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Immediately downstream effects of Three Gorges Dam on channel sandbars morphodynamics between Yichang-Chenglingji Reach of the Changjiang River, China

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Abstract: Sandbars are of vital ecological and environmental significance, which however, have been intensively influenced by human activities. Morphodynamic processes of sandbars along the Yichang-Chenglingji Reach of the Changjiang River, the channel immediately downstream of the Three Gorges Dam (TGD), are assessed based on remote sensing images between 2000 and 2016. It can be found that the entire area of sandbars reduces drastically by 19.23% from 149.04 km^2 in 2003 to 120.38 km^2 in 2016, accompanied with an increase in water surface width. Owing to differences in sediment grain size and anti-erosion capacity, sandbar area in the upstream sandy gravel reach (Yichang-Dabujie) and downstream sandy reach (Dabujie-Chenglingji) respectively decreases by 45.94% (from 20.79 km^2 to 11.24 km^2) and 14.93% (from 128.30 km^2 to 109.14 km^2). Furtherly, morphological evolutions of sandbars are affected by channel type: in straight-microbend channel, mid-channel sandbars exhibit downstream moving while maintaining the basic profile; in meandering channel, point sandbars show erosion and deposition in convex and concave bank respectively, with mid-channel sandbars distributing sporadically; in bending-branching channel, point sandbars experience erosion and move downstream while mid-channel sandbars show erosion in the head part along with retreating outline. We document that the primary mechanism of sandbars shrinkages along the Yichang-Chenglingji Reach can be attributed to TGD induced suspended sediment concentration decreasing and increasing in unsaturation of sediment carrying capacity. Additionally, channel type can affect the morphological evolution of sandbars. Along the Yichang-Chenglingji Reach, sandbars in straight-microbend channel are more affected by water flow than that in bending-branching channel.

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1 Introduction

A variety of alluvial sandbars are formed by riffle accumulations, floodplain avulsions, degradation of channel branches, and incision of existing bars (Knighton and Nanson, 1993; Xu, 1997; Wyrick and Klingeman, 2011), which undertake critical hydraulic and environmental functions, including stabilizing channel configurations, regulating floods and providing valuable habitats for a large number of organisms (Bridge, 1993; Ashworth *et al*., 2000). However, sandbars are one of the most threatened river geomorphological features as they are suffering from direct and accumulative hydrodynamic impacts (Kearsley *et al*., 1994; Phillips *et al*., 2005; Francis *et al*., 2010; Raška *et al*., 2017). Markedly, with the release of large-scale low suspended sediment concentration (SSC) flows from upstream dams, sandbars geomorphological systems can experience serious degradation in the channel immediately downstream of the dam (Petts, 1979; Friedman *et al*., 1998; Brandt, 2000a; Grams and Schmidt, 2005; Kleinhans *et al*., 2011). Understanding sandbars morphodynamics in response to water projects and the associated formation mechanisms is extremely pivotal critical and urgent for hydraulic engineering, channel regulation and fluvial management (Friedman *et al*., 1998; Graf, 2005; Magilligan and Nislow, 2005; Wyrick and Klingeman, 2011; Asaeda and Rashid, 2012; Dai *et al*., 2014; Grabowski and Gurnell, 2016).

To investigate how channel sandbars geomorphological processes respond to dam and reservoir construction, Petts (1979) reviewed potential sandbars variations subsequent to changes in discharge and bed-sediment load along multiple British rivers. Phillips *et al*. (2005) documented that the decreased channel slope and degradation in sandbars morphology can be attribute to the dam induced sediment supply decline with unchanged discharge regime. Raška *et al*. (2017) indicated that sediment starvation and erosion following the construction of dams and lock chambers caused island extinction in individual river segments. Generally, river sandbars formation and destruction are directly related with the dam induced downstream channel features variation, which have received special attentions in Britain (Petts, 1979), Australia (Erskine, 1985), New South Wales (Sherrard and Erskine, 1991), Bangladesh (Ashworth *et al*., 2000), American rivers (Graf, 2006; Hazel *et al*., 2006; Csiki and Rhoads, 2010; Skalak *et al*., 2013), Spain (Ibisate *et al*., 2013), France (Provansal *et al*., 2014) and Czech (Raška *et al*., 2017) rivers. Fluvial channel and drainage basin are critical zone of earth surface processes, especially for those immediately downstream of large dams. However, little information is available on the sandbars morphodynamics along the mega-river of Changjiang (Yangtze) River in China, which are regulated by Three Gorges Dam (TGD) since 2003, currently the world's largest water conservancy dam.

The Changjiang River originates from the Qinghai-Tibet Plateau and flows eastward into the East China Sea, with a length more than 6300 km (Figure 1a). The catchment covers an area of over 1.8×10^6 km^2 and includes multitudinous geomorphological, vegetation and tributary types (Dai and Liu, 2013; Wei *et al*., 2014). Since June 2003, the TGD has trapped vast majority of sediment in its reservoir, without significantly modifying downstream flow magnitude (Dai *et al*., 2015). Thus coupling of drastically decreased suspended sediment concentration (SSC) and discharge (SSD) with almost unchanged water discharge produces