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Rainfall contributes ~30% of the dissolved inorganic nitrogen exported from a southern Great Barrier Reef river basin

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ABSTRACT

A study was conducted to estimate how much of the annual load of dissolved inorganic nitrogen (DIN) from Great Barrier Reef (GBR) river basins could come from rainfall. Results suggest rainfall contributed ~37% of the average annual DIN load from the Fitzroy Basin over three wet seasons. Rainfall DIN contribution at plot to sub-catchment scale ranged from 5 to > 100% for study sites in the Fitzroy and Pioneer Basins. An estimate using measured and modelled data indicates ~28% of the longer-term average annual DIN load from the entire GBR catchment may originate from rainfall. These estimates may affect current GBR management and water quality targets. Numerous studies predict increases in atmospheric nitrogen pollution from Asia via fossil fuel combustion and more frequent severe La Nina events via global warming. Future GBR rainfall chemistry data may be required for assessing catchment management outcomes and regional trends in atmospheric DIN deposition.

1. Introduction

Water quality continues to be a major focus of attention in regards to Great Barrier Reef (GBR) ecosystem health with pollution from catchment runoff implicated in reef degradation (Wooldridge, 2009; Hughes et al., 2015). Current understanding of GBR water quality issues suggest that bioavailable nitrogen is a primary cause of algal blooms, chronic eutrophication and increases in the frequency of outbreaks of coral predators such as the crown-of-thorns starfish (Brodie et al., 2005; Wooldridge et al., 2006; Fabricius et al., 2010; Wooldridge and Brodie, 2015). Broader research findings suggest that primary production in the GBR lagoon is primarily nitrogen limited (Furnas et al., 2005), and that readily available forms of nitrogen exported from the GBR catchment in flood plumes are the main cause of concern (Devlin and Brodie, 2005; Brodie et al., 2011; Waterhouse et al., 2016).

Dissolved inorganic nitrogen (DIN), consisting primarily of nitrate and ammonium, is of particular interest because it is the most bioavailable form of nitrogen and is often applied as fertiliser to lands used for intensive cropping (Department of the Premier and Cabinet, 2009). Monitoring of catchment runoff at various scales has identified croplands as the primary source of high DIN concentrations. However, lower concentrations of DIN in considerable volumes are exported from the GBR catchment where cattle grazing, with limited fertiliser application, is the primary land use (Packett et al., 2009). The sources of DIN from grazing and conservation land use have remained uncertain and a need for data to fill these knowledge gaps has been identified to help inform catchment management and modelling (Waterhouse et al., 2012; Brodie et al., 2013; Dougall et al., 2014).

Numerous studies in the northern hemisphere have identified rainfall as a source of DIN due to reactive nitrogen emissions from industry, transport, and agriculture. Atmospheric wet deposition of DIN has been implicated in the eutrophication of coastal ecosystems globally. There is also a growing body of evidence of substantial increases in anthropogenic nitrogen emissions and atmospheric deposition in the south east Asian region to the north of Australia (Galloway et al., 2004; Duce et al., 2008; Gruber and Galloway, 2008; Vet et al., 2014; Keene et al., 2015; Kanakidou et al., 2016).

A review of available data for model validation found there was limited information on the chemistry of rain falling in the GBR catchment (author, unpublished) and there have been few studies regarding DIN concentration in rainfall in Queensland. Some exceptions are the rainfall studies of Brunnich (1909) and Probert (1976). Two valuable contemporary datasets are found in the broader GBR nutrient budget study of Furnas et al. (1995) conducted from 1987 to 1991 and the land use runoff study of Hunter and Walton (2008) conducted from 1991 to 1996. Apart from these studies, there is a 20 year knowledge gap concerning rainfall inputs to GBR catchment runoff loads of nutrients in general and DIN in particular. Further, there appears to very limited information on low level nutrient concentrations in rainfall for Queensland and Australia in general. Globally, limited data can be found for some southern hemisphere sites, with the bulk of rainfall chemistry information collected for the northern hemisphere (Galloway

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et al., 2004; Vet et al., 2014).

A pilot study was instigated to analyse rainfall chemistry in the Fitzroy region of the GBR catchment during the 2013–2014 wet season. Based on the results, sampling was expanded to other GBR catchment regions for the 2014–2016 wet seasons and continues. The primary objective of this study was to collect rainfall samples and estimate the potential contribution of rainfall DIN to GBR catchment runoff DIN loads. To date, the study has found that the combination of natural and anthropogenic DIN in rainfall can contribute a substantial percentage of the total average annual DIN load exported to the GBR lagoon.

2. Methods

Rainfall sample collection quality control procedures were aligned to those used in the Global Atmosphere Watch program for precipitation chemistry (Allan, 2004) and to a lesser extent the American National Atmospheric Deposition Program (Lehmann et al., 2007). Basic equipment and simple manual methods were used to reduce the likelihood of sample contamination. Sampling methods were similar to those of the China Agricultural University-organized Deposition Network (Liu et al., 2013) where open sampler containers collected rainfall on a daily basis. The main difference in methods for the current study is that sampler buckets were only employed during rainfall events. Current and historical study sites referred to in this paper are shown in Fig. 1, along with the main weather system types that cause widespread rainfall over coastal regions of northern Australia. Rain sampling for the current study took place at Emerald, Rockhampton, Mackay, Walkerston (~20 km SW of Mackay) and Cairns. Ongoing catchment study sites include Gordonstone, Brigalow Catchment Study (CS) and Victoria Plains (~26 km SW of Mackay). Runoff data from these sites were supplied by the study coordinators. Basin scale data was either collected (author - Fitzroy River) or supplied by GBR catchment study coordinators for the Fitzroy River at Rockhampton and the Pioneer River at Mackay. All other locations are historical rainfall study sites, except for the catchment runoff study location at Innisfail (Hunter and Walton, 2008).

The long-term annual weather pattern for coastal Queensland generally consists of a dry season from May to October. However, less frequently, southeast trade winds, northwest cloud-bands (from the Indian Ocean) and low pressure systems can bring substantial rainfall totals during this period. The wet season normally begins with bands of inland thunderstorms developing in the west and southwest from November onwards. These thunderstorm bands are often associated with west-to-east daily migration of the semi-persistent Inland Trough (Fig. 1). Convective thunderstorms can also develop in isolated cells during the latter part of hot summer days. Intense widespread rainfall is normally associated with the Australian monsoon trough moving south from the equator over northern Australia from late December to March (Klingaman, 2012). The majority of the average annual catchment runoff to the GBR originates from the monsoon trough and moist winds coming off the western Pacific Ocean. Tropical cyclones contribute about 10% of the average annual rainfall to the NE of Australia (Dare

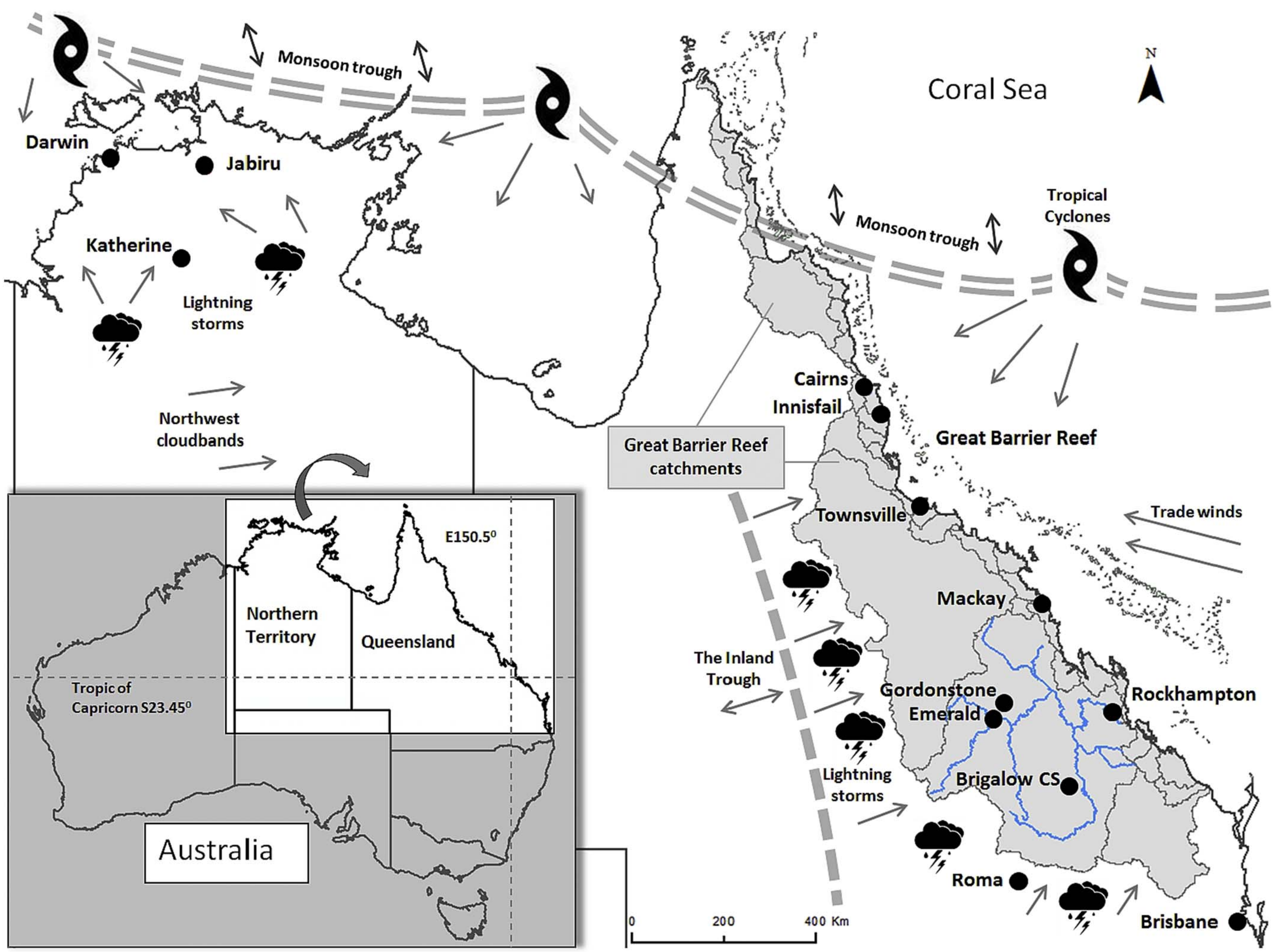

Fig. 1. Map of north eastern Australia showing rainfall collection sites for past and current rainfall studies and runoff study sites (weather patterns are adapted from Klingaman, 2012). Blue lines represent the major streams of the Fitzroy River Basin.