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Water quality variation along streams with similar agricultural development but contrasting riparian vegetation

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ABSTRACT

We measured water quality along four Australian tropical streams in two catchments with similar agricultural development (mainly sugarcane growing) but contrasting riparian vegetation (intact native rainforest vs. exotic weeds). There were strong gradients in water quality and consistent differences between streams. The most significant pattern was an increase in nitrate + nitrite (NO_x) concentration with distance downstream, reflecting the increasing discharge and proportion of fertilized agricultural land in the catchment, and indicating continuous export of contaminated groundwater along all streams. Measuring water quality along the longitudinal gradient was critical to the interpretation of the data and enabled us to confidently detect differences between streams. NO_x concentrations and loads were significantly lower in streams with greater riparian vegetation and regression analysis suggested some N-stripping in the riparian zone, albeit insufficient to meet regional water-quality guidelines. Our results demonstrate the benefit of accounting for longitudinal gradients in comparing water quality among streams and in detecting the effect of riparian vegetation at a catchment scale, but that adequate reduction in NO_x in streams can only be achieved by reduced fertilizer application rates in the catchments.

1. Introduction

Export of agricultural chemicals is of major concern worldwide because of negative impacts on aquatic ecosystems. It is of particular concern in north-eastern Australian catchments because of the juxtaposition of extensive agricultural land between the Queensland Wet Tropics World Heritage Area, within the Wet Tropics bioregion, and the Great Barrier Reef World Heritage Area (Baker et al., 2003; Rayment, 2003; Brodie et al., 2009a; Pearson et al., 2013). Run-off of sediment and nutrients from these catchments has increased several-fold as a result of the conversion of floodplains to agriculture, especially sugarcane growing (Kroon et al., 2012), with adverse effects on streams and wetlands (Tsatsaros et al., 2013) and coastal ecosystems (Brodie and Waterhouse, 2012; Brodie et al., 2012; De'ath et al., 2012). The combination of high contaminant concentrations and discharge volumes from Wet Tropics streams has resulted in the region being identified as a 'hotspot' for contaminant discharge to the Great Barrier Reef, especially for inorganic nitrogen (Brodie et al., 2009b; Kroon and Brodie, 2009; Waterhouse et al., 2012). Most soils in the Wet Tropics do not require the addition of P fertilizer (Hunter 2012), but use of nitrogenous fertilizers is ubiquitous and there is a strong correlation between the cumulative area of fertilized agriculture and nitrate concentrations in these streams (Mitchell et al., 2009), as elsewhere in the tropics (e.g. Filoso et al., 2004).

Riparian zones (i.e. stream banks and immediately contiguous land) with intact native vegetation have long been recognized for their roles in sustaining habit integrity and connectivity, biodiversity, stream bank stability and water quality (e.g. Naiman et al., 1993; Decamps et al., 2004; de Souza et al., 2013; Fernandes et al., 2014; Keir et al., 2015). In agricultural areas, riparian zones have been extensively reported to be major filters and/or processors of sediments and inorganic nutrients, particularly filterable reactive or dissolved phosphorus (FRP) and nitrate plus nitrite (NO_x) (e.g. Fail et al., 1987; Osborne and Kovacic, 1993; Hill, 1996; Goss et al., 2014). At small scales the nutrient-stripping effects of riparian zones are variable (e.g. Chestnut and McDowell, 2000; McDowell, 2001; McKergow et al., 2004a,b; Castillo, 2010; Connor et al., 2013) depending on characteristics of the riparian zone and contiguous land, including hydrology (water residence times in particular),

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soil (especially organic carbon status and reducing conditions in the sub-soil) and vegetation (Decamps et al., 2004; Fisher and Acreman, 2004; de Souza et al., 2013). On Wet Tropics floodplains, intact riparian forest comprises diverse assemblages of trees with dense canopy cover (mainly 'complex mesophyll vine forest'—Webb, 1959; Keir et al., 2015). However, many riparian areas have been cleared as a result of agricultural development, so any capacity of the riparian zone to assimilate pollutants has been reduced (Johnson et al., 1997; Furnas, 2003). However, effort has been put into riparian restoration in some Wet Tropics catchments in order to buffer agricultural impacts (Werren, 1998; Erskine, 2002).

While riparian vegetation can reduce entry of diffuse contaminants to surface waters, it is unclear how effective it is at the catchment scale as there is a lack of appropriate data (Dosskey et al., 2010). We addressed this issue in the Wet Tropics by determining the influence of riparian forest on water quality along stream gradients in representative catchments. Wet Tropics floodplains are intensively farmed, with sugarcane cultivation the major user of nitrogen fertilizers, causing significant impact on stream water quality and nutrient exports (e.g. Pearson et al., 2003; Hunter and Walton, 2008; Mitchell et al., 2009; Thorburn et al., 2011, 2013; Brodie et al., 2012). In the Mulgrave catchment, riparian forest, including vegetation along farm drains, has largely been retained and improved through replanting schemes (Werren, 1998; Mackay et al., 2010) so that these streams currently represent what may be achievable in other parts of the region with appropriate riparian rehabilitation and management. In contrast, riparian zones in the adjacent Russell catchment, like many other Wet Tropics floodplains, are highly degraded, with natural vegetation replaced by herbaceous weeds or with sugarcane grown up to the stream banks (Mackay et al., 2010). However, fertilizer application rates in these catchments are similar and representative of rates elsewhere in the region (approximately 160–170 kg N/ha—Rayment, 2003) thus providing an opportunity to compare the effect of riparian vegetation in moderating the export of fertilizer nutrients to streams. By comparing multiple sites in each study catchment, we aimed to (i) characterize and compare patterns of water quality along the stream gradient; (ii) measure the influence of riparian forest in

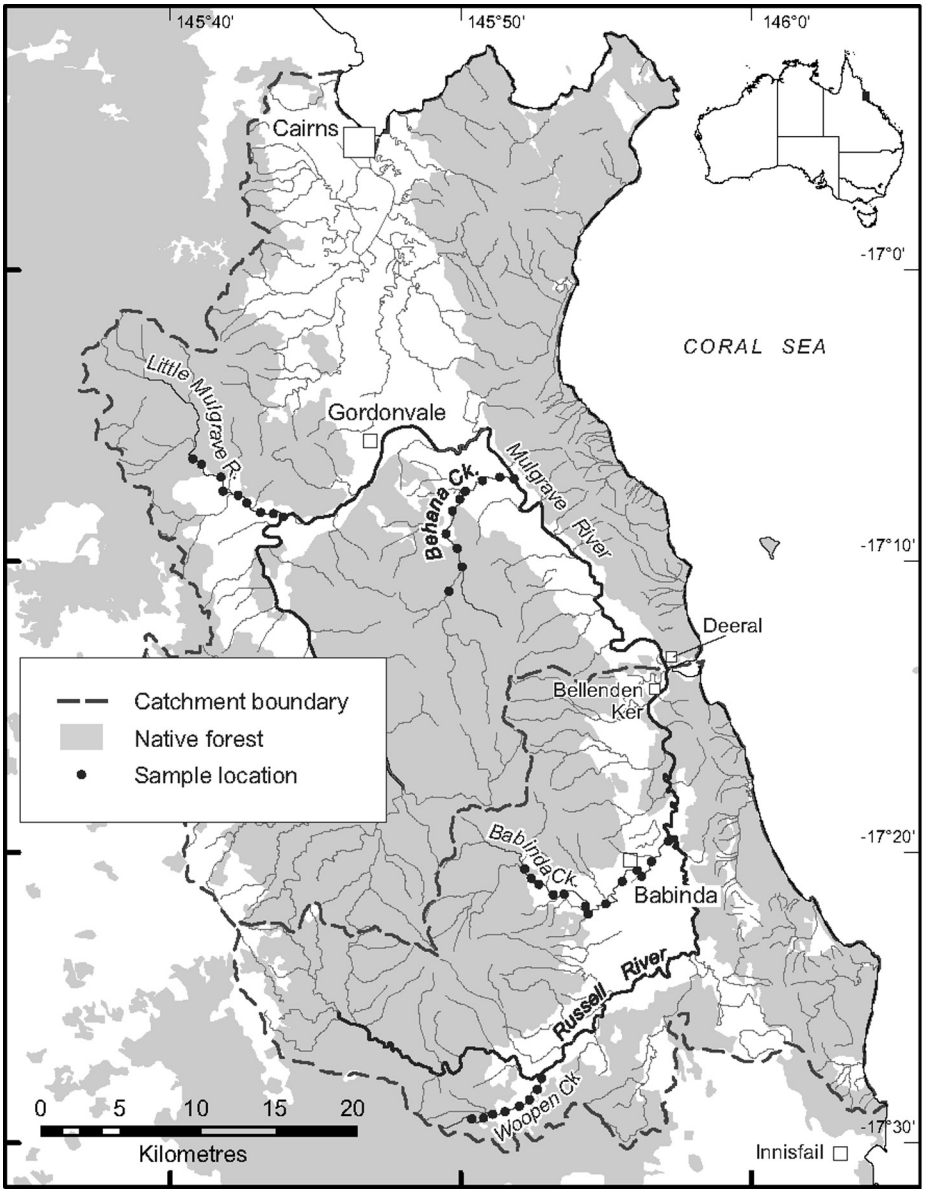

Fig. 1. Map of the central Wet Tropics bioregion showing the location of the Russell and Mulgrave catchments, the main study sites, and other places referred to in the text.