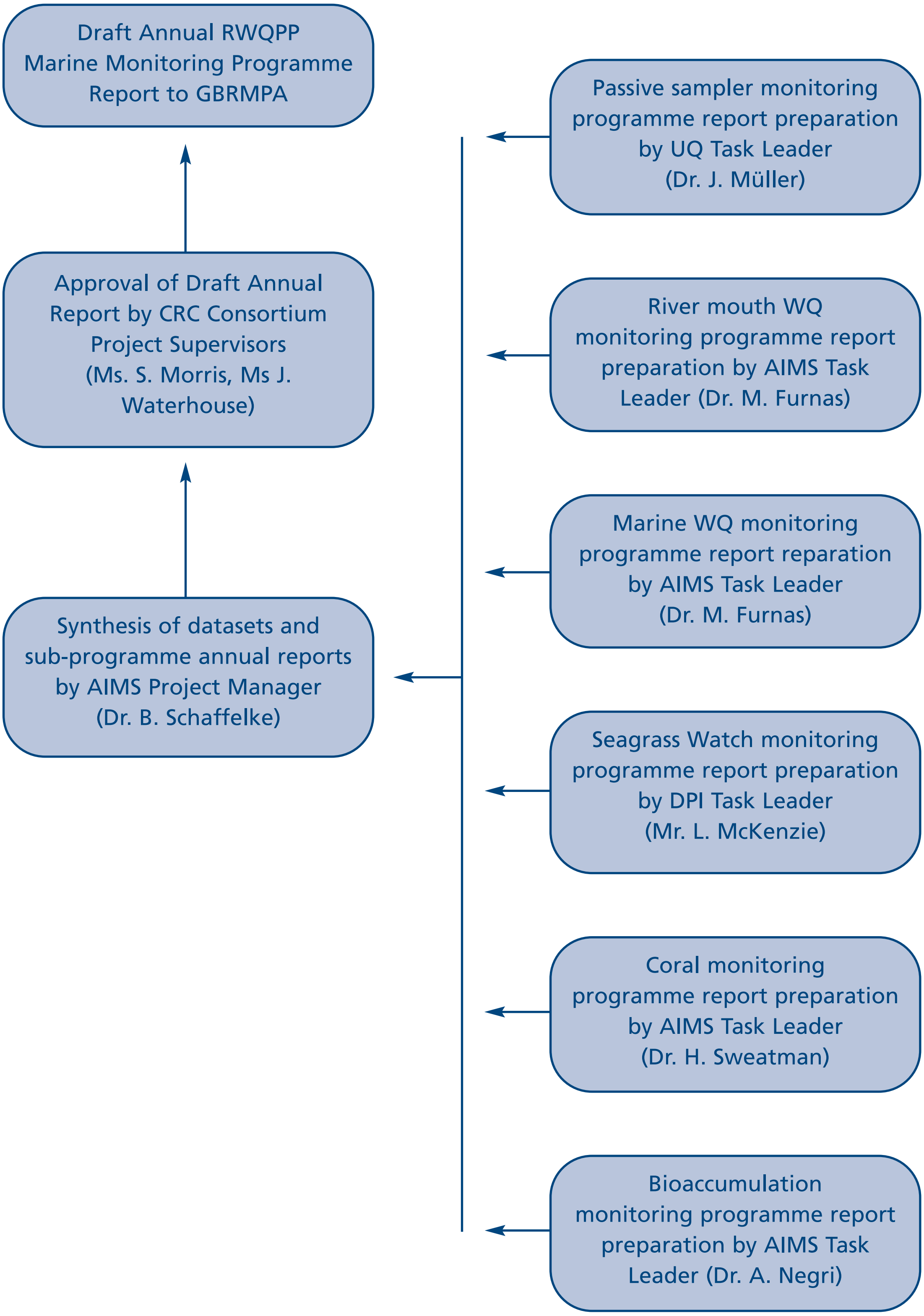

Figure 3b. Marine Monitoring Programme framework.

PART 2: INDICATORS FOR THE MARINE MONITORING PROGRAMME

The indicator concept

Biophysical indicators provide a measure of water quality or ecosystem condition (Environment Australia, 2000). The biophysical indicators used in a monitoring programme are usually chosen to maximise the information collected but minimise the effort that is needed to obtain the data. Figure 4 provides an illustration of the indicators used as part of the RWQPP Marine Monitoring Programme.

a & b . River mouth and inshore marine water quality monitoring

Why

River mouth water quality monitoring assesses trends over time in concentrations and loads of the major land sourced pollutants discharged from the land that have the potential to adversely affect coral reef and seagrass ecosystems. Similarly, marine water quality monitoring is carried out in the inshore waters of the Great Barrier Reef to assess trends in concentrations of key water quality indicators in the marine environment. Importantly, monitoring of marine water quality is required to establish the extent of any improvements or decline in inshore Great Barrier Reef waters as a consequence of changes to land based activities.

What

1. Suspended sediments and turbidity
As erosion occurs within a catchment, particles of clays, silts or small organic particles are washed into waterways. These sediments can be held by the water and are termed suspended sediments. The faster the water is moving the more suspended sediments it can carry. Sediments suspended in the water column are often transported out into the marine environment.

Turbidity is the result of suspended sediments and is a relative measure of the clarity of water: the greater the turbidity, the murkier the water. During dry weather, undisturbed streams usually have low concentrations of suspended sediments. Following rainfall, particles washed in from the catchment make streams more turbid. The degree of turbidity depends on the nature of the catchment. Where there is good vegetation cover, there may only be small or short-term increases in turbidity. In catchments developed for agriculture or in urban catchments, increases in turbidity may be much larger. Nutrients and pesticides often attach to sediment particles so that increases in quantities of sediments washed into a water body will usually also result in an increase in the input of other types of pollutants.

2. Nutrients
Phosphorus and nitrogen are both nutrients that occur naturally in water. They can occur in the dissolved (soluble) phase or may be attached to sediments (particulate). Different proportions of each are sourced from different types of land use (Figure 5).

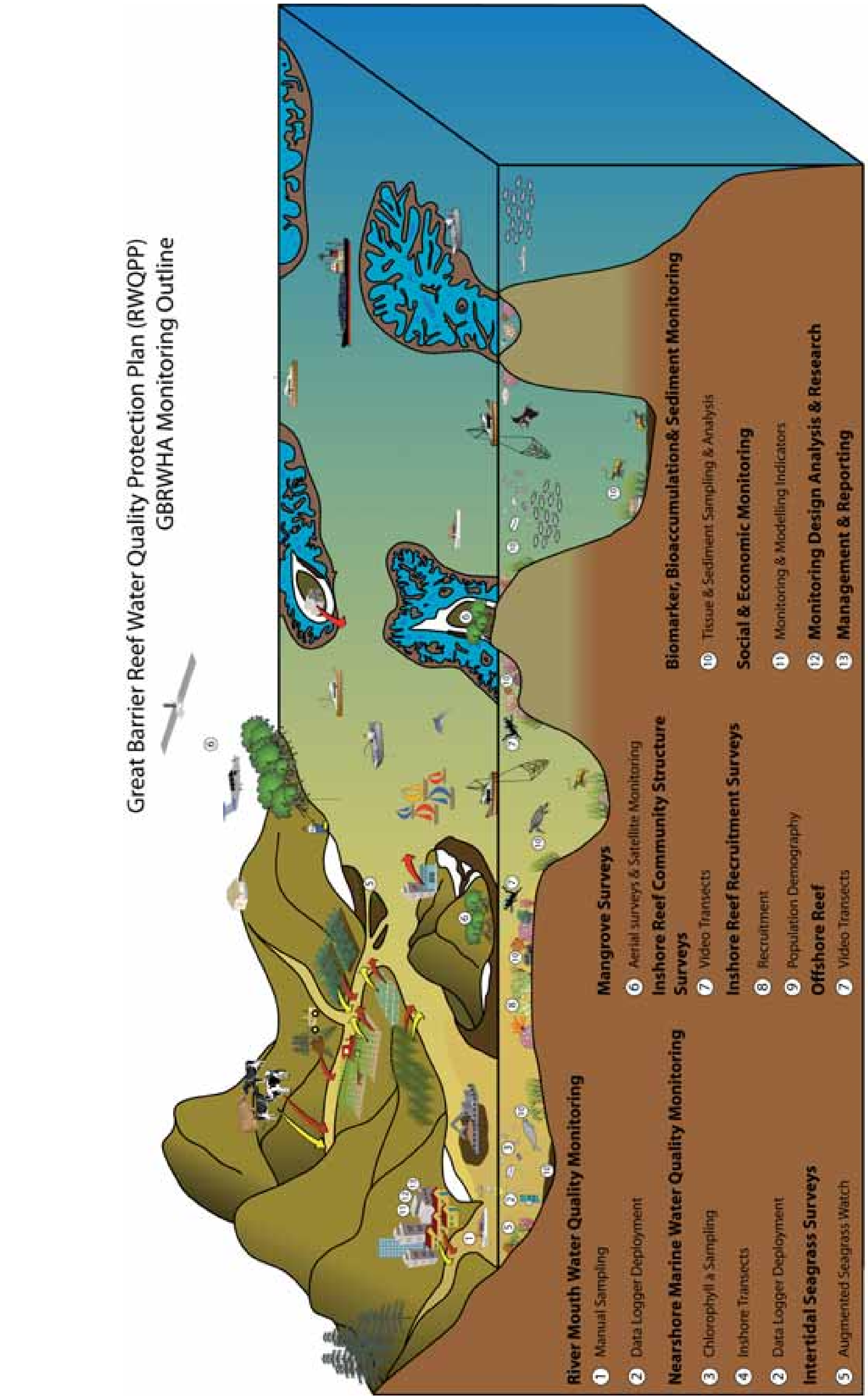

Figure 4. Conceptual model of the Marine Monitoring Programme.

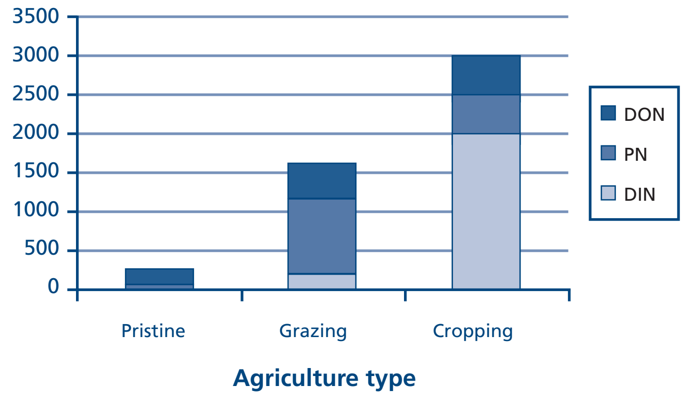

Figure 5. North Queensland land based nitrogen loss (after Brodie *et al.* 2005).

Nitrogen is an essential element required by animals and plants and exists in water both in inorganic and organic forms, and in dissolved and particulate forms. High concentrations of nitrogen can also be an important contributor to eutrophication, especially in estuarine and marine waters. The dissolved species of nitrogen (DIN) include nitrate (NO3), nitrite (NO2), ammonium (NH4+) and di-nitrogen gas (N2). These are generally considered to be the bioavailable component of nitrogen within the water column and are a significant source of nitrogen for algal growth. Total dissolved nitrogen (TDN) consists of dissolved inorganic nitrogen (DIN) and dissolved organic nitrogen (DON), and is readily available for plant uptake. DON is found in a wide range of complex chemical forms such as amino acids, proteins, urea and humic acids. The particulate nitrogen pool consists of plants and animals, and their remains, as well as ammonia adsorbed onto mineral particles. Particulate nitrogen can be found in suspension or in the sediment. Some portion of the particulate nitrogen pool is subject to rapid mineralisation, and is biologically available. Total nitrogen (TN) is a measure of all forms of dissolved and particulate nitrogen present in a water sample.

Phosphorus is also found in waterbodies in dissolved (filterable reactive phosphorus; FRP) and particulate forms. Dissolved phosphorus is readily available for plants, and consists of inorganic orthophosphates (for example, H2PO4-, HPO42-, PO43-) and organic phosphorus-containing compounds (DOP). The particulate phosphorus pool consists of plants and animals, and their remains, phosphorus in minerals (for example, apatite) and phosphate adsorbed onto iron oxyhydroxides on mineral surfaces. Particulate phosphorus can be found in suspension or in the sediment. Total phosphorous (TP) is a measure of all the various forms of phosphorus (dissolved and particulate) found in the water.

3. Chlorophyll a

Chlorophyll *a* is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in rivers, and in estuarine and marine waters. Elevated concentrations of phytoplankton (and chlorophyll *a*) can reflect an increase in nutrient loads and increasing trends can indicate eutrophication of aquatic ecosystems. Phytoplankton in tropical waters grow rapidly in response to nutrient inputs from all sources and make use of all bio-available forms of nutrients. Because Great Barrier Reef phytoplankton populations have typical turnover times of 24 hours, chlorophyll-based estimates of phytoplankton biomass provide an integrative measure of nutrient availability and the quantity of nutrients actively cycling in reef waters.

4. Pesticides

Pesticides are chemical contaminants that are artificially applied to kill problem plant and animal species, particularly in agricultural production areas and urban environments. Their application may also harm non-target organisms as they are transported through the environment. At high concentration, these types of contaminants can kill aquatic life. Other acute effects may include changes in the abundance, composition and diversity of biological communities and habitats. Some pesticides persist in the environment and may progressively accumulate in sediments or in biological tissues to concentrations that are much higher than water column concentrations (that is, bioaccumulation). This accumulation may result in chronic effects including alterations to growth rates and reproductive success.

Toxicants found in coastal waterways are derived from a range of agricultural, industrial and domestic sources. They are generally divided into four categories:

Insecticides are targeted at insect pests. They may be applied to the soil to protect roots, seeds or seedlings. They may also be applied to the crop to protect stems, leaves or fruit. Many insecticides kill insects by disrupting their nervous system, resulting in paralysis and death.

Herbicides are used to control weeds in crops. Herbicides can be selective, killing the weeds but not the crop, or can be non-selective, killing all plants they contact. Many herbicides have relatively low toxicity to insects, fish, or animals as they target specific enzyme systems found only in plants.

Fungicides are used to control fungi that cause disease in crops. They are applied to seeds, to soil, or to the crop to prevent or slow disease when conditions are favorable for the fungus. They generally kill the fungal spores before they can germinate and infect the plant.

Nematicides are targeted at nematodes (a worm like invertebrate) that infect plant roots and stunt or kill the crop. They are always applied to the soil. Nematicides are generally non-selective, killing many other non-target organisms they contact in the soil.

5. Seawater temperature
Water temperature has profound physiological effects on organisms, and if the water temperature goes too far above the tolerance range of an organism, the organisms ability to survive will be compromised. Corals are particularly vulnerable to increased seawater temperature as they live within a relatively narrow temperature range, and positive or negative temperature anomalies of only a few degrees can induce bleaching. The most extensive and intensive coral bleaching events on record occurred in 1998 and 2002. This phenomenon is now the subject of an international research effort.

How and Where

1. River mouth ambient monitoring
River water grab samples are collected (Figure 6) on a regular basis (at least monthly) from a selection of sites in the freshwater reach immediately above tidal influences in ten priority river mouths (Figure 7, Table 2). Sampling incorporates ambient baseflow and ambient low-flow conditions. Samples are analysed for chlorophyll *a*, dissolved inorganic nutrients (NH4, NO2, NO3, NO2, NO3, PO4 and Si) and total dissolved nitrogen and phosphorus (TDN, TDP), suspended sediments, particulate nitrogen and phosphorus concentrations, and pesticides. Each site is characterised by a hydrograph and information on antecedent conditions. GBRMPA is encouraging community-based samplers to play a key role in river sampling programmes.

Figure 6. River water sampling *(AIMS)*.

2. River mouth flood plume monitoring
River water samples are collected intensively during high discharge events from the same sites selected in the ambient monitoring programme, with samples collected across the hydrograph. Event sampling will aim to incorporate two high flow events, the 'first flush' for the catchments (in October to December) and a significant mid-season event (January to March) (Figure 8). Additional water samples will be collected from within the freshwater flood plume as it extends out into the marine environment beyond the mouth of the flooding river. Samples are analysed for chlorophyll *a*, dissolved inorganic nutrients (NH4, NO2, NO3, NO2, NO3, PO4 and Si) and total dissolved nitrogen and phosphorus (TDN, TDP), suspended sediments, particulate nitrogen and phosphorus concentrations, and -----

Figure 7. River mouth sampling locations.

Figure 8. Flood plumes from Cassady Creek,1997 and the Burdekin River mouth January 2005 *(GBRMPA, J. Brodie).*

Turbidity Loggers

Automated river turbidity loggers (Figure 9) will be deployed at sites near the mouths of rivers identified in Figure 7 over the wet season (November to June). These instruments provide high-frequency (30-minute) autonomous measurements of turbidity and water depth at deployment sites for long-term suspended sediment load monitoring. Loggers are mounted on bridge pylons or other structures in the rivers, these instruments are designed to operate submerged during large and small flood events. Turbidity logger data records are processed in concert with concurrent river discharge data to estimate wet season export of fine suspended sediment at the deployment site.

Figure 9. River turbidity logger *(M. Furnas).*

Passive water samplers

Passive sampling techniques (Figure 10) have been progressively developed as tools for the time-integrated, sensitive and accurate monitoring of a wide range of chemicals in the aquatic environment. Water column chemicals accumulate within the sampler to concentrations that exceed the concentration in the surrounding environment by orders of magnitude. As a consequence, the sampler is very sensitive. Passive samplers are being deployed to enable analysis of organic pollutants in the water column at sites near the mouths of rivers over the wet and dry seasons. Water samples that are collected by passive samplers are analysed for the determination of a range of water pesticide (chlorpyrifos, diuron, atrazine, hexazinone, endosulphan, simazine and ametryn) concentrations.

Figure 10. Passive samplers used to collect time integrated pesticide samples from rivers and ocean sampling sites *(ENTOX, D. Haynes).*

3. River pollutant flux estimation

A pollutant load refers to the total amount of pollutant (for example, nitrogen, phosphorus, sediment, pesticide) entering the water during a given time, such as "tonnes of nitrogen per year." The pollutant *concentration* refers to the amount of pollutant in a defined volume of water (such as milligrams of nitrogen per litre of water). Pollutant loads are estimated as the product of concentrations and streamflow. To estimate pollutant loading, it is necessary to sum the flux, which is commonly expressed as mass per unit time, over the period of interest. Since flux cannot be measured directly, flux is often expressed as the product of concentration and flow.

Thus the three basic steps for estimating pollutant load to the marine environment are:

- Measurement of water discharge (for example, cubic metres per second)
- Measurement of pollutant concentration (for example, milligrams per litre)
- Calculation of discharge weighted pollutant load (multiplying discharge by concentration over the time frame of interest).

Using this information, cross-sectionally weighted total sediment (suspended and bed load) and nutrient transport loads will be calculated. Cross sectional loads will be compared with concurrent load estimates derived from the river mouth turbidity logging programme (see above).

4. Marine nutrient, sediment, chlorophyll and pesticide monitoring
Marine water column profile samples are collected for chlorophyll *a*, nutrient (NH4, NO2, NO3, DON, PN, PO4, DOP, PP, Si), suspended sediment, salinity, and turbidity analysis in inshore waters of the Great Barrier Reef between Cape Tribulation and Keppel Bay twice per year (Figures 11 and 12). Sampling sites are located both in open lagoon waters, and in proximity to reefs identified for biological monitoring in order to characterise near-reef water quality status, and when possible, water quality in river plumes. Dry season water quality monitoring will take place in August – September and wet season monitoring in January – February each year.

Figure 11. Marine water quality monitoring *(D. Haynes).*

Figure 12. Seawater sampling transect map.

Remote Sensing

Remote sensing techniques will be used to produce weekly and monthly summaries of mean near-surface chlorophyll *a* and suspended sediment concentrations, turbidity and secchi disk depth for the Great Barrier Reef. This is achieved through acquisition, processing, validation, interpretation, and transmission of geo-corrected ocean colour imagery and data sets derived from MODIS satellite imagery data. AIMS have constructed an upwelling/downwelling spectrometer instrument to allow continuous underway measurement of sea-surface ocean colour over kilometre scales for comparison with and validation of ocean colour imagery, and are in the process of improving the performance of ocean colour processing algorithms for Great Barrier Reef conditions.

Data Loggers

New technologies are being investigated by AIMS to develop autonomous data loggers that measure chlorophyll fluorescence, turbidity, and temperature. Autonomous loggers can provide detailed proxy records of water quality at inshore reef sites, particularly changes associated with ephemeral wind-forced sediment resuspension events. Before these loggers are widely deployed, however, rigorous testing will be undertaken over a 12-month period to evaluate logger performance (accuracy, stability, reliability) and survivability (bio-fouling) in inshore waters of the Great Barrier Reef.

Passive Samplers and Sediment Pesticides

The GBRMPA is involving representatives of the tourism industry and other interested organisations to deploy and recover pesticide passive samplers at coastal reef sites on a monthly basis. Marine passive sampler deployment sites are shown in Figure 13. Marine water samples that are collected by passive samplers are analysed for the determination of a range of pesticide (chlorpyrifos, diuron, atrazine, hexazinone, endosulphan, simazine and ametryn) concentrations. Where pesticides are detected in passive sampling devices as part of the Marine Monitoring Programme, post wet season (April) sediment grab samples will be collected for analysis of pesticide concentrations. This will assist to further quantify the presence of pesticides at the selected locations.

Chlorophyll a monitoring

Sampling stations for inshore marine chlorophyll *a* monitoring are located at inshore locations and along seven discrete, regional cross-shelf transects (Figure 14). Within each transect, between five and eight fixed sampling stations are sampled at approximately monthly intervals in order to quantify seasonal changes in chlorophyll *a*. At each sampling station, a range of weather and physico-chemical measurements (salinity, temperature, secchi depth, depth, presence of *Trichodesmium* and weather conditions) are also collected to aid interpretation of the chlorophyll *a* results (Figure 15). The samples are frozen (-10ºC) prior to fluorometric analysis. Chlorophyll *a* is relatively easy and inexpensive to sample, process and store in the field, provided that strong light is avoided and samples can be kept frozen after filtration. The GBRMPA is seeking involvement of community groups, tourism industry or other interested organisations for the monthly collection of samples for the chlorophyll *a* sampling programme. The selected sites are listed in Table 4. The programme will provide information on inshore chlorophyll *a* concentrations to complement regional chlorophyll *a* sampling in the Great Barrier Reef lagoon.

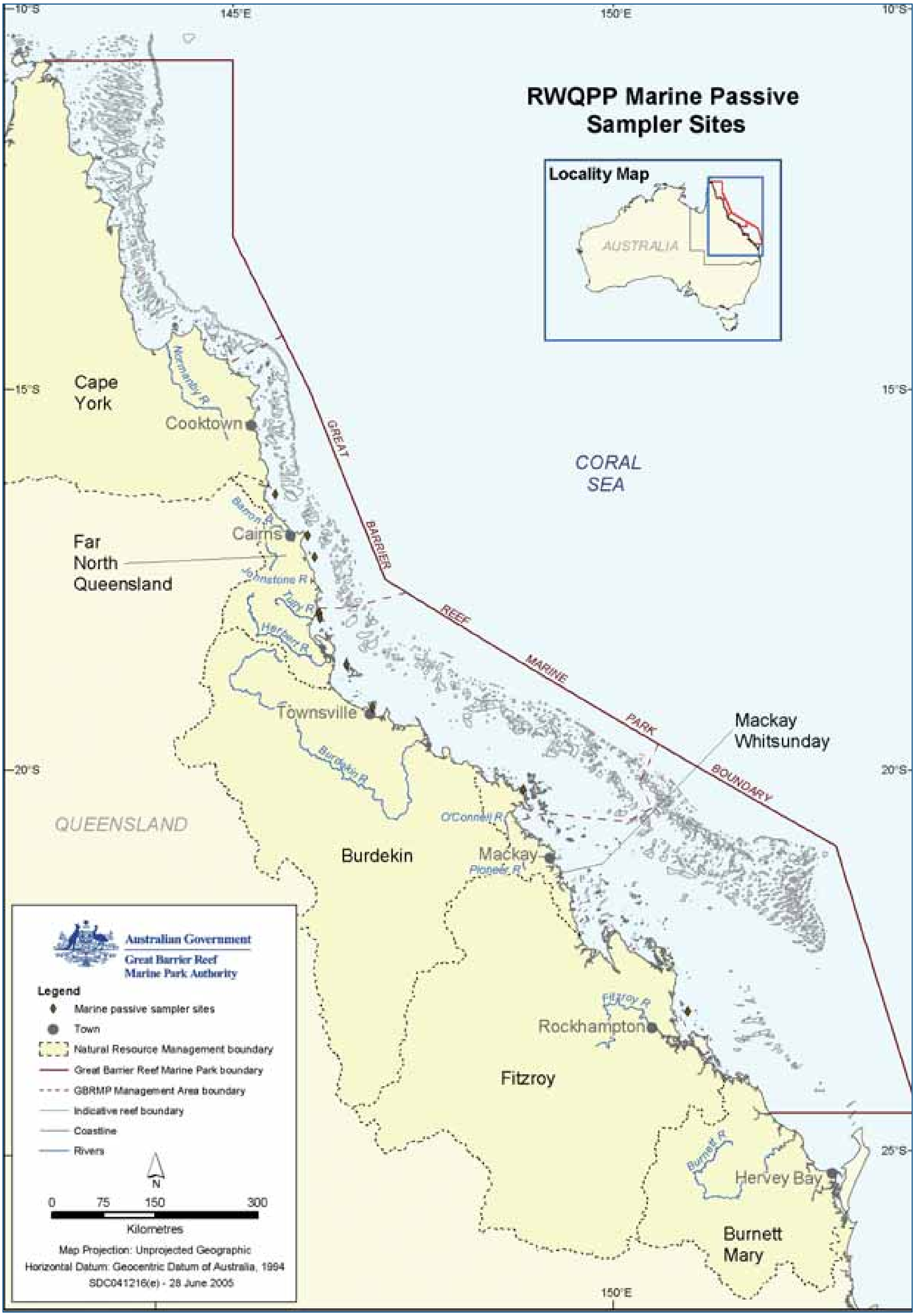

Figure 13. Inshore passive sampler deployment locations.

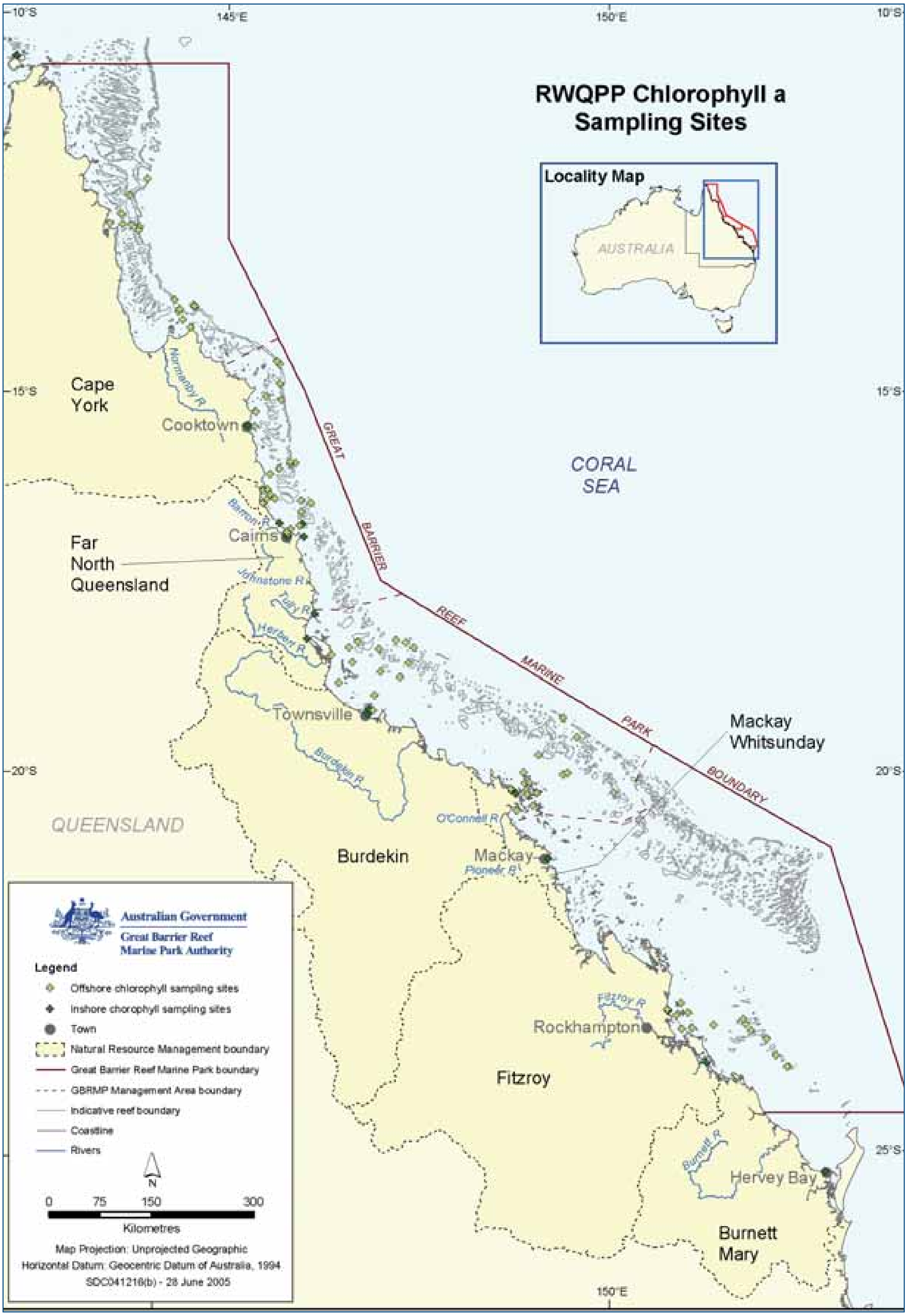

Figure 14. Chlorophyll *a* monitoring locations.

Table 4. Chlorophyll *a* sampling sites and cross shelf transects.

Region	Cross shelf chlorophyll monitoring transect	Potential inshore community chlorophyll sampling site
Far Northern	Far Northern	
	Cooktown	Cooktown – Wharf – end of Webber Esp.
Northern	Port Douglas	Port Douglas – Museum Wharf
	Cairns	Fitzroy Island – jetty
		Bedarra Island – jetty
	Wet Tropics	Cardwell – jetty
Central	Townsville	Magnetic Island – Picnic Bay jetty
	Whitsunday	Shute Harbour – jetty
		Mackay – Marina wall (Ron Searle Drive)
Southern	Keppel Bay	Rosslyn Bay – Marina wall
		Gladstone – Gladstone Harbour bund wall
	Hervey Bay	Urangan – Urangan Pier

Figure 15. Chlorophyll and nutrient sample processing *(GBRMPA).*

4. Seawater Temperature

Data are obtained from *in-situ* data loggers (Figure 16) deployed at selected sites shown in Figure 17. Temperature loggers instantaneously record sea temperatures every 30 minutes and are downloaded every 6 to 12 months, depending on the site. Loggers are double or triple calibrated against a certified reference thermometer after each deployment and are generally accurate to ± 0.2°C. Temperature loggers are generally placed at depths of 5 metres to 9 metres. These loggers will augment the AIMS Great Barrier Reef-wide temperature monitoring programme and provide a means to determine the extent to which observed coastal reef disturbances might be associated with coral bleaching or bleaching risk.

Figure 16. In situ seawater temperature logger (AIMS).

Further reading/information

- Community Waterwatch Programme
  http://www.waterwatch.org.au/
- Freshwater Ecosystem Health Monitoring Programme (EHMP)
  http://www.coastal.crc.org.au/ehmp/freshwater.html
- Marine Ecosystem Health Monitoring Programme (EHMP)
  http://www.coastal.crc.org.au/ehmp/marine_monitoring_overview.html
- Brodie, J., De'ath, G., Waterhouse, J., Furnas, M., Bainbridge, Z., Devlin, M., Haynes, D. and Wright, M. (2005). *Long-term chlorophyll monitoring in the Great Barrier Reef lagoon:* Status report no. 2, 1993-2005. ACTFR, Townsville, Research Report.
- Furnas, M., Mitchell, A., Skuza, M. and Brodie, J. (2005). In the other 90%: phytoplankton responses to enhanced nutrient availability in the Great Barrier Reef lagoon. *Marine Pollution Bulletin* 51: 253-265.

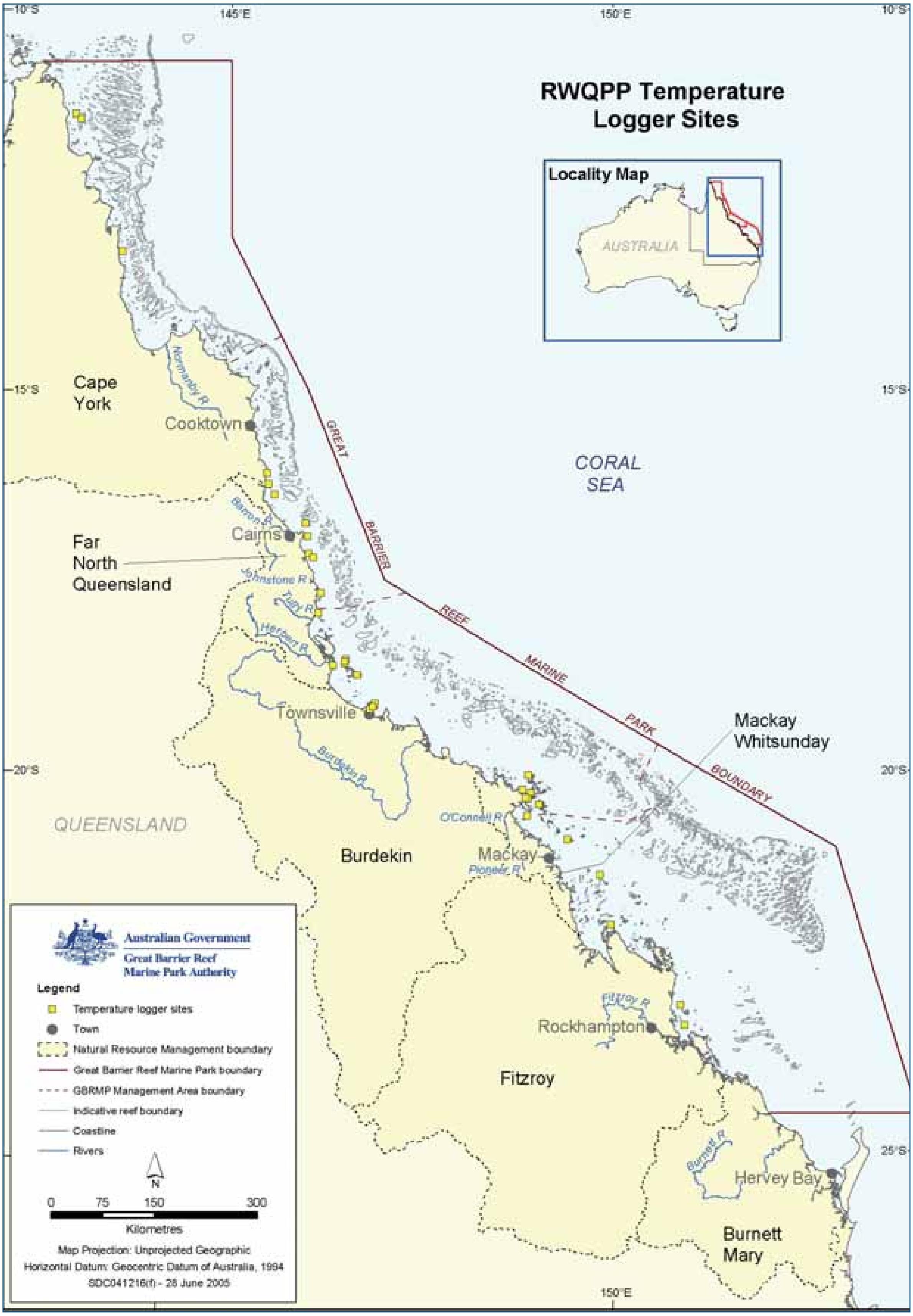

Figure 17. Seawater temperature monitoring sites.c. Marine biological monitoring.

c. Marine biological monitoring

Why

Monitoring of the major marine ecosystem types most at risk from land-based sources of pollutants (intertidal seagrass beds and inshore coral reefs) is carried out to ensure that any change in their status over the life of the Reef Plan is identified. Monitoring sites are associated with the inshore marine water quality monitoring programme to enable correlation with concurrently collected water quality information.

What

Marine biological monitoring involves assessment of inshore seagrass and coral ecosystem condition.

1. Inshore seagrass monitoring
Seagrasses are an important component of the marine ecosystem of the Great Barrier Reef World Heritage Area. They represent a highly productive habitat and nursery ground of value to many marine species including commercially important fish and prawns. There are nearly 6 000 km^2 of seagrasses in waters shallower than 15 metres, relatively close to the coast, and in locations that can potentially be influenced by adjacent land use practices. It is vital to monitor the health of these seagrasses, in terms of seagrass cover and species composition, and to feed-back to coastal managers early warnings of changes.

2. Inner-shelf coral reef monitoring
A significant number of reefs (ca 750) exist at 'inshore' or 'nearshore' sites, close to the coast, within the Great Barrier Reef Lagoon (Furnas and Brodie 1996). These reefs are regarded as being particularly at risk from degraded water quality from Great Barrier Reef Catchments. Monitoring the status of these inshore coral reef benthic communities is an essential component of the *Reef Water Quality Protection Plan* Marine Monitoring Programme.

How and Where

1. Inshore seagrass monitoring
The *Reef Water Quality Protection Plan* Marine Monitoring Programme uses the Seagrass Watch programme as a cornerstone for this component of the monitoring programme. The Seagrass Watch monitoring programme was established in 1998 as an initiative of the Queensland Department of Primary Industries and Fisheries (QDPI&F). The programme monitors the seasonal dynamics of seagrass meadows, the relationships between seagrass condition and climate change and the loss and recovery of seagrass meadows (Figure 20).

The Seagrass Watch sampling design and sampling parameters were developed in collaboration with the community and research scientists and provide an early warning of change of intertidal seagrasses of the Great Barrier Reef World Heritage Area. Seagrass Watch surveys are undertaken in winter and following the wet season in April at sites shown in Figure 18 and Table 5. Generally, three sites are established within each Seagrass Watch location. At each site, three parallel 50 metres transects (each 25 metres apart) are established, but generally only the middle transect is permanently marked. The seagrass habitats along each transect are sampled by visual observation. At each transect, eleven quadrats are sampled (1 quadrat every 5 metres), every three or six months, depending on the related impacts, site access and availability of volunteers. 27 percent of quadrats sampled are photographed to ensure standardisation/calibration of observers and to provide a permanent site record.

Additional information is also collected on sediment pesticide and nutrient concentrations within seagrass beds. The strength of the programme is that trained local community volunteers monitor seagrass cover and species composition at inter-tidal locations (Figure 20).

Table 5. Inshore seagrass and coral reef monitoring sites.

Region	NRM Board	Catchment	Intertidal seagrass onitoring	Inshore reef monitoring sites
Far Northern	Cape York	Endeavour	Cooktown	
Northern	Wet Tropics	Daintree		Snapper Is., Daintree Reefs
		Russell / Mulgrave Johnstone	Green Island Cairns	Fitzroy Is., High Is, Russell Is., Normanby Is.
		Tully	Mission Beach	Dunk Is., Sth Barnard Is., King R
Central	Burdekin	Herbert		Orpheus Is., Lady Elliot R
		Burdekin	Magnetic Island Townsville	Pandora R, Havana Is., Middle R, Geoffrey Bay
	Mackay / Whitsunday	Proserpine	Whitsundays	Pine Is, Shute Is., Daydream Is., Double Cone Is., Lindeman Is., Dent Is., Hook Is., Seaforth Is., Tancred Is.
		Pioneer	Mackay	
Southern	Fitzroy Basin Association	Fitzroy	Shoalwater Bay	Peak Is., Pelican Is., Humpy Is., Halfway Is., Middle Is., Nth Keppel Is., Barren Is.
	Burnett-Mary	Burnett	Gladstone	
		Mary	Hervey Bay	

Figure 18. Seagrass Watch seagrass monitoring sites.

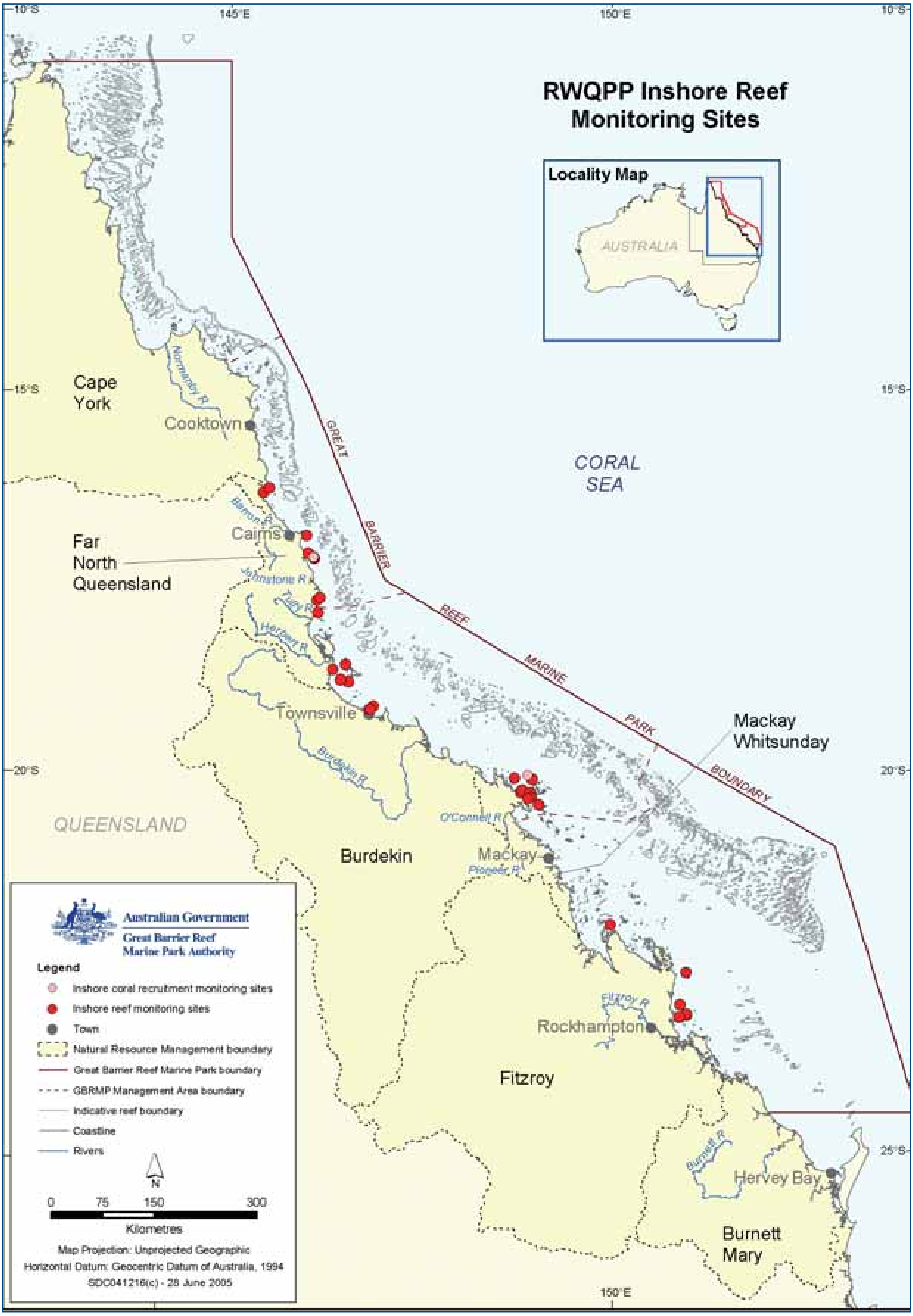

Figure 19. Subtidal coral reef monitoring sites.

Figure 20. Seagrass and coral monitoring *(L. McKenzie, GBRMPA).*

2. Inner-shelf coral reef monitoring

Video surveys
Annual underwater video surveys (Figure 20) are undertaken along transects established at sites identified in Table 5 and Figure 19 using AIMS Long-Term Monitoring Programme survey techniques that are specifically modified for inshore coastal reefs (http://www.aims.gov.au/pages/research/reefmonitoring/ltm/mon-sop7/sop7-2001a.html).

Video surveys of reefs are an effective way of recording the quantities (percentage cover) and types of organism present on a coral reef. The surveys are usually completed along 5 fixed transects or lines, 20 metres in length layed along the reef. A video camera in an underwater housing is used to record the plants and animals present along these transects (Figure 20). The video 'data' is subsequently analysed using dedicated computer software by identify and recording organisms and seabed cover. Organisms beneath randomly assigned points are identified to highest possible taxonomic resolution governed by image quality. Once identified, organisms and benthos are given a code and entered in a database. It is not always possible to identify plants or animals to species or even genus level due to the clarity of the image and due to lack of visibility of taxonomic features on the collected image.

Coral demographic monitoring
Coral demographic monitoring includes annual survey of sizes of coral colonies, by genus, at sites on reefs identified in Figure 19. The surveys carried out by SCUBA divers include assessment of juvenile corals within transects at fixed sites on reefs, and the recording of appropriate coral condition indices (for example, colour classification of selected corals).

Where possible, two replicate sites are surveyed at each location. Each site consists of a 120 metre belt transect along the reef perimeter at each of two depths, 2 and 5 metres below Lowest Astronomical Tide (LAT), although there are not coral communities at 5 metres below LAT at all locations. Hard and soft corals falling wholly or partially within a 34 centimetre by 50 metres section of a 120 metres transect are identified and then classified into one of six size-categories. The 50 metres of this 'demographicbelt' incorporates the first 10 metres of each of the 20 metres long video point intercept transects, though these 5 sections are combined in the data recording. The coral size categories used are <5 cm, 5 cm to <10 cm, 10 cm to <20 cm, 20 cm to < 50 cm, 50 cm to < 100 cm and >100 cm.

Coral recruitment monitoring
The coral recruitment monitoring involves survey of year-to-year variations in coral larval supply rates to inshore reefs in the Whitsunday Islands and the Wet Tropics region (three reefs in each location). The theory of the coral recruitment monitoring

is illustrated in Figure 21. Terracotta tiles (110 x 110 x 10 mm) which act as coral settlement plates are attached to the reef two weeks before the predicted mass spawning events. Three sets of five plates are attached approximately 50 metres apart, at shallow and deep locations at each of the locations. The plates are collected after eight weeks and bleached. Coral settlement plates are assessed under a dissecting microscope (Figure 21) for identification and enumeration of coral recruits.

Discontinuous size distributions of coral colonies at individual reefs can reflect past community dynamics (that is disturbance or differences in recruitment success). It is frequently suggested that low levels of stress from runoff, while not lethal to large, established colonies, may reduce recruitment of some species and so lead to a shift in community composition (Cortes & Risk 1985, McCook *et al.* 2001). If such stress was present at a reef, there would be substantial numbers of large colonies but few recruits of the same taxa.

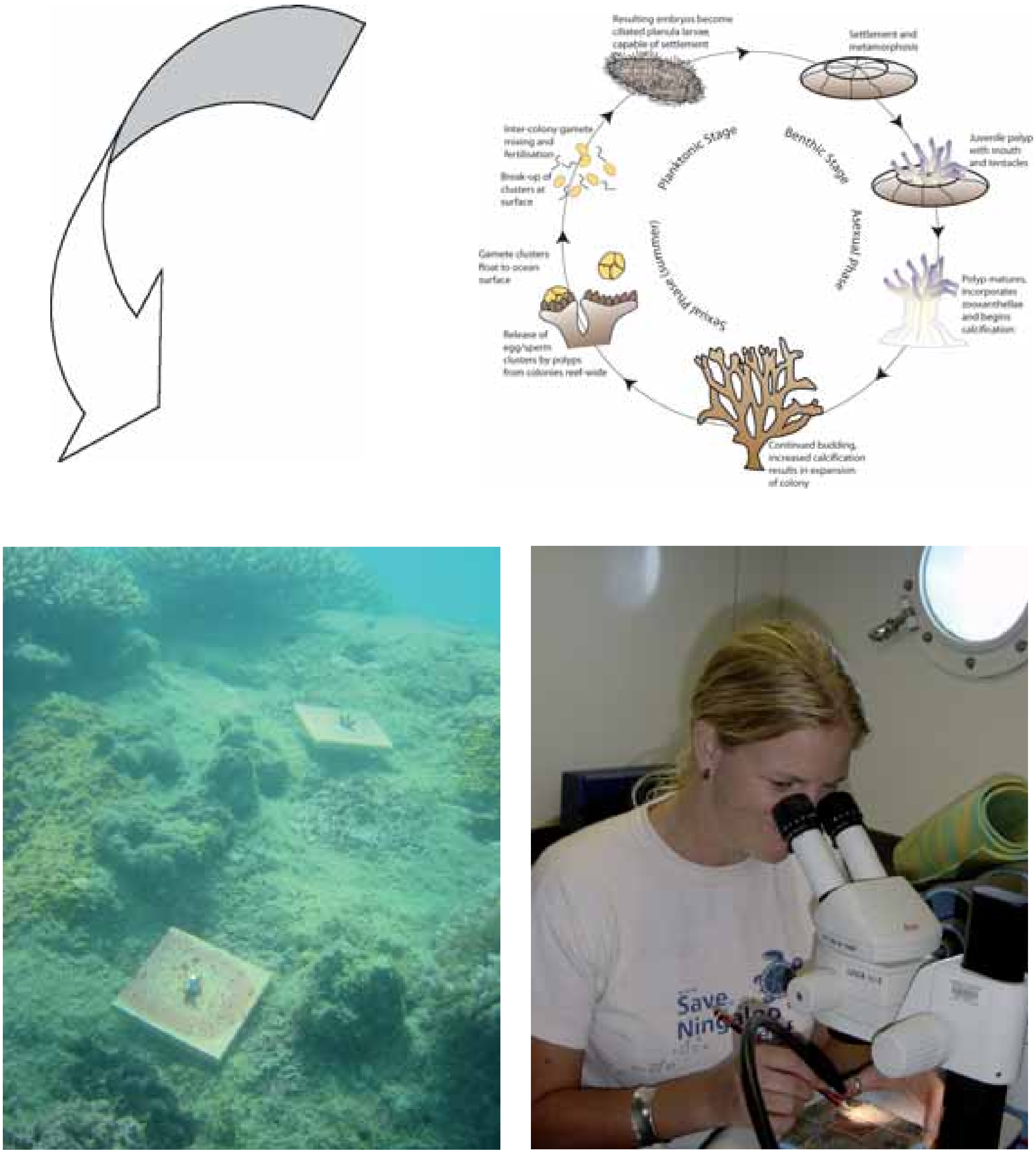

Figure 21. Coral life cycle and microscopic analysis of coral settlement plates *(L. Smith).*

Further reading/information

- Seagrass Watch http://www.seagrasswatch.org.au/
- Coral video monitoring http://www.aims.gov.au/pages/research/reef-monitoring/ltm/mon-sop7/sop7- 2001a.html
- AIMS Long Term Monitoring of the Great Barrier Reef. Status Report No. 6 http://www.aims.gov.au/pages/research/reef-monitoring/ltm/mon-statrep6/statrep6.html

d. Marine bioaccumulation monitoring

Why

Organisms exposed to pollutants often develop subtle cellular differences and may accumulate certain water quality toxicants. Measurement of these cellular changes and the assessment of body burdens of pollutants in key ecosystem indicator organisms can provide a sensitive, early warning of the presence of pollutants before conventional monitoring techniques detect them in the water column or bottom sediments. Crustaceans, and crabs in particular, are widely recognised as useful species for biomonitoring (Phillips and Rainbow, 1993).

What

Surveys of inshore crab pollutant concentrations have demonstrated that this type of organism is a useful monitoring vehicle to assess changes in pesticide concentrations in inshore marine biota, due to its capacity to bioaccumulate a range of contaminants (Figure 22), and its significance as a target species for subsistence, commercial and recreational fisheries (Mortimer 2000). It is readily collectable from each of the ten priority river systems, has a limited territorial range and is large enough to provide ample tissue for chemical analysis.

How and Where

Mud crab bioaccumulation monitoring
The mud crab *Scylla serrata* is common in estuaries along the entire length of the Queensland coast and is an important component of the recreational and commercial fishery (Mortimer 2000). These crabs are relatively easily harvested using baited wire mesh traps. *Scylla serrata* will be collected from at least ten coastal locations along the North Queensland coast between Torres Strait and Gladstone adjacent to the high priority river mouths (Figure 7, Normanby, Barron, Johnstone, Tully, Herbert, Burdekin, Pioneer, O'Connell, Fitzroy and Burnett). Adult male crabs (170-200 mm carapace width) will be collected between March and May each monitoring year. The hepatopancreas tissue is separated out from the crab's carcass and analysed for pesticides that tend to bioaccumulate in this organ (Figure 23).

Assistance is being sought from members of the commercial and recreational fishing industry to collect mud crabs in the regions of interest as part of this programme.

Further reading/information

- Mortimer, M.R. (2000). Pesticide and trace metal concentrations in Queensland estuarine crabs. *Marine Pollution Bulletin*, 41:357-366.

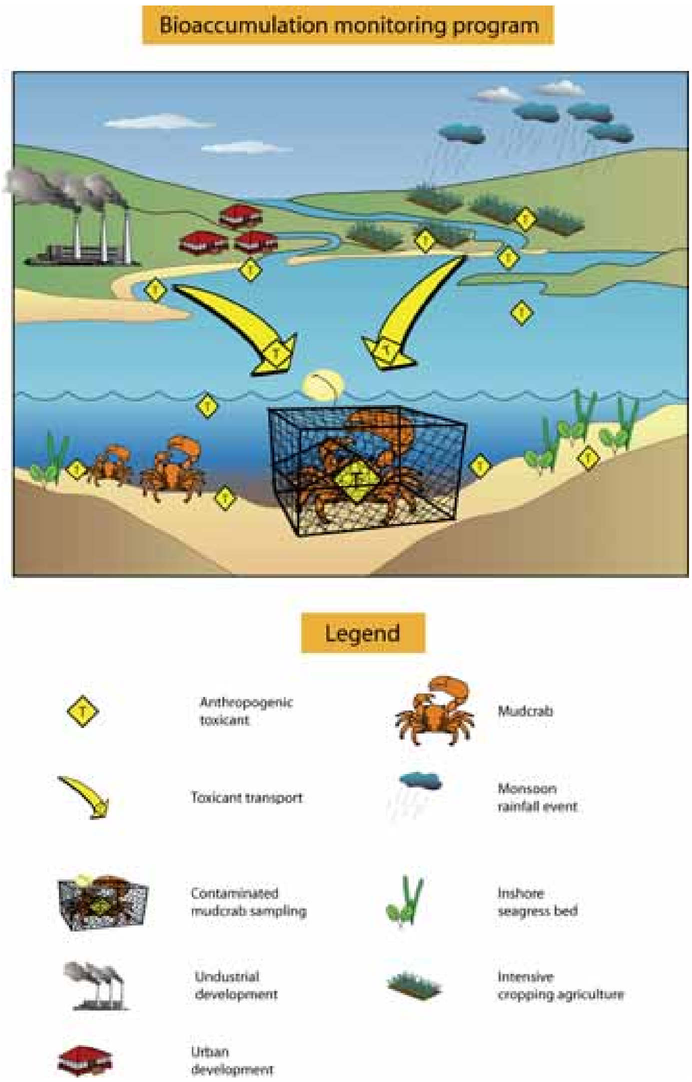

Figure 22. Bioaccumulation monitoring conceptual diagram.

Figure 23. Sampling of mud crab hepatopancreas tissue *(A. Negri).*

e. Monitoring of Social and Economic Indicators

Why

The Great Barrier Reef provides a range of vital ecosystem services and functions to Australian communities at a regional, state and national level. An outcome of the Reef Plan is to increase the quality of river outflows into the Great Barrier Reef ecosystem. In an economic context this can be viewed as an investment in the Great Barrier Reef's natural capital. Improved water quality will benefit reef-based industries.

What

The social and economic components of the Marine Monitoring Programme will report on three key indicators:

- Market values of Great Barrier Reef industries and their inputs to regional economies
- Patterns of recreational use of the Great Barrier Reef
- Community and visitor perceptions of and satisfaction with Great Barrier Reef health.

The three indicators for reporting the social and economic component of the Marine Monitoring Programme are broad and work is ongoing to refine these into a framework of criteria and indicators against which to assess and report the social and economic dimensions of the Great Barrier Reef.

How and Where

1. Monitoring Economic and Financial Values of the Great Barrier Reef
Recent economic valuation studies reporting the market use values (Productivity Commission 2003) provide a baseline upon which to monitor the market values of the industries that will benefit from improved water quality. The social and economic monitoring programme will annually report on:

1. The trends in gross financial values of the direct uses of the Great Barrier Reef Marine Park in the context of Queensland regional and state economies
2. The inputs marine based tourism and commercial fishing make to regional, state and national economies in terms of employment and other economic and social indicators
3. Estimates of the gross financial value to regional economies that can be attributed to the recreational use of the Great Barrier Reef Marine Park
4. The social and economic profile of Great Barrier Reef regional communities and presenting, where available, historical time series data showing trends in key social and economic indicators.

2. Monitoring Great Barrier Reef Recreational Use Reporting Great Barrier Reef patterns of use by recreational users will indicate the spatial extent of reef use. Drawing upon both primary and secondary data sources, the monitoring programme will annually report the spatial extent, intensity and type of activity of tourism and other recreational activities in the Marine Park. The aim of this monitoring programme is to develop a Great Barrier Reef visitor-monitoring programme. This programme will annually report on:

1. The spatial extent and intensity of use of the Great Barrier Reef Marine Park by visitors using marine tourism operators (Figure 24)
2. The range of activities undertaken by recreational users of the Great Barrier Reef Marine Park from Queensland coastal communities
3. The frequency of recreational visitation into the Marine Park and the proportion of the Queensland Great Barrier Reef coastal population that undertakes recreational activities in the Marine Park
4. The spatial extent of recreational use in the Great Barrier Reef Marine Park with reference to locations visited and point of entry into the Marine Park
5. The number of registered recreational visitors.

Figure 24. Tourism activities in the Great Barrier Reef *(GBRMPA).*

3. Community and Visitor perceptions of and satisfaction with Great Barrier Reef

Based upon previous visitor and community monitoring (Green *et al.* 1999; Moscardo *et al.* 2003, Norris *et al.* 2005), a schedule of surveys will be administered to collect data to report on visitor and resident satisfaction with their experience of the Great Barrier Reef and perceptions of the state of the Great Barrier Reef. This data will be collected through the aforementioned recreational use monitoring programme.

4. Monitoring Land Based Activities

An important component of the Reef Plan is to change farming practices and other diffuse source land-based activities that influence declining water quality. The Queensland government is proposing the development of a “Landscape Monitoring System for Water Quality” to monitor and report on land use and land management change, and associated changes in landscape attributes. This will require (amongst other things), regular monitoring at appropriate spatial and temporal scales using remote sensing techniques supported by on-ground verification. Datasets will include those for riparian vegetation condition and extent, land cover and condition, and land use and land management.

The Social and Economic External Expert Advisory Committee established by the GBRMPA for the socio-economic component of the Marine Monitoring Programme, recommended that monitoring of land users attitudes, perceptions, actions and behaviours with regard to water quality issues be undertaken. The committee specifically recommended that monitoring be undertaken to report reduction in the utilisation of farming practices and other land-use activities that lead to poor water quality outcomes. The development of these programmes will be pursued in partnership with the Queensland Government.

The core datasets for land use and land cover will be collated and adapted as necessary from the ‘Queensland Land Use Mapping Programme’ (http://www.nrm.qld.gov.au/science/lump) and the ‘Statewide Land and Trees Cover’ programme (http://nrm.qld.gov.au/slats).

PART 3: CURRENT STATUS OF INDICATORS

This section describes the current state of knowledge regarding critical water quality indicators in the Great Barrier Reef World Heritage Area. It describes what is known about the state of river and coastal waters and inshore ecosystems, to enable measurement of the progress towards achieving the goals of the Reef Plan. The information summarised in this section provides a baseline from which future changes in water quality and the status of key communities can be detected and tracked.

a. River mouth water quality

Runoff from the catchments bordering the Reef is the major source of nutrients, sediments and other pollutants entering the Reef lagoon. Exports of these materials from the 424 000 km^2 Reef Catchment are driven by episodic seasonal rainfall events which produce short-lived wet-season floods. While the Reef has always received freshwater runoff, modern (post-1850) land use has substantively changed the quantities of sediment, nutrients and other pollutant materials in the runoff. Most sediment and nutrients carried by rivers are derived from diffuse sources in agricultural lands. The pattern of land use varies widely across Great Barrier Reef Catchments. There are also noticeable differences between the water quality in and exports from wet- and dry-catchment rivers. In most cases, higher sediment and nutrient concentrations are found in rivers draining dry catchments.

At the present time, it is estimated that terrestrial runoff carries 11-14 million tonnes of fine sediment, 40 000 - 64 000 tonnes of nitrogen and 7 000 - 14 000 tonnes of phosphorus on average annually into the Reef. Although activities such as green harvesting, trash blanketing and zero till have reduced sediment loss in specific industries, a variety of evidence indicates that current inputs are 2 to 6 times greater than average annual inputs prior to European settlement of the catchment and the introduction of modern agricultural development. The primary reasons for the increases are enhanced soil erosion and losses of agricultural fertilizers. Much of the nitrogen (40-80 percent) and most of the phosphorus (70-80 percent) carried by rivers are transported in particulate form, attached to fine eroded soil particles. Loads of sediment, nitrogen and phosphorus carried by the large rivers of the Dry Tropics (Burdekin and Fitzroy) during flood events are 2 to 4 times those carried in wet tropics rivers. However, the Wet Tropics rivers have higher losses per-area due to steeper topographies and higher rain-driven erosion rates.

River sampling programmes in a number of catchments show that nutrient concentrations, particularly of soluble forms (for example, nitrate) increase as river waters cross floodplains with extensive agricultural development.

Increases (4-6 percent p.a.) in nitrate and particulate nitrogen concentrations were observed in the lower Tully River (Wet Tropics) over a 10-year period (1990-2000) following an intensification of agricultural land use in the catchment. Significant changes over time were not detected in the Burdekin River (Dry Tropics) due to high natural levels of variability in water flow, sediment and nutrient loads, and because patterns of land use have not materially changed over the last two decades.

Initial monitoring of some rivers and estuaries of the Reef Catchment reveal low levels of herbicides (several nanograms per litre) were measured in two Wet Tropics rivers (Russell-Mulgrave, Johnstone) with active cropping on the adjacent floodplain. Higher levels of herbicides at biologically significant levels (several micrograms per litre) were measured in floodwaters of the Johnstone and Pioneer Rivers, indicating that under certain conditions, significant amounts of these agricultural chemicals can be flushed into regional river systems and subsequently into the Reef.

The highly variable flow regimes of the monsoonal rivers of the Reef Catchment pose significant challenges for the monitoring of exports to the Great Barrier Reef World Heritage Area and tracking progress in implementation of the Reef Plan. Discharges, sediment loads and nutrient concentrations vary significantly on an episodic, seasonal and inter-annual basis. Statistical analyses of existing data sets indicate that monitoring time frames of 10 years, or longer, are necessary to reliably establish net changes in water quality characteristics. High quality data sets from water quality monitoring programmes of 2 to 13 years duration are now in place for a number of rivers draining into the GBRWHA. These data sets will provide the basis for benchmarks against which the Reef Plan can be evaluated.

Volume-normalised export loads are the most important performance measure of catchment status in terms of water quality in the Reef lagoon. However, high quality estimates of exports are only available for a small number of rivers and years. Effective sampling regimes to measure loads require high intensity sampling and high quality analysis of data from short-lived flood or high-flow events. Due to the high natural climate variability of the region, export-monitoring programmes must be sustained over periods of 10 years or longer to produce comparable results.

b. Water quality in the Reef Lagoon

Widespread and extensive water quality sampling has been carried out throughout the Reef lagoon since the mid-1970s as part of monitoring and biological oceanographic studies within the Reef region. High quality and readily comparable data are available since 1980. As part of this large effort, repeated sampling along a transect of coastal stations has been conducted between Cape Tribulation and Cairns since 1989. Broad-scale surface chlorophyll-monitoring programme has also been carried out through most of the Reef since late-1992.

Both broad-scale and time series data-sets of water quality in the Reef lagoon indicate that nutrient, suspended particulate matter and chlorophyll concentrations in Reef waters are generally low. This is in large part due to the low-nutrient status of source waters for the Reef (the Coral Sea) and very active biological uptake of nutrients by plankton communities in the Reef lagoon. This data also shows that there are persistent spatial and seasonal variations in average nutrient concentrations and other water quality parameters that reflect broad-scale and seasonal degrees of nutrient input to the Reef lagoon and regional-scale dispersion (mixing) rates. Efforts to measure the degree and direction of change in water quality within the Reef lagoon need to account for this inherent large-scale variability.

While ambient nutrient, chlorophyll and suspended sediment levels are generally low, high concentrations of nutrients occur episodically in plumes of flooding rivers and over regional domains disturbed by the passage of tropical cyclones. Flood plumes may occur between one to several times per year on a regular basis in the Wet Tropics, but less frequently (every several years to several decades) in the Dry Tropics bordering the southern regions of the Reef. These high nutrient loads associated with flood plumes or cyclonic disturbances lead to the formation of short-lived plankton blooms which re-convert the nutrients to organic matter. The spatial distribution of recurrent river plumes provides a basis for estimating risk to regional ecosystems from terrestrial runoff.

A gradual increase in suspended sediment, dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) concentrations has been observed over 15 years in coastal waters near Cairns. DON is the most abundant form of fixed nitrogen in Reef waters. Over the same time period, concentrations of dissolved inorganic and particulate nitrogen and phosphorus and chlorophyll *a* varied over a range of time scales, but showed no net change overall.

Regional-scale chlorophyll monitoring in coastal and lagoon waters from 1992 shows average concentrations between transects increase from north to south. Persistent cross-shelf gradients in chlorophyll concentration are found in the central and southern regions of the Reef, reflecting enhanced nutrient availability at the coast from terrestrial runoff and recurrent resuspension of nearshore sediments. To date, however, no significant net changes in chlorophyll concentration have been observed at the regional scale.

Large organic particles, one of the product's of nutrient inputs, also exhibit higher concentrations in nearshore waters. There is experimental evidence that mixtures of organic matter and fine terrestrial sediments are detrimental to hard corals and small sessile reef organisms. Little is known about the distribution, abundance and composition of this material in Reef waters. It is likely that particulate organic matter in Reef waters is a major driver of water quality effects on reefs and reef organisms.

Statistical analysis of existing water quality data sets indicate that appropriate monitoring over time frames of at least 10 years are necessary to resolve significant (at least two-fold) net changes in the naturally variable coastal waters of the Reef. There are now large-scale data sets in place (AIMS Regional Water Quality Sampling; GBRMPA Long-term Chlorophyll Monitoring), to define regional baseline levels of important water quality variables such as nutrients and chlorophyll *a*. Two time-series of sampling are currently operational (AIMS Cairns Coastal Transect [1989-present], GBRMPA Long-term Chlorophyll Monitoring [1993-present]) with the capacity to detect long-term changes in lagoonal water quality if they are continued. These programmes need to be expanded to better cover coastal waters bordering the Wet Tropics and southern regions of the Reef, which is part of the current Marine Monitoring Programme.

At present, long-term data sets are not available for agricultural chemicals or other anthropogenic pollutants in Reef lagoon waters. Low levels (to several nanograms per litre) have been measured at a number of nearshore reef sites bordering the Wet Tropics. While water column herbicide concentrations measured to date are below experimentally determined effect levels, their presence does indicate that these toxic anthropogenic chemicals (and other materials) in runoff are reaching nearshore ecosystems of the Reef. The herbicide diuron has been measured in coastal and intertidal sediments at a number of locations along the Reef coast. The highest levels in these samples (to 10 micrograms per kilogram of sediment) were measured at sites adjacent to rivers draining catchments with extensive sugarcane cultivation.

c. Aspects of coral communities in the inshore Reef

Of the 2 900 reefs within the GBRWHA, approximately 750 are located in the inshore zone which is most affected by terrestrial runoff and resulting alterations to water quality. Of these, ca. 450 reefs are considered to be at locations with a high risk of disturbance or other influence from terrestrial runoff. Very few of these reefs have been subjected to detailed or long-term biological surveys.

Regional-scale surveys of hard corals, soft corals, attached and encrusting algae, fish and bio-eroders clearly show that reef community composition and the presence of individual species or groups vary along gradients of influence by terrestrial runoff or water quality. More affected nearshore reef communities are dominated by fleshy macro-algae, while less affected (for example, offshore) reefs are dominated by hard corals. These gradients are observed within regional areas (Wet Tropics, Whitsunday Islands) and between regions with differing levels of influence from agricultural runoff (Princess Charlotte Bay, Wet Tropics). Bio-eroding organisms show clear cross-shelf differences with higher abundances of macro-borers at inshore sites, causing bio-erosion of the Reef framework. The small number of past surveys, however, precludes determination of whether the spatial extent of terrestrial runoff influence is stable or changing.

Long-term time series (late 1980s to the present) of changes in coral communities are only available for 12 inshore reefs over this time. Coral cover has declined in the region between Cairns and Townsville. The declines in cover coincide with outbreaks of crown-of-thorns starfish and major coral bleaching events in the region. However, this region, being in the Wet Tropics, is also assessed to be at high risk of exposure to runoff. Over the same period, coral cover was stable in the Cooktown and Whitsunday Islands sectors, a region not being affected to the same degree by major disturbances and generally assumed to be at moderate risk of exposure to runoff. The potential effects of exposure to runoff are likely to be confounded with effects of coral bleaching and other catastrophic events.

A detailed survey of coral communities on 27 inshore reefs in 2003-04 established regional baselines of spatial variability in nearshore reef communities and a basis for measuring future changes in coastal coral reef communities and their responses to water quality. Approximately half of the surveyed reefs are in areas considered to be at moderate-to-high risk to damage from nutrient runoff. These reefs had highly variable levels of coral cover and species mixtures within a few kilometres of each other. A number of high-cover reefs supported both fast and slow growing species, suggesting that these coral communities have persisted for decades. Within a particular region, inshore reefs may be more variable in terms of coral cover and community types than mid-shelf and outer shelf reefs. This suggests that environmental gradients, for example, turbidity and salinity, may be steeper in inshore regions, or that disturbances or conditions for recovery are more localised. At most sites in the northern and central regions of the Reef, the surveys showed reasonable levels of recruitment for the majority of coral genera. This could indicate that inshore reefs in these locations are now in the process of recovering from major disturbances such as bleaching, floods and in some cases, crown-of-thorns starfish outbreaks. However, neither regional patterns in coral cover nor the number of recruits indicated a clear relation to the estimated risk of exposure to runoff; a result requiring further exploration.

Currently available time series measurements of coral recruitment are limited to a few reefs and indicate large spatial and year-to-year variations in recruitment. There is also only limited information about the proportion of recruits surviving to adulthood and the factors influencing this process.

d. Status and trends of intertidal seagrass communities

Seagrasses are a highly productive habitat and valuable nursery ground for many marine species in the Reef. There are nearly 6 000 km^2 of seagrasses in waters shallower than 15 metres, relatively close to the coast, and in locations that can potentially be influenced by adjacent land use practices. Data from a supervised community-based seagrass monitoring programme (Seagrass Watch: 1994-present) has been collected at a number of sites along the Queensland coast. This monitoring indicates that most intertidal seagrass meadows have been relatively stable over the last decade. Seagrass meadows in the Hervey Bay region suffered extensive losses of area and cover in the early 1990s due to storm damage and flooding. These meadows are now in a recovery state. Meadows in some other regions (for example, Whitsunday), however, show net declines.

e. Bioaccumulation of pollutants in estuarine species

The mud crab *Scylla serrata* has been used as a bio-indicator species for trace metal and pesticide accumulation in biota from a limited number of Queensland rivers and estuaries. Elevated trace metal levels were measured in *S. serrata* hepatopancreas tissues collected at an industrialised location (Port Curtis - Gladstone) compared to an agriculture dominated site (Burdekin River). Pesticide analysis of *S. serrata* from Port Curtis, revealed historical contamination by DDTs and dieldrin.

f. The social and economic condition of the Great Barrier Reef

The information reported in this section provides a baseline for understanding the current social and economic condition of the Great Barrier Reef. Although the focus of the Marine Monitoring Programme is on the marine ecosystem, understanding the complex interrelated social-ecological dimensions of the Great Barrier Reef and associated catchments requires reporting on the social environment of the Great Barrier Reef region.

The Great Barrier Reef region is defined as the five statistical divisions of Far North, Northern, Mackay, Fitzroy and Wide-Bay Burnett specified by the Australian Standard Geographical Classification (ASGC) (ABS 2001a):

- *The Cairns Regional Economy* covers the geographical area of the **Far North Statistical Division (FNSD)**, which extends north to include the Torres Strait LGA, and south to include the Cardwell LGA
- *The Townsville Regional Economy* covers the geographical area of the **Northern Statistical Division (NSD)** which extends north to include the Hinchinbrook LGA, and south to include the Dalrymple LGA
- *The Mackay Whitsunday Regional Economy* covers the geographical area of the **Mackay Statistical Division (MSD)** which extends from Bowen Shire in the North to Sarina Shire in the south
- *The Fitzroy Regional Economy* covers the geographical area of the **Fitzroy Statistical Division (FSD)** which extends from Livingstone Shire in the north, south to Bauhinia Shire
- *The Wide Bay Burnett Regional Economy* covers the geographical area of the **Wide Bay Burnett Statistical Division (WBBSD)** which extends north to the Miriam Vale Local Government Area (LGA), west to Eidsvold LGA, south to the Nanango LGA and east to the Harvey Bay LGA (OESR 2005).

a. Population and Population Projection

As at 30 June 2003, the estimated resident population of the Great Barrier Reef Region was 839 138 persons, representing 22.1 percent of Queensland's population (OESR 2005). Based on medium series population projections, the Great Barrier Reef Region estimated resident population is expected to grow to just under one million persons by the year 2026 (OESR 2005). Population growth or change is likely to have a number of effects:

- The social fabric of the GBRCA changes over time through population change and as a result of the growth or decline of industries
- Population growth can be linked to higher employment rates, building investment, and greater gross regional product in the regions of focus
- Future population growth is likely to have an impact in the GBRCA through urbanising landscapes and increased recreational reef use. for example, the number of registered recreational vessels has steadily increased since data was collected for the GBRCA
- Further, increased visitation from both domestic and international visitors is likely to affect the GBRCA, with visitation expanding in all regions.

Figure 25. Local government areas, Great Barrier Reef Catchment.

b. Economic and financial values of the Great Barrier Reef

As measured using the quantitative data (primarily national accounts-based) available to it, Access Economics (2005) concludes that the total (direct plus indirect) economic contribution of tourism, commercial fishing, and cultural and recreational activity to the GBRCA in 2004-05 is as follows:

- For value-added, over $3.5 billion per annum.
  For gross product, (which adds net indirect taxes less subsidies to value-added) over $4.1 billion per annum.
  For employment (full time equivalent basis), about 51,000 persons.

- The corresponding estimates for Queensland are:
  For value-added, over $4.3 billion per annum.
  For gross product, over $4.9 billion per annum
  For employment (full time equivalent basis), about 59 000 persons.

- The corresponding estimates for Australia are:
  For value-added, over $5.1 billion per annum.
  For gross product, over $5.8 billion per annum.
  For employment (full time equivalent basis), about 63 000 persons.

- Tourism dominates these contributions:
  For value-added and gross product, tourism's share is about 86 percent - 87 percent.
  For employment, tourism's share is about 83 percent - 87 percent.

Access Economics' results are presented in more detail in Tables, 6, 7 and 8 below.

Table 6: Direct Plus Indirect Contributions of Selected Activities to the GBRCA, 2004-05.

Total contribution (direct plus indirect)	Total Value Added ($m)	Total GSP, GDP ($m)	Total Employment (FTE 000)
Total tourism within the GBRCA			
Visitors from GBRCA	637	747	9
Visitors from rest of Queensland	349	407	5
Interstate Visitors	941	1 093	12
by GBRCA residents for travel outside GBRCA	76	87	1
International Visitors	1 057	1 244	16
Total Tourism	**3 060**	**3 578**	**43**
Commercial Fishing	104	106	1
Recreational activity (net of tourism)	409	461	7
Total contribution to GBRCA	**3 572**	**4 145**	**51**

Source: Access Economics.

Table 7: Direct Plus Indirect Contributions of Selected Activities to Queensland, 2004-05.

Total contribution (direct plus indirect)	Total Value Added ($m)	Total GSP, GDP ($m)	Total Employment (FTE 000)
Total tourism within the GBRCA			
Visitors from GBRCA	743	854	10
Visitors from rest of Queensland	504	576	6
Interstate Visitors	1 103	1 257	14
by GBRCA residents for travel outside GBRCA	89	100	1
International Visitors	1 282	1 471	18
Total Tourism	**3 720**	**4 257**	**49**
Commercial Fishing	132	135	2
Recreational activity (net of tourism)	477	529	9
Total contribution to GBRCA	**4 329**	**4 920**	**59**

Source: Access Economics.

Table 8: Direct Plus Indirect Contributions of Selected Activities to Australia, 2004-05.

Total contribution (direct plus indirect)	Total Value Added ($m)	Total GSP, GDP ($m)	Total Employment (FTE 000)
Total tourism within the GBRCA			
Visitors from GBRCA	839	958	11
Visitors from rest of Queensland	566	645	6
Interstate Visitors	1 436	1 636	16
by GBRCA residents for travel outside GBRCA	99	111	1
International Visitors	1 550	1 757	20
Total Tourism	**4 490**	**5 107**	**54**
Commercial Fishing	145	149	2
Recreational activity (net of tourism)	548	610	7
Total contribution to GBRCA	**5 183**	**5 866**	**63**

Source: Access Economics.

c. Monitoring Great Barrier Reef recreational use

The recreational use monitoring programme reports recreational use undertaken as a private activity or as part of a commercial tour operation in the Marine park.

Annually there are approximately 6.4 million visits made into the Marine Park for recreational purposes. Of these recreational visits, 4.5 million visits occur by private means and 1.9 million visits occur when people travel with commercial tour operators. A recent survey of 14 524 people from Great Barrier Reef Coastal Communities and Brisbane, Sydney and Melbourne revealed that the most common activities undertaken in the the Marine Park for recreational purposes are:

- Swimming
- SCUBA diving and snorkelling
- Fishing
- Sailing
- Motor boating

As at April 2005 there were 68 565 registered recreation vessels within communities adjacent to the Great Barrier Reef. Recreational vessel registration within these communities has increased by 4 percent since July 1 2004. Visitation to the Great Barrier Reef with commercial operators also increased in the period 2000-2004 (Figure 26).

Cairns and the Whitsundays continue to be the major nodes of tourism activity in the Great Barrier Reef.

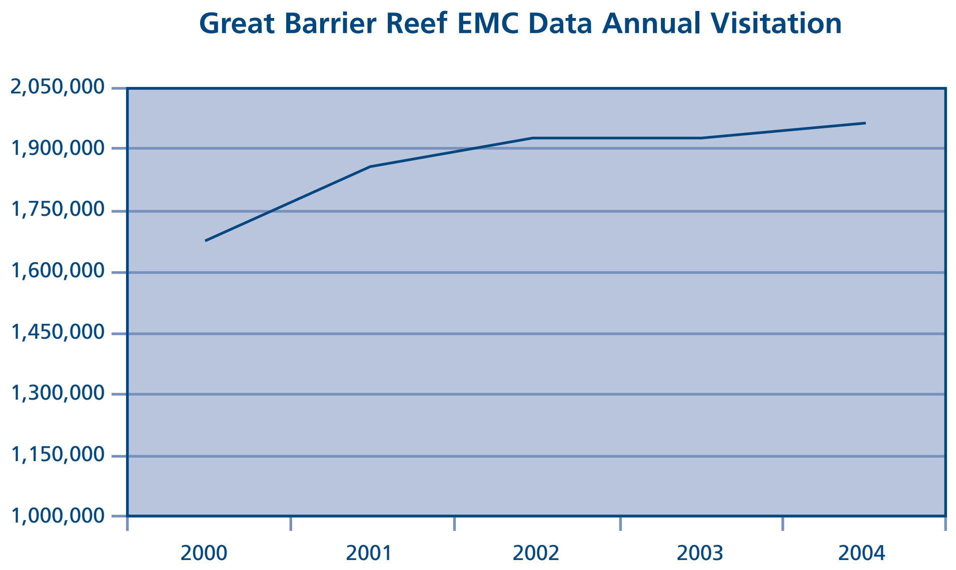

Figure 26. Annual visitation data.

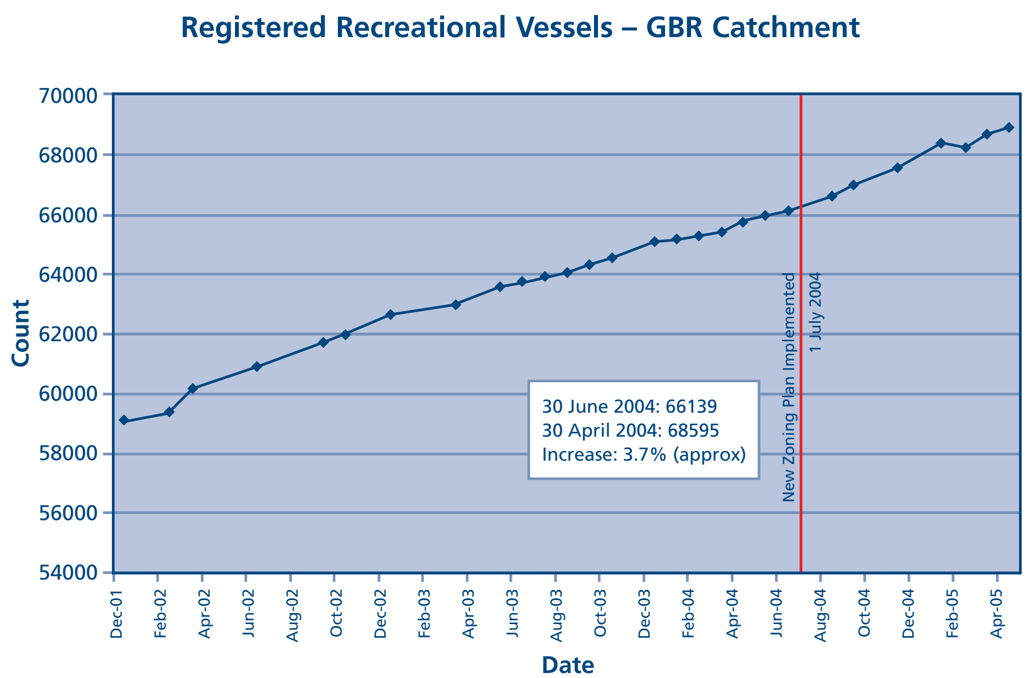

Figure 27. Registered recreational vessels.

Source: Queensland Department of Transport

d. Community and visitor perceptions of and satisfaction with the Great Barrier Reef
Community survey (AEC 2005) revealed the following perceptions of the Great Barrier Reef:

- 78.2 percent of survey respondents believe the Great Barrier Reef is under some degree of threat. The most commonly reported perceived threats to the Great Barrier Reef were: Shipping, Agricultural Activities, Commercial Fishing, Tourism, Urban Living and Recreational Use
- 82 percent of respondents who had visited the Great Barrier Reef reported that they were very satisfied with their experience of the Great Barrier Reef
- 82.2 percent of respondents believe that activities on land have an impact on the Great Barrier Reef
- 47 percent of respondents believe activities at home have an impact on the Great Barrier Reef whilst only 27 percent of respondents believe activities at work have an impact on the Great Barrier Reef
- 51.2 percent of respondents were optimistic about the future of the Great Barrier Reef
- 77 percent of respondents are aware the Marine Park has been rezoned
- 85 percent of respondents believe it is acceptable to increase the level of protection provided by green zones
- 74 percent of respondents believe it is acceptable for some users to give up current practices to increase protection for the Great Barrier Reef.

g. Conclusions

There is now abundant evidence, primarily from locations outside of Australia, that the overall health of coral reef and seagrass ecosystems are affected by the quality of water in which they live. Poor water quality for particular ecosystems or communities is a driver for ecological changes leading to the loss or displacement of dominant or desirable species, reductions in coral or seagrass cover, loss of ecosystem amenity value, and in extreme cases, the destruction of the physical structure of the ecosystem.

Not surprisingly, the best documented cases and clearest relationships between poor water quality and the health of coral reefs or seagrasses involves situations where acute changes were caused by large inputs of sediment or nutrients to relatively small areas (for example, Kaneohe Bay, Hawaii; Chesapeake Bay, Hervey Bay). Fortunately, these extreme situations have not appeared within the Great Barrier Reef World Heritage Area. However, the same processes and pressures that have caused these large changes elsewhere are evident in the Reef and its Catchment. In almost every case, major ecosystem degradation has begun with small, almost imperceptible changes that are essentially indistinguishable from the 'normal' range of environmental variability.

However, there are some situations relating to declining water quality which are now clear in the Reef. A variety of evidence now clearly indicates that exports of sediment and nutrients from the Reef catchment have increased substantially; at least two to four fold over the last 150 years. There is well-documented evidence within the Reef that benthic communities on nearshore coral reefs vary along measured or presumed gradients of water quality or terrestrial influence. Observed changes include variations in the cover, composition and relative abundance of macroalgae, encrusting algae, hard corals and soft corals, the recruitment of young hard corals and the abundance of coral bio-eroders.

The highly variable (episodic, seasonal, inter-annual) monsoonal climate of the Reef region, and the episodic nature of disturbance processes operating within the Reef (cyclones, crown-of-thorns starfish, bleaching) produce high natural levels of variability in data records of river discharge, riverine sediment and nutrient loads, lagoonal water quality, biological community structure and community distributions. Any successful monitoring programme to track progress toward achieving the goals of the Reef Plan needs to take a long-term perspective and be based on the existing reef-scale and long-term water quality and biological monitoring programmes with sufficient duration (5 - 15 years) and sampling density to provide useful baseline and trend/variability data to meet the objectives of the Reef Plan.

While there is a growing body of information on the distribution of key water quality parameters and affected biological communities within the Reef region, and of trends in a number of these parameters and communities over time, there is still very little information on the biological and physical processes by which water quality drives the performance of reef and seagrass communities. There is a considerable need for ongoing, targeted research to determine or clarify the links between water quality and the health of regional ecosystems.

Reporting the social and economic condition of the Great Barrier Reef and its associated catchments for understanding the human inter-relationships with the environment is a complex and ongoing task. The social and economic monitoring component of the marine monitoring programme reports against three indicators at a broad scale:

- Market values of Great Barrier Reef industries and their inputs to regional economies
- Patterns of recreational use of the Great Barrier Reef
- Community and visitor perceptions of and satisfaction with Great Barrier Reef health.

Monitoring to date has found that:
Great Barrier Reef industries contribute $5.86 billion to the Australian economy employing an estimated 63 000 people (full-time equivalent)

There were approximately 6.4 million visits made into the Marine Park for recreational purposes with 4.5 million by private means and 1.9 million of those visits made with commercial tour operators.

Community surveys revealed that 78.2 percent of respondents believed that the Great Barrier Reef is under some degree of threat from (in order of perceived magnitude), shipping, agricultural activities, commercial fishing, tourism, urban living and recreational use. However 52 percent of respondents were optimistic about the future of the Great Barrier Reef.

PART 4: IMPLEMENTATION OF THE MARINE MONITORING PROGRAMME

Considerable progress has been made towards the implementation of the Marine Monitoring Programme since the Reef Protection Plan was released in December 2003.

Specific milestones that have been met as at June 2005 include:

- The GBRMPA called for Expressions of Interest to conduct the Marine Monitoring Programme in September 2004 and subsequent appointment of the Reef CRC Consortium in March 2005 to this task.
- Completion of a statistical analyses of existing time series datasets produced by AIMS (river water quality: 1988-2000, Great Barrier Reef lagoon water quality: 1989-2004, inshore coral reef status: 1994-2004) and QDPI&F (intertidal seagrasses: 1999-2004) to assess the capacity of these levels and types of sampling to detect trends in water quality and community structure over a 10-year time frame (De'ath, 2005). The report includes a number of recommendations regarding sampling to track trends in water quality and coastal communities health. Many of the findings in this review will be utilised to inform a review of the Marine Monitoring Programme in May 2006 by an Expert Advisory Panel.
- The GBRMPA convened the first Expert Advisory Panel meeting in April 2005. Panel members reviewed the draft Terms of Reference and briefings were given by the Consortium's Task Leaders and scientists regarding the proposed structure of the river mouth water quality, inshore marine water quality, biological monitoring and bioaccumulation monitoring sub programmes, and associated data management issues.
- A Project Management Steering Committee with members at the Executive level of the CRC Reef, the GBRMPA and the AIMS was established in March 2005; a Project Committee with members of the CRC Reef, the GBRMPA, AIMS and Task Leaders for each sub programme, was also established at the same time.
- The GBRMPA submitted a Progress Report to meet the NHT contractual obligations in May 2005.
- The Consortium prepared a Benchmark report in May 2005, outlining the condition and trend of each component of the Marine Monitoring Programme (refer to Part 3, this Report).
- The GBRMPA convened the second Expert Advisory Panel meeting in June 2005. Panel members reviewed the CRC Reef Consortium Benchmark Report at this meeting.

Progress on the implementation of each of the sub programmes (as at June 2005) is outlined below.

a. River mouth water quality monitoring

- Turbidity loggers were deployed by AIMS in the Normanby, Barron, Russell, Johnstone, Tully, Burdekin and Fitzroy Rivers in December 2004 to monitor suspended sediment concentrations over the 2004-05 wet season. The instruments are scheduled for recovery in early June 2005.
- QDNRM hydrographers collected water samples from sites in the Burdekin and Barron Rivers during a number of wet season flood events in January and February 2005.
- The Consortium and GBRMPA initiated arrangements with community or other appropriate organisations to sample nutrients, particulate matter and pesticides in the ten priority river mouths. Planning is underway for field trips to identify appropriate sampling sites and train community participants.

b. Marine water quality monitoring

- The development of remote sensing techniques for chlorophyll and turbidity monitoring has progressed. An AIMS-constructed instrument will allow continuous underway measurement of sea-surface ocean colour over kilometre scales for comparison with and validation of ocean colour imagery. Updated versions of data sets from the existing GBRMPA, AIMS and CRC Reef chlorophyll monitoring programme were provided to CSIRO project collaborators to assist in ocean colour validation efforts. These data will assist CSIRO personnel in the ongoing process of improving the performance of ocean colour processing algorithms for Great Barrier Reef conditions.
- The Consortium and GBRMPA initiated arrangements with community and appropriate organisations to become involved in the inshore chlorophyll monitoring programme. Planning is underway for field trips to identify

appropriate sampling sites and train community participants.

- AIMS has commenced investigation of options for the purchase of autonomous environmental loggers (temperature, chlorophyll, turbidity).
- Temperature loggers have been deployed on all selected inshore reefs.
- Arrangements with community, tourism industry or other appropriate organisations to deploy and recover pesticide passive samplers at coastal reef sites have been completed.
- Passive samplers were deployed by the GBRMPA in November 2004 (on going) in the Russell and Mulgrave River mouths to capture wet season flows and have been retrieved and deployed monthly.

c. Marine biological monitoring

- Sites for all coastal reef locations have been established for the coral reef monitoring to be undertaken by AIMS and Sea Research Pty Ltd.
- Juvenile coral demographic and nutrient bio-indicator sampling is being undertaken in 2005-06 on the AIMS Long Term Monitoring Programme field trips.
- Operational planning for the recovery of larval recruitment monitoring in February 2006 has been completed.
- In March and April 2005, QDPI&F continued monitoring at established Seagrass-Watch long-term monitoring sites at locations listed in Table 5. With the exception of Mission Beach, Magnetic Island and Gladstone, monitoring was conducted at at least one site at each location. Sites have been monitored for seagrass cover and species composition. Additional information has also been collected on canopy height, algae cover and epiphyte cover and macrofaunal abundance. An assessment of *Halodule uninervis* reproductive health was also conducted via seedbank monitoring at Townsville, and Yule Point, Whitsundays. Monitoring of within canopy temperatures has also been completed at sites in Cairns, Townsville, Whitsunday's, Shoalwater Bay and Hervey Bay.

d. Bioaccumulation monitoring

- The Queensland Seafood Industry Association (QSIA) was approached for cooperation in providing contact details for Mud Crabbing Delegates as primary contacts for collecting mud crabs in the regions of interest. Crabbers willing to participate in the project have been identified from each region and have agreed to provide 12 – 16 live mud crabs as a commercial transaction.
- In April 2005, crabs were delivered successfully from 2 of the 10 sites (Burdekin and Barron Rivers). These crabs have been processed for analysis under the project procedures. It is expected that crab collections from all 10 sites will be complete by June 2005.

e. Monitoring of Social and Economic Indicators

Reporting Market Values

- Access Economics were commissioned to report on the market value of Great Barrier Reef industries through quantitative estimates of the economic and financial value of activity undertaken within the Great Barrier Reef Marine Park Catchment Area (the GBRCA) for the financial year 2004-05. A final draft report has been received by the GBRMPA and will be edited prior to publication by the GBRMPA.
- The Department of Environment and Heritage commissioned a report on the non-market values of the Great Barrier Reef. This project is due to deliver a report in November 2005.
- The Office of Economic and Statistical Research (OESR) were commissioned to present a social and economic profile of Great Barrier Reef catchment communities to provide a background report to the market values report. The report presents regional demographic information, as well as regional cultural, economic, and social characteristics at the level of Local Government Areas (LGA) for the LGAs that lie within the Great Barrier Reef Catchment and is compared to State and National data and trends where appropriate. A final draft report has been received by the GBRMPA and a subsequent process has been initiated to develop this information into a web-based presentation with expert interpretation of the secondary social and economic data profiling communities in the Great Barrier Reef Catchment.

Patterns of human use of the Great Barrier Reef

- Monitoring Human Use – through the Environmental Management Charge (EMC) data. Permitted tourist operators are required to provide quarterly reports of trip details to the GBRMPA and remit EMC payable for each visitor taken into the Marine Park on their service. Reports from the EMC database provide a spatial record of Marine Park the number of visits made into the Marine Park.
- The AEC Group were commissioned to undertake community telephone surveys to gather feedback from residents of coastal areas of Queensland, and three capital cities to obtain information about their recreational usage of the Great Barrier Reef Marine Park. A final report has been received by the GBRMPA.

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APPENDIX 1. GLOSSARY

Algae a collective term referring to several groups of simple photosynthetic plants, mostly microscopic, lacking roots, stems and leaves; they can be found in a variety of habitats; many species of algae exist as single cells, others form simple filaments or colonies and others exist as more complex structures like the larger seaweeds.

Algal bloom a particularly extensive growth of algae in a body of water; this is usually a result of increased nutrient content.

Ammonia a colourless gas consisting of nitrogen and hydrogen atoms; it is the main substance used by organisms as a source of nitrogen.

Basin an area drained by a given river and its tributaries.

Bedload the sediment that moves by sliding or rolling along the bed of a channel due to the action of the water.

Benthic the bottom layer of a water body.

Benthos those animals and plants living on the bottom of a water body.

Biological magnification the process where the concentration of a material increases in the animals higher in the food chain due to the increasingly larger rates of consumption by the higher organisms.

Biomass the amount of living material existing at a given instant of time in a unit volume or area.

Biota living organisms; all animal and plant life.

Buffer zone established zone of perennial grass or other erosion-resistant vegetation that minimises run-off and erosion.

Catchment the area of land that is, drained by a river and its tributaries; the watershed or dividing line between catchments is physically defined by mountains, crests of hills or the ridge of high ground.

Chlorophyll the green pigment in plants that enables them to use the energy of the sun for photosynthesis.

Contaminant a substance that renders another substance impure by contact or mixture; e.g., the introduction into a water supply of a substance that reduces the usefulness of the water to humans and other organisms.

Diffuse-source pollution contaminants that have originated from an unidentifiable source from various dispersed locations, such as roads, shopping centres and agricultural activity.

Ecosystem a system involving the interactions between the living organisms and their environs.

Epiphyte a plant that grows attached to the stems or leaves of another plant but is not parasitic.

Erosion the wearing away of the land by running water, rainfall, wind, or other geological agents.

Estuary an open drainage depression adjacent to the sea, typically at the mouth of a river, into which the tide ebbs and flows.

Eutrophication the accumulation of excessively high levels of naturally occurring nutrients. Symptoms of eutrophication include the development of algal blooms, which may be toxic, anoxia in bottom waters, high concentrations of metal ions in bottom waters and sediments, fish kills and other undesirable aspects of water quality.

Fertiliser any substance, natural or manufactured, added to the soil to supply essential plant nutrients for plant growth, and thereby either maintaining or increasing the general level of crop yield and pasture productivity.

First flush the initial flow of storm-water run-off that often contains high concentrations of contaminants that have built up during intervening dry periods.

Herbicide a chemical substance used for killing plants, usually weeds.

Hydrograph a graph showing the seasonal variation in the level, velocity or discharge of a body of water.

Hydrology an applied science concerned with the water cycle, which includes precipitation, run-off or infiltration and storage and evaporation.

Land degradation the decline in quality of natural land resources, commonly caused through improper use of the land by humans.

LMAC GBRMPA Local Marine Advisory Committee.

Load the volume or mass of a substance - derived by multiplying the concentration by the flow rate over a specific period of time.

Mean annual flow the average of the annual flow observed in the past; it is the most important parameter of a river in assessing its potential for water resources development; the larger the value, the higher is the potential.

ML megalitre one million litres (approximately the quantity contained in one Olympic- sized swimming pool).

Nitrate (NO3) Nitrate is an inorganic compound composed of one atom of nitrogen (N) and three atoms of oxygen (O); Nitrates are readily soluble in water. The presence of nitrates in the soil is of great importance, since it is from these compounds that plants obtain the nitrogen necessary for their growth.

Nitrogen (N) colourless, tasteless element usually occurring in the gaseous state. It forms approximately 80% of the earth's atmosphere and is essential for all organisms.

Non-point-source pollution a source of pollution that cannot be pinpointed, because it comes from many individual places or a widespread area (for example, urban and agricultural run-off); in a soil conservation context it typically applies to a sediment source that is, spread over a wide area; for example, an area of cropping land could be a non-point source of sediment contributing to the blocking of a road culvert.

Nutrient derived from living matter and including elements such as nitrogen, phosphorus and sulfur; nutrients are essential for plant growth but can adversely effect land and aquatic ecosystems if present at high levels.

Overclearing the removal of trees and shrubs, particularly from steep areas, to an extent that makes the land susceptible to appreciable soil erosion; the presence of permanent tree cover on many steep lands ensures their stability; but removal of the trees increases erosion hazard, due mainly to the slope and the typical shallowness and erodibility of soils on such land, can cause soil salting and may also leave insufficient shade and shelter for livestock; in arid and semi-arid areas the removal of trees and shrubs increases the risk of wind erosion.

Overgrazing continued grazing of pasture or rangeland at a level that permanently and adversely affects its plant components; this leads to a reduced capacity to produce forage, deterioration in pasture or range condition and increased erosion hazard.

Pesticide any chemical or biological agent that kills a plant or animal pest; herbicides, insecticides, fungicides, rodenticides, etc. are all types of pesticides.

Phosphorus (P) nutrient essential for plant growth that can play a key role in stimulating aquatic growth in lakes and streams.

Photosynthesis the process by which plants produce organic matter from inorganic chemicals, using solar energy, with the liberation of oxygen.

Phytoplankton free-floating microscopic plants that live suspended in a body of water.

Physico-chemical indicators measurable physical and chemical parameters of water.

Plankton small animals and plants which float or drift in the water body.

Point-source pollution a source of pollution that can be accurately located.

Pollution (of water) when the level of concentration of a contamination is high enough to impair water quality to a degree that has an adverse effect upon any beneficial use of the water.

RAC GBRMPA Reef Advisory Committee.

Riparian vegetation the vegetation occurring between normal river level and the edge of the floodplain.

Run-off the portion of rainfall or irrigation (e.g., lawn sprinkler) water that flows across the land's surface, does not soak into the ground and eventually runs into a water body; it may pick up and carry a variety of pollutants.

Sediment insoluble material suspended in water consisting mainly of particles derived from rocks, soil and organic materials; a major non-point-source pollutant to which other pollutants may attach.

Sedimentation (siltation) deposition of sediment.

Sediment load the solid material that is transported by water.

Stratification development or formation of layers where different conditions of temperature, light, nutrients, etc. prevail, in a body of water.

Suspended sediment the sediment that is being transported by water or air while held in suspension.

Toxic being harmful, destructive or deadly to organisms.

Turbidity the cloudy or muddy appearance is mainly indicative of the amount of solids suspended in the water and, to a lesser extent, the colour of the water.

APPENDIX 2. REEF PLAN EXPERT ADVISORY PANEL MEMBERSHIP AND TERMS OF REFERENCE

Membership

Member	Organisation
Professor Barry Hart (Chair)	Monash University
Dr Graeme Batley	CSIRO
Dr David Fox	Melbourne University
Dr Russ Babcock	CSIRO
Professor Bill Dennison	University of Maryland
Dr Eva Abal	University of Queensland
Ms Nicola Udy	Queensland EPA
Dr Caroline Gaus	University of Queensland
Dr Jenny Stauber	CSIRO
Mr Jon Brodie	James Cook University
Mr George Lucaks	James Cook University
Mr Luke Smith	AIMS
Dr Heather Hunter	Queensland NRM
Dr Andrew Steven	Queensland EPA
Ms Rachel Eberhard	Queensland Regional NRM Boards

Terms of Reference

1. Values of the Expert Advisory Panel
To provide independent, credible and unbiased advice on the Marine Monitoring Programme consistent with the objectives stated in the Reef Plan.

2. Role of the Expert Advisory Panel
Overall, the Panel is required to provide advice to GBRMPA on technical, scientific and communication aspects related to the monitoring and assessment tasks associated with the marine monitoring sub programmes and the overall Marine Monitoring Programme, and to contribute to the overall review of the programme beyond the current contract period. Specifically, the role of the EAP is to:

1. Provide strategic advice on the scientific rigour of the Marine Monitoring Programme including QA/QC protocols
2. To review annual reports (and where necessary, progress reports) produced by the Consortium for each monitoring sub programme
3. To provide advice on the possible inclusion of new and innovative monitoring and assessment practices in monitoring sub programmes
4. To provide advice on knowledge gaps associated with each monitoring sub programme and the overall programme.

3. Tasks and Strategies to address the ToRs

- At appropriate times discussion papers will be prepared and discussed by the EAP, with any recommendations fed back to GBRMPA. In the next 12 months, the specific tasks for the EAP will be to consider:

- June 2005: The May 2005 data synthesis report provided by the Consortium as a benchmark of the status of the Great Barrier Reef reported for each sub programme
- July/August 2005: The QA/QC protocols established for each sub-programme
- August 2005: The 2004-2005 Monitoring Progress Report
- May 2006: The 2004-2006 Monitoring Progress Report.
- May 2006: Possible aspects of the current Marine Monitoring Programme that might be modified in the second phase, that is from August 2006, including consideration of:
    - Significant knowledge gaps and how these might be addressed.
    - Actions that might be needed to be put in place now to ensure that the monitoring programme continues to be effective into the future.
    - Potential new and innovative monitoring and assessment practices.

Review of the elements of the sub programmes and overall programme which may include consideration of the following:

- Conceptual overview – is this provided; are the components and the linkages clearly identified
- Objectives - are these well defined
- Outputs and outcomes - are these clearly defined
- Monitoring plan – is it sensible and achievable with the allocated resources and time
- Scientific credibility – are the approach, methods and techniques used appropriate and interpretation consistent with current scientific knowledge
- Data analysis – are the statistical (or other) methods to analyse the collected data clearly identified and are they appropriate. Need to ensure that consistent methodologies adopted with respect to load estimation
- Modelling - how does the data inform decision support system frameworks
- Synthesis –what on-going activities will ensure best possible integration (for example, regular workshops/forums to come together and discuss results)
- Integration – is it clear how the information from the sub-programmes (and from other related monitoring programmes) will be linked to ensure the most effective integration of the relevant information is achieved
- Communications – how can the link between the catchment and the reef be best communicated based on the results from the Marine Monitoring Programme.

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