The Effects of the changes in Agriculture Practices along the Coast of Queensland on The Great Barrier Reef

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ABSTRACT

Agriculture practices, including land clearing and excessive use of fertilisers, along the coast of Queensland on the Great Barrier Reef are generating major environmental problems. The areas of major concern are the adjacent catchment areas along the coast. Some of the catchment areas are subject to constant rain, as is typical of the tropical climate. Flooding events during and after heavy rain result in high run-off, which carries nutrients, sediments and other toxic chemicals into the water ways along the catchment areas, and is eventually deposited into the Great Barrier Reef lagoon. Agriculture practices also result in the disappearance of the wetlands along the catchment areas, which further impacts water quality, resulting in instability of the reef marine community. The scientific community is concerned that unstable marine communities in the Great Barrier Reef will lead to the corals' in-ability to recover after natural disasters such as cyclones. Other developments in and around the neighbouring coastal cities are also contributors to reef pollution.

Government and the tourism agencies, such as the Great Barrier Reef Marine Park Authority, the tourist industry and Queensland Parks and Wildlife Service are currently working together to ensure better preservation and protection of the Great Barrier Reef. One of the outcomes of this working party is the development of the zoning plan for the marine park, which ensures that restrictions are in place in some of the more critical areas, and controls the type and location of activities in the marine park. Local governments, agriculture industries and the farming communities are also implementing some changes in the farming practices to minimise the current pollution input into the reef environment. Encouragement by the local governments to re-use effluents for golf courses and for pasture irrigation has been initiated but much more could still be done to address the current and future impacts of water contamination of the Great Barrier Reef.

KEY WORDS: **agriculture, Australia, crown of thorns, environment, Great Barrier Reef, nutrients, sediments, zoning plan**

INTRODUCTION

Australia has the largest and most diverse area of coral reefs in the world [DEH, 2001]. Research on global reefs reveals that there is a continuing trend of declination of the reefs around the world and a major cause of this is the climate-related coral bleaching events during 1998 [DEH, 2001]. Though the impact of the event in 1998 to Australia was quite minimal, where only around 3% of the reefs were destroyed, other factors such as sediment and nutrient runoff from the land, recreation, fishing, mining of sand and rocks, and crown-of-thorns starfish outbreaks contributed to further reef declination affecting another 1% of Australian reefs. This paper will focus on the Great Barrier Reef in Australia , one of the most famous reefs in the world, having been listed as among the World Heritage Areas and will explore the causes of how this 1% reef declination has occurred.

The Great Barrier Reef (GBR) catchment area, shown in Figure 1, is a very important region that needs to be better managed and controlled in order to ensure that the health of the marine environment is being sustained. There are problems with changes in agriculture practices, which are having a great impact on the coral reefs and the entire marine ecosystem of the GBR. The reef ecosystem and the current agriculture practices around the GBR catchment area have a mutually dependent relationship that cannot be ignored. Scientific research of the GBR in 2002 indicated that land use practices (e.g. land clearing) in the reef catchment region have promoted land degradation, such as soil erosion, which has led to a rapid increase in nutrient and sediment input over pre-1850 levels [Ringrose, 2003]. Land clearing is one of the current common agriculture practices around the area, a practice that can lead to land degradation. Soil erosion is one of the major impacts of land degradation. Application of fertilisers during cropping can lead to increased input of nutrients (Nitrogen and Phosphorus), which can have a devastating effect on the marine ecosystem in the GBR, particularly on the coral reef.

Although terrestrial runoff is a major source of the current environmental problems in the GBR, there are also some other developments and industries, such as aqua-culture, around the GBR catchment area, which affects one of the most important resources in the GBR, namely its water quality. This paper will explore the impacts of the current land use practices, such as land clearing and overgrazing, which promotes soil degradation, run-off, nutrient and sediment input to the GBR. The impacts of these problems on the GBR's marine life (e.g., coral) will also be explored.

THE GREAT BARRIER REEF SETTING

Catchment Region of the Great Barrier Reef

TOPOGRAPHY

The catchment area of the Great Barrier Reef World Heritage Area comprises 424,000 km^2; this area is a major source of the water, nutrients and sediments that are draining into the area [cRcReef, 2001]. The catchment region of the GBR consists of a combination of wet tropic coast and dry catchment area. The GBR catchment has 38 drainage basins, being mainland and large islands. The majority of the catchment areas are relatively small except for the Fitzroy River(142,000

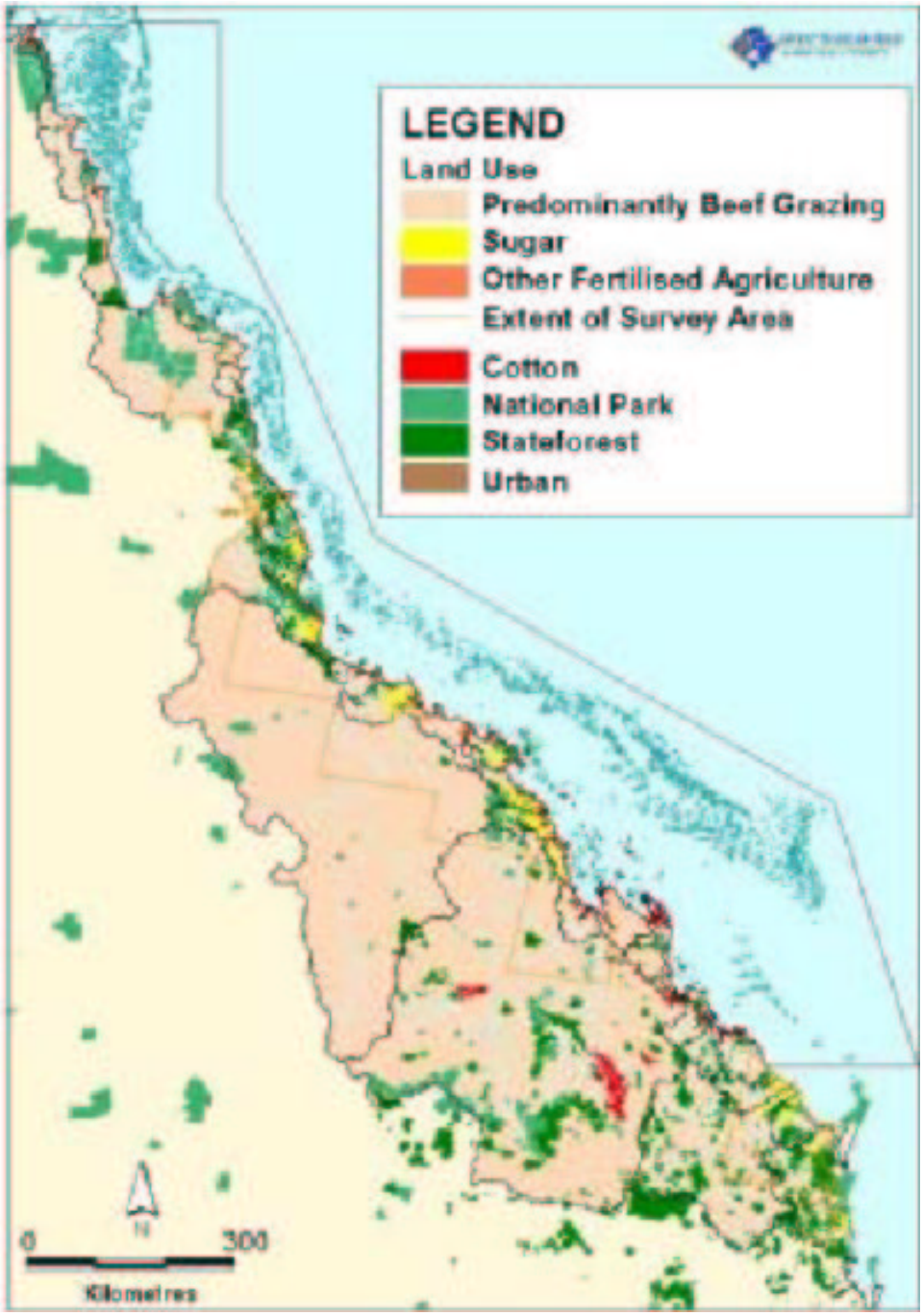

Figure 1. Great Barrier Reef catchment area [Ringrose, 2003]

km^2) and Burdekin (130,000 km^2). These two large catchment areas cover 64% of the GBR catchment area [cRcReef, 2001].

Open-grazing cattle farming occupies more than 75% of the GBR catchment area. These areas are a combination of native and cleared pastures. Sugar cane farms occupy approximately 1% of the GBR catchment and a variety of other crops (cotton, bananas, mangoes, etc) are also grown around the catchment region [cRcReef, 2001].

The population that live around the catchment region is approximately 1 million people, half of which live in the six coastal cities around the GBR region [cRcReef, 2001].

ECOSYSTEM

The marine ecosystem in the GBR World Heritage Area is very diverse. According to the Department of Environmental Heritage [DEH, 2001] it comprises the following:

- six of the world's seven species of marine turtles, along with the largest green turtle breeding area in the world;
- 2000 km^2 of mangroves;
- more than 3000 km^2 of seagrass meadows;
- 2904 coral reefs, built from 359 species of hard coral, and over a third of the world's species of soft coral and sea-pens; and

- more than 1500 species of fish, 1500 species of sponges, 800 species of echinoderms, and over 5000 species of mollusks.

Apparently, large areas of the GBR are currently in a near-pristine condition [DEH, 2001]. The GBR catchment area used to be covered with woodland, grassland and forest during pre-European settlement time. Land clearing of native forests and woodland had been very active since the 1850, due to the development of large grazing areas, other farming and also some mining activities. All these land clearing activities have occurred in the drier region of the catchment [cRcReef, 2001].

WETLANDS

Wetland and riverbank vegetation acts as a natural filtration system that protects the coastal river, estuaries and the shorelines from massive sediment and nutrient deposition during flooding. Filtration of the catchment run-off is very important in order to avoid water contamination in the GBR region.

Impact of Land Use and Agriculture Practices

Land use and changing agriculture practices are causing the greatest environmental threats to the Great Barrier Reef. The changing agriculture practices around the coastal region of the GBR are generating major problems such as run-off, soil erosion and input of a large amount of nutrients, which can lead to coral deaths and outbreaks of algae and other organisms (e.g., Crown of Thorns starfish).

LAND CLEARING

The large dry catchment region, which is composed of grazing lands, is a major source of nitrogen and phosphorus discharge in both dissolved and percolated forms [cRcReef, 2001]. Concerned scientists [Talbot et al, 1998] who studied the GBR World Heritage Area wrote a letter to the Wilderness Society to express their concern regarding land clearing activities adjacent to the Great Barrier Reef Heritage Area for sugar cane farming that resulted to the loss of wetlands, stream and river side vegetation [Talbot et al, 1998]. According to these scientists, this type of agriculture practice has resulted in a loss of 66%-78% of the original ecosystem. Disappearance of wetlands in the region is also affecting the quality of the water and the marine habitat in the GBR World Heritage Area. Agriculture practices such as intensive grazing of cattle is affecting the land surface cover (removal of vegetation cover due to over grazing) which make it susceptible to loss of top soil, which is transported to the river system, resulting in an increase in sediment deposition in the GBR water. The transported sediment contains phosphorus and nitrogen [Talbot et al, 1998].

INTENSIVE FARMING

Intensive farming activities around the coastline of the GBR catchment region are supported by heavy use of fertilisers. The rate of the fertiliser application has increased for the last five decades, and most of this application has occurred in sugar cane farming on the coastal plain. Currently, the approximate annual fertiliser application is around 100,000 tonnes of nitrogen and 20,000 tonnes of phosphorus in the GBR catchment areas. Half of these nitrogen fertilisers are used by sugar cane and other crops for growth, some is consumed for soil fertility and some are lost to either the atmosphere or soil surface run-off and ground water, resulting in an increase in concentration of soluble nitrogen in the waterways. Phosphorus bound to the soil is also carried to the waterways through soil erosion [cRcReef, 2001].

Australia is currently experiencing severe droughts and extreme dryness over grazing is causing a temporary loss of grass cover in large areas of the GBR catchment region. Exposure of land surface through the removal of vegetation, whether by clearing, cultivation, overgrazing or frequent burning will lead to the development of soil degradation, such as soil erosion, as removal of vegetation accelerates soil erosion and loss of nutrients from the land [cRcReef, 2003]. Approximately 85% of the Sediment deposition into the coastline are from the grazing land areas (Bowen river Basin, lower Burdekin) [cRcReef, 2003].

Water Quality

WATER QUALITY IMPACT

The whole marine ecosystem of the Great Barrier Reef is very susceptible to the quality of water. The quality of this water is highly affected by changing agriculture practices and other land use activities around the catchment area of the GBR, including grazing, agriculture, vegetation modification, urban development and aquaculture. Catchment areas adjacent to the Marine Park, such as Fitzroy and Burdekin, which are mainly in the driest part of the catchment, have experienced severe overgrazing and extensive tree clearing during the drought period, which has lead to widespread soil erosion, resulting in the eroded materials, such as sediment and nutrients, affecting water quality. Sugar cane cropping areas also promote soil erosion. Further development will increase the risk of losing more fresh water wetlands, which will reduce quality water. [GBRMPA, 1988].

The Cairns and far north environment centre (Cafnec) (2000) study on the GBR World Heritage Area has highlighted major issues and concerns with the water quality of the area. Goggin's research (2003) suggested the quality of the water of the GBR World Heritage Area is highly affected by the land use practices around the catchment regions of the GBR. This finding was also confirmed by Cafnec. Cafnec (2000) state that the threats to the water quality include:

- increased sedimentation, including from acid sulfate soils, as a result of land clearing;
- reduction in water flows caused by dams;
- increased nutrient inputs from the intensive agriculture industry, with sugar cane and aquaculture being the predominant source;
- discharge of contaminants such as pesticides, exotic organisms and accidental release of genetically modified plant and animal organisms; and

Figure 2. Flood plume from mainland Australia reaches inshore islands and reefs. Photo by GBRMPA from [cRcReef, 2001]

- increasing population and associated population pressures in the coastal zones of Queensland, resulting in effects such as excess physical damage from people traffic, increased discharge of sewage and other waste products.

The degradation of the quality of the water will have a devastating impact on the habitats of the GBR World Heritage Area. According to Cafnec (2000), these impacts include:

- mortality of marine and estuary plants and animals;
- increased stress on reef areas, including coral reefs;
- loss of breeding habitat, including for threatened species;
- increased disease; and
- direct and indirect alteration of ecosystems.

Run-off

The majority of the reef is more than 20 km away from the coast, and at this distance is very rarely affected by the run-off of sediment and nutrients from the land. However, 750 of these reefs are located within 10 km of the Australian coast (in-shore) and are affected by run-off and 209 of these reefs are considered to be at very high risk from run-off, as can be imagined from Figure 2 [Goggin, 2003]. In-shore reefs are constantly subjected to run-off from the land and the level of sediments and nutrients have been steadily increasing for the last one hundred and fifty years. According to Goggin (2003), the level of sediments, nutrients (nitrate and phosphate) and other pollutants have increased four-fold over this time. According to Williams (2000), the estimated increase of sedimentary deposit into the GBR lagoon since the European settlement is approximately 1.6 to 4.1, based on the sediment erosion model. This increase is a direct result of nutrient discharge from agricultural deforestation activities, heavy cultivation during cropping, increasing fertiliser applications and over grazing, in addition to mining.

Williams (2000) stated that the largest external source of nutrients to the GBR World Heritage Area is terrestrial run-off, the approximate estimation is around $70km^3$ of water per year, and recent estimates of run-off has increased in comparison to pre-1800; for phosphorus a 6 to 10 fold increase and for nitrogen a 2 fold increase.

The impact of terrestrial run-off is very hard to detect. These impacts are most likely to be on the coastal island fringing reefs, and on some reef patches in the near shore areas, that is within 20 km of the shore line, from Port Douglas to south of Hinchinbrook island and from Glauchester Island in the north of the Whitsundays to south of Mackay. These areas have approximately 28% of the total number of the near-shore reefs of the GBR. The areas cover 135 km^2, which is approximately 3% of the total near-shore reefs of the GBR. The reef area most affected by terrestrial run-off is in the near-shore waters less than 20m deep [Williams et al, 2000].

Impact of Sediments

Sedimentary deposits can be very devastating on coral, seagrass, and the diverse coral communities that occur in the periodically turbid waters in the near-shore areas of the GBR. While threats to seagrass and coral (in the wet tropics) of being buried by deposition of sediment are unconfirmed, it is an event that is very likely to occur. Changes in the community structure on the reef is likely to happen due to a significant increase in sedimentary deposition, with some coral species (soft bodied, hard corals, zooxanthellate, etc.) disappearing and this will also lead to the depletion of the herbivorous fish and eventually lead to the domination of macroalgae [Williams et al, 2000].

Seagrass beds generally occupy coastal areas susceptible to run-off. The major threat to the seagrasses in this area are through sediment burial, reduction in function caused by herbicide run-off contamination and reduction of light available for photosynthesis due to turbidity.

The increased deposition of nutrient rich sediments, due to terrestrial run-off, is based on the comparison of pre and post European settlement data. The concern about the declination of the building capacity of the near shore coral reefs in the Whitsundays, where the concerned areas are close to the mouths of the Proserpine and O'Connell rivers, is based on community observations in conjunction with field and laboratory experiments. Occasional high levels of nutrient and sediment contamination is also occurring on the near-shore reefs. Flood plumes, which usually only last for hours or days, are currently lasting for three weeks and over large areas away from the river mouth [Williams et al, 2000].

Gradual contamination of nutrients and sediments will promote changes in the community structure on the affected reefs with tolerant species adapting to changing environments. Williams (2000) claims that contaminations are affecting the reproductive system of the corals. Corals' inability to recover after a severe natural disaster is amongst the current main concerns regarding the impact of the land use and the gradual input of nutrients and sediments at the near-shore reefs.

Nutrient Impact

Nutrient requirements of the pelagic and reef communities of the GBR are generated from the biological materials that are recycled. The rivers, rainfall, up-welling from the Coral Sea and from nitrogen fixation of atmospheric nitrogen by the blue-green-alga are all external sources of additional nutrient

input into the GBR system. The growth of phytoplankton and seagrasses appears to be generally affected by the availability of nitrogen rather that by phosphorus or other minerals (e.g. silicate) [Williams et al, 2000].

Increased nutrient levels can destroy the community balance within the reef and promote the growth of the other species such as algae, a problem which could be exacerbated by over fishing of algal eating herbivores. Massive algae growth will over grow the corals and a study by Goggin (2003) indicates the high nutrient levels will promote the survival of certain species such as crown-of-thorns starfish, which will lead to dangerous starfish outbreaks. The seriousness of the run-off issue has resulted in increasing concern amongst the scientific community, which has led to a consensus statement amongst 15 scientists, which states that, "there is continued urgency to work towards a reduction in the run-off of sediments, nutrients, herbicides and other pollutants into the GBR WHA" [Goggin, 2003].

Crown-of-thorns Outbreaks on the Great Barrier Reef

Identification and dating of the spicules from the skeleton of the crown-of-thorns starfish mixed with the old reef sediments has lead to the conclusion that infestations in the GBR have occurred in the last 3,000 to 7,000 years, although dating has proven to be difficult because of the nature of the depositions over time. Therefore it is difficult to speculate if the outbreaks are a new trend or have been occurring as a natural cycle of the GBR ecosystem. Previous outbreaks (between the Whitsundays and Cairns) in 2003 have cost the tourism industry, the Queensland and Commonwealth governments at approximately 3 million dollars a year for management control. Crown-of-thorns starfish outbreaks have been one of the major issues amongst coral reef management over the last 40 years around the world, especially on the GBR and other Indo-Pacific reefs [cRcReef, 2003].

The breeding season of the crown-of-thorns starfish (acanthaster planci) occurs between December and April. Crown-of-thorns starfish feed mainly on tabular coral species (Acropora spp), and it is known to eat only a portion of the entire colony, therefore small numbers can be easily supported by the coral reef without damaging the entire reef population. But large numbers, due to outbreaks will promote huge competition for food, which will lead to the consumption of most types of corals in the reef.

Current understanding of the biology of the crown-of-thorns starfish, nature of the outbreaks and the pattern of the spread shall hopefully lead to better control of crown-of-thorns starfish on the GBR. The crown-of-thorns starfish begins breeding between 2-3 years old and will continue breeding for five to seven years. Sixty million eggs are produced during a single spawning for each individual female, and the larvae prefer low water salinity (as tends to occur after high rainfall) [cRcReef, 2003]. The approximate growth size of the crown-of-thorns starfish within 2 years is between 1cm and 25 cm in diameter. Large crown-of-thorns starfish can be greater than 40cm in diameter. There are many theories on the cause of outbreaks of crown-of-thorns starfish, however the main three theories that are currently supported by the scientific communities are;

1) fluctuation of the crown-of-thorns starfish population are a natural phenomenon;
2) expansion of the crown-of-thorns starfish population is directly related to the removal of predators, and
3) water quality, namely increased nutrient inputs caused by human activities, leads to the increased growth of the coralline algae in the water, providing abundant food to the growing crown-of-thorns starfish larvae [cRcReef, 2003], [Cafnec, 2000].

DISCUSSION

Great Barrier Reef Pollution Sources

The coast line of Queensland at the Great Barrier Reef has been and is still subject to constant change since European settlement. The catchment area of the Great Barrier Reef World Heritage Area consists of 38 drainage basins and is composed of small catchment areas and two large catchment areas.

The catchment area of the GBR has been subject to agriculture and other development over time. Agriculture, being the largest user (75%) of the catchment area, is currently the biggest contributer of pollutants and generators of contamination. Increasing pressures to achieve high productivity and profitability has led to the adoption of different practices (land clearing, high application of fertilisers, etc.) in the agriculture industries. These changes to agriculture practices have created major threats to the environment and to the health of the Great Barrier Reef in-shore ecosystem [GBRMPA, 2003].

Land clearing and open cattle grazing are actively promoting soil degradation around the GBR catchment areas. Soil degradation leads to soil erosion which is the major source of sediment deposition in the water ways. Land based run-off during flooding carries the sediments into the GBR catchment and eventually into the lagoon, creating turbidity problems. Some corals and other organisms in the reef are photosynthetic and high turbidity can have a devastating impact on these organisms. High usage of fertilisers amongst sugar cane farmers around the catchment areas delivers high levels of nutrients to the GBR reef during flood seasons. Like the sediments, increased levels of the nutrients such as Phosphorus result in destruction of some marine organisms. Increased nutrient levels can also promote the growth of some microscopic algae, which become a major food source for growing juvenile crown-of-thorns starfish, resulting in major outbreaks. Crown-of-thorns starfish feed on the massive corals, resulting in further damage to the reef .

Intensive farming in the catchment areas, involving high fertiliser usage, is affecting the quality of water that enters the GBR. Droughts have also resulted in some temporary loss of grass and other vegetation along the catchment areas and this has accelerated the soil erosion process, affecting the quality of the water that enters the catchment area.

Wetlands play a major role in maintaining and protecting the GBR as they improve run-off water quality and flow rates from up stream catchment. Along the coast, they act as filters

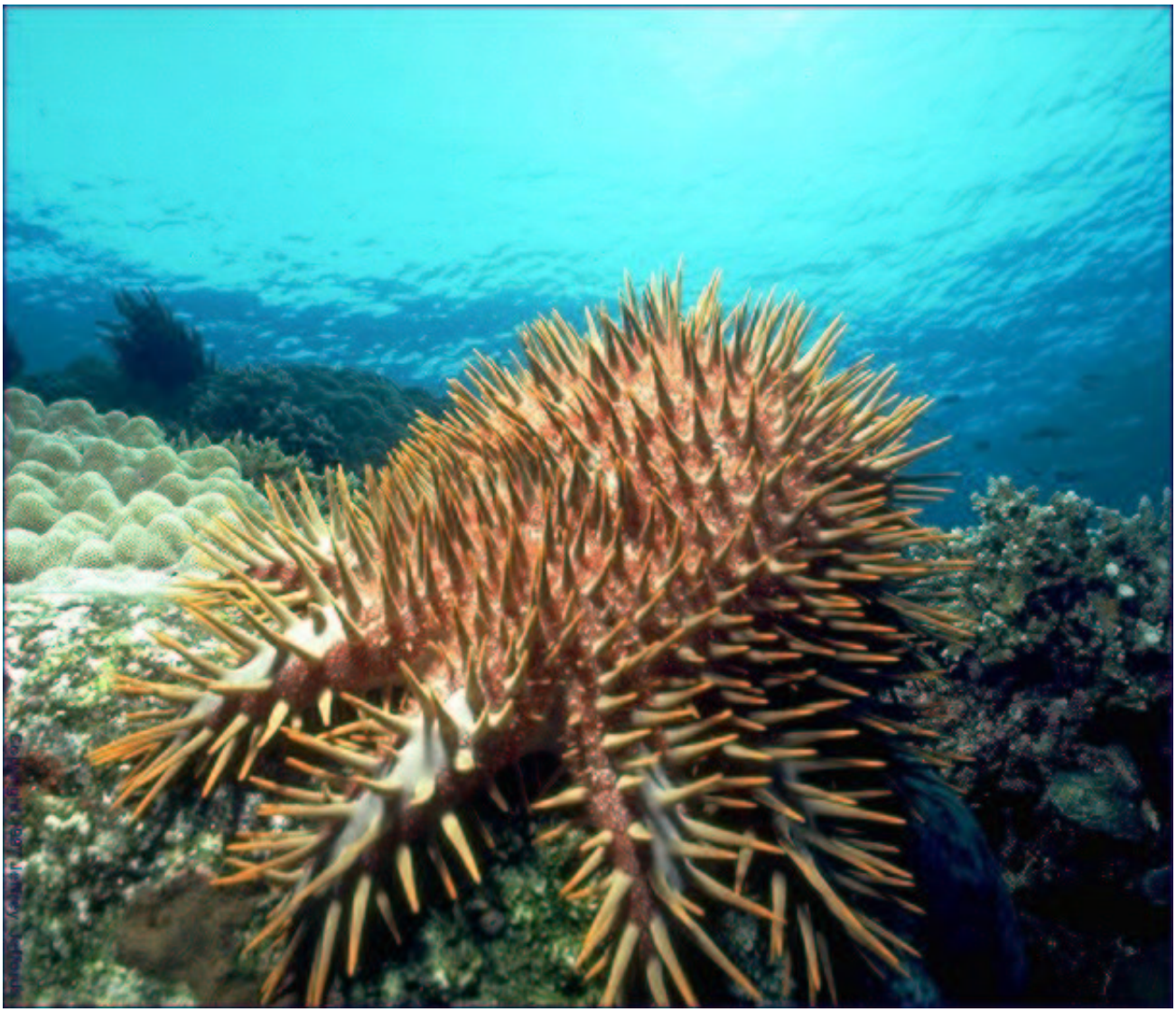

Figure 3. The crown-of-thorns starfish has 10 to 20 arms and grows to over 40 cm in diameter [Gallery III, 2003]

of sediments, nutrients and other toxic compounds by slowing down the speed of run-off, allowing the sediment, nutrients and toxic compounds to settle out of the water before it enters the GBR lagoon [GBRMPA, 1988]. According to GBRMPA (1998), one of the major roles of the wetlands is to act as nursery areas for marine species, maintaining some fishery productivity levels in the Great Barrier Reef.

Issues such as changes to agriculture practices are delivering a huge impact on the Great Barrier Reef marine ecosystem and these issues need to be addressed. Land based activities that are promoting degradation of the water quality that enters the Great Barrier Reef and harming the marine life in the GBR is also a major issue that needs to be addressed.

Further research on the impact of terrestrial run-off (nutrients, sediments, etc.) due to land use in the near-shore area of the GBR World Heritage Area is critically needed. Gradual contamination of nutrients and sediments over time due to land use practices are very difficult of detect in comparison to natural disasters such as cyclones or crown-of-thorns starfish out breaks [Williams, 2001]. This research should proceed as soon as possible in spite of offshore impacts of terrestrial run-off being less of a concern for the management of the GBR at present.

The Great Barrier Reef Pollution Management

Management of Great Barrier Reef Marine Park is controlled by both the Australian Federal Government and the Queensland Government, however it is largely administered by Queensland Government departments such as the Queensland Department of Environmental Heritage and the Queensland Department of Natural Resources. There are a number of protection acts that cover the GBR, although these acts are very limited in their ability to sufficiently protect the GBR and none of these laws have been tested. Large off-shore areas of the Great Barrier Reef, out to approximately 5 km from the coast, are not covered by either Queensland or Commonwealth protection laws. These areas cover almost 40% of the GBR coastline, which are principally affected

by pollutants generated by the mainland agriculture activities through run-off from the adjacent catchment areas. These catchment areas are located outside the boundaries of the World Heritage Area and the Marine Park. Therefore, land based activities along the catchment areas are not controlled or governed under the Great Barrier Reef Marine Park Act 1975 [GBRMPA, 2003].

The other main sources of pollutants, such as sewage and other effluents, are controlled under permit systems through regulation of treating effluents before being discharged into the marine park. This regulation only covers tourist resorts, for example, the Whitsundays. Mainland areas which are composed of large coastal cities, such as Townsville and Cairns, which are indirectly polluting the reef, are not covered by the policy. During the dry season, treated sewage water is the only flow that occurs in many water ways, and eventually flows into the reefs, resulting in algal blooms and anoxia (an example of an affected area is the Trinity Inlet near Cairns) [GBRMPA, 2003].

Local governments are addressing these pollutant issues through the encouragement of different organisations to increase the reuse of the effluents for purposes such as golf course and cattle pasture irrigation. One of the major government initiatives is the implementation of the Integrated Catchment Management Programme, a plan to reduce the run-off of nutrients, pesticides, fertilisers, sediments, and the like. This programme is only one of many land management strategies that has been initiated over the past ten years [GBRMPA, 2003]. The aim of this programme is to manage the land and water resources through coordination between stakeholders. The evolution of farm based management in conjunction with the implementation of industry codes is apparently slowly emerging. Sugar cane trash blanketing is a farm practice that is currently being adopted on a wide spread basis amongst cane farmers. This practice will minimise the exposure of soil surface to rainfall. This land management practice is apparently due to action by the Queensland agricultural industries and the local communities, which resulted a major reduction soil erosion, sediment deposition and nutrient input to the GBR [GBRMPA, 1988].

The Integrated Catchment Management Programme (ICMP) currently applies to local governments and attempts are being made to extend the application of this plan to farming communities [GBRMPA, 2003]. Some of the main components of the ICMP are:

1) Reduction of polluting discharge (e.g. sewage system);
2) Reduction of fertiliser use and changing cultivation practices to minimise sediment deposition from the farming areas;
3) Reduction in animal access to water ways; and
4) Maintaining vegetation coverage in both urban and farming areas.

The GBRMPA, in conjunction with other government agencies and marine tourist industries, are working together to ensure better management of the Great Barrier Reef. This effort has lead to the development of a management tools and processes for the marine park. This management processes will ensures that the impacts of tourism activities on the park environment are minimal. Existing legislation, such as 'Great Barrier Reef Marine Park Act 1975' and 'Queensland Marine Park Act 1990', become a framework and structure for the development of these management tools and processes [GBRMPA, 2003]. One of these management strategies is the establishment of zoning plans, which ensure allocation of access areas for tourists and the type of water activities in the allocated areas of the marine park. This will also ensure that fragile areas are protected.

It is recommend that the Queensland and Commonwealth governments engage in pro-active reversal measures such as the restoration of wetlands at key pollution sources, with a plan to restore 20% of the former wetlands over a five year period. They could achieve this by a combination of farmer subsidy, farmer compensation or, were necessary, compulsory land acquisition.

CONCLUSION

It is very apparent that changes in agriculture practices since the European settlement has been one of the major cause of the degradation of the Great Barrier Reef. Research on the Great Barrier Reef also shows that land based activities such as land clearing and high usage of fertiliser amongst farmers is increasing nutrient and sediment deposition into the GBR resulting coral deaths and crown-of-thorns starfish outbreaks. Commonwealth and state protection laws seem to be currently undergoing active modification in order to address the ongoing issues of pollutant input into the GBR through land based activities. The GBR Marine Park Authority, in conjunction with other government agencies, are trying to ensure that the Great Barrier Reef is being preserved and protected through development of the management tools and processes. One of the outcomes has been the development of the zoning plan. The management of the Great Barrier Reef is hard and complex. Its complexity can only be addressed through sensible management and better protection laws. Commonwealth and state governments, land owners and tourist operators should continue to work together, to maintain and continually improve current management tools and processes in order to ensure the sustainability of the Great Barrier Reef.

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