Case Study 35

Protecting and Sustaining the Ecological Functions of the Inshore Fish Spawning Grounds in the Yellow River Delta

Fu Mingzhu[1,2] and Zhang Zhaohui[1,2] *

[1] First Institute of Oceanography, State Oceanic Administration, No. 6 Xianxialing Road, Qingdao, People's Republic of China

[2] Key Lab of Science and Engineering for Marine Ecological Environment, State Oceanic Administration, Qingdao, People's Republic of China

This section is part of the book:
Chua, T.-E., L.M. Chou, G. Jacinto, S.A. Ross, and D. Bonga. (Editors). 2018. Local Contributions to Global Sustainable Agenda: Case Studies in Integrated Coastal Management in the East Asian Seas Region. Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) and Coastal Management Center (CMC), Quezon City, Philippines.

Key Message

- The ecological functions of inshore fish spawning grounds in the Yellow River estuary were degraded in the past few decades due to a dramatic decrease in freshwater discharge and sediment load.

- A water-sediment regulation (WSR) scheme, which has been incorporated as an essential management measure of the Dongying integrated coastal management (ICM) program, has helped protect and sustain these ecological functions.

Abstract

The Yellow River, the largest river in northern China, plays an essential role in maintaining the biogeochemical processes and ecological functions of the estuary and coastal ecosystems in the Yellow River Delta. The Yellow River estuary is an important spawning and fishing ground and habitat for many migratory commercial fish species of Bohai Sea and Yellow Sea. In the past few decades, there was a dramatic decrease in freshwater discharge and sediment load of Yellow River due to the combined impacts of climate change and increasing anthropogenic activities. This has considerable socioeconomic and ecological implications and hence, the need to manage water resources and sediment loads of the Yellow River delta. A WSR scheme was started in 2002 with good results and was incorporated as an essential management measure of the Dongying ICM program. Although positive ecological impacts were evident after over 10 years of WSR implementation, new challenges require adaptive measures to improve the current WSR to further protect and sustain ecological functions of inshore fish spawning grounds. This case study provides the rationale leading to implementation of the WSR scheme and identifies areas for further improvement.

* *Email: zhang@fio.org.cn*

Background

The Yellow River (Huanghe) is the second largest river in the People's Republic of China and the sixth longest in the world. It originates from the northern Qinghai-Tibet Plateau, flows eastward through the soil-rich Loess Plateau and the flat alluvial plains, and ultimately discharges into Bohai Sea (Figure 1). It flows through nine provinces in the country.

The Yellow River spans 5,460 km, has a wide drainage basin covering about 752,000 km^2, and exhibits a variety of geological and climatic features. Approximately 60% of its water is from the upper reaches of the Qinghai-Tibetan mountain ranges while about 90% of its sediments are derived from the middle reaches which cross the Loess Plateau. In the lower reach, from Huayuankou (hydrological) Station to Lijin Station (Figure 1), the river is characterized by raised riverbeds of up to several meters (locally > 10 m) above surrounding areas as it was subjected to frequent flooding in the past.

Each year, Yellow River discharges large amounts of freshwater, sediment, and nutrients into Bohai Sea. It plays an important role in maintaining the biogeochemical processes and ecological functions of the estuary and adjacent coastal ecosystems, as well as maintaining the morphological characteristics of the delta. The Yellow River estuary is an important spawning ground and habitat of many commercial migratory fish species of Bohai Sea and Yellow Sea. It also supports the major fishing grounds in northern China Sea contributing up to 40% of the total fish catch in Bohai Sea (Shan, et al., 2013).

Compared with other large rivers of the world, Yellow River has distinctive characteristics of high sediment load and low water discharge, thus rendering the river yellow. The suspended particulate concentration is over 20 kg/m^3, which is more than 100 times higher than most other large rivers (Milliman and Ren, 1995). Under normal conditions, water discharge from the river is highly dependent on the monsoon, with most of the runoff occurring during the flood season (July-October). Since the 1960s, in order to meet the demand for water (mainly for agricultural irrigation) and to prevent flooding, more than 3,000 reservoirs were constructed in the river

Figure 1. The Yellow River basin and the locations of the four largest reservoirs and major hydrological stations in the lower reaches (adapted from Yu, et al., 2013).

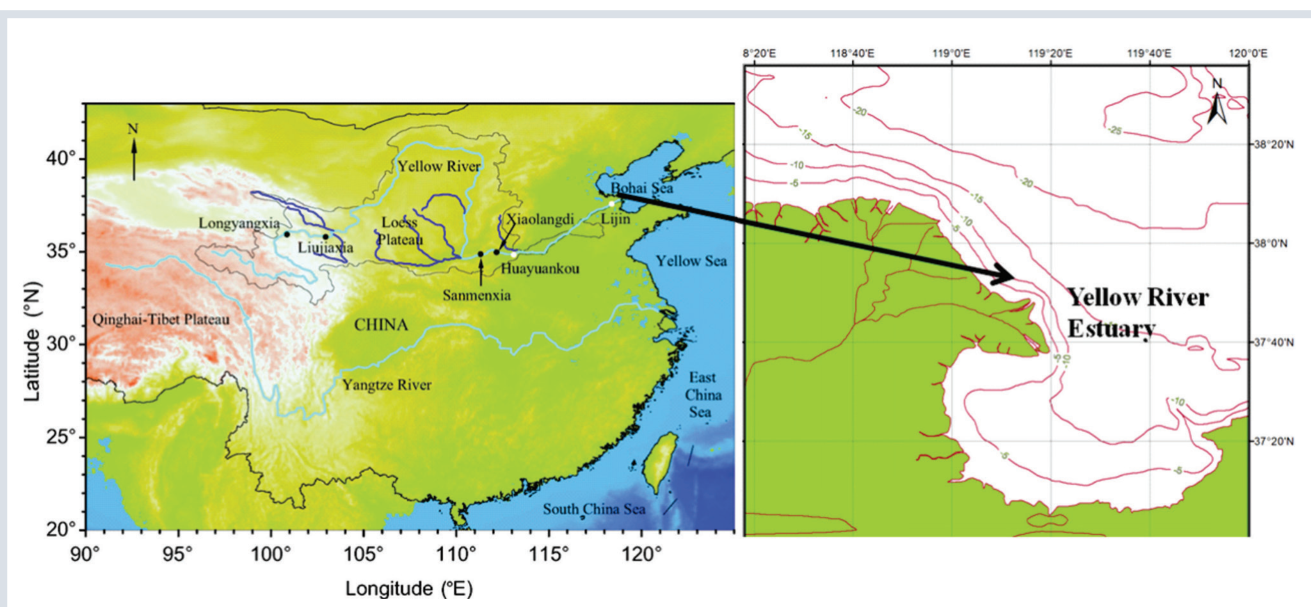
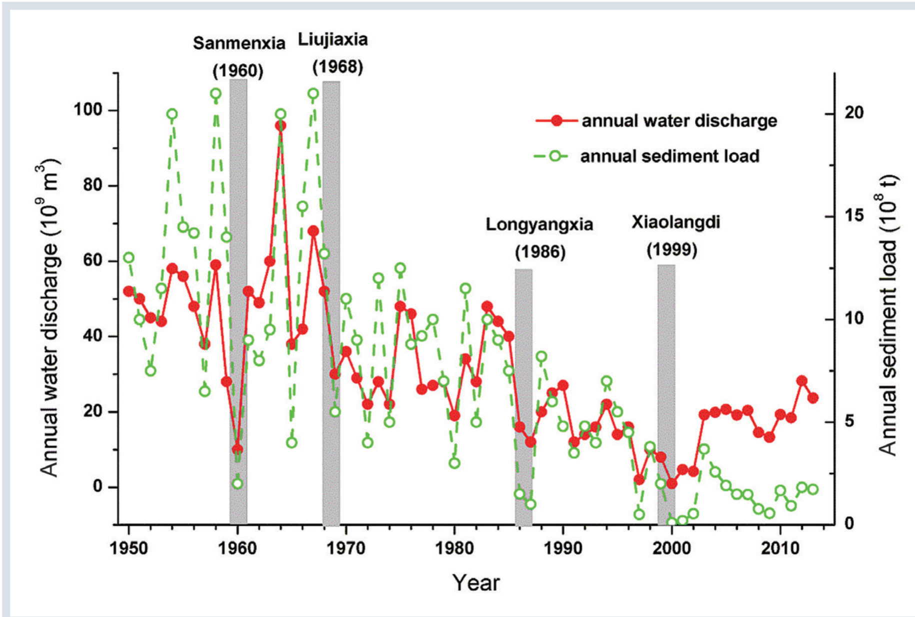


Figure 2. Long-term variation of annual water discharge and sediment load of Yellow River (Wang, et al., 2007; YRCC, 2012, 2013).



basin with a combined storage capacity of 57.4 $\times10^9$ m^3 that virtually matches the average annual discharge of the basin. Among these, four major reservoirs (i.e., Sanmenxia, Liujiaxia, Longyaxia, and Xiaolangdi, constructed in 1960, 1968, 1986, and 1999, respectively) play an important role in the regulation of water supply and retention of sediments (Wang, et al., 2006; Figure 2). As a consequence, the water regime of the Yellow River has changed from one regulated through natural (monsoonal) forces to a highly-regulated hydrologic system (Yu, et al., 2013). After the construction of large dams and reservoirs in the river basin, the seasonal variability of the river discharge considerably weakened. These changes have significant impacts on freshwater supply to the millions of people living in northern China.

The Yellow River is a major source of freshwater for the more than 107 million people living around the river basin. Since the 1970s, water consumption in the river basin increased due to population growth, as well as extensive agricultural development (Huang and Fan, 2004). Dramatic decline in water and sediment discharges of the Yellow River was observed in the past 60 years, especially since the operation of Liujiaxia reservoir in 1968 (Figure 2). Taking the average annual discharge level of 1950–1968 as the reference level, water discharge decreased to 66.9%, 30.8%, and 30.3% of the reference level during 1969–1985, 1986–1999, and 2000–2010, respectively, according to the Lijin Station records (Wang, et al., 2007; Yu, et al., 2013). Since 1972, the zero-flow events in the lower reach of the Yellow River have become a major concern. There were 1,088 dry-channel days from 1972 to 2000, including 86 days in the 1970s, 105 days in the 1980s, and 897 days in the 1990s (Fan and Huang, 2008). The number of zero-flow days peaked at 226 days in 1997, affecting 704 km of channel upstream from the river mouth.

Correspondingly, the sediment load showed a synchronous decreasing trend with the water discharge. The average annual sediment load showed stepwise decreases to 63.2%, 30.1%, and 10.7% against the reference level during 1969–

1985, 1986–1999, and 2000–2010, respectively (Wang, et al., 2007; Yu, et al., 2013).

The altered temporal and spatial distributions of the Yellow River water discharge and sediment load were the result of interaction between climate change and anthropogenic activities, including extensive construction of dams and reservoirs; and intensive implementation measures for soil and water conservation, water consumption and river use regulation. Approximately 51% decrease in the water discharge to the sea was attributed to natural impact represented by decreasing regional precipitation, and 49% mainly to anthropogenic impacts in the river drainage basin (Wang, et al., 2006).

Salinity is one of the most important factors influencing coastal and estuarine ecosystems, and is easily affected by river runoff. With the declining freshwater input to the coastal sea, the average sea surface salinity (SSS) increased by 2 parts per thousand (ppt) in Bohai Sea and by as much as 15 ppt in Laizhou Bay, south of the Yellow River Delta (Lin, et al., 2001; Wu, et al., 2004).

Corresponding with the decrease in runoff from the Yellow River and the reduction of low salinity area ($S < 28$ ppt) in the delta, the diversity, abundance, and recruitment of fish species in Bohai Sea declined, particularly for the fleshy prawn *(Fenneropenaeus chinensis)*. During the main spawning period in spring of 2008, the density of fish eggs decreased to ~30% of the 1982 level (Wang, et al., 2010). In addition, the synchronous decrease in sediment flux to the sea caused alterations in the Yellow River estuary coastline, thereby changing the circulation patterns. These changes further affected the distribution of fleshy prawn eggs and its nursery ground in Laizhou Bay (Huang and Su, 2002).

Coupled with intensive fishing activities, the composition of fish population has changed significantly. Since the 1980s, the dominant, large-size, high economic value, demersal species were replaced by short-lived, low-trophic-level, planktivorous, pelagic species (Jin and Deng, 2000; Figure 3). Traditional commercially targeted fishes, such as the largehead hairtail *(Trichiurus lepturus)*, red seabream *(Pagrus major)*, and Pacific herring *(Clupea pallasii)*, became locally extinct (Shan, et al., 2013). This shift in composition and abundance resulted in major changes in the biological cycle and restoration of the traditional fishery resources.

Approach and Methodology

To alleviate the sharp decrease in freshwater flux to the sea and unfavorable channel deposition of sediments in the lower reach, the Yellow River Conservancy Commission (YRCC) initiated WSR in 2002. The WSR is a human-controlled operational scheme which uses technology to manipulate floodwaters, mainly from the Xiaolangdi reservoir, to deliver the sediment and scour the lower reaches. The WSR is usually implemented once a year during mid-June and lasts for about 20 days. During the WSR, an abrupt increase in water and sediment discharge occurs at the river mouth. The flood amplitude during operation of WSR ranged from 2,400 to 4,000 m^3/s in the lower reach during 2002–2010 in comparison with <1,000 m^3/s when WSR was not in operation (Yu, et al., 2013). Thus, the operation of WSR significantly changed the runoff seasonality of Yellow River from a monsoon-controlled nature to a highly human-regulated system.

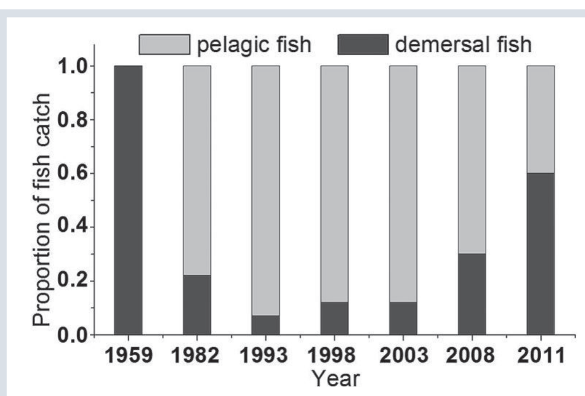
During the short-duration of the discharge pulses, about 27.6% and 48.9% of the annual water and sediment, respectively, were delivered to sea (Yu, et al., 2013).

Through WSR, it was expected that: (1) the abrupt water discharge would reduce the riverbed and prevent flooding in the lower reach of Yellow River; (2) the sediment load would help maintain the stability of Dongying coastline; and (3) the freshwater and nutrients discharged into the sea would help maintain the spawning ground function of the Yellow River estuary. These functions were linked with the mandates of several government departments such as YRCC, the Water Resources Bureau of Dongying, the Ocean and Fisheries Bureau of Dongying, and others. Hence, WSR was incorporated as an essential management measure in the Dongying ICM program, which started in 2005.

Results

The river channel in the lower reach was markedly scoured and its water transportation capacity significantly improved. No zero-flow event was recorded since the operation of WSR and the freshwater flux to the sea gradually increased in recent years. This facilitated positive ecological responses: (1) the low salinity area (S < 28 ppt), which is vital to sustain fish spawning, exceeded 370 km^2 during June – November from 2004 to 2009 (Xiao, et al., 2012); (2) the density of fish eggs in the Yellow River estuary increased from below 1.5 ind/m^3 in 2006 to over 2 ind/m^3 in 2014 (unpublished data); and (3) the proportion of demersal fish in the total catch gradually increased from about 12% in 2003 to 30% in 2008 and exceeded the proportion of pelagic fish in 2011 (ca. 60%) (Shan, et al., 2013; Figure 3).

Figure 3. **Proportion of fish assemblage structure caught in Yellow River** (Shan, et al., 2013).



Lessons Learned

Opportunities to improve the current WSR scheme. Although there was a positive ecological impact on the Yellow River estuary, there are still opportunities to improve the current WSR scheme. Generally, WSR activities are performed in mid-June or early July, but the main spawning period for most fish species is in May (Jin, et al., 2013; Shan, et al., 2013). This mismatch in freshwater replenishment time cannot provide sufficient flow to the low salinity area for spawning (Xiao, et al., 2012). In addition, the short-duration sediment discharge pulses had a great impact on the benthic environment. Field investigations in the Yellow River estuary during 2004–2010 showed that the biomass and individual density of benthos around the river mouth were significantly lower than those of the surrounding areas. Therefore, the time, duration, amplitude of flood peaks, and volume of released water should be further adjusted via the WSR scheme in order to meet the ecological freshwater requirement of the estuary and sustain the ecological functions of inshore fish spawning grounds.

References

Fan, H. and H.J. Huang. 2008. Response of Coastal Marine Eco-environment to River Fluxes into the Sea: a Case Study of the Huanghe (Yellow) River Mouth and Adjacent Waters. *Marine Environmental Research*, 65:378–387.

Huang, D.J. and J.L. Su. 2002. The Effects of the Huanghe River Delta on the Circulation and Transportation of Larvae. *Acta Oceanologica Sinica*, 24:104–111. (In Chinese with English abstract).

Huang, H. and H. Fan. 2004. Monitoring Changes of Nearshore Zones in the Huanghe (Yellow

River) Delta since 1976. *Oceanologia et Limnologia Sinica*, 35:306–314.

Jin, X.S. and J.R. Deng. 2000. Variations in Community Structure of Fishery Resources and Biodiversity in the Laizhou Bay, Shandong. *Biodiversity Science,* 8:65–72. (In Chinese with English abstract).

Jin, X.S., X.J. Shan, X.S. Li, J. Wang, Y. Cui, and T. Zuo. 2013. Long-term Changes in the Fishery Ecosystem Structure of Laizhou Bay, China. *Science China: Earth Science*, 56:366–374.

Lin, C., J. Su, B. Xu, and Q. Tang. 2001. Long-term Variation of Temperature and Salinity of the Bohai Sea and Their Influence on Its Ecosystem. *Progress in Oceanography*, 49:7–19.

Milliman, J.D. and M.E. Ren. 1995. River Flux to the Sea: Impact on Human Intervention on River System and Adjacent Coastal Areas, pp. 70-71. In: Climate Change: Impact on Coastal Habitation. Edited by D. Eisma. CRC Press Inc, Lewis Publishers, Boca Raton, Florida, USA.

Shan, X.J., P.F. Sun, X.S. Jin, X.S. Li, and F.Q. Dai. 2013. Long-term Changes in Fish Assemblage Structure in the Yellow River Estuary Ecosystem, China. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 5(1):65–78.

Wang, A.Y., R.J. Wan, and X.S. Jin. 2010. Decadal Variation of Ichthyoplankton Biodiversity in Spring in Laizhou Bay of the Bohai Sea. *Progress in Fishery Sciences*, 31(1): 19–24. (In Chinese with English abstract).

Wang, H.J., Z.S. Yang, Y. Saito, J.P. Liu, and X.X. Sun. 2006. Interannual and Seasonal Variation of the Huanghe (Yellow River) Water Discharge over the Past 50 Years: Connections to Impacts from ENSO Events and Dams. *Global and Planetary Change*, 50:212–225.

Wang, H.J., Z.S. Yang, Y. Saito, J.P. Liu, X.X. Sun, and Y. Wang. 2007. Stepwise Decreases of the Huanghe (Yellow River) Sediment Load (1950-2005): Impacts of Climate Change and Human Activities. *Global and Planetary Change*, 57:331–354.

Wu, D., L. Mu, Q. Li, X. Bao, and X. Wan. 2004. Long-term Variation Characteristic of the Salinity of the Bohai Sea and the Possible Dominant Factor. *Progress in Natural Science*, 14:191–195. (In Chinese with English abstract).

Xiao, C.C., L.J. Zhang, and J.Q. Yang. 2012. Study on the Change of Low-salinity Area in the Yellow River Estuary and Its Coastal Zone from 2004 to 2009. *Periodical of Ocean University of China*, 42(6):40–46. (In Chinese with English abstract).

YRCC (Yellow River Conservancy Commission). 2012. Yellow River Sediment Bulletin. YRCC, Ministry of Water Resources, PR. China. 7 p.

YRCC (Yellow River Conservancy Commission). 2013. Yellow River Sediment Bulletin. YRCC, Ministry of Water Resources, PR. China. 7 p.

Yu, Y.G., H.J. Wang, X.F. Shi, X.B. Ran, T.W. Cui, S.Q. Qiao, and Y.G. Liu. 2013. New Discharge Regime of the Huanghe (Yellow River): Causes and Implications. *Continental Shelf Research,* 69:62-72.