Ocean & Coastal Management 146 (2017) 43–49

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

Need to link river management with estuarine wetland conservation: A case study in the Yellow River Delta, China

Rui Zhou [a], Yunzhao Li [b], Jingjing Wu [c], Meng Gao [c], Xiaoqing Wu [c], Xiaoli Bi [c, *]

[a] Institute of Ecology and Geobotany, Yunnan University, Kunming, 650091, China
[b] School of Resources and Environmental Engineering, Ludong University, China
[c] Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai, 264003, China

ARTICLE INFO

Article history:
Received 21 March 2017
Received in revised form
22 May 2017
Accepted 16 June 2017

Keywords:
River management
Estuarine wetland conservation
Ecological water supplementation
Wetland network
The Yellow River Delta

ABSTRACT

Estuarine wetlands are valuable ecosystems of coastal zones. Traditionally, wetlands are preserved by establishing nature reserves within them. However, the driving forces of estuarine wetland degradation change at different temporal and spatial scales, rendering it necessary to evaluate the entire river–delta–wetland system. We analyzed the links between management of the Yellow River (YR) and estuarine wetland conservation in the Yellow River Delta (YRD). We measured changes in river runoff and sediment discharge from 1950, and spatial changes in the tail channels from 1855. Changes in the wetland areas of the entire delta, the natural reserves, and the river buffer areas were calculated. Finally, the effects of ecological water supplementation of the YR, mandated in 2008 by the Chinese government to protect estuarine wetlands, were also analyzed. The results indicated that not only the reductions in river runoff and sediment discharge, but also shifts in the tail channels, influenced estuarine wetlands. In addition, ecological water supplementation from the YR have improved wetland health. We suggest that increasing the connectivity between old and new rivers is important to improve the integrity of estuarine wetland ecosystems. Linking river management to estuarine wetland conservation would aid in the planning and improvement of the wetland network in the delta.

1. Introduction

The Yellow River (YR) is the most sediment-laden river in the world (Wang et al., 2016a). Annually, millions of tons of sediment reach the river mouth, ultimately forming the Yellow River Delta (YRD). The modern YRD is the youngest estuarine wetland ecosystem of all warm-temperate regions. The wetlands provide valuable services at both the local and regional scales, including water supplementation, flood regulation, wastewater storage, and natural water purification (Bai et al., 2015; Fan et al., 2012; Han et al., 2013; Wang et al., 2012b). In addition, the YR is one of the most important transfer stations for Asian and west Pacific birds during migration. Many rare birds, such as red-crowned cranes, storks, spoonbills, and geese, pause for nourishment and energy on these estuarine wetlands and then continue to other Asian and western Pacific regions (Li et al., 2011). However, global climate change and regional human activities have caused the estuarine wetlands of the YRD to decrease in area and/or to become seriously degraded over recent decades. For example, from 1980 to 2013, natural wetlands decreased from 1997 km^2 to 1485 km^2 in area, whereas artificially constructed wetlands increased from 112 km^2 to 560 km^2 in area, in the YRD (Li, 2014).

In the YRD, water is the most important determinant of the sustainability of estuarine wetland ecosystems (Cui et al., 2009a, 2009b). Precipitation, evapotranspiration, and temperature are the principal factors affecting water balance. In recent decades, changes in these climatic factors have significantly reduced river runoff, consequently compromising supplementation of the estuarine wetlands of the delta by sediment (Lu et al., 2016). A strong positive correlation between runoff and wetland area was evident in the lower reaches of the YR (Wang et al., 2016b), and both runoff and sediment discharge exhibited the potential to define the landscape patterns of the estuarine wetlands of the YRD (Li et al., 2009).

However, the shortage of river water commencing in the 1990s constituted great threats to the growth of estuarine wetlands in the delta (Li et al., 2016), including shrinkage of the areas of open water (Syvitski et al., 2009), sharp decreases in the numbers of indigenous

* Corresponding author.
E-mail address: xlbi@yic.ac.cn (X. Bi).

http://dx.doi.org/10.1016/j.ocecoaman.2017.06.004
0964-5691/

species, and their replacement by exotic species (An et al., 2007). Therefore, the health of the YR, especially in its lower reaches, plays a critical role in maintaining viable estuarine wetlands in the YRD.

Conservation management strategies for wetlands and rivers usually include flow recovery, changes in dam operations, and protected area and adaptive management (Kingsford, 2011). In efforts to regulate and control the flow and sediment transport of the lower reaches of the YR, a water-sediment regulation project (WSER) has been conducted annually since 2002 by the Chinese government in late June and early July. Reservoirs (such as the Xiaolangdi reservoir) on the principal streams are used to increase the sediment transport capacity of the YR downstream and to protect shrinking river channels (Li and Sheng, 2011). The estuarine wetland ecosystems have clearly benefited. For example, the estuarine wetland landscape became relatively stable during the period of water sediment regulation. In addition, the soil salinity of the YRD significantly decreased after regulation (Wang et al., 2016a).

To protect the new estuarine wetlands of the Yellow River Delta Nature Reserve (YRDNR), the Yellow River Conservancy Commission (YRCC) decided, in 2008, to directly deliver fresh water from the YR to estuarine wetlands within the reserve. The effects on degraded estuarine wetlands have been remarkable. Both the wetland areas and their ecosystem parameters have significantly improved (Dong et al., 2014; Li and Sheng, 2011).

In addition, the lower (or tail) channels of the YR frequently shifted, in the past, near the river mouth because of the physical characteristics of the river and interactions between the river and the tides. Such shifts facilitated the growth of the modern YRD and the estuarine wetlands (Xue, 1993; Ye et al., 2006; Yu, 2002). However, for many years, the YR was managed without consideration of wetland conservation. Few efforts were made to explore interactions between the river, the estuarine wetlands, and the delta.

In this study, we analyzed historical changes in the YR, including river runoff and sediment discharge in the lower YR and the spatial patterns of tail channels, and wetland changes caused by river variation at the scale of the delta, natural reserve, and river buffer. We suggest that conservation of estuarine wetland in the YRD must be approached from the viewpoint of a holistic river-delta-estuarine ecosystem.

2. Methods

2.1. Study area

The modern YRD is located on the estuary of the YR near the Bohai Sea (Bi et al., 2011). Before 1976, the channels by which the YR entered the Bohai Sea frequently changed, mainly because of natural disturbances. However, in late 1976, the principal channel to the river mouth was artificially dammed to protect the Shengli Oil Field from flooding and tidal storms in the delta. The soil, vegetation, climatic, and groundwater characteristics of the delta have been described in many reports (see Jin et al., 2016; Mao et al., 2016).

In 1992, the YRDNR was established to protect the new estuarine wetland ecosystem. The YRDNR was entered on the “List of Ramsar Wetlands of International Importance” in 2013 (Ramsar, 2014). Today, it is about 1530 km^2 in area, and has two separate parts, the YiQianEr (YQE) and the HuangHeKou (HHK) Nature Reserves. Both reserves have three regions, according to a nature reserve planning, including Buffer area, Core area as well as Experimental area.

2.2. Data and methods

Annual runoff, sediment discharge and precipitation data from 1950 to 2015 at Lijin, the last gauging station in the YR catchment, were collected from the YRCC. We calculated variation of three variables, as the formula 1, according to the annual mean values and the multi-year mean values. Data on ecological water levels supplied from 2008 to 2015 to the two separate nature reserves were also collected from the YRCC (www.yellowriver.gov.cn).

$$X_V = (X_a - X_M)/X_M \times 100\% \quad (1)$$

V: variation; a: annual value; M: multi-year mean value.

Estuarine wetlands were identified on thematic mapper (TM) images taken in 1990, 2000, 2010, and 2015, by the supervised classification procedure in ERDAS Image 8.0 software. The classification results were verified by field investigation in September 2015, and the accuracy of classification were higher than 80%. The tail channels of the lower YR at different periods were digitized from historical maps (Li, 2014) as well as those TM images, using ArcGIS 10.0 software. Administrative maps of the YRDNR were obtained from the local agency and also digitized by ArcGIS 10. The areas of deltas, nature reserves, and shifting river buffers were calculated using the spatial analysis tools of ArcGIS 10.0. The proportions at different times of the delta areas covered by wetlands, the two nature reserves, and the river buffer regions, were also calculated by its GIS tools.

3. Results

3.1. Changes in the YR and its delta

3.1.1. Variation in river runoff and sediment discharge

Historical records indicate that the annual values of runoff and sediment discharge at the Lijin station were higher before 1970 but decreased after 1970, especially became lower than the multi-year mean values. Both annual runoff and sediment discharge attained their lowest values in 2000 but increased after the water/sediment regulations were introduced in 2002, remaining relatively stable after 2003 (Fig. 1). However, the annual precipitation showed a relative stable trend.

3.1.2. Changes in the tail channels of the YR

Commencing in 1855, 13 principal tail channels of the YR entered the Bohai Sea and then shifted to form the modern YRD

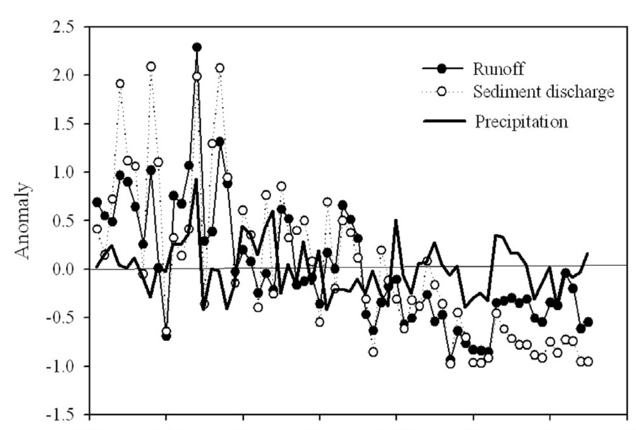

Fig. 1. Time series of anomalies in mean annual precipitation, runoff, and sediment discharge at Lijin station (1950–2015).