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REEF RESEARCH

GREAT BARRIER REEF
MARINE PARK AUTHORITY

VOLUME 9 No. 1
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WHAT'S IN THIS ISSUE

Editorial

REEF MANAGEMENT NEWS:

The new year is in full swing at the Authority, with staff having embarked on a number of challenging, yet exciting, new projects as well as having resumed work on the long-term programs associated with managing the largest Marine Park and World Heritage protected area in the world.

The Conservation, Biodiversity and World Heritage Critical Issue Group has begun initial planning for the introduction of a network of strictly protected representative areas in the Marine Park. These representative areas are aimed at ensuring that the Great Barrier Reef's rich biodiversity is maintained in years to come.

Long-term monitoring programs give insight into the complex workings of the marine environment, and with that understanding comes improved management. The Authority has welcomed public participation in the ongoing observation of the Reef and associated ecosystems, with the introduction of a new phase in the 'Eye on the Reef' monitoring program and the development of a water quality monitoring project which looks at flooding rivers.

A five-year study of the environmental effects of prawn trawling has been completed, with a report on the findings released early in January. The study has revealed new information on species depletion and bycatch. In response, the Authority has announced that it is committed to ensuring that prawn trawling in the Marine Park is ecologically sustainable. Reef Management News also looks at new funding from the Commonwealth Government for targeted surveillance and enforcement of the Marine Park.

On a lighter note, staff at the Authority, people involved in the areas of marine science and education, marine and coastal management, users of

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the Reef, associated industries and the North Queensland community are gearing up for this year's inaugural GREAT Barrier Reef Ball. The Ball aims to raise funds to provide opportunities for North Queenslanders with disabilities or life threatening illnesses to experience the wonders of the Great Barrier Reef first hand. Organisers are also hoping to increase community awareness of the Great Barrier Reef and its importance in Queensland, while providing a great night's entertainment for all!

The Ball will take place on Saturday 10 July at the Southbank Convention Centre. For more information contact: Suzie Davies at the Authority on (07) 4750 0700.

Editorial

REEF RESEARCH:

Welcome to another issue of *Reef Research*. Thanks to those of you who have returned your subscription forms. As I mentioned in the last newsletter, subscription to *Reef Research* is free but to receive future issues you must subscribe by filling in the enclosed form and returning it to the Authority. Please note that the deadline for receipt of forms is **1 July 1999**.

Unfortunately, we are missing two of our regular articles from this issue – *Slick Talk* and *CRC Reef Research Centre Update* – although, some interesting articles have replaced them.

For this issue's *What's Out There?* guest writers, Hamish Malcolm, Tony Fontes and Tania Ashworth, summarise the results of a project they've been undertaking at Butterfly Bay (Whitsunday Islands) to assess the levels of refuse and illegal fishing in the area.

Sylvia Spring provides a brief insight into the thoughts and feelings researchers often have when working with animals. It's a side that many people don't often think about — the emotions researchers experience as they think about how what they're doing affects the subject of their research.

Michelle Devlin draws upon a variety of sources as she discusses the relationship between seagrasses and increased nutrient levels.

Finally, staff from the Authority's Water Quality and Coastal Development Critical Issues Group present an update of the Authority's long-term water quality monitoring program, with particular emphasis on chlorophyll *a* monitoring.

We received a suggestion that we should perhaps dedicate a column within *Reef Research* to letters/feedback received from readers. This is a feasible idea but unfortunately we receive very few letters. Please remember, though, that feedback is invaluable and always welcome.

Kim Lally

MARINE & ENVIRONMENTAL POLLUTION '99

An intensive course in marine and environmental pollution will be run at the Orpheus Island Research Station from 12–18 July 1999. The course is suitable for third-year undergraduates and postgraduates and is designed to bring together students who have a strong interest in marine and environmental pollution, and who wish to go on to further study in this area. The course will consist of lectures, tutorial sessions and laboratory work. Assessment is by a literature review, seminar presentation and examination. The maximum number of participants is 20.

The core learning objectives are to:

- understand the basic principles and multidisciplinary nature of the subject, and to obtain an introduction to research in this area;
- become aware of some of the current major environmental issues, such as nutrients and eutrophication, heavy metal pollution, acid rain, acid-sulphate soils, acid mine drainage, toxic organic chemicals and marine and estuarine water quality;
- obtain through case studies new insights into the design and implementation of monitoring programs;
- understand processes that affect the fate and behaviour of pollutants in the environment; and
- understand how good sampling programs and state of the art instrumentation can assist pollution monitoring programs.

For further details of the course, including costs, contact the course coordinator Dr Graham Jones, Department of Chemistry, James Cook University, Townsville 4810 (email:graham.jones@jcu.edu.au).

An example of an ongoing refuse and illegal fishing problem at a popular anchorage in the Great Barrier Reef Marine Park

Hamish Malcolm[1], Tony Fontes[2] and Tania Ashworth[3]

[1] *Queensland Parks and Wildlife Service*, PO Box 5391, Townsville Qld 4810*

[2] *Order of Underwater Coral Heroes (OUCH) Volunteers, PO Box 180, Airlie Beach Qld 4802*

[3] *CoastCare, PO Box 5391, Townsville Qld 4810*

Introduction

Butterfly Bay is a popular anchorage in the Whitsunday Islands. Underwater surveys carried out in 1996 indicated that illegal fishing was occurring regularly in West Butterfly Bay (based on the amount of snagged fishing line) and that refuse was also a problem. Butterfly Bay is zoned Marine National Park 'B', where fishing is not allowed. Marine Park regulations also state that 'rubbish cannot be thrown overboard in any zone within the Marine Park'.

Ongoing assessments of refuse levels and illegal fishing have been carried out in West Butterfly Bay during the last three years. These assessments have also included an annual underwater clean-up. The clean-ups have been performed in conjunction with a local community group: the Order of Coral Underwater Heroes (OUCH) Volunteers. On other occasions, fishing line and refuse have been removed (and documented) from replicate bommies at West Butterfly Bay and nearby Stonehaven Bay.

Methods

An underwater clean-up of West Butterfly Bay was carried out on 28 October 1996, 29 January 1998 and 23 November 1998. All refuse items, including fishing line, were documented once removed from the water. The cumulative dive-time cleaning the reef was recorded to determine the overall effort required to collect the refuse.

In October 1996 and January 1998 the clean-ups were carried out in an area approximately 300 metres by 100 metres. This area was haphazardly searched and there were sections (during both clean-ups) that were not cleaned as visibility on the bottom was low (< 2 metres to 3 metres). In November 1998, due to the instalment of seven new public moorings in the bay, a different search method was used. Divers from OUCH searched the bottom around each of the seven public moorings, using a swim-circle search

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*** The Queensland Parks and Wildlife Service was previously known as the Queensland Department of Environment and Heritage (Ed.)**

technique out to 20 metres from each mooring (0.125 hectares were searched at each mooring).

Four replicate bommies in both West Butterfly Bay and North Stonehaven Bay have been established as fixed monitoring sites. These eight bommies have been surveyed at least three times over the last three years (Malcolm 1999). Fishing line and refuse was recorded and removed from each bommie during each survey to assess accumulation rates.

Results and Discussion

Refuse

Refuse in West Butterfly Bay has been an ongoing problem (table 1) throughout the duration of the survey period.

The results show a minimal reduction in the number of refuse and fishing items in most categories between 1996 and 1997–98 and the latest clean-up in November 1998.

A number of items (besides fishing line) were abundant during all three clean-ups; beer cans, stubbies and wine bottles; material items (especially towels and clothing); swim fins; and cooking items (figure 1).

Figure 1. An example of refuse collected on 29 January 1998 (18 diver hours)

The refuse recovered from the bottom appears to be a combination of intentional littering by throwing items overboard, and items that have probably been dropped or blown overboard by accident. The lack of plastic items, including plastic bags, suggests the recovered refuse is the component which sinks more readily. Substantially more items may be ending up in the water than indicated by these clean-ups. This combination of intentional littering

Table 1. Refuse removed from West Butterfly Bay

ITEMS RETRIEVED	Oct 1996 clean-up	Jan 1998 clean-up	Nov 1998 clean-up
Fishing line with assorted hooks/sinkers	106	176	76
Lures		2	1
Steel crab pot	1	1	
Fishing rods (or parts of rods)	1	3	
Cast net	1		
Spear gun rubber	1		
TOTAL FISHING GEAR ITEMS	**110**	**182**	**77**
Aluminium cans	61	51	54
Steel cans	2	3	5
Glass stubbies	44	33	68
Glass bottles	35	37	47
Glass jars	3	2	3
TOTAL DRINK/FOOD ITEMS	**145**	**126**	**177**
Drinking glasses	4	2	5
Drinking mugs			2
Plastic cups	2	2	
Glass plates	4	2	5
Kettles		1	
Cooking pots			3
BBQ grills	2	2	
BBQ plates	2	1	
Cooking utensils	10	3	5
TOTAL COOKING EQUIPMENT ITEMS	**24**	**13**	**20**
Swim fins	16	7	7
Masks	3	3	10
Snorkels	6	3	9
Varied dive equipment (dive torch, flag)	2	2	1
TOTAL DIVE EQUIPMENT ITEMS	**27**	**15**	**27**
Anchor + chain (various sizes)	3		
Chain (various lengths)	3		
Rope (various lengths)	4	2	2
Tools	2		
Batteries	4	1	1
Tilly lanterns		1	
Rubber items (rollock stopper, flap)	2		2
TOTAL MARITIME ITEMS	**18**	**4**	**5**
Solid plastic items (hose, perspex, pipe, walkman stereo)	11	5	6
Plastic bags	1		4
Plastic bottles	1	2	1
Plastic buckets	8	3	3
Clothes pegs	3	5	3
TOTAL PLASTIC / RUBBER ITEMS	**24**	**15**	**17**
Sunglasses	1	1	1
Shoes	3		3
Hats	1		
Pants		1	4
Shirts	1	4	8
Bathers	7	6	3
Raincoats		1	
Towels	1	7	12
Sheets	3	1	
Carpets			1
Sail covers	1	1	
TOTAL MATERIAL ITEMS	**18**	**22**	**32**
Oil filters		1	
Pieces of metal		2	1
TOTAL MISCELLANEOUS ITEMS		**3**	**1**
TOTAL REFUSE	**367**	**378**	**356**
EFFORT (= Diver hours)	**18**	**18**	**14**

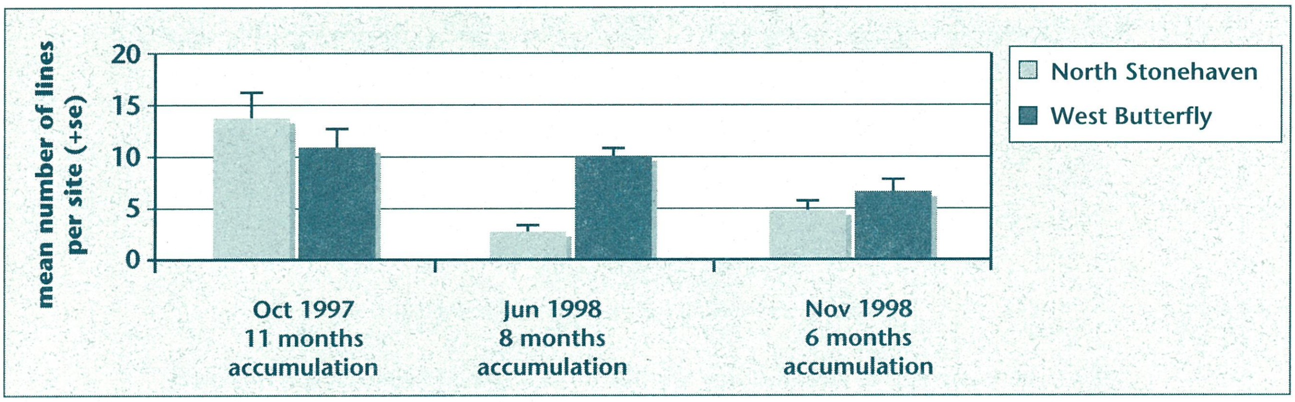


Figure 2. Mean number of fishing lines per bommie (where n = 4 bommies) in North Stonehaven Bay and West Butterfly Bay October 1997, June 1998, and November 1998 (+ standard error around the mean).

and lack of due care is polluting the Great Barrier Reef Marine Park at this location.

One area of concern in a coral reef environment is that of submerged clothing or materials. Clothing can wrap around the coral and smother it by cutting out light and water circulation. The wrapped material also traps silt, further smothering the coral and eventually killing it. Recent coral mortality from smothering by material has been observed a number of times in West Butterfly Bay (pers. obs.). Of particular concern is the apparent increase in the number of material items (especially T-shirts and towels) recorded between 1996 and 1998.

Illegal Fishing

The amount of snagged fishing line cannot be used to determine actual fishing effort. However, it can provide a relative indication of effort, albeit a very rough indication. Comparable fishing effort between adjacent bays (with similar benthic habitat) may be indicated by similar amounts of fishing line being snagged within each bay. Continued fishing pressure may be indicated if fishing line accumulates at a similar rate from one year to the next.

West Butterfly Bay is a Marine National Park 'B' zone where fishing is not permitted and, as such, there should be no fishing line in this bay. However, during each clean-up a large number of snagged fishing lines have been removed. Some of the fishing line recovered was also old, which means the above figures (table 1) do not represent accumulation over a set period of time or in a set area. However, a reasonable proportion of the recovered refuse was fresh line and hooks (i.e. line that had recently been snagged). Similar amounts of diver effort to recover refuse were expended on the first two clean-ups (approximately 18 diver hours), with slightly less diver effort on the November 1998 clean-up (approximately 14 diver hours).

This indicates that illegal fishing has been ongoing in this bay at a substantial level, and this is supported by the monitoring of replicate bommies.

The amount of fishing line removed from the four monitoring bommies in West Butterfly Bay in November 1998 was comparable with the previous amounts of line that had been removed from those bommies in October 1997 and June 1998 (figure 2), when the shorter period of accumulation is considered. This suggests that the level of illegal fishing activity has not decreased over the last three years in this bay.

Although snagged fishing line does not represent fishing effort, the above results suggest that levels of fishing in West Butterfly Bay (where fishing is not permitted) may have been as high or higher than North Stonehaven Bay (where fishing is permitted). Similar levels of fishing line were recorded in West Butterfly Bay and North Stonehaven Bay in October 1997 and November 1998, with more line recorded in West Butterfly Bay in June 1998.

Overall, the combined results from the refuse clean-up and the fixed site monitoring show that marine park zoning has been disregarded by a number of visitors to West Butterfly Bay. These results suggest that where there are higher levels of use, there will probably be higher levels of non-compliance with 'no take' zoning, at least at this location. This has wider implications regarding the effectiveness of zoning in particular areas within the Marine Park, unless this is a unique case.

Reference

Malcolm, H. 1999, High use abuse: An example of an ongoing refuse and illegal fishing problem at a popular anchorage in the Great Barrier Reef Marine Park, Unpublished draft final technical report to Queensland Department of Environment and Heritage, January 1999.

Satellite Telemetry and Green Turtles

C. Sylvia Spring
Great Barrier Reef Marine Park Authority

When you carry out research there are often risks associated with the research, usually for the subject of the research. In designing projects researchers have to weigh up whether the benefits are worth the risks involved. Sometimes you never find out how the research has affected the animal concerned. My experience working with marine turtles is outlined below. It is an example of a good outcome when there were risks for the turtle involved.

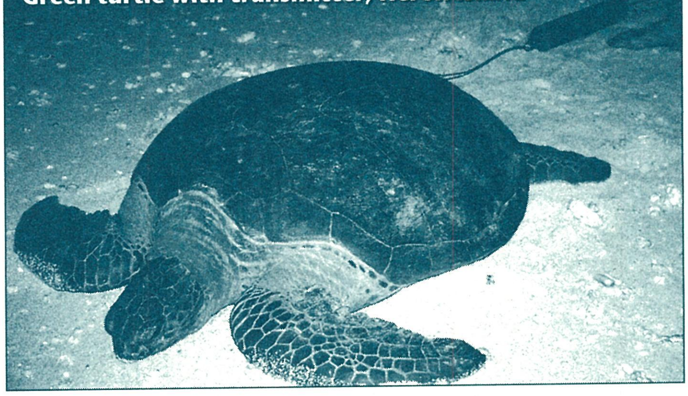
On 7 April 1990 I attached a Platform Terminal Transmitter (PTT) to a post-nesting green turtle at Heron Island in the Capricorn-Bunker Group to track its movements away from the nesting beach (Spring 1994). The turtle, who I called 'Rosie', was a new recruit into the Heron Island nesting colony and had been tagged, by the Queensland Parks and Wildlife Service staff, nesting for the first time on Heron Island on 13 January 1990. The turtle nested again on 26 January, on 7 April and finally on 25 April 1990 before setting off on her migration to her feeding grounds. The PTT attached to her carapace would track her movements during this migration. This information is important because if we are to conserve green turtles, which are vulnerable to extinction, conservation measures need to be applied across their entire range, not just at the nesting beaches.

The PTT (ST-3 Model) was constructed by Telonics Inc. USA and contained software developed by researchers in the United States, which recorded water temperature, dive times and dive counts. The PTT, powered by two lithium D-cell batteries, was housed inside a waterproof PVC tube eight centimetres in diameter and thirty-four centimetres long. The housing was pressure resistant to 150 metres depth.

The PTT was attached to the turtle with a 0.5 metre flexible stainless steel cable linked to stainless steel attachment plates which were bolted to the rear edge of the turtle carapace. Ferrous bolts were used as these would corrode in approximately 12 months, releasing the PTT and the attachment plates from the turtle about the same time as the batteries failed.

A saltwater switch built into the housing was designed to activate the PTT whenever the turtle was at the water's surface. While switched on, the PTT transmits signals at regular intervals. Orbiting National Oceanic and Atmospheric Administration (NOAA) satellites receive transmissions from PTTs in visibility during passes and are equipped with the Argos Data Collection and Location System[1] which calculates the location of the turtle for each transmission received. In this way the turtle can be tracked on its migration.

Green turtle with transmitter, Heron Island



There were several concerns for the turtle as a result of this research. There was the possibility of the tether becoming entangled and trapping the turtle, as well as the possibility of infection or damage from bolt holes drilled through the edge of the carapace. While procedures were designed to minimise any discomfort or the likelihood of infection for the turtle as a result of this research, it was not known whether the turtle would become entangled. This was a risk that was weighed against the information about the

[1] The Argos system is a cooperative project of the Centre National d'Etudes Spatiales (CNES) of France, the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration (NASA). The primary purpose of Argos is to collect environmental data.

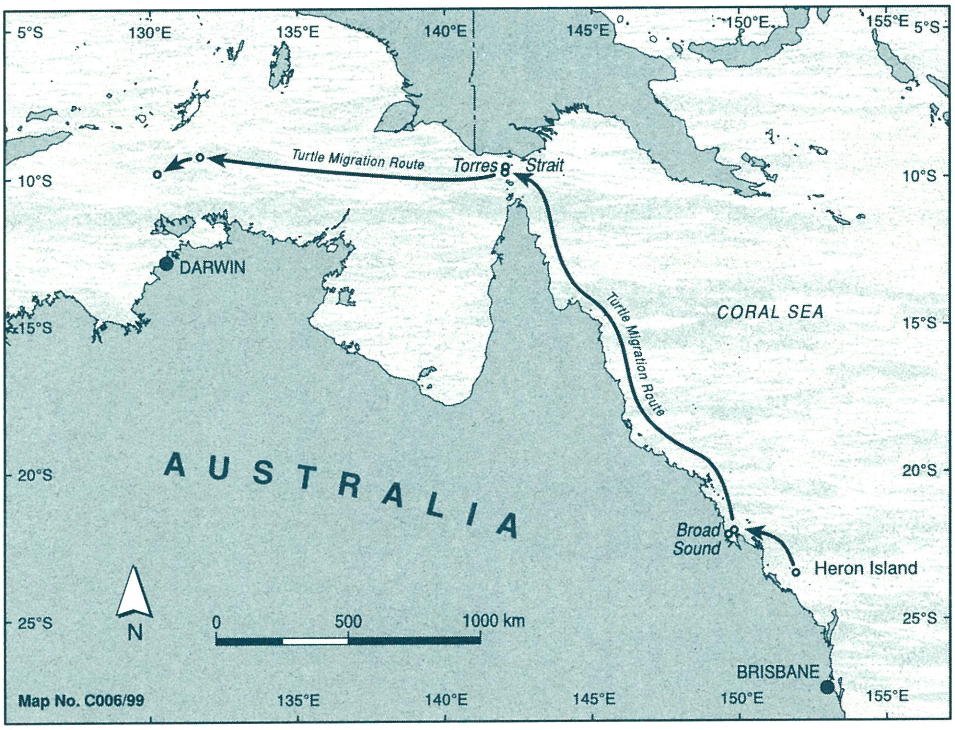


Figure 1. Post-nesting migration of green turtle from Heron Island into the Arafura Sea, a distance of over 3300 kilometres.

turtle migration which might be gained by the research. The project was thoroughly scrutinised and passed by the then Australian Nature Conservation Authority Animal Ethics Committee.

The satellite telemetry data showed that after leaving Heron Island the turtle travelled 300 kilometres north to Broad Sound. From there she travelled 1800 kilometres north to Torres Strait and then a further 1200 kilometres west into northern Australian/southern Indonesian waters. The turtle was tracked for 234 days and migrated over 3300 kilometres from her nesting site (figure 1).

Despite the success of the research in terms of its results, I often wondered about the fate of this turtle — had I caused its death as a result of this research? I recently received a letter from Dr Colin Limpus, head of the Queensland Turtle Research Project, Queensland Parks and Wildlife Service, informing me that the turtle had returned to Heron Island for the 1997–98 nesting season after an eight-year absence or remigration interval. The turtle was detected by the Queensland Parks and Wildlife Service turtle research team during their beach census study and they observed that there was no obvious injury from the PTT attachment and no attachment metal remained on the turtle.

The news that the turtle was alive and well was great news to me. She remained at Heron Island for the full nesting season, nesting six times before setting off on her migration north. And this time we have a good idea of where she is going.

Reference

Spring, C.S. 1994, Satellite Tracking Green Turtles in Australian Waters — Preliminary Results, in *Proceedings of the Australian Marine Turtle Conservation Workshop held at Sea World Nara Resort, Gold Coast*, 14–17 November 1990: Queensland Department of Environment and Heritage and the Australian Nature Conservation Agency, pp.192–197.

Research Consultancy Opportunities

Prospective consultants are advised that research consultancy opportunities with the Great Barrier Reef Marine Park Authority will be advertised on the Authority's web site (http://www.gbrmpa.gov.au/). Those interested in tendering for consultancy work in any aspect of the physical, biological, social, cultural and economic environments of the Great Barrier Reef are encouraged to check this site regularly.

The Authority also maintains a Register of Consultants and professional firms are invited to register or update their present registration with the Authority. The information provided should not exceed 10 pages and should outline skills and qualifications, relevant experience, the basis for fee calculation and the names and addresses of referees. A short summary of skills should also be included.

Any queries or requests for further information should be directed to Rozel Brown at the Authority on +61 7 4750 0740. Please forward registrations to: Great Barrier Reef Marine Park Authority, PO Box 1379, TOWNSVILLE QLD 4810, Attention: Rozel

REEF MANAGEMENT NEWS

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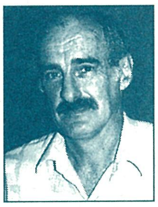
At the forefront of critical issues



Director: Water Quality and Coastal Development

Jon Brodie

Jon was Director of the Research and Monitoring Section of the Great Barrier Reef Marine Park Authority for four years and has been with the Authority since 1990. Previously, he was with the Australian Centre for Tropical Freshwater Research at James Cook University in Townsville and the Institute of Natural Resources at the University of South Pacific in Fiji. Jon has worked in the water quality science and management field for 30 years, and has extensive knowledge of water quality management principles and contemporary water quality and coastal development management issues.

Director: Tourism and Recreation

Annie Ilett

Annie Ilett has extensive experience in environmental resource management and policy development in environmental protection, marine and coastal management, sustainable development, community education, tourism, public awareness and media. Before coming to the Authority, Annie worked for five years in the Commonwealth Department of Environment' s Education Policy and Projects Unit, the Coastal Unit, the Marine Strategies Unit, and the Marine and Coasts International Section and the Clean Seas Section.

FISHERIES CRITICAL ISSUE GROUP

ON THE BOIL

GBRMPA PLEDGES ECOLOGICAL SUSTAINABILITY

The ecological sustainability of prawn trawling in the Great Barrier Reef Marine Park has come into question after a study commissioned by the Great Barrier Reef Marine Park Authority revealed disturbing new information about species depletion and bycatch.

The study found that a single trawl removed 5–25 per cent of seabed life, while 13 trawls removed 70–90 per cent. Research also showed that 6–10 tonnes of bycatch, such as fish and crustaceans, were discarded for every tonne of prawns caught.

A report on the findings of the study estimates that Marine Park plant and animal species most vulnerable to trawling have been depleted by more than half in intensively-trawled areas over the past 20 years.

The Authority's Director of the Fisheries Critical Issue Group, Dr Phil Cadwallader, says that the study has revealed vital information about the cumulative impacts of trawling.

"We have to seriously address the sustainability of an activity that has the potential to remove such a large portion of seabed life," he says. "Of particular concern is the level of bycatch of species other than the targeted prawns and scallops."

During the course of the study 1000 new seabed species were discovered in the lagoonal and inter-reefal areas targeted for trawling. It was previously assumed that these were relatively barren areas between the more spectacular coral reefs.

"We now know that inter-reefal and lagoonal areas have quite a high level of biodiversity," says Dr Cadwallader.

"We are concerned about whether or not these seabed communities can replenish themselves after trawling disturbance.

"The species living on the seabed that are easily dislodged by trawl sweeps, or are slow to recover, have very little chance to recover in areas trawled intensively and frequently."

For many of the non-target species inadvertently caught in trawl nets, there is very little information, if any at all, from which to assess their sustainability.

The five-year project was the first large-scale study on the ecological effects of prawn trawling in the tropics. Simulated trawling experiments were conducted by CSIRO and QDPI in the cross-shelf closure, or 'green zone', in the Far Northern Section of the Marine Park. Commercial trawling activity typically targets aggregations of prawns by repeatedly trawling over patches of productive seabed and then moving to another aggregation.

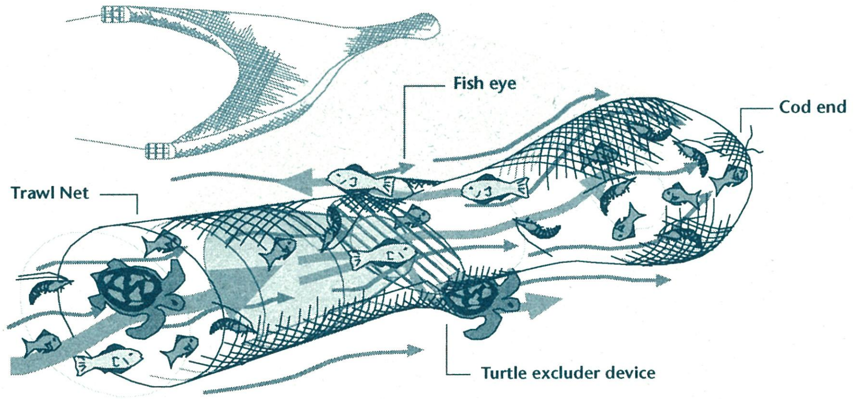
The Queensland trawl fleet currently consists of about 840 vessels, of which some 650–700 operate in the Marine Park. The majority of this fishing effort is concentrated in about 20 per cent of the inter-reefal and lagoonal areas.

"The marine ecosystem is a complex community of plants and animals that all fit together to make a healthy whole. We cannot severely deplete one part of that whole without compromising the sustainability of the entire system," says Dr Cadwallader.

Although the number of vessels in the east coast trawl fleet has not increased, new technology such as GPS (Global Positioning System), improved fish-finding equipment and improved trawl gear has increased efficiency.

"The use of improved technology has put more pressure on the prawn stocks and their habitats," Dr Cadwallader says.

While the Authority's management philosophy makes provision for multiple uses of the Marine Park and World Heritage Area, including fishing, these uses must be demonstrated to be ecologically sustainable.



The Authority aims to have turtle excluder devices and bycatch reduction devices installed in all trawl nets used in the Marine Park by March 2000. TEDs enable turtles to escape through an opening in the trawl net, preventing them entering the cod end. Fish have a tendency to swim against a current; BRDs such as 'fish eyes' allow them to swim out through special panels in the trawl net. Even with these devices fitted, the target species are still caught in the cod end.

"Trawling effort must be reduced as part of the Authority's stance on ecological sustainability in the Marine Park and World Heritage Area," says Dr Cadwallader.

Although recovery rates of disturbed seabed life are poorly known, it is thought that some species may take up to 20 years to recover. The Authority has commissioned further research into recovery rates of seabed life.

The Authority has also commissioned the production of a reef-wide management model for the Marine Park to assess how various planning regimes will reduce the impacts of trawling. This model will incorporate a network of conservation-based representative areas in which the taking of fish and prawns will be prohibited.

"The model will give us an overall picture of what should be happening where in the Marine Park, consistent with ecological, social and economic values and established uses," says Dr Cadwallader.

To reduce the volume of bycatch caught in trawl nets, some trawl operators have included bycatch reduction devices (BRDs) and turtle excluder devices (TEDs) in their nets (see diagram).

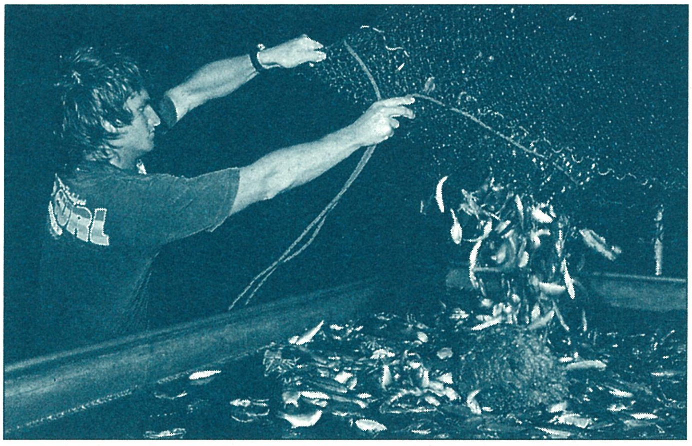
Although these devices help reduce the number animals being caught in trawl nets, they don't prevent damage to the seabed or stop soft corals and sponges being hauled from the seabed.

Dr Cadwallader says the use of much lighter trawl gear, which doesn't have such an impact on the seabed, may be one way of minimising the impacts of repeated trawl sweeps.

The Authority will move to ensure that the installation of BRDs and TEDS in trawl nets used in the Marine Park is compulsory by March 2000.

"These measures will help to reduce the impacts of trawling but they will not ensure the sustainability of the activity," says Dr Cadwallader.

"The Authority will ensure that harvesting of prawns is ecologically sustainable. We must actively pursue measures that will sustain not only the targeted prawn stocks, but the integrity of the whole ecosystem," he says. ■



A fisher empties a prawn trawl catch onto the sorting tray. For every tonne of prawns, there may be up to 10 tonnes of bycatch.

REEF BRIEF

REEF BRIEF

AN EVEN GREATER BARRIER REEF MARINE PARK

The Commonwealth Government has proposed to extend the Great Barrier Reef Marine Park to include a further 6000 square kilometres. The proposal would see all 27 currently excluded coastal areas of the Great Barrier Reef Region annexed by the Marine Park.

"We now know we've got to be concerned with nearshore waters as well as offshore waters," says former Chairman of the Authority Dr Ian McPhail. "This was not clearly understood at the time the Marine Park was created."

The series of coastal pockets stretch along the Queensland coastline from Cape York to just north of Bundaberg and include inshore waters off Cooktown, Mission Beach, the Burdekin, Mackay and Yeppoon. Significant strips run from Daintree to Mourilyan and from Lucinda to the Bohle River.

The extensions are expected to provide for more contiguous management of the Great Barrier Reef Region and will help to fill in 'the gaps in the management jigsaw', according to the Authority's Manager of Planning, John Baldwin.

"The significance of the proposed extension lies in the fact that areas previously excluded from the Marine Park will be brought under the umbrella of sustainable management by the Authority," says Mr Baldwin.

The proposed extensions play host to a variety of activities, including shipping and fishing, and range from areas of remote wilderness to areas of high human use.

"Management planning for these areas will take into account these uses in recognition of their value to a variety of people," says Mr Baldwin. ■

TOURISM AND RECREATION CRITICAL ISSUE GROUP

ON THE BOIL

TOUR OPERATORS KEEP AN EYE ON THE REEF

The Great Barrier Reef Marine Park Authority, CRC Reef Research and the marine tourism industry have combined forces to develop a new phase in a collaborative Reef monitoring project called 'Eye on the Reef'.

Pioneered by two innovative marine scientists some five years ago in conjunction with Reef Tourism 2005, the project has since been reviewed and refined to make it simpler for tour operators to record ecological data.

Daily interaction with the Reef means that marine tourist operators are in a prime position to be the 'eyes' and 'ears' for Reef managers and the marine tourism industry alike. By recording the marine life observed at their routine destinations, tour operators are able to collect valuable baseline data on the Reef.

Tour operators will be on the lookout for distinctive marine animals like dugong and whales, ecological disturbances like coral bleaching or irregular events such as algal blooms.

Newly-appointed project coordinators Robin Aiello and Udo Engelhardt say the project is like keeping a 'nature's diary' of what is happening out on the Reef.

"We will be revising the current log sheets and then developing a training program so that tour operators will be able to record data quickly and easily," says Ms Aiello.

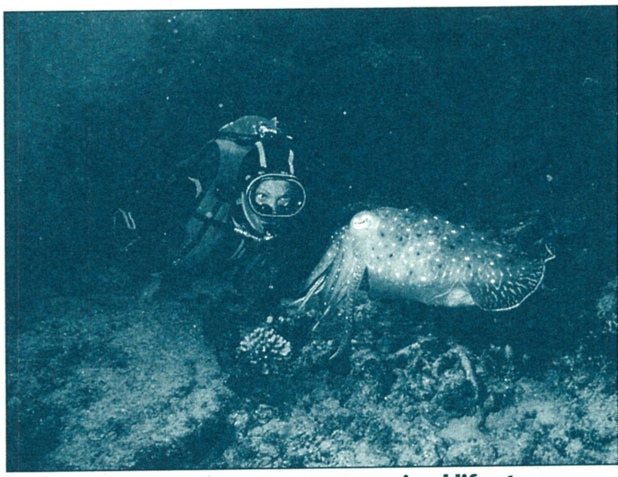
"Tour operators are very enthusiastic about participating in the new phase of the project and we have more than enough volunteers."

Each participating tour company selects representatives to attend training workshops on how to gather site-specific data and use it to facilitate Reef education and interpretation.

"Although it is not strictly necessary, many of the representatives have degrees in marine biology or science and are very keen to contribute to research that will help with the management of the Great Barrier Reef," says Ms Aiello.

Project benefits are two-fold, according to the Authority's Manager of Research and Monitoring, Ray Berkelmans.

"Tour operators acquire valuable site-specific information that can be used as an on-board interpretive tool, while Reef managers will get a clearer picture of the ecological status of the Reef," he says.



Tour operators will keep an eye on animal life at their routine destinations

Revamping of the project will include extensive liaison between coordinators, Reef managers and the marine tourism industry.

"We will be providing feedback to operators about their individual sites; information will flow in a loop from operators to the coordinators and Reef managers, and back to the operators," says Ms Aiello.

The project will be partly modelled on the COTSWATCH crown-of-thorns monitoring program—which has been running successfully since early 1983—and will adopt the same focus on two-way communication between the industry and Reef managers.

Although the project will initially only operate in the Cairns Section of the Marine Park, its success may mean expansion to include other Sections of the Reef.

Ms Aiello says that tourist operators will be able to use the data to predict seasonal trends in the abundance of marine animals, spawning activity and unusual occurrences.

"Most operators have certain charismatic animals, like whales and large fish, that they encourage tourists to come and see and it will be great for operators to know when those animals are likely to turn up," she says.

Mr Berkelmans says that most importantly for Reef managers, incoming data would act as an early warning mechanism for events such as coral bleaching or outbreaks of crown-of-thorns starfish.

"This information will help us to detect trends in ecological disturbances which might give us a better understanding of these phenomena," he says.

Mr Berkelmans says Reef managers will also be able to use this baseline data to know exactly what is out there today, so that in the future it will be easier to detect what might have changed.

In terms of the bigger picture, the monitoring project is in line with the Authority's sharper focus on partnership management and self-regulation by the marine tourism industry.

"Monitoring the Reef will help us to understand it," says Ms Aiello. "The more we understand the Reef, the more we can teach visitors about how to take care of it. Strong partnerships between Reef managers and the tourism industry are an integral part of good Reef management." ■

FEATURE I

Three-year crackdown on illegal activity

The Commonwealth Government has made $3.4 million available over the next three years for targeted enforcement and surveillance of the Great Barrier Reef Marine Park.

The Great Barrier Reef Marine Park Authority proposes to use the funding to increase patrols of the Marine Park, investigate the use of new enforcement technology and continue the currently high level of enforcement of Dugong Protection Areas within the Marine Park. This year, additional funding of $230 000 has also been provided for further enforcement of Dugong Protection Areas.

As part of day-to-day management of the Marine Park, aerial surveillance and boat patrols are used to monitor vessel activity. The Queensland Parks and Wildlife Service (QPWS), Coastwatch, the Queensland Boating and Fisheries Patrol (QBFP) and the Queensland Water Police all undertake surveillance for illegal activity within the Marine Park.

The Authority is increasingly focussing on a co-ordinated multi-agency approach to management, using available resources in the most efficient way. All aerial and vessel surveillance is currently being reviewed to ensure maximum coverage of the Marine Park by all agencies involved in enforcement activities—Coastwatch, the QBFP, the Australian Maritime Safety Authority (AMSA) and the Water Police.

Of particular interest will be the heavily trafficked 'green zone' in the Far Northern Section and the new closed areas that have been introduced as part of the Far Northern Section Zoning Plan. It is proposed to develop tactical and strategic programs with external agencies to use remote night surveillance, radar and cover/saturation enforcement action to further target illegal activities.

Another area of high priority relates to illegal line fishing occurring throughout the Marine Park around protected reefs. These activities will also be given increased attention in regard to surveillance and enforcement of Marine Park zoning regulations.

The Authority has re-established its Enforcement Co-ordinating Committee, which brings together Queensland Parks and Wildlife Enforcement Co-ordinators and external agencies patrolling the Marine Park. A workshop to be held in coming months will investigate the cost and effectiveness of new technology to detect both pollution and fishing infringements in protected areas, including Vessel Monitoring Systems (VMS), radar and undersea surveillance systems.

VMS provides a means of tracking the location of vessels using satellite monitoring systems. Vessels are fitted with a transmitter which is polled by a ground station at predetermined intervals. Vessel identification, speed and position can be recorded. The Queensland Fisheries Management Authority is fitting VMS to the Queensland trawl fleet and has proposed to extend the technology to other fisheries over the next few years. The Authority is seeking to have access to this system.

Also under scrutiny is undersea surveillance, involving the placement of an array of acoustic sensors on the sea floor to monitor traffic levels and allow for more targeted enforcement. Local and over-horizon radar will also be investigated as a potential means of providing information on vessel movements and activity patterns. ■

ON THE BOIL

TOURISM AND RECREATION CRITICAL ISSUE GROUP

HIGH USE SHOULDN'T MEAN HIGH ABUSE

The Whitsunday island group is one of the most heavily visited areas in the Great Barrier Reef Marine Park, making management of human-use impacts on the natural values of the area particularly important.

Of major concern has been the impact on delicate fringing coral reefs of the many anchors dropped by boating visitors. Careless anchoring can cause chains and anchors to drag along the seabed, damaging coral—the foundations of the reef—which can take years to recover.

Concern from Reef managers, local tourist operators, community groups and users prompted the Great Barrier Reef Marine Park Authority and the Queensland Parks and Wildlife Service (QPWS) to establish a Reef Protection Program in 1993.

The Program included the installation of reef protection markers and public moorings at various sensitive sites throughout the Whitsundays.

Anchoring is prohibited inside reef protection markers, and public moorings provide a secure anchorage for boats, with minimal disturbance to the seabed.

A number of monitoring programs have been established in the Whitsundays to assess the effectiveness of human-use management in the area. One such monitoring program revealed a significant decrease in coral damage at sites where reef protection markers had been installed.

Initial surveys by the QPWS found that anchor damage was widespread at North Stonehaven and West Butterfly Bays. Further monitoring has shown, however, that the installation of reef protection markers at North Stonehaven Bay has been effective in protecting corals from anchor damage.
In comparison, coral damage due to anchor drag in West Butterfly Bay—which did not have reef protection markers at the time the initial surveys were conducted—had continued. Reef protection markers and public moorings have now been installed in West Butterfly Bay, with positive results expected.

"Monitoring of the sites by QPWS staff and feedback from Reef users has indicated that there has been significant recovery of corals that had been damaged by anchors," says QPWS District Manager (Coastal Management) for the Whitsundays Mr Artie Jacobson.

By defining the reef and providing good anchorage, Mr Jacobson says the reef protection markers and public moorings have helped to ensure that people 'don't destroy what they have come to enjoy'.

Whitsundays volunteer group, the Order of Underwater Coral Heroes (OUCH), has been instrumental in establishing the Reef Protection Program by providing diver-support for the installation and monitoring of the markers and moorings.

"The Whitsundays community is really enthusiastic about caring for the Reef," says Ms Bryony Barnett, the Authority's Project Manager for Industry Training/Accreditation. "The Reef Protection Program is a real success story of community and government agencies working together to effectively manage a high-use area."

REEF BRIEF

CRACKDOWN ON CARGO RESIDUE

One of the little known problems associated with shipping in the Great Barrier Reef Marine Park and World Heritage Area is the sweeping of dust and cargo residue off ships' decks into the ocean.

The Great Barrier Reef Marine Park Authority and the Australian Maritime Safety Authority (AMSA) recently announced plans to crack down on the illegal disposal of this material into ports along the Queensland coastline, with the introduction of a compliance program.

The loading of cargoes such as coal and iron ore frequently results in dust and residues collecting on ships' decks and superstructure.

"Many vessels wash their decks soon after leaving port," says AMSA Chief Executive Clive Davidson.

"But international regulations prohibit the washing of this pollutant material overboard until ships are more than three nautical miles from the outer edge of the Great Barrier Reef."

There are, however, exceptions where cargo residues can be discharged for safety reasons.

Dr Ian McPhail, former Chairman of the Great Barrier Reef Marine Park Authority, says that while many dry bulk cargoes may be considered harmless to the marine environment, the main concern was that the build-up of these residues may have an effect on ocean sediments and seabed life.

"This particularly applies in port areas and the relatively shallow shipping lanes though the Reef," he says.

The compliance program was implemented on 1 January 1999 and will involve education material for shipmasters and their crews, aerial surveillance and shipboard inspections.

Dr McPhail says that surveillance of ship-sourced pollution in the Great Barrier Reef is being tightened after the recent announcement by the Queensland Government of measures to focus on prevention and better detection of pollution from ships.

AMSA surveyors will carry out shipboard inspections in Queensland ports and will be checking shipboard arrangements and record books for evidence of non-compliance.

The compliance program has been developed in consultation with the Queensland Department of Tourism and the shipping industry, which is fully supportive of the program. A number of Australian ship operators have already modified procedures on-board so as to fully comply with the international regulations. ■

Monitoring of anchor damage to coral reefs in West Butterfly and North Stonehaven Bays has also highlighted the problems with litter from boats visiting the area. A number of surveys by OUCH volunteer divers and the QPWS over the past three years have revealed a continuous accumulation of litter on the sea floor of these bays. Refuse collected included fishing line, beer cans, stubbies, wine bottles, towels, clothing, swim fins and cooking items.

"Litter can provide some major hazards for marine life, not to mention the unpleasant aesthetic impact of rubbish on the seabed," says Ms Barnett.

"Clothing and towels smother and cut off water circulation from coral, while plastic items can be a death-trap for marine animals. Some of these items would have been purposely thrown overboard—for example, some of the beer cans had been ripped in half so they would sink.

"Other refuse, such as cooking items and towels and clothing, probably ended up in the ocean because they were carelessly fastened to the boat or were lost while people were washing up over the side."

Reef managers are concerned by the large amount of fishing line hauled up during the refuse-collection dives. West Butterfly Bay is a 'green zone' which means that fishing is prohibited.

"The presence of this fishing line indicates that people are disregarding Marine Park zoning plans," says Ms Barnett.

The Authority's Whitsundays Plan of Management, which will come into effect in July of this year, has a strong focus on tourism management and aims to minimise the effects of use on the area's natural and cultural values. The Authority has also developed guidelines for best environmental practice when mooring and anchoring.

"To address the problems of litter, illegal fishing and careless anchoring we are educating locals and visitors alike about how to take care of the marine environment that has attracted them in the first place," Ms Barnett says.

The Authority has also introduced training workshops for Whitsundays bareboat operators. The bareboat industry is keen to set new standards of operation and training for its staff to ensure that the bareboat hirers are well briefed in environmental issues and best environmental practices.

"We also need to get the message out to recreational users and charter operators," says Ms Barnett. "It really isn't very hard to leave the environment just how you found it." ■

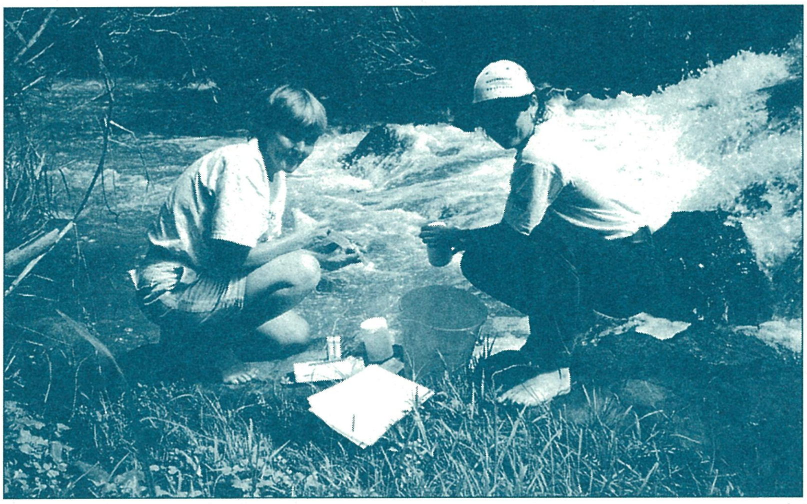
ON THE BOIL

WATER QUALITY AND COASTAL DEVELOPMENT CRITICAL ISSUE GROUP

CATCHMENT CARERS BRAVE WET WEATHER

As the coastal rivers of Far North Queensland swell during the summer cyclone season, a dedicated team of catchment carers brave the wet weather to gather water samples in a bid to learn more about the effects of nutrient and sediment run-off on the Great Barrier Reef.

At the height of monsoonal downpours, volunteers can be seen perched on the muddy banks of the Barron and Russell–Mulgrave Rivers collecting water samples for a long-term monitoring project coordinated by the Great Barrier Reef Marine Park Authority, and run in conjunction with the Queensland Department of Natural Resources' (DNR) Waterwatch program.
Atherton volunteer Helen Adams hauls buckets of water from a bridge over the torrid waters of the upper Barron River, apparently unperturbed by the sometimes cyclonic weather conditions.



Waterwatchers Helen Adams (left) and Michelle Devlin

She is one of 14 volunteers who venture outdoors every four hours for up to 48 hours at a time to take samples from the rushing rivers during heavy rainfall. According to the Authority's Water Quality and Coastal Development Project Manager, Michelle Devlin, the monitoring effort aims to give scientists and Reef managers a clearer understanding of the downstream effects of flooding.

"We still don't completely understand what happens to sediment and nutrients during flooding and how they might affect the inshore areas of the Reef," says Ms Devlin.

Brown flood plumes, carrying sediment and nutrients washed from the land by heavy rainfall, billow into the coastal lagoons of the Great Barrier Reef where the sediment and nutrients are deposited on to inshore corals and seagrass beds.

"Although it is a bit wet and muddy, sampling is most important when a river is flooding because at other times of the year the rivers may not be flowing much at all," says Ms Devlin.

Travelling 10 kms to her monitoring point on the upper Barron River, Mrs Adams admits that this type of volunteer work is 'definitely for those with an adventurous spirit'. It is Mrs Adams' second year 'waterwatching', and she is joined by volunteers of all ages and from all backgrounds, including university graduates, landholders and retired persons.

Mrs Adams says that programs like DNR's Waterwatch and the Authority's flood monitoring program have 'harnessed a wealth of community enthusiasm', with locals not only supporting scientific research but contributing to it. "The rivers tell the story of the catchment," she says. "It is at the community level that we can all help to keep our rivers healthy."

Coordinators from the Authority and DNR have received expressions of interest from residents in other areas such as Airlie Beach and the Pioneer catchment, with locals more than willing to get a bit wet for a good cause. Waterwatch volunteers already monitor ambient water quality in rivers from the Daintree to Ingham and Ms Devlin says there is similar support for flood monitoring.

"Our dedicated volunteers make it possible to take samples at more sites, more often," says Ms Devlin. "This study on the Barron and Russell–Mulgrave Rivers is one of the largest-scale flood monitoring projects undertaken in the area, but it wouldn't be possible without help from the community."

Samples taken by volunteers are sent to Townsville to be assessed for dissolved nutrient and suspended sediment content. "The results will go hand-in-hand with the other water quality monitoring and research projects carried out by scientists in the area," Ms Devlin says.

Ultimately, Reef managers will be able to use the results to assist in the development of better land management practices, which will help to reduce the impacts of sediment and nutrient run-off on the Great Barrier Reef. ■

FEATURE II

GBRMPA TARGETS ILLEGAL ACTIVITY IN RESTRICTED MARINE PARK ZONES

Surveillance by officers of the Queensland Parks and Wildlife Service (QPWS), the Queensland Boating and Fisheries Patrol (QBFP), Coastwatch and other agencies continues to find inappropriate commercial and recreational fishing activity in restricted zones of the Marine Park and World Heritage Area.

In the three-month period from July to December 1998, a total of 107 infringements of the Marine Park Act were reported. Of these, 38 were forwarded to the Department of Public Prosecutions for court action and numerous offenders were issued letters of caution. A number of incidents remain under investigation.

The Bowen Magistrates Court recently set a precedent when the QPWS was awarded $6000 for the loss of a turtle from a protected species. The case marks the first time in Queensland that an environmental agency has been successful in gaining compensation for the loss of a protected animal.

Additional funding from the Commonwealth Government totalling approximately $230 000 was provided in late 1998 for the increased enforcement and surveillance of the 16 Dugong Protection Areas (DPAs) situated along the Queensland coastline. Both the QPWS and the QBFP are involved in undertaking patrols and aerial surveillance under the DPA Enforcement Program.

In addition to specific DPA patrols, both QPWS and QBFP officers conduct non-DPA funded standard patrols in DPAs, or are on an opportunity basis altering standard patrols to transit and conduct enforcement in DPAs while attending to other matters. Increased patrolling in certain DPAs has also been timed to coincide with the expected high-use period during the barramundi fishing season which commenced on 1 February 1999.

"The DPAs are receiving the maximum amount of surveillance and enforcement possible with the resources we have available," says Acting Chair of the Great Barrier Reef Marine Park Authority John Tanzer.

Twenty-nine dugong deaths were reported in Queensland south of Cooktown from July to December 1998—less than in previous years. Significantly, no deaths resulting from nets were reported in the designated DPAs.

A commercial fisherman caught illegally netting in a DPA was successfully prosecuted and fined in September 1998. Marine Parks officers issued 32 warnings to people within DPAs and a further 28 incidents in these areas initiated enforcement action. The majority of the enforcement action related to technical infringements, such as licence errors and vessel side numbers, rather than environmental infringements within the Dugong Protection Program.

"Surveillance and enforcement of all Marine Park zones is accorded a high priority by the Authority," says Mr Tanzer.

"We will seek, through the court system, to award maximum penalties to those who continue to do the wrong thing and we make no apologies for doing so." ■

Please report any injured or dead dugongs, turtles or dolphins in the Great Barrier Reef Region by phoning the MARINE ANIMAL HOTLINE on 1300 360 898*. Report immediately for maximum chance of recovery and benefit to species management and science.

*For the cost of a local call

CONSERVATION, BIODIVERSITY AND WORLD HERITAGE CRITICAL ISSUE GROUP

A NEW ERA IN CONSERVATION

A detailed brochure outlining the Representative Areas Program will be published by the Authority in April. Anyone interested in additional information should contact the Great Barrier Reef Marine Park Authority on (07) 4750 0700 or email registry@gbrmpa.gov.au

As the Great Barrier Reef Marine Park Authority embarks on a new era in conservation planning and management, it will call on the public for input into the identification and selection of a series of highly protected representative areas to be introduced into the Marine Park.

The Representative Areas Program aims to identify the various broadscale habitat and community types that exist within the Marine Park and then select examples of each habitat type to be given a high status of protection.

Although the protection of representative areas is well established in terrestrial environmental management philosophy, the Authority's Representative Areas Program is probably the largest-scale application of such a process to the marine environment in the world.

"The protection of adequate examples of representative areas is widely accepted in Australia and around the world as playing a vital role in the conservation of biodiversity and will ensure that marine species, ecosystem processes and World Heritage values are maintained," says the Authority's Conservation, Biodiversity and World Heritage Critical Issue Group Director, Jon Day. "This program will also enable Australia to meet its international obligations for the conservation of biodiversity."

Conservation efforts have traditionally been focused on the Great Barrier Reef's spectacular coral reef habitats and unique or threatened species, while little protection has been afforded to other habitats such as soft bottom communities, seagrass beds and various nearshore communities.

"Although approximately five per cent of the Marine Park currently falls into highly protected, or 'no-take', zones, a number of less charismatic, yet vitally important, habitats and communities are seriously under-represented," says Mr Day.

"Providing a network of highly protected areas will enable all species to continue to flourish and evolve, and will provide a safety margin against human-induced disasters or other impacts."

Representative areas therefore serve as environmental 'insurance policies' in that they provide a sound ecological base from which to work on recovery and repair of disturbed or threatened species, communities and habitats.

Within the marine ecosystem, plants and animals are dependent upon each other and their physical environment, the parameters and complexity of which scientists still don't fully understand.

"If we allow parts of this diverse ecosystem to be removed or lost, the entire system is likely to become weaker and, in a worst-case scenario, has the potential to collapse," says Mr Day.

The Representative Areas Program has three broad stages. Initially, habitats will be classified according to the geophysical features, such as substrate composition and water depth, that characterise particular habitats and therefore the communities and species found there.

Incomplete biological data on much of the World Heritage Area's flora and fauna has prompted managers and scientists to base this initial stage on geophysical criteria, although any available biological data will be factored into the classification process.

"We cannot wait until we have exhaustive data on marine life before introducing these protective measures," says Program Manager David Lloyd.

"It may be too late by then. We have to take a precautionary approach, act with the knowledge that we have now and leave the door open to new discoveries as they come to hand. The representative area rationale will provide for the protection of all species, both common and unique—even the ones we may not have discovered yet."

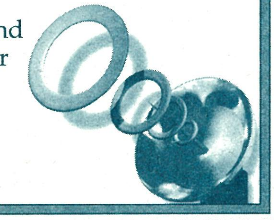
The second stage of the program involves identifying a series of candidate sites as areas potentially requiring a high status of protection based on their capacity to represent the diverse range of marine habitats that have been identified.

The third stage will be crucial in refining and finalising the selection of the highly protected representative areas and will involve a detailed consideration of the social, economic, cultural and practical values of the candidate sites. Other considerations will include an area's significance to unique and threatened species.

Two public-input phases will be included in the Representative Areas Program, with the initial public participation beginning in April this year. Input is expected to come from a wide base of stakeholders including commercial and recreational fishers, conservation groups, indigenous groups, the tourism industry, scientists and Queensland environment and fisheries agencies.

"There will be ongoing communication and consultation with stakeholders throughout the selection process," says Mr Lloyd. "We want to be consistent with the Marine Park's multiple-use management philosophy, while allowing for the ecological sustainability of the Marine Park and World Heritage Area."

Final outcomes and revised zoning for the Marine Park are not expected to be completed until 2001.



SEAGRASSES AND NUTRIENTS: WHAT ARE THE POTENTIAL EFFECTS OF INCREASING NUTRIENT LEVELS?

Michelle Devlin
Great Barrier Reef Marine Park Authority

Seagrasses: Why are they important?

Seagrass beds are of considerable ecological importance in coastal and marine ecosystems (Poiner et al. 1992) where they play a significant role in the processes and resources of nearshore coastal ecosystems. They are among the most productive and dynamic elements of an aquatic ecosystem.

The growth and survival of seagrass communities is of major importance to coastal waters as seagrasses are:

a. primary producers that contribute large quantities of fixed carbon (the basis of all food chains) to coastal ecosystems (Larkum et al. 1989);
b. important in stabilising bottom sediments (Fonesca and Kenworthy 1987) because they slow water movement which promotes sedimentation of particulate matter (Phillips and Menez 1988);
c. part of the nutrient cycle in the aquatic system (Moriarty et al. 1984);
d. important in supplying shelter and refuge for adult and juvenile animals and contributing large amounts of substrate for encrusting animals and plants; and
e. essential food for dugongs (*Dugong dugon*) and green turtles (*Chelonia mydas*).

Where do they grow in the Great Barrier Reef?

Seagrasses grow in shallow-water ecosystems, notably the inshore lagoon of the Great Barrier Reef. The Great Barrier Reef lagoon is a largely sheltered area and offers special protection to seagrass beds within the reef itself and on the lee or landward side of reefs or embayments (Larkum et al. 1989).

Surveys conducted of seagrasses between Cape York and Hervey Bay show that they are most often found in areas that receive shelter from the prevailing winds, such as in bays, behind northerly facing peninsulas, behind islands, reefs and shoals, and on some reef platforms and fringing reefs (Lee Long et al. 1993). The regional contribution of these seagrass beds to primary production and as habitat for marine fauna is likely to be extremely important.

The large majority of seagrasses found in the Great Barrier Reef Region grow in the inshore lagoon in waters no deeper than 10 metres and no greater than 10 kilometres from the coast (Lee Long et al. 1993; Larkum et al. 1989). Large areas of deepwater seagrass (in waters of between 10 and 30 metres depth) have also recently been found in the Great Barrier Reef. Seagrasses in close proximity to land are more likely to be affected by material flowing from land and vulnerable to changes in coastal processes. Recent studies of the factors contributing to seagrass decline have shown that increased anthropogenic inputs to the coastal zone are often linked to seagrass loss (Walker and McComb 1992; Dennison et al. 1996; Short et al. 1996).

Seagrass beds play a very significant role in coastal ecosystems

The species of seagrass found between Cape York and Hervey Bay are common throughout northern Australia, including the Gulf of Carpentaria and Torres Strait. Fourteen species have been recorded from the seagrass habitats of north-eastern Australia (Larkum et al. 1989). Tropical Australia supports well-developed seagrass communities and a large proportion of all known seagrass species (> 22%). Tropical Australia has a greater diversity of seagrass species than elsewhere in the tropical Indo-West Pacific (Larkum et al. 1989).

Key environmental factors

The distribution and growth of seagrasses is regulated by a variety of water quality factors such as temperature, salinity, nutrient availability, substratum characteristics, turbidity and submarine irradiance (Dennison and Kirkman 1996; Abal and Dennison 1996). For example, it is well known from overseas and temperate Australian studies that the availability of nutrient resources affects the growth, distribution, morphology and seasonal cycling of seagrass communities (Short et al.1995). In addition, seagrasses depend on an adequate degree of water clarity to sustain productivity in their submerged environment (Short and Wyllie-Echeverria 1996). Increased turbidity and sedimentation reduce water clarity, which can affect the health and productivity of seagrass communities (Abal and Dennison 1996).

Although natural events have been responsible for both large-scale and local losses of seagrass habitat, recent evidence suggests that human population expansion is now the most serious cause of seagrass habitat loss. Increasing anthropogenic inputs to the coastal oceans are primarily responsible for the enhanced nutrient input from the land and the worldwide decline in seagrasses (Abal and Dennison 1996). Human activities that most affect seagrasses are those that alter water quality or clarity. These activities can include nutrient and sediment loading from agricultural run-off and sewage disposal, dredging and filling, urban stormwater, upland development, and certain fishing practices.

How do increased nutrients affect seagrass survival?

Nutrient loading is the primary factor responsible for both reduction of water quality and stimulation of algal growth in coastal marine waters (Short et al. 1996; Short and Wyllie-Echeverria 1996). Several studies (Neverauskas 1987; Johansson and Lewis 1992; Phillips and Menez 1988; Short et al. 1996) have related the decline of seagrass distribution to the degree of nutrient loading within various catchments. Causes of seagrass degradation include various forms of nutrient loading, including sewage enrichment (Neverauskas 1987; Johansson and Lewis 1992), enrichment of groundwater supplies (Short et al. 1996) and run-off from agricultural lands (Phillips and Menez 1988). Loss of seagrasses in Cockburn Sound in Western Australia is strongly correlated with the increase of discharge rich in plant nutrients over a period of increasing industrial development (Cambridge and McComb 1984).

Once impacted, seagrass colonisation and regrowth can be very slow, or nonexistent, because of possible ongoing impacts and poor dispersal capabilities of most seagrass species (Preen et al. 1995; Dennison and Kirkman 1996). Loss of seagrasses can bring about a change in the marine food chain with an accompanied shift in main primary producers from benthic to planktonic and a reduction in leaf detritus production. Continued seagrass loss can result in an ecosystem shift to a lagoonal system dominated by high turbidity and algal growth or bare sandy/silty substrate which may remain after the decline of the seagrass beds (Cambridge and McComb 1984). This change results in a considerable loss of diversity.

Seagrasses respond to changes at both a global and local scale but, for the scope of this paper, only local or regional changes in the environmental nutrient regime will be considered. At a regional scale, increases in nutrient loading associated with eutrophication and changes in light quality can adversely affect seagrass beds, resulting in either their reduction or disappearance (Short et al. 1995). Effects on seagrasses can be evident in four different stages, these being structural impacts, diseases, reduced photosynthesis (directly linked with reduced light) and ecosystem shifts.

Structural impacts

Under conditions of high nutrient loading, seagrasses take up additional nutrients from the water. This can cause stress in the plant as there is little intercellular tissue space available for nitrate accumulation. As a consequence, high quantities of nitrate will be converted into ammonia, either immediately, or following vascular storage (Brown 1993). Ammonia production, in turn, requires the plant to divert substantial carbon resources for immediate conversion into amino acids. After an extended period of elevated nutrient uptake, the plant, even with abundant carbon available, will not have the capacity to fix enough carbon to meet its total carbon demand. Lack of carbon in the cellular tissue ultimately severely affects the structural integrity of the seagrass, and results in the death of the plant.

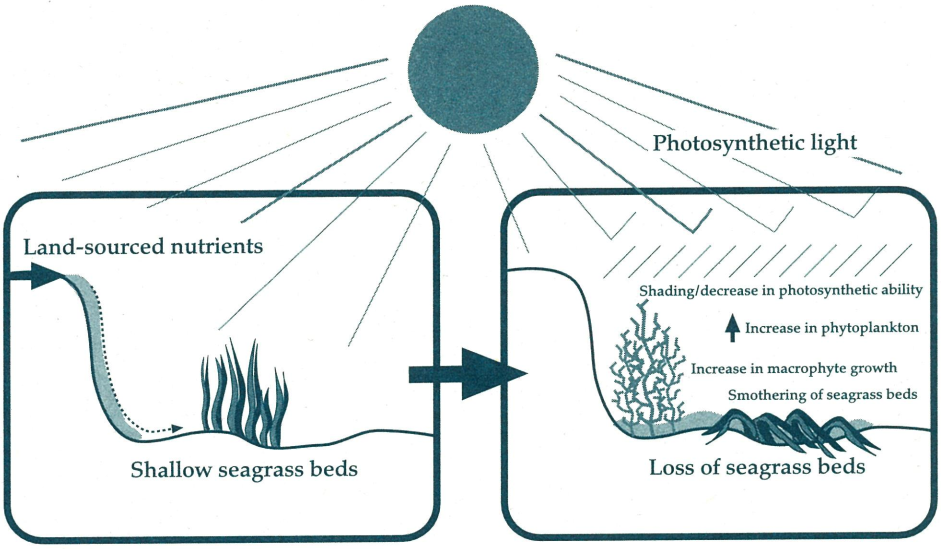
Diseases

Physiological stresses imposed by nutrient supply imbalances may also affect weakened plants by enhancing susceptibility to opportunistic pathogens (i.e. wasting disease) (Brown 1993; Den Hartog 1996). This may be due to a decrease in the production of anti-microbial compounds under conditions of enriched nitrate (Buchsbaum et al. 1990).

Reduced photosynthesis

A reduction in light reaching the seagrass can be brought about by increased turbidity arising from living or non-living particulates in the water, or increased shading by the deposition of silt on photosynthetic tissue (Larkum et al. 1989). Elevated algal growth on the leaf surfaces or stems, resulting from the uptake of additional nutrients by the epiphytic algae, can also limit the amount of light reaching the underlying seagrasses. A reduction in light reaching the seagrass chloroplast precludes effective seagrass photosynthesis. Loss of structural integrity and increased incidence of disease may be exacerbated by reduced photosynthesis.

Figure 1. Summary of effects of nutrients on shallow seagrass beds



Many documented cases of seagrass loss have followed eutrophication of coastal embayments where enhanced nutrients have resulted in a reduction in light penetration of the water column, or a reduction in light reaching seagrass levels due to its interception by epiphytic algae (Walker and McComb 1992; Preen et al. 1995). In enhanced nutrient regimes of coastal areas, there is a strong potential for interactions between water-column nitrate and suspended sediment loading (or other sources of light reduction, such as macroalgal overgrowth).

Ecosystem shifts

Nutrient enrichment can enhance the growth of macroscopic and microscopic algae on seagrass leaf surfaces (Neverauskas 1987). Nutrients are required for seagrass growth but the concentrations in tissues are lower than in macroalgae. Due to differences in the carbon:nitrogen:phosphorus ratio, macroalgae can dominate seagrasses under conditions of marked eutrophication, both as epiphytes and as free-floating species which may originate as attached epiphytes (Batyan 1986). Increased epiphytic growth results in shading of seagrass leaves by up to 65%, which reduces the photosynthetic rate and leaf densities (Walker and McComb 1992).

Nutrient concentrations and seagrasses in Great Barrier Reef waters

Eutrophication effects on seagrass beds are most severe in sheltered habitats with reduced tidal flushing, where nutrient loadings are both concentrated and frequent, and where temperatures fluctuate more widely than in areas with greater water exchange. Shallow seagrass beds found in the inshore Great Barrier Reef lagoon are exposed to potentially higher nutrient inputs, infrequent flushing and temperature variability, making them vulnerable to any changes in the nutrient and light regime.

In protected waters similar to those facing northward along the Queensland coast, epiphytes and macroalgae respond so quickly to water-column enrichment that they can seasonally outgrow grazing pressure, leading to severe light reduction and decline of the underlying seagrass (Burkholder et al. 1992).

Recent studies (Burkholder et al. 1992; Short et al. 1996) have shown that under conditions simulating poorly flushed coastal habitats, even low levels of nitrate enrichment can promote the decline of seagrasses. Growth and survival of seagrass species significantly decreased at all enrichment levels, with the most rapid decline occurring at the highest nitrate loading. Plant death was preceded by loss of structural integrity in above-ground tissues.

Laboratory studies have found that the seagrass species *Zostera marina* declined under low to moderate (3.5–7.0 μM) water-column nitrate enrichment (Short et al. 1995; Burkholder et al. 1992). Long-term nitrate additions cause severe seagrass decline, likely to be enhanced by increasing temperatures and light reduction. Enriched levels of ammonia (1.85–5.41 μM) and phosphate (0.22–0.50 μM) lead to a reduction in shoot density and biomass of the seagrass population (Short et al. 1995). Conversely, laboratory studies on Great Barrier Reef algae have demonstrated increased algal growth associated with nutrient enrichment (Schaeffelke and Klumpp 1997). Growth of epiphytic algae is also likely to be promoted by excess water column nutrients. Small increases in water column nutrient concentration can also result in increased growth of seagrasses. This has occurred around Green Island following prolonged discharge of untreated sewage (Steven et al. 1990; van Woesik et al. 1990).

On nearshore reefs, the water column nutrients are highly variable, ranging from non-detectable to levels indicative of a eutrophication state (Schaeffelke and Klumpp 1997; Bell 1992). Approximate ranges for (non-flood) inshore water quality concentrations have been measured between non-detectable and 2 μM for dissolved inorganic nitrogen (predominantly ammonia) and non-detectable and 0.2 μM for phosphate (Furnas et al. 1995; Furnas and Brodie 1997; Devlin et al. 1997; Schaeffelke and Klumpp 1997).

Nutrients and suspended particulate concentrations associated with cyclones and floods are the highest that most Great Barrier Reef communities are likely to be exposed to (Brodie and Furnas 1996). Inshore seagrass communities are episodically subjected to high dissolved nutrient and suspended loads more typical of a eutrophic system. Water samples taken in flood plumes have consistently recorded elevated ammonia (0.6–4.2 μM), nitrate-nitrite (0.24–14.36 μM) and phosphate (0.13–1.98 μM) (Steven et al. 1997). In large flood events, nutrient levels have remained high in the inshore lagoon for a number of days to weeks (Brodie and Furnas 1996).

Conclusion

Within the past few decades, catastrophic losses of thousands of hectares of seagrass habitat have occurred throughout the world (Gieson 1990). Seagrass losses in recent years in Australian coastal waters have been extensive with over 45 000 hectares lost (Walker and McComb 1992). This loss may result from natural events, e.g. 'wasting disease' (Den Hartog 1996) or flooding resulting from cyclones or high energy storms (Preen et al. 1995) but most seagrass losses have been correlated with increases in human activities (Neverauskas 1987; Walker and McComb 1992). Evidence suggests that human population expansion and the increasing input of anthropogenic materials into the coastal oceans are primarily responsible for the worldwide decline in seagrasses (Short and Wyllie-Echeverria 1996).

Out of all possible scenarios, the factors most frequently correlated with the disappearance of seagrass beds are nutrient enrichment from sewage and agricultural drainage, and reduction in available light caused by increased suspended solids and floating and epiphytic algae (Abal and Dennison 1996). This paper has presented a brief summary of the potential for seagrass decline with increases in nutrient loading. Seagrasses are an important ecological system in the Great Barrier Reef lagoon and while there is no evidence to date of any major decline in seagrass abundance or destruction on the Great Barrier Reef, ongoing monitoring and conservation are essential. Conservation of the seagrass beds existing in the Great Barrier Reef Region will be a major part of any sustainable management plan for the Region.

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NEW PUBLICATIONS

	Price ($)
Driml, S. 1999, *Dollar Values and Trends of Major Direct Uses of the Great Barrier Reef Marine Park*, Research Publication No. 56, Great Barrier Reef Marine Park Authority, Townsville.	n/c
Haynes, D., Kellaway, D. and Davis, K. (eds) 1998, *Protection of Wetlands Adjacent to the Great Barrier Reef, Proceedings of a Workshop held in Babinda, Queensland, Australia, 25–26 September 1997*, Workshop Series No. 24, Great Barrier Reef Marine Park Authority, Townsville.	16.50*
Preliminary study of potential impacts on the GBRWHA from coastal urban development: a scoping study to identify projects suitable for future funding proposals, 1998, Prepared for Great Barrier Reef Marine Park Authority in association with North Queensland Government Association, represented by Townsville City Council, Central Queensland Local Government Association, represented by Livingstone Shire Council, Queensland Department of Environment, Environment Australia and Great Barrier Reef Marine Park Authority.	10.35
Poiner, I. et al. 1998, The environmental effects of prawn trawling in the Far Northern Section of the Great Barrier Reef Marine Park: 1991–1996, Final report to the Great Barrier Reef Marine Park Authority and Fisheries Research and Development Corporation. **(Summary and Introduction is free. For the price of the full report please contact the Authority's Fisheries Critical Issues Group on +61 7 4750 0727)**	
Review of the Marine Tourism Industry in the Great Barrier Reef World Heritage Area, Parts 1 & 2, 1997, Prepared by the Tourism Review Steering Committee with assistance from the Great Barrier Reef Marine Park Authority and the Office of National Tourism	n/c
Steven, A.D.L., Trott, L., Pantus, F. and Brooks, D. 1998, *Long-term Chlorophyll Monitoring in the Great Barrier Reef Lagoon: Status Report 1, 1993–1995*, Research Publication No. 55, Great Barrier Reef Marine Park Authority, Townsville.	8.60*
Wachenfeld, D.R., Oliver, J.K. and Morrissey, J.I. (eds) 1998, *State of the Great Barrier Reef World Heritage Area 1998*, Great Barrier Reef Marine Park Authority, Townsville.	25.00*

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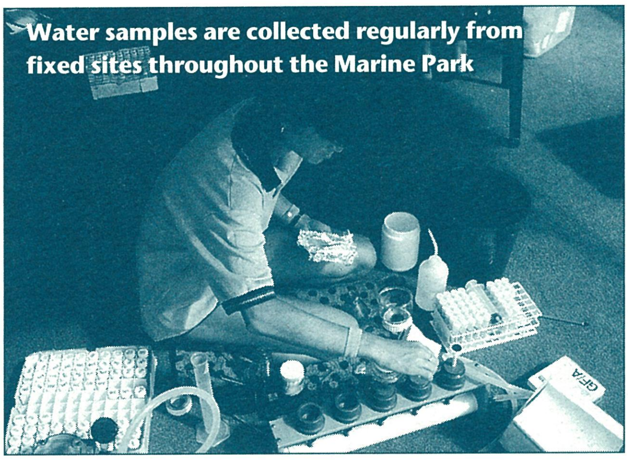
LONG-TERM MONITORING OF CHLOROPHYLL IN THE GREAT BARRIER REEF: AN UPDATE

Michelle Devlin, Jane Waterhouse and David Haynes
Great Barrier Reef Marine Park Authority

Why monitor long-term water quality changes in the Great Barrier Reef?

As a part of its central purpose of protecting the ecosystems of the Great Barrier Reef, the Great Barrier Reef Marine Park Authority manages a variety of reef-based economic activities, including tourism, shipping and fishing. A diverse range of agricultural and mining activities also occur in the watersheds draining into the Great Barrier Reef. The concern is that these activities may cause long-term changes to water quality that will ultimately lead to the degradation of the inshore ecosystems of the Great Barrier Reef.



Water samples are collected regularly from fixed sites throughout the Marine Park

Figure 1a

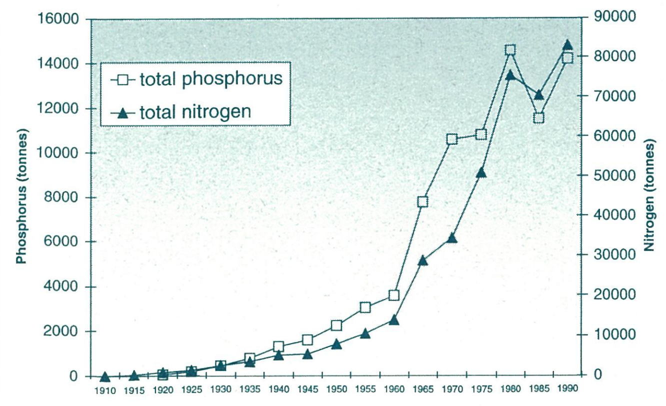


Figure 1b

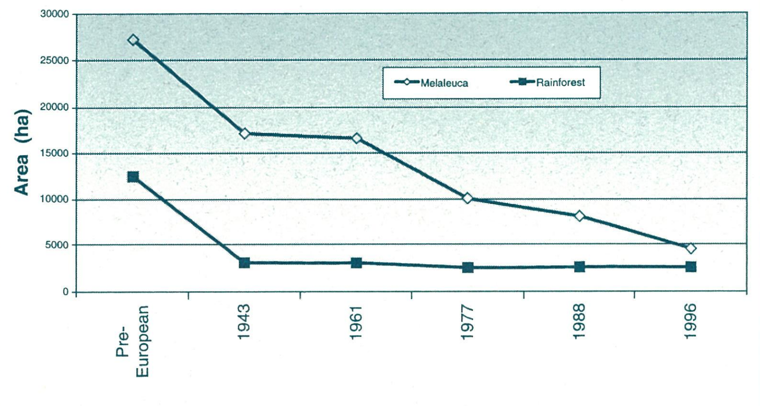


Figure 1. a. Total nitrogen and phosphorus fertiliser applications in the Great Barrier Reef catchment. b. Decline in melaleuca (wetlands) and rainforest adjacent to the Great Barrier Reef since pre-European times (Source: Gilbert, in review)

Terrestrial run-off is the largest source of nutrients and sediments to the Great Barrier Reef that is likely to be increased by human activities. Activities of concern are the increase in fertilisers (figure 1a) and increased clearing of natural vegetation for agriculture (figure 1b). Concern has been expressed that the movement of nutrients and eroded sediments from the adjacent land presents a serious threat to the complex ecosystem of the reef.

It is estimated that total nutrient input into the Great Barrier Reef has risen by about 30% in the last 140 years (Pulsford 1996). The modern increase in nutrient load discharge into reef waters has created a potential long-term threat to Great Barrier Reef ecosystems.

Elevated nutrient concentrations have been demonstrated to cause a range of impacts on coral communities, including decreased calcification rates, changes in coral composition, reduced recruitment rates and juvenile mortality (Tomascik and Sanders 1985; Morrisey 1988; Hoegh-Guldberg 1994; Muller-Parker et al. 1994; Ward and Harrison 1996). Increased nutrients and turbidity can also adversely affect seagrasses (Short et al. 1996) by causing a shading-induced reduction in seagrass photosynthesis (Walker and McComb 1992; Abal and Dennison 1996).

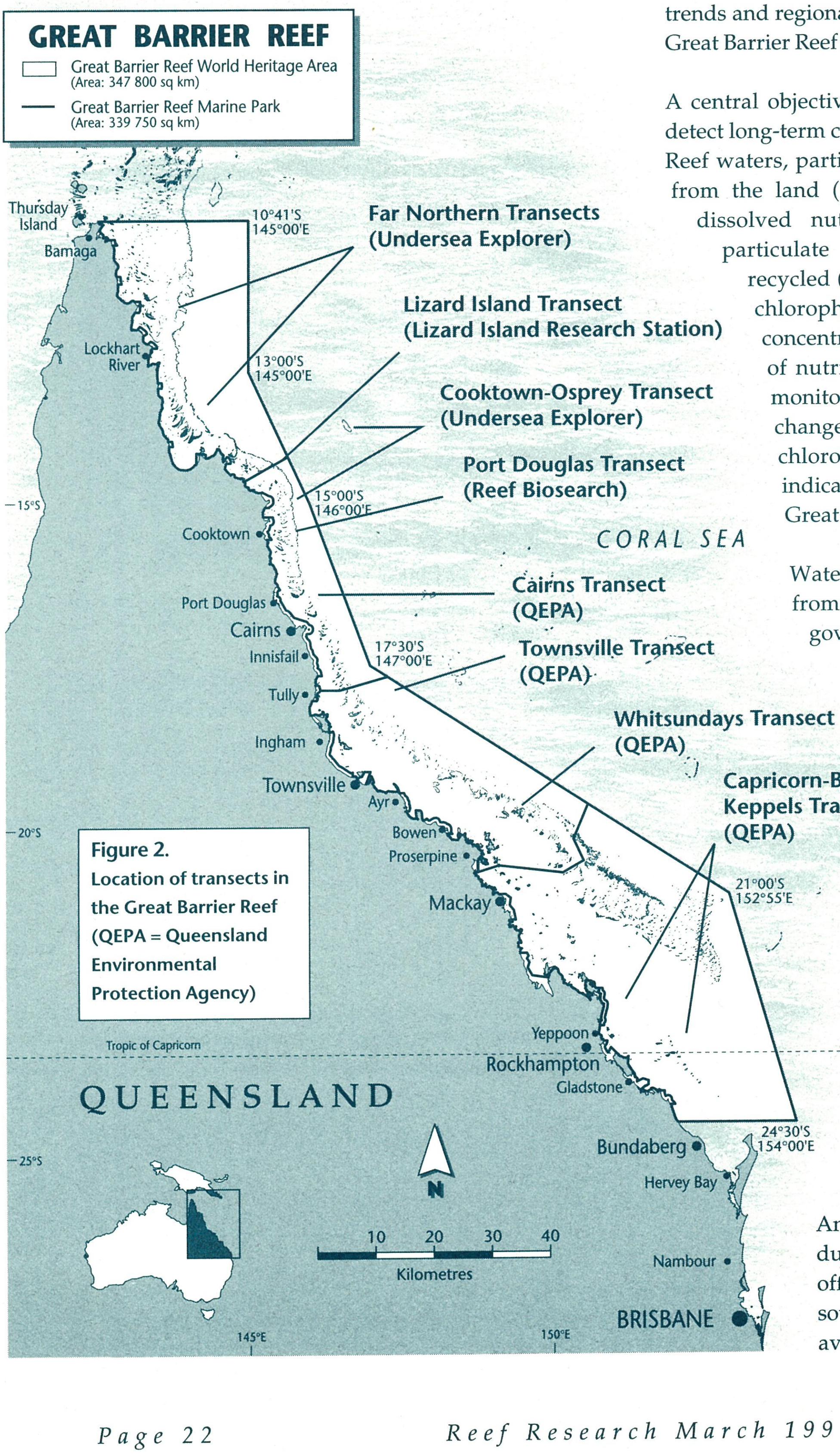


Figure 2. Location of transects in the Great Barrier Reef (QEPA = Queensland Environmental Protection Agency)

Why monitor changes in the phytoplankton (chlorophyll *a*)?

One of the key elements in the understanding and management of water quality within the Great Barrier Reef Marine Park is the establishment of a monitoring program to detect and quantify changes in water quality over time. The Great Barrier Reef Marine Park Authority's long-term water quality monitoring program was established in 1992 to provide long-term data on trends and regional differences in the nutrient status of Great Barrier Reef waters.

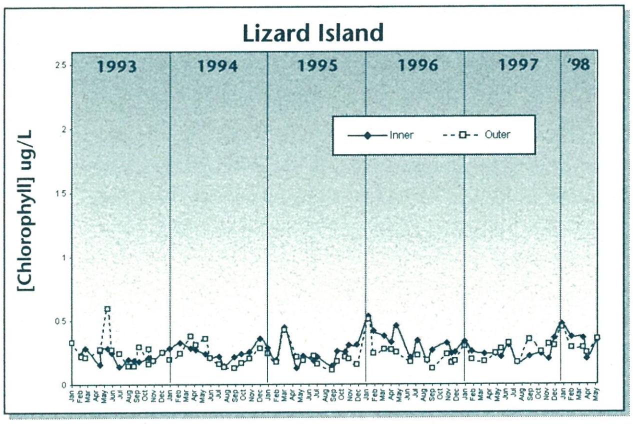
A central objective of this monitoring program is to detect long-term changes in the quality of Great Barrier Reef waters, particularly as a result of nutrient input from the land (Brodie and Furnas 1992). Because dissolved nutrients are rapidly converted to particulate forms, which are in turn rapidly recycled (Furnas et al. 1997), measurement of chlorophyll *a* (the major algae pigment) concentration was chosen as a proxy indicator of nutrient status (Brodie et al. 1997). The monitoring, at a regional scale, of long-term changes in phytoplankton biomass (as chlorophyll *a*) can be used as a proxy indicator of land-based nutrient input to the Great Barrier Reef lagoon.

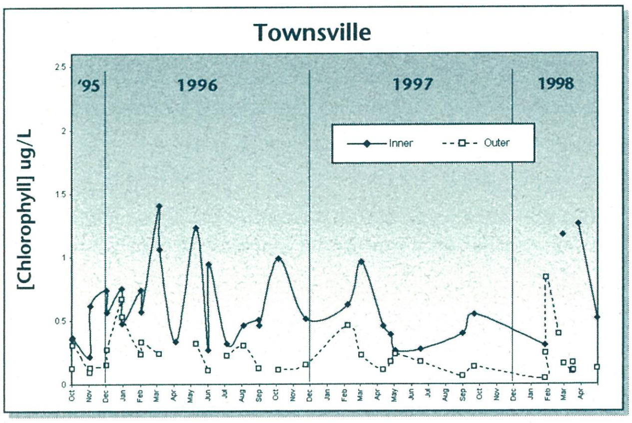
Water samples are collected by personnel from a number of government and non-government agencies and organisations. Samples are collected at fixed sites at approximately monthly intervals along transects located throughout the Marine Park (figure 2). Measurements of salinity, turbidity and sea conditions are also made at the time of sampling.

Continued routine sampling will define regional ambient chlorophyll *a* concentrations, which can be used to benchmark future changes in the nutrient status of Great Barrier Reef waters.

Results – cross-shelf differences

Analysis of chlorophyll data collected during the program from inshore and offshore sites in the northern, central and southern Great Barrier Reef indicates that average chlorophyll *a* concentrations





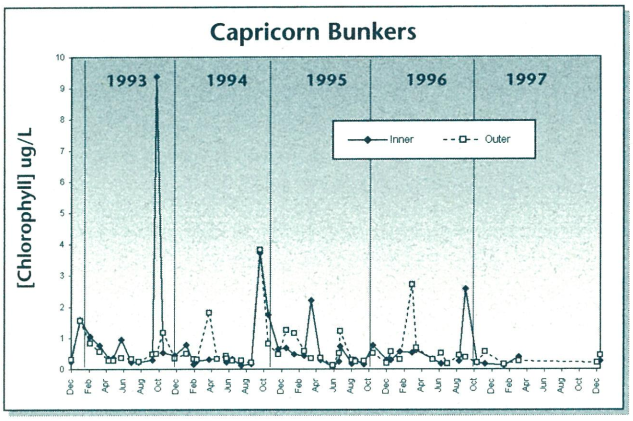
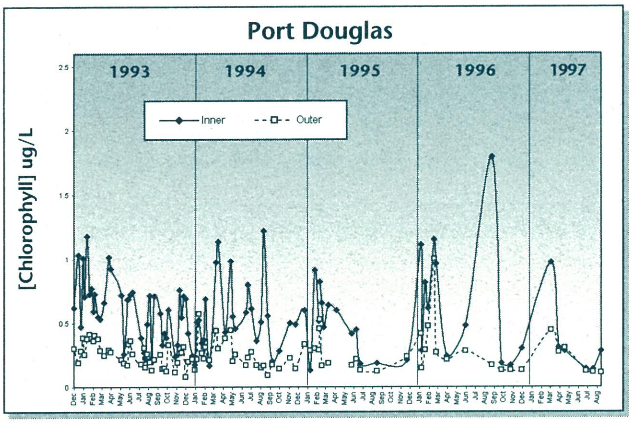
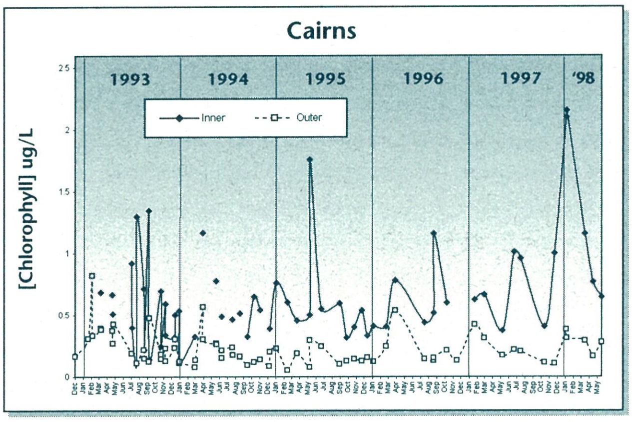


Figure 3. Chlorophyll time series, separated by inshore and offshore transects across the Great Barrier Reef





were significantly higher and more variable in nearshore waters than in samples collected further from the shore (figure 3). Regionally, chlorophyll *a* concentrations were greatest in the Keppel Bay/Capricorn cluster. These high chlorophyll *a* concentrations were related to the presence of *Trichodesmium* aggregations, which were present in over 30% of all samples (Steven et al. 1998).

Shallow nearshore Great Barrier Reef waters are subject to river run-off, urban point-source discharges and wind-forced re-suspension of suspended sediment loads. Each of these factors contributes variable and irregular low-level increases of nutrients to the nearshore water column which, in turn, result in variable and irregular elevations in biological production in shallow waters.

Regional differences

In addition to cross-shelf variations in chlorophyll concentration, there are persistent and significant regional (quasi-latitudinal) differences in mean chlorophyll concentrations through the whole of the Great Barrier Reef (Brodie et al. 1997; Haynes et al. 1998; Brodie 1997; Brodie and Furnas 1996). These differences arise as a consequence of the diverse geographic structure of the Great Barrier Reef shelf at the regional scale and from the combination of marine, atmospheric and terrestrial nutrient sources to Great Barrier Reef waters (Furnas et al. 1997).

The 1993–1998 chlorophyll time series (figure 4) illustrates local variability in chlorophyll concentrations under non-disturbed conditions as concentrations of the phytoplankton are representative of the higher concentrations present inshore of the lagoon. The length of this time series, however, is too short to resolve long-term trends in phytoplankton biomass as a proxy for nutrient loading.

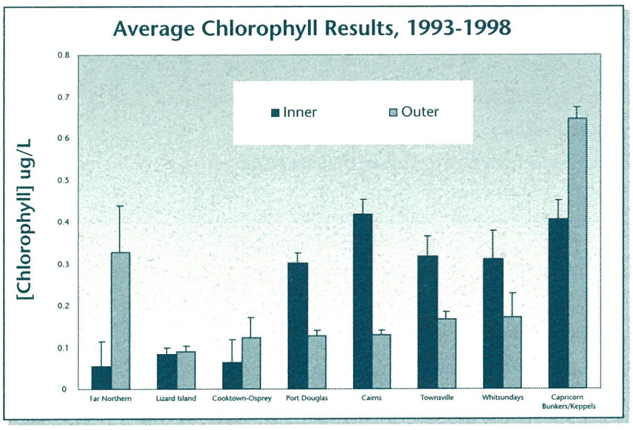


Figure 4. Average chlorophyll results across eight transects along the Great Barrier Reef from 1993–1998 (error bar = 1 SEM)

Conclusion

Broadscale, long-term chlorophyll *a* sampling in the Great Barrier Reef reveals significant regional differences in chlorophyll concentrations and variability over time. However, the time scale over which the Great Barrier Reef Marine Park Authority's monitoring program has been carried out is too short to resolve the issue of large-scale eutrophication in Great Barrier Reef waters. Further sampling over longer time scales and correlation with adjacent land use and proximity of river mouths to position of transects and chlorophyll *a* concentrations may provide new information on the status of water quality in the Great Barrier Reef lagoon. Data from this project will ultimately help quantify latitudinal and cross-shelf trends, and allow closer correlation to be drawn between the quality of Great Barrier Reef waters and changing land-use practices.

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