Spatial and temporal patterns of flood plumes in the Great Barrier Reef, Australia

Thesis submitted by

Michelle Jillian Devlin

BSc (Bendigo College of Advanced Education (Latrobe University)

Msc (James Cook University)

February 2005

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Tropical Environment Studies and Geography Department,

James Cook University.

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Papers arising from this thesis

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Abstract

This thesis considers the eutrophication of our coastal systems and the potential for anthropogenic driven change in these systems. The influence of river waters and plume driven nutrients and sediments into nearshore systems is also documented. Known changes in the Great Barrier Reef and associated Queensland catchments, including land use change, river water quality, flood plume extent and variation, coral cover, coral reef processes and any related changes are presented.

This research spans a number of large, long term data sets collected over the last 10 years, including long term chlorophyll *a* data set, and flood plume extents and water quality concentrations both in plumes and around inshore coral reefs. Modelling of all this data demonstrates that the inshore reef of the GBR is becoming more productive, with assessment of risk being highest for the inshore reefs adjacent to the Wet Tropics catchments.

This thesis outlines the potential changes in the nutrient availability by summarising a long term data set of chlorophyll *a*. The data collected in the seven years demonstrate persistent cross-shelf and regional differences in chlorophyll concentration. Seasonal trends are generally consistent between regions. There are pronounced gradients between inshore and offshore sites, indicating a strong terrestrial influence in the inshore lagoon of the GBR. Results from chlorophyll monitoring support the idea of an inner-shelf polluted zone adjacent to the developed catchments from Port Douglas to Harvey Bay (end of southern region), and relatively unpolluted zone on the inner-shelf north of Port Douglas and generally on the middle and outer shelf. The middle shelf between Cape Grafton and Cape Tribulation (central region) is also somewhat polluted due to its proximity to the coast and polluted rivers. In general, Coral Sea and outer shelf mean chlorophyll concentrations are close to 0.2 μg/L, areas of the GBR Lagoon without polluted river influence have mean concentrations near 0.3 μg/L, long-term mean concentrations in areas subjected to polluted river influence are near 0.6 μg/L while event concentrations in waters affected by flood plumes from polluted rivers are near 3 μg/L.

This larger part of this body of work has looked at the dispersal and extent of flood plumes, the importance of flood plumes as a source of nutrients and sediments and the

potential risk of riverine influence on the nearshore ecosystems of the GBR. Through the course of this work, I have monitored and measured flood plumes associated with cyclones from 1991 to 2000. The sampling events were Cyclone Joy (1991), Sadie (1994), Violet (1995), Ethel (1996), Justin (1997), Sid (1998), Rona (1999) and Steve (2000).

Plume distributions presented in chapter 4 establish that the main driving influence on plume dispersal is the direction and strength of wind and discharge volume of the river. Wind conditions are dominated by south-easterly winds which drive the plume north and towards the coast. The greater number of plumes mapped over this study (Violet, Ethel, Justin, Sid and Rona) were restricted to a shallow nearshore northward band by stronger south-easterly winds following the cyclone. However, under relatively calm conditions such as those following Sadie, light offshore winds allowed the plume to disperse seaward and north over much of the shelf and there was a short period of direct impingement upon mid and outer-shelf reefs. The flood plumes associated with Cyclone Joy in the Fitzroy River also moved offshore, following light northerly winds, eventually impinging on reefs of the Capricorn-Bunker group.

The amount of rainfall that falls over a particular catchment can have a marked effect on distribution of the plume. Another factor in the distribution of flood plumes is the influence of headlands on the movement of the plumes (‘steering’). This can be observed most clearly in the vicinity of Cape Grafton (slightly south-east of Cairns) in extent of the Sadie, Violet and Ethel plumes where northward moving plumes are steered across the Green Island Reef. Green Island Reef appears to the one mid-shelf reef of the GBR, south of the Daintree, which is regularly covered by river plume water. Therefore the assessment of plumes impacting on the mid-shelf reefs adjacent to the Barron River (Green Island) are expected to be underestimates due to effects from other river systems to the south “steering” past Cape Grafton.

Data presented in chapter 5 demonstrates that the composition of plumes is strongly dependent on particular events, between days and through a single event, depths and catchment. Timing of sampling is critical in obtaining reliable estimates of material exported in the flood plumes. There is a hysteresis in the development of a flood plume, which is related to catchment characteristics (size, vegetation cover and gradient), rainfall intensity and duration and distribution of flow volume. The time lag difference is significant in the smaller Wet Tropic rivers (Herbert to Daintree) compared to larger Dry Tropic Rivers of the Burdekin and Fitzroy.

Measurements of all parameters taken further away from the river are influenced by physical and biological processes occurring over time as the elevated concentrations in the river water mixed with the lagoonal waters of the GBR. Concentrations on NO_x and DIP ranged from 10-15µM and 0.2-0.5µM at sites close to the river mouth and declining to levels between 0-2µM (NO_x) and 0 – 0.2µM at higher salinity concentrations. Though these later concentrations are still high in comparison to baseline concentrations they do reflect influences by other processes. The distribution of nutrients within the plume is a function of riverine inputs, mixing and biological activity which add or remove nutrients.

Modelling of the plumes associated with specific weather conditions has demonstrated that inshore reef areas adjacent to the Wet Tropics Catchment (between Townsville and Cooktown) regularly experience extreme conditions associated with plumes. Inshore areas (north of the Burdekin and Fitzroy Rivers) receive riverine waters on a less frequent basis. Spatial distribution of the frequency of plume coverage delineates the inshore area of the GBR, which is annually inundated by flood plume waters. Chapter 4 presents a summary of the frequency and distribution of the all flood plumes mapped in the GBR over the last 10 years.

As part of the assessment of the impact of flood plumes on GBR ecosystems, an estimate is required of the areal and volumetric extent of plumes emanating from the rivers draining to the GBR. The observed distribution of flood plumes between 1994 and 1999 serves as a baseline for evaluating baseline distribution with respect to variables controlling plume extent. Based on these observations, a summary of plume distribution for waters discharging in the vicinity of the Russell-Mulgrave and Barron Rivers has been developed with six qualitative fields of plume distribution (inner1, inner2, inner-mid, mid, mid-outer and outer). A model was developed to estimate the expected distribution of a plume using variables which include wind speed and direction coupled with river flow data. Formulation of expected plume distribution over a longer time period than individual observations allows for the identification of reefs that are subject to plumes and an estimate as to the frequency of impact. Based on the model an estimate of spatial extents of plumes has been made using the Barron River as a case study. The hindcasted model provided a preliminary estimate of how frequently plumes extend to a particular area of the GBR. Based on the data for the Barron River it is estimated that in the past 58 years, a plume may have reached the mid-shelf reefs (outer category) on 18 occasions.

Acknowledgements.

This thesis would not have been possible without the help and support of many people, and I thank every single one of them. In particular, I would like to thank Jon Brodie for being a great supervisor, a wonderful inspiration and a great friend. His direction and overview have been instrumental in understanding the connections between catchment and reef processes. Thanks to David Haynes, his support, advice and friendship was very much appreciated. I would also like to thank Jane Waterhouse who also worked with us in the Marine Park Authority. She was legendary in being able to keep calm when all else was not, and her help in the many reports and papers that came from this research was exceptional. I was part of a great team in the Water Quality section of the Great Barrier Reef Marine Park Authority, and without their help, this work would never have been completed. The majority of this work was supported and funded by the Great Barrier Reef Marine Park Authority, and I thank them for their vision and support. I would like to thank Scott Smithers, who took over as my James Cook University supervisor at a later date and has remained a calming force through the last couple of years.

I would like to thank everyone who was involved with the stormy fieldwork that has taken place under these programs, especially Debbie Bass Caroline Christie and Luke Smith for being with me in the field and offering much needed advice for the success of this program. Thanks to the gang at the Long-term Monitoring Program (Australian Institute of Marine Science), Rob McGill, Andrew Stevens (Great Barrier Reef Marine Park Authority), Alan Mitchell (Australian Institute of Marine Science, Master and crew of the research vessels *Sirius* (AIMS), *Satisfaction* (Cairns), *Aquarius 3* (Cairns) and the crew of the Queensland Department of Primary Industries (Cairns) and Queensland Parks and Wildlife Service vessels based at Dungeness and Cairns for their assistance with field work.

I would like to thank my current work, Centre for Environment, Aquaculture and Fisheries in the UK for being supportive of my time here in Australia finishing off this work, in particular I would like to thank Steven Malcolm for his support.

I would like to send a very big thank you to my family who have been a constant in my life for a very long time. Thanks for making me smile when I needed it the most.

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