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Editorial

Key strategies for the restoration of Dongting Lake in Middle Yangtze, China

The Yangtze River Economic Belt (YREB) has been established since 2015 by the Chinese Government as a strategy in regional economic development. Approximately 40% of China's polulatin resides in the YREB aera, and YREB contributes more than 40% of the total Gross Domestic Product of China (Chen et al., 2017). With rapid economic growth and urbanization, the YREB has experienced challenges of severe environmental pollution (Ma et al., 2019; Tan et al., 2020; Yuan et al., 2020). Because of the extensively promoted green development philosophy by the Chinese Government, China's national strategy emphasizes the priority of environmental protection over economic growth (Lu *et al.*, 2019). The ecological quality of the Yangtze River Basin (YRB) is critical to the sustainable development of the YREB. However, the construction and the impoundment of cascade dams in the Three Gorges Dam (TGD) in the upper Yangtze has brought some negative impact, including hydrological regime changes and drastic decreases of river sediments in the middle and lower Yangtze (Guo et al., 2019; Qiu, 2011), which cannot be ignored in China's economic development in the future.

The largest dam in the world, the TGD has impounded for more than fifteen years since June 2003. The construction of TGD has faced numerous criticisms over the potential adverse impacts, and China has recognized problems with the TGD (Qiu, 2011). This world-famous dam has brought significant economic benefits to China, as well as the benefits of flood control. However, it also caused some environmental problems to the downstream of the Yangtze River, affecting an area of more than 600,000 km^2 over eight provinces (Wang et al., 2019; Wang et al., 2021). Among various environmental issues result from the TGD, changes in the hydrological process of downstream have been considered to be most important, especially to the two largest freshwater lakes of China (Poyang Lake and Dongting Lake-DTL) (Feng *et al.*, 2013).

As one of the "Double Kidneys" of Yangtze River, DTL plays an important role in the protection of ecological quality of the YRB. An example of the importance of DTL is on the fishery resources and the resident of migratory birds. As one of the first nature reserves in "The List of Wetlands of International Importance in China", DTL mainly receives water and suspended sediments from the Yangtze River via three channels, including Songzi River, Hudu River and Ouchi River. The runoff accounts for about 30% of water sources to the DTL, and the suspended sediments constitute most suspended sediment sources to the DTL (Zhou et al., 2016; Dai et al., 2005). With the maximum inundation areas reaching > 2200 km^2, DTL has a considerable influence in not only regulating the water cycle and sediment budget of the Yangtze River, but also providing local water supplies and modulating dry/wet conditions (Feng *et al.*, 2013). However, the operation of the TGR has seriously disrupted these services since 2003.

In the past nearly 60 years, the annual runoff of the DTL from the Yangtze River maintained a long-term downward trend, which was accelerated by TGD (Fig. 1a). The mean quantity of runoff during the post-TGD period (2003–2014) decreased by more than 40% compared with the level in the pre-TGD period (1960–2002), while the runoff diversion ratio from the DTL to the Yangtze River decreased from 19% to 11% (Fig. 1b). There was a significantly decreasing trend (3.6%/year) in the inundation area of the DTL since the TGD's impoundment in 2003 (Feng *et al.*, 2013). In addition, the regulation of the TGD has great impacts on the water resource balance of the DTL (Fig. 1c), which has led to frequent and severe droughts in the DTL in the last decades (Feng *et al.*, 2012). Inadequate runoff has become a major challenge for ecological restoration in the DTL, much more severely than water pollution.

Sediment load of the DTL from the Yangtze River has decreased by over 90% after TGD impoundment, and most of the decreases occurred in the first several years. By 2015, sediment load from the Yangtze River fell to only one million ton per year (Fig. 1d). The decline in sediment load can be attributed to the changes in water discharge and sediment concentration from the Yangtze River, which are both influenced by the TGD (Guo *et al.*, 2019). As a result, the bottom of DTL has changed from sedimentation to erosion. The annual sediment trapping of the DTL has reached below zero since 2008, and the average sediment trapping ratio has decreased from 72% (pre-TGD period) to -49% (post-TGD period) (Fig. 1e and 1f). In this case, the historical lakebed siltation caused by large amounts of suspended sediments from the Yangtze River is no longer a problem to the DTL.

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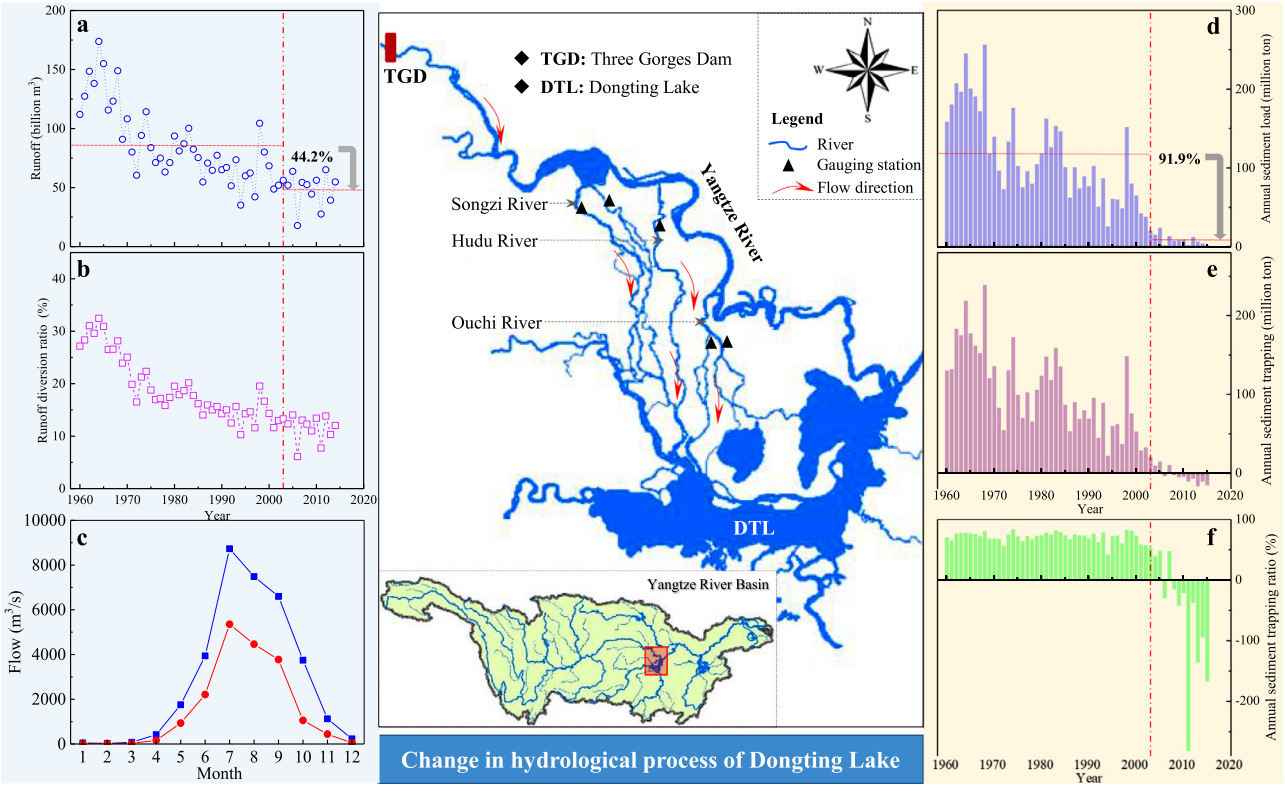

Fig. 1 – Location of the Dongting Lake (DTL) in the Yangtze River Basion and changes in the hydrological process in the past 60 years. (a) total runoff of three channels (Songzi River, Hudu River and Ouchi River), (b) runoff diversion ratio of the DTL to the Yangtze River, (c) total flow of three channels, (d) annual sediment load of three channels, (e) annual sediment trapping of the DTL, (f) annual sediment trapping ration of the DTL.

In order to restore runoff diversion capacity from the Yangtze River for ecological restoration of the DTL, proper dredging strategy should be carried out in the three channels linking the Yangtze River to DTL. Although the Chinese Government set out a strict management plan for sand mining in the YRB in 2012 (Chen *et al.*, 2017b), it is in great request to dredge the three channels, which have been silted up seriously due to the sediment transport of the Yangtze River. On the one hand, precipitous descent of sediment load due to the TGD has led to persistent erosion in the Yangtze River main stem since 2003 (Guo *et al.*, 2019). This process keeps widening the height difference between the Yangtze River main stem and its channels. On the other hand, regulation on TGD has sharply lowered the flow of the three channels from June to October (Fig. 1c). As a result, the transport of water from the Yangtze to the DTL is difficult, but dredging the three channels will be an effective and feasible way to overcome this problem.

In summary, our results show that a new lake-to-mainstem transport pattern of water and sediments is forming because of the impoundment of TGD. We should take advantages of this new pattern to maintain the ecological health and longevity of DTL. We suggest the Chinese Government to reasonably dredge the three channels for better connecting the Yangtze River and the DTL. The benefits of dredging channels for DTL include the supply of more water resources from the Yangtze River for ecological restoration requirements and less siltation because of low sediment load. For, Improving the runoff diversion fron the Yangtze River to DTL by dredging the three channels could help to eliminate floods. Dredging the three channels is a crucial strategy to maintain aquatic ecosystem health of DTL. More studies are needed on how to dredge the channels in the future.

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