13 September 2002

Greg Murtough
Great Barrier Reef Study
Productivity Commission
Locked Bag 2
Collins Street East
MELBOURNE VIC 8003

Dear Greg,

Thank you for the invitation the Great Barrier Reef Marine Park Authority (GBRMPA) of the 16 August 2002 to prepare a submission to the Productivity Commission's Great Barrier Reef Study. Please find attached the GBRMPA's submission for the Great Barrier Reef Study.

The GBRMPA 's submission generally addresses the Terms of Reference for the Great Barrier Reef Study as outlined in the Issues Paper posted on the Commission's web site. However, in discussions with the Commission staff in Townsville on the 5th September 2002, it was noted that given the relatively tight timelines for preparing submission, the Commission would entertain further submissions so long as the initial submission addressing the first three Terms of Reference was submitted by the due date of the 13 September 2002. This was to enable the Commission to complete its Interim Report as required by the Government within the agreed timeframes. While the GBRMPA's submission has outlined existing management arrangements in Queensland for catchment activities, the GBRMPA may like to take up this option of further expanding on the potential policy options for the management of industry activities with the Great Barrier Reef World Heritage Area and its Catchment in a supplementary submission.

Please find attached the GBRMPA's Submission to the Great Barrier Reef Study including a draft Social and Economic Profile of Great Barrier Reef Coastal Communities recently prepared by GBRMPA staff.

If you would like to discuss any material in this submission please feel free to contact me on 07 47500723.

Yours sincerely

Hugh Yorkston
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Water Quality and Coastal Development Group

A submission to the Productivity Commission's research study
on
Industries in the Great Barrier Reef Catchment and Measures to Address Declining Water Quality

1. Executive summary

The Great Barrier Reef (GBR) is the largest system of coral reefs in the world. The Great Barrier Reef World Heritage Area (GBRWHA), inscribed on the World Heritage List in 1981, contains coral reefs, a large number of different community types, plants, animals, and their habitats including extensive seagrass beds, mangrove forests, sandbanks, sponge and soft coral gardens, and soft bottom and island communities.

The Great Barrier Reef Marine Park (GBRMP) and GBRWHA have an inter-dependent relationship with adjacent coastal river catchments. The GBR region is a focus of agricultural production, tourism, industry, shipping and urban centres. All of these activities present a range of risks to the water quality of the GBR.

Some of the major threats to the values of the GBRWHA include:
- Loss of terrestrial, coastal and marine habitats;
- Alteration of geological landscape;
- Disruption of ecological processes;
- Declining water quality;
- Loss of flora and fauna; and
- Loss of scenic amenity.

Human activities on the catchment and in the GBRWHA have the potential to cause these impacts by actions including:
- Vegetation clearing;
- Erosion and sediment run-off;
- Leaching from acid sulfate soils;
- Water pollution by input of fertilisers, pesticides, toxic chemicals, sewage, rubbish, detergents, heavy metals, and oil;
- Clearing, filling, and draining of wetland areas;
- Poor stormwater management.
- Alteration of scenic landscape;
- Alterations to the hydrodynamic regime (freshwater, estuarine, and marine)
- Dredging
- Sea dumping; and
- Introduction of exotic species

Fifteen years of marine and land-based research on the GBR and the adjacent catchment have shown that water quality and ecological integrity of the coastal area of GBRWHA are being affected by material originating from a range of human activities, both on the land and in the water, such as primary industries (agriculture, aquaculture), urban and industrial development (Haynes 2001, Williams 2002). Land-use, primarily agriculture, delivers approximately 80 % of the pollution loads to the GBR. Protection of the ecological systems of the GBRWHA from chronic impacts these pollutants is recognised as one of the most critical issues for the long-term viability of the World Heritage Area.

Using the concept of Total Economic Value (TEV), non-use values, such as option and existence values supplied by the Great Barrier Reef Marine Park have been estimated to be around $45 million per year. Most of the indirect use values, the ecosystem services provided by the GBRWHA, have to date not be estimated. Examples for such values are: shoreline protection, maintenance of migration and nursery habitats, maintenance of biological diversity, waste assimilation and reception, maintenance of biological processes, visual amenity and lifestyle values. There is also no quantification of existence and bequest values. These values, however, are accepted to be significant, as is indicated by the World Heritage listing of the GBRWHA.

The economic value of the GBR for marine tourism, commercial fishing, and recreational use is estimated at over $1 billion annually, suggesting that the flow-on effects of the use of the reef underpins a significant portion of Queensland's regional economy. All of these industries rely on intact World Heritage attributes for their continued existence.

Many of the land-based activities that affect the water quality of the GBRWHA can impact on the social and economic values associated with the GBRWHA, and hence compromise the protection of the values of the GBRWHA.

With 99.26 % of the GBRWHA falling within the boundaries of the GBRMP, the vast majority of the GBRWHA is managed through the provisions of the *Great Barrier Reef Marine Park Act 1975*, and subordinate regulations. The Act and other regulatory tools have evolved over the last 25 years to incorporate the world's best environmental practices into management of the GBRMP.

World Heritage areas not included in the GBRMP comprise: islands under State jurisdiction; internal waters of Queensland; and a number of small exclusion areas, mainly located around major ports and urban centres. While small in size, these excluded areas are priority areas of coastal and marine development, and hence are potential sources of pollution and disturbance to the GBRWHA.

The *Environment Protection Biodiversity Conservation Act (1999)* provides for assessment and approval of developments that may have a significant impact on matters of National Environmental Significance, such as the values of the GBRWHA values.

The Queensland and Commonwealth governments are currently jointly drafting a Reef Water Quality Protection Plan (the Plan) for the catchment of the GBRWHA. In August 2002, the Prime Minister and Premier Beattie adopted a Memorandum of Understanding on developing practical actions to improve water quality and reduce impacts on the Great Barrier Reef Marine Park. An Inter-governmental Steering Committee is guiding the development of the Plan based on guidelines included in the MOU.

Queensland has approached the management of water quality with regard to point source and non-point source pollution primarily through regulation, planning and assessment instruments. The Queensland *Environmental Protection Act 1994* (QEP Act) provides for regulations of point source discharge requirements and facilitates the preparation of industry voluntary codes of practice for non-point source discharges. Point source pollution can also be addressed at a regional or State level by setting water quality objectives and standards for receiving waters under the *Environmental Protection (Water) Policy 1997* and the recently released State Coastal Management Plan.

Local government Planning Schemes for the management of development activities for all Queensland local government areas are presently being prepared under the *Integrated Planning Act 1997* (IP Act) with the aim of achieving ecologically sustainable development. The level of assessment for different types of development is at the discretion of each local government, except where a development is identified as impact assessable in the IP Act. Currently, most agricultural activities are not impact-assessable under the IP Act. The discretion provided to local government in addressing development activities in their area can lead to significant differences in addressing downstream water quality impacts of coastal developments on the values of the GBRWHA.

2. The Great Barrier Reef Region

The Great Barrier Reef (GBR) is the largest system of coral reefs in the world. It includes approximately 2,900 reefs and covers an area of approximately 350,000 km^2 on the north-eastern Australian continental shelf. The GBR is one of the world's richest areas of biological diversity.

The Great Barrier Reef World Heritage Area (GBRWHA) contains more than just coral reefs. It also contains many different community types, plants, animals, and their habitats including extensive seagrass beds, mangrove forests, sandbanks, sponge and soft coral gardens, and soft bottom and island communities. The reef is not a continuous barrier, but a broken maze of coral reefs and coral cays. It includes some 2,900 individual reefs, of which 760 are fringing reefs close to the coast.

The Great Barrier Reef Marine Park (GBRMP) and GBRWHA have an inter-dependent relationship with adjacent coastal river catchments. The GBR Catchment covers 22% of Queensland's land area (~370,000 square kilometres) and contains 20% of its population (~730,000 people). This region accounts for approximately 30% of the Gross State Product and around 60% of exports. The twenty-six local government areas adjacent to the GBRWHA contain 20% of Queensland's resident population with an estimated growth rate of 1.5%. Apart from Cairns City, Douglas and Whitsunday Shires that have tourism as their major industry, the region is economically dependent on agriculture, manufacturing and mining. Significant growth is projected for urban areas in Queensland's coastal zone. As a consequence, local governments along the coast face the challenge of balancing the demands of economic development associated with changes in land use, associated with shifts in agricultural activity, urban and industrial expansion with maintenance of healthy local coastal ecosystems. An integral component of this is protection of local water quality and maintenance of aquatic habitats.

3. Catchment sources of pollutants to the GBWHA

The coastal region adjoining the GBRWHA is divided into a number of wet and dry tropical catchments, with 26 major catchment areas draining directly into the GBR lagoon (Gilbert in press). The region is a focus of agricultural production, tourism, industry, shipping and urban centres (Lucas et al. 1997, Gilbert 2001). All of these activities present a range of risks to the water quality of the GBR by:

- Land run-off from agricultural lands;
- Loss of wetlands and riparian vegetation;
- Discharge of aquaculture waste;
- Discharge from industrial operations.
- Discharge of stormwater; and
- Discharge of sewage effluent;

The majority of the discharge of pollutants occurs during flood events (Devlin 2001). Based on this information and knowledge of the spatial extent of flood plumes, the estimated extent of near-shore areas at risk from present land management activities has been defined (Figure 1). This risk is primarily due to agricultural practices, such as vegetation clearing, removal of riparian areas and wetlands, and use of fertilisers and other chemicals. The major direct impact of agricultural practices on the GBRWHA is the degradation of water quality resulting in impaired functionality, health and productivity of marine organisms, and loss of supporting habitats.

Figure 1 Location and extent of the GBR, with identified near shore areas ‘at risk’ from land based runoff.

The GBRMPA’s recently released “Great Barrier Reef Water Quality: Current Issues” (Haynes 2001) and the “Great Barrier Reef Catchment Water Quality Action Plan” (GBRMPA 2001, the Action Plan). Both documents discuss the above outlined water quality issues and measures to address them. The Action Plan suggests a number of water quality targets for 26 drainage basins adjacent to the GBRWHA and measures to achieve them.

Agriculture

The primary land use on the GBR catchment is cattle grazing for beef production, which occupies 77% of the total catchment area (Gilbert in press). Other land uses, namely cropping (mainly of sugarcane) and urban/residential development, each occupy approximately 3% of the total catchment area.

The largest crop grown on the GBR Catchment is sugarcane, which is primarily grown in lowland coastal areas. The catchment area used for sugarcane cropping has increased steadily over the last 100 years (Gilbert in press). Cropping requires the application of fertiliser which has resulted in a rapid increase in total fertiliser application since 1950 (Pulsford 1996).

For example, the upper Tully River catchment, flowing through a largely undisturbed rainforest catchment has maximum dissolved inorganic nitrogen (DIN) concentrations of 1-12µM (Faithful and Brodie 1990, Mitchell et al. 2000). 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 of 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 associated with increased cane area and increased banana cultivation. From 1990 to 1999, the combined usage of nitrogenous-fertiliser for both sugarcane and bananas is estimated to have increased by 55% in the Johnstone River catchment and 118% in the Tully - Murray River catchments.

In the central GBR it is estimated that terrestrial runoff of nutrients provides approximately 41% of the 'new' nitrogen (N) and 60% of the 'new' phosphorus (P) inputs to shelf waters from external sources (Furnas et al. 1995).

Significant proportions of these nutrients reach the waters of the GBR, especially during the intense flood events that dominate North Queensland rainfall and river flows. For example, dissolved inorganic nitrogen (DIN) concentrations in flood plumes range between 10 to 100 times ambient concentrations, as well as high levels of particulate nitrogen (Devlin et al. 2001).

Soil erosion from cane land was recognised as a major sediment source to river systems when the conventional cultivation technique was "burnt cane harvesting"(Prove and Hicks 1991). In contrast, green cane harvesting/trash blanketing using minimum tillage, can result in dramatically lower soil erosion rates (average losses of 10 tonnes/ha/year; Prove and Hicks 1991, Rayment and Neil 1997).

Sediment and nutrient runoff from the coastal catchments of Queensland have been estimated using existing data and catchment models (Moss et al. 1992; Neil & Yu 1996; Rayment & Neil 1997). The most current and sophisticated modelling effort has been completed within the National Land and Water Resource Audit (NLWRA) by CSIRO Land & Water (NLWRA, unpub. data; methodology in Prosser et al. 2001). According to these latest estimates 12 million tonnes of sediment, 47 thousand tonnes of nitrogen and 10 thousand tonnes of phosphorus are exported to the inner GBR lagoon via river discharge annually. Even though there are large differences between the catchment models employed (Wasson 1997) all estimates indicate an increase in terrestrial nutrient and sediment delivery to the GBR of at least four-fold since European settlement.

A number of pesticides are used by the Queensland agricultural industry (summary for the cane industry in Hamilton and Haydon 1996). Broadscale surveys of sediment herbicide concentrations in nearshore GBR waters during 1998 and 1999 have detected the herbicides atrazine and diuron (Haynes et al. 2000a). Low concentrations of diuron (0.2-10.1 µg kg-1) were found in marine sediments along the wet tropics coastline between Port Douglas and Lucinda. The herbicide was detected in both subtidal and intertidal samples. Highest concentrations of diuron were detected adjacent to the mouths of the Herbert and Johnstone Rivers. Highest northern Queensland agricultural usage of the herbicide occurs in these two river catchments (Hamilton and Haydon 1996). Models predicted that concentrations are likely to be higher during monsoon rainfall periods as first rainfalls of the wet season flush herbicides from the catchments (Haynes at al. 2000a).

Broadscale surveys have also detected the pesticides lindane, dieldrin and DDT (and its breakdown product DDE) in nearshore marine samples collected along the Queensland coast in 1998 and 1999 (Haynes et al. 2000a). Dieldrin was detected in sediments collected from the mouth of both the Barron and Johnstone Rivers (0.09-0.37 µg kg-1) and in sediments from Halifax Bay (0.05 µg kg-1).

A range of organochlorine pesticides have been detected in catchments and subtidal sediments in the GBRWHA (Clegg 1974, Cavanagh et al. 1999; Kannan et al. 1995; Russell et al. 1996c; Rayment et al. 1997) and in fauna in marine environment adjacent to agricultural activity (Mortimer 2000, Russell et al. 1996c, von Westernhagen and Klumpp 1995). As a consequence, organochlorine pesticide residues may present a localised threat to nearshore marine organisms along the wet tropics Queensland coast (Haynes et al. 2000a). Lindane was only detected in sediments from the vicinity of the mouth of the Johnstone River. Lindane has not been detected in water or riverine sediment samples collected in the Johnstone catchment in the 1990s (Hunter et al. 1999). However, the pesticide is still detectable in northern Queensland agricultural soils and in sediments from irrigation drains (Cavanagh et al. 1999; Müller et al. 2000).

It has been assumed that no significant sources of dioxins exist in Australia's northeast tropical region as it has a relatively low population density with little industrial activity. However, high concentrations of octachlorinated dibenzodioxin (OCDD) and a relatively unusual PCDD/F congener profile have been found in topsoil samples from a sugar cane field in northern Queensland (Müller et al.. 1996a, b).

Vegetation clearing associated with expansion of agricultural lands has led to major losses and alteration of wetland habitat in catchments adjacent to the GBR (Russell and Hales 1994; Russell et al. 1996a,b; Skull 1996; Johnson et al. 1998, 2000).

Urban wastewater

The majority of the large coastal cities and most of the smaller coastal and island settlements adjacent to the GBRWHA have secondary treatment sewage systems, which reduces the organic loading in the effluent (Waterhouse and Johnson 2002). Many of these treatment plants use a proportion of the effluent for land irrigation and several have sewage outfalls, as point-source discharges, either into coastal streams or directly into the GBRWHA. In some areas with significant urban populations septic systems are still in operation. A number of local councils are currently investigating plans to upgrade their sewage systems in line with the recently released policies in the Queensland *State Coastal Management Plan 2001*.

Sewage effluent contains a number of substances that may have adverse impacts on the marine environment. These include organic matter, nutrients, suspended solids, and micro-organisms (bacteria, viruses, fungi, protozoa, parasitic worms), some of the latter may be pathogenic. There may also be heavy metals, toxic synthetic organic substances such as pesticides, herbicides and solvents; crude oil products such as petroleum; detergents; biologically active drug residues such as vitamins and steroids; and litter (Brodie 1994). Sewage discharges contribute less than 10% to the overall nutrient load to the Great Barrier Reef lagoon (Furnas et al. 1995), however, these inputs may be significant on a local scale e.g. close to coastal urban areas. Problems may arise from these point-source discharges, particularly in dry season conditions, where discharge into a stream may constitute the total stream flow.

Urban stormwater is defined as the runoff generated from urban areas and includes major flows during and following rainfall events, as well as dry weather flows (ANZECC 2000). Dry weather flows may originate from sources such as groundwater, garden watering, wash down, dewatering activities, leaking water pipes and illegal discharges. Urban development results in an increase in stormwater quantity and a decrease in water quality due to an increase in impervious surfaces and the loss of infiltration potential. The tropical climate of the GBR Region with a pronounced summer wet season leads to significant seasonal run-off with a high risk of pollutants from urban and industrial areas being transported by stormwater to the coastal areas of the GBRWHA. This increase in impervious surfaces in significant areas of the urban and industrial environments also leads to greater quantities of stormwater entering the rivers and streams in a shorter space of time, increasing the potential for erosion in these areas.

The composition of urban stormwater reflects the residential and industrial developments in the area and may contain sediments (especially from construction sites), nutrients, faecal matter, metals, hydrocarbons, pesticides, litter, organic debris, and air pollution depositions. The water quality of stormwater can be lowered further by sewer overflows and leaching from landfill sites and septic tanks.

The Calliope, Gladstone and Townsville/Thuringowa shires contain the greatest proportion of heavy industry in Great Barrier Reef Catchment. There are thirteen existing heavy industry operations (including an alumina refinery and aluminium smelter and a power generation station) as well as five proposals for further development of heavy industry in the Gladstone area. In the Townsville/Thuringowa area the principal heavy industries are a zinc refinery and smelter, a copper refinery and a nickel refinery. There are at least two major industrial effluent outfalls that discharge directly into the marine environment – the Queensland Nickel Refinery, Thuringowa; and the trade waste discharge facility at Fisherman's Landing Wharf, Gladstone. A number of sites discharge wastewater into coastal streams flowing directly into the estuarine environments of the GBRWHA. These discharges are regulated under the Queensland Environmental Protection Act 1994. Recently developed industrial sites are encouraged to use recycling and re-use technologies and to have no ocean wastewater discharge, for example, the Korea Zinc smelter in Townsville.

Coal production is the major mining operation carried out in the Great Barrier Reef catchment area, with mines in the region producing approximately 96% of Queensland's 95 million tonnes of annual black coal production (Gilbert in press). The Stuart Oil Shale operations are also a significant industrial development in the Great Barrier Reef catchment, particularly if it proceeds to Stage 3 of the development where mining is proposed to extend into the GBRWHA. Other mining operations close to the coast include silica mining near Cape Flattery and magnesia mining north of Rockhampton.
Mine rehabilitation is an ongoing concern in the GBR Catchment. There are a number of largely non-operational old tin, copper and gold mines in the Great Barrier Reef catchment that have been abandoned and the sites left unrehabilitated. A good example is the Mt

Morgan mine site which contains an old open cut pit filled with acid mine drainage with a pH of around 2.8 and unknown quantities of toxic heavy metal contaminants in the pool sediments. Liability for the site has been transferred in 1992 from the previous operator to the State of Queensland. Overflowing of the pit after extreme rain has resulted in fish kills in the receiving Dee River, which through the Don, Dawson and Fitzroy Rivers drains into the GBRWHA. There is a concern that a severe rain event could lead to catastrophic release of the acidic water and contaminated sediment from the pit into the adjacent river system. An NHT-funded project has identified the clean-up options for the Dee River. The rough estimate of the cost to rehabilitate the mine is $35 million over a 10-20 year period. This is just one example of an unrehabilitated mine sites that has potential to adversely affect water quality in the Great Barrier Reef catchment.

Industrial runoff can contain elevated concentrations of suspended solids, nutrients, metals such as copper, manganese, mercury, nickel, cadmium, and numerous other chemicals such as ammonia, fluoride, arsenic, cyanide, silica, sulphate, ethylene glycol, and methanol. These operations may also affect the pH of water being released to the environment. Industrial operations on the coast may also result in accidental hydrocarbon discharge associated with equipment failure or shipping operations.

Earth and drainage works during construction phase of urban and industrial developments in the coastal zone are considered to have the capacity to expose potential acid sulfate soils (Powell and Ahern 1999). Queensland has extensive areas (an estimated 2.3 million ha) of potential acid sulfate soils (PASS) located in low lying areas near the coast (Sammut and Lines-Kelly 1996; White et al. 1997). PASS soils contain iron sulfides that are normally protected from contact with the air in a layer of waterlogged soil. When these soils are disturbed, drained, and exposed to the air, they oxidise to produce sulphuric acid that can acidify soil water, groundwater, and eventually surface waters.

Increased quantities of metals such as arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn) have been released, and continue to be released into the aquatic environment through urban stormwater and wastewater discharges. Heavy metals are natural constituents of rocks and soils and enter the environment as a consequence of weathering and erosion (Förstner 1989). Many metals are biologically essential, but all have the potential to be toxic to biota above certain threshold concentrations.

Larger cities or populations also require a dependable water supply and this has been the impetus for the construction of many dams in Queensland. There are 123 official dams and weirs within the Great Barrier Reef catchment (Gilbert in press). Provision of water for expanding agricultural activities and human settlement has led to a number of proposals to construct new water storage facilities. These existing and proposed facilities have the capacity to modify water regimes and alter environmental flows with potential for significant downstream impact on the GBRWHA. Local river impacts include impediment of the movement of fauna along waterways, alteration of water temperature and flow regimes, loss of habitat and degraded water quality through reduced oxygen levels and release of toxicants such as hydrogen sulphide (Bunn and Arthington 1997). Marine impacts are often related to loss of breeding habitat for fish and altered hydrological regimes in estuarine areas.

Aquaculture

The aquaculture industry is a relatively young industry in the GBR catchment and still in an expansion phase. There are currently ca. 40 licensed aquaculture operations adjacent to the GBRWHA. Operations include pond and tank-based aquaculture for finfish and crustaceans as well as hatcheries.

Aquaculture operations adjacent to the GBRWHA can be considered as users of the GBRWHA for the assimilation of aquaculture waste. Discharge of aquaculture waste has the potential to cause:

- Nutrient enrichment (eutrophication) of estuarine and near shore ecosystems (see above for detailed discussion of effects),
- Changes to estuarine and near shore ecosystems due to alterations of light, salinity, and oxygen regimes;
- Disease and genetic contamination (by escapees) of wild fisheries stocks;
- Competition with and displacement of wild stock through accidental release of farmed stock; and
- Potential loss of coastal habitat for migratory (land / sea) species.

There is a history of environmental problems resulting from the rapid expansion of prawn farming during the 1980s to 1990s in a number of Asian countries. Environmental impacts of prawn farming and the subsequent costs to local communities when prawn farming fails due to pollution and disease are often attributed to a lack of government environmental regulation of the industry. It is argued that the high level of pollution in effluent discharged from prawn farms has contributed to the collapse of the industry in Taiwan and China (Phillips et al., 1993). Taiwan's production collapsed from 80,000 t in 1987 to 20,000 t in 1988 / 89 (Lin, 1989). Concern over the social costs of shrimp farming led to an Indian Supreme Court ruling against prawn farming, which included the cessation of prawn farming operations in a 100,000 ha region and banning of prawn farming in sensitive areas (Hagler 1997). This ruling was made on the basis of a cost benefit analysis that found the social costs of prawn farming were up to 4 times greater than the benefits (Primavera, 1998). The development of prawn farming in Queensland has been constrained by environmental regulations and to date large-scale environmental impacts caused by land-based aquaculture have not been identified. There are, however, a few examples of demonstrated impacts on local scales.

Being a relatively young industry there have been a number of technological and economic failures. A number of these non-operational farms are located along the coast of the GBR catchment. These farms have not been rehabilitated and their proximity to the coast may pose an ongoing risk of release of acidic run-off from excavated acid sulfate soils into receiving waterways. Other impacts may also be caused by such derelict developments, for example destruction or alteration of habitats of coastal or estuarine species, in particular birds; and increased erosion from cleared and excavated sites. A rough estimate of rehabilitation costs for a small (< 10 ha) site close to Townsville was $ 600,000 (Vern Veitch, Sunfish, pers. comm.). This site has 24,000 m^3 of oxidised acid sulfate soils above the ground, which poses a significant risk of acidic wastewater leaching into the GBRWHA.

Shipping

Even though shipping is not strictly a catchment-based industry, it is connected to catchment activities by port operations and commodity export activities. The risk of pollution of the GBRWHA is associated with these transport and trading activities.

The GBRWHA contains several important commercial trading routes. There are between 2500 and 3000 ships using GBR shipping routes annually. Approximately 75 % of these ships navigate the inner route, whilst the remainder transit Grafton, Palm and Hydrographers Passages. Approximately 20% of these vessels are transit vessels, not trading at Queensland ports.

Bulk carriers comprise the greatest proportion of shipping which is consistent with the large amount of trade through the bulk ore ports of Gladstone, Hay Point, Abbot Point and Cape Flattery. Less than 10% of ships using GBR shipping routes are oil or chemical tankers, with most conducting a northerly transit carrying refined product to northern ports from southern refineries. Crude oil is transported to southern refineries via the outer GBR route.

Shipping operations present two forms of pollution risk to the GBRWHA. These are:
- Pollution derived from normal ship operations; and
- Pollution as a result of shipping accidents.

The normal operation of a ship generates a number of different waste products that can impact upon the marine environment. These wastes include oil, chemicals, sewage, garbage, toxic compounds released from anti-fouling paints (such as TBT) and ballast water. In general terms the impacts tend to be greatest in areas where shipping is concentrated at offshore anchorages and around berths in ports, although discharges of oil and garbage have the potential to cause impacts some distance from the point of discharge.

There is significant potential for exotic marine pests to be translocated in ballast water or through hull fouling. The issue has not been well addressed in tropical areas, as most introductions have been identified in temperate waters. However, the outbreak of the black striped mussel in Darwin demonstrated the vulnerabilities of tropical regions, particularly in disturbed environments. Recently the introduced Asian green Mussel has been identified in Cairns Harbour and an incursion response (quarantine and removal) is currently underway. The environmental risk associated with introduced marine pests may be a greater problem than large oil and chemical spills as the environment will recover from an oil and chemical spill, whereas it has proven impossible to remove introduced pests once they become established.

The poor navigation, operation, or maintenance of ships can lead to grounding, collision, and mechanical or structural failure of a vessel. These forms of maritime accidents can lead to the loss of fuel and /or cargo. The impacts resulting from these events tend to be dramatic and may be long lasting depending upon the type of pollutant lost to the environment.

The GBRMPA and Queensland Transport jointly conducted an oil spill risk assessment (Huggett et al. 2001). The assessment identified the following areas of the GBRWHA as being at risk of a maritime accident:

- Inner Shipping Route, north of Cape Flattery;
- Whitsunday Islands, though the risk profile is influenced by a single maritime sector, cruise shipping;

- Hydrographers Passage;

The risk assessment also identified several recommendations designed to alleviate the risk of a maritime incident in the GBRWHA. The key recommendations included the declaration of Marine Environment High Risk Areas (Inner Shipping Route, between Cape Flattery and Torres Strait, Whitsunday Islands and associated passages, Hydrographers Passage), increasing preparedness capacity along the Queensland coast and implementation of new technologies for improving vessel safety.

Since 1985 there have been 33 reported incidents (11 collisions and 22 groundings) involving trading ships in the Torres Strait and the GBR. This equates to two incidents per year. These accident rates are higher than for any other areas of Australia.

In 1990, the International Maritime Organisation (IMO) declared the GBR region a *Particularly Sensitive Sea Area* (PSSA). The GBR was the first area in the world to be recognised in this way. The declaration allows the Australian Government to implement initiatives to manage shipping with an aim to minimise shipping incidents and the environmental impact of shipping activities on the GBRMP. The first such initiative was the implementation of compulsory pilotage in certain areas within the GBRMP. This legislation requires vessels over 70 m in length, and all loaded oil, gas, or chemical carriers, to carry a pilot within the compulsory pilotage areas of the GBRMP. The compulsory pilotage areas were selected because they are considered navigationally difficult routes, with high vessel traffic volumes. The compulsory pilotage areas within the GBRMP are the Inner-Route of the GBR from Cape York to just north of Cairns, Hydrographers Passage off Mackay and within the Whitsunday Islands group (as of July 2001).

The GBRMPA has been working closely with other Commonwealth and Queensland government agencies in order to develop strategies to better manage shipping activities within the GBRWHA. The Australian government recently conducted a review of ship safety and pollution measures in the GBR (Great Barrier Reef Shipping Review Steering Committee 2001) and has established a Shipping Management Group to implement the recommendations of this review. Initiatives include the provision of compulsory pilotage areas over the entire GBRMP, upgrading of the mandatory ship reporting system called REEFREP, and Differential Global Positioning System coverage over the entire GBRWHA. In addition, new technologies such as the Automatic Ship Identification systems are being considered as part of the development of a coordinated Shipping Management Plan.

Commercial and recreational vessels are also a source of wastewater discharged into the GBRWHA. Current GBRMPA vessel sewage legislation allows the discharge of vessel sewage from vessels that do not contain a storage tank designed for storing sewage; or if vessels are more than 500 metres seawards from the seaward edge of the nearest reef; or if the discharge was for the purpose of saving life at sea or securing the safety of the vessel. Legislation by GBRMPA and the Queensland government relating to vessel sewage is currently under review.

4. World Heritage values potentially impacted by declining water quality

The Great Barrier Reef World Heritage Area (GBRWHA) was inscribed on the World Heritage List in 1981 and includes approximately 2,900 coral reefs covering about 20,055 km^2, 600 continental islands, 300 coral cays and the inter-reefal lagoon. In listing the GBRWHA the World Heritage Committee assessed the region against four major world heritage criteria:

- Criterion (i) an outstanding example representing a major stage of the earth's evolutionary history.
- Criterion (ii) an outstanding example representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment.
- Criterion (iii) contain unique, rare and superlative natural phenomena, formations and features and areas of exceptional natural beauty.
- Criterion (iv) provide habitats where populations of rare and endangered species of plants and animals still survive.

The GBRWHA is characterised by a high diversity of biota. In the original nomination of the GBRWHA a number of natural heritage attributes were identified:

- geological and geomorphological evolution of the reef structure;
- morphological diversity of the reef;
- evolution of coral cays;
- bird and plant colonisation of coral cays;
- area of great natural beauty;
- diversity of life-forms including:
    - endemic species;
    - 400 species of coral in 60 genera;
    - foraminifera;
    - echinoderms;
    - crustaceans;
    - polychaete worms;
    - ascidians;
    - over 4000 species of molluscs;
    - 1500 species of fish;
    - 6 species of sea turtle;
    - whales and dolphins;
    - sea birds with breeding colonies;
    - land birds;
    - fleshy algae;
- diverse ecosystems:
    - coral communities;
    - seagrass beds;
    - mangrove communities;
    - low wooded islands;
    - sand cays.

To clarify and to expand the justification for World Heritage listing of the Great Barrier Reef Region, Lucas et al (1997) compiled further information on 29 natural heritage attributes (some contained in the original list of natural heritage attributes and some additional) from 60 local experts. A conclusion of this study was that the GBRWHA is justifiable upon all four current natural heritage criteria (as amended 1996, World Heritage Committee 1996). Also it was concluded that the outstanding universal value of the GBRWHA rests on:

- The scale of the area; and
- Its potential for effective conservation management.

A report exploring the economic values of a range of good and services supplied by the Great Barrier Reef Marine Park has used the concept of Total Economic Value (TEV), which includes indirect use values as well as values accepted in the existing market system (Driml, unpublished). The indirect use values, such as option and existence values have been estimated to be around $45 million per year. The range of estimates of a per-hectare-value for coral reefs in other parts of the world is US$120 to $6000 per annum. However, a detailed assessment of the TEV of the GBR is currently not available. The components of the TEV of the GBWHA have been identified as (after Driml, unpublished):

Direct use values, which include industries that rely on the GBRWHA as a resource:

- Commercial fishing
- Commercial tourisms;
- Recreational fishing;
- Recreational boating;
- Indigenous uses;
- Education and research;
- Bioprospecting; and
- Shipping.

Indirect use values, which include:
- Shoreline/coastal protection;
- Maintenance of migration and nursery habitats;
- Maintenance of biological diversity, including fish stocks;
- Organic mater storage and recycling;
- Waste assimilation and reception; and
- Visual amenity.

And:
- Option values
- Existence values, and
- Bequest values.

In order to protect the World Heritage status of the GBRWHA the World Heritage values must be identified and recognised at a regional and local scale and appropriate management strategies implemented to protect the integrity of the site and therefore the GBRWHA as a whole. Activities that occur in the coastal zone and on the islands have the potential to impact directly and indirectly upon the World Heritage values. Activities such as vegetation clearing, excavation, filling of wetlands, application of fertilisers and pesticides, wastewater discharge, alterations to waterway flows and inputs of pollutants can adversely impact areas outside in the immediate footprint of the activity, i.e. adjacent estuarine and marine habitats.

Some of the major threats to the values of the GBRWHA include:
- Loss of terrestrial, coastal and marine habitats;
- Alteration of geological landscape;

- Disruption of ecological processes;
- Declining water quality;
- Loss of flora and fauna; and
- Loss of scenic amenity.

Human activities on the catchment and in the GBRWHA have the potential to cause these impacts by actions including:

- Vegetation clearing;
- Erosion and sediment run-off;
- Leaching from acid sulfate soils;
- Water pollution by input of fertilisers, pesticides, toxic chemicals, sewage, rubbish, detergents, heavy metals, and oil;
- Clearing, filling, and draining of wetland areas;
- Poor stormwater management.
- Alteration of scenic landscape;
- Alterations to the hydrodynamic regime (freshwater, estuarine, and marine)
- Dredging
- Sea dumping; and
- Introduction of exotic species

Fifteen years of marine and land-based research on the GBR and the adjacent catchment have shown that water quality and ecological integrity of the coastal area of GBRWHA are being affected by material originating from a range of human activities, both on the land and in the water, such as primary industries (agriculture, aquaculture), urban and industrial development (Haynes 2001, Williams 2002). Protection of the ecological systems of the GBRWHA from chronic impacts these pollutants is recognised as one of the most critical issues for the long-term viability of the World Heritage Area.

Increased inputs of nutrients ("eutrophication") often have critical impacts on marine ecosystems, especially tropical systems such as coral reefs. There is now a considerable body of evidence demonstrating these impacts, including:

- Examples of ecosystem degradation due to eutrophication: (e.g. Hawaii: Smith et al. 1981; Reunion Island: Naim 1993; Red Sea: Walker and Ormond 1982, Genin et al. 1995; S.E. Asia (Wilkinson and Rahman 1994; and the Caribbean (Lapointe et al 1994, Lapointe 1997). In general, the impacts noted include major declines in abundance and diversity of corals and fishes, and replacement of corals by a range of algae (seaweeds). Importantly, reef decline often involves a failure of community recovery from other disturbances at impacted sites;
- Evidence for reef decline on GBR in wet tropics (CRC) and Whitsundays (van Woesik et al 1999)
- Experimental evidence demonstrating nutrients as the cause of changes: (e.g. enhanced algal growth and coral overgrowth: Schaffelke and Klumpp 1998; Schaffelke 1999, Jompa and McCook 2002; phytoplankton blooms: Smith et al. 1981; reduced coral viability: Ferrier Pages et al. 2000; Harrison and Ward 2001; Koop et al. 2001).
- Increases in nutrient availability may promote seagrass growth in ecosystems that are generally nutrient-limited, such as coral reef environments (Carruthers et al. in press). In sheltered environments, epiphytic macroalgae respond quickly to water-column enrichment and may outgrow grazing pressure, leading to a decline of the underlying seagrass (Orth & Moore 1983, Bulthuis 1983, Cambridge & McComb 1984, Neverauskas 1987, Walker & McComb 1992, Burkholder et al. 1992, Short et al. 1996, Short & Wyllie-Echeverria 1996). Recent seagrass fertilisation experiments in Morton Bay, Weipa, and

Rottnest Island indicate that mainly nitrogen rather than phosphorus stimulates seagrass growth, however, the addition of both nitrogen and phosphorus lead to the strongest response (Udy & Dennison 1997a, b).

There is unequivocal evidence that high, chronic input of terrestrial sediment and organic matter will lead to the destruction of reefs through direct burial, increased turbidity, disruption of recruitment or deleterious community shifts (detailed review in Haynes 2001). For example, both detailed organism-level experiments and population/ecosystem-level evidence have demonstrated:

- Increased coral mortality (Dollar and Grigg 1981; Rogers 1990; Hodgson 1990a; Hodgson 1990b; Stafford-Smith 1992, 1993; Stafford-Smith and Ormond 1992);
- Reduced coral photosynthesis and growth (Rogers 1990; Anthony 1999; Anthony & Fabricius 2000; Philipp and Fabricius in review);
- Reduced removal of competing algae by herbivorous fishes (Purcell 2000);
- Reduced recruitment and growth of important reef seaweeds (Umar et al. 1998; Fabricius and De'ath 2001)
- Smothering of organisms when particles settle out (Fabricius and Wolanski 2000);
- Reducing light availability which potentially reduces photosynthesis of seagrasses (Kirkman 1978, Hatcher et al. 1989, Robertson & Lee Long 1991, Preen et al. 1995); and
- Reduced coral recruitment (Fabricius et al. in review; Babcock and Davies 1991), which is likely to be particularly critical regarding population recovery after disturbances.

There is some evidence that the quantity of suspended sediments delivered to nearshore reefs has not changed as a result of human landuse, but it is probably that the quality (i.e. size composition, and sediment bound nutrient and pesticide levels) has changed. Nearshore and coastal reef systems have evolved in relatively turbid environments where suspended sediment and turbidity are influenced by local wind and wave regimes rather than by sediment supply (Larcombe and Woolfe 1999). Despite high turbidity levels and sedimentation rates, a number of inshore reefs sustain high and healthy coral cover and diversity, suggesting local adaptation to intense sedimentation regimes (Ayling and Ayling 1998). However, changes in the nutrient and pesticide levels associated with these sediments are likely to cause a number of significant stresses to reef organisms, such as increased phytoplankton blooms, increased algal trapping of sediments resulting in decreased coral recruitment, and the formation of marine snow (discussed below).

Increased sediment loads combined with eutrophic (nutrient rich) conditions may result in the formation of marine snow. Marine snow are high densities of sticky, suspended particles embedded in a mucus-like matrix. 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 (nutrient poor) waters (Fabricius and Wolanski 2000). This creates a metabolic energy drain which may reduce reproductive capacity and the organism's capacity to grow and even survive.

The diuron levels detected in nearshore sediments along the GBR coast (Haynes et al. 2000b) are of concern as laboratory trials have indicated that diuron concentrations of less than 1 µg L-1 significantly reduce photosynthetic rates in seagrass commonly found along the Queensland coast (ibid.). Diuron has also been found in mangrove communities on the central Queensland coast (Duke et al. 2001).

Concentrations of octachlorinated dioxin were found to be high in dugong fat tissue compared with concentrations detected in marine mammals elsewhere (Haynes et al. 1999).

Polychlorinated dibenzodioxins (PCDDs) appear to be the most significant organochlorine pollutant bioaccumulated in dugong, however, the most important consequences of coastal contamination for GBR dugong populations are likely to be indirect through herbicide impacts to their nearshore seagrass food resource (Haynes 2001). Dioxins are a group of 210 chlorinated compounds consisting of chlorinated dibenzo-para-dioxins (PCDDs) and chlorinated dibenzofurans (PCDFs). They are formed during various chemical and industrial manufacturing processes, by combustion of organic material (Kjeller *et al.* 1991), and also via lesser known natural processes (Hashimoto *et al.* 1995; Alcock *et al.* 1998). They are known to display a diverse and complex array of toxicological properties (Buckland *et al.* 1990) and have been detected in a variety of marine mammals (Buckland *et al.* 1990; Norstrom *et al.* 1990; Oehme *et al.* 1995; Jarman *et al.* 1996; Muir *et al.* 1996; Tarasova *et al.* 1997)].

Discharges of urban and industrial wastewater to the marine environment have the potential to cause:

- The eutrophication of coastal waters due to localised and chronic inputs of nutrients and organic matter;
- Impacts associated with the accumulation of toxicants such as heavy metals in marine organisms and sediments;
- Changes to the species composition of marine communities to higher abundances of species that are tolerant to pollution; and
- Long-term degradation of sensitive environments such as coral communities and seagrass meadows by chronic exposure to urban wastewater.

The environmental impacts of sewage discharges vary depending on volume and pre-treatment of effluent, effluent dispersal characteristics and location of the effluent discharge point in the marine environment. The extent of biological impacts ranges to more than 5 km from the discharge point (Costanzo et al. 2001). Sewage discharges into enclosed bays may have extensive adverse impacts. Sewage impacts in the marine environment are predominantly caused by nutrient and organic matter enrichment.

The discharge of secondary treated sewage from Hayman Island in the Whitsunday Group has caused localised effects on adjacent coral reefs with areas closest to the outfall having the lowest number of taxa, lowest net growth of coral colonies and highest mortality (van Woesik et al. 1990, Steven & van Woesik 1990). Rose & Risk (1985) reported increased growth of certain species of sponges overgrowing corals after discharge of untreated sewage at Grand Cayman Island. Seepage of sewage constituents (nutrients, pathogens) from septic tanks into marine waters has led to measurable impacts on a Brazilian coral reef system such as excessive growth of macroalgae (Costa et al. 2000).

The best-known example of the long-term effects of sewage on a coral reef system has been documented from Kaneohe Bay, Hawaii (Smith *et al.* 1981). Sewage discharges into the Bay from the 1940s to 1978 saw the waters become increasingly rich in phytoplankton (Clutter 1971) and reefs closest to the outfall were overgrown by filter-feeding organisms, such as sponges, tube-worms and barnacles (Banner, 1974). Reefs in the centre of the Bay further from the outfalls were overgrown by the green alga *Dictyosphaeria cavernosa* (Smith *et al.* 1981). After diversion of the outfall into deep water in 1978 some recovery of corals has been observed (Maragos *et al.*, 1985). However, 20 years after the sewage diversion the bay sediments still have elevated nutrient levels, causing the high cover of macroalgae to persist (Stimson & Larned 2000, Smith et al. 2001). This case study is particularly relevant to the GBR situation as here sewage effluent is generally discharged into sheltered waterbodies such as lagoons and embayments that are located near sensitive environments including coral reefs and seagrass beds.

Well-known effects of sewage discharge into the GBRMP have also been documented at Green Island, near Cairns. Prolonged discharge of primary treated effluent (1972 to 1992) led to unusual, luxuriant growth of seagrass in a coral reef ecosystem (van Woesik 1989). Since that time, the sewage treatment system has been upgraded to tertiary treatment with a high level of effluent recycling. The seagrass meadows around Green Island still persist, which Udy et al. (1999) attribute to increased nutrient availability from mainland runoff, but could have also been caused by a long-term increase in sediment nutrient stocks like in Kaneohe Bay. Sewage effluent discharges into Pioneer Bay, Whitsundays Region, are associated with increases in seagrass epiphytes and macroalgal cover (FRC 1999, Campbell & McKenzie 2001). Changes to marine systems by increased macroalgal growth caused by urban wastewater discharge have also been reported from elsewhere (Fairweather 1990, Smith 1996, Chisholm et al. 1997).

A water quality monitoring program in Trinity Inlet, Cairns, which is draining into the GBRWHA, indicated that sewage discharge is the primary driver of eutrophication of this estuary (Sinclair Knight Merz 2001).

Other demonstrated effects of sewage discharge include:

- Significant changes to local fauna and flora communities including the bioaccumulation of trace contaminants by fish in the vicinity of inshore outfalls (Lincoln-Smith & Mann 1989, Mann & Ajani 1991, McLean et al. 1991, Scanes 1992);
- Elevated levels of chloro-hydrocarbon, organochlorine compound and trace metal contaminants in sediment and fish around outfalls (Krogh & Scanes 1996);
- Changes in trace metal contamination in sediments around outfalls (Gray 1996);
- Elevated concentrations of organochlorines in oysters grown around ocean outfalls (Scanes 1996);
- High rates of organic matter deposition affecting biogeochemical processes within sediments (Bickford, 1996); and
- Changes to offshore fish and invertebrate assemblages, for example increases or decreases in abundance (e.g. Puffer *et al*, 1982, Grigg 1994, Otway 1995, Hall *et al.* 1997), reproductive impairment (Hose *et al.* 1989) and histopathological changes (Brown *et al.* 1987).

Inputs of sediments from construction works or erosion from agricultural, urban, and industrial areas may lead to the demise of coral reefs and seagrass meadows through burial, disruption of recruitment or deleterious community shifts (see above).

Stormwater and sewage also carry large volumes of freshwater into the marine environment. Reef corals exist in seawater salinities ranging from 25 to 42‰ (Coles and Jokiel 1992). Many examples exist of lethal and sublethal effects of lowered salinities following storm and flood events (Coles and Jokiel 1992, van Woesik *et al.* 1995, Ayling and Ayling 1998). Symptoms of coral stress caused by lowered salinities include excessive mucus release and loss of zooxanthellae (bleaching). Salinity impacts to corals are confounded by other flood related stresses such as sedimentation, turbidity and increased ultraviolet radiation exposure.

Organochlorine compounds enter the environment as contaminants contained in effluent discharges and in urban stormwater run-off. Organochlorine compounds are highly hydrophobic and once in the water column, tend to adsorb to fine particulates or be bioaccumulated into lipids in aquatic biota (Olsen *et al.* 1982). The final distribution of organochlorine compounds in the aquatic environment is complex (Connell 1995). Tissue accumulation of organochlorine pesticides and polychlorinated biphenyls (PCBs) have been implicated in reproductive and immunological abnormalities observed in terrestrial bird populations and in marine mammal populations (Boon *et al.* 1992). While the impact of organochlorines are still unclear for lower invertebrates such as corals, their potential toxicity to immune systems and reproductive processes is of concern. The few studies on the impacts of organochlorine compounds carried out in Australian freshwater and marine environments indicate that environmental contamination by organochlorine substances has occurred at relatively low concentrations in Australia. Highest concentrations have been associated with centres of urbanisation (Richardson 1995).

Metals are strongly associated with particulates and enter the marine environment in a similar fashion to organochlorine compounds. They mostly enter the environment via the atmospheric transport of dust and through sediment movement in overland flows and in waterways (Bryan 1971). Particulate metals are not generally directly available to aquatic organisms, an exception to this are sediment-feeding organisms (Waldichuk 1985). Once dissolved in the water column, metals may be accumulated by marine invertebrates from solution via passive uptake across permeable surfaces such as gills and the digestive tract (Rainbow 1990). Cellular metal toxicity is primarily due to the chemical inactivation of cellular enzymes responsible for normal organism survival and function (Förstner 1989). Organism growth, reproduction and behaviour are also potentially affected by elevated environmental metal concentrations (Langston 1990).

Acidic leachate from exposed and oxidised acid sulfate soils can also mobilise soil-bound heavy metals and make these biologically available (Sammut et al. 1994), as well as reduce water column dissolved oxygen concentrations to critical levels (Cook et al. 2000). Acid production can persist for years following PASS exposure, rendering surrounding soil toxic and barren, and killing fish and aquatic plants and invertebrates in adjacent waterways (White et al. 1996; White et al. 1997).

Thirty-five confirmed fish kills from acid sulphate soil disturbance have been documented along the north Queensland coast between 1997 and 1998. Nine of these were major events that 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. Low water column dissolved oxygen concentrations were cited as the cause of all incidents (Anon 1999).

Earth and drainage works are also considered to have the potential to change the hydrology of waterways leading to increased erosion potential and an increase in the sediment load and associated contaminants entering waterways that may then drain into the adjacent marine environment of the GBRWHA. Diversion of streams and drainage channels may directly impact on coastal mangroves, associated fringing vegetation, salt flats, and salt marshes. The modification of the hydrological regimes may result in a reduction of suitable habitat for seagrass, mangroves, birds, and juvenile fish. An estimated 600 ha of mangroves were lost in Trinity Inlet, Cairns, to industrial development in the 1970s (Olsen 1983).

5. Industry values potentially impacted by declining water quality

The economic value of the GBR for marine tourism, commercial fishing, and recreational use is estimated at over $1 billion annually, suggesting that the flow-on effects of the use of the reef underpins a significant portion of Queensland's regional economy. Many of the land-based activities that affect the water quality of the GBRWHA can impact on these social and economic values and compromise the protection of the values of the GBRWHA.

Commercial and recreational fishing industry

The annual value of the landed catch gross catch of the commercial fishing industry is about $ 200 million (Cadwallader et al. 2000), and is a significant source for local and international exports. The recreational fishing and boating activities have been valued at $ 107.5 million (KPMG 2000). An assessment of the value of the commercial fishing industry, including flow-on effects estimated a gross financial value of $ 243 million (Innes & Gorman, unpubl.). The local government areas with the greatest proportion of the gross value production are Cairns, Mackay, and Townsville (ibid.). From a total GBR coastal workforce of 348,506 approximately 1.03 % are employed in commercial fishing, with higher employment rates in the local government areas of Miriam Vale, Johnstone, and Bowen (ibid.).

The recreational fishing and boating activities, including flow-on values, were estimated to have an annual value of $ 191 million (Innes & Gorman, unpubl.). 40% of the gross expenditure for recreational boating and fishing was attributed to the Townsville-Thuringowa, Cairns, and Mackay local government areas (ibid.).

Around 75 % of the commercial and recreational fish species rely on estuaries and other tidal habitats for at least part of their life cycle, especially as nursery grounds (Couchman et al. 1996; cited in Clarke 1998). These species are Barramundi, Mackerel, Blue Salmon, King Salmon, Mangrove Jack, Grunter, Red Emperor, Perch, Mullet, mud crab, Banana prawn, Tiger prawns, King prawns, and baitfish (Clarke 1998). Estuarine and shallow-water coastal seagrass beds are very important as nursery habitat for juvenile prawns and fish (Derbyshire et al. 1995), and are, due to their proximity to the coast, very susceptible to impacts from human activities.

Catchment activities have lead to habitat loss and declining water quality in tidal wetlands, estuaries, and nearshore areas, especially with regard to physical alteration (draining, bunding), nutrient enrichment, siltation, alteration of oxygen content (e.g. by discharge of organic waste), and pH levels (e.g. by leaching of acid sulfate soils). Habitat loss and alteration may lead to displacement of fish and crustacean species. Contaminants may cause direct effects on fish and other biota, for example "red spot' disease in fish caused by acid leachate (Sammut et al. 1996). Deleterious effects on organisms from bio-accumulation of heavy metals and organic toxicants have been discussed above.

Declines in inshore fish populations, through water quality problems, could lead to disturbance of natural ecosystems even in offshore habitats beyond the direct influence of the water quality problem.

Tourism

The direct value of reef-associated tourism has been estimated as $ 454.5 million (KPMG 2000). This sector employs 7421 people directly and 5469 people indirectly in 1997/98 (KPMG 2000). Driml (unpublished) also cites an estimate of the total visitor expenditure to the reef region of a minimum of $ 653 million per annum (Hundloe et al. 1987). A more recent assessment of the value of the tourism industry, including flow-on effects estimated a gross financial value of $ 589 million (Innes & Gorman, unpubl., see Attachment 1).

81 % of the total income from GBR tourism is concentrated in three major areas, the local government areas of Douglas (15 %), Cairns (31 %), and the Whitsundays (35 %).

The reef-based tourism is very much reliant on the existence and integrity of the natural heritage attributes of the GBRWHA. Hence, the impact of declining water quality on commercial reef tourism is very much in line with the impact on world heritage values, which have been discussed above.

A major threat to the tourist industry are outbreaks of the crown-of-thorns starfish (COTS). Even though it is still discussed to be a natural phenomenon, other hypotheses link the increased frequency and severity of outbreaks to fishing impacts on predators of the starfish (Seymour & Bradbury 1999), and human impacts on water quality (Birkeland 1982).

In 2001 the Queensland government committed $1 million for reef management issues, including $700,000 to assist the tourism industry undertake a COTS control program at key tourism sites. The Commonwealth government has also committed $700,000 towards the COTS control program, currently being undertaken by the Association of Marine Park Tourism Operators (AMPTO).

Aquaculture

The aquaculture industry in Queensland generates a gross value $56 million annually (Lobegeiger 2002) and employs approximately 550 people. 80% of this value is contributed by land-based aquaculture of marine prawns.

The discharge of aquaculture waste into the GBRWHA or into waterways draining into the GBRWHA can be considered to be an indirect use of the GBRWHA, as an important ecosystem service. Declining water quality may lead to this use being no longer available and the costs to the industry would be equivalent to the development and implementation of better technologies for the treatment of aquaculture waste and / or alternative means of disposal.

Even though the aquaculture industry is considered to be a source of pollution entering the GBWHA the industry is also reliant on a certain standard of water quality for their operations. A water supply that is high in nutrients and suspended sediments, contains heavy metals or, pesticides, has low oxygen content, or high acidity is unsuitable to support coastal aquaculture. A major threat for the future of the industry is declining water quality in freshwater courses and estuaries, which would force the industry into more pristine areas.

Offshore aquaculture such pearl oyster culture has currently a value of $ 489,000 and employs 16 full time equivalent staff (Lobegeiger 2002). Pearl oyster operation are predominantly located it more remote areas. Development of a larger offshore aquaculture sector, such as the development of finfish cage culture, is being discussed as an industry goal for the next decade (WBM Oceanics 1996). Finfish aquaculture, even though it may be a significant pollution source, will depend on good water quality in the coastal to midshelf areas of the GBRWHA. The industry is also likely to compete with other users (commercial and recreational fishing, tourism, recreation) for sites in the vicinity of regional centres, as it relies on the availability of labour and transport such as international airports.

Other industries

The discharge of sewage and industrial wastewater into the GBRWHA or into waterways draining into the GBRWHA can be considered to be an indirect use of the GBRWHA, as an important ecosystem service. Declining water quality may lead to this use being no longer available and the costs to the community would be equivalent to implement alternative means of wastewater treatment and disposal. Current estimates for an upgrade of the Townsville and the two Cairns sewage treatment plants to tertiary treatment standards are $20 million (Townsville City Council pers. comm.) and $ 19 million (JWP 2001), respectively.

In the future, the shipping industry may incur higher future costs for pilotage with the additional costs of pilotage likely to be borne by the shipping industry. Higher costs are also expected due to increases in assessment fees for compulsory pilotage exemptions.

Queensland Transport will be developing an environmental management system for ports. This will help Queensland Transport to incorporate environmental considerations in business and strategic planning and lead to better environmental outcomes for ports generally. However, the environmental management costs of ports adjacent to the GBRWHA may increase in recognition of the obligation of industry to reduce port-sourced pollution inputs to a minimum.

All vessels using Australian ports incur port levies and these monies help fund oil spill response and cleanup under the National Plan for Responding to Pollution of the Sea by Oil and other Hazardous and Noxious Substances. These levies may also increase in the future in recognition of the increasing costs associated with maritime incident response and environmental assessment, cleanup and monitoring operations associated with any incident. Associated insurance costs (e.g. P&I Club and Lloyds) are also likely to increase significantly to reflect an increases in penalties, any clean-up and assessment requirements and other associated costs.

Australia's share of the world seaborne trade continues to grow, increasing from 8.2% in 1990/1 to 9.9% of the world trade in 1999/00. Queensland port system total throughput in 2000/1 exceeded 185 million tonnes. This represents a growth of 7.7% over the previous year (Queensland Transport 2002). The value of commodity exports from ports adjacent to the GBRMP alone is valued at around A$ 14,589 million (Innes & Gorman, unpubl.).

The GBR Shipping Review (Great Barrier Reef Shipping Review Steering Committee 2001) and the Oil Spill Risk Assessment (Huggett et al. 2001), which were recently conducted for the GBR region, also recommended an increase in penalties for vessel owners and masters of vessels involved in maritime incidents or breaches of regulations. To this end, the GBRMPA has increased its penalties significantly recently to be consistent with Commonwealth Criminal Law Policy.

6. Current management regimes and policies for addressing the issue of declining water quality entering the GBRWHA

Commonwealth regimes

In 1975, the Great Barrier Reef Marine Park was proclaimed under the *Great Barrier Reef Marine Park Act* 1975 (GBRMP Act). This Act provides for regulation of human activities in the Great Barrier Reef Region (GBRR). The listing as a World Heritage Area occurred in 1981. The GBRMPA operates in partnership with the Commonwealth and Queensland

Government agencies to ensure that the World Heritage values of the Great Barrier Reef are preserved and protected for future generations.

With 99.26 % of the GBRWHA falling within the boundaries of the GBRMP, the vast majority of the GBRWHA is managed through the provisions of the GBRMP Act, the *Great Barrier Reef Marine Park Regulations* 1983 (the Regulations), other specific regulations (e.g. GBRR [Prohibition of Mining] Regulation 1999), GBR Section Zoning Plans and most recently, Plans of Management for specific areas of the GBRMP. The Act, Regulations and other regulatory tools have evolved over the last 25 years to incorporate the world's best environmental practices into management of the GBRMP.

World Heritage areas not included in the GBRMP comprise:

- Islands under State jurisdiction;
- Internal waters of Queensland; and
- A number of small exclusion areas, mainly located around major ports and urban centres.

Whilst small in size, these excluded areas are priority areas of coastal and marine development, and hence are potential sources of pollution and disturbance to the GBRWHA.

Whilst plenary rights for land and water management remain with the Queensland Government, the Commonwealth *Environment Protection Biodiversity Conservation Act (1999)* provides for assessment and approval of developments that may have a significant impact on matters of National Environmental Significance, such as the values of the GBRWHA values. The GBRMP Act, Section 66 2(e), also provides for the regulation or prohibition of activities outside the GBRMP that may pollute water in a manner harmful to plants and animals in the GBRMP. Under this provision, the *Great Barrier Reef Marine Park (Aquaculture) Regulations 2000* were proclaimed to regulate aquaculture effluent discharges into waters that drain into the GBRMP.

The GBRMPA has an obligation both under the GBRMPA Act and as a leading agency responsible for the protection of the values of the GBRWHA to manage water quality impacts on the GBRMP. This obligation has been recognised in the 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area (GBRMPA 1994), which contains objectives relating to water quality: "4.11 To investigate the effects of nutrients, sediments, toxic pesticides, herbicides and other toxic pollutants with a view to reducing their inputs and impacts in the area." Strategy 4.11.4 encompasses the future reduction of waste discharges from lands adjacent to the GBRMP: "Encourage the development of methods of reducing undesirable land-based inputs and other pollutants to the Area".

The GBRMPA has jurisdiction over outfalls discharging sewage effluents directly into the GBRMP, currently for six island ocean outfalls. Four coastal ocean outfalls are located within or adjacent to areas recently proclaimed as new sections of the GBRMP. In 1991 GBRMPA developed the policy *Sewage Discharges from Marine Outfalls into the Great Barrier Reef Marine Park*, which was implemented in 1993. This Policy requires that operators upgrade their sewage treatment plants to tertiary treatment standard (i.e. nutrient removal), as defined in the *Great Barrier Reef Marine Park Regulations* 1983, by 1 March 2002. The GBRMPA sewage discharge policy is currently under review. Latest available sewage treatment technology is likely to produce effluent of an even better quality than currently prescribed by Queensland and Commonwealth legislation.

The GBRMPA's issues with regard to discharges from industrial operations generally relate to the management of water resources on the development site to ensure that any potentially toxic substances are removed and downstream impacts on water quality in the GBRWHA are minimised, and that increased shipping activities and port expansions associated with industrial development and mining activities do not impact on the values of the GBRWHA.

The GBRMPA is addressing the issue of pollutants affecting the water quality entering the GBRWHA through the identification of water quality targets as suggested in the Water Quality Action Plan (GBRMPA 2001) and is working with Queensland agencies responsible for effluent management in the adjacent GBR catchment.

The Queensland and Commonwealth governments are currently jointly drafting a Reef Water Quality Protection Plan (the Plan) for the catchment of the GBRWHA. In August 2002, the Prime Minister and Premier Beattie adopted a Memorandum of Understanding on developing practical actions to improve water quality and reduce impacts on the Great Barrier Reef Marine Park. An Inter-governmental Steering Committee is guiding the development of the Plan based on guidelines included in the MOU.

The Plan will incorporate existing natural resource management (NRM) mechanisms, and use the regional NRM planning process to develop water quality targets and to identify and implement on-ground actions. In addition, the Plan will detail possible actions that can be implemented prior to finalisation and accreditation of the Regional NRM (RNRM) Plans. It is envisaged, that the major component of the funding for these actions will be from NAP and NHT II initiatives.

Queensland regimes

Queensland has approached the management of water quality with regard to point source and non-point source pollution primarily through regulation, planning and assessment instruments. Point source pollution is addressed through the assessment of 'environmentally relevant activities' under the Queensland *Environmental Protection Act 1994* (QEP Act). The QEP Act provides for regulations of point source discharge requirements and facilitates the preparation of industry voluntary codes of practice for non-point source discharges. Point source pollution can also be addressed at a regional or State level by setting water quality objectives and standards for receiving waters under the *Environmental Protection (Water) Policy 1997* (EPW Policy).

The recently released State Coastal Management Plan requires sewage discharges into Queensland coastal waters to achieve appropriate nutrient removal by 2010, for islands by 2005, in areas where nutrients have been identified as being an environmental problem. The GBRMPA has identified in previously noted publications the environmental problem of increased nutrient inputs and –levels in nearshore GBRWHA environments and as such this policy will apply to most sewage treatment facilities servicing population centres adjacent to the Great Barrier Reef World Heritage Area. The operation of sewage treatment plants (greater than 21 equivalent persons capacity) is licensed by the EPA under the QEP Act. Smaller systems are regulated by the Department of Natural Resources and Mines (DNRM) and local government.

Stormwater management is addressed under the EPW Policy. Section 42 of this policy states that local governments must implement an environmental urban stormwater quality management plan that improves stormwater quality to be consistent with the water quality objectives of the receiving waters. These plans should incorporate the principles of water sensitive urban design and ecosystem health and are required to be in place under the EPW

Policy by 2003. In existing areas where retrofitting of a new stormwater system may be cost prohibitive, engineering or “end of pipe” solutions should be considered. The policy requires the cooperative development of water quality standards and objectives and stormwater management plans between local government, industry, and the Environmental Protection Agency, however, this has progressed little in the GBR Catchment.

To date, only one small area in Queensland, Trinity Inlet near Cairns, has developed environmental values, water quality objectives and standards since the legislation was introduced. A recent report on ambient water quality in Trinity Inlet (Sinclair Knight Merz 2001) shows that the guideline values are seriously exceeded. Currently, six of the coastal shires adjoining the GBR coast and seven of the major coastal urban centres are planning to have developed stormwater management plans in 2002.

Local government Planning Schemes for the management of development activities for all Queensland local government areas are presently being prepared under the *Integrated Planning Act 1997* (IP Act). These new Planning Schemes must be finalised by March 2003. The primary goal of this legislation is achievement of ecologically sustainable development. The level of assessment for different types of development is at the discretion of each local government in developing their Planning Scheme except where a development is identified as impact assessable in the IP Act. The new Planning Schemes are fundamentally different from the old schemes as they are 'performance-based' rather than prescriptive plans. There are 21 local government areas, which share coastal boundaries with the GBRWHA, and a further 21 in the Great Barrier Reef catchment. The discretion provided to local government in addressing development activities in their area can lead to significant differences in addressing downstream water quality impacts of coastal developments on the values of the GBRWHA.

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