Marine Pollution Bulletin 58 (2009) 976–986

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Agricultural lands are hot-spots for annual runoff polluting the southern Great Barrier Reef lagoon

Robert Packett [a,b,c], Cameron Dougall [d,*], Ken Rohde [e], Robert Noble [b,c]

[a] National Action Plan for Salinity and Water Quality, Rockhampton, 4700, Australia
[b] The Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Rockhampton, 4700, Australia
[c] Department of Natural Resources and Water, Rockhampton, 4700, Australia
[d] Department of Natural Resources and Water, Emerald, 4720, Australia
[e] Department of Natural Resources and Water, Mackay, 4740, Australia

ARTICLE INFO

Keywords:
Great Barrier Reef
Water quality
Hotspots
Inshore pollution
Fitzroy Basin
Agriculture

ABSTRACT

The world's largest coral reef ecosystem, the Great Barrier Reef (GBR), continues to be degraded from land-based pollution. Information about the source of pollutants is critical for catchment management to improve GBR water quality. We report here on an 11-year source to sea study of pollutant delivery in runoff from the Fitzroy River Basin (FRB), the largest GBR catchment. An innovative technique that relates land use to pollutant generation is presented. Study results indicate that maximum pollutant concentrations at basin and sub-catchment scales are closely related to the percentage area of croplands receiving heavy rain. However, grazing lands contribute the majority of the long-term average annual load of most common pollutants. Findings suggest improved land management targets, rather than water quality targets should be implemented to reduce GBR pollution. This study provides a substantial contribution to the knowledge base for the targeted management of pollution 'hot-spots' to improve GBR water quality.

1. Introduction

1.1. Great Barrier Reef water quality issues

Globally, coral reefs and associated inshore ecosystems continue to be degraded from land-based pollution via flood runoff (Fabricius, 2005; Pandolfi et al., 2005, 2003). The Great Barrier Reef (GBR) along the coast of Queensland, Australia is the largest World Heritage Area and represents about 17% (in area) of the world's coral communities (Wilkinson, 2002). Recent studies suggest that degradation of inshore reefs may be linked to an increase in pollutants from land-based flood runoff since the European settlement of GBR catchments. Agricultural activities are thought to be a primary contributor to this increase in pollutant delivery (DeVantier et al., 2006; Fabricius et al., 2005; McCulloch et al., 2003).

The Fitzroy River Basin (FRB) has been identified as a major source of pollutants to the GBR lagoon (The State of Queensland and Commonwealth of Australia, 2003). Agricultural activities account for ~95% of land use in the FRB and historically there have been numerous water quality issues at a sub-catchment scale (Noble et al., 1997). Recent estimates of modelled post-development, long-term annual suspended sediment export from the FRB to the GBR lagoon range from 3 to 4.5 million tonnes per year. This represents ~33% of the modelled annual suspended sediment load from all GBR catchments and represents a substantial increase compared to pre-development contributions from the FRB (Dougall et al., 2005).

Coral bleaching caused by rapid climate change and warming coastal waters has now become a regular occurrence in the southern GBR and current climate change forecasts predict an increase in bleaching events. In addition, there is likely to be an increase in intense storm frequency for northern Australia, which could generate extended flood plumes (Intergovernmental Panel on Climate Change, 2007). It is now well accepted that poor water quality can compromise corals and other reef organisms and impede the recovery of reef systems from bleaching events (Wilkinson, 2002). Recent studies of the impacts of nutrients and pesticides on corals, seagrass and algae have highlighted the potential for some agricultural pollutants to damage marine organisms at relatively low concentrations (Smith et al., 2006; Nugues et al., 2004; Jones et al., 2003; Haynes et al., 2000). Water quality is therefore predicted to play a major role in the resilience and capacity of the GBR to recover from bleaching events and adapt to rapid climate change (Hennessy et al., 2007; McCook et al., 2007).

Recent initiatives, such as the Reef Water Quality Protection Plan (The State of Queensland and Commonwealth of Australia,

* Corresponding author.
E-mail addresses: robert.packett@nrw.qld.gov.au (R. Packett), cameron.dougall@nrw.qld.gov.au (C. Dougall).

0025-326X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpolbul.2009.02.017

2003), aim for changes in land management to improve water quality and decrease pollutant loads. A water quality target-setting framework has been proposed to monitor improvements in catchment management. However, this agenda is inhibited by a lack of knowledge on the sources, transport and fate of flood-borne pollutants from GBR catchments. Guidelines for high flow (flood) pollutant concentrations are not available and there is an urgent need for research on load-based (quantity of pollutants in the particular flood event) rather than concentration-based assessment of floods (ANZECC and ARMCANZ, 2000).

Traditionally, large volume floods that have return periods of decades have been the main consideration for pollutant delivery from large dry tropical catchments like the FRB (Australian Government and Queensland Government, 2005; Williams, 2001). This has mainly been due to the fact that large loads of pollutants can be delivered as far as middle and outer reefs during major flood events. However, in recent years, more attention has been given to inshore reef zones and the possible impacts from smaller volume floods (Devlin et al., 2003; Brodie, 2002). Smaller volume floods occur at a far higher frequency and often have a direct impact on the inshore water quality of the GBR lagoon. There is also the possibility of indirect impacts to middle and outer reef zones as a result of inshore impacts, for example, via changes in community structure brought about by increased nutrient availability (Fabricius and De'ath, 2004; Schaffelke, 1999).

Information about the source and transport of pollutants in large as well as small floods is crucial for effective catchment management to improve the quality of water in runoff discharging into the GBR lagoon.

1.2. The Fitzroy River Basin (characteristics)

The FRB, in the dry tropics of central Queensland, Australia is the largest drainage system in area (~142,600 km^2) to discharge into the GBR lagoon and accounts for ~36% of the total GBR catchment (Fig. 1). Average annual rainfall for the FRB varies in a gradient from ~530 mm in the west to ~850 mm in central regions and ~2000 mm in the northeast ranges near the coast. Widespread heavy rainfall is usually generated by monsoonal depressions and tropical cyclones during summer. Isolated thermal storms in early summer can also deliver considerable, and, at times, intense rainfall to less extensive areas of the catchment. The relatively short wet seasons are typically separated by long dry periods, and drought conditions can often persist for several years.

The dominant land use in the FRB is cattle grazing (~88% of area) while cropping and horticulture occurs on ~7% of the basin (mainly on cracking clays). National parks and other managed areas account for ~ 4%, with coal mining and other activities making up the remaining 1% of land use. The basin has undergone extensive modification by clearing of woodland communities dominated by Brigalow (*Acacia harpophylla*) for grazing and cropping (Bailey, 1984). By 1999, around 60% of the remnant vegetation in the Fitzroy had been substantially altered or cleared (Accad et al., 2001). A long-term study in the FRB on the impacts of agriculture has demonstrated a significant loss in the natural productivity of cropping and grazing lands indicating a potential and continuing decline in overall catchment condition (Radford et al., 2007). The same study also found that annual runoff from cropped or pastured catchments was approximately twice that from native vegetation (Thornton et al., 2007). Recent studies of beach ridge sedimentation near the Fitzroy River mouth indicate a substantial increase in sediment transport to the coast in the last 100 years. An increase in the percentage of basaltic soils in these recent sediment deposits was also observed, most likely a result of tree clearance and agricultural activity (Brooke et al., 2008). The FRB has therefore undergone significant modification since European settlement (1856 onwards) and like other GBR catchments this has resulted in substantial increases in pollutant delivery to the GBR lagoon (Baker, 2003; McCulloch et al., 2003).

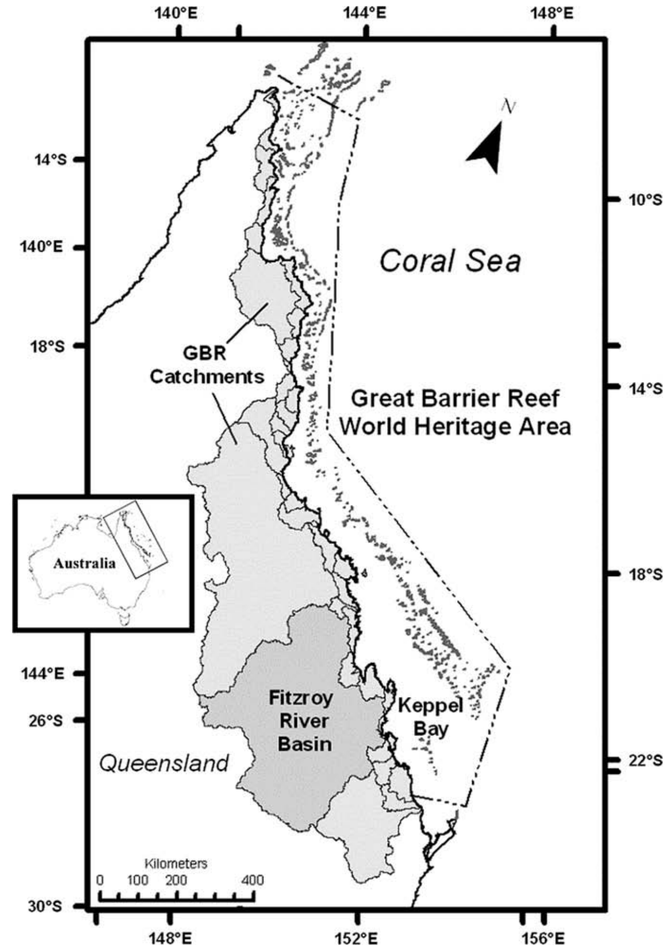

Fig. 1. The Fitzroy River Basin Queensland, Australia in relation to the Great Barrier Reef World Heritage Area. Other GBR catchments are shown in light grey.

1.3. Study overview

Historically there has been limited information available in regards to the source and delivery of pollutants from the FRB to the GBR lagoon. This reduces the ability of regional catchment management organisations such as the Fitzroy Basin Association to arrive at practical water quality targets. Guidelines are only available for a limited range of pollutants during base-flow and ambient conditions. The Queensland Water Quality Guidelines (QWQG) suggest it is inappropriate to apply the current guideline concentrations to high discharge events and that there is insufficient information available to provide load-based guidelines (Environmental Protection Agency, 2006). Further, the ANZECC guidelines suggest that there is an urgent need for the development of more load-based guidelines, rather than concentration-based approaches to water quality targets (ANZECC and ARMCANZ, 2000).

The term "pollutants" refers to suspended sediments, nutrients, organic carbon (OC) and pesticides. It is difficult to determine with certainty the range of concentrations for the first three chemical constituents that would have been in floodwaters from the FRB prior to catchment modification. However, the only reference values available for what are considered environmentally acceptable concentrations are greatly exceeded in almost all cases for flood-