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Critical review

Sustaining China's large rivers: River development policy, impacts, institutional issues and strategies for future improvement

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ABSTRACT

The sustainable management of China's rivers is very important to the well-being of both the environment and its people. Yet the country's rivers are now facing imminent threats from river overexploitation. The deteriorating condition serves as a stark reminder that relevant policies must be revised to ensure their wiser stewardship. In this short critical review, we first briefly stated river development history and various impacts arising from river overexploitation. We then elaborated the issues in river management, which connived numerous behaviors neglecting river degradation happened at all institutional levels. Based on the weakness, we proposed some policy recommendations to sustain China's rivers and balance river development and conservation. The article concludes by proposing the development of a national river protection law to reinforce integrated river management, improve the implementation of environment impact assessments, and fulfill long-term goals for river conservation and sustainable development.

Contents

1. Introduction

The sustainable management of China's rivers is crucial to the well-being of both the environment and the country's people. Rivers in China provide enormous benefits: they irrigate 48% of arable land to safeguard 75% of food production (Ministry of Water Resources, 2009), supply water to generate 96% of the country's energy (Wilson Center, 2015), on top of being home to more than 6000 freshwater species (The State Council of the P.R. China, 2006). However, despite their immense importance, the country's

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rivers are now facing imminent threats from severe human interference (Word Bank, 2009).

The recently inaugurated East and Middle routes of the South-to-North Water Transfer Project (SNWTP), along with many other mega-dams like the Three Gorges Dam (TGD), are salient examples of how the country are shredding its rivers. The deteriorating condition is a stark reminder that policies must be revised to ensure their wiser river stewardship. As China's already large population continues to burgeon amidst rapid economic growth, the demand for freshwater and other riverine commodities has increased dramatically. Although the current shortfall in freshwater in China is 50 billion m^3 per year, the freshwater demand is projected to exceed supply by 25% by 2030 (Addams et al., 2009), which will exacerbate already existing conflicts between the freshwater demands of river ecosystems and human beings. Therefore, the effective governance of rivers is the bedrock upon which a sustainable Chinese society must be built.

2. River development and river overexploitation

Since economic reform initiated in 1979, China's economy has experienced remarkable growth, but the rapid economic growth has been associated with unprecedented progress in river development to obtain hydropower energy, freshwater and other resources from its large rivers. At present, growing investments and stimulus policies continued interest in water infrastructure projects (hydropower dams, water transfer projects and irrigation systems) to exploit the rivers, particularly with hydropower installed capacity and eventually participation in carbon markets, which have also contributed to the upswing. The country's rivers are now facing imminent threats from the unprecedented river development and anthropogenic disturbances.

Including the world's largest hydropower project (the TGD), China's rivers have become the home to the world's largest number of reservoirs (98,000) with the world's largest hydropower capacity. China has also constructed over 45,000 small hydropower (SHP) dams on the small streams, supplying 97% of total renewable energy demand in rural areas. Taking the reservoirs still under construction into account, China has created a total reservoir storage capacity of around 1000 billion m^3 in only 50 years.

Furthermore, China has believed that diverting water from rivers can remodel the country's spatially and temporally uneven water distribution. Aside from the SNWTP, numerous other water diversion projects (totaling a length of over 4000 km) have also been constructed to meet growing water demands in agriculture, industry, and domestic uses. Total water withdrawals have jumped from 103 billion m^3 in 1940 to 600 billion m^3 in 2013 (National Bureau of Statistics, 2014). Almost all large rivers in China are now being diverted to surrounding regions or even to faraway regions thousands of kilometers away.

In the released "Twelfth-Five Year Energy Plan", the State Council proclaimed that China will double its hydropower capacity to 1200 billion kW h per year by 2020. It has planned 13 key hydropower bases to build more and bigger dams, many of which are on trans-border rivers, such as the Salween, Mekong (Lancang) and Brahmaputra rivers. The ongoing hydropower plan will cause the country's only two remaining free-flowing rivers (Salween and Brahmaputra) to be dammed successively. The upcoming damage to the two river ecosystems is inevitable.

3. The heavy prices

Despite the considerable economic payoffs, the river overexploitation is undermining the capacity of rivers to fulfill their ecological functions. China's large rivers have paid heavy prices for river overexploitation over the past decades.

The 98,000 reservoirs alone regulate nearly 70% of the country's total annual water discharge. The large reservoir storage capacity, coupled with the huge amount of water withdrawals, has resulted in many of China's rivers being unable to maintain minimum environmental flow (Yang and Lu, 2014). Approximately 28,000 rivers (watershed area $\geqslant 100\ km^2$) across China have completely dried up due to high water regulation (i.e., from 100% to more than 300% for individual river catchments) (Ministry of Water Resources and Natural Bureau of Statistics, 2011). Despite possible statistical discrepancies, such an extreme decline undoubtedly indicates the adverse impacts of water overuse on river health, distribution, and accessibility.

The numerous dams, large and small, have also heavily fragmented the integrity of the rivers. Large rivers, like the Yellow, Yangtze, and Pearl rivers have at least 10 cascade dams each along their main stems. Most of these dams, including the TGD, are absent of integrated fish ladders for migratory fishes. Consequently, these fishes' immigration routes are interrupted and the biodiversity greatly diminished. For example, in the initial three years following the completion of the TGD, the annual harvest of carp and the abundance of carp eggs were decreased by 50–70% and 95%, respectively (Xie et al., 2007). The World Wildlife Foundation (WWF) and China's Ministry of Agriculture (MOA) jointly reported that only 17 fish species were present in the upper Yangtze River after their latest scientific survey, a dramatic decline from more than 140 species found decades ago (WWF and MOA, 2013).

Water regulations have also caused downstream sediment starvation, lower water levels due to channel incision, and less water storage in adjoining floodplain lakes. For example, with sharply reduced sediment delivery due to the retention by the TGD and other large dams in the upper Yangtze reaches, the channel bed of the middle and lower Yangtze River has suffered from serious deepening (Yang et al., 2014). The resultant water level reduction has exacerbated the recent extreme droughts in the Dongting and Poyang lakes, the two largest freshwater lakes in China (Zhang et al., 2015). These external human impacts have significantly deteriorated river ecosystem health.

River-linked floodplain ecosystems, including floodplain lakes and wetlands, have also been anthropogenically disturbed and disconnected from rivers. During the 1950–2010 period, for example, the middle and lower reaches of the Yangtze River lost two thirds of their lakes to land reclamation for agriculture and industrial development (WWF, 2012). The flow reduction in the rivers was also a major cause to the drastic shrinkage and drying up of numerous lakes in North and South China (Tao et al., 2015; Yang and Lu, 2014). In fact, almost all lakes in Central and East China have been isolated by nearly 100,000 sluice gates (Ministry of Water Resources and Natural Bureau of Statistics, 2011). The disruption of connectivity to rivers has significantly affected the migration routes of Chinese sturgeons, Yangtze finless porpoises, and other endemic fish species, which adversely affects their reproduction and thus population quantity.

China's rivers are often used as dumping grounds for garbage, disposal materials (e.g., from road constructions), and wastewater. Nationwide, 44% of municipal sewage is directly dumped into rivers, resulting in serious river pollution (Word Bank, 2009). Among the 71 monitored exoreic rivers in 2013, for example, 51 fell into the Grade V standard (that is, unsafe for any use) (The State Oceanic Administration of the P.R. China, 2013). Surprisingly, economic losses induced by river water pollution are conservatively estimated at US$157 billion, or 1.7% of China's gross domestic product (Word Bank, 2009).