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# Suspended sediment grain size and mineralogy across the continental shelf of the Great Barrier Reef: Impacts on the physiology of a coral reef sponge

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ABSTRACT

Declining water quality associated with increased suspended sediments has been closely linked to the reduced health status of benthic marine ecosystems and their associated organisms, including marine sponges. The mechanisms driving the impacts of elevated suspended sediments on marine sponges are poorly investigated. This study elucidates spatial and temporal variations in sediment size and mineralogy of inorganic suspended sediments within sponge habitats (reef environments) across the continental shelf of the central Great Barrier Reef (GBR), North-eastern Australia. Inshore sponge habitats were dominated ( $>80\%$) by fine-grained suspended sediments consisting of both terrigenous (clay and quartz) and biogenic material (carbonates) with grain sizes $<100$ µm. In contrast, mid- and outer-shelf sponge habitats were dominated by carbonate material with grain sizes $>100$ µm. The abundance and distribution of the common coral reef sponge *Rhopaloeides odorabile* across the GBR shelf shows a clear correlation between habitat and the distinct patterns in suspended sediment size and mineralogy. Experimental exposure of *R. odorabile* to clay and carbonate sediments in this study provides the first evidence that the metabolic demand (respiration) of coral reef sponges increases (up to 40%) in response to fine terrigenous (clay) sediments. This physiological response supports sediment load, size, and mineralogy as key factors affecting the distribution and abundance patterns of *R. odorabile* across the continental shelf of the central GBR.



## 1. Introduction

The global health of coral reef habitats is declining as a result of changes in water quality due to increased anthropogenic disturbances to coastal marine systems (reviewed in Lough, 2008). Changes to suspended sediment loads and increased frequency of sedimentation events are a large contributor to declining water quality in coastal marine systems (McCulloch et al., 2003; Fettweis et al., 2010), which can have a negative impact on benthic biota (Balata et al., 2005; Fabricius, 2005; Connell, 2005; Carballo, 2006).

In coral reef habitats, exposure to excessive levels of suspended and deposited sediments can reduce coral cover, biodiversity, recruitment, reproduction and fertilisation and change the overall community structure (reviewed in Fabricius, 2005; Humphrey et al., 2008). These changes are driven by physiological responses of corals to smothering, and the physio-chemical properties of suspended sediments (reviewed in Fabricius, 2005; Weber et al., 2006). Most of these findings rely on short-term (few months to few decades) experimental or observational studies. Conversely, evidence from palaeoecological studies of sediment and fringing reef cores suggest that inner-shelf coral reef communities of the GBR have been adapting to turbid and muddy environments for thousands of years (Johnson and Risk, 1987; Smithers and Larcombe, 2003; Perry et al., 2008).

In contrast to the increasingly rigorous examination of the effects of sediments and other human induced changes on corals (reviewed in Lough, 2008), the effects of sediments on the physiology and resultant ecology of coral reef sponges has received much less attention. This is surprising, given that sponges form an integral component of benthic systems (reviewed in Bell, 2008), inhabiting both high and low sedimented areas (Wilkinson and Cheshire, 1989; Wilkinson and Evans, 1989; Bell and Barnes, 2000a, 2000b). However, living in high sedimented areas may be sub-optimal for some sponges with clear evidence suggesting that elevated suspended sediments and increased frequency of sedimentation events negatively impact marine sponges (Gerrodette and Flechsig, 1979; Carballo, 2006, Tompkins-Macdonald and Leys, 2008).

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Increased levels of sedimentation can influence sponge morphologies (Maldonado and Uriz, 1999; McDonald et al., 2002; Bell, 2004) and the structure, abundance and diversity of sponge assemblages (Zea, 1994; Bell and Barnes, 2000a, 2000b; Carballo, 2006). In addition, exposure to higher rates of sedimentation can reduce growth rates (Roberts et al., 2006), impede reproduction (Roberts et al., 2006; Whalan et al., 2007) and reduce the survival of sponges (Maldonado et al., 2008). In extreme cases, high concentrations of fine-suspended sediments induce prolonged reductions in pumping activity of sponges, due to the clogging of sponge inhalant canals and filtering apparatus (Gerrodette and Flechsig, 1979; Tompkins-MacDonald and Leys, 2008). Despite such evidence, the energetic constraints of living in these sub-optimal habitats have yet to be determined. Furthermore, it remains unclear whether the impacts described above are related to suspended sediment grain size or mineralogy, or primarily a function of sediment deposition rates or elevated suspended sediment concentrations.

With recent evidence that coral reef sponge populations are changing over longer-term time scales (Bannister et al., 2010), there is increasing interest in understanding the potential drivers of these changes. Therefore, this paper aims to elucidate spatial and temporal variations in deposition rates, size and mineralogical composition of inorganic suspended sediments associated with known sponge habitats across the continental shelf of the central Great Barrier Reef (GBR). Furthermore, this paper demonstrates experimentally the effects of sediments representative of inshore and offshore mineralogical composition on the energetics of *Rhopaloeides odorabile* and linking responses to known active and passive mechanisms initiated by sponges to cope with environmental stress.

## 2. Materials and methods

### 2.1. Study sites

Suspended sediment grain sizes and mineralogy within sponge habitats across the central GBR, were sampled along an east–west cross shelf transect at an inner-shelf reef (Pelorus Island, 18°33′S, 146°29′E), a mid-shelf reef (Rib Reef, 18°29′S, 146°52′E) and an outer-shelf reef (Pith Reef, 18°11′S, 146°29′E) (Fig. 1). These reefs span a entire environmental gradient present across the GBR shelf (Devlin and Brodie, 2005) and are common habitats for the sponge *R. odorabile* and more than 90 other identified coral reef sponge species (Wilkinson and Cheshire, 1989; Wilkinson and Evans, 1989; Bannister et al., 2010). Sediment traps (5 cm wide and 15 cm height) were deployed at two replicate sites (separated by 150 m) of similar habitat structure at each reef. Sites were located on the southeast exposed side of each reef, proximal to the major southeast trade winds and wave inputs. These locations were chosen as previous studies have identified high numbers of *R. odorabile* in high-energy environments (Wilkinson and Cheshire, 1989; Wilkinson and Evans, 1989; Bannister et al., 2007, 2010).

### 2.2. Sediment collection, storage and preparation

Suspended sediments were collected during the Austral winter (tropical dry season) 2005 and Austral summer (tropical wet season) 2005/06 in three replicate sediment traps, at each site, at a depth of 10 m on the fore-reef slope of each reef using a structured hierarchical sampling design. Replicate sediment traps were mounted to individual star pickets elevated 1 m above the benthos and separated by 1 m. Sediment traps remained for three successive 30 d intervals during winter (July, August and September) and summer (December, January and February). Each sediment trap had a trapping area of 19.63 cm$^2$ and a height to width aspect ratio of 3:1 to prevent sediment re-suspension within traps (Butman 1986).

Sediment samples were stored at 4 °C until processed. Due to the length of time the sediments remained within the sediment traps (up to 30 d), the organic fractions present in the samples may be at different stages of decomposition. Therefore, to obtain accurate measurements of inorganic sediment grain size and mineralogical composition, the organic fractions of each sample were removed using a treatment of 30% hydrogen peroxide ($H_2O_2$) prior to sediment characterisation following methods described by Jackson (1985).

### 2.3. Sediment particle size

Sediment grain size distributions ($n = 108$) were analysed with a Malvern Mastersizer 2000 laser particle sizer using a

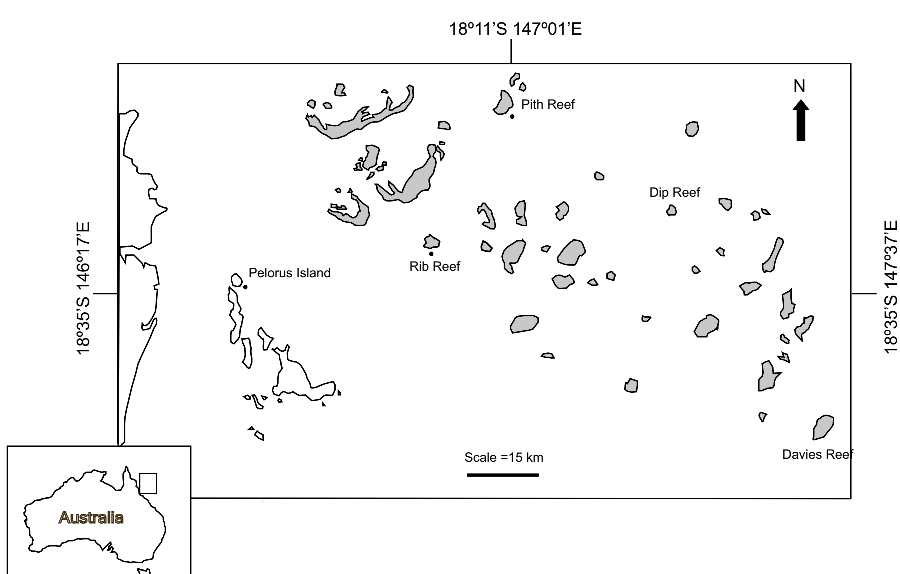


**Fig. 1.** Map of reefs sampled across inner-, mid-, and outer-shelf locations on the central GBR, Australia. Small black circles indicated the reefs sampled. White objects represent land and grey objects represent reef complexes.