Ocean & Coastal Management 133 (2016) 28–36

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

# Land-ocean-human interactions in intensively developing coastal zone: Demonstration of case studies

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ARTICLE INFO

*Article history:*
Received 10 October 2015
Received in revised form
24 August 2016
Accepted 12 September 2016

*Keywords:*
Land-ocean-human interactions
Coastal zone
Coastline change
Estuary and bay
Sea-level rise

ABSTRACT

Land-Ocean-Human (L-O-H) interactions in intensively developing coastal zones are demonstrated using four case studies in the western Bohai Sea, China. Three aspects of L-O-H interactions are discussed: 1. Coastlines are the result of Land-Ocean (L-O) interactions, but human activities have changed many coastlines from natural to artificial. In recent years, sea reclamation projects have moved the land and its coastline towards the sea, leading to hydrodynamic changes and affecting both the topography and sediment-erosion dynamics in western Bohai Bay (case study 1). 2. Estuaries are key areas for L-O interactions; river sediments, together with ocean power, shape the topography of the estuarine delta, while river nutrients impact offshore biological productivity. However, due to irrigation and reservoir construction up-stream, runoff and sediments have decreased resulting in increased coastal erosion in the Yellow River Delta (case study 2). Rivers carry industrial and agricultural point and non-point source pollution into the sea, causing marine pollution in Jinzhou Bay (case study 3). 4. Sea-level rise caused by global climate change enhances the role of the ocean. At a local scale, in Binhai New Area, sea-level change is also influenced by vertical land movement along with some land subsidence caused by over-exploitation of groundwater. Rising sea levels exacerbate storm surges and floods, and increase the risk of socio-economic and ecological impacts (case study 4). Because of rapid economic growth in Chinese coastal areas, L-O-H interactions have become the most significant factors changing natural and artificial environments. If the coastal zone is to be developed sustainably, human activities must be regulated.



## 1. Introduction

Land, atmosphere, and ocean systems interact in the coastal zone, where the exchange of material, energy, and information is frequent and intensive (Olsen et al., 2009). This zone is an important part of the earth's system, and plays a supporting role in economic development. (Lakshmi and Rajagopalan, 2000; LOICZ, 2005). The coastal zone is also home to both intensive human activity and fragile ecological areas, which latter are not only exposed to storms (Klemas, 2009), land subsidence (Clabby, 2010), sea-level rise (Williams et al., 1999), salt water intrusion (Newton and Icely, 2008), and other environmental risks (Xu et al., 2013; Wang et al., 2014), but are also under pressure from rapid urban and industrial expansion, population growth, and over-exploitation of marine resources (Dennison, 2008; Kesgin and Nurlu, 2009; Pasquaud et al., 2013). Therefore, sustainable development of the coastal zone is important to both the global environment and human society and, as such, has become an important research area (Cicin-Sain, 1993; Shi et al., 2001; Portman et al., 2012). Land-Ocean Interactions in the Coastal Zone (LOICZ) is listed as a core programme in the International Geosphere-Biosphere Programme (IGBP) and

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http://dx.doi.org/10.1016/j.ocecoaman.2016.09.006
0964-5691/

the International Human Dimensions of Global Environmental Change Programme (IHDP) (LOICZ, 2003). Launched in 1993, LOICZ first concentrated on biogeochemical cycles in coastal zones, with coastal natural processes and matter fluxes as its focus (Pernetta and Milliman, 1995). The second phase of the programme (LOICZII) was launched in 2003 and extended its research to include human factors, with human activity and its impact on land-ocean interactions as a new central theme. This expansion made LOICZ II a key platform for research about coastal human activities and resource utilization (LOICZ, 2005). Since January 2015, LOICZ has been incorporated into the new Future Earth Programme (www.futureearth.org), a larger initiative coordinating up to 30 international projects relating to coasts, food security, energy, water, ocean research, the atmosphere, and governance.

Under normal circumstances, the environment is less affected by human activities than by natural processes. But in intensively developing coastal zones—densely populated areas with concentrated industry and rapid development—human activities can have a greater influence than natural processes. Many studies have shown that the more human activities change, dominate, or even replace natural ecosystems, the more environmental vulnerability increases, and both the occurrence and scale of extreme events will be exacerbated (Linton and Warner, 2003; Geographical Society of China, 2007; Bullimore, 2014). IGBP research has shown that human activity has made a more notable impact on the global environment than natural changes. Modern geography is now moving from the study of environmental changes caused by natural processes only to changes caused by both natural and human interaction (Leng and Song, 2005a, 2005b). In intensively developing coastal zones, the classic L-O-interaction framework can be replaced by an L-O-H-interaction framework to include the huge impacts resulting from human activities (Fig. 1).

L-O-H interactions include H-L interactions reflecting the human-land relationship, H-O interactions reflecting the human-ocean relationship, and L-O interactions reflecting the land-ocean relationship. These 3 relationships converge in the coastal zone and complicate its issues.

There are 3 typical intensively developing coastal zones in China: around the Bohai Sea, the Yangtze River Delta, and the Pearl River Delta. In this project, the western Bohai Sea coastal zone was chosen as the study area and L-O-H interactions were reviewed in three contexts: coastline changes, estuary and bay environment, and risk of sea-level rise. This study will help expand the comprehensive research of the human-land relationship to the human-land-ocean relationship, which has important scientific significance.

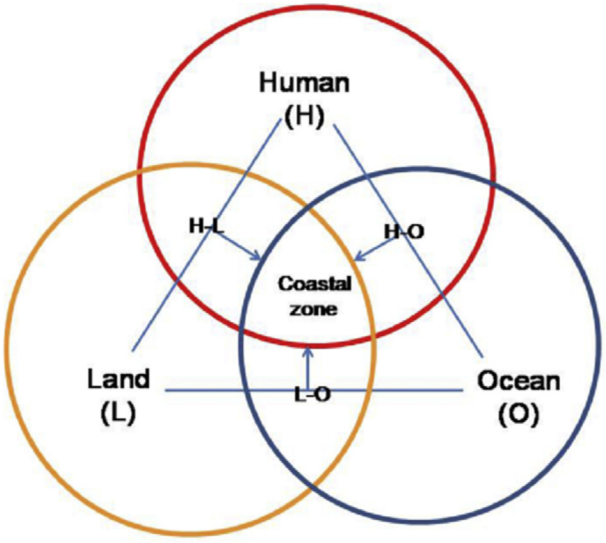


**Fig. 1.** L-O-H interaction framework.

## 2. Material and methods

### 2.1. Study area

The western Bohai Sea coastal zone is located in the Bohai Rim, one of the top three hotspots of China's rapid economic development regions (the other two are the Pearl River Delta and the Yangtze River Delta) (Zhu et al., 2012). It comprises 35,720 $km^2$ of land(the Bohai Sea itself comprises 77,000 $km^2$),with a coastline of 1160 km, and a human population of 21.39 million. The study area includes the country's largest comprehensive port, Tianjin Port, and the large ports of Caofeidian, Qinhuangdao, and Huanghua, as well as several mid-sized and small ports. Near Tianjin city, a municipality directly governed by the central government, 7 prefecture-level cities, and 21 counties. This coastal zone is also a base for a number of industries—iron and steel industry, oil industry, salt chemical industry—and also has dense traffic channels and a logistics center. Already, the rate of increase in density of economy, shoreline utilization, fixed assets, and construction sprawl is one of the highest in China, and is still increasing. Moreover, several national-level economic development zones and key construction projects are located in the Yellow River Delta, the Haihe River joint Delta, and the Luanhe River Delta. The western Bohai Bay coastal zone is both an intensively developed area and a site where typical river-sea and land-sea interactions occur.

This paper reports on the results of 4 case studies: (1) Coastline change and its impact in Bohai Bay; (2) estuarine environmental changes in the Yellow River estuary area; (3) land-based sources of pollution in Jinzhou Bay; and (4) risk of sea-level rise in the Binhai New Area of Tianjin (see Fig. 2).

### 2.2. Methods

#### 2.2.1. Case study 1: coastline change and its impacts

The northwest coast of Bohai Bay, where the ports of Tianjin and Caofeidian are located, is a typical land-reclamation coastal zone. For this study, the coastline was delineated using ArcGIS 9.3 and annual MSS/TM/ETM remote sensing images dating from 1974 to 2010 (www.rsgs.ac.cn) and then compared with historical coastline maps (Chen, 2000) to calculate the rate at which land has expanded seaward.

In order to analyze the impacts to marine hydrodynamics caused by ocean-engineering projects such as land reclamation, the tide flow of a representative year during the time period 1974 to 2010 was simulated using the ECOMSED—3D tidal current model and verified by an October 2010 survey of tidal levels and currents in Bohai Bay, to show the relationship between coastline change and Bohai Bay hydrodynamics.

#### 2.2.2. Case studies 2 and 3: environmental changes in the estuary and bay

Two case studies reported on here illustrate how L-O-H interactions influence estuary and bay environments.

In case study 2, which reviews environmental changes in the Yellow River Estuary area, 60 years of runoff and sediment accumulation data were gathered and analyzed to study the relationships between water and sediment and siltation/erosion in the river delta. The spatial distribution of siltation, erosion, and stability states were then mapped, using a remote sensing image (www.rsgs.ac.cn)