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Viewpoint

Oyster reef restoration in controlling coastal pollution around India: A viewpoint

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ABSTRACT

Coastal waters receive large amounts of nutrients and pollutants from different point and nonpoint sources through bays and estuaries. Excess supply of nutrients in coastal waters may have detrimental effects, leading to hypoxia and anoxia from eutrophication. Reduction in concentrations of excess nutrients/pollutants in bays/estuarine system is must for healthy coastal ecosystem functioning. Conservations of bays, estuaries and coastal zones are must for sustainable development in any maritime country. Excellent ability of oyster in removing and controlling the concentrations of nutrients, pollutants, suspended particulate matters from bays and estuarine waters stimulated me to provide a viewpoint on oyster reef restoration in controlling nutrient/heavy metals fluxes and marine coastal pollution around India. Oyster reefs restoration may decrease nutrient and heavy metals fluxes in coastal waters and reduce the intensity of oxygen depletion in the coastal Arabian Sea (seasonal) and Bay of Bengal. However, extensive research is recommended to understand the impact of oyster reef restoration in controlling coastal pollution which is essential for sustainable development around India.

1. Introduction

Coastal zones of India are experiencing rapid development (Gallup et al., 1999; Sachs et al., 2002). Conservation of bays, estuaries and coastal zones around India is must for sustainable development. The effects of anthropogenic activities, industrialization and urbanization on heavy metals and nutrients fluxes in marine coastal environment around India are not well known and can be matter of big concern (Chakraborty et al., 2014a, 2014b).

In general, coastal waters receive large amounts of nutrients/trace metals/heavy metals/polyaromatic hydrocarbon etc. from different point and nonpoint sources. In particular, estuaries/bays receive more nutrients/trace metals/heavy metals/polyaromatic hydrocarbons (PAH) inputs per unit surface area than any other type of ecosystem. Excess supply of nutrients can be highly damaging, leading to effects such as hypoxia and anoxia from eutrophication, harmful algal blooms, die-back of seagrasses and corals, and reduced populations of fish and shellfish in coastal waters (https://www.nap.edu/read/2049/chapter/9; Zimmerman and Canuel, 2000). Trace/heavy metals have also been reported to act as toxicant at elevated level (Chakraborty et al., 2010). Thus, it is necessary to control nutrients/trace metals/heavy metals fluxes in coastal waters.

Excellent ability of oysters in removing and controlling the concentrations of nutrients, pollutants, suspended particulate matters from bays and estuaries (Jones et al., 2001; Cerco and Noel, 2007; Epifanio and Srna, 1975; Lane et al., 2003; Meyer and Townsend, 2000) stimulated me to provide a viewpoint on oyster reef restoration in controlling marine coastal pollution around India. The diverse geology of adjacent land, the long coastline (~7000 km), climatic variability, different oceanographic settings, different agricultural and anthropogenic activities along the coastline of India make it extremely difficult to predict distribution patterns and fluxes of nutrients and pollutants in coastal and estuarine systems. The vast coastlines of India were divided into two regions (i) east coast and (ii) west coast of India. There are marked oceanographic differences between the east and west coasts of India (Murthy et al., 2008). Part of western Bay of Bengal (BoB) (bordering the east coast of India) receives huge freshwater discharges from the Indian rivers compared to the eastern Arabian Sea (bordering the west coast of India) (Kumar et al., 2002). BoB has already been reported as less productive zone than Arabian Sea due to its stratified surface layer (Kumar et al., 2002). The recent studies have pointed out that anthropogenic forcing (high nutrient supply, eutrophication and climate change) may enhance the intensity of oxygen depletion in the western Shelf of BoB (Sarma et al., 2013). It has been reported that removal of traces of oxygen (10 to 200 nM range) from BoB may increase nitrogen loss from OMZ of Bay of Bengal and could accelerate to global significance (Bristow et al., 2016). Increase in nutrients supply from anthropogenic sources may further deteriorate the environment.

However, prolific monsoon-driven upwelling system is found along India's west coast (Shetye et al., 1991). The presence of perennial oxygen minimum zone and development of seasonal oxygen depletion (during July–October) in the coastal areas of the Arabian Sea makes west coast completely different from the east coast of India (Naqvi et al., 2006). Primary production in the Arabian Sea has been reported to be controlled primarily by the availability of nitrate

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(NO^{-}_{3}) (Sen Gupta and Naqvi, 1984; Naqvi et al., 2003), as concentrations of iron (Fe), the principal micronutrient, have been found to be above levels that limit primary productivity (in the west coast of India) (Measures and Vink, 1999). However, off Oman coast has been reported to be Fe limiting (Moffett et al., 2015).

There are good numbers of studies that have rigorously reported about the distributions and speciation of nutrients/trace and heavy metals in coastal and estuarine water/sediments around India (Sarma et al., 2010; Panda et al., 2006; Martin et al., 2008; Panigrahi et al., 2009; Prasad and Ramanathan, 2008; DeSousa et al., 1996; Satpathy et al., 2010; Chakraborty et al., 2012a; Chakraborty et al., 2012b; Chakraborty et al., 2014a; Chakraborty and Babu, 2015). However, limited information are available on the fluxes (fluvial, benthic, atmospheric and submarine) of nutrients/toxic metals/persistent organic pollutant from freshwater/atmospheric/benthic sources to coastal marine environments around India. The current state of knowledge suggests that increase in supply of nutrients in the BoB may deteriorate water quality by decreasing dissolved oxygen concentration (by increasing eutrophication) in the system (Diaz and Rosenberg, 2008). Similarly, increasing nutrients supply in the coastal Arabian Sea may increase the intensity of seasonal oxygen depletion during south west monsoon.

Restoration of oyster reefs in bays and estuaries has been reported to absorb up to 10 times more nitrogen and mineralization of phosphorous (Newell et al., 2005). Recent studies have reported that living oysters and their shells as sites of nitrification and denitrification (Kellogg et al., 2013; Caffrey et al., 2016). Oysters, the filter feeder, have also been identified to remove toxic heavy metals from bays and estuaries (Chakraborty et al., 2015, 2016). Mineralization of phosphorus by oyster has also been reported in literature. Newell et al. (2005) have reported that oysters remove organic matter, nutrients, and potentially reduce the negative effects of phytoplankton blooms caused by anthropogenic nutrients pollution. However, ammonium excretion can recycle some of the nitrogen to the water column, where it is available to support additional algal growth (Boucher and Boucher-Rodini, 1988; Mazouni, 2004). Nitrate release from oysters and scallops cultured on ropes is evidence of nitrification associated with bivalves (Mazouni, 2004; Richard et al., 2007). It is important to mention that quantitative information on these processes are scarce. It has been shown that oysters can potentially removed toxic metals from suspended particulate matters in estuarine system (Lee et al., 1996; Hedge et al., 2009; Chakraborty et al., 2016). Thus, oyster reefs restoration in bays and estuarine around India may help in controlling excess nutrients (NO_3^{-1}, PO_4^{-3}) and toxic metals fluxes in coastal water. In this view point article, an effort was made (qualitatively) to realize the probable implications of oyster reef restoration on marine environment in the east and west coast of India.

2. How does oyster reef control coastal water pollution

Oyster are known to remove suspended particulate matters, different nutrients and toxic species from water column by filter feeding and clean Bay's/estuarine water. Dyer and Orth (1994) have found that oysters lower ammonium concentrations in sediment porewater. Several oyster species (*Crassostrea virginica*, *Crassostrea gigas*, *Crassostrea hongkongensis*) has been identified to facilitate denitrification processes (Pietros and Rice, 2003; Pollack et al., 2013; Kellogg et al., 2013; Caffrey et al., 2016; Beck et al., 2011). It has also been reported that oysters remove toxic metals from water column of bays and estuaries (George et al., 1978; Chakraborty et al., 2016; Chakraborty and Babu, 2015; Chakraborty et al., 2015; Rodriguez-Iruretagoiena et al., 2016). It has also been mentioned that loss of historic oyster reefs may affect resilience of estuaries to eutrophication (Caffrey et al., 2016). Fig. 1 shows the possible pathways of nitrification/denitrification and toxic metals removal processes by oysters.

The exact mechanism of denitrification process on oysters is not known. In estuarine and marine environments, nitrification limits denitrification (Jenkins and Kemp, 1984). However, denitrification by oyster is an important process to remove fixed nitrogen from the ecosystem. Caffrey et al. (2016) have measured nitrification and denitrification in living oysters (Crassostrea virginica and Crassostrea gigas) and empty oyster shells (see Fig. 1a). They have suggested that denitrification process is significantly high on living oysters. However, denitrification rates, inside oyster cages and in sediments under them and how they vary by season and by oyster density are not known. Thus, further extensive research is required to understand the detail nitrification and denitrification mechanisms by oysters in tropical estarine systems.

The most plausible pathway of trace/heavy metals/toxin removal from estuarine water by oysters is depicted in Fig. 1b. Oysters (filter-feeder) filter in and out the surrounding water for food. Fine particles (suspended) in the water enter inside the organism during filter feeding. Metals associated with finer particles also enter inside the oysters. Bioaccumulation of metals in oysters depend on the speciation of metals/toxin in suspended particulate matters. Bioaccumulation of metals/toxin in oyster increases with increasing concentrations of labile metal-complexes in the finer particles. Thermodynamically stable (inert) metal complexes do not participate in bioaccumulation process in oyster.

However, denitrifying capacity and metal removal efficiency of the oyster species (*Crassostrea madrasensis*, *C. gryphoides*, *C. rivularis* and *Saccostrea cucullata*) (www.fao.org) found in the Indian coast are not well documented in the literature. These species have been reported to remove suspended particulate matters and toxic metals from coastal marine system. However, the information is scarce. Hence, further extensive studies are required to identify the oyster species that may

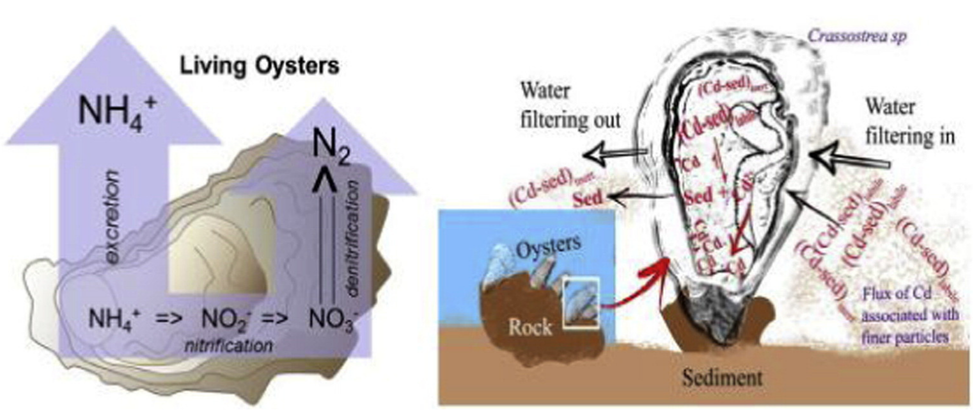

Fig. 1. Mechanisms of nutrient (NO_3^-) and toxic metals possible mechanism being rapid denitrification removal from estuaries and bays by oysters (adapted from Caffrey et al., 2016; Chakraborty et al., 2015; Chakraborty et al., 2016).

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