REEF RESEARCH

GREAT BARRIER REEF MARINE PARK AUTHORITY

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NEWSLETTER OF THE RESEARCH AND MONITORING SECTION

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Editorial

REEF MANAGEMENT NEWS:

The times they are a-changin', as Bob Dylan would gutturally croon. Many changes have taken place since the last issue of *Reef Management News* – not only in the Authority but also on the Reef.

A new phase has begun for the Authority. As of 1 July the restructure was complete and new positions filled. We have farewelled those staff who volunteered for redundancy (they will be sorely missed) and we welcome the new comers. The restructure has provided a focus on four key issues: conservation, world heritage and biodiversity; tourism and recreation; water quality and coastal development; and fisheries.

Mass coral bleaching saw changes on the Great Barrier Reef when corals turned a snow white, while others turned psychedelic. The debate still rages over the phenomenon that affected many of the world's reefs and it is the feature story for this issue.

There is also much to peruse with the releases of 'The environmental effects of prawn trawling in the Far Northern Section of the Great Barrier Reef', 'Whitsundays Plan of Management' and the 'Cairns Area Plan of Management', and the second report of the Long-term Monitoring Program.

Keeping with the song theme – 'It's not easy being green', as Kermit the frog would testify to, but the sugar cane industry is giving it a go. They held their first Environment Forum in March and also released a 'Code ▶

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Readers are invited to submit material for publication. Inclusion is the decision of the Editor. All contributions or inquiries should be addressed to:

The Editor REEF RESEARCH
Great Barrier Reef Marine Park Authority
PO Box 1379, TOWNSVILLE QLD 4810
Phone: (07) 4750 0700
Fax: (07) 4772 6093
E-mail: k.davis@gbrmpa.gov.au

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RESEARCH AND MONITORING STAFF

Jon Brodie	*Director*
David Haynes	*Coordinator – Water Quality*
Michelle Devlin	*Acting Project Manager – Water Quality*
Jane Waterhouse	*Project Officer – Water Quality*
Udo Engelhardt	*Acting Coordinator – Crown-of-thorns Starfish*
Michael Hartcher	*Acting Project Manager – Crown-of-thorns Starfish*
John Robertson	*Coordinator – Effects of Fishing*
Martin Russell	*Project Officer – Effects of Fishing*
Angela Grice	*Assistant Project Officer – Effects of Fishing*
Paul Davies	*Administrative Assistant*
Jamie Oliver	*Coordinator – Monitoring*
Ray Berkelmans	*Project Manager – Monitoring*
David Wachenfeld	*Project Officer – Monitoring (State of the Reef)*
Kim Davis	*Acting Project Officer – Monitoring and Editor, Reef Research*
James Innes	*Acting Project Manager – Socioeconomic*
Joan Crawford	*Acting Project Officer – Socioeconomic*
Maree Gilbert	*GIS Officer – Socioeconomic*
Francis Pantus	*Information Coordination Consultant*
Rozel Brown	*Assistant Project Officer – Administration*

continued from front page

of Practice for Sustainable Cane Growing' in June. The Authority is in full support of these initiatives.

This is the third *Reef Management News* issue and although I have received some feedback I would love to hear from more people. Please let me know what you like about it, what you don't, and what you would like to see included.

Jacqui Hyne

REEF RESEARCH:

Welcome to another, albeit slightly different, issue of *Reef Research*. As Reef Management News will be a permanent feature of this newsletter, some changes have been made to our cover to reflect the continued inclusion of Reef Management News. Further minimal changes will also be made in future issues to reflect the newly restructured Authority. The Research and Monitoring Section will no longer exist. Instead, some of our staff will be based in two of the new critical issues sections, 'Water Quality and Coastal Development' and 'Fisheries' while the rest of us will make up the Monitoring and Research Coordination Unit within the new Information Support Group.

This issue contains a varied sweep of articles. *What's Out There?* features the topic that's on everybody's lips at the moment – bleaching! Ray Berkelmans provides a synopsis of the bleaching event that is currently under way on the Great Barrier Reef. Following on with this theme, Jamal Jompa and Laurie McCook inform us that *Sargassum* canopy may actually decrease the amount of coral bleaching on inshore reefs.

We farewell the Director of the CRC Reef Research Centre, Chris Crossland, and instead of the usual CRC Update, have two articles from CRC researchers. Tanya Greenwood summarises the results of a national survey that was carried out to determine what Australian's think about the Great Barrier Reef. Following on from an article he wrote in 1995 (Ballast water in Queensland, *Reef Research* Vol. 5, No. 3), Darren Oemcke reports on various treatments, including filtration, ultraviolet irradiation and ozonation, that are currently being investigated as potential disinfectants of marine pests in ballast water. A summary of the 10 Augmentative Research Grants that were awarded to students in 1998 is included. Joan Crawford summarises a report by Sally Driml entitled *Dollar value and trends of major direct uses of the Great Barrier Reef Marine Park*, while Steve Raaymakers reports on a workshop that brought together representatives from the Asia-Pacific region to develop a Regional Strategy and Action Plan to address ship-sourced pollution.

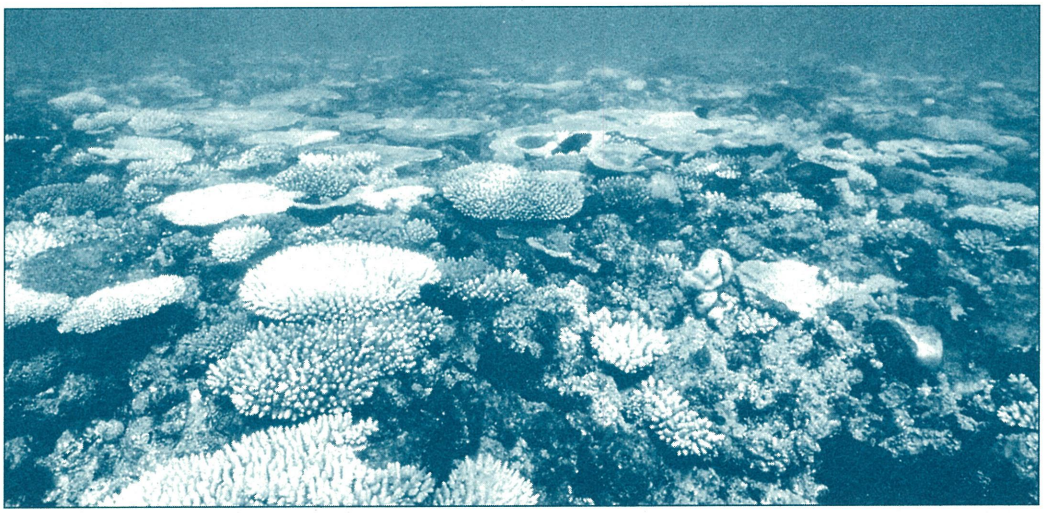
Kim Davis

CORALS BLEACHED WHITER THAN WHITE, BUT WHAT WENT WRONG IN THE FINAL RINSE?

Ray Berkelmans

The coral bleaching event in early 1998 might have been expected by some, but it was a surprise to others, me included. Why? Although the El Niño signal was strong and bleaching had already been reported from a number of locations in the eastern Pacific prior to our summer, the north Queensland lead-in to the summer, weather wise, was exceptionally mild. We had an early start to our 'wet' in mid-December and if it wasn't raining, most days between mid-December and mid-January (normally our hottest month) were cloudy, thus keeping water temperatures down. In fact, at the time of the deluge in Townsville on 10 January (550 mm in 24 hours), sea temperatures at Magnetic Island were around 27°C, about 2°C below normal for this time of year.

According to the Walker circulation of global seasonal climate variation (see Exploring CRC Research, April '98), northern Australia is meant to experience cooler oceanic water temperatures during El Niño years, while a warm pool of oceanic water is situated off the South American coast at this time. In theory at least, El Niño years should make western Pacific reefs **less** vulnerable to bleaching and eastern Pacific reefs more vulnerable to bleaching. In practice too, we find that there is no clear relationship between the Southern Oscillation Index (SOI) and coral bleaching at Magnetic Island off Townsville. In fact, during three of the six recorded bleaching episodes (1980, 1982 and 1994) the SOI was either positive or nil at the onset of bleaching, while during the other three episodes the SOI was negative.



Scenes such as this were typical of Great Barrier Reef inshore reefs during the 1998 coral bleaching event

Moreover, the most severe bleaching event on record (until this year, that is) was considered to be the 1981–82 event, which preceded the 1982–83 El Niño event by at least one year. Therefore, for the Great Barrier Reef at least, the relationship between El Niño events and coral bleaching is certainly not straightforward and, if one does exist, it may take some unravelling. Clearly, local and regional scale climate conditions also play a significant role in coral bleaching events on the Great Barrier Reef.

A very bleached Lorne Reef, Central Section Great Barrier Reef

Our first trip to look for coral bleaching was on 13 January 1998 at Magnetic Island, three days after the floods in Townsville. Although visibility was limited to around 50 centimetres, corals appeared to be in good health, despite the salinity being down to 26 parts per thousand (ppt) in Cleveland Bay (and probably lower in surface waters at the time of the rain). Two weeks later on 23 January 1998, there were still virtually no signs of bleaching at Nelly Bay and only a few pale or white corals at Geoffrey Bay. The salinity at this time had risen only marginally to 29 ppt (0–6 m depth). In Ross Creek however, a site we have been monitoring for five years, all coral colonies were dead except for some hardy *Goniastrea* colonies. It was not until 30 January 1998 that widespread coral bleaching was evident in both Geoffrey Bay and Nelly Bay. By this time, average daily sea temperatures had climbed to 31°C (6 m depth) and in the following week rose to slightly over 32°C. For nearly four weeks, the average daily temperature on the reef slope at Nelly Bay exceeded 31°C, while seawater salinity at this time ranged between 31 and 34 ppt. Bleaching intensified at Magnetic Island and by mid-February, reports of coral bleaching were also coming in from reefs near Bundaberg and from Orpheus Island. Coral bleaching forms (the crown-of-thorns starfish (COTS) forms you use when you are serious about white coral) were printed in haste and distributed to all and sundry.

By mid-March 1998, coral bleaching at inshore reefs was so intense that the extent and intensity of bleaching could be assessed by aerial survey methods. Around 660 reefs (still only 23% of reefs on the Great Barrier Reef) were surveyed for coral bleaching at an altitude of 500 feet. The results confirmed that coral bleaching was indeed happening from the top end of the Great Barrier Reef Marine Park near Horn Island to the bottom of the Marine Park near Bundaberg. The inshore reefs were clearly more affected than offshore reefs with notable exceptions to bleaching occurring on all reefs in the Swains, the Hardline, T-Line and offshore reefs around Proserpine. Offshore reefs north of Lizard Island also appeared to have escaped coral bleaching. Ground truth surveys were conducted at around 30 reefs and we have roughly 900 video transects awaiting analysis at the time of writing (watch out for marine scientists with square eyes, they could be dangerous!).

By the end of April 1998, extensive mortality (> 80% of living coral cover) was being reported from the worst affected reefs in the Palm Island group, while reefs which experienced less intense bleaching were showing signs of slow recovery. By this time, it was also clear that coral bleaching was occurring in many other parts of the world, including Lord Howe Island, Western Samoa, Christmas Island, Maldives, Galapagos, Reunion Island, Netherland Antilles, Florida Keys, Yucatan Coast, Cayman Islands, Brazil, Seychelles, Comoro Archipelago, Borneo, California and Panama. The bleaching event on the Great Barrier Reef was clearly part of a major global bleaching episode and may well prove to be the most extensive on record.

Assuming this coral bleaching event on the Great Barrier Reef follows the chronology of the 1982 event, we could expect the last vestiges of white coral to disappear from our reefs by the end of September 1998. Follow-up surveys are planned at this time to document the extent of mortality and recovery at most of the ground-truthed sites. We will need to wait until then before we can be certain what the overall effect of the 1998 bleaching event on the Great Barrier Reef has been.

Finally, to the 45+ people who reported coral bleaching to the Great Barrier Reef Marine Park Authority from over 60 locations on the Great Barrier Reef, a big thank you. These reports have been a great help in helping us keep track of the extent and intensity of bleaching and, importantly, in a timely manner. Please keep the reports coming over the next few months, especially as corals start to recover or die. The Great Barrier Reef is a big place and clearly we can't be everywhere to find out what is going on. You are our eyes and ears, so please keep up the good work!

SEAWEEDS SAVE THE REEF?!

Sargassum Canopy Decreases Coral Bleaching on Inshore Reefs

Jamal Jompa[1,2] and Laurence McCook[1]
[1]Australian Institute of Marine Science & CRC Reef Research Centre
[2]Department of Marine Biology, James Cook University

Widespread bleaching of reef corals has recently been reported from inshore reefs in the Townsville region, apparently as a result of exceptional weather conditions and flooding during January 1998. The likely causes of this bleaching include low salinity, high temperature, and high ultraviolet light intensity. In this article we report on a surprising increase in coral bleaching in plots from which the normally abundant canopy of seaweeds had been experimentally removed.

Many inshore reefs of the Great Barrier Reef have abundant beds of large brown seaweeds or macroalgae on the reef flat, often dominated by species of *Sargassum*. The abundance of these seaweeds have been suggested to be a result or even a cause of reef degradation, as increased terrestrial runoff causes makes reef waters less suitable for corals and more suitable for algae. However, there is remarkably little direct evidence for effects of macroalgae on corals. It may be that these conditions allow algae to outcompete corals, causing reef decline. In order to test for such effects, we have established and maintained large (5 metre x 5 metre) plots at several sites on two inshore reefs, one at Goold Island, north of Hinchinbrook Island, near Ingham, Queensland and the other at Cannon Bay, on Great Palm Island. For nearly 18 months we have been removing *Sargassum* from these plots. We also have control plots, in which the *Sargassum* has been left in place, forming a thick canopy often 1–2 metres high, with 100% cover. Despite this *Sargassum* canopy, the plots had quite high cover of live corals (up to 50%).

In the middle of February 1998, more than a month after the major flooding events, we noticed considerable bleaching of corals at both reefs. We consequently surveyed the amount and types of bleached corals in both *Sargassum* canopy (control) and removal plots. There are two sites at each reef and each site includes two plots of each treatment (*Sargassum* removal and control). Four 5-metre line intercept transects within the plots were used to measure coral cover (in centimetres). Corals were recorded at genus level and the condition of each coral scored in one of four categories: bleached (0), pale/mostly bleached (1), slightly bleached (2), and healthy/no bleaching (3). In this report, we consider categories 0 and 1 as 'bleached corals' and categories 2 and 3 as 'healthy corals'.

The percentage of corals which were bleached in removal and control treatments is presented in figure 1. At both reefs, the average percentage of bleached corals was significantly higher in plots which had had the *Sargassum* canopy removed than in plots with an intact canopy of the macroalgae ($P < 0.05$). Overall, 19.6% of corals were bleached under 'normal' conditions for these reefs, but 36.4% were bleached when the *Sargassum* canopy had been experimentally removed.

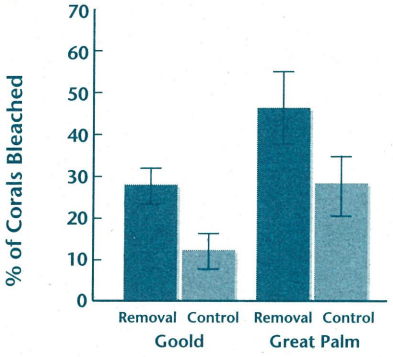


Figure 1. Percentage of all corals considered bleached in plots with *Sargassum* canopy removed (Removal) or left intact (Control), shown separately for reefs at Goold Island, north of Hinchinbrook Island, and Cannon Bay, on Great Palm Island

Species of *Acropora* seem to be the corals most affected, especially at Great Palm Island, where almost 100% of *Acropora* were bleached. At Goold Reef, corals of the genera *Acropora, Porites, Montipora* and *Favites* were most affected by the bleaching event. However, bleaching was common among all taxa noted. Further, it seems that the protection afforded by the *Sargassum* canopy was not limited to particular coral species. It seems likely that the seaweed canopy reduces damage to the corals by decreasing exposure to high temperatures, high ultraviolet light intensities, or perhaps by reducing mixing of low-salinity waters. Evidence is available for similar effects of algal canopies from temperate areas: such canopies can dramatically reduce thermal stress and water movement. The significance of this result is considerable, since it raises the possibility that algal canopies could actually provide protection to corals, instead of, or as well as, competing with them. Although the results by no means disprove the possibilities that corals are inhibited by macroalgae, they certainly provide further evidence that abundant macroalgae should not be assumed to be detrimental to inshore reefs without much more information.

1998 AUGMENTATIVE RESEARCH GRANTS SCHEME

The Great Barrier Reef Marine Park Authority awarded ten grants this year to students undertaking research relevant to the management of the Great Barrier Reef Marine Park. All students are working towards a Doctorate or Masters degree. Kim Davis reports.

KEY: **Researcher** / Supervisor,
Project title ($ awarded) Description of project

JAMES COOK UNIVERSITY

Andrew Baird / Dr B Willis & Dr T Hughes,
The length of the larval phase in corals: new insights into patterns of reef connectivity ($1000) Andrew lists the main objectives of this project as being: 1) to determine the likelihood of localised recruitment by quantifying the number of larvae settling over time from single cohorts from a range of coral species; and 2) by quantifying the capacity of coral larvae to delay metamorphosis, to establish if they can disperse long distances. Andrew believes that data produced from this project will enable Reef managers to determine ecologically relevant boundaries for marine reserves, identify reefs which are vulnerable to human impact due to their distance from regular larval replenishment, and identify probable sources and sinks of larval recruits.

Andrew also received a grant in 1997 to support this work. Preliminary results indicate that patterns in the geographic distribution of the scleractinia suggest that the species found in remote locations, such as the Hawaiian Archipelago, are not a random subset of the species pool. Andrew states that in the case of the Acroporidae this pattern can be explained by differences in the capacity of species to delay metamorphosis. Andrew now plans to continue this work with other species.

Michelle Horne / Dr P Southgate,
Reproductive seasonality and culture techniques of* Hippocampus *sp. throughout the Townsville region of the Great Barrier Reef ($900) Seahorse and seadragon species (Sygnathidea) are marketed world-wide for the aquarium trade and traditional medicine culture in South-east Asian countries. Some parts of the world have experienced localised declines in stock sizes due to uncontrolled export and excessive consumption of sygnathids (Vincent 1994). Of the 220 known sygnathid species half are found in Australian waters. Without stringent control of the Australian sygnathid fishery and the development of captive culture techniques, Michelle predicts that Australian species may follow a similar decline to those in other parts of the world. The main objectives of this study are: 1) to identify the seahorse species taken by commercial fishing vessels in the Townsville region; 2) to examine the reproductive biology of *Hippocampus kuda* and *Hippocampus hystrix*; and 3) to develop culture techniques for tropical seahorse species. Results from this study will be invaluable during the development of management strategies for sygnathids in the Great Barrier Reef region.

Vincent, A 1994, The improbable seahorse, *National Geographic* 186: 126–140.

Jacob Kritzer / Prof. JH Choat & Dr CR Davies,
Determinants of variation in life history strategies among lutjanid fishes on the Great Barrier Reef and their implications for exploitation ($1400) Jacob states that a lot of research has been directed toward the life history traits of adults of exploited coral reef fish species, while less attention has been paid to post-settlement individuals during the first year of life. He aims to conduct a mark–recapture study of newly recruited (0+ age class) lutjanids (primarily *Lutjanus carponotatus*) at Orpheus Island, near Ingham, Queensland, Australia. This study will enable Jacob to investigate the habitat preferences of settlers and to estimate growth and mortality rates during the early stages of development. Jacob believes that via this study, reef habitats that might be important refuges for young fish could be identified, monitored and protected. Also, empirically derived juvenile mortality rates could be estimated. These rates could then be used in quantitative models that predict the responses of populations to exploitation.

Michael Pido / P Valentine & M Fenton,
Evaluation of resource management in small-scale tropical marine fisheries: A comparison of marine reserves/parks in the Philippines and Australia ($1000) Michael was awarded a grant in 1997 for this project to evaluate the performance and outcomes of resource management in small-scale tropical marine fisheries. Michael's main objectives were to: 1) develop performance and outcome indicators that cover the relevant facets of management of small-scale fisheries; 2) use performance and outcome indicators in a comparative evaluation of selected small-scale marine fisheries sites under marine reserves/parks in the Philippines and Australia; and 3) evaluate the core findings in terms of relevance to the broader fisheries management issues. Michael reports that in-depth interviews have been carried out dealing with objective 1) while a

second survey, which deals with perceptions of the performance of fisheries management regimes is currently being carried out. This second social survey targets commercial fishers in the Townsville (Queensland, Australia) region and small-scale fishers in the reef areas of the Philippines. The survey of fishers in the Philippines has been completed and results are being analysed. This research will generate information on people–resource interactions as they relate to the management of inshore fisheries.

Mary Power / Dr E Gyuris & Dr S Turton,
Impact of visitor disturbance on nesting seabird colonies on Michaelmas Cay ($1000) Mary reports that over the last decade, a significant decrease (> 40%) has been observed in population levels of several species of nesting seabirds at Michaelmas Cay, Cairns Section of the Great Barrier Reef Marine Park. While the exact cause of this decline is unknown, the cay is subject to high levels of commercial and recreational tourism. With the aid of video camera observations, Mary aims to measure the ecological consequences of the presence and activities of visitors on the seabird populations of the Cay. She also aims to identify visitation management arrangements which minimises on-site anthropogenic impacts and to design and implement a cost effective monitoring program that maximises the ability to detect and understand population trends of nesting seabirds of Michaelmas Cay.

Michelle Ramsey / W Shipton & R Hill,
Influence of oil and bioremediation strategies on mangrove microbial communities ($1500) Fortunately, large oil spills rarely occur in Australian waters but on a smaller scale the marine and estuarine environments are faced with oil pollution from a variety of sources such as urban and agricultural run-off, vessels and pipelines. There is a real need to apply effective clean-up strategies in marine and estuarine environments to control the pollution spills cause and reduce the loss of habitat. Existing techniques for cleaning mangroves contaminated by oil include digging trenches and low pressure flushing but these methods can be quite destructive. Michelle states that a more effective management strategy needs to be developed to ensure the integrity of the mangrove environment for generations. Through this research, Michelle aims to assess the effects of oil and bioremediation strategies (specifically the addition of oxygen and nutrients) on the microbial community in mangrove sediments from Port Curtis, Gladstone, Queensland.

Janine Sheaves / Dr J Collins & Dr B Molony,
Ontogeny of diet of sesarmid crabs inhabiting mangrove forests ($1000) Adult sesarmid crabs play a very important role in nutrient recycling in mangrove forests as by capturing and consuming fallen mangrove leaves, they prevent important nutrients from being lost to coastal waters and, in effect, enhance mangrove forest productivity. Although juvenile sesarmid crabs are common in mangrove forests, information on their diet or role in mangrove ecosystems is scarce. Janine will investigate the development and selection of diet in sesarmid crabs and aims to determine the ecological roles that sesarmid crabs play at various life-history stages and their dietary requirements. Janine states that an understanding of the role of juvenile sesarmids in nutrient recycling and consequent enhancement of primary productivity must lead to more informed planning and management of these important nursery areas. In 1997 Janine received an award to determine the importance of mangrove leaves and seagrasses to the diet of alpheid shrimps. Janine reports that the abundance of alpheids and their aggressive capture of mangrove leaves suggests that, like sesarmid crabs, alpheids could play a very important role in nutrient recycling in the mangrove forests.

James True / Dr B Willis,
Tissue layer thickness variation in massive* Porites *corals as a response to environmental changes ($1000) In order to develop a technique for monitoring coral health, James will examine short-term acclimation and survivorship of scleractinian corals exposed to environmental stress. He states that by improving our understanding of how environmental factors influence growth of scleractinian corals, this study will also validate assumptions which underlie models of coral growth. Among other things, James will document natural variation in the tissue thickness of *Porites* corals and investigate the mechanisms which cause tissue uplift and control its timing. He will also identify the potential for *Porites* corals to acclimate to chronic low-magnitude stress. James says that knowledge of coral survivorship and acclimation potential when exposed to both acute and chronic stress (natural or anthropogenic) will be of benefit to management authorities interested in the sustainable use of coral reefs worldwide. The Authority also supported James with this project in 1997.

University of New South Wales

Sikandar Khan Khatri / Prof. IR Young,
Development of a shallow water wave prediction model ($1000) Sikandar aims to develop a shallow water wave prediction model which, contrary to the approach of using deep water wave models, takes into account the sound physics of wave generation and evolution. This model will serve as a useful tool for coastal engineers for practical applications such as the design of coastal structures and sediment movement studies. The development of this model will increase the knowledge of wave modelling and allow engineers to provide a more accurate assessment of the wave climate of the Great Barrier Reef.

University of Queensland

John Platten / Dr IR Tibbetts & Dr S Blaber,
The feeding, growth and reproduction of the labrid fish,* Choerodon venustus *(De Vis) ($1200) John states that *Choerodon venustus* (venus tuskfish) appears to be one of the most common demersal species taken by recreational fishers on offshore reefs south of Mackay, Queensland. However, very little information, if any, has been published on the biological characteristics of the species. John aims to:

- estimate the age and growth characteristics of the species in the Capricorn Bunker group and Swain reefs;
- establish any apparent breeding season and reproductive cycle characteristics with regard to size at first maturity, potential fecundity, sex ratio and protogynous hermaphroditism;
- investigate the effects of varying fishing pressure on these characteristics;
- establish the major food items of the species; and
- investigate the relative importance of the food items.

Knowledge of the species' biology will be necessary to ensure that catch rates remain at a sustainable level.

REEF MANAGEMENT NEWS

Editor/Writer: **Jacqui Hyne** *Sub-Editor:* **Craig Sambell**
Email: **J.Hyne@gbrmpa.gov.au** *Email:* **C.Sambell@gbrmpa.gov.au**

Bleaching The Great Unknown

Recent mass bleaching of corals in the southern hemisphere has received much attention and speculation as to its occurrence. Simply put: nobody really knows for sure.

The phenomenon of coral bleaching was noted as early as the late 1920s during the Great Barrier Reef Expedition. However, mass bleaching events have only been recorded since the late 1970s and became a more closely studied event in the 1980s.

Some of the factors that are thought to cause the bleaching are elevated sea temperatures, exposure to excessive irradiance and lowered salinity. However, when corals approach their upper thermal limits, even small additional doses of ultra-violet light or other sunlight spectra can cause them to bleach.
In some parts of the world coral bleaching has occurred every three to four years since the late '70s. The subsequent research has led to increased knowledge about the event but much is still unsubstantiated.

Bleaching and its Extent

Bleaching is often referred to as the whitening of corals. However, bleaching has now been observed in just about all marine organisms that host zooxanthellae.

Many marine invertebrates such as most species of hard and soft corals, sea anemones, zoanthids (related to hard corals), giant clams, some sponges, and foraminifera have a symbiotic relationship with types of algae known as zooxanthellae. The invertebrates host these photosynthetic algae within their tissues.

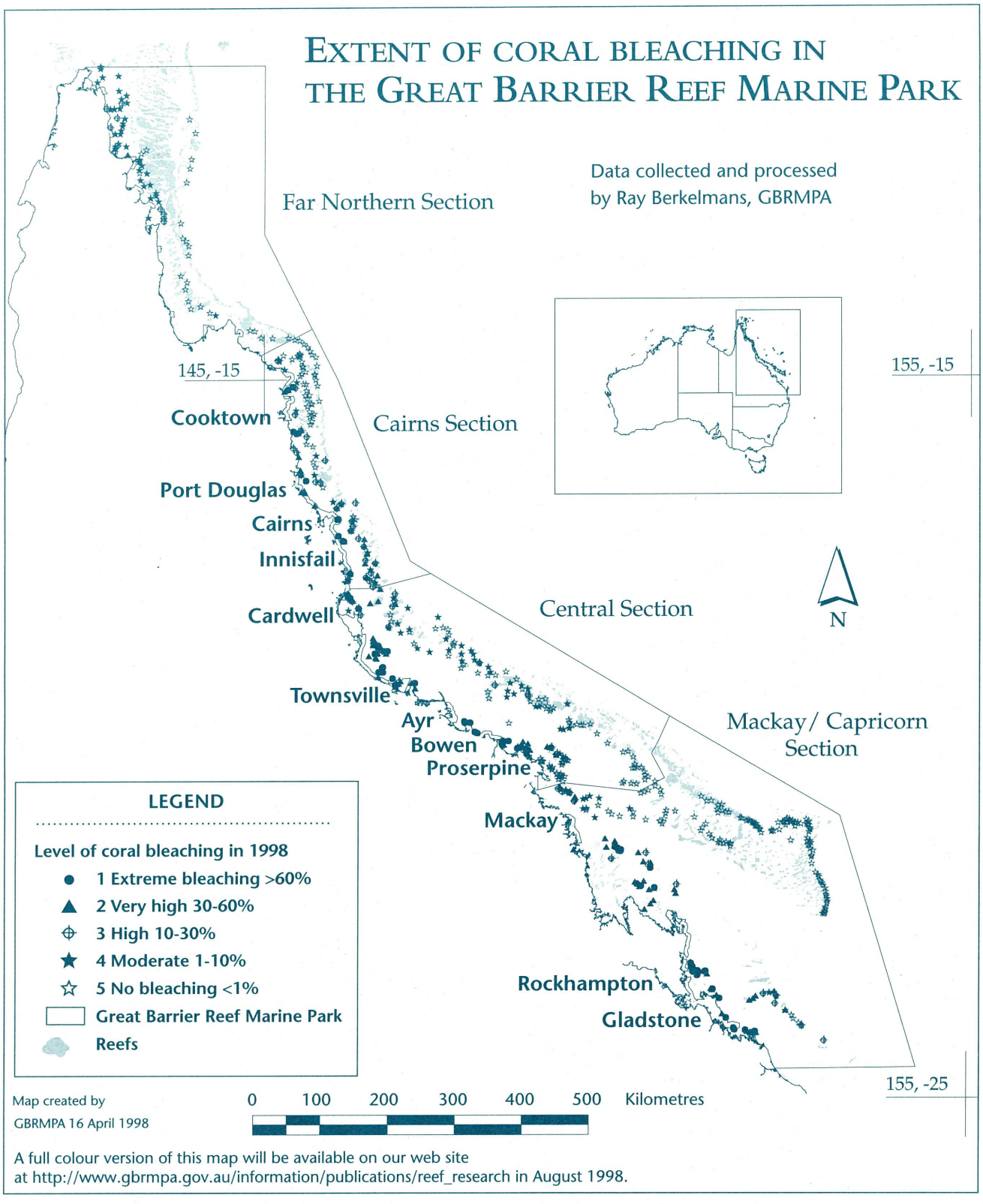
Bleaching usually occurs when environmental stress causes the host species to suffer a loss of zooxanthellae. However, it can also occur when the host retains the zooxanthella but the alga expels its brownish-green pigmentation.

Psychedelic colours can also result during partial bleaching. Although hosts commonly turn white when fully bleached, there are some host species that turn pink, yellow, purple, blue or iridescent green when partially bleached.

Of the invertebrate hosts, it is the corals and giant clams that appear to rely most heavily on zooxanthellae for the production of energy for metabolic processes. More than 90 per cent of their energy requirements, for some coral and giant clam species, are provided through the process of photosynthesis.

It is not known if invertebrates, such as coral, expel the zooxanthellae, or if the algae leave their host, says a Research Scientist from the Australian Institute of Marine Science (AIMS), Katharina Fabricius. 'We don't know what initiates bleaching. Most people think it is the animal host, but at this stage the data are insufficient,' Dr Fabricius said.

Reports on coral bleaching have attested to the fact that the 1997–98 event has been the most geographically extensive bleaching event scientifically recorded.



A full colour version of this map will be available on our web site at http://www.gbrmpa.gov.au/information/publications/reef_research in August 1998.

Sites that have been identified as being affected by the phenomenon are in Kenya, the Netherlands Antilles, Cayman Islands, Florida Keys, the Yucatan coast, Baja California, Galapagos Islands, French Polynesia, Christmas Island, Lord Howe Island and the Great Barrier Reef. Dozens of other sites have been affected also.

Surveys of the Great Barrier Reef, conducted by Ray Berkelmans (see page 3), indicate that 88 per cent of inshore reefs from Gladstone to Cape York are bleached to some extent (25 per cent severely bleached) and around 28 per cent of mid-shelf reefs have been affected (5 per cent severely).

It is the inshore reefs that have been most susceptible during this year's

event. Most bleaching occurs in the top few metres of the water column due to the temperatures being highest at the surface. Because most inshore reefs are in shallower waters than mid-shelf reefs, more of the inshore reef corals are affected.

Speculative Causes

Links between the Great Barrier Reef bleaching event and this year's El Niño Southern Oscillation (ENSO) event as well as to global warming have been drawn. However, to date there are no data available to support or reject these links.

Director of Research and Monitoring at the Great Barrier Reef Marine Park Authority Jon Brodie says regional weather patterns experienced in north Queensland this summer are the opposite to those expected during 'normal' El Niño years.

'Normally during an El Niño year the east coast of Australia experiences cooler waters and lowered rainfall. This year we experienced the reverse,' Mr Brodie said.

Mr Brodie also says while increased bleaching may be linked to global warming there is no conclusive evidence to prove this at present. Rises in sea water temperatures may be due to natural global climate or regional changes.

'We are at the peak of a warming phase in geological terms and sea temperatures are naturally still on the rise. Global climate change has occurred throughout the history of the earth,' Mr Brodie said.

'It is difficult to determine the difference between a natural sea temperature rise and an unnatural one.'

Although an agreement has not been reached on the cause of sea temperature rises, the general consensus appears to be that on the central Great Barrier Reef, in early 1998, a combined effect of high sea temperature and exposure to high irradiance caused widespread bleaching. In addition, lowered salinity caused extensive bleaching on inshore reefs.

In January, north Queensland was subject to floods that saw a deluge of fresh water run-off pour onto the inshore reefs between Townsville and Cooktown.

'These inshore reefs suffered up to 5 weeks of depressed seawater salinity due to flooding of major river systems. The low salinity level is likely to have exacerbated the severity of bleaching in this area,' Mr Brodie said.

On 13 January, salinities ranged from 19 to 26 parts per thousand (ppt) on the surface and 21 to 32 ppt at 3 metres depth (normal is 36 ppt). The water column gradually became better mixed but six weeks after the event, salinities were still depressed at around 33 ppt throughout Cleveland Bay.

In addition, three weeks after the floods an unusual hot spell occurred. This saw an exceedence in ocean maximum summer temperatures of 1–2°C, that is, from 30°C up to 31–32°C and the occasional peak of over 33°C.

'The mirror-calm seas which prevailed at the same time allowed unusually high transmission of light onto the reef and increased the exposure to irradiance. Therefore, corals became both heat and light stressed,' Mr Brodie said.

'Coral reef systems naturally live close to their thermal limit in summer. Therefore, it doesn't take much of a temperature rise to stress them and make them more susceptible to other factors that can contribute to bleaching.'

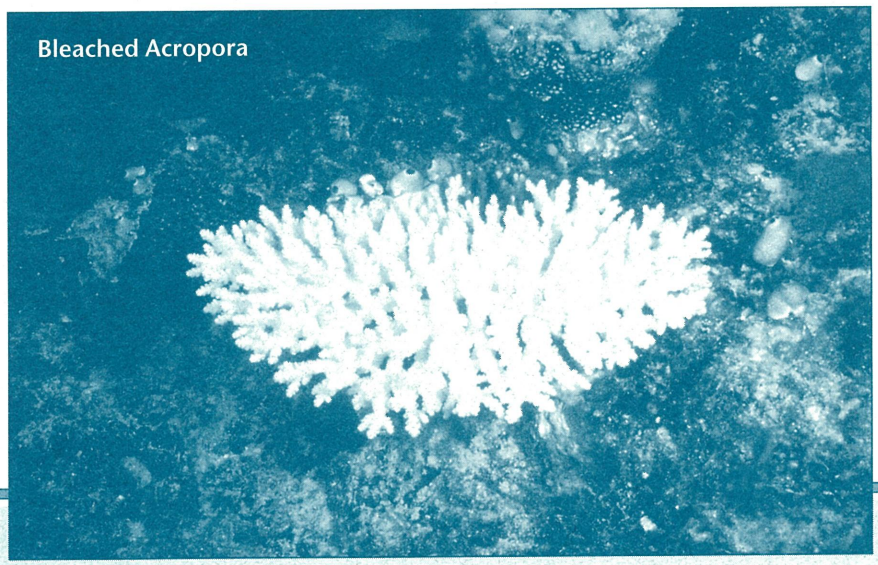
Different Tolerance levels

Preliminary studies, such as those conducted by Hoegh-Guldberg and Salvat (1995), have shown that different species of coral show different tolerance levels.

The three hard coral genera looked at in this study were *Acropora* spp. (least tolerant), *Pocillopora* spp. (intermediately tolerant), and *Porites* spp. (most tolerant).

Results indicated those coral genera with fast growth rates and high metabolic rates, such as *Acropora* spp., are the most susceptible. The study also showed that *Acropora* spp. recovered less well, if at all, compared to 100 per cent recovery of *Porites* spp.

This would then suggest that mass bleaching has the potential to change the structure of coral communities,



Bleached Acropora

that is, tolerant genera or species may temporarily dominate.

Additionally, the study states that 'reef connectivity and larval supplies are also likely to play key roles in determining the extent to which particular reefs will recover from mass bleaching'.

Adaptation

The big question is whether or not corals and other marine invertebrates can adapt to the likely increases in sea water temperature predicted to occur due to global climate change.

'In the Red Sea and Persian Gulf corals exist in relatively high temperatures that average up to about 34°C in summer. This is 4°C higher than the average maximum summer temperatures normally experienced on the central Great Barrier Reef,' Mr Brodie said.

'Many of the coral species that live in these high temperatures are identical to those found on the Great Barrier Reef.

'The present reefs of the Red Sea, formed around the same time as the Great Barrier Reef, were colonised by coral larvae from the Indian Ocean. Therefore, the larvae had to adapt to the higher sea temperatures.

'Once the corals acclimatised to the average local maximum sea temperatures of 34°C there was no need for them to be any more robust or heat resistant than was required. So we now see that when the sea temperatures in these regions rise 1–2°C above the maximum average they too experience bleaching.'

The rate and the ways in which marine invertebrates may be able to adapt to bleaching episodes is not known. Preliminary studies do suggest though that the ecology of both corals and zooxanthellae and their interrelation needs to be studied further.

A study by Ware, Fautin and Buddemeier, 'Patterns of coral bleaching: modeling the adaptive bleaching hypothesis' (1996), suggests that bleaching is an adaptive mechanism that increases stress resistance.

They state that 'bleaching is not merely pathological, but is also adaptive, providing an opportunity for recombining hosts and algae to form symbioses better suited to altered circumstances.'

Dr Fabricius of AIMS has concerns about some assumptions expressed in the paper. She says the problem with their hypotheses is that there is no evidence that corals can simply take up more robust strains of zooxanthellae.

'Firstly, nobody has ever been able to show that corals can get infected later than in the very initial larval or, post-settlement, phases,' Dr Fabricius said.

'Secondly, zooxanthellae are asexual and thus may not be able to adapt rapidly. There obviously exist more temperature robust zooxanthellae, however they may have other disadvantages, otherwise corals would have selected for those already.'

While there may be uncertainty over the mechanism in the short-term, in the long-term Jon Brodie points to adaptation over longer periods. Some evidence suggests that corals and zooxanthellae have 'acclimatised' to the average temperatures of the local area.

'In the inshore areas of the southern Red Sea with the highest water temperatures, reefs are dominated by the species most tolerant to higher temperatures, for example *Porites* spp. and *Siderastrea savignana*, as well as encrusting coralline red algae,' he said.

The Future

An accurate picture of the level of recovery of affected corals from the 1998 mass bleaching event on the Great Barrier Reef could take at least six months. In 1982, coral bleaching started in early January but it took until September for the last vestiges of white coral to disappear.

Preliminary reports of some mid-shelf reefs indicate that the recovery rate of the bleached invertebrates is around 90 per cent. Surveys of inshore reefs are still being conducted and the results from these surveys should be available in a few months.

There are still no definitive answers as to why this mass bleaching event happened on such a large scale or what the short- and long-term consequences may be.

Many questions are being asked. For example, why do entire coral colonies bleach? Why do some corals have a mohawk or striped bleached appearance? Why do adjacent colonies of the same genus as those bleached, apparently subject to the same thermal environment, not bleach at all? Is bleaching a recent phenomenon? Are we in some way responsible for current episodes of bleaching?

As with the crown-of-thorns starfish phenomenon, the answers will not come easily and the research could go on for many years before theories that attempt to explain widespread bleaching are accepted.

Although the causes of the mass bleaching phenomenon, such as the rise in sea temperature (albeit, what causes that rise is questioned), are known, it is not yet known what the long-term consequences are. The answers to this question will not come easily and the debate will rage amongst scientists indefinitely. ■

Reorganisation provides clear focus and effective management

Reforms to the administration of the Great Barrier Reef Marine Park Authority have been completed to achieve a more efficient and effective organisation.

Overseen by Environment Minister Robert Hill, the effective protection and management of one of Australia's greatest natural assets is a high priority for the Federal Government.

'The goal of the Government is to produce an organisation with a greater focus on outcomes, and which is more responsive to all stakeholders,' Senator Hill stated in a press release early this year.

'The Authority has an important role to play in protecting the Great Barrier Reef for all Australians. This new structure will enhance the protection of the Reef,' Senator Hill said.

The administrative reforms to be implemented by the Authority will deliver savings of $1.2 million each year. These savings will offset the fall in revenue to the Authority resulting from the reduction in the Environmental Management Charge from $6 to $4.

Authority Chairperson Ian McPhail says management of the world's biggest marine park is a complex task with great demands and challenges, such as human impacts. However, the task is a rewarding one with positive results, he reassures.

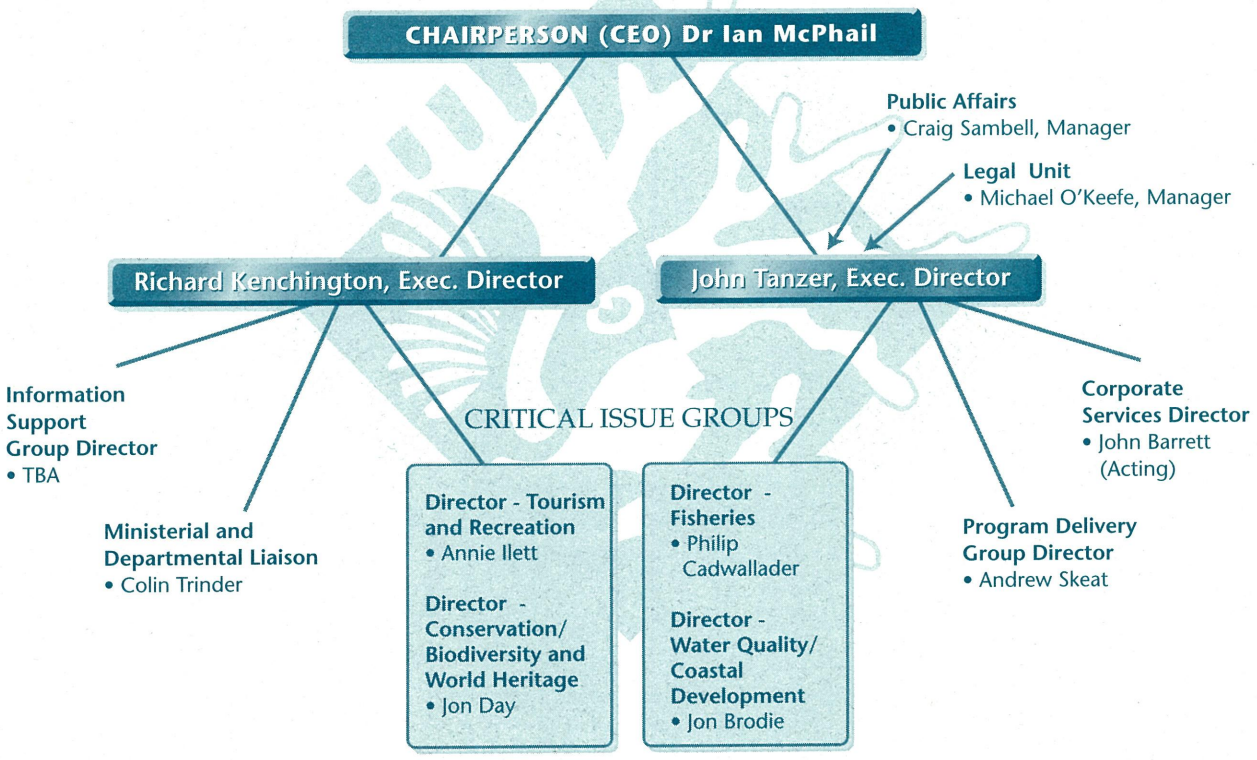
'In the past decade we have tackled many challenging tasks in the Marine Park. The success we have had has gained for us very positive national and international recognition,' Dr McPhail said.

'The methods and systems we have pioneered here on the Great Barrier Reef are now being employed by other marine managers around the world.'

In a move to ensure that it has the best skills and information to enable it to perform even more effectively in the future the Authority has reorganised its staffing structure (see chart) and approach to policy development.

The restructure is based upon four critical issue groups: conservation, world heritage and biodiversity; tourism and recreation; fisheries; and water quality and coastal development. These groups are seen to reflect the key challenges in protecting and managing the Great Barrier Reef.

GREAT BARRIER REEF MARINE PARK AUTHORITY - SENIOR STRUCTURE



Key players in the reorganisation Executive Directors John Tanzer and Richard Kenchington believe the adoption of an issues-based approach for policy development and operational management will be highly beneficial.

'Effective operations require us to focus our limited resources to make sure we are dealing directly with the most critical issues and in a manner which includes clear and direct outcomes,' they said.

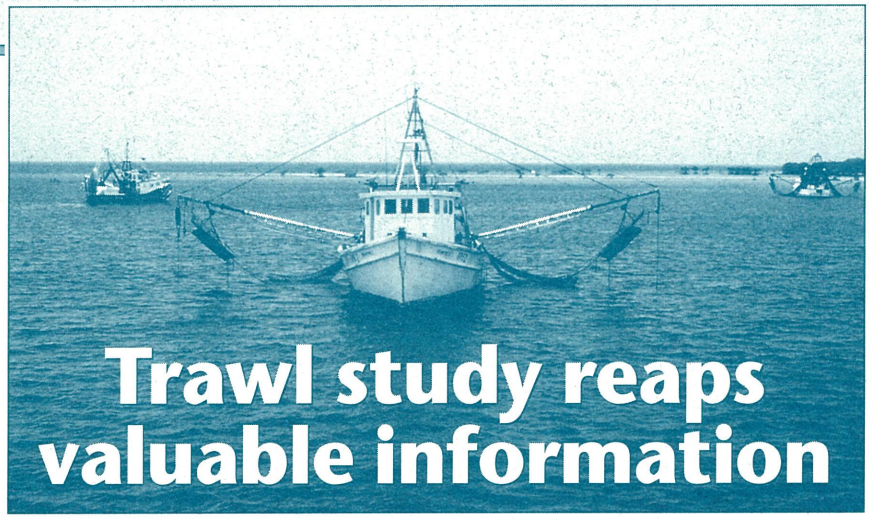
'Putting in place a structure which is based on identifying and managing critical issues rather than processes is an important step towards achieving clear priorities and hence effectiveness in the management of the Marine Park and World Heritage Area.'

The Authority will be preparing a strategic plan to guide its activities over the next 5 years. This plan will be released for public comment before being provided to Senator Hill for endorsement.

Senator Hill also highlighted, in the press release, the need to address governance issues, including any legislative reforms that may be necessary. A consultation paper is being prepared on this issue and will also be released for public comment.

'The legislative structure of the Authority is now over twenty years old. It is time to examine that structure to decide if it is still the best possible mechanism to protect and manage the Great Barrier Reef,' Senator Hill said.

'Our goal is to maintain the outstanding international reputation the Authority has earned for its stewardship of the Great Barrier Reef.' ■



Trawl study reaps valuable information

The final discussion report on 'The environmental effects of prawn trawling in the Far Northern Section of the Great Barrier Reef' is soon to be released.

The five-year study began in April 1992 and was conducted in and adjacent to the Marine National Park 'B' Zone cross-shelf closure area in the Far Northern Section to determine the impacts of prawn trawling.

In addition to providing information about the primary and secondary effects on the seabed, the study has aimed to provide information on the composition and fate of prawn trawl by-catch and the possible impacts on seabird populations.

Conducted jointly by CSIRO and the Queensland Department of Primary Industries, the study was commissioned by the Authority to aid with the management of the prawn trawl industry in the Marine Park.

John Robertson, Coordinator of the Effects of Fishing program at the Authority, says there has been public concern that trawling is an indiscriminate method of fishing that produces devastating effects.

'The Authority has taken a collaborative approach with science institutions, government agencies, the trawling industry, conservation groups and the public to address the impacts of trawling,' he said.

'In 1996, trawling was publicly nominated as a 'Key Threatening Process' under the Endangered Species Protection Act, for the incidental by-catch of marine turtles, fish and other native species.

'This year will see the implementation of compulsory By-catch Reduction Devices and Turtle Exclusion Devices on trawlers in some critical areas. The next two years will see a progressive implementation into larger areas.

'The results of this study will likewise see us working with all stakeholders to implement management strategies that take into consideration a broad scope of concerns,' Mr Robertson said.

Management strategies to conserve prawn stocks and by-catch, based on the preliminary research findings, have already been proposed under the current review of the Queensland Fisheries Management Authority's Queensland Trawl Fisheries Plan. The array of strategies include effort capping and the implementation of By-catch Reduction Devices and Turtle Exclusion Devices.

Copies of 'The environmental effects of prawn trawling in the Far Northern Section of the Great Barrier Reef' discussion report can be obtained from the Great Barrier Reef Marine Park Authority. ■

Authority supports 'greener' sugar industry

Recently the sugar cane industry showed its 'green' side at the first national Sugar Environment Forum held in Mackay from 24–25 March, signalling the industry's serious attempt to tackle the need to improve environmental awareness and practices.

Speaker at the forum Harry Bonanno Chair of CANEGROWERS believes it was a turning point for the sugar industry, and says cane growers are now indisputably greener.

In his address Mr Bonanno said an independent audit of cane growing practices was commissioned by CANEGROWERS in June 1995 to help address the impacts the industry had on the environment.

'It was clear from the Audit that many environmental issues needed to be addressed, particularly poor awareness of environmental issues. While most growers wanted to do the right thing they did not have sufficient information or knowledge to do so,' Mr Bonanno said.

'The CANEGROWERS Council has approved guidelines for sustainable cane growing and, once approved by the Department of Environment, these will be distributed to all growers to meet their obligations under the *Queensland Environment Protection Act 1994*.

Indeed, the 'Code of Practice for Sustainable Cane Growing' was officially launched in Brisbane by former Queensland Minister for the Environment, Brian Littleproud, on 2 June.

Expenditure on research by the industry, to support initiatives such as the Code of Practice, has been in the millions. However, additional research is still needed to clarify the extent of factors affecting issues such as, nutrient loss and water quality and to identify the causes.

Most of the research to help improve the industry's environmental practices is conducted by the Cooperative Research Centre for Sustainable Sugar Production with funding from the Sugar Research and Development Corporation.

Keynote speaker at the forum, Dr Peter Ellyard, Director of Preferred Futures Pty Ltd, pointed out that what is needed is the creation of new technologies and approaches designed specifically for the tropics and subtropics.

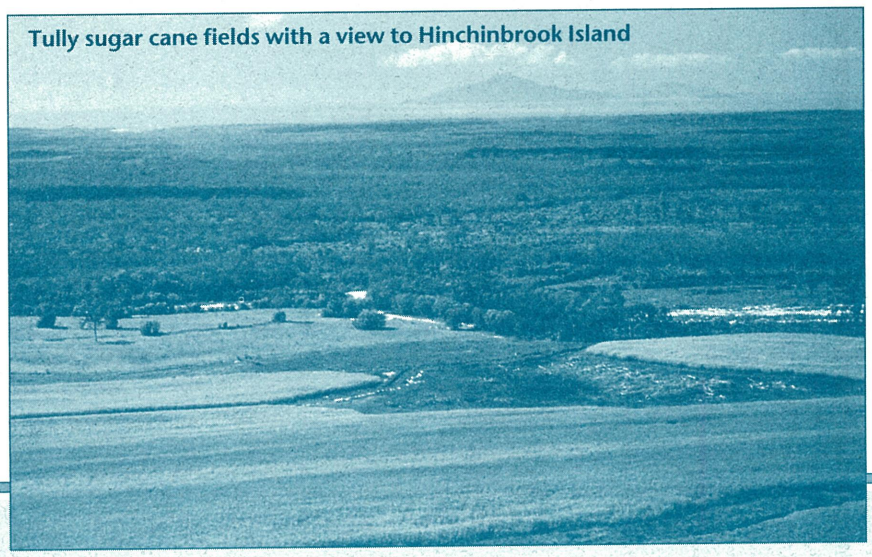
'Sustainability in the tropics and subtropics will not be achieved by the transfer of approaches and technologies from temperate zones. Tropical and sub-tropical areas are much more ecologically sensitive.

'Designing and innovating a sustainable sugar cane industry in tropical and subtropical Australia also can result in the creation of products and services for large global markets. This is an opportunity for Queensland to do economically well by doing ecological good.'

Mr Bonanno says the industry has come a long way with improved practices such as increased green harvesting and trash blanketing, revegetation and conservation of riparian zones, construction of artificial wetlands, tailwater recycling, trickle irrigation, soil conservation and integrated pest management.

'Green cane harvesting and trash blanketing have taken off. Last year over 65 per cent of the cane crop was cut green and most northern areas were close to 100 per cent. Also, the technique of trash blanketing that leaves a layer of cane 'trash' on fields to reduce soil and water run-off and evaporation and improve soil condition is on the increase.

'Few primary industries face such serious environmental challenges as we do. Our industry is located in a narrow coastal strip that is, for the most part, subjected to high rainfall, characterised by numerous coastal



Tully sugar cane fields with a view to Hinchinbrook Island

streams and is in close proximity to large population centres and the Great Barrier Reef.'

Since 1989 there has been an increase of more than 770 new producers in Queensland. The assignment of caneland has increased from 360 000 hectares to over 500 000 hectares for an industry that produces over 95 per cent of Australia's sugar output.

John Tanzer, Executive Director at the Great Barrier Reef Marine Park Authority believes the future relationship between the Authority and the sugar industry requires an understanding of the needs of both groups.

'Expansion of cane land offers increased opportunities to individuals within the industry but responsible development must be supported by coordinated planning schemes and compliance with best environmental practice,' he said.

'The Authority acknowledges the sugar industry's growing awareness of the need for sustainable practices. However, much is still to be achieved.

'Problems are still occurring due to industry practices, such as, the clearing of wetlands and other sensitive areas like riparian forests, and high nitrogen loss from fertilisers.

'Importantly, understanding the affects such changes are having on the Reef environment is critical to its long-term health.

'Acknowledging the costs to downstream users of poor practices and adopting best practices to minimise future impacts will allow the sugar industry and the Great Barrier Reef to coexist into the future. The Authority looks forward to a continued cooperative partnership with the sugar industry to achieve these goals.' ■

Final plans ensure better protection

The Great Barrier Reef Marine Park Authority has announced the release of the final Whitsundays Plan of Management and the Cairns Area Plan of Management.

Both plans were adopted by the Marine Park Authority in April this year after considerable consultation took place over the draft plans, released in 1997, with Queensland Department of Environment, stakeholders and the local communities.

Dr Ian McPhail, Chairperson of the Authority, says that although the Plans are now finalised they will not remain static.

'Amendments will be made to the plans as new information on user impacts is acquired. Both areas have outstanding nature conservation, cultural and heritage values that need to be afforded the highest protection.

'The consultation process and the subsequent plans have allowed the Authority to reduce or eliminate threats to the values of these areas while allowing for a range of activities, including the economically important tourism industry'.

Issues addressed by the plans include coral conservation, protection of breeding and migratory animals, Indigenous sites of significance and fisheries, tourism and recreation uses and impacts.

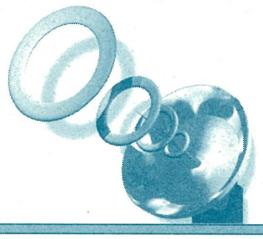
Impacts reported at many sites suggest that the levels of use are already approaching environmentally sustainable limits said Director of Planning Peter McGinnity.

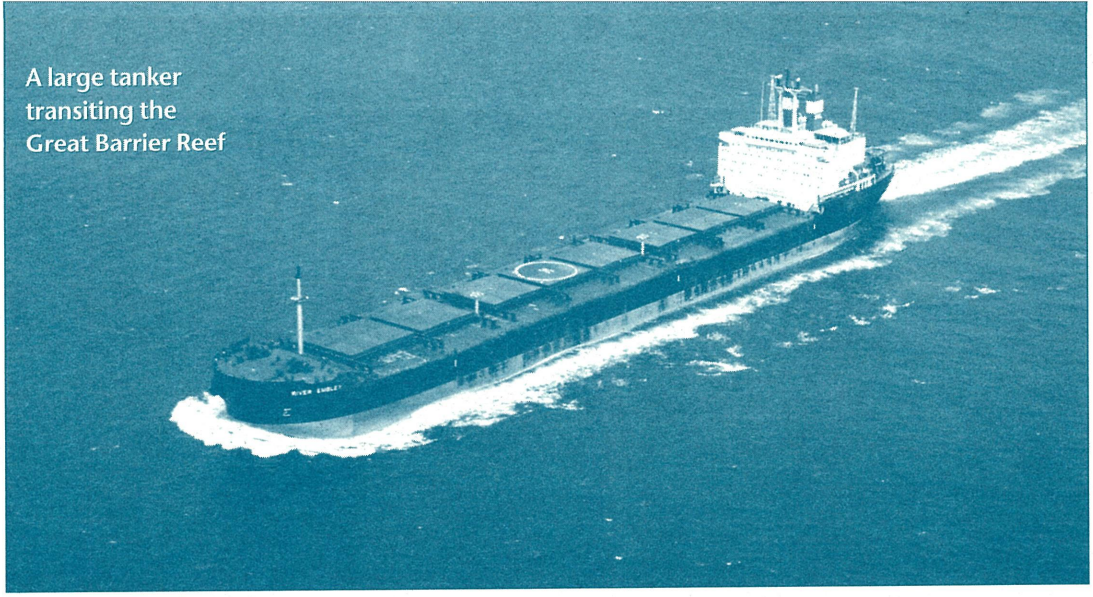
'Michaelmas Cay is the most significant seabird nesting site in the Cairns area. Tighter restrictions have been put in place on all modes of transport and recreation activities due to disturbance of nesting seabirds that has lead to breeding failure,' Mr McGinnity said.

'Also, in the Whitsundays area, sites like Deloraine Island and Hill Inlet have been afforded a high level of protection due to their natural conservation values and Aboriginal stone fish-traps and rock art sites of national significance.

'We are working with stakeholder groups, such as the tourism industry, to develop accreditation, training and education programs and materials that promote best practices guidelines to ensure the protection of both these unique areas.'

Copies of the Whitsundays Plan of Management and the Cairns Area Plan of Management can be obtained from the Great Barrier Reef Marine Park Authority or the Queensland Department of Environment. ■





A large tanker transiting the Great Barrier Reef

The Treatment of Ships' Ballast Water to Remove Exotic Marine Pests: Research in North Queensland

Darren Oemcke
Civil and Environmental Engineering, James Cook University Qld 4811

The Australian coast is host to more than 175 introduced marine pests, 45 per cent of which were probably carried here in the ballast water of international ships (these numbers do not include microorganisms such as bacteria, virus and protozoa). Some of these species – the 'rabbits of the coast' – such as the northern Pacific seastar, the European fan worm and species of dinoflagellate algae have become significant pests in Australia's coastal zone.

Concern about the potential impacts on the north Queensland coast of exotic species introductions led to a research project being set up to investigate ways to control the importation of exotic species by ballast water. With funding and support from the Ports Corporation of Queensland and the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef (CRC Reef Research Centre), the investigators have been able to make significant advances towards developing ballast water treatment methods. Filtration, ultraviolet irradiation and ozonation have been investigated as potential disinfectants, and the roles which these technologies could play in ballast water treatment have been more fully defined than previously. The results from ultraviolet irradiation, in particular, have been both surprising and promising. A chemical and physical characterisation of ballast water was conducted, which has implications for ballast water sampling methods and supports views that ballast exchange at sea is probably not a long term solution to ballast water introductions.

A brief history of ballast water

Ballast water is carried by ships when they are carrying little or no cargo, so as to maintain adequate propeller depth, to adjust their depth in the water and to compensate for currents and wind forces. Water was first carried as ballast in the mid-1800s, slowly replacing solid ballast such as rock and bags of sand, (which is also implicated in the translocation of coastal species such as insects). Today all ballast carried by shipping is water, pumped from the port at which cargo is unloaded or en route. Australia is a net importer of ballast water – 121 million tonnes in 1991 – as we export large amounts of bulk product, such as coal, sugar, ore and wheat. Ships travel with these cargoes to our overseas trading partners and return to Australia 'in ballast'. Ballast water is also transported between Australian ports by coastal trade, which can further spread introduced species.

The first rigorous examination of these organisms was by Medcof and Scribner on ballast water arriving in Australia from Japan in 1975 (Medcof 1975). They found

adult and larval zooplankton in the ballast water. Since then, the evidence for ballast water being a significant carrier of exotic species has become overwhelming and pressure to manage ballast water properly has been increasing.

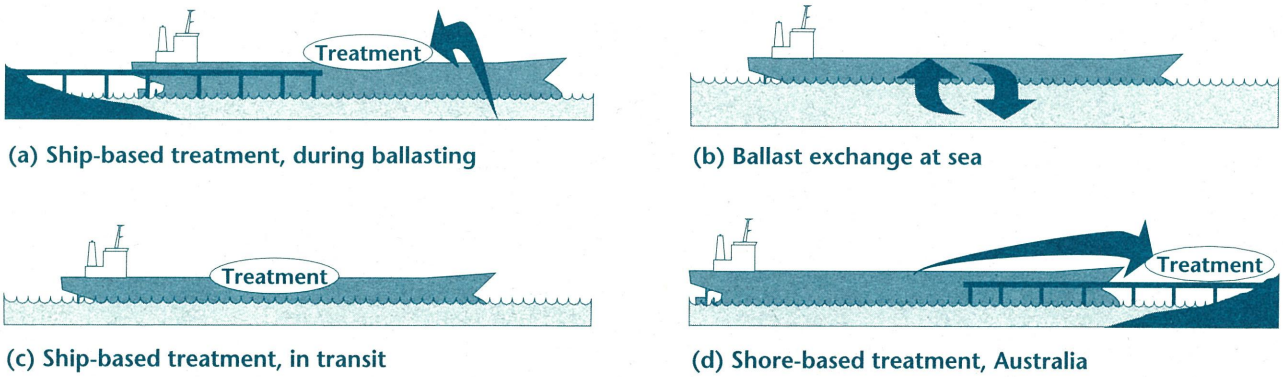
Ballast water has been responsible for the introduction of some very high profile invaders in Australia and overseas. The zebra mussel, *Dreissena polymorpha*, which was accidently introduced to the North American Great Lakes, is thought to have cost $5 billion by blocking water intakes at heavy industry, power and water treatment plants and by fouling fishing nets, boat hulls and buoys. In Australia, the northern Pacific seastar, *Asterias amurensis*, has invaded the Derwent River estuary, Tasmania threatening yields in nearby scallop fisheries, and has recently spread to Port Philip Bay. The paralytic shellfish poisoning species of dinoflagellate alga *Gymnodinium catenatum*, also introduced to Tasmania, has been responsible for the closure of shellfisheries in southern Tasmania for periods of up to six months to protect public health. Several authors have speculated on the potential role of ballast in the dissemination of cholera since *Vibrio chloerae*, the cause of cholera, has been found in the ballast water of vessels entering the United States of America from South America.

A number of countries have introduced measures to reduce the risk of exotic species introductions via ballast water. In 1989, the voluntary Great Lakes Ballast Water Control Guidelines were established for vessels entering the North American Great Lakes, requiring them to exchange all coastal and freshwater ballast with mid-ocean water before entering the St Lawrence seaway. These regulations were recently extended to the whole of the United States of America and made mandatory for vessels entering Vancouver and the Great Lakes. In 1990 Australia was the first country to introduce national guidelines for voluntary ballast exchange at sea which were recently ratified by the International Maritime Organization for voluntary adoption on an international basis. New Zealand currently requires that ballast water from Tasmania be exchanged at sea during the northern Pacific seastar spawning period, and other ports have introduced mandatory ballast water exchange at sea.

Ballast water treatment processes

Ballast exchange at sea is conducted either by emptying and refilling tanks whilst in the ocean or by continuously flushing oceanic water, equivalent to three to four ballast volumes, through the ballast tanks during transit. Ships currently in service are not designed for these processes, which are considered dangerous by some members of the shipping industry, as they put stress on the structure of vessels. The rates of compliance with the voluntary ballast exchange guidelines are thought to be reasonably high, but serious concerns about the effectiveness of the process remain. Ballast exchange at sea is inefficient as it fails to remove all the original ballast water, and fails to remove sediments present in ballast tanks. A recent refinement on flow through ballast exchange is to pump the seawater through the engine cooling circuit and to use the waste heat to warm the ballast tanks up to about 38°C, which kills many species of plankton. This process has the potential to improve the ballast exchange process significantly for some vessels and routes. However, it takes a number of days, does not work for parasites and may not be possible for trips through cold waters, due to the difficulty of increasing ballast water temperatures.

The alternative to ballast exchange at sea is to disinfect the ballast water with a biocide either as it is pumped aboard, during transit, or after it is discharged. These options are shown in figure 1. Very little data has been available on the performance of water treatment technologies against the species which are of concern in ballast water, and it is essential to obtain good disinfection data so that cost-benefit analysis of ballast water treatment options can be conducted. Important treatment research has been conducted in Australia and overseas, which has improved the data available, but



(a) Ship-based treatment, during ballasting

(b) Ballast exchange at sea

(c) Ship-based treatment, in transit

(d) Shore-based treatment, Australia

Figure 1. Some potential locations for ballast treatment processes

much more is needed. A lot of the research has focused on the control of dinoflagellate hypnocysts as they are considered, with reason, to be extremely difficult to disinfect. Treatment of ballast water with screens can remove dinoflagellate cysts, so the failure of a treatment to inactivate these cysts does not mean that it should be rejected as a treatment option.

Results from the Ports Corporation of Queensland–CRC Reef Research Centre experimental program

The ballast water project of the CRC Reef Research Centre and the Ports Corporation of Queensland started in 1995. The first component of the project was the measurement of physical and chemical characteristics of ballast water to determine characteristics which may affect screening, filtration, ultraviolet irradiation or ozonation, and to examine the potential of chemical characterisation to determine if ballast had been exchanged at sea. The second component of the program is testing the efficacy of ultraviolet and ozonation for their use as ballast disinfectants. The third phase is to assess the results and recommend a design for a pilot treatment plant.

Screens have excellent potential as a primary ballast water treatment. There are two benefits of screening; firstly the removal of organisms which cannot pass the filter, and the clarification of the water for a secondary ballast water treatment. For ship-based treatment during ballasting, for example, screens of between approximately 10 and 50 micrometres are likely to be appropriate for primary treatment. The actual size of screen which could be used can only really be determined by pilot testing.

Experiments on ultraviolet irradiation have been very promising and have demonstrated considerable potential for ultraviolet irradiation as a ballast water treatment. Ultraviolet has been demonstrated to be effective for the control of the dinoflagellate alga *Amphidinium* sp. and vegetative cells of *Gymnodinium catenatum* under conditions approximating those in ships ballast tanks. Research is continuing into the use of ultraviolet on these, and other species. Pre-screening would probably be required for ultraviolet irradiation during ballasting, to remove large flocs which can protect organisms from the effects of the ultraviolet. For ultraviolet treatment at deballasting (option *d*, figure 1) a more complex treatment plant would be required as iron from the ballast would need to be removed.

Ozone is not appropriate for the removal of species such as dinoflagellate cysts and most zooplankton, but could be used to control bacteria, viruses, amoebae and some protozoa. The most likely application for ozonation would be in a land-based treatment plant following a filtration system capable of removing organisms larger than about 5 micrometres. Ozone is also likely to be affected by oxidant demand from sediments in ballast tanks, may cause corrosion or interfere with corrosion protection, and be reduced by iron if used for shipboard treatment.

Finally, the physical and chemical characteristics of ships' ballast water were compared with what would be expected from oceanic water. The results suggested that either the process of ballast exchange at sea is inefficient at replacing the original ballast water, or that the compliance rate with guidelines for voluntary exchange at sea is poorer than has been thought.

Further research needs

It is vital that research into the efficacy of disinfectants on the species which are likely to be transported in ballast water is continued, as the current set of data is too small to choose between many of the treatment alternatives. This data is needed to estimate both the size and cost of ballast water treatment plants, and to determine optimal combinations of screens and disinfectants.

Pilot testing is also essential for the development of good ballast water treatment processes. A pilot treatment plant design will be one of the major outcomes of this research. It is anticipated that such a pilot treatment plant will be containerised and transportable from port to port, for testing in coastal waters. In this way the effect on treatment of many different ports with different suspended solids and organisms present can be tested. Such a pilot plant could be moved relatively quickly if a bloom of algae or spawning of a starfish were occurring in a port. In this way the effects of many different conditions and organisms on treatment plant performance could be assessed within a few years.

Worldwide, the rate of introduced marine pests arriving in ballast water appears to have been increasing for some time, possibly due to environmental changes in ports, faster ships or changing patterns of trade. It will continue unless effective control measures are implemented, which depends on continuing research into treatment processes.

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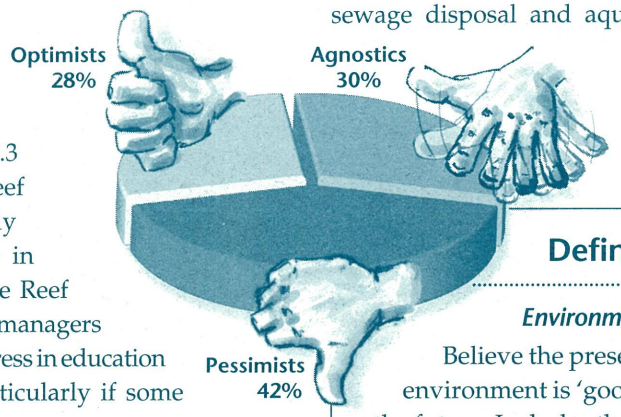
Australians divided about Reef's future

Tanya Greenwood
School of Commerce, Economics & Administration, James Cook University Qld 4811

A national survey conducted by tourism researchers from the Cooperative Research Centre for the Ecologically Sustainable Development of the Great Barrier Reef (CRC Reef Research Centre) at James Cook University has revealed a number of Australians (42 per cent) are becoming pessimistic about the Great Barrier Reef environment. The view is characterised by a perception that the Reef's natural condition is poor and will remain so, or even get worse in the future.



Professor Philip Pearce, chief investigator of the CRC Reef Research Centre's Project 2.2.3 'Evaluation of Great Barrier Reef Interpretation', says the study identified groups who differ in their overall perspective of the Reef and may be important for reef managers and the tourism industry to address in education and marketing programs, particularly if some public perceptions are inaccurate.

'Along with 42 per cent who are environmental "pessimists",' says Professor Pearce, 'another group which emerged from the survey data are environmental "optimists", which made up 28 per cent and believe the condition of the Reef will be better in the future, or at least as good as it is now. We also found 30 per cent to be environmental "agnostics" who said they do not know what the current state of the Reef environment is, or will be.'

Professor Pearce believes the findings are consistent with changing public perceptions toward the environment generally. 'More people are concerned these days about natural resources and World Heritage Areas than a decade ago,' he says. 'This trend is common around the world.'

Tanya Greenwood, who is a primary research analyst on this project, found distinct variations in visitor knowledge and attitudes towards the Great Barrier Reef environment. 'Our survey of 1003 adults in major east-coast population centres shows a clear division in public opinion about the Reef's overall health,' she says. 'Although the national sample is relatively small, it raises a number of issues for further analysis.'

The survey found all groups claim they already knew that tourism, recreational fishing and traditional hunting activities are permitted on the Great Barrier Reef. Differences became apparent however, when the 'pessimist' group said they believed other 'environmentally damaging' activities are also allowed, mentioning commercial fishing and sewage disposal as examples. 'Optimists' on the other hand believe that certain activities are not permitted, in particular mining, sewage disposal and aquaculture. The environmental 'agnostics' are uncertain whether any other activities are allowed in the Great Barrier Reef or not.

Defining the Groups

Environmental Pessimists

Believe the present state of the Great Barrier Reef environment is 'good or very good' but will be worse in the future. Includes those who class the present condition as 'poor or very poor' and believe this condition will remain the same or get worse in the future.

Environmental Optimists

Believe the present state of the Great Barrier Reef environment is 'good or very good' and will maintain this condition in the future. Includes those who believe the current state is 'poor or very poor' but will improve in the future.

Environmental Agnostics

Do not know what the current state of the Great Barrier Reef environment is, or have an opinion about its condition for the future.

The survey found 'pessimists' have different perceptions about potential threats or impacts confronting the region compared to the other groups. 'Pessimists' are notably more concerned over impacts characterised by general human activity, industry practices and development. They specifically mentioned pollution, general human impact, over-fishing, anchor damage, commercial fishing, agricultural and urban/industrial run-off. 'Optimists' and 'agnostics' show a higher level of concern over possible impacts resulting from industrial accidents such as an oil spill, or from natural disturbances like cyclones or

crown-of-thorns starfish outbreaks. The concerns of the latter two groups tend to be influenced by information and publicity generated by the media.

Ms Greenwood says she found different attitudes over why the Great Barrier Reef should be protected between each group. 'Results show a strong emphasis by the "pessimist" group to regard the Reef as worthy of protection because it is such a unique Australian natural environment. A relatively higher proportion of "optimists" believed opportunities for leisure and recreation on the Reef is the underlying reason for its protection,' she said.

Ms Greenwood also found the 'pessimist' group show activity differences and are more likely to enjoy active, exploratory reef activities. 'They want active outdoor activities such as scuba diving, snorkelling, swimming, fishing, and reef and island exploration,' she says. 'Optimists" however, seem to enjoy more relaxed water activities such as swimming, snorkelling and sunbathing, and "agnostics" prefer specific reef viewing activities such as glass bottom boat rides.'

The survey found that 'pessimists' are more likely to visit the Reef and are predominantly younger than the other groups. While all three groups indicate television as their primary source of information about the Reef, the pessimistic group place a significantly higher emphasis on personal experience and newspapers as an important information source. 'Optimists' place a higher importance on tourist information bureaus, radio and cinema for their sources of information.

Ms Greenwood says the results of the study raise interesting implications for managers and educators of the Great Barrier Reef World Heritage Area. 'It provides a profile of a significantly large public audience whose views of the Reef environment are negative.'

'This group is important to reef tourism operators not just because of its size, but because it is made up of people with a relatively high level of knowledge of the tropical marine environment. They are concerned about this environment, enthusiastic towards active, participatory reef activities and may frequently visit the area. Yet they have a grim outlook on the Reef's present and future condition,' she explained.

'Perhaps there are more specific questions for resource managers and industry leaders to evaluate such as: Do people think natural resource management agencies are doing enough to protect this environment? Do they know how they can personally improve the state of the Reef environment, turning concern into action? And are these perceptions based on knowledge or sensationalised media coverage?' says Greenwood. 'The challenge may now be for resource managers and the tourism industry to consider these different attitudes and improve the quality – and perhaps more importantly the reach – of environmental information, interpretation and education programs.'

Farewell to CRC Director, Chris Crossland

Director of the CRC Reef Research Centre, Chris Crossland, has left the Centre to take up a new position overseas.

As inaugural Director, Chris was responsible for setting up the Centre in 1993 and deserves much of the credit for establishing it as one of Australia's leading environmental Cooperative Research Centres. His research leadership and management skills, spanning twenty years in Australia and overseas, have been highly regarded by the Centre's partner organisations and research staff. There is no doubt Chris's personal skills also played a key role in creating a strong culture of collaboration between reef researchers, students, industry groups and resource manager.

Chairman of the Centre's Board, Sir Sydney Williams, said Chris had forged stronger links between the many disparate groups involved in the Great Barrier Reef World Heritage Area.

'Much of the cooperation between government-funded research and industry development can be attributed to Chris's leadership and networking skills,' Sir Sydney said.

Chris, his wife Jan and their two daughters left Townsville in May for Holland. Chris has taken up the position of Executive Officer with Land Ocean Interaction in the Coastal Zone (LOICZ). Dr Terry Done was appointed Acting Director until 30 June 1998. Mr Simon Woodley has been appointed as Director from 1 July 1998 to 30 June 1999.

Dollar Value and Trends of Major Direct Uses of the Great Barrier Reef Marine Park

Joan Crawford

The Great Barrier Reef Marine Park Authority holds conservation of the Great Barrier Reef as its primary objective. At the same time the management of the Great Barrier Reef Marine Park involves managing for sustainable multiple use while allowing for economic development. From an economic perspective the management for sustainable multiple use involves the equitable allocation of the Park's resources between competing users as well as the ongoing maintenance of these resources. Economic information gathered on various user groups in the Marine Park is a useful tool for ensuring equitable resource allocation decisions via zoning and management plans. To inform the Authority on the impacts of the different user groups, Sally Driml, Senior Environmental Economist of Kinhill Economics was commissioned to estimate the gross financial value of the major direct uses of the Marine Park for the 1995–96 financial year. Data estimated for 1996 were compared with the results of a similar exercise undertaken for 1991–92, as reported in *Protection for Profit* (Driml 1994).

The major direct uses as reported by Driml in *Dollar Values and Trends of Major Direct Uses of the Great Barrier Reef Marine Park* are commercial tourism, commercial fishing and recreational fishing and boating. Where possible the financial values for 1995–96 have been compared to previous years to examine trends. The financial values calculated for this period are also compared to funding for day-to-day management of the Great Barrier Reef Marine Park. All estimates in the report are approximations based on data available from existing sources. In many cases, the available data was not sufficiently disaggregated, or of proven accuracy, to allow for anything but broad estimates and are to be considered 'order of magnitude' only.

A summary of the findings of Driml's report is presented below.

1. Commercial tourism

According to the Authority tourism accounts for the main commercial use of the Great Barrier Reef Marine Park, attracting over 1.5 million visitors to the area each year.

In Driml's report commercial tourism consists of:

- trips on vessels to the Marine Park;
- accommodation on the mainland associated with the trip to the Marine Park; and
- holidays on Island Resorts (excluding reef trips).

Other forms of tourism such as aircraft trips over the Marine Park were excluded due to a lack of reliable data. Therefore, commercial tourism may be understated.

Expenditure on commercial tourism for the 1995–96 financial year converted to June 1996 dollars is reported in table 1. These figures for 1995–96 are not directly comparable with 1991–92 expenditure figures due to changes in the data collection methods.

Table 1. Gross financial value of commercial tourism

Expenditure on:	1995–96 expenditure data converted to June 1996 ($)
Reef trips	167 402 000
Mainland accommodation	236 307 000
Island Resorts	243 263 000
Total	**646 972 000**

2. Commercial fishing

The gross economic value of commercial fishing is the value of product landed, which is a function of the volume of catch and the price received for the product. While catch is recorded in the Log Book program run by the Queensland Fisheries Management Authority, complete information on the volume of catch from the Great Barrier Reef Region in 1996 was not available for this study. Comparisons were made between catches in 1991–92 and 1996 for some major species. The total catch of king prawns plus tiger prawns in 1996 was 1.6 times that of 1991–92, and the volume of four major species of fish caught in 1996 was 1.2 times that of 1992. However, Log Book data show that catches of fish

and prawns are variable from year to year, so the conclusion that catch volumes are increasing should not be drawn from these data. Records of prices for landed seafood kept by the Department of Primary Industries show average prices remaining steady over the period, therefore declining in real terms. In the absence of complete data on catch volume for 1996, the value of catch in 1991–92 was used for this report, inflated to 1996 dollars as illustrated in table 2. This provides an order of magnitude estimate of the likely value of commercial fishing in 1996.

Table 2. Gross financial value of commercial fishing

Sales of Product:	1991–92 $	June 1996 $
Commercial Fishing	128 000 000	143 000 000

3. Recreational fishing and boating

The third major economic activity conducted in the Great Barrier Reef Marine Park is recreational fishing and boating.

Estimated expenditure on recreational fishing and boating is reported in table 3 indicating a real increase in expenditure over this period.

Table 3. Gross financial value of recreational fishing and boating

Expenditure on:	1990 data in June 1996 $	June 1996 $
Recreational Fishing & Boating	105 085 000	122 478 000

Combined value

The combined value of the three main direct uses of the Marine Park is shown in table 4, indicating a total gross financial value of $912 million.

Table 4. Gross financial value for three direct uses of the Great Barrier Reef Marine Park

Expenditure on:	June 1996 $
Commercial Tourism	646 972 000
Commercial Fishing	143 000 000
Recreational Fishing and Boating	122 478 000
Total	**912 450 000**

Trends

When a comparison is made between the current gross financial values ($912 million) recorded in table 4 and the probable value for 1991–92 ($723 million in 1991–92 dollars, which represents $803 million in 1996 dollars)[1] Driml observed the following trends:

- The real value of production of commercial fishing is relatively constant.
- Effort in recreational fishing and boating, as indicated by boat registrations, has increased and the dollar value has increased in real terms.
- Commercial tourism passenger days have increased since 1993–94.

Day-to-day management funding

Day-to-day management funding is required to maintain the resources that produce these gross financial values from direct use as well as other values gained from indirect uses.

Table 5 reports the actual expenditure on day-to-day management for the Marine Park for the years 1991–92 and 1996–97 indicating an increase of only 5.4% in real terms. The calculated increase in the value of direct uses of the reef over the same period is reported by Driml to be 13.5% in real terms. These figures indicate that expenditure on the management of the Marine Park has not kept pace with the increase in value of direct uses of the area.

Table 5. Day-to-day management funding 1991–92 to 1995–96

Year	Expenditure $	Expenditure in June 1996 $
1991–92	6 539 337	7 280 786
1996–97	7 672 675	7 672 675

Copies of Sally Driml's report entitled *Dollar Values and Trends of Major Direct Uses of the Great Barrier Reef Marine Park* can be obtained by phoning Kim Davis at the Great Barrier Reef Marine Park Authority on (07) 4750 0814.

Reference

Driml, S 1994, *Protection for Profit: Economic and Financial Values of the Great Barrier Reef World Heritage Area and Other Protected Areas*, Research Publication No. 35, Great Barrier Reef Marine Park Authority, Townsville.

[1] Values reported in *Protection for Profit* (Driml 1994) were higher, however these were based on an estimate made at the time by the Authority that there were 2 million visitors per annum. The results from the data collection program instituted in 1993–94 are consistently lower, and it is probably that visitor numbers in 1991–92 were approximately 1.4 million. The value of $723 million for 1991–92 has been estimated on the basis of 1.4 million visitors.

with Steve Raaymakers

Asia-Pacific Tackles Ship-sourced Pollution

Shipping is an international industry and the natural connectivity of the oceans is not bound by political borders. Pollution of the oceans from shipping is therefore best addressed on an international basis, through multi-lateral cooperation between nations at international and regional levels.

Cooperative arrangements to address ship-sourced pollution in Asia-Pacific received a boost recently with a workshop entitled 'Working Together on Preventing Ship-based Pollution in the Asia-Pacific Region', being held in Townsville, 20–23 April 1998.

The purpose of the workshop was to develop a Regional Strategy and Action Plan to address ship-sourced pollution.

The workshop was attended by around 60 delegates, including several high level delegates from Asian countries and the United States of America. All south-east Asian countries were represented, as were New Zealand and Australia. There was a strong presence from the shipping industry. The Pacific islands were represented by myself and delegates from the Cook Islands, Fiji, Federated States of Micronesia and Tuvalu (funded by Environment Australia).

A number of technical papers were given on various types of ship-sourced pollution, including introduced marine species and ballast water and ships' waste management. Papers were also given on current developments with the international regulatory regime for shipping and various initiatives being undertaken by different organisations throughout the Asia-Pacific region. The Townsville Port Authority hosted a tour of their port facilities, with a focus on environmental management initiatives being undertaken at the port.

Whilst the workshop agreed that the geographical or political definition of the Asia-Pacific region would be left open-ended at this stage, within this broader region there is already a clearly defined 'Pacific Islands region'. This comprises the Pacific Island countries which are members of the South Pacific Regional Environment Programme (SPREP).

Prior to the Townsville workshop, a separate strategy to address ship-sourced pollution in the Pacific islands region was already being developed by SPREP. This strategy is called PACPOL – the Pacific Ocean Pollution Prevention Programme. An important objective for the Pacific Islands delegates was to ensure consistency between what is developed for the Asia-Pacific region and what is already under development for the Pacific Islands region under PACPOL (for an introductory overview of this strategy refer to Slick Talk #21, *Reef Research*, Vol. 8, No. 1))

The workshop was held under the auspices of the Australian and New Zealand Environment and Conservation Council (ANZECC) and Asia Pacific Economic Cooperation (APEC). It was sponsored by

APEC, the Australian Institute of Marine Science (AIMS), the Australian Agency for International Development (AusAID), Broken Hill Proprietary Limited (BHP), Environment Australia, the Great Barrier Reef Marine Park Authority (GBRMPA) and the International Maritime Organization (IMO). The workshop was organised by Environment Australia.

During the workshop, several working-group sessions were held at which the regional Strategy and Action Plan was developed and put to paper. The final Strategy and Action Plan is to be published by Environment Australia and circulated in mid-1998. It was agreed that the Strategy and Action Plan would not be binding in any formal sense, but would simply provide a framework to assist regional organisations and countries to develop their own initiatives to address ship-sourced pollution if they so desired.

From a Pacific Islands perspective, the major benefits of the workshop were:

- Greater familiarity and understanding of ship-based pollution issues by delegates.
- Raising awareness amongst all stakeholders about SPREP generally and PACPOL in particular.
- Establishing recognition of the Pacific islands region as a significant stakeholder in the broader Asia-Pacific region.
- Establishing networks and contacts with significant players in the ship-based pollution field throughout the Asia-Pacific region.
- A commitment from BHP Transport to provide SPREP with its seafarer's environmental awareness training package, for evaluation for possible adoption/ adaptation for use in the Pacific region.
- The International Maritime Organization is considering funding a proposal to establish an electronic network and discussion group throughout the Asia-Pacific region, for the exchange of information on ship-based pollution. The IMO has previously indicated that it is prepared to transfer US$50 000 to assist the Regional Workshop.

Shortcomings included no representation from environmental non-government organisation's and the fishing and tourism industries, all of whom are stakeholders in ship-based pollution issues.

For further information about the workshop contact:
Mrs Louise Emmett
Director, Marine Section
Environment Protection Group
Environment Australia
Email: lemmett@ea.gov.au

NEW PUBLICATIONS

Price*

Seagrass Communities in the Shoalwater Bay Region, Queensland : Spring (September) 1995 and Autumn (April) 1996. WJ Lee Long, LJ McKenzie and RG Coles. GBRMPA, Townsville, 1997. Research Publication No. 44. 38 pp.
ISBN 0 642 23035 8 $24.60

Norman Reef Great Adventures Pontoon : 1997 Biological Survey and Summary of Damage from Cyclone Justin. AM Ayling and AL Ayling. GBRMPA, Townsville, 1998. Research Publication No. 46. 16 pp.
ISBN 0 642 23038 2 n/c

An Investigation of Optimum Methods and Unit Sizes for the Visual Estimation of Abundances of Some Coral Reef Organisms. BD Mapstone and AM Ayling. GBRMPA, Townsville, 1998. Research Publication No. 47. 70 pp.
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Habitat, Cross Shelf and Regional Patterns in the Distributions and Abundances of Some Coral Reef Organisms on the Northern Great Barrier Reef with Comment on the Implications for Future Monitoring. BD Mapstone, AM Ayling and JH Choat. GBRMPA, Townsville, 1998. Research Publication No. 48. 71 pp.
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Scales and Magnitudes of Variation in Population Densities of Some Coral Reef Organisms: Implications for the Design of Sampling and Monitoring Procedures. BD Mapstone, AM Ayling and JH Choat. GBRMPA, Townsville, 1998. Research Publication No. 49. 77 pp.
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