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An indicator to quantify the effects of hydrodynamic disturbances caused by coastal reclamation on aquatic organisms

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ABSTRACT

In order to provide effective measures for reclamation management and alleviate damages on ecosystems under multiple anthropologic interferences, quantification of coastal reclamation hydrodynamic disturbance (CRHD) and determination of the related threshold value of ecosystem are presented in this research. Eleven monitoring areas (approximately 1 km^2 each) in Dongying Port of China are considered. Each monitoring areas were further divided into the affected and non-affected areas based on impact of coastal reclamation engineering by comparing the distribution of hydrodynamic disturbance. According to c the CRHD, which enhance quantification method in terms of (a) quantifying the CRHD for coastal environment under different types of coastal habitants, (b) developing the definition of hydrodynamic disturbance based on ecological threshold, and (c) prognosticating the distribution of IHD with the case study of Dongying port. As the results, IHD for most of affected area was 23.58% higher than that non-affected area in average. Also, CRHD was insensitive to sessile organisms' growth, relatively sensitive to suspended organisms, and extremely sensitive to swimming organisms. The maximum ecological threshold value for sessile organisms was approximately 3.5, exceeding 45.32% and 38.83% actual intensity for the affected and non-affected areas, respectively. Also, the threshold value for suspended organisms was approximately 2.56, which was 3.55% less than that of the affected area. Comparatively, the threshold value for swimming organisms was approximately 2.05, which was 10.75% less than that of affected area. Therefore, it is not suitable to invest constructional project of coastal reclamation engineering at the northeast and northwest of Dongying port administrative regions. Overall, the quantitative modeling of CRHD is advantageous for policy maker to manage coastal reclamation engineering and protect aquatic biodiversity.

1. Introduction

Rapid urbanization and industrialization tend to be concentrated in many coastal areas. Over 40% of coastal areas are heavily impacted by a variety of anthropogenic perturbations (Borja and Dauer, 2008; Halpern et al., 2008; Naser, 2011). Coastal reclamation is considered as an effective approach to solve the contradiction between land shortage and the growing demand. This will induce many negative effects on marine and coastal ecosystems under varying degrees with respect to the reclamation phases and functions (Feng et al., 2015). For example, in China, as a result of the newly proposed national coastal zone plans, an additional 5780 km^2 of coastal area will be reclaimed by the year 2020, which will inevitably cause a series of impacts on marine environments and ecosystems (Peng et al., 2013). Especially for river estuary areas where exist vulnerable ecosystems, coastal reclamation engineering can easily cause intensive hydrodynamic disturbance due to changes of original landscape structure and the corresponding hydrological parameters (Cai et al., 2009a,b,c; 2011; Tan et al., 2011). This disturbance caused by excessive reclamation engineering can lead to decreasing channel flow during the process of long-time operation, reducing number of creatures in the coastal shoreline and deteriorating water quality around coastal region (Cheong et al., 2013; Gao et al., 2014; Maren et al., 2016). Such unplanned land reclamation in coastal areas for supporting urban expansions can cause a number of disasters such as floods and land subsidence. Therefore, hydrodynamic disturbance caused by coastal reclamation of great concerns due to the

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change of topographical and hydrodynamic conditions, as well as cascades of consequential impacts upon environmental quality and ecological processes (Stefano et al., 2015; Wang et al., 2010).

In recent decades, the disturbances caused by any coastal reclamation activities have became a major anthropogenic factor to impact coastal water environment. Many studies were undertaken for analyzing impacts of ecological environment disturbance resulting from human activities upon ecosystems in many areas including estuaries. According to theory of landscape ecology, many researchers stated that the disturbances could be explained as a ratio of non-affected area and the total areas through using remote sensing images to predict human disturbances and tendency of ecological responses (Alahuhta and Aroviita, 2016; Lan et al., 2014; Shen et al., 2016; Tian et al., 2016). On the other hand, the disturbances were usually defined as the load of pollutants which can damage the original coastal environment (Tang et al., 2016); or were considered as the source of environmental variations generally, and as the parameters to control in previous studies (Chen and Jiao, 2008). Additionally, the coastal reclamation hydrodynamic disturbances (CRHD) were described as the variation of many key physical factors such as flow velocity, water temperature and tidal range (Canu et al., 2016; Elhakeem and Elshorbagy, 2015; Lin et al., 2016). However, most of the researchers mainly focused on environmental impacts that were directly caused by human disturbances, and did not make an intensive analysis and discussion of formation mechanisms of the disturbances. The quantitative definition of hydrodynamic disturbances caused by coastal reclamation activities still had not fully understood. Especially for hydrodynamic disturbances, few studies explored the intensity of hydrodynamic disturbance with the consideration of relevant thresholds for relevant ecosystems. Consequently, it was insufficient to investigate and analyze impact pathways on different living habits of aquatic creatures under coastal reclamation hydrodynamic disturbances (CRHD). It can be considered as one of the most important elements affected the growth characteristics of hydrobiological organisms in coastal and estuarine regions. For instance, in the Danube River Bay, bio-mass of aquatic plants peaked at flow velocity around 0.3 m/s. At the same time, low bio-mass was observed for the dominant algae mosses when the flow velocity was greater than 0.7 m/s (Janauer et al., 2010). Earlier research (Manolaki and Papastergiadou, 2013) believed water flow velocity was a critical parameter that could disturb nutrient structure in water and thus affect stability of ecosystems. Velocity of 0.04 m/s was considered as the optimal one for algae growth for Jialing River, China (Long et al., 2011). Additionally, if water flow rate was greater than 1 m/s, the mollusks would be difficult to survive (Babko and Kuzmina, 2009). The effective cover of sea grass population, which incorporates the sheltering area, had important controls on the distributions of shear stress, suspended sediment, light environment, and consequent sea-grass habitat suitability(Carr et al., 2011).

Therefore, the objective of this research is to quantify coastal reclamation hydrodynamic disturbances (CRHD) in estuary areas. According to mechanical characteristics for aquatic creatures underwater, an improved method for typical creatures will be established in study area. Three typical behaviors and habits of aquatic organisms will be considered to analyze the intensity of hydrodynamic disturbances. Additionally, the related ecological threshold values will be calculated for predicting the distribution of intensity of hydrodynamic disturbance (IHD) by using the case of Dongying port in China. The representative creatures located near Dongying port will be classified as three types in the Yellow River estuary. The proposed dimensionless index of IHD will enhance the traditional methods which mainly focused on environmental impacts in terms of (a) quantifying of the CRHD for coastal environment under different types of coastal habitants, (b) improving definition of hydrodynamic disturbance based on ecological threshold, and (c) prognosticating the distribution of IHD with the case study of Dongying hydrodynamic model. This represents an improvement in management and design of coastal reclamation engineering. It is advantageous for planning ecological red lines along the coastline in China and protecting the aquatic biodiversity in areas of coast and estuarine.

2. Overview of the studying area

In this research, the studying case is established based on monitoring data and literatures of Dongying port (DYP) as a part of Yellow River Estuary, located in the southwest coast of Bohai Bay, northeast of Dongying city, and about 50 km north of the Yellow River delta, Shandong province, China (38°04′N to 38°06′N, 118°51′ to 118°58′E). The total studying area is approximately15 km^2. It is effected by Eurasia and Pacific Ocean, enjoying a wild climate and four distinctive seasons where located in the warm temperate continental monsoon climate zone. The quarterly average temperatures are approximately 10.2, 26.7, 12.8 and −4.9 °C, respectively. The mean tidal range is 0.73 to 1.77 m (Sun et al., 2016). Because of serious soil salinization surrounding Dongying port, major vegetations in the Yellow River estuary(YRE) are mainly salt-tolerant plants, such as *Suaeda heteroptera*, *Triarrhena sachariflora*, *Tamarix chinens*, *Phragmites australis* and *Limonium sinense* (Cui et al., 2009; Jiang et al., 2013). Since the construction of DYP in 1997, the scale of port had expanded continually. The total areas of DYP economic zone was approximately 60 km^2 (Fig. 1), the land use of port was increased, which was approximately 20% of total area of Yellow River estuary in 2010s. Damage on ecological environment caused by marine-based reclamations had been reported for the destruction of anoxic benthic habitats (Lee et al., 2014).

The attention of this research was focused on hydrodynamic

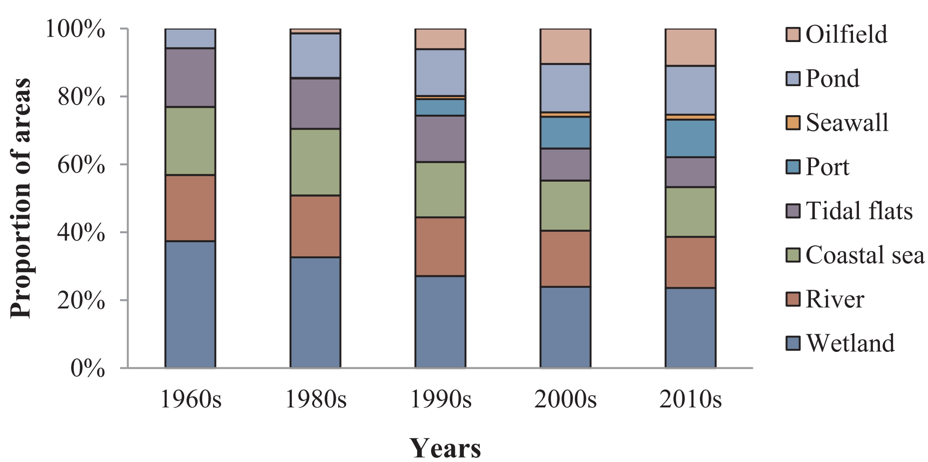

Fig. 1. The Land use ratio from 1960s to 2010s in the Yellow River estuary.