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Phyto-pigment composition in a GBR World Heritage Area affected by Fitzroy outflow

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HIGHLIGHTS

- Research undertaken in southern Great Barrier Reef World Heritage Area.
- Profound water quality changes at Capricorn Coast associated with Fitzroy River outflows.
- Phyto-pigment composition related to water quality using multivariate analyses.
- Phyto-pigments depict presence of cyanobacteria, diatoms, and green flagellates.
- DSi:DIN foremost in defining phytoplankton assemblages indicated by phyto-pigments.

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ABSTRACT

This research reports on the phyto-pigment composition (by High Performance Liquid Chromatography) within the southern Great Barrier Reef World Heritage Area at the end of a 15-year dry spell, and then during and after an intervening flood event. The study period covers the wet season of 2007–08 and involves four main estuaries of the Capricorn Coast, namely Corio Bay, Ross Creek, the Causeway Lake and Cawarral Creek. These flow into the southern Great Barrier Reef World Heritage Area (GBRWHA) and are situated about 20–60 km north of where the Fitzroy River estuary meets the sea in north eastern Australia. The four estuaries were sampled on three occasions, during the study period, while one estuary was sampled continuously on a fortnightly basis for water quality and phyto-pigment concentrations. Phyto-pigment concentrations indicated the relative presence of different phytoplankton functional groups such as diatoms (fucoxanthin), cyanobacteria (zeaxanthin) and green flagellates (chlorophyll *b*). Trends in phytoplankton assemblages were analysed using multivariate analyses, including the relationship between phyto-pigment composition and water quality. Overall, cyanobacteria were dominant in spring and summer before large river outflows stimulated diatoms, and green flagellates followed in the cooler and lower-nitrogen waters of autumn. We propose that large Fitzroy River outflows have profound biogeochemical importance for the Capricorn Coast and can cause significant phytoplankton shifts in this world heritage area. Moreover, this study provides a valuable contribution towards understanding the presence/absence of phytoplankton functional groups with extreme climate conditions in this southern GBRWHA region.

1. Introduction

The cumulative effects of industrial, agricultural and urban coastal settlement continue to threaten the world heritage status of the Great Barrier Reef World Heritage Area (GBRWHA) and, combined with rising atmospheric levels of CO_2, challenge our understanding of future implications for this significant area (Brodie et al., 2012; Jones et al., 2005; Maynard et al., 2015; Munday et al., 2015). The list of threats include contamination from industrial activities, nutrient enrichment from agricultural practices and coastal development, effects of rising CO_2 levels on fish behaviour and damage to coral reefs from bleaching, tropical cyclones, crown-of-thorns starfish outbreaks and freshwater inundation (Brodie et al., 2012; Jones et al., 2005; Maynard et al., 2015; Munday et al., 2015). There are also the effects on phytoplankton communities at the base of important marine

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food webs (Hallegraeff et al., 2012; McKinnon et al., 2007; O'Neil et al., 2012). Evidence suggests a higher frequency and magnitude of cyanobacterial blooms with future nutrient enrichment and climate change, as well as declines in diatom populations in areas with depleting silicate supply (Hallegraeff et al., 2012; O'Neil et al., 2012). These effects have implications for marine food webs, including those of the GBRWHA where diatoms form the base of highly productive food webs in contrast to those with the cyanobacterium, *Trichodesmium*, as the base (McKinnon et al., 2007). Much research is needed in this area to better understand typical phytoplankton communities and how they may change with future environmental scenarios (Devlin et al., 2013b).

Currently, a combination of in-situ monitoring, remote sensing and modelling of chlorophyll *a* provide the phytoplankton biomass knowledge for the GBRWHA (Brodie et al., 2007; Schaffelke et al., 2012; Schroeder et al., 2012), and various past field studies provide an understanding of GBRWHA phytoplankton communities (Alongi et al., 2015; Devlin et al., 2013b; Furnas et al., 2005; Revelante et al., 1982). Such studies have identified *Synechococcus* spp. and *Prochlorococcus* spp. as the dominating taxa in the phytoplankton biomass and primary production of the GBR waters, and diatoms as being prominent in populations closer to shore in more turbid waters (Furnas et al., 2005). However, this knowledge almost entirely stems from studies of northern and central sections of the GBRWHA. Alongi et al. (2015) examined the southern section to just north of 21°30′ S, but there is a dearth of published information about phytoplankton groups and related environmental conditions from this point south within this world heritage area.

The GBRWHA extends from 10° S to 24° S along the coast of NE Australia and includes the GBR lagoon and adjacent estuarine waters and shorelines to high water mark (UNESCO, 2015). The southern section contains the Fitzroy management area (Schroeder et al., 2012). Our focus is on this southern GBRWHA section between latitudes 22°50′ S and 23°30′ S (Fig. 1). Existing knowledge of phytoplankton communities in this particular area pertains to two brief dry-season field campaigns and cruises of the Australian coast that describe diatom prevalence in relation to the turbid Fitzroy estuary (Oubelkheir et al., 2006; Thompson et al., 2011). Notably, no past reports describe such for this area in terms of the 'wet' season, which involves the Austral spring and summer, and the peak growing period for phytoplankton in this area, based on long-term chlorophyll *a* monitoring (Schaffelke et al., 2012). Obtaining suitable wet season data in such areas is challenging given the sporadic nature of wet season events that typically require spontaneous coordination of sampling resources (Saeck et al., 2013).

The Fitzroy Section of the GBRWHA is infrequently affected by large flows from the Fitzroy River, which has a drainage system of over 140 000 km^2, and accounts for more than a third of the GBRWHA catchment area (Packett et al., 2009). High-volume outflows from this river affect adjacent coral reefs during sporadic wet season events, with little to no effect otherwise, when river flow is mostly $<1\ m^3\ s^{-1}$ (Radke et al., 2010). Webster et al. (2005) identified the Fitzroy River estuary as an immense nutrient source in flood time and a nutrient sink during dry spells. During the flood times, its low salinity plumes, laden with nutrients, extend hundreds of kilometres offshore (Devlin et al., 2012; Radke et al., 2010).

Our study examines water quality and phytoplankton composition along the Capricorn Coast, which is situated to the north of where the Fitzroy River estuary meets the sea (Fig. 1). We use diagnostic phyto-pigments to characterise phytoplankton composition, similar to those used elsewhere in both tropical and temperate studies, including in other areas of Australian Pacific waters (Barlow et al., 2007; Dandonneau and Niang, 2007; Thompson et al., 2011). The diagnostic pigment approach has advantages over microscopy in that it can quantify the diminutive phytoplankton that have few discernible features for successful microscopic identification (Thompson et al., 2011). The study covers the wet season of 2007–08 and captures the effects of major flooding that followed almost two decades of extreme dry conditions (Kennard et al., 2009) and thus, reports on water quality and phytoplankton groups during alternating climate extremes, making it a valuable contribution in understanding phytoplankton functional groups with changing environments in this southern GBRWHA section.

2. Materials and methods

2.1. The study area

The Capricorn Coast has a population of about 20 000, which is forecast to double by 2040 (Queensland Government Statistician's Office, 2015). Low mountain ranges border the west, a shallow Keppel Bay (<20 m deep) the east, while Shoalwater Bay sits to the north and the Fitzroy River estuary to the south. The four main estuaries of the Capricorn Coast: Corio Bay, Ross Creek, the Causeway Lake and Cawarral Creek, are situated within 40 km between latitudes 22°50′ S and 23°20′ S, at about longitude 150°45′ E (Fig. 1), within the southern GBRWHA, and form the basis of this study. In order from north to south, Corio Bay has a catchment $> 500\ km^2$, Ross Creek $< 15\ km^2$, Causeway Lake 35 km^2 and Cawarral Creek about 200 km^2 (Coastal Zone Australia Ltd, 2006; Logan, 1988). The most southern, Cawarral Creek, is located about 20 km north of the Fitzroy River estuary.

This is a macrotidal zone (tidal range > 4 m) with semi-diurnal tides. All estuaries are shallow (<5 m depth at sampling sites) and tide-dominated, with sand flats and gullies exposed at low tides. The exception is the Causeway Lake, which has a causeway sill and seawall that maintains a shallow estuarine lake with tidal exchange restricted to a few days per month on average. Only Corio Bay has perennial freshwater inflow, fed by large dunal aquifers.

The Capricorn Coast has a small coastal catchment, separate and remote to that of the adjacent large Fitzroy River. Average annual freshwater flow to date for the largest of the study estuaries, Corio Bay, is approximately 0.13 million ML, from 50 years of data at Waterpark Creek, Byfield. This compares to the average annual flow of about 6.16 million megalitres (ML) for the Fitzroy River at the Gap over the same period (The State of Queensland, 2015). Total monthly flows emanating from the Fitzroy during the wet season 2007–08 of this study were greater than any recorded since 1991 for the Fitzroy, which typically displays strong intra- and inter-decadal flow variations (Fig. 2). The Fitzroy catchment is predominantly agricultural in land use, while the study area entails urban and small rural lots, forestry and horticulture.

2.2. Sampling

The study examined the estuarine sections with oceanic salinities, as ascertained from longitudinal depth profiling during dry-season reconnaissance surveys, with sampling points chosen from grids over these sections. The four estuaries were sampled, over three consecutive days, when weather permitted, during the lunar phase of spring tides in November 2007 (spring), February 2008 (summer) and May 2008 (autumn), as specified in Table 1. In addition to 3-monthly sampling, continuous fortnightly measurements were taken at Ross Creek from late October 2007 to mid-May 2008 (Section 2.3).