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Biogeochemical response of tropical coastal systems to present and past environmental change

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ABSTRACT

Global climate and environmental change affect the biogeochemistry and ecology of aquatic systems mostly due to a combination of natural and anthropogenic factors. The latter became more and more important during the past few thousand years and particularly during the 'Anthropocene'. However, although they are considered important in this respect as yet much less is known from tropical than from high latitude coasts. Tropical coasts receive the majority of river inputs into the ocean, they harbor a variety of diverse ecosystems and a majority of the population lives there and economically depends on their natural resources. This review delineates the biogeochemical response of coastal systems to environmental change and the interplay of natural and anthropogenic control factors nowadays and in the recent geological past with an emphasis on tropical regions. Weathering rates are higher in low than in high latitude regions with a maximum in the SE Asia/Western Pacific region. On a global scale the net effect of increasing erosion due to deforestation and sediment retention behind dams is a reduced sediment input into the oceans during the Anthropocene. However, an increase was observed in the SE Asia/Western Pacific region. Nitrogen and phosphorus inputs into the ocean have trebled between the 1970s and 1990s due to human activities. As a consequence of increased nutrient inputs and a change in the nutrient mix excessive algal blooms and changes in the phytoplankton community composition towards non-biomineralizing species have been observed in many regions. This has implications for foodwebs and biogeochemical cycles of coastal seas including the release of greenhouse gases. Examples from tropical coasts with high population density and extensive agriculture, however, display deviations from temperate and subtropical regions in this respect. According to instrumental records and observations the present-day biogeochemical and ecological response to environmental change appears to be on the order of decades. A sediment record from the Brazilian continental margin spanning the past 85,000 years, however, depicts that the ecosystem response to changes in climate and hydrology can be on the order of 1000–2000 years. The coastal ocean carbon cycle is very sensitive to Anthropocene changes in land-derived carbon and nutrient fluxes and increasing atmospheric carbon dioxide. As opposing trends in high latitude regions tropical coastal seas display increasing organic matter inputs and reduced calcification rates which have important implications for calcifying organisms and the carbon source or sink function of the coastal ocean. Particularly coral reefs which are thriving in warm tropical waters are suffering from ocean acidification. Nevertheless, they are not affected uniformly and the sensitivity to ocean acidification may vary largely among coral reefs. Therefore, the prediction of future scenarios requires an improved understanding of present and past responses to environmental change with particular emphasis put on tropical regions.

Contents

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1. Introduction

Throughout the major part of its 4.6-billion-year history element cycles on earth have been driven mainly by solar radiation and the water and rock cycles which are natural control factors (e.g. Degens, 1989; Berner and Berner, 1996). The development of life about 3.8 billion years ago added another factor affecting element cycles. Humans started to shape their environment earliest approx. 2.5 million years ago as shown by fossil evidence of primitive tools. Man's influence grew with growing population and developing technology (Goudie, 2006 and references therein) which culminated in the activities during the so-called 'Anthropocene', the period starting with the beginning of industrialization in the late 18th century (e.g. Crutzen and Stoermer, 2000). Coastal zones are of prime importance in this respect, because they offer living space and goods and services to humans and rich habitats to organisms. Consequently, they are among the most-densely populated regions of the world. This, in turn, makes them particularly vulnerable to environmental and ecological changes especially in tropical regions (Fig. 1). Tropical coastal zones receive major part of the annual river inputs of freshwater and dissolved and particulate substances (Fig. 2; e.g. Fekete et al., 2002; Smith et al., 2003; Syvitski et al., 2005; Milliman and Farnsworth, 2011) and they harbor some of the most productive and diverse ecosystems on earth like coral reefs, sea grasses and mangroves (Fig. 3; Groombridge and Jenkins, 2002). The rate of population increase in coastal zones is higher than for the whole world and more than 50% of the coastal countries have 80–100% of their population living within 100 km of the coast (Martinez et al., 2007). The intensity of human uses has led to severe environmental degradation in coastal zones which is of particular importance in the tropics (Burke et al., 2001). Sea level rise as a consequence of climate change poses an additional threat to the coasts. In the past years tropical coastal ecosystems came into focus because of their importance for ecology and economy on the one hand and their vulnerability to environmental change on the other hand.

Climate oscillations of the Quaternary were driven by earth's orbital parameters, the natural factors which are determining the earth's movement around the sun. The Pleistocene was characterized by major climate oscillations culminating in the Last Glacial Maximum about 20,000 years ago. At that time temperatures dropped by up to 15 °C in Polar Regions and by 5–8 °C in low latitudes. A large volume of water was bound in glaciers and consequently sea level was lower by about 120 m than today. Concurrent with the temperature drop the level of atmospheric carbon dioxide (CO_2) was lower by 80–100 ppm (e.g. Bradley, 1999). The recent geological epoch, the Holocene, which started about 12,000 years ago, is the most stable

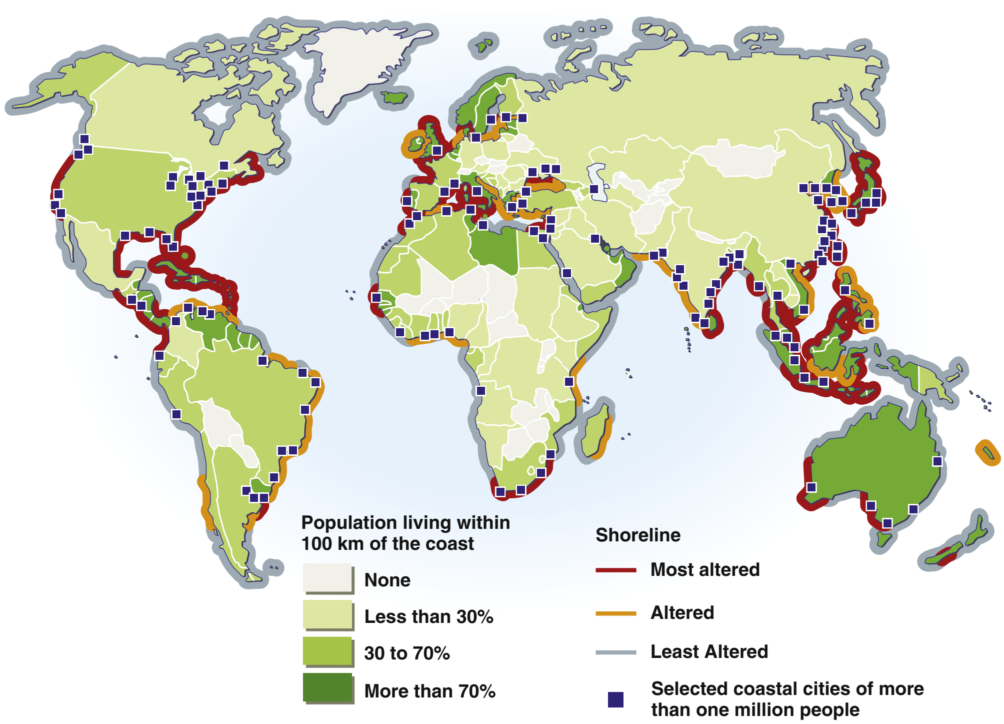

Fig. 1. Global distribution of population living within 100 km of the coast and degree of shoreline degradation. Sources: Burke et al. (2001) and Harrison and Pearce (2001).