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Variation of water level in Dongting Lake over a 50-year period: Implications for the impacts of anthropogenic and climatic factors

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SUMMARY

Understanding the variation regularity of water level and the potential drivers can provide insights into lake conservation and management. In this study, inter- and inner-annual variations of water level in Dongting Lake during the period of 1961–2010 were analyzed to determine whether anthropogenic or climatic factor should be responsible for the variations. The results showed that water level decreased significantly during the period of 1961–1980, while increased significantly during the period of 1981–2002 at the 5% significance level. However, the variation trend of water level after 2002 did not reach a significant level. The variation in the dry season was more obviously than that in the wet season. The date when water level was firstly below 24 m during the period of 2003–2010 appeared about 27 days earlier than usual, and the date was even advanced to mid-September in 2006. As for the duration, water level was below 24 m for about 185 days in the period of 2003–2010 and 20–30 days longer than the other two periods. In conclusion, water level might be influenced by a combination of anthropogenic and climatic factors, with rainfall probably as the main driver responsible for hydrological alteration during the period of 1961–1980 and 1981–2002 while dam construction as the main driver during the period of 2003–2010. Under the circumstance of uncontrollable climate change, effective measures for reservoir operation should be put forward to maintain the ecological integrity and ensure water release and storage capacity of aquatic ecosystems.

1. Introduction

Lakes not only provide valuable economic resources for human beings but also play important roles in regional environmental and ecological issues, such as hydrological cycle and wetland vegetation growth (Wantzen et al., 2008a). Water level, a sensitive sentinel of changes, could influence the biodiversity community patterns and functions in lake ecosystems. In recent years, the variations of water level in lakes all over the world have attracted increasing global attention from the filed of engineering design, ecological conservation and environmental management (Wantzen et al., 2008b; Wen et al. 2011; Reid et al., 2013).

Considerable researches have been performed on hydrological alterations to maintain a healthy river ecosystem (Timme et al., 2005; Russell et al., 2009; Adamowski et al., 2013; Al-Faraj and Scholz, 2014). Some of the researches focused on anthropogenic activity (McDonald et al., 2009; Ou et al., 2011; Gao et al., 2014), while other works were concerned with climatic factor (Guo et al., 2012; Song et al., 2014). Numerous studies have shown that natural and anthropogenic perturbations might be responsible for the variation of water level (Scuderi et al., 2010; Wang et al., 2011; Zeng et al., 2013a; Zeng et al., 2013b). Anthropogenic activity, such as agriculture, dam construction, reservoir operation, landscape modification, river channelization etc, would affect the lake hydrological processes and change water level (Altinbilek, 2002; Xu and Milliman, 2009; Sun et al., 2012). Dam constructions especially the large ones have been pointed out that they would bring some new challenges in hydrological regime of the global river systems (WCD, 2000; Li, 2009). Meanwhile, climatic factor as one of important inductive factors has been in hot debate for a long time. It may alter water level by precipitation, evaporation, temperature variation (Ludwig et al., 2014). Climate-induced changes may affect the fundamental ecological function and species distribution in lake ecosystems (Woodward et al., 2010; Pall et al., 2011; Holm et al., 2012). Numerous previous researches indicated that the alteration

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of water level caused either by anthropogenic or climatic factor could result in adverse and lasting impacts on the ecosystem function, such as natural habitats loss and fragmentation (Nilsson et al., 2005; Xu and Milliman, 2009; Adamowski et al., 2013; Wang et al., 2013; Yuan et al., 2014). The variations of water level, especially the extent, frequency and duration, play important roles in affecting the ecological processes and patterns of lakes. Even small changes in water regime can lead to some irretrievable ecological results, such as dwindling of lake area, degradation of water ecosystem, and damage of biodiversity (Jöhnk et al., 2004; Fang et al., 2006; Wilcox and Nichols, 2008; Li et al., 2009; Lishawa et al., 2010; O'Farrell et al., 2011; Paillisson and Marion, 2011; Song et al., 2014).

Dongting Lake, the second largest freshwater lake in China, is directly connected with the Yangtze River. Among the dams constructed in the Yangtze River, the Three Gorges Dam (TGD) is one of the world's largest dams, which began to be built in 1994 and firstly impounded water and sediment discharge in 2003 (Xu and Milliman, 2009; Du et al., 2011). Numerous researches indicated that the impoundment of the TGD changed the hydrological regime downstream and the patterns of the lake wetlands, which in turn disturbed the ecological function of the wetlands as habitats for migratory birds (Tullos 2009; Sun et al., 2012; Wang et al., 2013). Many attentions were paid to the influence of TGD on hydrological alteration in Dongting Lake, especially in recent years (Xu and Milliman, 2009; Gao et al., 2013). According to statistics of Hunan Provincial Water Resources Department, four severe droughts occurred in Dongting Lake during 2000–2010 (in 2000, 2002, 2005 and 2006, respectively). The coincidence between occurrence of droughts and the operation of TGD has attracted much attention from all over the world. Besides, it triggered a debate whether TGD or climatic factor should be responsible for the variation (Xu and Milliman, 2009; Dai et al., 2010). However, the effects of climatic factor were neglected to some extent. Moreover, the relationship between water level variation and anthropogenic or climatic factor keeps still unclear in Dongting Lake.

Consequently, it is urgent to achieve the better understanding of the alteration of water level under the condition of anthropogenic and climatic factors. We took both anthropogenic and climatic factor into consideration in this paper, rather than single factor analysis. And it will be beneficial for providing theoretical basis and potential insight into the understanding of ecological environment changes in Dongting Lake. Specifically, the objectives of this study were (1) to reveal the inter- and inner-annual variations of water level during the period of 1961–2010; (2) to estimate the alteration in the wet and dry seasons; (3) to determine whether anthropogenic or climatic factor should be responsible for the variations.

2. Materials and methods

2.1. Study area

This study was conducted in Dongting Lake, which is situated in the middle reach of Yangtze River region (approximately 28°30′N–30°20′N, 111°40′E-113°10′E) (Ding and Li, 2011; Li et al., 2013). Dongting Lake, the second largest freshwater lake in middle China, is also one of the most important international wetlands. This region locates in the subtropical monsoon climate zone, with a wet season between July and September while a dry season between November and next February. Dongting Lake is directly connected with the Yangtze River. The water from the Yangtze River flows into the lake via the "Three Outfalls" (Songzi River,

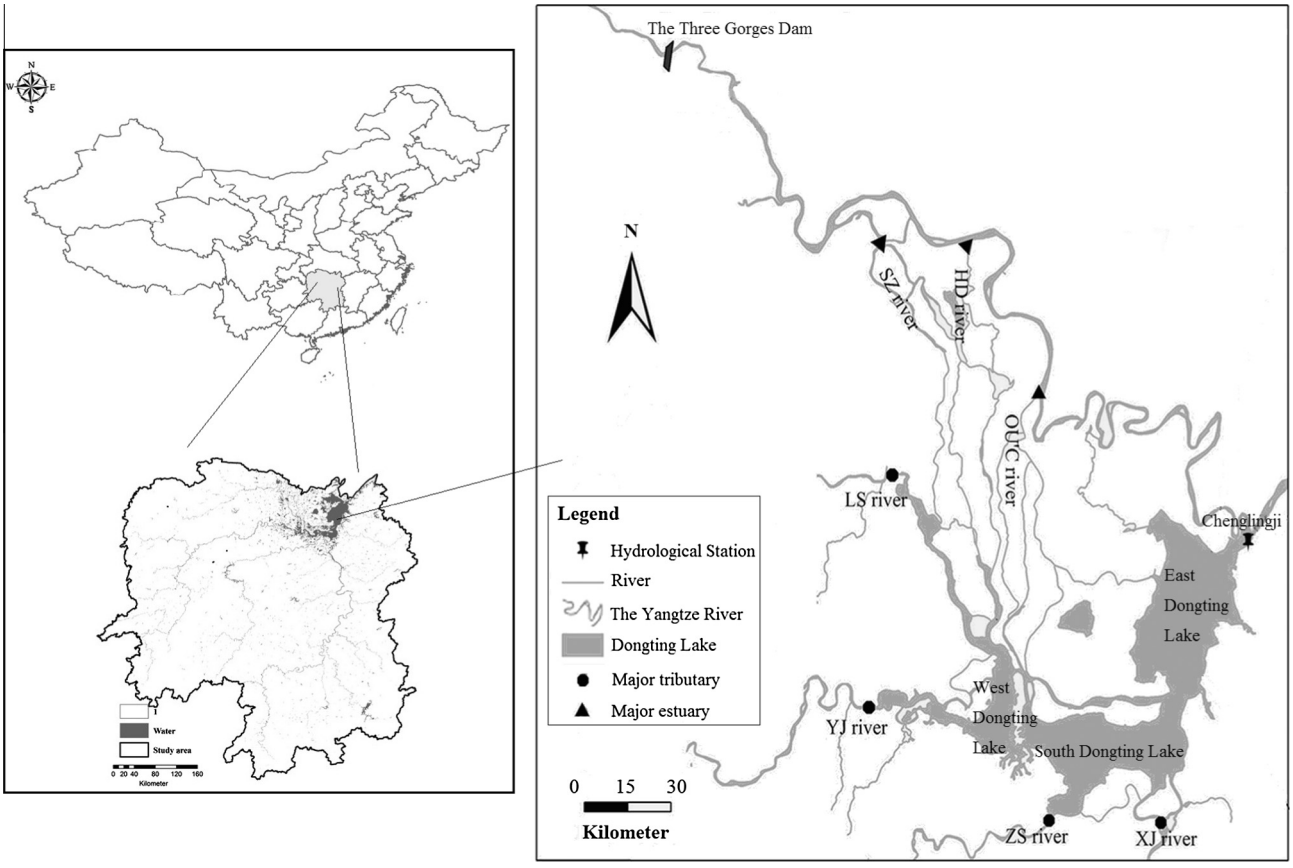

Fig. 1. Diagram of Dongting Lake. SZ – Songzi; HD – Hudu; OUC – Ouchi; LS – Lishui; YJ – Yuanjiang; ZS – Zishui; XJ – Xiangjiang.