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Water Quality

our great barrier reef
let's keep it great

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Water Quality

Contents

Summary

- The Great Barrier Reef region is a focus for agricultural production, tourism, shipping, and expanding urban centres that present a risk to the Reef from pollution.
- Although the region is relatively sparsely populated, the land has been extensively modified during the last 200 years of European settlement. Run-off from activities such as cattle grazing, vegetation clearance and intensive cropping, and from urban development, are the main human influences on water quality in the Great Barrier Reef.
- Raised concentrations of sediment and nutrients have long been regarded as the principal water quality threats to the Great Barrier Reef. The threat from other pollutants such as persistent pesticides has been more recently recognised. The major anthropogenic source of excess nutrients, sediments and pesticides on the Great Barrier Reef is agriculture.
- Urban waste and stormwater discharges, and aquaculture, are locally important. These threats are compounded by high rainfall and erosion rates in the wet tropics region of the North Queensland coast.
- The potential impacts of pollution on the Great Barrier Reef range from reduced growth and reproduction in reef animals and plants through to major shifts in the community structure and functioning of coral reef and seagrass ecosystems. Coastal and near shore coral reefs and seagrass communities adjacent to human settlement are most at risk from pollutants contained in run-off from the mainland. Declining ecosystem health in estuarine and inshore areas will affect the biodiversity and other values of the Great Barrier Reef.
- Governments agree that there is an overwhelming case for halting and reversing the decline in water quality entering the Great Barrier Reef. This view is supported by expert opinion (see *A report on the Study of Land-Sourced Pollutants and Their Impacts on Water Quality in and adjacent to the Great Barrier Reef*).
- The future health of the inshore areas of the Great Barrier Reef relies on complex institutional and jurisdiction arrangements. The strategies and actions set out in the *Reef Water Quality Protection Plan* are the first steps in addressing the decline in water quality and protecting industries that rely on the long term health of the Great Barrier Reef.
- Land-based activities, particularly agriculture, grazing and urban development, pose significant threats to water quality on the Great Barrier Reef. Management of water quality requires an integrated approach to land and coastal use and management from catchments to the reef and integration of action between all levels of government and industry.
- Excess nutrient run-off from adjacent catchments has been identified as the major water quality issue facing the Great Barrier Reef. Implementation of integrated catchment management together with better land management methods and industry codes of practice will result in reduction of nutrient and sediment inputs to the coastal zone.
- Wetlands and riparian areas play an important role in the management of water quality. Recognition of wetlands as valuable natural resources have prompted renewed action to provide for their protection.
- Coastal urban population growth and large individual developments can increase human pressure on the Great Barrier Reef. Discharge of sewage and other effluent directly into the Great Barrier Reef Marine Park is regulated, and coastal communities are increasingly recycling rather than discharging treated effluent.
- The GBRMPA participates in State and local government impact assessment processes for proposed developments adjacent to the Great Barrier Reef Marine Park. It is also

working with State and local governments in regional planning processes to promote complementary land use and management of the Great Barrier Reef Marine Park.

- In conclusion, there is a rising load of nutrients and sediment entering the Great Barrier Reef system. It is in the nature of nutrient runoff that it changes once it reaches the sea, so it is hard to measure directly. Changes to the ecosystem are being observed. Scientific evidence so far suggests that this increasing load is already having an impact on the recovery capacity of nearshore reefs. It is important to reduce the load on the system as soon as possible, and this is the principal goal of the *Reef Water Quality Protection Plan*.

Introduction

The scientific consensus on water quality and the Great Barrier Reef

The relationship between land-use practices and adverse impacts on the Reef was reviewed by an independent panel of experts in 2002 as part of the Reef Water Quality Protection Plan. 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*, the Panel (2003) found that:

- There are clear indications that land use practices have led to major changes in the Reef catchments, most importantly accelerated erosion and greatly increased delivery of sediment and nutrients above 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 (i.e. up to 20 kilometres from shore) have been disturbed, remain in a disturbed state and show characteristics of degraded reef systems;
- Impacts on offshore areas of the Reef are not well understood, but the health of offshore regions is linked to that of inshore areas, estuaries and rivers. Overseas experience shows that by the time widespread effects are obvious, the system would be almost irreparably damaged; and
- These findings confirm that in the best case, there is a serious risk to the long-term future of the inshore Reef area and that there is potential for damage to other inter-related parts of the Reef system. It is also clear that urgent action is necessary to avoid further damage and to allow affected areas to recover.

The waters of the Great Barrier Reef

The Great Barrier Reef separates the waters of the Great Barrier Reef lagoon from the adjacent Coral Sea (Furnas and Mitchell 1997). Oceanic water is freely exchanged between the Coral Sea and outer barrier reef. Coastal runoff and nearshore processes are the main factors influencing the water quality of the inshore lagoon. The movement of water through the Reef is affected by the East Australian Current (Church 1987), shelf waves (Wolanski and Bennett 1983), tidal currents (Church *et al.* 1985) and wind (Wolanski and Pickard 1985). Wind and mixing in the reef matrix is sufficient to keep the water column well mixed vertically (Furnas and Mitchell 1997). However, significant but short-lived stratification of the water column occurs due to upwelling along the continental shelf-break and through the movement of flood plumes. South of the Daintree River (16°S), south-east trade winds tend to force surface and coastal waters northwards in opposition to the southward flow of water driven by the East Australian Current (Burrage *et al.* 1997). As a result, waters in the outer portion of the Great Barrier Reef lagoon and the outer shelf reef matrix are separated from the coastal zone by a dynamic front in the Great Barrier Reef lagoon (King 1995). This front also traps terrestrial material within 10-15 km of the coast, forming a nearshore wedge of terrigenous sediments (Belperio 1983; Johnson 1996; Larcombe *et al.* 1995). Only during rare periods of low wind speed or northerly winds, do river flood plumes spread across the Great Barrier Reef shelf and directly impact the reefs of the mid-shelf and outer shelf (Devlin *et al.* 2001).

Factors that affect Water Quality

Processes that affect water quality in the Great Barrier Reef include rainfall, terrestrial run-off, Coral Sea upwelling, Coral Sea surface water exchange, nitrogen fixation and internal recycling. Many of the 'new' nutrients entering the system come from terrestrial runoff. For example, in the central Great Barrier Reef, 40% of external nitrogen and 50% of external phosphorus come from land-based sources (Furnas *et al*. 1995). Inputs of catchment-sourced nutrients have risen by a factor of four since 1850 (Moss *et al.* 1993; Rayment and Neil 1997). Considering that inputs from the other sources of nitrogen and phosphorus have not changed over time, this four fold increase in inputs from land-based sourced has resulted in a 30% rise in the total nitrogen and phosphorus loads of the central Great Barrier Reef since 1850. Because nutrients may be retained in the inshore regions of the Great Barrier Reef, nutrient input loads to these inshore regions (a small fraction of the area and volume of the Great Barrier Reef lagoon), have risen by much greater than 30% following catchment development.

The primary source of pesticide residues in the Great Barrier Reef is also the adjacent catchment (Haynes and Johnson 2000) with only minor amounts of some volatile compounds possibly originating in other areas via transport through the air (Kurtz and Atlas 1990). Pollution from shipping is generally low. Small volumes of sewage are discharged, operational oil-spills occur and anti-fouling compounds are released into the water but, in general, pollution from shipping is relatively minor. However, there is a risk that exotic species and disease organisms, such as toxic dinoflagellates, may be introduced to the Great Barrier Reef through the release of ballast water or by hull fouling. The primary risk from shipping as a source of pollution is the chance of a major oil-spill or shipping accident releasing toxic cargo – that is, an acute rather than chronic threat.

Rivers and water flows

River flows in all catchments adjacent to the Great Barrier Reef are seasonal and highly variable between years. River water entering the Reef normally flows northward and is held against the coast by factors such as wind and the physical structure of the coast. Direct effects of sediment and water from river run-off on Reef ecosystems are thus largely concentrated near the coast. Sediment mapping and coring studies in river estuaries on the continental shelf indicate that most of the sediment transported by river systems is deposited within 10 kms of the coast. North-facing embayments trap large amounts of sediment and these sites reveal changes consistent with historical land-use patterns in the adjoining catchments. Heavy metals such as mercury from historic gold mining activity and modern fungicides containing mercury (used in sugar cane cultivation) can be detected. Another heavy metal, Cadmium, an impurity in super phosphate fertiliser, has also been detected (Walker and Brunskill, 1997). Only small volumes of terrestrial sediments appear to reach the outer-shelf reefs, primarily during major cyclonic floods when river plumes can cover extensive areas of the shelf. Mid-shelf and outer-shelf reefs contain very low proportions of sediments from the land.

Floods

Discharges from rivers in both wet- and dry-tropics river systems are dominated by large flood events from tropical cyclones and monsoonal rainfall (Mitchell *et al.* 1997; Mitchell and Furnas 1997). The largest sediment and nutrient inputs to the Great Barrier Reef originate from the large dry catchments, due to their larger average water flows and extensive drainage areas (Moss *et al.* 1993) (see Figure 1). While the large 'dry' catchments of the Burdekin and Fitzroy Rivers have the greatest average flows, significant flood events only occur irregularly, typically at intervals of between 1 to 10 years. River systems in the wet tropics by contrast typically flood several times a year. The Australian Water Resources Council (1987) lists 46 catchments as draining into the Great Barrier Reef. The smallest is 115km^2 in area (Whitsunday Island) and the largest is 143,000km^2 (Fitzroy River). The specific discharge is highest on average in small catchments, a well-known hydrologic phenomenon in which the run-off ratio (run-off/precipitation) is greatest in small catchments (Wasson 1997).

Flow variability is important for several reasons:

- **Geomorphologically**, variable flows maintain the complexity of in-stream environments. In turn, river channel complexity influences the diversity of habitats available for various aquatic organisms and certain ecological processes.
- **Ecologically**, flow variability underpins the rates of ecosystem processes and the transport of organisms, nutrients, organic carbon, and other materials within rivers and on flood plains (Thoms and Sheldon 2000).
- Alteration of river discharges can ultimately impact on estuarine and nearshore seawater **salinity** regimes.
- Platten (1997) examined correlations between fishery catch rates on coral reefs offshore from the Fitzroy River and flow volumes emanating from that river. He found a significant correlation between **catch rates and flood events**, suggesting residual benefits from flood events such as increased reproductive success and recruitment to adult population in fish stocks.

Figure 1. Major catchments of the Great Barrier Reef World Heritage Area

Water quality issues

Overview

Water quality in the Great Barrier Reef Marine Park (GBRMP) is principally affected by land-based activities in the adjacent catchments, including vegetation modification, grazing, agriculture, urban development, industrial development and aquaculture.

Water quality in the Great Barrier Reef is principally affected by land-based activities in the adjacent catchments.

Queensland is a highly decentralised state with a pleasant climate conducive to coastal settlement. There are 21 local governments with boundaries contiguous with the Great Barrier Reef Marine Park and twice this number lie within the catchment area. Several coastal local governments adjacent to the World Heritage Area are among the fastest growing population centres in Queensland and encompass all but two of the state's major ports.

Beef cattle grazing on the large, dry catchments adjacent to the Great Barrier Reef Marine Park (in particular the Burdekin and Fitzroy) have involved extensive land clearing and over-grazing during drought conditions. Widespread soil erosion occurred, and associated nutrients have drained into the Great Barrier Reef. Cropping, particularly sugarcane, involves intensive fertiliser use and has created substantial soil erosion. As a result, large quantities of nutrients and sediment have been discharged into the Great Barrier Reef. Pesticide residues from cotton and sugarcane cultivation may pose a threat in some inshore waters.

Increasing settlement along the North Queensland coast also threatens water quality. Extensive loss of coastal freshwater wetlands due to urban and agricultural development has affected their ability to filter catchment run-off in the coastal zone. Discharge of sewage effluent and storm water is a localised problem in some communities.

Most marine tourism infrastructure, ports and harbours, and industrial development are located in the coastal zone. Given the potential for conflict between many of the competing activities on the coast, land use must be integrated into planning and management of the Great Barrier Reef Marine Park.

The management of the land-based impacts on the GBRMP is difficult as the problem activities lie beyond the jurisdiction of the Great Barrier Reef Marine Park Authority (GBRMPA). The *25 Year Strategic Plan for the Great Barrier Reef World Heritage Area* identified integrated land and coastal development management as an important process in minimising pollutant input from the land to the sea.

Policies of the Great Barrier Reef Marine Park Authority call for tertiary treatment of sewage, cooperative arrangements between the GBRMPA and Queensland Government departments to reduce pollutant inputs, and case by case management of activities such as dredging and spoil disposal and the discharge of aquaculture wastewaters. Protection of water quality also relies on enforcement of legislation such as that regulating dumping from ships.

Nutrients

Nutrient supply to the Great Barrier Reef is affected by a wide variety of inputs, including:

- river discharges (Mitchell *et al.* 1997);
- urban stormwater and wastewater runoff (Brodie 1994; Mitchell and Furnas 1997);
- atmospheric inputs following rainfall events (Furnas *et al.* 1995);
- planktonic and microphytobenthic nitrogen fixation (Furnas and Brodie 1996); and
- from deeper ocean supply following Coral Sea up-welling (Furnas and Mitchell 1986).

The two principal nutrients, nitrogen and phosphorus, exist in several forms in marine waters. Nitrogen in the water column includes inorganic nitrogen species (NH_4, NO_2 and NO_3), dissolved organic nitrogen (DON) and particulate nitrogen. Similarly, phosphorus exists as dissolved inorganic and organic phosphorus (PO_4 and DOP) and particulate phosphorus. Primary production on the Great Barrier Reef is partially controlled by the availability of dissolved inorganic nutrients (nitrogen and phosphorus), which are taken up directly by phytoplankton communities and converted to particulate organic matter. Coral communities and their symbiotic zooxanthellae also absorb dissolved nutrients directly from the water column. Under non-flood conditions, the amount of total dissolved inorganic nitrogen stocks (DIN) is only sufficient for the phytoplankton biomass to double (Furnas and Mitchell 1997). In contrast, sufficient phosphorus and silicon are usually available for phytoplankton biomass to double many times.

Transport of nutrients in rivers

Studies of North Queensland rivers have described the movement and activity of particulate and dissolved nutrients in river water flowing into the Great Barrier Reef lagoon (Mitchell *et al*. 1991; Mitchell and Furnas 1994: Furnas *et al*. 1995). The first significant rainfall of the season generally produces seasonal peak concentrations of dissolved inorganic species. The oxidised nutrients built up in the catchment during the dry season can be flushed downstream during these events. Nutrient concentrations in first flush river water can exceed 70µM for NO_3 and 1µM for PO_4 (Mitchell *et al*. 1996). Consequently, dissolved inorganic nitrogen (DIN) declines rapidly over time as river water moves downstream, though relatively high concentrations of inorganic nutrients remain in river waters in the initial mixing with inshore Great Barrier Reef lagoon waters. Concentrations of inorganic nutrients decline progressively during the wet season. Concentrations of dissolved organic N and P remain low and relatively constant through the year. Dissolved organic nitrogen (DON) may decline with increasing discharge, suggesting, as might be expected, that the relatively constant input from the watershed is diluted during major flood events. The concentrations of particulate nitrogen (PN) and particulate phosphate (PP) vary directly with river flow and typically peak during major seasonal flood events, reflecting the transport of organic matter and soil particles through the watershed (Mitchell and Furnas 1997).

Concentrations of DIN vary by between 3 and 50 times in rivers draining to the Reef, depending on whether the catchment is highly or lightly developed (Figure 2). As might be anticipated, concentrations of particulate and dissolved nutrients in flood flows are often higher from catchments with substantial agriculture and urban development when compared to relatively pristine catchments (Eyre and Davies 1996; Mitchell and Furnas 1997). For example, the Jardine River (a relatively un-impacted catchment) has DIN concentrations of 4 µM compared with the Johnstone River (in a relatively developed catchment) that has DIN concentrations of 40-60 µM during high flow conditions. Similarly, the upper Tully

River catchment, with a largely undisturbed rainforest catchment, has maximum DIN concentrations of 1µM (Faithful and Brodie 1990). However, the lower Tully River catchment, dominated by sugarcane, horticulture, grazing and urban land uses, has DIN concentrations of 40 µM (Mitchell and Furnas 1997). Analysis from a long-term sampling program in the Tully River has demonstrated an increasing trend in nitrate and particulate nitrogen concentrations over a 13-year period (Mitchell *et al*. 2000). These trends have occurred at the same time as a substantial expansion of intensive agricultural activity within the Tully area and a large increase in fertiliser use.

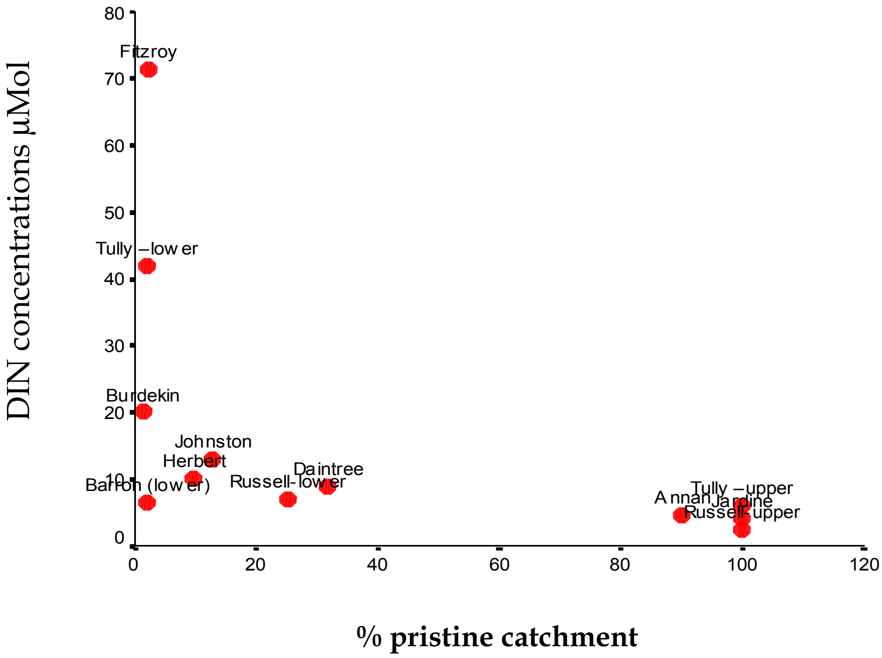


Figure 2. Relationship between DIN (dissolved inorganic nitrogen (nitrate + ammonia)) flood flow concentrations and percentage area of developed catchment within the Great Barrier Reef catchment (Wachenfeld *et al*. 1998)

Nutrient resuspension
Resuspension of nearshore sediments and their associated nutrients is also a major source of nutrient recycling during strong wind events (Walker and O'Donnell 1981; Gagan *et al.* 1987). In the inshore areas of the Great Barrier Reef, riverine discharge is the single biggest source of nutrients (Furnas *et al.* 1997). The bulk of this nutrient discharge to the inshore areas of the Great Barrier Reef occurs during tropical monsoon flood flows.

The fate of nutrients in the Great Barrier Reef
Dissolved nutrients have a relatively short life span in reef waters as they are actively acquired by phytoplankton. Chlorophyll concentrations act as a sensitive indicator of phytoplankton biomass and hence, the nutrient status of sampled water masses (Bell and Elmetri 1995; Brodie *et al.* 1996). Forty-eight stations situated along nine inshore-offshore transects are currently sampled monthly in a Great Barrier Reef wide water quality monitoring program (Haynes *et al.* 1998). Data collected has confirmed that chlorophyll *a* concentrations (and therefore nutrient concentrations) recorded from nearshore waters are significantly higher and more variable than samples collected further from the coast (Figure 3). Central and southern regions of the Reef have higher average inshore chlorophyll *a* concentrations than the northern region. The northern catchment, north of Cooktown, is essentially undisturbed, with limited cropping, and grazing characterised by low stocking

rates. In contrast, the Wet and Dry Tropics catchments of the central and southern parts of the region (Burdekin-Haughton and Fitzroy River catchments respectively) are characterised by intensive cropping in the lower catchments and high cattle stocking rates in inland areas. Fertiliser use in most catchments has increased significantly in recent decades (Pulsford 1996), and this has been linked strongly to increased nutrient concentrations in the aquatic environment (Neil 1994). It is supposed that increased fertiliser use in the central and southern catchments may be a principal cause for the higher chlorophyll *a* concentrations in lagoon waters adjacent to these catchments. Further monitoring is required to clarify the long-term trends in nutrient status (Figure 4) (Brodie *et al*. 1994; Steven *et al*. 1998; Devlin *et al*. 2001b).

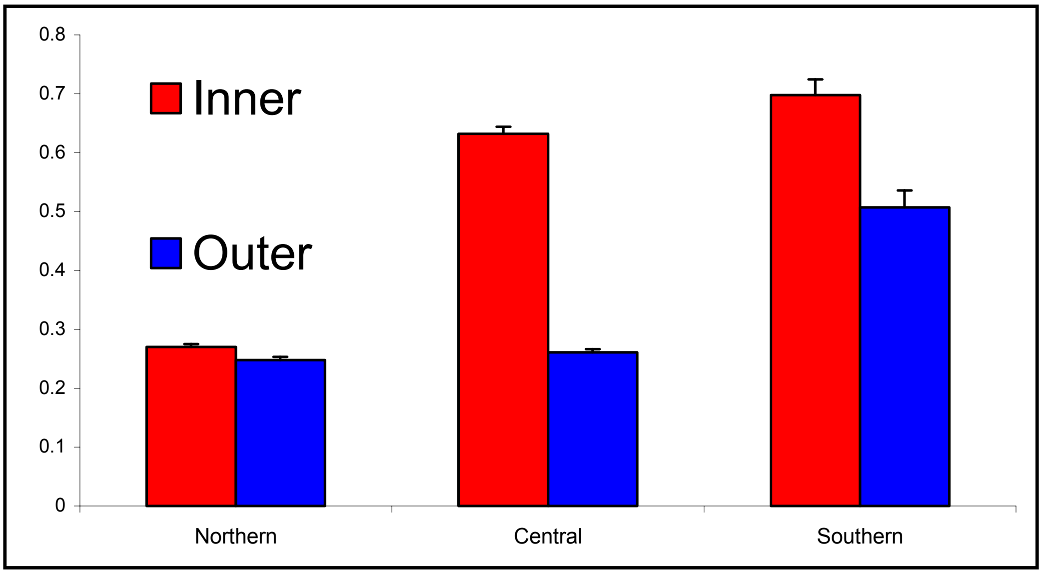
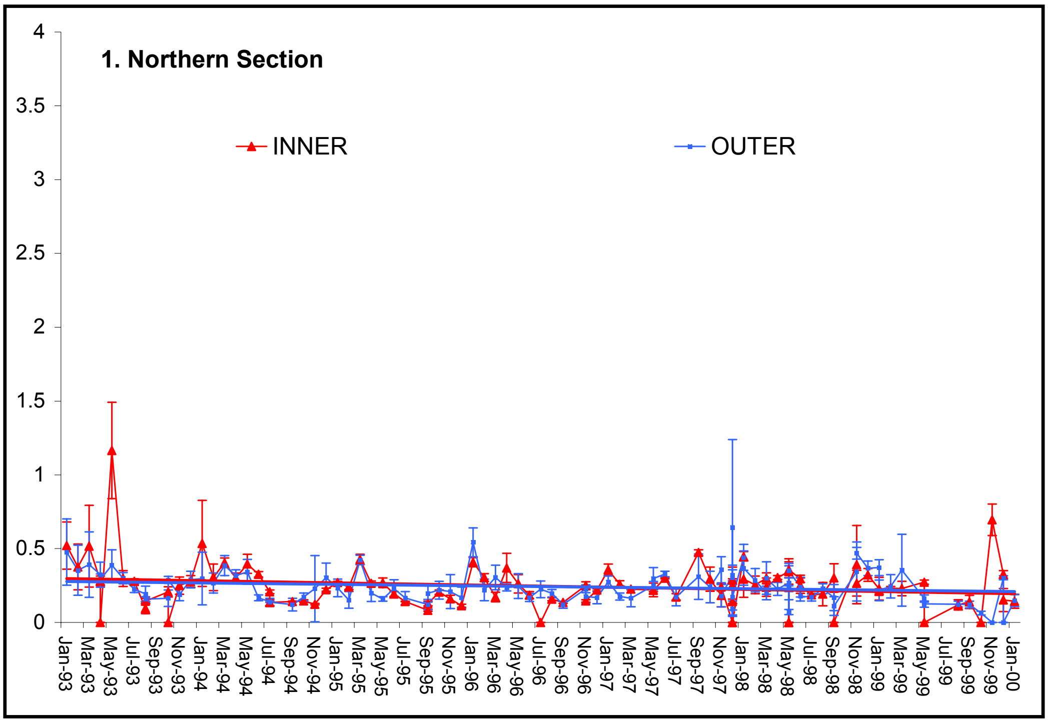


Figure 3. Mean (SEM) chlorophyll *a* concentrations, Great Barrier Reef, 1991-2000 (Devlin *et al*. 2001b).



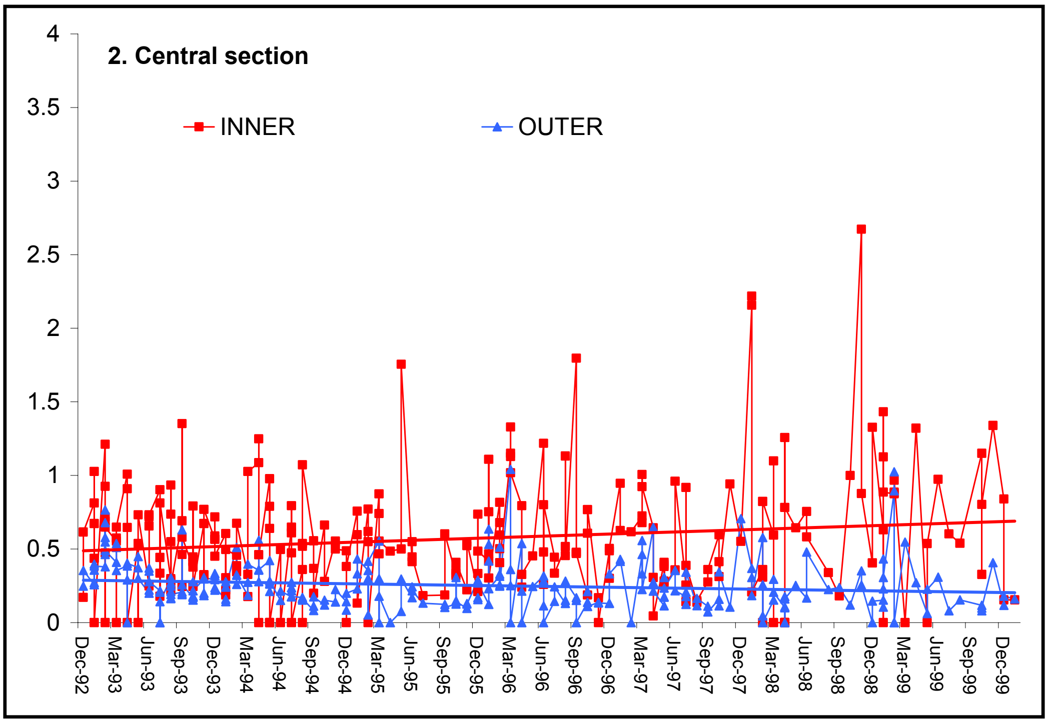


Figure 4. Mean chlorophyll concentrations over time for the northern (1) and central (2) Great Barrier Reef, 1993-1999 (Devlin *et al*. 2001b).

Sediment and turbidity

Estimates of total discharges of sediment from rivers into the Great Barrier Reef have been derived from models relating erosion and regional land use patterns (Moss *et al*. 1993; Rayment and Neil 1997). The influence of the large "dry" catchments where cattle grazing is the dominant land use is evident in these models. Overall, 66% of the estimated nutrient and sediment flux is estimated to come from grazing lands, with 8% from cropping lands and

26% from 'pristine' areas (Neil and Yu 1996). The flux of sediment is estimated to be 3 to 5 times higher than that prior to European settlement (Moss *et al*. 1993; Rayment and Neil 1997).

Increased sediment supply from land use changes and soil erosion results in greater loads of fine sediment moving out into the lagoon areas (Pulsford 1996). However, sediment movement studies (Woolfe *et al.* 1998) suggest that inshore regions of the Great Barrier Reef typically have high sediment loads that have accumulated over thousands of years as sediment from river water falls out of the water column and is trapped in north-facing bays. Consequently, the Great Barrier Reef coast receives relatively little modern terrigenous sediment. However, the combination of both eutrophic conditions and turbid water may have adverse impacts on inshore coral reefs (Fabricius and Wolanski 2000).

Pesticides

Agriculture is the principal user of pesticides on the Great Barrier Reef catchment, with minor use for urban termite control, by local government in roadside weed control, and public health mosquito control. The types of pesticides in present use in the sugar industry include the insecticide chlorpyriphos and the herbicides atrazine, diuron, 2,4-D, glyphosate and ametryn. The organochlorine pesticides aldrin, lindane, DDT, dieldrin and heptachlor were commonly used historically in the cultivation of sugarcane and other crops, but use discontinued many years ago. The organochlorine endosulfan is still widely used in the cotton industry.

Pesticide residues are commonly detected in stream waters, sediment and biota after rainfall events and it is expected that some of these residues will be transported by rivers to the Great Barrier Reef. Significant levels of endosulfan, diuron and atrazine have been found in the Fitzroy River and low levels of diuron, 2,4-D, atrazine and 2,4,5-T in the Johnstone River. In recent monitoring work in the Pioneer River, atrazine and diuron have been found to be significant pollutants of a local river and reservior. Dioxins (a particularly toxic group of organochlorine compounds) have a variety of sources. The source of dioxins found recently in the Great Barrier Reef environment is currently being investigated.

Heavy metals

Mining, metal refining, manufacturing, agriculture and other industrial processes have the potential to release increased levels of toxic heavy metals (primarily lead, zinc, copper, cadmium, mercury, nickel, chromium, arsenic and selenium) into the Great Barrier Reef. There is little evidence of elevated heavy metal levels from present-day mining in rivers or the on Great Barrier Reef. Elevated copper levels, present in Fly River from waste from the Ok Tedi gold and copper mine in Papua New Guinea have not been detected in water, biota or sediments of the northern Great Barrier Reef. Evidence for elevated metal levels from past mining activity has been found in buried sediment off the Burdekin River. Significantly elevated mercury levels (up to 20 μg/kg) were found in sediment cores and these have been linked to the use of mercury in gold recovery during the heyday of gold mining in Charters Towers (1870-1890).

Acid sulphate soil run-off

Acid sulphate soils are present along the entire Great Barrier Reef coast. While some well-known areas, such as east of Trinity Inlet, are recognised as a problem, few major instances of acid sulphate run-off, subsequent fish kills or 'red spot' disease in fish, have been documented. Recent development of low-lying coastal lands for sugarcane cultivation (e.g.

the Tully-Murray floodplain), tourism development (e.g. Point Hinchinbrook near Cardwell or Earl Hill near Cairns) and ponded pasture for beef cattle production (e.g. coastal areas north of Rockhampton), have raised concerns of acid sulphate soil problems. Little data are available on existing problems but increasing incidences of 'red spot' disease are being reported.

Litter

Stormwater discharges, particularly from urban areas, carry litter to the Great Barrier Reef. Surveys of litter on Great Barrier Reef islands and sand cays have shown that while much of the material comes from ships, a significant proportion is likely to come from local land-based sources. Aside from aesthetic concerns litter, can entangle marine animals and poses a significant risk to birds, turtles and cetaceans that may ingest litter, especially plastic bags which may be mistaken for prey.

Pressures

Changing land use

Although population growth and urban expansion in Queensland has been rapid, the northern Queensland coast still remains relatively sparsely populated (Anon 1999b). Only 700,000 of the State's 2.9 million residents live in the coastal areas adjacent to the Great Barrier Reef World Heritage Area. Despite this low population pressure, extensive land modification (land clearing) has occurred over the last 200 years since European settlement (Anon 1993). Today, 80% of the land area of catchments adjacent to the Great Barrier Reef support some form of agricultural production (Gilbert 2001). To place Queensland land-use and vegetation clearing activities into perspective, more than 50% of the State's original 117 million hectares of woody vegetation has been cleared primarily for agricultural purposes since European settlement (Anon 1999b). Consequently, run-off resulting from land-based agricultural activities (eg. cattle grazing, vegetation clearance and intensive cropping) and urban development is the primary anthropogenic influence on water quality in the Great Barrier Reef. (Bell 1991; Moss *et al.* 1993; Anon 1993; Brodie 1997).

Sugarcane cropping, Great Barrier Reef catchment.

Grazing of cattle for beef production is the largest single land use on the Great Barrier Reef catchment, with cropping (mainly of sugarcane) being a significant agricultural industry in coastal areas between Bundaberg and Port Douglas. Other significant catchment land uses include mining of coal and various metals.

Cattle grazing

Approximately 4,500,000 beef cattle graze in Great Barrier Reef catchments, with highest stock numbers in the Fitzroy and Burdekin catchments. Beef grazing on these large, dry catchments adjacent to the Great Barrier Reef Marine Park has resulted in extensive tree clearance and over-grazing, especially during drought conditions. This has resulted in widespread soil erosion (Anon 1993). The majority of the Great Barrier Reef catchment is used for rangeland beef grazing. This development has involved wide-scale clearance of woodland vegetation, particularly Brigalow, for conversion to pasture (Gilbert 2001). The principal consequence for the Great Barrier Reef from the introduction of beef grazing on catchment lands stems from increased soil erosion (Ciesiolka 1987). Soil erosion increases arise from woodland removal; overgrazing, (especially in drought conditions, where vegetation cover falls below 60%); and streambank erosion when cattle have direct access to streams (Finlayson and Brigza 1993).

Estimates of the increase in soil erosion from natural conditions to modern conditions (Ciesiolka 1987; Lawrence and Thorburn 1989; Rayment and Neil 1997) range from:

- 0.9 tonnes per hectare per year on catchments with minor gully erosion;
- 1.6 tonnes with one active gully; and
- 27-30 tonnes with severe gully erosion.

Intensive agriculture

The area under sugarcane cultivation in Great Barrier Reef catchments has increased steadily over the last 100 years with a total of 400,000 hectares at present (Figure 5). Cultivation areas are located near the coast in many of the lowland areas of catchments. Many environmental impacts have not been accurately quantified, but in the Herbert River catchment, clearing for sugarcane cultivation has significantly decreased the area of freshwater wetlands. Fertiliser use is closely linked to sugarcane cultivation and with continuously expanding cultivation fertiliser use has risen rapidly since 1950 (Figure 6). The use of pesticides (herbicides, insecticides and fungicides) is also significant in areas of intensive crop cultivation (Hamilton and Haydon 1996).

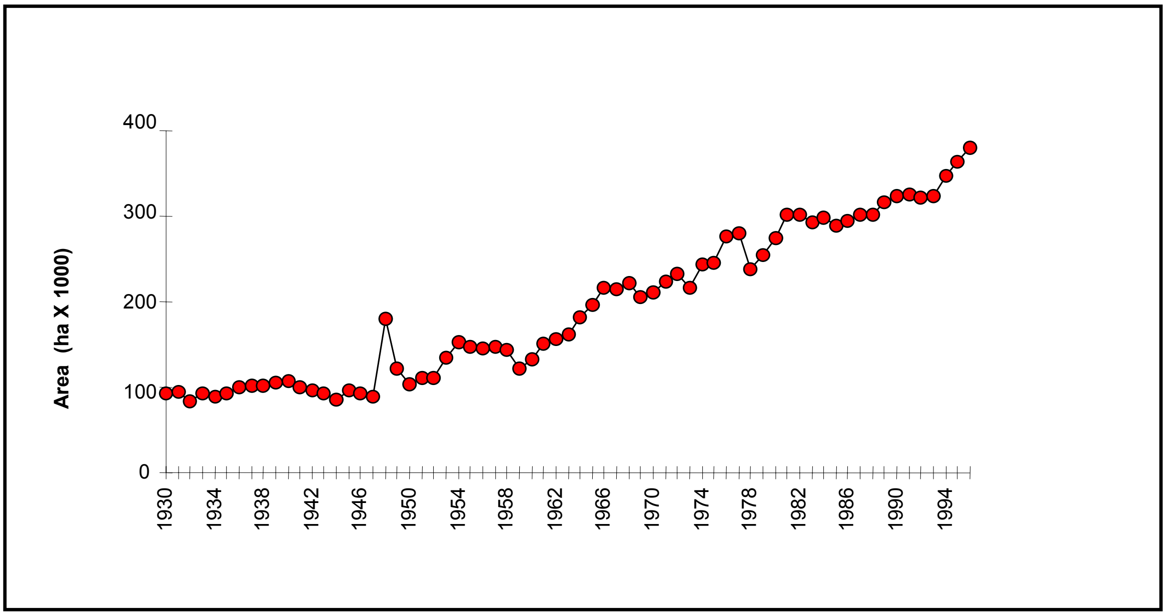


Figure 5. Increase in Queensland land area used for sugar cultivation from 1930 to 1996 (Gilbert 2000).

Soil erosion from cane lands was recognised as a major sediment source to river systems when the predominant cultivation techniques were cane harvesting through burning ('conventional cultivation') (Prove and Hicks 1991). Erosion rates of greater than 270 tonnes/ha/year were measured on Johnstone River cane lands under conventional cultivation (Prove and Hicks 1991). With the move to green cane harvesting/trash blanketing (GCTB) with minimum tillage, soil erosion rates have dropped dramatically with average losses now in the order of 10 tonnes/ha/year (Prove and Hicks 1991; Rayment and Neil 1997). Considerable soil loss still occurs in the plant cane stage (up to 50 tonnes/ha/year) but with minimal loss in ratoon (regrowth) crops under GCTB (about 5 tonnes/ha/year). With ratoon crops comprising on average four crops in every five, the overall average loss for the complete five-year crop cycle is about 10 tonnes/ha/year, only marginally higher than the natural rate of soil erosion on the flood plain. With the exception of the Burdekin Region, most of the cane grown in the Great Barrier Reef catchment now uses GCTB. Nutrient loss associated with soil erosion is also minimised under GCTB cultivation, and as such, losses of Nitrates and Phosphates from sugar cane lands are now more likely to be associated with fertiliser. Soil loss in new cane lands can be severe and this has been anecdotally noted in the expansion areas of the Tully/Murray floodplain during the 1990s. Such losses may partially explain the major rise in particulate nitrogen concentrations in the Tully River during the 1990s (Mitchell *et al.* 2000).

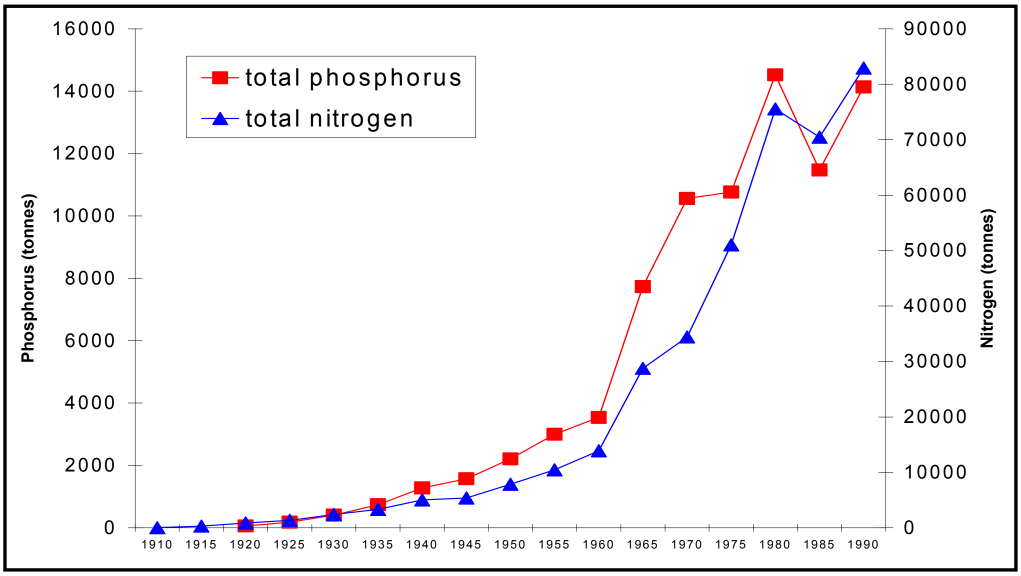


Figure 6. Increases in the use of nitrogen and phosphorus fertiliser on the Great Barrier Reef catchment (Pulsford 1996).

In summary, sugarcane cultivation on the Great Barrier Reef catchment probably contributes on average about 20,000 tonnes of Nitrates per year to the Great Barrier Reef. This is about 25% of the total load (Moss *et al*. 1993; Rayment and Neil 1997). In areas of intense sugarcane cultivation, such as the Wet Tropics, it contributes the majority of the dissolved inorganic nitrogen (nitrate and ammonia) transported by the rivers (Hunter 1997; Hunter and Walton 1997; Mitchell *et al*. 1997). This contribution is rising with increasing cane area and fertiliser rates. Elevated particulate Nitrates and nitrate concentrations in the Tully River over the last 13 years are attributed to increased soil loss in expansion areas and increased fertiliser use associated with increased cane cultivation and increased banana cultivation (Mitchell *et al*. 2000).

Other major crops grown on the Great Barrier Reef catchment, are cotton and horticultural crops (particularly bananas), tree crops such as mangos and lychees, and vegetable crops such as tomatoes. Nitrogen fertiliser application rates on such crops can be high, eg. for bananas approximately 400 kg/ha/year of nitrogen. Loss of fertiliser from bananas follows a similar path to sugarcane grown in the same area (Prove *et al.* 1997) and presents a similar, although slightly smaller source due to the smaller areas involved (Hunter *et al*. 1997). Cotton grown on the Fitzroy catchment uses nitrogen at rates of about 150 kilograms/ha/year and considerable loss of nitrogen from cotton cultivation has been measured downstream from the cropping areas (Noble *et al*. 1997).

Coastal Aquaculture

Coastal pond-based aquaculture now occupies about 450 hectares on the Great Barrier Reef coast. This area is dominated by penaid prawn cultivation with much smaller areas of finfish cultivation. The discharge from aquaculture using present techniques contains high concentrations of suspended solids and nutrients (Nitrates and Phosphates). The loss of nitrates and phosphates in the discharge per hectare of pond is about ten times that lost from an equivalent area of sugarcane cultivation (with GCTB) (Brennan 1999). The use of settlement ponds and cleanup ponds containing algae, bivalves and fish can significantly reduce the levels of suspended solids and nutrients in pond discharges (Prinsloo *et al.* 1999; Troell *et al.* 1999). With the introduction of these techniques in new aquaculture farms and the upgrading of existing farms, discharge of sediment, nitrates and phosphates from coastal aquaculture should be minimised.

Discharge of prawn pond effluent can also lead to changes to local salinity regimes. Recent research conducted by the Cooperative Research Centre (CRC) for Aquaculture has found that regular discharge of highly saline effluent from prawn farms affects the salinity of the water in estuarine areas and in the mixing zone. The long-term effects of these changes are yet to be determined (Trott and Alongi 1999). Aquaculture also presents the risk of release of disease to the environment. The key disease risks include the accidental introduction of exotic parasites and pathogens to wild stock and other marine species; undetected importation of infectious contagions in prawns and prawn feeds; and the magnification of endemic diseases associated with the intensive culturing of aquaculture species. Pathogenic organisms from Queensland prawn farms comprise a wide variety of taxa. These include the pathogenic bacteria *Vibrio* spp. (*Vibrio anguillarum, V. harveyi* and *V. alginolyticus*) (Smith 1993).

Wetland loss

The watersheds of rivers in north and central Queensland have been extensively modified since European settlement through land clearing followed by forestry, mining, urbanisation and agriculture. Clearing of forest and woodland has continued throughout the last 130 years with early loss of rainforest areas in coastal lowlands and on the ranges and tablelands, as well as loss of coastal wetland forest and extensive loss of open woodland. In the Herbert catchment, Melaleuca wetlands have been reduced in area from 30,000 hectares in pre-European times to less than 5,000

The area of wetlands has been dramatically reduced by land clearing activities hectares in 1996, while in the lower Johnstone catchment, a 78% loss occurred between 1951 and 1992. In the Fitzroy catchment, during the brigalow (*Acacia harpophylla*) woodland clearance schemes (1950 to 1975), approximately four million hectares of brigalow woodland were cleared for conversion to grasslands for beef cattle grazing. Forest and woodland clearing in Queensland has been assessed using satellite imagery.

Pollution impacts

Nutrients
Elevated nutrient concentrations result in a range of impacts on coral communities (Tomascik and Sander 1985; Ward and Harrison 1997; Koop *et al.* 2001) and under extreme situations, can result in the collapse of the coral reef community (Smith *et al.* 1981; Lapointe and O'Connell 1989, van Woesik *et al*, 1999). There a number of ways in which elevated nutrients affect corals:

- Elevated nutrient concentrations promote phytoplankton growth which in turn supports increased numbers of filter feeding organisms such as tubeworms, sponges and bivalves, which compete with coral for space (Smith *et al.* 1981).
- Enhanced levels of nutrients may also result in blooms of macroalgae that may overgrow coral structures, out-competing the coral polyps for space and shading the coral polyps. This has been demonstrated in numerous coral reef systems around the world including the Red Sea (Walker and Ormond 1982) and in Barbados (Tomascik and Sander 1985), with the best documented example in Kaneohe Bay, Hawaii (Smith *et al.* 1981).
- Excessive phosphorus concentrations can also result in coral colonies with less dense, and hence weakened skeletons, which make colonies more susceptible to damage from storm action (Wilkinson 1996). Neither macroalgae nor most filter feeders are reef building organisms, the reduction in coral reef growth will likely result in the erosion of coral reef structures.
- Elevated nutrients have also been demonstrated to inhibit fertilisation rates and embryo formation in the corals *Acropora longicyathus* and *A. aspera*, as well as causing direct coral mortality (Ward and Harrison 1997; Hoop *et al*. 2001).

Recent comparisons of inshore reefs in the relatively undisturbed far northern Great Barrier Reef with inshore reefs in the wet tropics region have indicated that considerable differences exist between reefs in the two areas. Coral reefs adjacent to heavily impacted catchments have lower coral biodiversity, lower rates of coral recruitment and different coral community structure compared with reefs in relatively pristine areas. This difference has been linked to changes in water quality caused by human activity. For more information about the condition of coral reefs see *Environmental status – Corals*.

Sediments, turbidity and marine snow

Regardless of whether the cause is natural or the result of human activity, there is clear evidence that prolonged exposure to levels of terrestrial sediment and organic matter in excess of normal conditions, can kill affected coral reefs through:

- smothering and burial when particles settle out (sedimentation);
- reducing light availability (turbidity) and potentially reducing coral photosynthesis, growth and reproduction; and
- altering the ecology and nutrient dynamics of reef surfaces (Rogers 1990; Anthony 1999a; Anthony 1999b).

Increased sediment loads combined with eutrophic conditions may enhance the formation of *marine snow* which may also impact corals (Fabricius and Wolanski 2000).

Corals and other small sessile invertebrates have to expend considerable energy to rid themselves of large *marine snow* particles compared to the normal, smaller 'clean' sediment particles of oligotrophic waters (Fabricius and Wolanski 2000). This creates a metabolic energy drain, which may reduce reproductive capacity, and the organisms capacity to grow and to cope with additional stress factors.

Effects on corals

Offshore coral reef environments are generally regarded as being adapted to low turbidity and low-nutrient conditions. In contrast, nearshore and coastal reef systems have evolved in relatively turbid environments where suspended sediment and turbidity are influenced more by local wind and wave regimes than by sediment supply (Larcombe and Woolfe 1999). Despite high turbidity levels and sedimentation rates, inshore reefs naturally sustain high and healthy coral cover and diversity, suggesting local adaptation to intense sediment regimes (Ayling and Ayling 1998). One reason for this may be that coral populations from inshore turbid environments have a greater capacity than offshore species to feed and thus obtain energy from sediment particles (Anthony 1999a). Energy obtained in this way could balance phototrophic energy reductions caused by shading in shallow turbid waters. However, particle feeding is unlikely to provide a total alternative energy source under consistently turbid waters (Anthony 1999b). Sediment smothering in inshore waters can also be prevented in more exposed, high energy areas as water movement removes excessive sediment before it harms coral (Johnson 1996), enabling successful coral growth and recruitment. For more information about the effects of water quality on coral reefs see *Environmental status – Corals*.

Effects on seagrass

Elevated sediment and nutrient concentrations can also negatively affect seagrass beds. Australian seagrass communities are generally characterised by low ambient nutrient loadings and increased nutrients and water turbidity can adversely affect seagrasses by lowering ambient light levels (Walker *et al.* 1999). Three major factors cause a reduction in light availability (Shepherd *et al.* 1989; Walker and McComb 1992; Abal and Dennison 1996):

- Chronic increases in dissolved nutrients leading to a proliferation of light adsorbing algae including water column phytoplankton, benthic macroalgae or algal epiphytes on seagrass stems and leaves;
- Chronic increases in suspended sediments leading to increased water column turbidity; and
- Pulsed increases in suspended sediments and/or phytoplankton blooms that cause a dramatic reduction of water column light penetration for a limited time.

All these will reduce the photosynthetic capability of affected seagrass. For more information about the effects of water quality on coral reefs see *Environmental status – Seagrass*.

Acid Sulphate Soils

Thirty-five confirmed fish kills have been documented along the north Queensland coast between 1997 and 1998 (Anon 1999a). Nine of these were major events and are expected to have a lasting impact on local regional fishery resources.

A majority of these have been attributed to agricultural developments, however, in some incidences urban development may be the primary cause. Reduced dissolved oxygen concentrations in the water column was cited as the cause of all incidents. Acidic water draining from acid sulphate soils are generally poorly oxygenated, have a low pH and may contain elevated concentrations of heavy metals (Cook *et al.* 2000). These conditions have the potential to impact fish habitat and behaviour, although the impact on Great Barrier Reef fauna has yet to be quantified (Cook *et al.* 2000).

The impacts of changing land use on river flow

Loss of forests, reduction in vegetation cover and increased drainage areas, as well as road networks and hardened surfaces in urban areas continue to produce increased run-off ratios (run-off/precipitation). This causes larger river floods with greater discharge volumes as well as faster, more concentrated discharge patterns. Construction of major dams will result in alterations in the supply of sediment and water as both become trapped behind the dam wall. Generally, dams will decrease the occurrence of high flows and alter the pattern of water delivery. The impact of an altered water regime will result in longer periods of low flow, reduced variability of flows, reduced frequency of small to medium flows and poor quality water from impoundments (Burrows and Butler 1998). Throughout the world, there are numerous examples of river regulation devastating estuarine and marine fisheries resources due to:

- greatly reduced freshwater flow drastically reducing export of nutrients that forms the basis of food chains;
- coastal erosion and habitat loss due to reduced sediment supply; and
- the loss of mangrove habitats due to hyper-saline conditions resulting from restricted freshwater flows.

In the Great Barrier Reef catchment there is a combination of impacts. In the dry season, the presence of dams, weirs, water regulation and irrigation result in a reduced dry season flow and may also act to moderate flows to some extent. About 10% of the average annual discharge from the Great Barrier Reef catchment (75 km^3) can potentially be captured in existing large reservoirs (Gilbert 2001). However with the onset of the wet season, and extreme flow events, there is the possibility of more water moving off the catchment due to loss of vegetation cover and increased run-off ratios. Downstream effects include larger floods with greater discharge volumes as well as a faster, more concentrated discharge pattern. Ongoing research into Sr/Ca ratios and $\delta^{18}O$ in corals, has quantified the changes to river run-off into the Great Barrier Reef lagoon (McCulloch *et al*. 2003).

Effects of Sewage Effluent

Sewage effluent contains many polluting substances including:

- organic matter capable of causing oxygen depletion in receiving waters;
- suspended solids capable of causing turbidity in receiving waters;
- micro-organisms (bacteria, viruses, fungi, protozoa, parasitic worms), some of which may be pathogenic;
- nutrients, particularly nitrogen and phosphorus compounds;
- toxic trace metals such as lead, cadmium and chromium;
- toxic synthetic organic substances such as pesticides and solvents;

Pollution from land-based sources can affect nearby marine ecosystems, such as increasing the incidence of coral disease

- petroleum oil;
- detergents;
- biologically active drug residues such as vitamins and steroids; and
- litter.

The nutrients - nitrogen and phosphorus - are the pollutants that most threaten the Great Barrier Reef. Most other substances are reduced to low levels by secondary and tertiary sewage treatment or by prevention of industrial waste entering the sewage system.

The discharge of sewage effluent into the Marine Park is regulated under the *Great Barrier Reef Marine Park Act* 1975 and *Regulations 1983* and the *Sewage Discharges from Marine Outfalls into the Great Barrier Reef Marine Park Policy*. Marine outfalls are regulated by the GBRMPA permit system. Under present policy, all effluent discharged into the GBRMP must be treated to a tertiary standard (i.e. nutrient removal) prior to being discharged. Secondary treated effluent can be reused for land irrigation or other activities. Outfalls discharging within the GBRMP were required to meet these standards by March 2002.

In the Great Barrier Reef catchment, the majority of urban settlements have secondary treatment facilities that discharge into waterways that drain into the GBRMP, but sewage effluent from these areas still has the potential to impact on the Great Barrier Reef. The GBRMPA has no jurisdiction over these discharges, however it is promoting the reduction of discharge volumes through increased effluent reuse and improved effluent quality. The *Queensland State Coastal Management Plan*, which came into effect in 2002, requires that where nutrients are identified as an environmental problem, all coastal sewage treatment plants are to upgrade the quality of discharges to coastal waters to nutrient removal standards by 2010. Local Governments must consider the Plan when revising all planning schemes.

The GBRMPA has identified present nutrient loads in inshore waters of the Great Barrier Reef as a problem . The Queensland Environment Protection Agency licenses most island and coastal facilities (those with a capacity greater than 21 *equivalent persons)*, while the Department of Natural Resources and Mines and local government regulate smaller treatment facilities designed for less than 21 *equivalent persons*. Effluent seepage from smaller systems may be an issue in sandy soils. Those that provide only primary treatment may be inadequate to protect the water quality of the receiving waters of the Great Barrier Reef.

Discharge of wastewater into the Great Barrier Reef Marine Park from industrial installations is regulated under the *Great Barrier Reef Marine Park Act 1975* and *Regulations 1983* (in the GBRMP) and the Queensland *Environmental Protection Act 1994*. Discharges from aquaculture facilities are regulated by State and Federal legislation.

Industrial discharge
The small number of major industrial sites along the Great Barrier Reef coast are generally concentrated near Gladstone and Townsville. Some of these industries discharge wastewater to the ocean and they are controlled under the Queensland *Environmental Protection Act 1994* licensing system. Plants being constructed in more recent times have been required to have no ocean wastewater discharge (e.g. the zinc smelter operating south of Townsville).

Aquaculture of saltwater prawns is a small but expanding industry along the Great Barrier Reef coast. Prawns are raised in ponds near the coast and fed processed feed. Unused feed, high in organic matter and nutrients, may be discharged into the ocean. These potentially nutrient-rich discharges are controlled under the *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000* and the Queensland *Environmental Protection Act 1994* through operating licences. New prawn farms are being required to install systems to minimise the volume of discharge and to reduce the pollutant load in the discharge. Systems using pond filtration through beds of bivalves (e.g. oysters and mussels) and algae are being used as well as filtration through mangroves.

Aquaculture is a small but expanding industry that can potentially released nutrient rich discharges into the GBRMP

Other Development impacts

Population growth in adjacent urban centres invariably leads to increased pressure for access to the resources of the GBRMP. This becomes a management issue when it results in overuse of certain sections of the GBRMP or where sensitive environments are exposed to excessive human impacts such as damage to corals from anchoring or interference with bird nesting and breeding areas.

The use of section zoning plans allows the GBRMPA to prescribe the allowable and permissible uses of areas of the GBRMP while providing for a variety of recreational opportunities. Plans of Management provide more detailed information on the management arrangements for high use areas or for specific issues such as dugong protection.

The development of new urban centres in sensitive areas, or the unplanned expansion of existing centres, has the potential to adversely affect marine ecosystems in the GBRMP in a variety of ways. Growth in residential nodes often leads to increased demand for marine tourism and recreation infrastructure such as marinas, ferry terminals, safe harbours and jetties, which, if not properly managed, can have adverse impacts on the GBRMP. Likewise, the scale, location and character of individual developments, such as large integrated residential and tourist resorts, or aquaculture farms can pose similar challenges to the management of the GBRMP, particularly if they are located adjacent to marine areas with a traditionally low-intensity use and high conservation values (eg some Dugong Protection Areas (DPA's)).

Population growth in urban areas adjacent to the GBRMP invariably leads to increased pressure for access to Marine Park resources

In addition to the broader issues of population pressure associated with coastal development, there are also a number of site-specific impacts. Sediment loss during construction and operational stages of development can reduce water quality. Dumping of dredge spoil from the construction and maintenance of canal and marina developments can effect estuarine and marine environments. Vegetation clearing associated with residential development and recreational uses often occurs adjacent to foreshore areas. There are increases in quantities of litter, especially plastics, entering the marine environment and adversely affecting marine animals including birds and mammals. Coastal development may also result in a change in the character of coastal areas, often involving a loss of the cultural or amenity values placed on the area by some users.

Management issues and responses

Jurisdictional Issues

The western boundary of the Great Barrier Reef Marine Park (GBRMP) follows the mean low water mark along the Queensland coast, excluding internal waters. Some inshore areas are State Marine Parks and some areas, such as ports, are not included in State or Commonwealth marine protected areas.

The *Great Barrier Reef Marine Park Act 1975* (the Act) provides limited scope to control catchment activities that produce run-off which, in turn, may degrade or damage the Great Barrier Reef. However, some power exists in the Act that provides for 'regulating or prohibiting acts (whether in the Marine Park or elsewhere) that may pollute water in a manner harmful to animals and plants in the Marine Park'.

Point source pollution is primarily controlled by Queensland state agencies through the *Environmental Protection Act 1994* and Regulations, administered by the Queensland Environment Protection Agency (EPA), and the *Water Act 2000*, administered by the Queensland Department of Natural Resources, Mines and Energy (NRME). Local government regulations and plans may also have relevance to urban sources of pollution.

The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) came into effect in July 2000 and gives the Commonwealth Minister for Environment the power to regulate environmental impact assessment and the approval of activities, such as development. The EPBC Act is administered by the Department of the Environment and Heritage.

Management responses

Managing point source discharge
Water quality has been identified by the GBRMPA as a critical issue for the management of the Great Barrier Reef Marine Park. Management of water quality is difficult as many of the activities causing the deterioration of water quality lie outside the boundaries of the GBRMP and involve complex institutional and jurisdictional arrangements.

The management of point source pollution for the GBRMP involves policy decisions such as sewage discharge standards, cooperative arrangements between government and industry to reduce inputs, case-by-case assessment and management of activities such as coastal developments and dredging.

Relationships between government agencies (point source)
The Authority's decision-making jurisdiction is generally limited to areas inside the GBRMP, however the *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000*, were introduced by

the Commonwealth when the Queensland system for aquaculture management was not considered sufficiently robust to provide protection for the Great Barrier Reef ecosystem.

The commencement in April 1998 of the *Queensland Integrated Planning Act 1997* has introduced major changes to the coordination of assessment and approval processes of State agencies and local governments. The GBRMPA has developed an informal relationship with the Queensland State government to act as an advice agency under an integrated development assessment system to ensure that issues affecting the GBRMP are considered in this assessment process.

The GBRMPA provides specialist advice on the referral, assessment and conditioning of approvals granted by the Department of the Environment and Heritage for developments adjacent to the GBRMP.

In addition to its involvement in project specific impact assessment, the GBRMPA has also developed relationships with State and local governments in the preparation of planning frameworks such as Regional Coastal Management Plans and Local Government Planning Schemes. Through these planning instruments, State and local governments can increase the level of protection and management afforded to coastal resources, which in turn, assist in the protection and management of the Great Barrier Reef. Other areas of joint concern where the GBRMPA is working closely with local governments include the development of design standards and guidelines for stormwater drainage, wastewater treatment and marinas.

Managing non-point source discharge
Non-point source discharge, is managed jointly by the Commonwealth and State governments through the arrangements outlined in the *Reef Water Quality Protection Plan*.

In June 2001, the Great Barrier Reef Ministerial Council, concerned with the trends in water quality directed the GBRMPA to prepare a *Great Barrier Reef Catchment Water Quality Action Plan* (the Action Plan). The objectives of the Action Plan included the identification of the major catchment-based threats to water quality in the Great Barrier Reef; identification of priority catchments and sub-catchments in terms of potential risks to the World Heritage values of the Great Barrier Reef; and the suggested specific water quality targets (including pollution loads and concentrations) for individual rivers and for reef water quality consistent with the ANZECC tropical marine guidelines. The Action Plan was released by the Commonwealth Minister for Environment and Heritage in September 2001.

On 13 August 2002, the Commonwealth and Queensland Governments recognised the importance of jointly addressing the issue by announcing a Memorandum of Understanding on developing a *Reef Water Quality Protection Plan*. Through the Plan, the Governments will act on the risk posed to the Great Barrier Reef from declining water quality. In particular, the Plan addresses diffuse sources of pollutants, which are the major source of pollution entering the Great Barrier Reef.

The initiative between the Commonwealth and State Governments recognises that the management of catchment pollution is primarily under the control of Queensland. Substantial funding by the Commonwealth and State Governments will be sourced from the Natural Heritage Trust and the National Action Plan for Salinity programs. These programs are the primary tools for the community in cooperation with Commonwealth and Queensland Governments to reduce catchment-based pollutant discharge. Under this strategy, local and State governments, land-holders and community and agricultural organisations join together to manage catchments on a whole-of-catchment basis. This process is now being progressively coordinated through regional Natural Resource Management (NRM) Boards that are developing regional NRM Plans. These plans will set out regional targets for salinity, water quality, water flows, and biodiversity, among others.

The Plan recognises that changes in land management introduced by some rural industries have helped to reduce the levels of sediment and nutrient run-off. The most notable examples are the green cane harvesting, trash blanketing and minimum tillage techniques in sugarcane cultivation. In rangeland grazing situations, fencing off streamlines to prevent cattle access and subsequent bank erosion and provision of off stream watering are being introduced, as well as the use of variable stocking strategies which seek to remove cattle from grazing lands before, and as drought conditions occur. Codes of practice and best management practices have also been developed for many agricultural industries to give direction on environmental issues related to the industry.

The Plan also recognises that wetlands and riparian vegetation protection are vital for the protection of the Great Barrier Reef as they ameliorate the impacts of run-off from catchments. Coastal wetlands disperse and slow the velocity of run-off, allowing entrained sediments and nutrients to settle out before they enter Great Barrier Reef waters. Preservation of remaining wetlands and riparian vegetation in the coastal zone adjacent to the World Heritage Area and the rehabilitation of degraded wetlands and riparian areas are therefore important to the management of Reef water quality.

REEF WATER QUALITY PROTECTION PLAN

Halting and reversing the decline in water quality entering the Reef within ten years.

Objective 1
•*Reduce diffuse sources of pollutants in water entering the reef.*

Objective 2
•*Rehabilitate and conserve areas of the reef catchment that have a role in removing water borne pollutants.*

Nine Key Strategies

A - Self Management Approaches
Industry, Governments and Communities working together to improve on current initiatives and to develop new practices.
•Property Resource Management Plans
•Statutory Covenants And Agreements
•Best Management Practice
•Environmental Management Systems
•Codes Of Practice

B - Education and Extension
Providing coordinated and integrated information to the community on all aspects of the water quality of the Great Barrier Reef.
•Utilise Indigenous information arrangements
•Education, Extension and trialing programs
•Regional NRM, catchment and property resource management planning
•Community-based water quality information collection programs

•Monitor and reduce chemical use
•Support property managers to protect riparian areas and wetlands

C - Economic Incentives
Providing economic incentives to achieve better environmental outcomes as well as achieving improved economic performance.
•Incentives for sustainable management practices and property level planning. (FarmBiz, EMS subsidy)
•Identify policies, incentives and schemes with a detrimental impact
•Investigate linking property resource management plans to incentives
•Trading in natural resource products
•Investigation of an offsets policy
•Philanthropic investment

D - Natural Resource Management and Land Use Planning
Better use of existing planning mechanisms to achieve improvements in land use planning and development decisions.
•Regional Coastal Management Plans
•Regional Vegetation Management Plans
•Agriculture Planning Scheme (APS)
•Review planning and statutory instruments
•Examine options to manage pesticide, herbicide and fertiliser use
•Nutrient Sensitive Zones
•Assessment of activities which impact on water quality

E - Regulatory Frameworks
Review, investigate and enhance aspects of existing legislation to ensure it supports protection of the reef water quality
•Draft Leasehold Strategy
•Wetlands Protection
•Development Assessment

F - Research and Information Sharing
Ongoing access to the best available scientific data
•Provide technical information
•Data collection and analysis
•Undertake research and development programs
•Review the herbicide Diuron
•'Fertiliser sales by catchment' reporting system

G - Partnerships
Partnerships between Industry, Government and the Community are critical to improving the quality of water entering the Great Barrier Reef.
•Build on partnerships with indigenous communities
•Regional NRM Bodies
•Research organisations – CSIRO, AIMS, CRC
•Eco-efficiency Agreements
•Industry Sectors

H - Priorities and targets
A risk based approach to identify priority areas – to concentrate on protecting healthy waterways and to rehabilitate areas that require immediate action

•Water quality targets
•Prioritise catchments
•Identify "hotspots"
•Wetland and riparian rehabilitation

I - Monitoring and evaluation
Co-ordinated and integrated Monitoring Programs
• Commonwealth – lagoon
• State – rivers and catchment

Reporting

Heads of Agencies will provide reports on the progress towards the goals and objects of the Plan to the Great Barrier Reef Ministerial Council for consideration. In turn the GBR Ministerial Council will provide the reports with recommendations to the Prime Minister and Premier. The first report will be completed by 1 July 2005. This report will focus on whether satisfactory progress has been made towards the objectives. The second report will be prepared by 1 July 2010 detailing the extent of achievements against the objectives.

Further information on the *Reef Water Quality Protection Plan* is available at:
www.premiers.qld.gov.au/whatsnew.htm or
www.deh.gov.au/coasts/pollution/index.html

Further reading

Water quality in the Great Barrier Reef
- http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/index.html
- http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/current_issues/wq_threats_brochure.html
- http://www.reef.crc.org.au/aboutreef/coastal/waterquality.html
- http://www.reef.crc.org.au/publications/brochures/index.html
- http://www.deh.gov.au/coasts/pollution/reef/

Research publications on the Great Barrier Reef and water quality:
- http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/current_issues/
- http://www.deh.gov.au/coasts/pollution/reef/science/
- http://www.gbrmpa.gov.au/corp_site/info_services/publications/index.html
- http://www.reef.crc.org.au/publications/techreport/index.html

Wetlands
- http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/wetlands.html
- http://www.deh.gov.au/water/wetlands/index.html
- http://www.epa.qld.gov.au/cgi-bin/w3-msql/environment/environment/conservation/msqlwelcome.html?page=wl.html

Management

- http://www.gbrmpa.gov.au/corp_site/key_issues/water_quality/management.html

Great Barrier Reef Catchment Water Quality Action Plan 2001

- http://umparra.gbrmpa.gov.au/testweb/corp_site/key_issues/water_quality/action_plan/

Reef Water Quality Protection Plan

- http://www.deh.gov.au/coasts/pollution/reef/index.html

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