WORKSHOP SERIES No 25

Sources, Fates and Consequences of Pollutants in the Great Barrier Reef and Torres Strait

Conference Abstracts
Mercure Inn, Woolcock Street, Townsville
29–30 June 1999

Compiled by Dominica Kellaway

GREAT BARRIER REEF
MARINE PARK AUTHORITY

AUSTRALIAN INSTITUTE
OF MARINE SCIENCE

ISSN 0156-5842
ISBN 0 642 23070 6

National Library of Australia Cataloguing-in-Publication data:

Sources, fates and consequences of pollutants in the Great Barrier Reef and Torres Strait : conference abstracts.

ISBN 0 642 23070 6.

1. Water - Pollution - Queensland - Great Barrier Reef Region - Congresses. 2. Water - Pollution - Torres Strait - Congresses. 3. Great Barrier Reef (Qld.) - Environmental conditions - Congresses. 4. Torres Strait - Environmental conditions - Congresses. I. Kellaway, Dominica. II. Great Barrier Reef Marine Park Authority (Australia). (Series : Workshop series (Great Barrier Reef Marine Park Authority (Australia)) ; no. 25).

333.91609943

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Port Management and Environmental Protection — A Case Study from the Port of Townsville

Caryn Anderson
Townsville Port Authority, PO Box 1031, Townsville Qld 4810

The Port of Townsville, managed by Townsville Port Authority, is located within Cleveland Bay in north Queensland, and is adjacent to the Central Section of the Great Barrier Reef Marine Park. The Great Barrier Reef World Heritage Area lies directly offshore, supporting a range of sensitive habitats including fringing coral reefs, mangrove forests, seagrass beds and associated fauna to which these habitats play host. Due to the sensitive nature of the Port environment, particular care must be taken to ensure that the potential impacts of port operations on the receiving environment are mitigated. Just as the Port of Townsville strives to meet the highest possible standards in all port operations, these high standards have also been set for environmental performance. To achieve these high standards, appropriate environmental management techniques need to be incorporated into the overall management of port operations. This paper summarises Townsville Port Authority's approach to environmental management and highlights the challenges of managing an industrial port environment within a World Heritage Area. Specifically, this paper addresses the environmental management initiatives adopted by the Port of Townsville in relation to port operations and development, dredging and dredge spoil disposal and general maintenance activities.

An Episode of Mercury Contamination of Bowling Green Bay 1870–1900

G. J. Brunskill, J. Pfitzner, I. Zagorskis, G. S. Walker and Peter Isdale
Australian Institute of Marine Science, PMB 3, Townsville MC Qld 4810

A 3.8 metre long sediment core from Bowling Green Bay was radiochemically dated using ^{210}Pb and ^{137}Cs tracers. Bulk sediment accumulation rate was very high (~17 kg m^{-2} yr^{-1}), and the sediment mixed layer thickness was approximately 50 cm. The time history of variation in the ratio Al/Ca in the sediment core suggests that there has been an increase in proportion of terrestrial river-borne sediment to this site in the last century. Increases in Pb and Cu concentrations in surface sediments are probably due to increases in the proportion of river sediment, and not due to local pollution. A large input of excess mercury (Hg in excess of 2 nMoles/g dry weight of sediment, background Hg being 60–100 pMoles/g) was found at 2.5–3.0 metre sediment depth in the core, and this was dated to the period 1870–1900. In this period, Hg concentrations in surface sediment may have exceeded US EPA sediment quality guidelines for this element. During this time, quicksilver mercury was used in Charters Towers' stamping mills to extract gold from crushed rock in the catchment of the Burdekin River, which flows into Upstart Bay and the Great Barrier Reef lagoon. Also during this time (1870–1900), rainfall and Burdekin River flood-event frequency were much higher than in the period 1900–1996, as revealed by coral core fluorescence profiles. Frequent flood events in the catchment were probably important to ensure the rapid delivery of contaminant Hg to the Great Barrier Reef lagoon. Present day Hg concentrations in surface sediments of Bowling Green Bay are still about three times higher than pre-1850 background Hg concentrations. Sediment delivery from the Burdekin River is cascaded from Upstart Bay to Bowling Green Bay, where most river mud is trapped. Only a small proportion of Burdekin River mud reaches Cleveland and Halifax Bay.

The Gladstone Field Experiment: Weathering and Degradation of Hydrocarbons in Oiled Mangrove and Salt Marsh Sediments with and Without the Application of an Experimental Bioremediation Protocol

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This field study was a combined chemical and biological investigation of the relative rates of weathering and biodegradation of oil spilled in sediments and testing the influence of a bioremediation protocol. The aim of the chemistry work was to determine whether the bioremediation protocol affected the rate of penetration, dissipation or long-term retention of a medium range crude oil (Gippsland) and a Bunker C oil stranded in tropical mangrove and salt marsh environments. Controlled oil spills were performed in the Port Authority area of Gladstone, Queensland (Australia). Sediment cores from three replicate plots of each treatment for mangroves and four replicate plots for the salt marsh (oil only and oil plus bioremediation) were analysed for total hydrocarbons and for individual alkane markers using gas chromatography with flame ionization detection (GC-FID). Sediments were collected at day 2, then 1, 2, 5/6 and 12/13 months post-spill for mangroves and day 2, then 1, 3 and 9 months post-spill for salt marshes. Over this time, oil in the oil-treated plots decreased exponentially. There was no statistical difference in initial oil concentrations, penetration of oil to depth, or in the rates of oil dissipation between untreated oil and bioremediated oil in the mangrove plots. The salt marsh treated with the waxy Gippsland oil showed a faster rate of biodegradation of the oil in the bioremediated plots. In this case only, degradation rate significantly impacted the mass balance of remaining oil. The Bunker C oil contained only minor amounts of highly degradable n-alkanes and bioremediation did not significantly impact its rate of degradation in the salt marsh sediments. The predominant removal processes in both habitats were evaporation and dissolution, with a lag-phase of 1 to 2 months before the start of microbial degradation. The chemistry data provided the context for interpretation of the biological and microbiological observations that are given in companion papers.

Induction of Hepatic Mixed Function Oxidase (MFO) in Pikey Bream (*Acanthropagrus berda*) Collected from Agricultural and Urban Catchments in Far North Queensland

J.E. Cavanagh[1,2,3,4], *K.A. Burns*[3], *G.J. Brunskill*[3], *R.J. Coventry*[4] *and J. Ahokias*[5]
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Hepatic mixed function oxidase activity, in particular, ethoxy-resorufin *O*-deethylase (EROD) activity has been widely used as an indicator of exposure of fish to organic contaminants such as PCBs, organochlorine pesticides and PAHs. EROD activity was measured in *Acanthropagrus berda* (Pikey Bream) captured from seven creeks in the Herbert, Burdekin and Ross River catchments. Significant induction was observed in fish captured from Ross Creek (urban catchment) and Cromarty Creek (agricultural catchment) (535 and 480 pmol/min/mg protein respectively). Increased activity was also observed in fish captured from other creeks which drain agricultural land (Plantation Creek, Victoria Creek, Seymour River, 138–188 pmol/min/mg protein) as compared to those captured from creeks in undisturbed catchments (Baldy Creek, Fisher Creek, 63–79 pmol/min/mg prot). Potential sources of organic chemical contamination include boating activity, pesticide usage on farms, storm-water drains and road run-off. Analyses are currently being conducted to identify chemical contaminants present in fish tissue and sediments.

Changing Risks of Pest Control in the Sugar Industry — An Historical Perspective

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Sugar-cane farming is the major agricultural industry along the coastal margin of north Queensland. Pest control forms a large component of the management of any agricultural industry. Over recent years there has been increasing concern over potential off-site environmental impacts related to various agricultural practices, including pest control. However, in addition to potential off-site environmental impacts a number of different issues also need to be addressed by an individual farmer when considering pest control alternatives. These include the cost of pest control, the efficacy of different controls, risks to the operator (e.g. application of chemicals) and potential economic loss through pest damage in the absence of control. Over time the magnitude and types of these risks change. This paper examines the changing risks of pest control in the sugar industry over time with a focus on pest control in the Herbert and Burdekin Regions.

Research, Extension and Industry — Working Together can Achieve Results

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[2] *Cooperative Research Centre for Sustainable Sugar Production, James Cook University, PO, Townsville Qld 4811*

Sustainability and environmental protection are high on the expectations of the Australian community. Stakeholders in areas adjacent to valuable natural assets, such as the Great Barrier Reef, are expected to adopt practices which will minimise any impacts. Information is critical to help understand what these practices are. Significant resources have been invested in research to determine the scale of impacts on the reef. How well are these findings communicated to stakeholders to enable a change of practice? Technology transfer and the delivery of on-ground results are being increasingly demanded by the community and by funding agencies. In response to this demand, researchers and environmental managers are bombarding industries with information regarding the efficiency and potential environmental implications of their practices. The interpretation of some of these results is sometimes as diverse as the topics researched, or there may not appear to be any direct relevance to the stakeholders. Despite the investment in environmental research, practical environmental management options remain something of a mystery to many people. In fact, it may well be leading to feelings of hopelessness and finally contempt among landholders. The end result — limited uptake of information and implementation of change. As research, development and extension providers, we need to ensure that messages are clear, and designed and presented in a mode which will more readily facilitate development and adoption of beneficial management practices. Greater interaction between all groups — research, industry and extension — will help to achieve this result. A possible approach may be to draw upon the extension and advisory skills that already assist industries. A project to manage the impacts of acid sulfate soils in northern NSW sugar lands provides some insights into how science and extension skills work best together, not opposite one another, and into how an industry group can respond to a community concern.

Behaviour of Toxicants in the Great Barrier Reef System

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Toxicants of potential importance in the Great Barrier Reef area can be conveniently classified into three categories: petroleum and related compounds, persistent organochlorine compounds and heavy metals. The petroleum compounds are mainly hydrocarbons that include a wide array of different chemical groups such as alkanes, aromatic compounds and polycyclic aromatic hydrocarbons. These substances occur in low concentrations throughout the world's oceans originating from nature as well as anthropogenic sources. A similar situation occurs with the persistent organochlorine compounds that include the chlorohydrocarbon pesticides such as DDT, dieldrin, lindane and so on, as well as the dioxins and PCB's. These substances are persistent and lipophilic and distribute in the marine environment with very low concentrations in water, higher concentrations in sediment and the highest concentrations in biota. Most chemicals in this class are bioaccumulative and can have sublethal effects such as disruption of the endocrine system. The heavy metals and related substances can originate from a range of sources and can occur in the marine environment in relatively high concentrations. Common heavy metals in marine systems are cadmium and mercury. A range of sublethal effects on human health and natural ecosystems are attributed to these substances.

Export of Acidity in Drainage Water from Acid Sulfate Soils

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Disturbed acid sulfate soils are potent sources of acidity in coastal waterways. The acidity consists of the hydrogen ions, plus soluble ferrous and aluminium ions exported in the drainage water from these soils. When mixed with fresh or marine waters, the ferrous iron oxidises releasing acidity and decreasing dissolved oxygen concentrations. Dissolved aluminium hydrolyses releasing acidity. Low dissolved oxygen concentration results in poor habitat conditions for aquatic fauna. Released acidity lowers bicarbonate levels and may contribute to poor shell growth for shellfish and crustaceans. Monitoring studies of the drainage water for sites at Trinity near Cairns and at Pimpama in South East Queensland indicate that considerable concentrations of iron and aluminium are found in the drainage water from these sites. The drainage water has the potential to lower the dissolved oxygen in the receiving water. During the processes of oxidation and hydrolysis iron and aluminium flocs are formed which can smother benthic communities. Heavy metals are also found in the drainage water at elevated levels and may also be of concern for aquatic organisms.

Application of Linear Regression to Estimating Natural Gradients in the Concentration of Trace Metals Hosted in Sediments of Cleveland Bay, Great Barrier Reef Lagoon, Australia

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[2] *Australian Institute of Marine Science, PMB 3, Townsville MC Qld 4810*

The natural variation in the concentration of trace metals in sediments can be modelled by simple linear regression models as a gradient from low concentration to high concentration using either aluminium iron or grain size fractions as conservative independent variables. Samples that exceed the upper 95% prediction interval of regression models are classified as enhanced, but are not necessarily contaminant. Enhancement is a function of the regression model, and natural conditions will exist outside of the model that confound the application of simple regression models to discriminate contaminants. The regression model does provide an estimate of the natural gradient in concentration over a wide range of sediment compositions, particle size classes and sedimentary environments. In the absence of meaningful sediment quality guidelines, the modelled natural gradient in concentration of trace metals in sediment is a useful guideline to estimate the natural concentration of a trace metal in a sediment sample.

Research into the Bioremediation of Oil Spills in Tropical Australia: With Particular Emphasis on Oiled Mangrove and Salt Marsh Habitat

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A three-year project (1995–1998) assessed short-term effects of commonly transported oils and bioremediation strategies on tropical Australian mangrove and salt marsh habitats. Field trials in mangroves and salt marsh habitats gave mixed results for the effectiveness of bioremediation. There was no apparent reduction in mortality of vegetation in either habitat where bioremediation was applied to oiled plots. However, in mangrove plots one year after oiling, canopy leaf densities were greater than controls in bioremediation plots, and less than controls in oil only plots. Concentrations of oil and prior condition of leafy canopies, along with levels of insect folivory and densities of grapsid crabs killed, all influenced mortality of mangrove trees. Densities of sipunculid worms in sediments one year after oiling appeared to have recovered in oiled plots treated with bioremediation. These findings form the basis for improved guidelines and recommendations for the restoration of oiled mangrove habitat around Australia.

Sources and Bioaccumulation of Dioxins in Queensland's Marine Environment

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Marine sediments are important sinks for persistent hydrophobic environmental pollutants such as polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (generally referred to as dioxins). PCDD/F contamination in marine environments is typically found in proximity to highly urbanised and industrial centres. Catchments adjacent to the Great Barrier Reef Marine Park, however, are largely rural and lack major industry. Nevertheless, high concentrations of PCDD/Fs, and in particular octachlorodibenzodioxin (OCDD), have been detected in soil, marine sediments and dugongs found stranded along the Queensland coast. While the process that results in the formation of the PCDD/Fs is unclear, the existing data suggests a land-based source for these pollutants. Here an outline and preliminary results of a three-year study are presented. This study was initiated to provide more information on distribution, pathways and sources of PCDD/Fs in Queensland's coastal environment. The aims are to:

- determine the distribution of PCDD/Fs in Queensland marine sediments with respect to potential land-based sources;
- identify pathways and factors governing the distribution of PCDD/Fs in the marine environment; and
- investigate bioaccumulation and biomagnification of PCDD/Fs with respect to trophic levels and organism specific characters.

Special focus will be on the sediment-seagrass-dugong system due to their vulnerability and unique position within the trophic food web of marine environments.

Oil Spills in the Great Barrier Reef and Torres Strait: Impact of Oil Spills in Tropical Ecosystems and the Use of Chemical Dispersants

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Major oil spills in the Great Barrier Reef and Torres Strait have up till now been a rare occurrence. Each year, however, numerous small accidental and intentional oil spills are reported within the region. Of greater significance, have been a series of groundings, collisions and near misses which have had the potential to result in substantial losses of bunker fuel or oil cargo. Oil spills in tropical ecosystems like coral reefs and mangrove systems can have dramatic short- and long-term environmental consequences as well as significant economic impacts on tourism and fisheries. In an attempt to mitigate and minimise such effects, chemical dispersants are considered a prime response tool to deal with oil spills at sea. However, their use has become the subject of much debate and controversy during spill incidents. This can paralyse decision making of the combat agency as well as delay the application of dispersants to avoid oil impacting foreshores or reef systems. This paper reviews the environmental implications of oil spills in tropical marine and foreshore ecosystems. Examples of recent shipping incidents within the Great Barrier Reef and Torres Strait region are used to demonstrate the difficulties associated in responding to oil spills, especially in remote regions. Furthermore, a review of local and international research addresses the toxicity and environmental costs and benefits associated with the use of chemical dispersants in oil spill response.

Oil Pollutants Inhibit Fertilization and Larval Settlement in the Scleractinian Reef Coral *Acropora tenuis* from the Great Barrier Reef, Australia

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Oil pollutants are potentially toxic to reef corals, however, little information is available on the effects of oil pollutants on coral reproduction. This study examined the effects of fuel oil and dispersant on the fertilization success and settlement rates of larvae from the broadcast spawning reef coral, *Acropora tenuis*, from the Great Barrier Reef, Australia. Spawned gametes were exposed to four concentrations of fuel oil: 467, Ardrox 6120 dispersant, dispersed oil or normal seawater for controls. Percentage fertilization was reduced or inhibited in all pollutant treatments, and fertilization rates decreased with increasing pollutant concentration. Water-accommodated fractions of fuel oil 467 reduced fertilization rates at 0.002 to 0.02 ppm hydrocarbon, and embryos developed irregularly or lysed in higher hydrocarbon concentrations. Fuel oil dispersed with Ardrox 6120 completely blocked fertilization at 0.15 ppm hydrocarbon, and reduced fertilization rates at 0.015 ppm. Ardrox 6120 dispersant also blocked fertilization at similar dosage concentrations. Settlement rates of *A. tenuis* larvae were reduced in dispersed oil treatments compared with seawater controls. These are the first data to demonstrate that oil pollutants inhibit fertilization success and larval settlement in broadcast spawning reef corals, and have important implications for management of water quality near coral reefs.

Pesticide and Herbicide Residues in Sediments and Seagrasses from the Great Barrier Reef World Heritage Area and Queensland Coast

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Pesticides and herbicides including organochlorine compounds have had extensive current and past application in Queensland's intensive coastal agriculture industry, as well as for a wide range of domestic, public health and agricultural purposes in urban areas. The persistent nature of these types of compounds together with possible continued illegal use of banned organochlorine compounds raises the potential for continued long-term chronic exposure to plants and animals of the Great Barrier Reef. Sediment and seagrass samples were collected from 16 intertidal and 25 subtidal sampling sites between Torres Strait and Townsville, near Mackay and Gladstone, and in Hervey and Moreton Bays in 1997 and 1998, and analysed for pesticide and herbicide residues. Low levels of atrazine (0.1–0.3 $\mu g\ kg^{-1}$), diuron (0.2–10.1 $\mu g\ kg^{-1}$), lindane (0.08–0.19 $\mu g\ kg^{-1}$), dieldrin (0.05–0.37 $\mu g\ kg^{-1}$), DDT (0.05–0.26 $\mu g\ kg^{-1}$), and DDE (0.05–0.26 $\mu g\ kg^{-1}$) were detected in sediments and/or seagrasses. Contaminants were concentrated in samples collected along the wet-tropics coast between Townsville and Port Douglas and in Moreton Bay. This is a consequence of their rate of past (and present) use and the extent of runoff that occurs in these areas. Of the contaminants detected, the herbicide diuron is of most concern as the concentrations detected may have some potential to impact local seagrass communities.

Urban Stormwater Quality Monitoring and Management in Townsville

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Scientific research aimed to establish and maintain the health of waterways and bays in North Queensland has, in the past, focused primarily on the short-term investigation of contaminants released from point-sources. This approach has neglected the significant impact stormwater run-off and associated toxicant/contaminant loading have had on our waterways. In keeping with its commitment to ecologically sustainable development, Townsville City Council has implemented strategies and programs aimed at integrating water quality and quantity management. Management strategies include the preparation of an Urban Stormwater Quality Management Plan, Environmental Management Plans for catchments, rivers and drainage waterways under Council jurisdiction, and Acid Sulfate Soil risk mapping. Established management programs involve biological, sediment and water quality monitoring, rehabilitation of degraded aquatic and terrestrial ecosystems and the implementation of best practice maintenance procedures and techniques for all its activities. This paper briefly reviews the Council's current research activities and outlines management strategies and actions implemented across Townsville.

Pesticide Residues in Surface Waters of two North Queensland Catchments

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Pesticide residues were monitored in two separate water quality studies undertaken over several years in (i) the Burdekin River Irrigation Area (18 sites) and (ii) the Johnstone River catchment (23 sites). Both studies sought to provide a baseline assessment of the nature and extent of pesticide residue contamination in the respective catchments. Most sites were sampled on at least two occasions and samples were analysed for a wide range of pesticide residues. The Johnstone study included sampling at four sites during a major run-off event. In both studies, the herbicides atrazine and 2,4-D were the most frequently detected residues in surface waters, although frequencies of detection were generally low, particularly in the Johnstone. Residue concentrations, where detected, were also generally low although at times they may have been of environmental significance. Results from the two studies provide evidence of the presence, on occasions, of certain pesticide residues in waterways of both catchments. By inference, it is likely that there is some pesticide movement to the Great Barrier Reef lagoon from these two catchments, but probably only at low concentrations and frequencies of occurrence.

Changes in the Benthic Fauna of Urbanized Estuaries in the Great Barrier Reef Region

Graeme J. Inglis and Jacob Kross
School of Tropical Environment Studies and Geography, James Cook University, PO, Townsville Qld 4811

Urban development causes substantial physical changes in coastal waterways through hardening and reclamation of river banks, alteration of water flow, and diffuse and point-source discharges of pollutants. The cumulative effects of urbanization on the fauna of estuaries are not well understood. This study examined the benthic infauna of two urban and three non-urban estuaries adjacent to the Great Barrier Reef Marine Park. A range of univariate and multivariate statistics was used to relate variation in the benthic assemblages to differences in the concentrations of pollutants within the sediments of each estuary. Sediments obtained from the most developed estuary contained concentrations of heavy metals and petroleum hydrocarbons that were several orders of magnitude greater than those from non-urban waterways. The fauna at these sites was dominated by cirratulid and sternaspid polychaetes and lacked filter-feeding bivalves and other molluscs that were common in less developed estuaries. These differences were consistent throughout multiple sampling locations within each waterway, indicating estuary-wide patterns of change, and were most strongly associated with spatial patterns in the distribution of lead, copper and hydrocarbons.

Quantifying Inputs of Pesticides and Other Contaminants to the Great Barrier Reef Marine Park — A Case Study in the Herbert River Catchment of North-East Queensland

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There is a need to evaluate the downstream impacts of changes in land-use and management practices in river catchments and associated marine environments. An understanding of historical events in a river catchment is central to this activity. This paper quantifies pesticide inputs on rural lands in the Herbert River catchment in the context of changes in land use over the last 100 years. It

shows that since European settlement, three major phases of rural land use and land cover change have occurred on the coastal floodplain of the lower Herbert. In contrast, land use in the upper catchment has remained relatively constant. The area of rural land receiving regular inputs of pesticides is shown to be approximately 7% of the total catchment area. However, with increasing land area for agriculture, inputs of pesticides have increased significantly with time. These trends raise a number of significant challenges for agricultural industries in terms of their ability to comply with the principles of ecological sustainability.

Chlorophyll Fluorescence '*Biosensing*': An Operational Toxicity Test Using Pulse Amplitude Modulation (PAM) Chlorophyll Fluorometry

Ross J. Jones and Ove Hoegh-Guldberg
The School of Biological Sciences, The University of Sydney NSW 2006

There has been a growing realisation that marine and coastal systems worldwide are being degraded by land-based pollution, inorganic sediments, organic matter, inorganic nutrients, and toxic pollutants. One of the difficulties faced by managers of coral reefs, is that there is little knowledge of the effects of pollutants on reef-building corals and a lack of adequate techniques for sublethal stress assessment. There is a need to develop sound scientific information on the threats to, and the conditions of, coral reef ecosystems and to move from informed-opinion to information-based decision making. Recently, we have made significant progress in stress assessment in corals using Pulse Amplitude Modulation (PAM) chlorophyll fluorescence techniques. In corals, PAM fluorometry can rapidly (within <1 s) and non-destructively measure changes in the fluorescence characteristics of the unicellular symbiotic dinoflagellate microalgae (Pyrrophyta) in the coral tissues. The algae are found intracellularly within corals and engage in nutrient recycling with the host (the latter is based in its simplest form on the transport of photosynthetic products to the host and the receipt of inorganic nutrients). This recycling, and the enhancement of coral calcification by the symbiotic algae, is thought to be responsible for the success of reef-building corals in oligotrophic waters. Our studies have shown that any change in external conditions that causes a long-term decrease in the photosynthetic efficiency of the symbiotic dinoflagellates will also result in the dissociation of the coral–algal symbiosis. This separation results in *coral bleaching*, a well-known stress response of corals that refers to the discolouration (whitening) of the tissues. Additionally, by examining changes in chlorophyll fluorescence upon illumination, PAM fluorometry can be used to provide a diagnostic analysis of the effects of a pollutant on photosynthesis. This attribute may prove particularly useful in identifying which component of a complex mixture (i.e. drilling mud from the offshore oil and gas industry) is causing toxicity to corals. Thus, the chlorophyll molecules of the symbiotic algae can be viewed as *intrinsic biosensors* of the health of the coral. So far, we have used the PAM fluorometry/*coral bleaching* toxicity test to assess the effects of cyanide (from cyanide fishing in SE Asia), the effects of heat stress and excess irradiance. The toxicity test can be used year-round to examine water quality issues and is currently being employed to provide the first quantitative measurements of a herbicide (3',4'-dichlorophenyl-1,1-dimethyl urea [DCMU]) and a heavy metal (copper) on adult corals. Preliminary experiments examining the effects of produce formation water (PFW — an effluent of the offshore oil and gas industry) on corals are shown.

Antifoulants in Sediment of the Great Barrier Reef: Concentrations and Risk Assessment of Tributyltin and Copper

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The Great Barrier Reef Marine Park is a sensitive environment containing a diverse array of unique flora and fauna. It is a multi-purpose park and consequently under impact from a number of different activities. Shipping has a major potential influence on reef health with antifouling contaminants being a current concern. The toxic effects of antifoulant agents such as tributyltin and copper to non-target marine organisms have been well documented for northern hemisphere aquatic systems, but information on environmental contamination and biotic response in Great Barrier Reef systems is limited. Sediment samples have been collected from four regions within the Great Barrier Reef Marine Park: Port Douglas, Cairns, Townsville and the Whitsundays. Samples from recreational, commercial, island resort harbours and outer reefs will be analysed for tributyltin and copper to determine any differences in sediment concentrations of these toxicants between regions and/or harbour types. These results will provide baseline data for management consideration and future risk assessment of the use of antifouling paints. Acquired environmental antifouling toxicant levels, in conjunction with newly developed sediment guideline values, will be used to determine the necessity for any modification of ship maintenance practice and/or passage routes within the Great Barrier Reef Marine Park.

How to Communicate Information on Toxicants to Change Land Management Practices — Rodent Control in North Queensland. A Case Study

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Primary producers manage 87% of the landmass of Queensland. If new information is to be effectively communicated and result in changed land management practices, it must be effectively communicated to this relatively small and homogenous group of 22 000 people. Major differences exist in the way scientists, conservationists and primary producers source and use new information. This is particularly the case in the area of natural resource management, where the use of toxicants in agricultural production systems is but one of many issues. These differences create the potential for major conflict that can result in the creation of barriers to the adoption of improved land management practices. In contrast, when scientific information is presented in a non-threatening and solution-focused way, improved land management practices are likely to follow. The Bureau of Sugar Experimental Stations' integrated pest management program for rodent control is a proven example of how information on toxicants can be effectively communicated to change land management practices.

Pesticide and Heavy Metal Concentration in Queensland and Estuarine Crabs

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A survey of bioavailable metals and pesticides accumulated in the tissues of common estuarine crabs between Brisbane and Cairns has shown that, as a legacy of the past use of persistent organochlorines in agriculture and for a variety of domestic and public health purposes, there is a background of environmental contamination by these compounds. The most commonly detected organochlorine is dieldrin, detectable in almost all samples, followed by DDT and its metabolites.

Estimations based on partitioning relationships indicate that the ambient aqueous concentration of dieldrin in some waterways exceeds the ANZECC Water Quality Guidelines for the protection of aquatic ecosystems. Where data is available for both sediments and biota the figures are consistent with a widespread contamination of estuarine sediments with these persistent organochlorines. This has implications for potential contamination of the Great Barrier Reef Lagoon in flood events involving the off-shore transport of suspended material from these estuaries. Contamination by metals in a bioavailable form, as indicated by analysis of crab tissues, is not widespread and only notable in a few discrete estuarine areas associated with urban and/or known metalliferous sources.

Pesticides in Sediments from Irrigation Channels and Drains in Queensland

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Sediment samples collected from irrigation channels and drains in 11 agricultural areas of Queensland were analysed for a series of past and presently used pesticides including various organochlorines, synthetic pyrethroids, benzoyl ureas, triazines and organophosphates. The most often detected compounds were endosulfan (α,β and/or endosulfan sulfate) which were detectable in 78 of the 103 samples and levels of total endosulfan (Σendosulfan) which ranged from below the detection limit (0.1 ng g^{-1} dw) up to 840 ng g^{-1} dw. DDT and its metabolites were the second most often detected pesticide investigated (74 of the 103 samples) with concentrations up to 240 ng g^{-1} dw of total DDTs (ΣDDTs). Mean Σendosulfan and ΣDDT concentrations were 1–2 orders of magnitude higher in sediments from the irrigation areas which are dominated by cotton cultivation compared to those which are dominated by sugar cane cultivation. The herbicides diuron, atrazine and ametryn were the compounds most often detected in sediments from irrigation drains in sugar cane areas. In contrast to the contaminants from the inland cotton growing areas, a significant proportion of the contaminants found in sediments from the sugar cane cultivation areas may be transported to the marine environment. Their ecotoxicological effect requires assessment.

How did the Dioxins get into the Dugongs? — What we Know and What we Don't Know

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Polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs), all of which are often referred to as dioxins, are ubiquitous environmental contaminants that have been detected in marine mammals from both the northern and southern hemisphere. Samples from three mature dugongs, found stranded between northeast of Townsville and south east of Mackay in 1996, were analysed for 2,3,7,8-substituted PCDD/F congeners and selected polychlorinated biphenyl congeners at the University of Bayreuth. The results showed that the PCDD/F congener profile was dominated by PCDDs (Haynes et al. *Chemos.* 38: 255, 1999). While the concentrations of PCDFs and PCBs were relatively low, the concentrations of octachlorodibenzodioxin (OCDD), in particular, in the blubber samples (170, 200 and 250 ng g^{-1} fat) from the three dugongs found stranded in the Great Barrier Reef were all significantly higher than in other known marine mammal samples. To determine the pathways of these pollutants into the dugongs, sediment and seagrass samples were collected from dugong habitats near the sites where the dugongs were stranded. A range of PCDD/Fs could be quantified in all sediment and seagrass samples. OCDD was also the dominant congener in all samples and contributed with more than 90% in seagrass and 95% in sediment samples to the sum of all congeners. OCDD and to a lesser extent heptachlorodibenzodioxin and lower chlorinated PCDDs, were also detected as major contaminants in surface soil samples from sugar cane farms in a previous study (Müller et al., in: Wilson, Hoggarth, Campbell and Garside. Sugarcane: Research Towards Efficient and Sustainable Production CSIRO, 273, 1996). This paper will summarise the past and current work on dioxin sources and pathways in the Great Barrier Reef Marine Park area.

Coral Fertilisation and Larval Metamorphosis: Inhibition by Crude Oil, Dispersants and Production Formation Water

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Acute accidental oil spills from ships or rigs and chronic inputs of effluent such as production formation water (PFW) are key perceived threats from shipping and petroleum industry activities. In line with increasing industry activity in Australian tropical waters, there is a priority need for more information on the expected effects on Australian tropical biota. Scleractinian corals are a key functional component of tropical reefs and the abundance, diversity and resilience of coral communities can be used as an indicator of ecosystem health. In this paper we report newly developed laboratory-based techniques to study the effects of petroleum products, including water accommodated fractions (WAF) of crude oil, PFW and dispersant (Corexit 9527), on fertilisation and larval metamorphosis of the widespread scleractinian coral, *Acropora millepora* (Ehrenberg 1834). While fertilisation was inhibited by high concentrations of PFW (>100 ppt), larval metamorphosis was more sensitive to the effluent, with 50% of metamorphosis inhibited at 39 ppt. Crude oil WAF did not inhibit fertilisation of gametes until dispersant was introduced. Dispersed oil was no more toxic to fertilisation than dispersant itself, suggesting toxicity to that event was due to the dispersant alone. Larval metamorphosis was more sensitive to crude oil WAF than was fertilisation and this toxicity also increased in the presence of dispersant. The most toxic dispersed oil combination inhibited 50% of larval metamorphosis at 1.2 ppt WAF. Both crude oil WAF components and dispersant contributed to inhibition of larval metamorphosis. Management of petroleum-related risks to reef-building corals should take into consideration not only the annual coral spawning event, but also the subsequent 1–3 week period during which most larval recruitment is likely to occur. The approach taken for these laboratory experiments is applicable to assess acute toxicity to a wide range of corals and other sessile marine invertebrates with dispersive larval life histories.

Physiological Responses of Five Seagrass Species to Trace Metals

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Trace metal run-off associated with urban and industrial development pose potential threats to seagrasses in adjacent coastal ecosystems. Seagrass from the largest urban (Moreton Bay) and industrial (Port Curtis) coastal regions in Queensland, Australia were assessed for metal concentrations of iron (Fe), copper (Cu), aluminium (Al), zinc (Zn) and chromium (Cr). Trace metal concentrations in seagrass (*Zostera capricorni*) leaf and root/rhizome tissue had the following overall trend: [Fe] > [Al] > [Zn] > [Cr] > [Cu]. Rainfall events and anthropogenic disturbances were suggested to influence metal concentrations in seagrasses with the exception of Al, which does not appear to bioaccumulate. In laboratory experiments, five seagrass species (*Halophila ovalis, Halophila spinulosa, Halodule uninervis, Zostera capricorni* and *Cymodocea serrulata*) were incubated with iron (1 mg Fe L^{-1}) and copper (1 mg Cu L^{-1}) and responses assessed

by changes in photochemical efficiency (F_v/F_m), free amino acid content and leaf/root-rhizome metal accumulation. Iron addition experiments only affected *Halophila spp.*, while copper additions affected all seagrass species. Trace metal contamination of seagrasses could have ramifications for associated trophic assemblages through metal transfer and seagrass loss. The use of photochemical efficiency and amino acid concentrations and composition proved to be useful sublethal indicators of trace metal toxicity in seagrasses.

Impact of Diuron Exposure to Tropical Seagrasses Assessed by Chlorophyll Fluorescence

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The impact and recovery from the herbicide Diuron (DCMU) was assessed at environmentally relevant levels on three tropical seagrasses, maintained in static outdoor aquaria. Photosynthetic stress was detected using chlorophyll a fluorescence. It was found that exposure to 10 and 100 μg/L Diuron resulted in a decline in maximum quantum yield (Fv/Fm ratio) by about 70% for *Cymodocea serrulata* and *Halophila ovalis*, while *Zostera capricorni* declined by 50% over a five-day exposure period. The decline in the Fv/Fm ratio was strongly influenced by a 2–3 fold increase in the initial fluorescence (Fo). Quantum yield recovered within 1–2 days of the samples being placed in fresh seawater, therefore the short-term damage appeared to be temporary. Total chlorophyll and carotenoid levels indicated a degree of inhibition, greatest in *H. ovalis* and least in *Z. capricorni*. Growth data was inconclusive. These data indicate that short-term (< 7d) exposure of seagrasses to environmentally relevant concentrations of the herbicide Diuron result in temporary damage to the photosystems for which recovery is rapid. Longer term toxicological studies are required.

Effect of Bioremediation on the Microbial Community in Oiled Mangrove Sediments

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Bioremediation was conducted in the field on a mature *Rhizophora stylosa* mangrove stand on land to be reclaimed near Fisherman's Landing Wharf, Gladstone. Gippsland crude oil was added to six large plots (>40 m^2), bioremediation was used to treat three plots and the three remaining were left untreated as oiled controls. The bioremediation strategy consisted of actively aerating the sediment and adding a slow-release fertiliser in order to promote oil biodegradation by indigenous micro-organisms. Oil addition stimulated the numbers of aliphatic-degrading bacteria slightly to levels of 10^4–10^5/ g sediment. Bioremediation of the oiled sediment had a dramatic effect on the aliphatic-degrading population, increasing the population size by 5 orders of magnitude (to <10^{10}/g). The effect of bioremediation on the growth of aromatic-degraders was not as dramatic. Morphological analysis suggested that the microbial population had a diverse population of hydrocarbon-degrading micro-organisms in mangrove sediment. Active aeration and nutrient addition stimulated significantly the growth of hydrocarbon-degraders in oiled mangrove sediment in the field.

Indicator Tissues for Heavy Metal Monitoring — Time for a Rethink

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Most of the preferred characteristics of indicator organisms used in condition and trend monitoring in marine ecosystems were documented in the early 1970s. Desirable characteristics include: abundance in the study region, easy recognition, convenient to collect, sessile and thus representative of the locality, hardy enough to survive both relocation and high concentrations of heavy metals, of sufficient size to provide adequate samples for analysis, and sufficiently long-lived to permit sampling of more than one year-class. A high concentration factor, allowing direct analysis without a concentration step was also sought, primarily for analytical convenience. This characteristic is less relevant these days and may even be inappropriate. Heavy metal data from Raine Island, an uninhabited 30 ha coral cay located on the outer Great Barrier Reef (11°36'S, 144°01'E), are presented to question the 'pre-disposition to accumulate or concentrate heavy metals' hypothesis for reasons associated with methodology, species and tissue selection, and food standards for marine organisms. Examples using kidney tissues, visceral mass and adductor muscle from the giant clam (*Tridacna maxima*), muscle tissue from *Trochus niloticus* and axial muscle from four species of fish, all from waters surrounding Raine Island, are given for a selection of heavy metals. For example, the kidneys of giant clams had concentrations of heavy metals from 2 (Zn) to 2780 (Ni) times higher than corresponding concentrations in adductor muscles. Also, tissues of giant clam and the muscle of trochus gave different signals with respect to bio-available heavy metals. Linear correlations involving different heavy metals, both within and between tissues of giant clam and within muscle tissue of trochus, offer opportunities for the use of surrogates for some metals as well as a possible mathematical basis for commenting on trends in heavy metal pollution.

The Effect of Some Trace Metals on Various Lifestages of Scleractinian Corals

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Repeated successful spawning years are necessary for the long-term maintenance of reef coral populations and, therefore, quantifying the effects of contaminants on fertilisation success, larval survival and larval settlement is important. This study provides new baseline information for managers and policy makers on the effects of metals on sensitive life stages of scleractinian corals, and therefore makes useful contributions for determining biologically appropriate water quality criteria and waste discharge levels in coral reef areas. The effect of trace metals including copper, lead, nickel, zinc and cadmium, on the fertilisation success, larval survival, larval motility and larval settlement of several species of scleractinian corals was investigated in this study. Copper toxicity is greatest compared to all metals tested for all life stages of corals where copper EC50 values for fertilisation success are between 15 µg/L and 40 µg/L. The mobility of coral larvae, and larvae settlement success are inhibited by copper concentrations similar to those that inhibited fertilisation success. Larval survival is less affected by copper at short exposure times (e.g. 6 hour LC50 248 µg/L to 260 µg/L for 6 hours 121 µg/L). However, after longer exposure times (e.g. 48 hours) LC50 values for larval survival are reduced to 34 µg/L to 87 µg/L. Lead is also toxic to coral fertilisation success and EC50 values are between 1453 µg/L and 2467 µg/L. The EC50 for the effect of lead on larval motility after 72 hours exposure was 2900 µg. However, larval survival is more resilient to lead at all exposure times and the 72 hour LC50 value is 9890 µg/L. Other metals tested (zinc, nickel and cadmium) are less toxic to fertilisation success, larval motility and/or larval survival than lead or copper.

An Historical Record of Cadmium Input to the Herbert Estuary

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An historical record of cadmium (Cd) inputs to the Herbert River estuary was reconstructed from Cd profiles in sediment cores for which estimates of dates of sediment deposition could be inferred from mass accumulation rates. Cd concentrations were found to range between 40 and 380 pmol/g. Non-parametric statistical analyses were used to compare the period of intensive phosphatic fertiliser use on Herbert River canefields (~1960s to present) with the 'background' period (pre-1960s). Statistically significant increases in Cd were observed in three cores collected from the Hinchinbrook Channel, a significant decrease was observed in a core collected from north of Hinchinbrook Island, and Cd concentrations appear to have remained constant in a core collected from south of Hinchinbrook Island. A geochemical model was developed to identify contaminant Cd associated with phosphatic fertilisers. Using this method, only two of the five cores demonstrated evidence of an increase in Cd loadings to sediments during the period of intensive fertiliser use.

Relevance of DNA Adducts as a Biomarker of Exposure to Carcinogenic PAHs in the Aquatic Environment

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Polycyclic aromatic hydrocarbons (PAHs) can be metabolically activated to electrophilic metabolites which covalently bind to DNA to produce adducts. The occurrence of DNA adducts in tissues from marine organisms in Moreton Bay and the Brisbane River and its tributaries has been investigated using the ^{32}P-postlabelling assay. The levels of adducts in DNA from livers of fish and hepatopancreases of crustaceans were found to be higher in the city reach of the Brisbane River and Oxley Creek, in line with higher environmental concentrations of PAHs. Tissue concentrations of PAHs in organisms did not correlate with concentrations in the abiotic environment. In organisms from Oxley Creek, higher levels of adducts were found also to be associated with elevated concentrations of higher molecular weight PAHs in their tissues. The relative degree of adduct formation has been shown to vary depending on the structures of the individual PAHs.

Torres Strait Regional Authority

GENERAL INFORMATION AND RESEARCH/PROJECTS OVERVIEW

The purpose of this paper is to enable those present and their agencies to obtain some general information and a summary of activities occurring in Torres Strait. Should you wish to enquire further about items listed please contact myself during the workshop or at the addresses below. Both the Island Coordinating Council (ICC) and the Torres Strait Regional Authority (TSRA) need your cooperation should you wish to undertake research in the outer islands of Torres Strait.

Area Description

Basically the area between Cape York and Papua New Guinea bounded by the northern extremity of the Great Barrier Reef in the east and longitude 141E in the west. The northern end of the Gulf of Carpentaria and the eastern extremity of the Arafura Sea form the sea country boundaries to the south-west and west. The Torres Strait Protected Zone (TSPZ) is an area within the above location description — the TSPZ exists consequent to the arrangements contained in the Torres Strait Treaty between Australia and Papua New Guinea.

The Island Coordinating Council (ICC)

The ICC represents those island communities and two Cape York Islander communities that operate under Queensland State Government administrative arrangements deriving from the Community Services (Torres Strait) Act 1984. The chairperson of each community is an ICC member. All enquiries relating to visitation to the outers islands for research purposes should be brought to the attention of the ICC in the first instance.

The Torres Strait Regional Authority (TSRA)

The TSRA derives from the *Aboriginal and Torres Strait Islander Act 1989* (as amended) — the ATSIC Act. In 1994 the amended Act enabled the TSRA to represent the interests of Torres Strait Islanders in the region in respect to Commonwealth Government indigenous programs of assistance. Currently the ICC membership plus two others elected under the ATSIC Act form the TSRA membership. Considerable improvements to quality of life infrastructure on islands have occurred since the formation of the TSRA. It coordinates Torres Strait environment and heritage matters among all agencies.

Protected Zone Joint Authority (PZJA)

The Torres Strait Treaty 1985 defines the border and traditional access arrangements to resources, trade, visitation etc. The principal purpose of the PZJA *'is to acknowledge and protect the traditional way of life and livelihood of the traditional inhabitants including their traditional fishing and free movement'*. This mechanism recognises both PNG and TSI interests in Torres Strait. There are separate jurisdiction lines for the seabed and fisheries.

Current Issues

Native Title
Commercial Fisheries Management
Gas Pipeline
Cross-border Concerns
Greater Autonomy
Community-based Management (of Environment, Heritage and Culture)
Mining Moratorium in PNG/Australian waters

Indigenous Protected Areas
Pollution from mining and shipping
Research Protocols

Environment Management Policies/Strategies

A Marine Strategy for Torres Strait (MaSTERS)
Torres Strait Conservation Plan
Establishing a Geographical Information System
Straitcare (in preparation)

Research/Projects

Torres Strait Heavy Metals Monitoring Program
Dugong Life History Parameters Study
Indigenous Protected Areas (two identified)
Resource Use Mapping
Fly-way site Mapping (awaiting IPA approval)
Commercial Fisheries Stock Assessment and Monitoring
Socio-economic studies of fisheries (awaiting TSFSAC approval)
Anthropological Studies for IPA and Pipeline
Flora and Fauna Survey
Vegetation Mapping
Turtle Nesting Sites Mapping (awaiting TSFSAC approval)

Research and/or Industry Committees

Torres Strait Fisheries Scientific Advisory Committee (TSFSAC)
Commercial Fisheries Working Groups/ Management Advisory Committees
Torres Strait Regional Employment Committee

Infrastructure Development on Inhabited Islands

Housing
Water Supplies
Waste Management
Aerial Photography

Agencies Located in Torres Strait

Australian Fish Management Authority (includes turtle and dugong management)
Australian Customs/Coastwatch
Queensland Transport/Boating and Fisheries Patrol
Australian Quarantine Inspection Service
Dept. Immigration and Multicultural Affairs
Dept. Foreign Affairs and Trade (Treaty Liaison Officer)
Office of Aboriginal and Torres Strait Islander Affairs (State)

A Researcher Protocol

The ICC has been concerned over a number of years about lack of consultation with it by agencies/ researchers wanting to work in the area. The political intensity surrounding greater administrative autonomy has generated the need for a researcher protocol and the Anthropologist in the TSRA's Native Title Representative Body is preparing one. There are also quite specific behaviour and dress standards required of visitors by island communities. Until a protocol is adopted, researchers are well advised to contact the Secretary of the ICC or the Coordinator before coming to Torres Strait.

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