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Major threats of pollution and climate change to global coastal ecosystems and enhanced management for sustainability

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ABSTRACT

Coastal zone is of great importance in the provision of various valuable ecosystem services. However, it is also sensitive and vulnerable to environmental changes due to high human populations and interactions between the land and ocean. Major threats of pollution from over enrichment of nutrients, increasing metals and persistent organic pollutants (POPs), and climate change have led to severe ecological degradation in the coastal zone, while few studies have focused on the combined impacts of pollution and climate change on the coastal ecosystems at the global level. A global overview of nutrients, metals, POPs, and major environmental changes due to climate change and their impacts on coastal ecosystems was carried out in this study. Coasts of the Eastern Atlantic and Western Pacific were hotspots of concentrations of several pollutants, and mostly affected by warming climate. These hotspots shared the same features of large populations, heavy industry and (semi-) closed sea. Estimation of coastal ocean capital, integrated management of land-ocean interaction in the coastal zone, enhancement of integrated global observation system, and coastal ecosystem-based management can play effective roles in promoting sustainable management of coastal marine ecosystems. Enhanced management from the perspective of mitigating pollution and climate change was proposed.

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1. Introduction

Coastal zone is the interface between the land and sea, and represents one of the most important areas of the world oceans from a human perspective. Coastal marine ecosystems, which

include estuaries, sea grass beds, salt marshes, tidal flats, mangroves, coral reefs and shelves, provide various beneficial services such as nutrient cycling, detoxification of pollutants, food production, raw materials and habitats, regulation of storm-induced disturbances, as well as recreational and entertainment activities (Costanza et al., 1997). Coastal and marine ecosystems provide about 2×10^{10} kg of demersal fish and 8×10^9 kg of pelagic fish, which occupied 28% of the global fish production in 2013 (FAO, 2013; Christensen et al., 2014). Coral reefs are estimated to be habitats for 830,000 species globally (Fisher et al., 2015). Salt

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marshes, mangroves and seagrasses store more carbon than the whole terrestrial ecosystem.

As the site of land and ocean interactions, coastal zone also acts as buffer zone between land and ocean. It protects uplands from storms and flooding and serves as filters removing pollutants and other land-derived materials before entering the ocean (Ferreira et al., 2017). Because of the enormous value provided, coastal zone is among the most densely populated regions of the world. Dense population and frequent exchange of material and energy in the coastal zone will in turn make it particularly sensitive and vulnerable to both natural and anthropogenic changes. Thus, land-based human activities, climate change and extreme events have led to severe environmental degradation in the coastal zone. They continue to pose an increasing threat to the coastal ecosystems. Major coastal marine ecosystem challenges are present worldwide, such as coral reef degradation, coastal eutrophication, coastal hypoxic, reclamation of coastal wetland, increasing heavy metals and emerging pollutants due to coastal exploitation (Halpern et al., 2008; Doney, 2010; Hoegh-Guldberg and Bruno, 2010; Jennerjahn, 2012; Statham, 2012; Halpern et al., 2015).

In order to “conserve and sustainably use the oceans, seas and marine resources” as stipulated by one of the United Nations Sustainable Development Goals since 2015 (ICSU and ISSC, 2015), a better understanding of the status quo and major threats to the coastal marine ecosystem including the impacts of land-based human activities and climate change is needed at several levels. Most studies addressing these issues have focused on nutrients or traditional pollutants on a regional or national scale. However, a global overview of major pollution issues caused by excess nutrients, metals and persistent organic pollutants, and major challenges due to climate change (Fig. 1) has not been conducted but is important to achieve the sustainable management of coastal zone.

2. Major problems and challenges in the coastal zone

2.1. Over enrichment of nutrients

2.1.1. Excess nutrient input and spatial distribution

Eutrophication caused by excessive land-based nutrient inputs has affected many areas in the coastal zone. Based on the latest global coastal data of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) concentrations available from literature (Table S1), East Asia and Western Europe are identified as hotspots of nutrient pollution while it is less severe in eastern North America (Fig. 2). In China, nutrients pollution in coastline mainly concentrates on Liaodong Bay, Bohai Bay, Yangtze Estuary, Hangzhou Bay and Pearl River Estuary (Liu et al., 2011; Wang et al., 2012; Stokal et al., 2014; Zhang, 2016). Nutrients over-enrichment also poses a serious threat to many coastal bays such as the Gulf of Mexico, North Sea and the Baltic Sea (Carstensen et al., 2014; O'Higgins and Gilbert, 2014; Rabotyagov et al., 2014; de Mutsert et al., 2016). The highest concentrations of DIN and DIP in the coastal surface water are 260 μM at Hangzhou Bay in China and 5 μM at Helgoland in Germany, respectively (Wiltshire et al., 2015; Zhang et al., 2015). Coasts along China, Western Europe and eastern North America have been seriously influenced by red tides and other ecological catastrophic events associated with eutrophication (Selman et al., 2008; Erisman et al., 2013). There is still paucity of coastal water quality data from Africa, Latin America and the Caribbean (Selman et al., 2008).

2.1.2. Sources and drivers of nutrients

Overall, agricultural runoff is the largest source of nitrogen pollution to many coastal ecosystems (Duce et al., 2008; Howarth, 2008; Hale et al., 2015). In addition, deforestation, human waste and aquaculture waste have also driven nutrient transported into

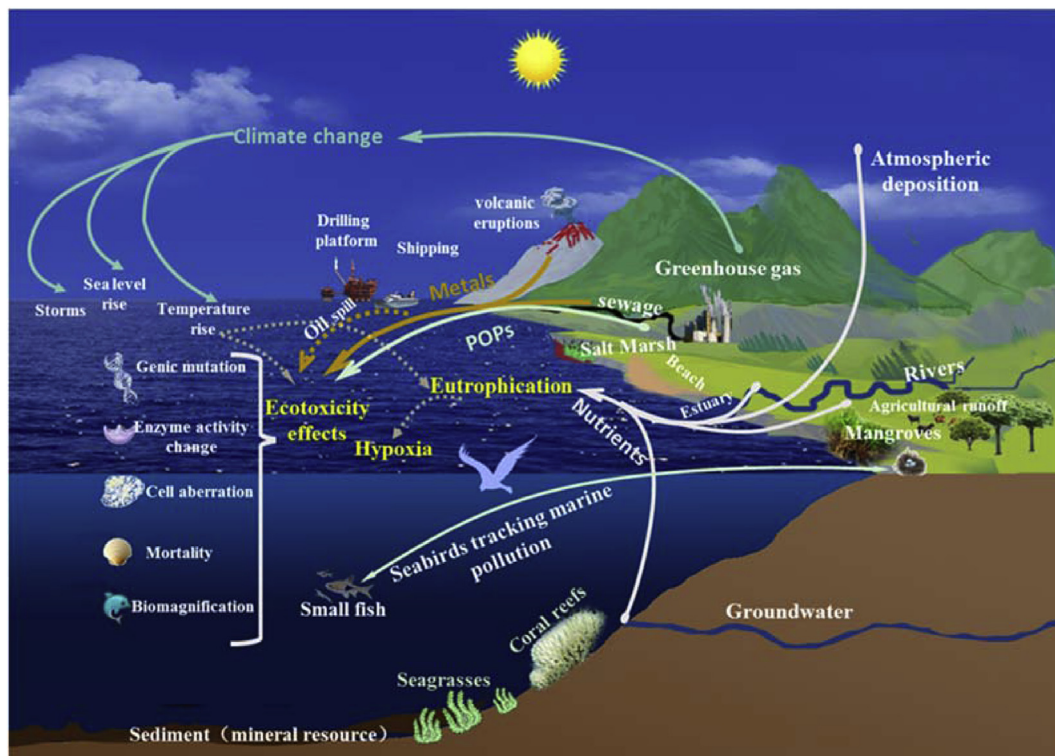


Fig. 1. Conceptual map of major challenges in the coastal zone.

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