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Coral skeletal geochemistry as a monitor of inshore water quality

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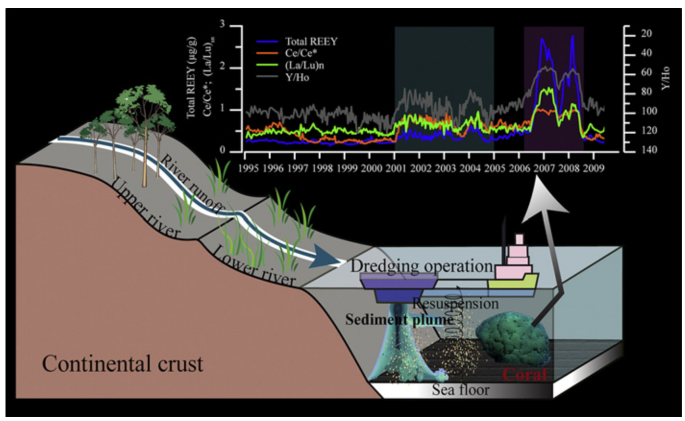
HIGHLIGHTS

- Coral skeleton is an excellent archive of metal proxies to monitor water quality.
- Uncertainty remains regarding complex cycling and control mechanisms of proxies.
- Water quality reconstruction is hindered by vital effects and diagenesis.
- Identification and elimination of external factors is the major challenge.
- Rare earth elements have great promise for water quality monitoring.

GRAPHICAL ABSTRACT



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ABSTRACT

Coral reefs maintain extraordinary biodiversity and provide protection from tsunamis and storm surge, but inshore coral reef health is degrading in many regions due to deteriorating water quality. Deconvolving natural and anthropogenic changes to water quality is hampered by the lack of long term, dated water quality data but such records are required for forward modelling of reef health to aid their management. Reef corals provide an excellent archive of high resolution geochemical (trace element) proxies that can span hundreds of years and potentially provide records used through the Holocene. Hence, geochemical proxies in corals hold great promise for understanding changes in ancient water quality that can inform broader oceanographic and climatic changes in a given region. This article reviews and highlights the use of coral-based trace metal archives, including metal transported from rivers to the ocean, incorporation of trace metals into coral skeletons and the current 'state of the art' in utilizing coral trace metal proxies as tools for monitoring various types of local and regional source-specific pollution (river discharge, land use changes, dredging and dumping, mining, oil spills, antifouling paints, atmospheric sources, sewage). The three most commonly used coral trace element proxies (i.e., Ba/Ca, Mn/Ca, and Y/Ca) are closely associated with river runoff in the Great Barrier Reef, but considerable uncertainty remains regarding their complex biogeochemical cycling and controlling mechanisms. However, coral-based water quality reconstructions have suffered from a lack of understanding of so-called vital effects and early marine diagenesis. The main challenge is to identify and eliminate the influence of extraneous local factors in order to allow accurate water quality reconstructions and to develop alternate proxies to monitor water pollution. Rare earth elements have great potential as they are self-referencing and reflect basic terrestrial input.

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Contents

1. Introduction

Anthropogenic deterioration of inshore water quality is a worldwide concern owing to its adverse effects on marine organisms and ecosystems. Offshore coral reefs face threats from a variety of changing global parameters, such as CO_2-induced rising sea surface temperature (SST) with associated coral bleaching and ocean acidification. Inshore coral reef ecosystems also face those threats, but commonly are impacted to a greater degree by local anthropogenic changes in water quality, including increased turbidity causing sedimentation and shading, increased nutrient loads, and contamination by agri-chemicals and industrial toxins and metals (Brodie, 2014; Brodie et al., 2012; Brodie and Waterhouse, 2012; Brodie et al., 2013; Cortés and Risk, 1985; D'Olivo et al., 2015; De'ath and Fabricius, 2010; Erftemeijer et al., 2012; Gardner et al., 2003; Hughes, 1994; Hughes et al., 2003; Pandolfi et al., 2003; Weber et al., 2012). The growth and health of inshore coral reefs are essential not only to provide habitats to maintain their incredibly high biodiversity, but reefs also offer many other ecosystem services, including serving as physical barriers against destructive storm surge and tsunamis (Spalding et al., 2014).

As a consequence of coastal water pollution associated with rapid land use changes and coastal development over the last two centuries, the coverage (De'ath et al., 2012; Sweatman et al., 2011) and biodiversity (De'ath and Fabricius, 2010) of marine calcifiers, such as corals, and their rates of growth and $CaCO_3$ production have decreased significantly (D'Olivo et al., 2013; Sowa et al., 2014). At the same time, their physical breakdown and export as sediment has grown exponentially (Erftemeijer et al., 2012). Consequently, even though many inshore coral communities are adapted to high degrees of natural turbidity and stochastic turbidity events (Anthony and Larcombe, 2002; Hennige et al., 2010; Perry et al., 2012; Roff et al., 2015), they are the most proximal reef communities to many anthropogenic developments (e.g., agriculture, ports) and concerns have been raised that the accelerating rate of decline in water quality could exceed the adaptive capacity of inshore coral communities, thus disrupting these ecosystems and their dependents (Brodie et al., 2012; Brodie and Waterhouse, 2012; Grech et al., 2013; Hoegh-Guldberg et al., 2007; Wooldridge, 2009).

Anticipation of the effects of future environmental changes in coastal water quality depends on our understanding of what has happened in the geological past and what is happening currently. Instrumental