Staff Papers

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"Don't love me to death". Part 2 : managing impacts of human activity in the Great Barrier Reef Marine Park.

Lecture 2 - Lecture series, School of Biological Sciences, Flinders University, September 1993.

Staff Paper 1993-35

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"DON'T LOVE ME TO DEATH Part 2"

Managing Impacts of Human Activity In The Great Barrier Reef Marine Park

Lecture 2

Lecture Series. Flinders University
School Of Biological Sciences
September 1993

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Lecture Series. Flinders University Adelaide 17 Sept 93

Acknowledgment: Much of the material for this paper comes from: "The Great Barrier Reef - Its Health and Hazards" Graeme Kelleher, Chairman, GBRMPA, and Dr.Wendy Craik, Executive Officer GBRMPA - paper presented to Colloquium and Forum on Global Aspects of Coral Reefs. Sacramento USA July 1992 and "Review of Management of Impacts of Commercial Tourism and Private Recreation in the Great Barrier Reef Marine Park", unpublished report by Dr.Jan Carey, GBRMPA 1993.

Introduction

Tourism and recreational use and the way they were managed were dealt with in the first lecture, so it is left for this second lecture to examine more closely the zoning system and more detail of the impact of human use on the biological systems. Both ecological and amenity impacts are discussed along with the management method currently applied, and options for future management are indicated as well (see Table 1). This brief paper can only expose the tip of the future options "iceberg" but the Authority is taking a very detailed look at how it can improve management so that the future of the Reef can be assured.

Managing The Great Barrier Reef Marine Park

The Great Barrier Reef began to figure in the Australian conscience in the 1960's when concern about limestone mining and oil drilling on the Great Barrier Reef generated two Royal Commissions, which were followed in 1975 by the passage through Federal Parliament of the Great Barrier Reef Marine Park Act, supported by all political parties.

The Great Barrier Reef Marine Park Act was one of the first pieces of legislation in the world to apply the concept of ecologically sustainable development to the management of a large natural area.

The **objective** of the Great Barrier Reef Marine Park Act is the conservation of the Great Barrier Reef. The Act established the Great Barrier Reef Marine Park Authority (the Authority). The Great Barrier Reef Marine Park Authority has derived a primary goal and a set of aims from the provisions of the Act and recognition of the political, legal, economic, sociological and ecological environment in which it operates. These were detailed in Lecture 1.

Zoning

As described earlier, zoning, education, and the environmental impact assessment syatem and permits are the principal tools the GBRMPA uses to manage the Marine Park. Zoning plans generally have three broad types of zones, the names of which reflect the kinds and levels of human use that are permitted within them:

General Use Zones	-	most human activities (other than mining) are permitted, at levels which are ecologically sustainable
National Park Zones	-	activities are permitted which do not remove living resources, or which remove only small quantities
Preservation or Scientific Research Zones	-	scientific research is the only activity allowed

Management of the GBR Region is characterised by a great degree of cooperation between Queensland State agencies and the Federal Government.
Under a unique State-Federal agreement in relation to management of the Great Barrier Reef, zoning plans for the different jurisdictions are developed simultaneously and to be complementary. At a more localised scale, reef and island management plans are also being jointly developed for areas of high use and for high conservation value.

The objectives to be considered in developing a zoning plan are set out in the Great Barrier Reef Marine Park Act. They are:

(a) the conservation of the Great Barrier Reef;
(b) the regulation of the use of the Great Barrier Reef so as to protect the Great Barrier Reef while allowing the reasonable use of the Great Barrier Reef Region;
(c) the regulation of activities that exploit the resources of the Great Barrier Reef Region so as to minimise the effect of those activities on the Great Barrier Reef;
(d) the reservation of some areas of the Great Barrier Reef for its appreciation and enjoyment by the public; and
(e) the preservation of some areas of the Great Barrier Reef in its natural state undisturbed by man except for the purposes of scientific research.

Policy guidance developed by the Authority is also taken into account in drawing up a zoning plan; for example: the zoning plan should be as simple as practicable and the plan should minimise regulation of and interference in human activities, consistent with the goal of the Marine Park Authority.

In determining the areas which are zoned in particular ways in the development of zoning plans, many considerations are taken into account. These considerations include:

- the precautionary principle eg the unknown effects of trawling on non target species and the environment
- reducing conflicts between users eg spearfishing and diving
- recognition of existing uses by all user groups (Craik, 1992).

In early zoning plans (1980), individual reefs were generally used as the zoning unit and an attempt was made to ensure a reasonable spread of closed and open reefs to all users, consistent with conservation, (GBRMPA 1983). In more recent zoning plans, an attempt has been made to encompass larger areas as the zoning unit, and two sizeable cross shelf transects free from all fishing were established as reference and conservation areas. (GBRMPA, 1985).

"Sink" and "Source" Reefs

In planning to conserve resources in the Great Barrier Reef Marine Park, consideration has been given to the fact that many coral reef organisms, including the vast majority of fishes, produce pelagic larvae which may be carried some distance from their **"source" reef** before settling on a **"sink" reef**. Resilience to exploitation is in part a function of available recruits, i.e. good "sinks" may be better able to withstand exploitation and good "sources" may be valuable to protect on the basis of their connectivity to targeted reefs. James et al. (1990) suggested that reefs in the northern half of the Cairns Section may form a partially closed self-recruiting system from which populations to the south are maintained by larvae dispersal. An effort was made to ensure that a connected set of reefs with protective zoning stretched throughout the Cairns Section when it was being rezoned. A larval dispersal model was applied to evaluate the effectiveness of 46 reefs. The simulation of larval dispersal is based on a numerical hydrodynamic model representing tides, wind driven flows and the East Australian current. Analyses were carried out for larvae with a long precompetent period (14 days) followed by a 14 day competent period, and for larvae exhibition and a 4 day precompetent period followed by a 14 day competent period.

These analyses enabled the identification of good "source" reefs which export larvae to a large number of sink reefs and those where the probability is high and good "sink" reefs which receive a large number of larvae and the chances of connectivity is good (James et al. 1990). Preliminary visual censuses of these reefs have been undertaken prior to the introduction of the revised Cairns zoning plan. It will be interesting to see the results of closures at "good" sink and source reefs relative to "poor" sink and source reefs in the future (James 1989, James et al. 1990).

ECOLOGICAL IMPACTS

Stresses on coral reefs have been typified as "acute," such as violent storms, freshwater flooding and crown-of-thorns infestation, or "chronic," such as regular sediment or sewage input, or the effects of tourism (Kinsey, 1988). Reefs recover rapidly from an acute impact when it is the only stress, and they can withstand chronic stress for an extended period. Chronic stresses can prevent normal recovery from the damage of an acute stress.

Kinsey (1988) cited the tourism operations on Heron Island as an example of chronic stress withstood by the reef system for a long period. The acute stress of crown-of-thorns on John Brewer Reef in 1970 was, in the absence of any chronic stress, followed by rapid recovery. Green Island, however, experienced the chronic stresses of tourism activity, petroleum products from boat traffic, localised sewage discharge together with the acute stress of crown-of-thorns in combination in the 1960s and 1980s. Seagrasses and algae have taken over the reef flats. Only very limited coral recovery has occurred (Baldwin, 1990).

The impacts of acute and chronic stresses can be managed to remove or reduce their effects. Tourist program operators tend to attribute impacts to reef corals and fish to recreational users exclusively, claiming that they themselves have an interest in protecting and maintaining sites because their livelihood depends on it. Recreational users in turn blame the high levels of tourism use for causing impacts. Discussions with management staff suggest the effects of use of the two groups do not differ greatly, and that both are responsible for impacts.

Water Quality

There is general agreement in the scientific community that the quality of coastal reef ecosystems has deteriorated, and in particular that there are high levels of nutrients in inshore waters and some localised areas may be reaching an undesirable threshold (Baldwin, 1988). The causes of the deterioration are probably many, and it is an issue that is difficult to tackle because the changes are gradual and involve both land- and water- based activities. The major concerns at present are not pesticides; to date, levels of these are generally low enough to not be of major concern. **What is of concern is increasing levels of nutrients coming into the system - particularly nitrogen and phosphorus.** High levels of phosphorus are correlated with increasing porosity of the coral skeletons and this phenomenon appears to have been observed at Low Island and Green Island (Rasmussen, 1986; 1988). High levels of nitrogen can lead to increases in the standing crops of plankton and attached algae, competing successfully with corals for light and nutrients. Planktonic algae increases sedimentation and benthic filter feeders increase in numbers, providing another stress to the coral reef.

While "normal" nutrient levels of the Great Barrier Reef are not well understood and reefs can survive elevated levels of nutrients for periods of time, concentration of nitrogen higher than those which have caused problems in other parts of the world have been observed, and high levels of nitrogen in the Great Barrier Reef Aquarium have been correlated with coral death in the Aquarium.

The other aspect of water quality which is of particular concern is that of **water clarity**; increased silt and sediment in the water reduce light penetration which affects coral health, and increased settling of sediment on coral, (if greater than the corals can remove or tolerate), can smother and cause the death of coral. Nearshore reefs are obviously most at risk - they occur in highly turbid, higher nutrient waters and added loads of these factors may mean that in the event of a crown-of-thorns starfish attack, or prolonged exposure to fresh water or some other assault, their capacity to recover may be severely reduced - Green Island Reef may be such a case. It is the synergistic effect of multiple impacts that may be the most difficult to comprehend and remedy, and yet the most insidious and serious.

The Authority accepts the problem of the effects of nutrient runoff as its major scientific priority. We believe that there is a serious risk of misinterpretation of the real facts if the investigations are not carried out on an adequate time and spatial scale in adequate detail. In further recognition of the need to resolve this issue, the Queensland Minister for Primary Industries created a Catchment Management Co-ordinating Committee, which has a sub-committee that specifically considers the down stream effects of agricultural practice. These committees, with memberships representing all relevant private and public sector bodies, will advise the Minister, among other matters, on relevant research requirements.

Management of water quality within the Great Barrier Reef Marine Park itself relates to **sewage discharges**, for which a Great Barrier Reef Marine Park Authority permit is required. The Great Barrier Reef Marine Park Authority has decided that all existing sewage systems must have effluent discharge pipes which, by the end of 1992, conform acceptably to a minium requirement to extend 200m beyond the shore-line (the reef edge where adjacent fringing reef exists) and to a minimum water depth of 10m. Further, within five years, all material discharged directly into the Park, will be required to be treated to tertiary standard involving nutrient removal. Any *new* operator is required to meet all these standards immediately, before permission to operate is issued. It is important, however, to stress that the control measures mentioned above will be of significant benefit only in the vicinity of the relatively small outfalls involved. Clearly, the major contributors to any general anthropogenic nutrient build-up which may be found in the GBR lagoon as a whole will be urban sewage and land-use practices on the Australian mainland.

Sewage Discharge from Outfalls

Eutrophication and reef damage from increases in the levels of nutrients are known from localised sites at sewage outfalls, e.g. at Green Island. A permit is required for waste discharge into the Marine Park. Applications are considered on a site-specific basis, taking into account the nearness of environmentally sensitive sites, hydrodynamics, ambient water quality and the condition of any sensitive communities of organisms.

Approval of effluent discharge standards is required from GBRMPA and QDEH and (in most cases) the relevant City or Shire Council. The updated Guidelines for Sewage Discharges into the Great Barrier Reef Marine Park (GBRMPA, January 1991) place a strong emphasis on nutrient removal to protect the coral environment. Sewage treatment facilities are now required to involve secondary treatment and be capable of upgrading to tertiary treatment (nutrient removal) by 1995.

A secondary sewage treatment plant was installed at Hayman Island in 1981. Treated sewage is used for irrigation to the some extent but during the wet season more than 60% of the effluent is discharged at sea. There was significantly less coral and fish diversity and abundance in the vicinity of the sewage discharge, compared to control sites (Steven and Van Woesik, 1990).

The standard of wastewater treatment and disposal at Green Island have been upgraded to meet the requirements of the Authority and to cater for the proposed redevelopment of the island. Day tripper facilities for a maximum of 1900 persons per day and overnight accommodation for a maximum of 90 guests are proposed. An environmental impact assessment was carried out (Gutteridge Haskins Davey, September 1991). Effluent standards and effluent discharge requirements for Green Island were agreed by the relevant authorities and a process was designed to meet the stringent standards and implement the GBRMPA Guidelines.

Treated effluent will be discharged via a deep water ocean outfall. The route and discharge point location were determined according to the hydrodynamic characteristics of the island, to minimise disturbance and any effects on recreational activities and coral. Treated effluent will be re-used in toilet flushing, fire fighting and irrigation (in areas isolated from the groundwater system). Ocean dumping of the sludge and land disposal were rejected in favour of transferring it to the mainland for disposal into the council sewerage system , with subsequent treatment and disposal at the council's water pollution control plants (Gersekowski, 1992).

In recognition of the problem the Federal Government has given GBRMPA over $A2 million for research into the question of nutrients. This has enabled the establishment of a **Water Quality Program** which aims to address the following broad questions:

- What are the present levels of nutrients in various parts of the GBRMP?
- What trends are observable in nutrient levels in the GBRMP?
- What are the effects of elevated nutrient levels on coral reef and seagrass communities.
- Are the effects of elevated nutrient levels (known and quantified from overseas experience) detectable in the GBRMP?
- How much of the observed changes in nutrient levels and reef degradation is due to human influence and how much to natural change?
- Are there elevated levels to other toxic and persistent chemicals in Marine Park waters, and if so, are they likely to be having an adverse effect on GBR ecosystems?

The Program has monitoring, regulatory/management and research components. The **monitoring component** is integrated with the Authority's general monitoring program covering long term biological and physical monitoring and this program is, in turn, integrated with the expanding reef wide monitoring of the Australian Institute of Marine Science, Townsville. The water quality monitoring program involves repeated measurements of water quality parameters, directed primarily at nutrient processes, at a large number of sites in both the water column and sediment phases. There is a concentration of sites at what are believed to be critical areas e.g. off Cairns and in the Whitsundays Islands, and completing monitoring under the Crown-of-Thorns Starfish Research Program, which will concentrate in the area to the north of Cairns where previous primary outbreaks are believed to have started. Some coordination of the Monitoring program with research programs in selected areas will be possible. One-off "snapshot" surveys of selected contaminants such as TBT and organochlorines will be included in the monitoring component.

The **regulatory/management component** of the program will continue to work to upgrade sewage disposal systems into the Park; cooperate with state authorities on sewage discharges, land management and coastal development; and manage developer-funded monitoring programs for specific water quality impacts of various developments.

The **research component** of the program consists of a large number of individual projects which mostly fall into the following categories:

- Experimental enhancement of nutrients;
- Estuarine and river plume nutrient dynamics;
- Nutrient fluxes, budgets, dynamics;
- Historical records, sediment and coral cores, terrestrial marker chemicals;
- Correlation of water column nutrients and benthic conditions;
- Sewage impact studies;
- Landuse and nutrient runoff studies; and
- Other toxic and persistent materials.

Oil Pollution

Shipping incidents such as collisions and groundings that result in oil spills are a threat to the Great Barrier Reef. Minor fuel spills and leaks and oily bilgewaters from vessels can also cause environmental harm through the accumulation of hydrocarbons and toxic additives in marine sediments, especially in semi-enclosed waters such as port areas and marina basins or calm shallow areas where personal watercraft (jet skis, water scooters) are used. Marine pollution legislation makes large and small spills of oil and oily mixtures an offence in Australian waters.

We have been remarkably fortunate in escaping a large oil spill in the Great Barrier Reef Region. In 1970 the *Oceanic Grandeur* grounded in Torres Strait spilling an estimated 1400 to 4000 tonnes of oil and this event generated considerable public concern over oil spills in the Great Barrier Reef (Queensland Department of Harbours and Marine, 1970). At that time there was also active discussion of oil exploration in the vicinity of the Great Barrier Reef. Together they generated significant public anxiety because of the belief at that time that coral reef ecosystems were fragile (Connel, 1974; Harrison et al 1992.). Although the threat of oil drilling has been removed from within the Great Barrier Reef Marine Park by the Great Barrier Reef Marine Park Authority Act and regulations, it has recently been suggested that drilling may be considered in the adjacent Coral Sea.

The current major treat of an oil spill comes from ships. The major shipping route through the Great Barrier Reef Region bisects the main group of reefs and the coastline and is known as the inner route. There are also a number of passages from the Coral Sea into the inner route. The inner route is an historic trading route between the Eastern Indian Ocean and the Southwest Pacific. The most important cargo carried through the Great Barrier Reef is bauxite from Weipa to Gladstone, and the coal export trade from central Queensland ports. Coal-fired bulk carriers of about 70,000 dwt are used in the bauxite trade, while coal is carried in vessels up to 139,000 dwt. Although the carriage of general cargo to Queensland and Papua New Guinea gulf ports has declined, the distribution of petroleum products by sea has increased. Refined products, principally from Brisbane Refineries, are distributed by sea to other Queensland ports. Refined products carriers transitting the Great Barrier Reef are commonly in the 25,000- to 35,000- dwt range.

Crude oil and fuel oil cargoes carried through the Great Barrier Reef are destined for Cairns, Townsville and Brisbane. Oil tankers transitting the Great Barrier Reef Region can range in size up to about 100,000 dwt. In the longer term it is possible that the development of oil shale resources may result in larger tankers shipping oil from the Central Queensland coast through the Great Barrier Reef. About 2,000 vessels pass through the Great Barrier Reef each year. About 200 are tankers carrying oil, chemicals or molasses.

With the declaration by the International Maritime Organisation of the Great Barrier Reef Region as a Particularly Sensitive Area in 1990, the Federal Government passed an amendment in 1991 to the Great Barrier Reef Marine Park Act which requires all vessels over 70 metres and all tankers regardless of size to take on a qualified pilot when travelling the inner route between Torres Strait and the area north of Cairns or Hydrographer's Passage. This should reduce the incidence of groundings in the Great Barrier Reef Region.

Suggestions have been made that shipping should be forced to travel outside the Great Barrier Reef Region in the Coral Sea i.e. in what is known as the "Outer Route".

There are some good arguments against the use of the Outer Route, including the following:

- the Coral Sea is largely unsurveyed;
- few navigational aids exist in the Coral Sea;
- prevailing south east winds would blow any spill onto the Great Barrier Reef;
- the waters of the inner route are relatively calm compared with the swells and storms of the Coral Sea. The prospects of a vessel "breaking up" outside the Reef are far greater than inside the Reef;
- clean-up logistics would be even more difficult outside the Reef; and
- over 80 per cent of vessels using the Inner Route are bound for Queensland ports north of Brisbane. The Outer Routes via Port Moresby, in Papua New Guinea, is approximately 230 miles longer than the Inner Route.

Two major oil companies have instructed their vessels to proceed via the Outer Route. These vessels still engage a pilot in Torres Strait.

GBRMPA is planning to have a relative risk anaylsis of these routes undertaken to assist in resolving this question.

In 1984 the Great Barrier Reef Marine Park Authority requested the then Federal Department of Transport and Communications, as part of its responsibilities under the Australian National Plan to Combat Pollution of the Sea by Oil, to draw up an **Oil Spill Contingency Plan** for the Great Barrier Reef. This contingency plan, **REEFPLAN**, came into effect in March 1987. The specific aims and objectives of REEFPLAN are as follows:

- To provide guidelines for an efficient, co-ordinated and effective response to all pollution incidents in the marine environment.
- To provide guidelines for systematic planning in an effort to minimise potential damage from oil spills.
- To develop guidelines within the framework of the National Plan for cooperation between the Commonwealth and Queensland governments and other authorities in the operational aspects of oil spill surveillance and response (DOTC, 1989).

The amount of equipment available to clean up a spill in the Great Barrier Reef Region is obviously limited e.g. only 5km of boom is immediately available in Queensland. The Region extends 2,000 kilometres and covers some relatively remote areas away from major centres of population. The major equipment centre adjacent to the Region is in Townsville. The nearest major equipment base is in Brisbane. Under National Plan arrangements, equipment from other Australian states can be brought into play if it is required, but obviously significant time lags may occur. The oil industry has recently established a new $A10m response centre in Victoria. International arrangements now provide that equipment from other countries can be called on if required.

The Australian National Plan as it now stands is designed to deal with spills up to 10,000 tonnes. If a large spill occurred in the outer Great Barrier Reef, access would be difficult as parts of this area is some 200 kilometres offshore. The difficulty of getting equipment on site to respond effectively is almost insurmountable. It is most likely that, depending on prevailing conditions, little could be done until the oil approached the mainland. A similar response would be likely if a spill occurred off Cape York, in the northern Great Barrier Reef. As the prevailing winds in the Great Barrier Reef Region are generally from the southeast, and less frequently from the northeast, a spill is likely to move towards the shore. Again, particularly in such remote areas, it is very likely that little could be done until the spill approached the mainland. Even then, the effectiveness of booms in strong winds is limited, and, because the spill will have dispersed considerably, the effectiveness of a response close to the shore would probably be very limited. The likelihood of doing anything useful to a spill of 1000 tonnes spreading oil from a grounded tanker in 30 knot winds, 20 km from the mainland is remote.

An effective response is more likely near the major centres of population such as Cairns, Townsville, Mackay and Whitsunday Islands, where resources and infrastructure are much greater. However, since the total population adjacent to the Great Barrier Reef Region is probably less than 400,000 and the nearest major centre, Brisbane, has a population of only about one million, it is difficult to see how an intensive response could be implemented very rapidly. Again, containment equipment is likely to be of limited effectiveness in bad weather, wherever a spill occurs. A recent spill in the Townsville harbour of only 1-2 tonnes utilised all available clean-up equipment in the vicinity.

On the basis of available equipment and infrastructure, it must be concluded that for a small spill in an accessible area, defensive booming to deflect of oil from a few sensitive areas, possible aerial application of dispersant in appropriate areas, and some limited bird cleaning (if required) would be about the likely extent of a possible active response. A large spill or a spill in a remote area would be impossible to combat effectively.

GBRMPA's focus is very much on prevention and recently convened a workshop to identify and recommend measures to enhance prevention, eg. tanker design considerations, operational issues and navigation issues.

Crown-of-Thorns Starfish

1. The crown-of-thorns starfish (*Acanthaster planci*) phenomenon remains one of the Authority's most controversial issues. In 1989 an independent review of the conduct of the crown-of-thorns starfish research program as well (as GBRMPA's policy of controlling starfish numbers only in small areas of special scientific or tourist interest), was undertaken by Professor Don Anderson, Challis Professor of Biology at the University of Sydney. He concluded that the policy of limited intervention was soundly based and that while local control techniques (injection of poison) are available and effective, large-scale control or eradication was impracticable and unaffordable. Professor Anderson also made a number of recommendations to improve the operation of the program and he suggested some areas of research that required additional emphasis. He recommended the research program be continued for another 3-5 years at a dedicated and committed funding level of at least $A1million a year.

As a result of the review, the Federal Government allocated $2.75 million for the research program over a three year period (1989/90 - 1991/92). All research is supervised by the research program co-ordinator appointed by the GBRMPA. The program focuses strongly on discovering possible influences of human activities on crown-of-thorns starfish outbreaks. A number of projects funded through the previous research program were continued and several new, major projects were commenced to address Professor Anderson's recommendations. A large proportion of the budget has been allocated to projects investigating the possible **role of predation** in controlling outbreaks. These include **computer modelling** studies to determine the biological and ecological characteristics a predator needs to display in order to control crown-of-thorns starfish populations; an investigation of some of the fish species that are likely to be **significant predators** of the starfish; a field study of predation on early life history stages of A. planci; and **a survey of marine scientists** to find out what predators have been seen eating crown-of-thorns starfish and how often predation occurs. Other major research areas are - broadscale surveys; starfish ageing; reproduction studies; dispersal of crown-of-thorns starfish larvae between reefs; larval nutrition; and coral recovery following outbreaks.

Earlier suggestions that evidence of outbreaks may be found by sorting through sediments around reefs have not been fully confirmed. Because there is still no evidence that crown-of-thorns starfish die on reefs *en masse* at the end of outbreaks (or alternatively, move off the reef to search for more food), it cannot be assumed that large numbers of starfish remains found in sands represent outbreaks. There are some reefs on the Great Barrier Reef that have quite high 'normal' populations of crown-of-thorns starfish that appear capable of existing for a long time without having a widespread detrimental effect on the reef. Burrowing animals in reef sands have also confused the picture by mixing ancient and recent sediments. This mixing of sediments means that no clear relationship exists at many sites between depth in the sediment and age. Perhaps the major problem with this research is that techniques are not available to enable accurate measurement of the age of starfish remains. Until the age of remains can be determined to within 10-20 years (the interval between outbreaks over the last 30 years), we cannot be certain whether or not outbreaks are now more frequent or more intense than they have been in the past. **Even if outbreaks are natural, it is possible that human activities exacerbated the situation.** The GBRMPA still believes that the answers lie in research. We have come a long way in understanding the crown-of-thorns starfish phenomenon over the past 5 years, **but the ultimate question of the role of human activities in causing outbreaks remains unanswered.**

The broadscale surveys undertaken by the Australian Institute of Marine Science of approximately 150 reefs (surveyed each year throughout the Marine Park) are to determine the broad distribution and abundance of the starfish and its effects of the Reef system. To date, a total of 377 reefs have been surveyed using the manta tow technique.
The results of the surveys can be summarised as follows:

- The estimated percentage of reefs which have experienced outbreaks in the last 10 years over the entire Great Barrier Reef is between 17% and 21%.
- The number of reefs currently affected by outbreaking populations of crown-of-thorns starfish has declined to about 3% over 1991. These are mostly between Townsville and Bowen.
- Outbreaks have mainly occurred on reefs in the central third of the Reef, between Lizard Island and Townsville. Many of these are in an early stage of recovery.
- The proportion of reefs with outbreaks in the Townsville region has steadily declined over the last few years (75% in 1985/86 to 33% in 1990/91). In contrast, this proportion initially increased on reefs immediately to the south off Cape Upstart (5% in 1986 to 37% in 1990), but then decreased over the last year (20%).

- These data suggest a southward moving wave of outbreaks which began in the region between Cairns and Cooktown towards the end of the 1970's.
- Almost 20% of the reefs surveyed with outbreaks were considered to be seriously affected (i.e. the average level of dead coral cover was greater than 30%).
- Outbreaks of crown-of-thorns starfish produce an estimated 11% increase on average in the cover of dead coral on reefs. (Moran, 1992).

A major breakthrough confirming some theories about the spread of crown-of-thorns starfish outbreaks came through **computer modelling** of the movement of larvae. The models show that water currents alone can provide an explanation for the southward movement of crown-of-thorns starfish populations and why particular reefs are more likely to have larger populations than others.

The models provide a large-scale picture of water currents and the movement of larvae between reefs, and also suggest explanations for the observed patterns of outbreaks. In the northern region behind the ribbon reefs the water currents provide a physical environment which allows populations to spread from reef to reef within the same region and to be maintained indefinitely by the movement of larvae. This is quite different to the central region south of Cairns where the water currents mostly transport larvae southwards and towards the coast. Here, populations of starfish on reefs rely on replenishment of juveniles by larval transport from reefs to the north. For as yet unknown reasons, populations of starfish in the northern region behind the ribbon reefs apparently build up and, from time to time, spread southwards to the reefs off Cairns, Innisfail and Townsville. By the time the populations reach the reefs off Cape Upstart, the water currents appear to carry most larvae away from any reefs where they can grow to adults, and they simply die (Dight, 1992).

TABLE 1 Impacts of Commercial Tourist Programs and Private Recreation
Source: QDEH

User Group	Activity	Ecological Impact	Amenity Impact
Group 1 - Mutually compatible activities			
Both	Swimming	low	low
Both	Snorkelling	low	low
Both	Diving - SCUBA	low	low
Commercial	- SNUBA	low	low
Commercial	- Resort	moderate	low
Commercial	- Tunnel	low	low
Both	Reef Walking	moderate	low
Group 2 - Compatible with low levels of Group 1 activities - mutually compatible			
Private Recreation	Collecting - Shell	low	low
Commercial	Collecting - Shell	low to moderate	low to moderate
	- Coral	low to moderate	low to moderate
	- Fish	low to moderate	low to moderate
Both	Wilderness Cruising	low	low
Both	Whalewatching	low?	low
Both	Photography	low	low
Group 3 - Require spatial separation from Group 1 and each other			
Both	Windsurfing	low	low
Commercial	Fish Feeding	moderate	low

TABLE 1 (cont)

User Group	Activity	Ecological Impact	Amenity Impact
Both	Fishing - Line	not known	low
Both	- Spear	not known	moderate
Commercial	Glass Bottomed Boat	low	moderate
Commercial	Semi-submersible	moderate	moderate
Group 4 -	*Incompatible with Groups 1-3 unless spatially and /or temporally separated*		
Both	Water Skiing	low	high
Both	Manta-boarding	low	high
Commercial	Para-flying	low	high
Commercial	Aircraft Joyrides	low to high	high
Commercial	Boom-netting	low	moderate to high
Commercial	Sausage-riding	low	moderate to high
Both	Trolling	low	low to moderate
Both	Parties/Functions	low	moderate to high
Group 5 -	*Compatible with all other groups providing spatially separated for safety*		
Both	Anchoring	low to high	low to high
Both	Mooring	low	low

Notes: Ratings subjective, representing most likely impact if conducted according to Marine Park requirements. In general, impact will increase according to number of people engaged in activity, but may vary if conducted in different places or in specific ways, e.g. intensive fishing for one species could raise the ecological impact rating.

Site Impacts from Structures, Moorings and Anchoring

Tourist operations may involve the installation of man-made structures (day-trip pontoon, floating hotel) or structures partially in or on the seabed (underwater observatory, jetty, marina berths, moorings). The impacts of construction typically include increased stress on corals and other organisms from direct sediment smothering, increased suspended sediments and reduced light penetration, the effects of changes in water quality especially from increased nutrients and oil pollution, physical damage from the use of machinery and explosives, shading effects, etc. Some of these impacts may be slow to show adverse effects on the reef structure, but can have severe effects over a longer time period.

Through the permit assessment process, potential impacts are either removed from the proposal or reduced by negotiation or prohibition of certain activities (such as the use of antifoulings). Ecological impacts of pontoons and other structures are monitored through operator-funded monitoring programs to confirm that the operations are ecologically sustainable in the short and long term (Woodley, 1992).

A constraint upon reef use is the limited area of suitable anchorage. At many reefs areas with suitable water depth and protection from swell are quite small. Pontoons are currently popular and widespread facilities on the reefs, operating as a base for day trip passengers. Pontoons arguably reduce visitor pressures. On a vessel carrying 250-300 people on a Reef tour, probably less than a quarter of the visitors actually enter the water, being content to have the cruise out and do a semi-submersible or glass-bottomed boat trip, according to the Association of Marine Park Tourism Operators (Senate Standing Committee, 1992).

Impacts associated with the placement of pontoons include coral damage while manouevering the pontoon or damage by anchor chains abrasion. Shading effects on corals and other organisms occur over a larger area than the pontoon itself as the sun's angle changes. Fish are attracted to the pontoon, which may result in local changes to the fish community, particularly in relation to predators. The restriction of flow underneath the pontoon can allow sediment accumulation which may adversely affect corals

A walkway was designed for Wistari Reef to improve visitor safety and prevent coral damage by the small craft used for access, and a monitoring program commenced as a permit condition. The walkway and pontoon were subsequently removed. The pontoon had attracted a large number and diversity of fish. A month after the removal of the pontoon, and following the passage of a cyclone, fish numbers and diversity at the site had returned to pre-installation levels (Fisheries Research Consultants (1992).

Anchor damage was identified as a problem by tourism operators at all workshops held by the Authority. To prevent coral breakage due to anchoring, Marine park policy in the offshore Cairns area is that operator-funded vessel moorings are required for vessels that access a particular site more often than twice a week. Moorings may also be required as a permit condition at particularly sensitive sites. Coral damage can be caused by dragging chains and incorrectly sited moorings and sites may be required to be monitored until impacts have stabilised.

Few operators are willing to incur the expense of installing moorings unless they have a reasonably viable operation to one or a few sites. Roving operators and recreational users use the existing moorings or continue to anchor at some prime sites, causing coral damage and site use conflicts

Public moorings are planned to be installed by GBRMPA as funds allow. Their installation and upkeep are costly. The fact that recreational users will not contribute to their costs in the same way as commercial operators is likely to be a source of resentment.

Coral Damage from Diving and Reef Walking

Coral breakage underwater at regularly used sites is a constant problem. Swimmers, snorkellers and divers, especially inexperienced ones, tend to break and damage coral with feet, hands and flippers when orienting themselves, resting or clearing their masks. "Resort diving" can cause problems at specific sites because of the high numbers engaged in this activity. One major dive company conducts some tens of thousands of dives a year at a single reef. The Authority has distributed an educational video titled *"Pardon My Bubbles"* on the subject of diver/snorkeller damage to corals. Many dive operators are aware of the potential for coral damage and endeavour to educate their clients. Although awareness of the problem will help, it is unlikely to be prevented in highly used areas. Private recreational users can cause similar impacts.

Reef walking is a favourite occupation of visitors to island resorts, reefs and cays. Even very limited trampling causes damage to corals on the reef flat, where people are most likely to walk. In experiments at Heron Island, trampling at high intensities significantly altered the community composition on the outer reef flat by reducing the abundance of arborescent corals, particularly *Acropora* species (Kay and Liddle, 1985; 1989). Eroded pathways become deeper and more extensive with prolonged use. Corals more resistant to physical damage including trampling are found in more exposed situations like the reef crest. The research indicated that the unrestricted reef walking is unlikely to degrade reef crest areas but could severely damage the outer reef flat, and reef walking routes should be chosen with this in mind.

Removal of Coral and Shells

In the past, large quantities of corals and other reef organisms were collected from the world's coral reefs to supply the market for coral and shell products. The coral collecting industry in Australia is strictly controlled through both State and Commonwealth legislation and only very small quantities are exported. In 1983-85 about 45 tonnes of scleractinian coral were harvested annually from the Great Barrier Reef (Oliver and McGinnity, 1985).

In the Great Barrier Reef Marine Park commercial and recreational collecting permits are issued for a variety of products including aquarium fish, coral, coral sand, shell. trochus, beche-de-mer, seasnakes, pearl oysters and spat, and clams. About 80 collecting permits were issued in 1991-92, many for research purposes. Collecting is controlled by QDPI permits as well as Marine Parks permits. Collecting activities are usually confined to a few sites because of the specific habitats of the species sought and the limited means many collectors have for accessing sites. Some sites are closed to fishing and collecting because priorities for conservation or tourism are higher.

The reefs support some 4,000 species of shell-bearing molluscs. Shell collecting is a popular pastime, practised by casual collectors and clubs but only one or two commercial collectors. The main concerns are depletion through habitat destruction and over-collection, particularly of the rarer target species and at accessible fringing reefs (Barnett, 1987).

One form of collecting sometimes practised by tourism or dive operators is the "improving" of sites by transfer of coral and other organisms. This activity also requires a permit.

Garbage Disposal and Littering

Australian legislation to implement Annex V - 'Garbage' of the International Convention for the Prevention of Pollution from Ships (MARPOL) came into effect on 14 November 1990, in the form of amendments to the Protection of the Sea (Prevention of Pollution from Ships) Act, 1983. Additional protection is afforded to the Great Barrier Reef. Disposal of any kind of garbage including plastic - except fish and fish cleaning wastes - is prohibited under the MARPOL legislation and littering is an offence punishable with a $200 fine under the Great Barrier Reef Marine Park Regulations.

Complaints from tourist operators about recreational users dumping garbage overboard were common in the workshops. It may not be generally realised that burying garbage on a beach and discarding biodegradable waste are also infringements of the law. Despite the legislation, littering and illegal garbage disposal are common occurrences. These problems cannot be effectively tackled through the permit system as the majority of offenders are probably private recreational users. Since education alone appears to be insufficiently effective, on-the-spot fines are to be implemented.

Tourist program operators who have attempted to intercept or report littering by other users say that their efforts are unsuccessful and their reports are not acted upon.

Some operators who are permitted to feed fish have used food waste for the purpose. This is no longer encouraged in the Marine Park because of the potential impacts on the fish.

Sediment Disturbance and Dredging

Planning for major tourism developments within the Marine Park having the potential to raise turbidity, increase sedimentation and cause damage to corals and other organisms normally includes detailed studies on hydrodynamics and sediment transport, including modelling, in the environmental impact assessment stage. Coral reefs do not make good foundations for structures, design of foundations is difficult, and design water levels need special consideration to take into account cyclonic storm surges (Gourlay, 1987). If approval for such developments is given, conditions are attached to the permit to mitigate any adverse effects during construction and operation, and monitoring programs are also required.

Dredging to create boat harbours, channels, marinas and other developments to serve the tourism industry can cause impacts on corals through direct removal or destruction, smothering by sediment, reducing light penetration and nutrient release. As part of the Townsville Port Development the Townsville Port Authority has carried out dredging to deepen the port entrance channel, used by cruise vessels and other shipping. Potential impacts included turbidity and sedimentation effects on fringing reefs at Magnetic Island and seagrass beds in Cleveland Bay. A multi-agency approach was adopted to undertake the environmental assessment and develop an encvironmental management framework for the works. A reactive monitoring program was required that could be linked to the legislative powers of the regulatory agencies to ensure the dredging could be modified or stopped if prescribed levels of impact were observed, i.e. of coral bleaching and mortality (Raaymakers, 1993).

This approach was taken because the background levels and natural variation in the environmental parameters causing the impact such as turbidity, light attenuation and sedimentation were poorly understood for Cleveland Bay, as is the ecological significance of their various levels. Controls were established at the most suitable sites. Acceptable natural levels of coral bleaching and mortality were agreed to by the scientific advisory group and three management trigger levels were determined for the coral condition parameters. All parties involved were aware of the response process that would take place should the management triggers be exceeded. The monitoring generally indicated that natural tidal and weather influences may be more significant than the dredging.

Major developments of this type are often located outside the boundaries of the Marine Park, but where the development may affect areas of the Marine Park the Authority becomes involved in management of the impacts and may require a permit. A recent proposal for remedial work in the vicinity of the channel at Heron Island is a further case in point.

***A Case for Permission:* Heron Island Remedial Work**

A Case for Permission: Heron Island Remedial Work

Heron Island has a history of problems relating to the dredging of the harbour. A channel was blasted in the reef rim in 1945 and by 1964 a change was evident in the location of sand deposition, originally on the northwest side of the cay. Retaining walls built to arrest erosion probably contributed to the problem by reflecting wave action back onto the reef flat. In 1966 a channel was dredged through the reef flat to provide a boat harbour. A cyclone filled in the harbour, which had to be redredged, the sand being dumped on the southwest beach. A helipad was built from dredged sand in 1968. A bund was constructed around the harbour and a retaining wall around the helipad. Guttering occurred in the harbour bund. Exacerbated by cyclones, continued losses of sediment occurred through the harbour. A major change in the morphology of the island fringing sediments is now apparent, with a net loss of sand from the island via the channel (Lawn and Prekker, 1992).
Other impacts were an increase in the deposition of fine sediments on the reef flat adjacent to the harbour, causing coral mortality, and damage to corals from vehicles (Gourlay and Jell, 1992). During maintenance dredging in 1987, which caused extensive sediment plumes, monitoring was begun. A further proposal has been made for remedial work to correct the loss of sediment and is being assessed. Consultation by the proponent with GBRMPA was not initiated until a late stage as there was a perception that a permit would not be needed.

Issues relating to the environmental impacts and the Marine Park boundary need to be resolved before funding is available for the works. These are important matters that would not have been addressed had a permit not been required. The series of *ad hoc* decisions that led to the problem were taken in the main before the permit system was set up. However despite permits being obtained for the more recent of the major activities there is no long-term planning perspective for the area and until management priorities are agreed the potential for impacts will remain.

Water Pollution - Nutrients

Vessel impacts including sewage discharge, minor oil spillage, together with dredging for developments, have been blamed for the degradation of inshore reefs (together with the effects of agricultural run-off).

Concerns arising from increases in nutrient levels of the continental shelf (Bell & Gabric, 1990) about algal displacement, toxic poisoning of corals and future destruction of reefs have been aired but according to Walker (1991) there is no evidence to demonstrate the existence of elevated nutrient or phytoplankton levels anywhere on the Reef apart from the vicinity of a few outfalls.

Pollution studies in Kanehoe Bay, Hawaii (Smith *et al.*, 1981) and the Barbados (Tomascik and Sander, 1985) have underlined the need for monitoring and management of developments involving sediment disturbance and wastewater discharge. Some impacts from resort sewage discharges have been reported in the Great Barrier Reef Marine Park. Such discharges can stress the surrounding coral reef environs (Veron and Borschmann, 1985; Steven and Van Woesik, 1990). Road construction for tourist access have the potential to damage fringing reefs (Craik and Dutton, 1987).

Background quantitative information on the effect of wastewater on Australian coral reef ecosystems is lacking (Steven *et al.*. 1990). Water quality monitoring studies required as part of permit conditions for major tourism-related and other developments in the Great Barrier Reef Marine Park have highlighted the need for better background water quality data. A specially funded major monitoring program has begun (Brodie and Furnas, 1992). As part of this program a project named ENCORE (Elevated Nutrients on COral REefs) is underway, extending an earlier reef fertilization experiment at One Tree Island (Kinsey and Domm, 1974). The project will investigate how reef organisms respond to raised concentrations of nitrogen and phosphorus, separately and in combination.

Monitoring to assess water quality impacts in the Reef region is complicated by a number of distinctive features and logistic problems (Brodie, 1992). High natural variability including that resulting from tropical cyclones can affect the best designed monitoring program. For example, the 10 year program to monitor the effects of an ammoniacal discharge from a nickel refinery in Halifax Bay adjacent to the Great Barrier Reef Marine Park (Carey, 1981), commenced in 1972 soon after the very destructive Cyclone Althaea. The species richness and diversity of the soft bottom benthos subsequently increased progressively from the low values of the baseline survey, confounding the interpretation of the results.

Similarly, the phytoplankton blooms (*Oscillatoria (Trichodesmium)*) common in Great Barrier Reef waters, have been associated with both low nutrients (Revelante and Gilmartin, 1982) and increased nutrients (Steven *et al.*, 1990). Changes in nutrient status may therefore be related to the onset or waning of phytoplankton blooms and the succeeding increase and decline of their zooplankton predators, or simply to the sampling of differing bodies of water (Brodie, 1992).

Heavy Metal Pollution

Vessels can contribute heavy metals to the reef ecosystem. Heavy metals associated with petroleum residues are a potential pollutant associated with marinas and vessels, but in one report were not considered to have a significant adverse impact (Australian Environment Council, 1988). Antifouling paints may be significant contributors of heavy metals in enclosed bays and places where large numbers of boats congregate, including popular reefs and areas such as the Whitsundays.

Copper, nickel, zinc and organotins (such as tributyl tin), together with PCBs, thiuran, DDT and various other toxins, have been used in antifouling paint formulations over the last decade. All of these active ingredients are detrimental to marine life at certain levels. For tributyl tin the level at which marine life is affected is measured in minute quantities (tens of nanograms). TBT causes shell deformation in Australian oysters at extremely low levels (Batley *et al.,1989)* . Scammell (1990) offered evidence that in a near pristine estuary the introduction of two small boats antifouled with TBT (area 24 sq.m) resulted in oyster shell deformation over an area of 154 sq. km. TBT causes imposex (male characteristics in females) in whelks and other gastropod molluscs (Gibbs *et al.*, 1987; Bryan *et al.*, 1988; Wilson and Ahsanullah, 1991)). Copper, paint matrix and environmental stress may also induce this deformity (Nias *et al.*, 1993).

Antifoulings are banned from use on structures in the GBRMP. The use of tributyl tin based paints on vessels of 25m and under is prohibited in Australian states and there are controls on licensing of boatyards that use, store and dispose of chemical residues from vessel cleaning. Larger vessels, including many international vessels such as cruise and container ships traversing the GBRMP escape this prohibition and can, and do, use TBT based antifoulings.

Heavy metals in estuaries and rivers draining metroplitan and industrial areas also have the potential to affect nearshore coral reefs and have aroused public concern. Known discharges of effluents carrying such pollutants are usually strictly controlled at the point of discharge by state authorities. However, sewage discharges from urban centres into marine areas carry substantial loads of heavy metals and other pollutants. These sources are much more significant than vessels.

Under the Great Barrier Reef Marine Park Act 1975, vessels that are fitted with holding tanks are not permitted to discharge sewage within 500m of the edge of a reef, but may discharge anywhere else within the Park. No similar restrictions apply to vessels not fitted with holding tanks, which means that such vessels can discharge raw untreated sewage or sewage treated with formaldehyde, chlorine or other chemicals anywhere around a reef. The majority of vessels using the Marine Park, particularly private recreational vessels, have no holding tanks.

Studies have shown that a few congregated vessels can generate a measurable impace on bacteriological water quality (Washington State Department of Health, 1989; NSW National Parks and Wildlife Service, 1991). This is an important consideration where sewage is discharged in the vicinity of growing areas for shellfish for human consumption. In the vicinity of coral reefs used for tourist programs other concerns are the effects of increased nutrients and the aesthetic impact.

Raised nutrients were recorded at Agincourt Reef, the site of a 300 person per day tourist operation (Richards, 1989). The research was inconclusive as to whether the high levels were due to a natural oceanic intrusion, user activity or a sampling error. Further monitoring at Agincourt Reef has shown signs of pathology of corals. Fish feeding may also contribute to enhanced nutrients. Although not quantitatively significant on the regional scale, vessel sewage and fish feeding may have localised impacts, particularly at mid to outer shelf reefs where corals are unaccustomed to enhanced nutrient loads (Baldwin, 1990). The ENCORE experiment is expected to provide input on the question of the significance of raised nutrients.

The perceived incongruity of collecting vessel sewage merely to pump it back into the ocean has led to spirited opposition to holding tank requirements by the recreational boating fraternity in coastal Australia. This attitude, together with the costs to government of providing sewage receival infrastructure both in ports and in areas with no on-land disposal system , and the costs and safety/stability aspects of installing holding tanks to owners of existing vessels, has tended to deter the implementation of vessel sewage programs.

There are alternatives to conventional holding tanks including small treatment systems suitable for commercial vessels, and temporary retention systems for small boats (Low *et al,* 1992). Manufacturers are moving towards the fitting of holding tanks in recreational vessels intended for the Australian market but since sewage discharge controls apply in only a few locations, e.g. Murray River, Sydney Harbour and Lake Macquarie, there is no incentive to fit tanks where legislation does not require it. Until Annex IV - Sewage, of the International Convention for the Prevention of Pollution from Ships (MARPOL), is ratified by a sufficient number of countries and incorporated into Australian law, this situation is unlikely to change. (Carey *et al,* 1992).

GBRMPA can require commercial vessels to fit holding tanks as a permit condition, and has applied this requirement to operators who spend the majority of their time at one reef location. The GBRMP Act prohibits the discharge of sewage less than 500m seawards from the seaward edge of the nearest reef, but this does not apply to vessels that do not have a holding tank (the majority, whether commercial or private). Some such vessels, and others that have unused holding tanks, discharge on the reefs in the vicinity of divers (evidenced by a letter of complaint and discussion with day-to-day management).

A requirement for holding tanks (or suitable substitutes) should be applied to all commercial vessels with toilets that visit reefs in the Marine Park (beginning with new vessels) and ultimately to private recreational vessels with toilets. Holding tanks can be fitted with y-valves to enable discharge at the required distance from the reef or for safety reasons. The distance for discharge off-reef could be increased.

Impacts of Marinas

There are two marinas in operation in the Marine Park, at Daydream and Hayman Islands (the marina at Hamilton Island is in Queensland internal waters). Magnetic Quay is permitted but not completed. There are many other existing and proposed marinas adjacent to the Marine Park and likely to impact on it. Impacts of the construction stage may include turbidity and sedimentation and are reasonably controllable, but there are additional difficulties in siting marinas in coral reef areas due to the porosity of coral substrates and the sensitivity of reef biota. Potential operational impacts of marinas include noise, litter, the effects of vessel sewage discharges and antifouling, hull cleaning wastes, and raised levels of nutrients, heavy metals and hydrocarbons from minor oil spillages.

The permits for construction of the marinas at Daydream Island and Magnetic Island issued jointly in 1990 by the Authority and the Queensland Department of Environment and Heritage, required a Code of Environmental Practice to be developed. The Codes included agreed techniques to control the release of sediment from construction and the conduct of a reactive monitoring and management program during construction. In each case the Authority and QDEH appointed an environmental supervisor, funded by the permittee, to oversee the construction and monitor the effects. The reactive monitoring programs comprised an agreed protocol, standards and agreed measurement methods which allowed the environmental supervisor to suspend or stop works if impacts exceed the pre-determined standards (Gillies & Craik 1990).

The Magnetic Quay Marina baseline monitoring program (Mapstone *et al.*, 1989; Brodie *et al.*, 1989, 1992), was commissioned as a result of permit requirements and is a model of sound statistical design and analysis. It studied the sedimentation, corals and sessile benthic biota on the fringing reefs of the southeast coast of Magnetic Island, including Nelly Bay, the site of the development. The study examined the potential for harm to corals from sedimentation during the dredging and construction, and recommended that efforts should be made to avoid increasing natural sediment loads during calm weather, specifying the levels that should not be exceeded. A post-construction monitoring program was outlined.

The Magnetic Quay proposal did not proceed because of the company's financial difficulties. The project generated strong controversy and criticism of management aspects, particularly by the local environmental association "Island Voice," and was subject to an independent review. While critical of certain aspects, in particular the follow-up of the insurance requirement and the giving of approval in principle at an early stage, the review in general vindicated the Authority's management of the planning decision process (Whitehouse, 1992).

Marinas have a reputation for environmental damage which may have been justified in the past, but today is arguably more exaggerated than deserved. A study of four marinas in southern Queensland found the major impact was from the accumulation of hydrocarbons and heavy metals but the levels were not considered to indicate significant water or sediment pollution (Australian Environment Council, 1988).. Monitoring of corals at Hamilton Island in the vicinity of the marina (Van Woesik and Ayling, 1992) showed that bleaching and die-off of the coral species *Seriatopora hystrix* was a regional phenomenon due to the monsoonal overpass, and not a direct result of discharge from the marina, as had been suggested.

The biophysical impacts of a marina of modern design and service facilities, sited and constructed according to environmental guidelines, and properly operated, are probably less than the impacts of a car park of comparable size, taking into account water pollution from runoff and ease of restoration of typical sites. Vigilance by environmental managers is essential to ensure that safeguards are in place and high housekeeping standards are maintained (Ross, 1989, 1990; Hinwood, 1987).

Impacts on Islands

The majority of resort islands are not included in the Great Barrier Reef Marine Park but are managed as Queensland National Parks and Marine Park. The impacts of tourist operations and recreational use on sea-bird nesting islands and cays are managed by QDEH. Motorised watersports are likely to be inappropriate in such areas. Noise impacts may result from aircraft accessing or approaching close to sea-bird nesting islands. Aircraft tourism operations are controlled through the GBRMPA permits with overflight and approach distances and other operational requirements detailed on the permit.

Vegetation communities, especially the extensive *Pisonia grandis* forests, and consequently bird nesting habitats are altered by soil and sand compaction, fire, clearing and the introduction of weeds, pests and fungal diseases Chaloupka and Domm, 1986).

Michaelmas Cay, an important sea-birdnesting island in the offshore Cairns area, and its surrounding reef are subject to intense levels of tourism use. The site offers a unique opportunity for visitors to see a sea-bird colony and a coral reef in close proximity. Research shows bird numbers have decreased since tourism increased (Hicks *et al.*, 1987). Potential impacts include the degradation of the vegetation cover by fire, trampling and compaction, and disturbance of nesting sites. Coupled with exceptional natural events such as cyclones, overwash by storm surge, king spring tides, dune migration, or mortality from disease or starvation in adverse weather conditions, the human induced impacts affect breeding success in the populations of sea-birds (Muir and Chester, 1991; Muir, 1990).

A Management Plan for Michaelmas Cay was approved in 1986. Management guidelines were being compromised when weather conditions make tourist access difficult or reduce the area of beach. The limit on visitor numbers needed reconsideration and better controls on visitor access to restricted areas became necessary. The Management Plan was therefore revised (GBRMP, 1992). Under the Zoning Plan, a number of other important bird nesting sites identified in the Cairns Section are nominated for seasonal closure, during which most activities except some research are prohibited.

Occupation of Heron Island has affected the habitats of nesting terns, particularly *Sterna dougallii*) and wedgetailed shearwater (*Puffinus pacificus*). Tourists walking tend to disturb the birds and damage their burrows. The predator gull population (*Larus novoehollandiae*) has increased as a result of the attractiveness of garbage to this species, with an impact on the breeding of terns (Hill *et al.* 1985; Hill and Rosier, 1989).

Most cays provide sites for the nesting of green turtles - North West Island is particularly significant. Wreck Island is an important loggerhead turtle rookery. Problems from human disturbance include:

- human interference, beach compaction and erosion lower nesting rate and hatching success;
- noise, lights and campfires may disorient hatchlings heading for the water, resulting in higher mortality;
- shading and discoloration of sand caused by camp-fires may alter nest temperature and cause an imbalance in the sex ratio of hatchlings, (Draft Interim Management Strategy for the Capricorn and Bunker Groups, April 1992).

Fishing Impacts

"Over-fishing" was identified by tourism operators as a problem in most parts of the Marine Park. While overfishing was attributed by them to private recreational boaters, it is clear that some commercial operators also contribute to the problem when they supply access for some of their charter customers who seek to fill the freezer or perhaps sell some of their catch to cover the costs of the trip. Both tourism operators and private recreational anglers tend to blame commercial fishers for depleting stocks. Commercial fishermen claim that they move out as areas become unviable for commercial fishing, leaving sufficient fish for other users.

To ensure that the resource is shared efficiently and conserved for the future, the effects of both recreational and commercial fishing need to be considered in a single management framework and the stocks shared (ABARE, 1992). Various output controls, e.g. quotas, are in place for commercial fishing. Co-operation between the managing agencies is taking place, but explicit allocations of fish catch quotas between recreational and commercial sectors have not been made. While there are limits on the numbers of commercial line anglers and the number of dories attached to the main vessel, etc. there are no restrictions on vessel size or numbers for recreational anglers. Licensing for recreational anglers has been considered in the "Burns Inquiry."

Overfishing in the Marine Park context usually means growth overfishing, which occurs when the population is so intensively fished that fish do not have time to grow before they are caught - so average size declines as well as numbers in particular areas. However a decrease in average fish size is not necessarily evidence for over-fishing, as fish size decreases when any virgin stock is fished. Sex reversal, common in reef fishes, is a further factor affecting reproduction when fish of a particular species do not attain the size at which sex changes occur.

The Boult Reef experiment (Beinssen, 1988) measured the rate at which fish stocks on a typical coral reef can be fished out. Under the Zoning Plan for Capricornia, Boult Reef is zoned a "replenishment area" and may be closed from time to time to fishing and collecting to allow resources to recover. Boult Reef and North Island Reef were closed in mid-1983 - the first such closures in the Marine Park - and reopened in December 1986. The experiment involved tagging fish at the reef in the weeks preceding the re-opening and then recording the catch, fishing hours and tags caught for two weeks after re-opening. The local community was invited to join in the fishing effort, with cash incentives for returning tags. In two weeks about 1200 fishing hours were spent and about 2000 coral trout were caught, one quarter of the number at the reef prior to the opening, showing that reefs can be very rapidly depleted by fishing. Replenishment areas are clearly effective in restoring stocks, but management needs to consider ways of controlling the reopening process.

Output controls such as bag limits are common in recreational fisheries management in all states, and have been introduced for some species in the Reef region. Most recreational anglers in the workshops believed they are ineffective in limiting the catch .

High intensity fishing for selected species, particularly large predators, can cause changes throughout the food chain which may or may not have adverse effects on other coral reef biota. Anglers in the recreational users workshops referred to heavy fishing of plate-sized coral trout for international markets as a problem. Minimum length limits on popular species are frequently ignored, and fishing in "green" zones (Marine National Park B Zones, where fishing is prohibited) is common, according to the comments made. This points to a need for increased education and management presence.

Anglers with many years experience believe that catch per unit effort is declining in reef waters. Anecdotal evidence of this kind is being followed up by research in the Effects of Fishing Program. Information from this research is needed before any move is made towards output controls on recreational fishing to sustain the resource.

Fish Feeding

Fish feeding is a popular feature in permitted tourist programs and may be part of the underwater experience for recreational divers. Shark feeding also occurs but is illegal, i.e. permission for this activity is <u>not</u> given. These activities may:

- change the local communityof fish species;
- locally increase nutrient levels;
- be used for garbage disposal;
- result in aggressive behaviour in fish and attract sharks, increasing the risk of injury to people;
- accustom fish to an excess of unsuitable foodstuffs, with the possibility of pathological reactions;
- make tame fish more vulnerable to being caught.

At some tourist sites where fish feeding occurs, recreational fishing is also allowed by the current zoning. Although some conflict between the two activities has been reported, GBRMPA has decided that further regulation beyond the current policy is not justified, but where appropriate, zoning will be applied to protect tame fish and to enable viewing, for example at the Cod Hole.

Guidelines for fish feeding have been prepared which address the amounts and types of foods that should be used. Tourist programs that conduct fish feeding are required to comply with the guidelines as a permit condition, but many operators do not comply. Many regular operators have been observed feeding the cod at the Cod Hole in contravention of the guidelines (Cod Hole/Ribbon Reef Operators Meeting - 23.4.92: the Association has been known to fine its members for practices contrary to its rules). Private recreational users are alleged to cause problems such as excessive harrassment of the fishes. Increased education and management presence in the field may be the only answer to this behaviour.

At other reef locations, operators continue to feed fish unsuitable foods, usually galley leftovers. Again, education may be an answer to this practice. Inclusion of a sequence in interpretive videos and brochures explaining why fishes should be fed only as the guidelines prescribe, may help - customers may then do the policing.

Impacts of Research and Monitoring

Permits are needed for all research activities in the GBRMP, including those benefitting or relating to tourism. Structures such as pontoons installed for tourist programs invariably have a monitoring requirement in the permit. Relatively less monitoring is done in relation to private recreational activities, the "Effects of Fishing" program excepted.

Manipulative research can have impacts on the coral structure or on organisms at individual, population or community levels. Thoughtless or careless researchers have been known to leave research materials and equipment behind when projects are finished or abandoned. A permit condition can require the researcher to remove all gear, markers, waste and debris. Collecting of materials and organisms is usually kept to a minimum by a condition which specifies the exact amount or number to be collected.

The Authority is not primarily a research agency, but generally contracts out research to individuals or institutions with the relevant expertise. Monitoring associated with tourism developments and structures in the Great Barrier Reef Marine Park and adjacent areas allows the impacts to be more accurately assessed and more effectively controlled. Monitoring of the effects of permitted operations is managed by the Authority through the use of consultants, at the expense of the proponent. It is often a costly obligation upon commercial users but is one of the most valuable adjuncts of the permit management system in terms of the information provided to assist impact management.

Overall co-ordination of monitoring is necessary to enable the greatest benefits to be achieved. Monitoring under the permit system is tied to the specific sites and activities nominated in the permit, and this may lead to repetition of effort in monitoring a limited range of impacts. In addition to site- and structure-specific projects there is value in broader baseline monitoring that will supply the background data that is generally lacking, particularly in areas that are likely to be the locus of future tourism development. The identification of such areas is itself a vitally important exercise. For example, the Draft Cairns Offshore Strategy identifies reefs capable of further development for various tourist activities: these areas should be monitored to establish background conditions *before* their use increases.

There is a case for diverting funds from repetitive monitoring of structures, for example pontoons, to more general environmental issues arising from pontoon installation and operation, e.g. baseline monitoring at potential locations for future tourism use.

Conclusion

The management of impacts inevitably involves at a particular level the management of the users - where they go and what they do. The Authority has followed the path that, in managing the Marine Park, it has responsibility, primarily

for the control of ecological impacts, and secondarily for managing a range of user opportunities.
The Authority does not seek to manage Great Barrier Reef tourism at the level of the industry's business activities, economic competition, finance, marketing, innovation, internal standards, etc. It could become involved in such aspects only if asked to do so by the industry and where such matters impinge directly on the achievement of the Authority's Goal and Aims.

In the eyes of the commercial operator and the private recreational user there are a number of impacts that are not effectively managed or where management problems are emerging. The present high management effort in assessment and issue of permits for tourism activities may not be sustainable, particularly if tourism in the next ten years expands as predicted. Would the overall level of impact be any different if there were no permits, only zoning and management plans? What are the options for management of impacts resulting from commercial tourism and private recreation? How should sites for commercial use be allocated? Which options would result in greater consistency between the management of impacts of permitted activities and activities not requiring permits?

In answering these and many other management questions, the Authority is intent on conserving the Great Barrier Reef and on adapting itself continuously to the Reef's management needs.