Ocean & Coastal Management xxx (2014) 1–13

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

The Saemangeum tidal flat: Long-term environmental and ecological changes in marine benthic flora and fauna in relation to the embankment

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ARTICLE INFO

Article history:
Available online xxx

ABSTRACT

The present article presents a historical overview of the Saemangeum reclamation projects and key findings from the ecological studies of the Saemangeum tidal flat, highlighting the ecological impact against the grand reclamation project, as a model example, in Korea. First, the scientific efforts given to the area of interest, mainly the inner part of the dikes, during the construction periods of series of four dikes (1991–2006) were summarized in terms of the change of environmental condition followed by the ecological responses over the past 20 years. As part of review, we selected and reanalyzed our series of the Saemangeum data including the current works relating to the microphytobenthos and macrozoobenthos, where the spatio-temporal variations cross the benthos in association with dike effects were carefully discussed in detail. The species composition in the upper intertidal zone, situated relatively far from the dikes, have been lesser changed between the periods of before (1988) and during the dike construction (2003–05). However, the benthic assemblages appeared to be changed in the mid to the lower intertidal zones of several transects and such phenomenon strengthened for the locations near the completed dike, e.g., Sandong transect near the dike of sector IV. Meanwhile, changes of the representative zoning in benthic assemblages during the dike construction were much clearly observed for the faunal species rather than flora. Such long-term ecological impacts including the timely increase of the opportunistic species during the dike construction were further evidenced the compositional change of the dominant benthos spanning two decades or so. In general, a long-term change in benthic community structure clearly reflected the community level impact apparently due to the attenuation of tidal energy by the embankment, varying the degree of impacts depending on the geographical location. Interdisciplinary monitoring and modeling studies are highly recommended to track natural variations in water quality and ecosystem health. Overall a long-term ecological monitoring should be applied to direct sound policy toward conservation of tidal wetlands, by emphasizing the significant biodiversity decline and coastal landscape depreciation.

1. Introduction

Estuaries are recognized as one of the important ecological transition zones, with functional linking terrestrial to marine aquatic ecosystem (Gray, 2002). This ecological allocation would be a key reason for the highest value of significance in the estuarine and coastal regions supported by the enriched nutrient cycling in terms of ecosystem services (Costanza et al., 1997). Tidal flats (or wetlands) in such linking ecosystem are known to play an important role as one of the principal energy transfers from primary producers to high-level consumers, including fish, waterfowls, and finally to human (Levin et al., 2001; Wall et al., 2001). In particular, the benthic ecosystem inhabiting various tidal flat organisms plays a central role in the food web, encompassing primary producers, consumers, and also decomposers. Further, the importance of tidal flats for migratory birds, say the top predator in the food chain of

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http://dx.doi.org/10.1016/j.ocecoaman.2014.07.020
0964-5691/

tidal flats, has also been highly acknowledged (Ryu et al., 2011a). For above reasons, the estuarine tidal flats should have been considered as a critical ecosystem zone, warranting the protection of the nature and wildlife.

However, unfortunately, the Saemangeum tidal flat located in the Mangyeong-Dongjin estuary disappeared in the late 2000s by the embankment from the Saemangeum reclamation project. The area is recognized as one of the largest uniscale wetlands in Korea possessing valuable ecosystem services such as biodiversity, fisheries, and coastal landscape etc. (Koh et al., 2010). In particular, the provisioning service for waterfowl resting area in the Saemangeum tidal flat should have supported large populations of internationally migratory shorebirds following the East Asian/Australasian pathways (Rogers et al., 2006). Meanwhile, this area was also economically acknowledged in terms of local fisheries on tidal flats, particular for artisanal fisheries such as clam harvesting (Koh and Khim, 2014). With such socio-economic recognition and concerns over the human use of the Saemangeum area, many benthic ecological studies have been concentrated in the given area during the past two decades, in Korea (An and Koh, 1992; Oh and Koh, 1995; Koo et al., 2008a, b, c; Ryu et al., 2011a, b).

Currently, the artificial lake created inside the dikes of the Saemangeum lowered 1.5 m below the mean sea level for the next step of landfilling, and this resulted in drying up the significant areas of tidal flat followed by collapsing the entire tidal flat ecosystem. The present article aimed to address the long-term ecological changes in marine benthic flora and fauna of the Saemangeum against the environmental changes due to the embankment. To do this, a set of selected data from our previous and current works relating to the microphytobenthos (MPB) and macrozoobenthos (MZB) in the given area was scrutinized targeting their species composition and spatio-temporal distributions. A detailed description of previous natural ecosystems would be meaningful to fully restore the ecological structure and function of the tidal flat, like the Saemangeum, by sound restoration efforts, if necessary. Chronological description on the dominant benthos species in the given area over the past 20 years are highlighted in order to find the long-term ecological changes against the timely events including the construction of series of four dikes. Finally, the future research and policy directions challenging the conservation of tidal wetlands and/or possible restoration campaign in the Saemangeum area are carefully suggested, by emphasizing the significant loss of biodiversity and coastal landscape.

2. History of the Saemangeum project

2.1. Geographical and oceanographical settings

Along the west coast of Korea (West Sea), several types of tidal flats including embayed, semi-enclosed, estuarine, and open-coastal groups are extensively developed totaling ~2 500 km^2 of wetland areas. In general, the Korean tidal flats belong to the macro tidal regime, with maximum of ca. 10 m tidal height in several places around the Gyeonggi Bay. Similar to the Gyeonggi Bay, the Saemangeum tidal flat (35°30′ to 35°50′ N and 125°40′ to 126°00′ E) have experienced the macrotidal condition up to ~7 m tidal height at spring tide, until the world longest seawall (33.9 km spanning four dikes) created in 2006 (Fig. 1).

The Saemangeum area formerly covered ~233 km^2 of tidal wetland in the 1980s, with >5 km width in many places, extending up to 15 km offshore direction from the mouth of the Mangyeong and Dongjin estuary in the 1980s (Fig. 1A). The large amount of freshwater flows into the tidal flat area through the well developed tidal channels along the two major rivers, subsequently flowing into the West Sea. Before the dikes completed, it was reported that

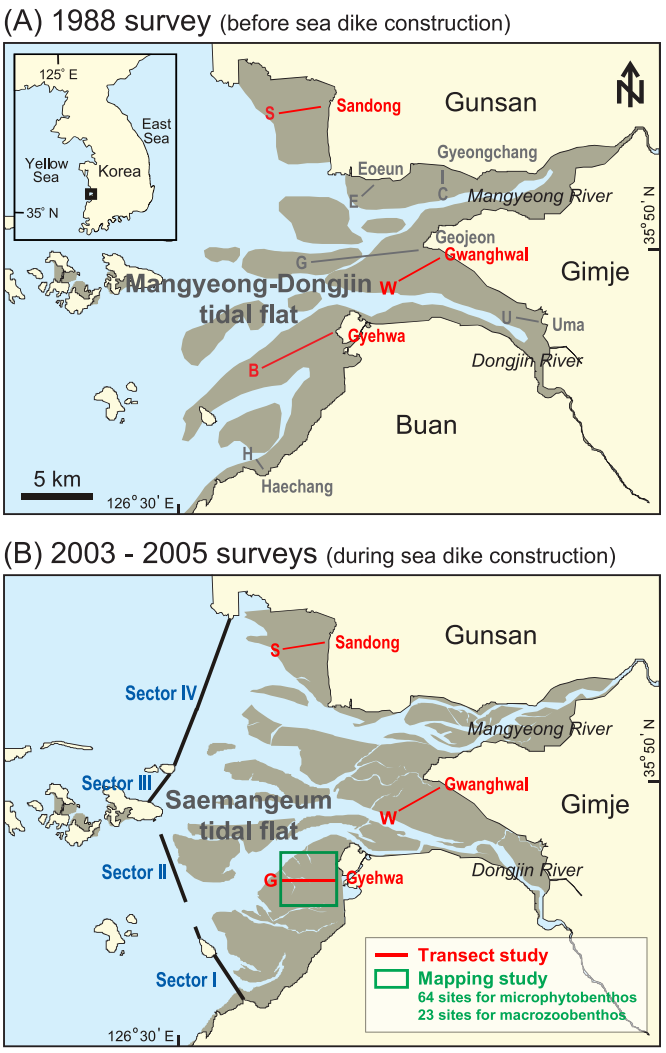

Fig. 1. Map of the Saemangeum tidal flat showing the boundary of tidal flat and dike construction, and the location of transect lines studied in (A) 1988 and (B) 2003–05.

the year-round freshwater input reached ~6.4 billion tonnes and more than half (~60%) was concentrated during the summer monsoon period only (Kim and Chung, 1988). Strong year-round salinity gradient from 10 to 24 due to intermittent discharges from those rivers and possible submarine groundwater discharges would be the typical characteristics in the estuarine tidal flat of the Saemangeum (Kim et al., 2010; Waska and Kim, 2011). Meantime, sediment bottom in the Saemangeum area used to be muddy in the upper intertidal zone and sand-dominated in the lower part, which represents a typical sedimentary distribution of the Korean tidal flats. As a result of the embankment, the sedimentation and topography of the tidal flat particularly in the subtidal regions have been totally changed (Lee and Ryu, 2007, 2008), subsequently disturbing the marine benthic assemblages in the given area (Ryu et al., 2011a).

2.2. Chronological description on long-term socio-political conditions

The historical understanding of the key environmental conditions related to the Saemangeum reclamation project, including political, administrative, sociological, and legal activities would be of critical backgrounds to link scientific demands into its outcome

Please cite this article in press as: Ryu, J., et al., The Saemangeum tidal flat: Long-term environmental and ecological changes in marine benthic flora and fauna in relation to the embankment, Ocean & Coastal Management (2014), http://dx.doi.org/10.1016/j.ocecoaman.2014.07.020