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The development of China's Yangtze River Economic Belt: how to make it in a green way?

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The Yangtze River is one of the largest and longest rivers in Asia. The river originates in the Tibet-Qinghai Plateau (headwater reach), passes through the mountainous provinces of Sichuan, Yunnan and Chongqing (upper reach), flows into the Central Plain (middle reach) and Lower Plain (lower reach), and finally empties into the East China Sea in Shanghai (estuary). The Yangtze River Economic Belt (YREB; Fig. 1) has a surface area of 2.1 million km^2, which includes 11 provinces and municipalities from Yunnan and Sichuan in the west to Shanghai in the east. The YREB contributes over 40% of both the population and Gross Domestic Product (GDP) of China [1]. In 2014, the State Council of China developed and implemented a national policy to oversee sustainable development of the YREB [1]. Since then, governmental agencies and departments have been working on ambitious development plans with milestones in 2020 and 2030, that target primarily transportation (water, ground, and air) and urban development sectors. Ideally, this framework will extend from the central government to local authorities. However, the environmental and ecological conditions of the Yangtze River Basin have been heavily impacted by prior anthropogenic activities [2–4]. Since January 2016, the Chinese government has begun emphasizing the ecological conservation component in its development [5]. Although this in itself is an encouraging sign, science-based protocols are lacking to guide this development in a real "green" way (i.e., a sustainable way or a way with minimal environmental impact). In this paper, we present current stressors, environmental and ecological status and challenges in the YREB, and offer policy recommendations on how to include ecological conservation into its development. We also synthesize the findings from multiple field investigations (e.g., field investigations by a team of Chinese Academy of Sciences from August 2015 to January 2016; one field investigation and consultation organized by China Association for Science and Technology) and monitored data (e.g., Ministry of Water Resources and Chinese Academy of Sciences) to provide guidance that could potentially mitigate impacts of future development.

1. Basin wide climate change, anthropogenic stressors, and ecological and environmental deteriorations

1.1. Precipitation and ice melting related hydrological change, and air pollution

Basin wide climate change has been affecting hydrological conditions in major water bodies in the Yangtze River basin. First, typical dry (e.g., the year of 2011) and wet (e.g., the year of 2016) years increase the possibilities of drought and flooding, respectively, throughout the entire basin [6]. Second, the increased ice and snow melting in the headwater region (i.e., the Tibet-Qianghai Plateau Mountains) also increases discharge in adjacent lakes and the Yangtze River mainstem downstream [7]. In addition to hydrological changes, air pollution at a continental scale affects ecological conditions throughout the basin, with the exception of the most extreme headwater regions (the area with the least human disturbance). These effects impact both the terrestrial and aquatic systems, as photosynthesis is potentially reduced by the dense particle concentrations in the air [8].

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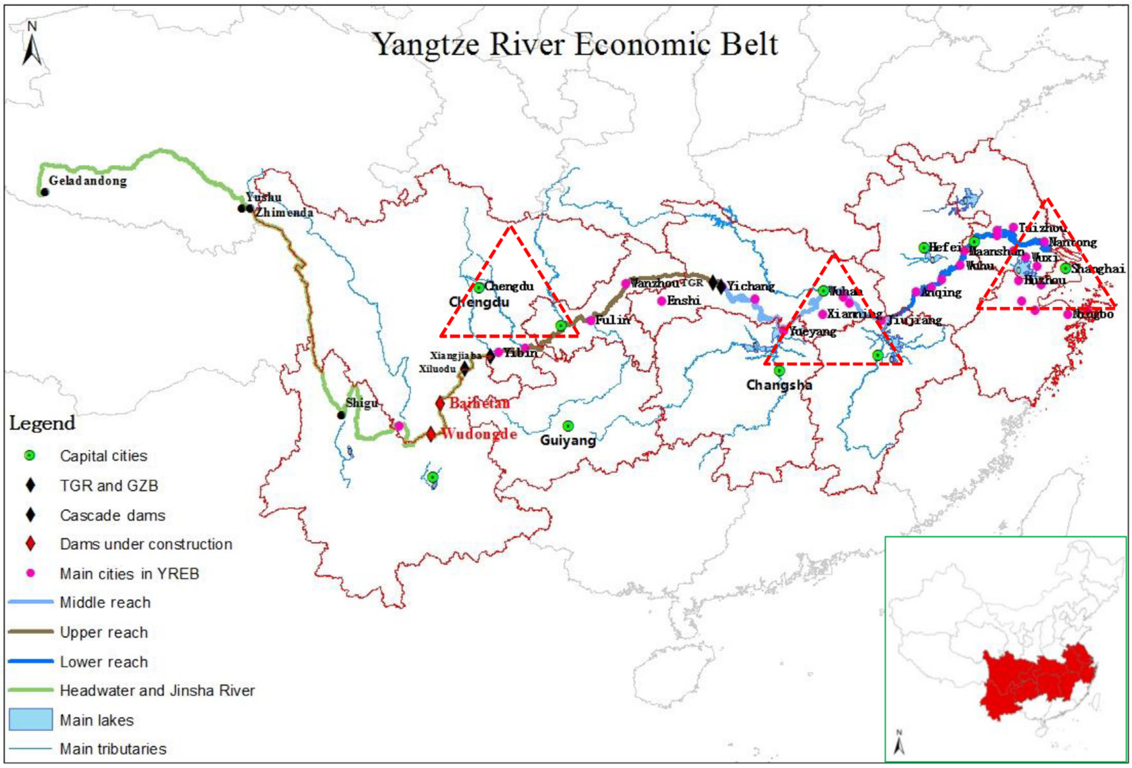

Fig. 1. (Color online) The location of the Yangtze River Economic Belt (YREB) and its urban groups (in red triangles) and subregions. TGR = Three Gorges Reservoir, GZB = Gezhou Ba Dam.

1.2. Urban, industry, agriculture and mining-related water pollution, and overfishing

Water pollution is a basin wide stressor on water bodies throughout the Yangtze River basin. Major stressors include urbanization, industry, mining activities, and agriculture. In 2014, the China State Council released the National New Urbanization Plan [9], which contained components that involved optimizing and promoting the urban group (i.e., a metropolitan area) in the Yangtze Delta (including Shanghai, Jiangsu, and Zhejiang), and fostering urban groups in the Central Yangtze (including Hubei, Hunan, and Jiangxi) and Cheng-Yu (including Sichuan and Chongqing) [9]. These urban groups include the majority of the Yangtze River basin from the estuary downstream to the upper reaches (Fig. 1). Moreover, industry (e.g., chemical-producing factories), agriculture (e.g., animal and crop production), and mining (e.g., metals and phosphorus) discharge additional pollutants into water bodies in the basin [2]. Overfishing is another key human stressor in the basin. Although overfishing primarily targets fishes, it also impacts other aquatic animals indirectly through food-web interactions (e.g., the Yangtze finless porpoise *Neophocaena asiaeorientalis asiaeorientalis*) (Table 1) [10].

1.3. Water quality and ecological problems

Basin wide water quality problems in the Yangtze River drainage include: (a) nutrient (e.g., nitrogen and phosphorus), which drives eutrophication associated issues such as algal blooms; (b) biodegradable organic pollutants (e.g., indicated as chemical oxygen demand or COD); (c) heavy metals such as copper, zinc, lead, arsenic and others; (d) persistent organic pollutants (POPs), which include pesticides and polychlorinated biphenyls (PCBs); and (e) pharmaceuticals and personal care products, such as antibiotics [11]. These water quality problems are severe in both Yangtze River mainstem (e.g., below Hukou) and associated lake areas (e.g., Taihu Lake) throughout the lower reach (Fig. S1). From a basin wide perspective, smaller tributaries have more severe water quality deteriorations because of their limited flows and closer proximities to pollution sources [12]. Due to higher flows and volumes, water quality in most reaches of the Yangtze River mainstem exceeds the national criteria and standards despite that the total wastewater discharge to the river has increased (Fig. S2) [12]. These basin wide ecological problems include: (a) functional extinction of endangered species such as the Yangtze River dolphin *Lipotes vexillifer* and Chinese paddlefish *Psephurus gladius*, and dramatically reduced populations of endangered Chinese sturgeon *Acipenser sinensis* and Yangtze finless porpoise *Neophocaena asiaeorientalis asiaeorientalis* (Table 1) [10]; (b) reduced total number of fish species [10]; (c) reduced naturally reproduced fishery resources such as the four major carps (Silver carp *Hypophthalmichthys molitrix*, Bighead carp *Hypophthalmichthys nobilis*, Grass carp *Ctenopharyngodon idella*, and Black carp *Mylopharyngodon piceus*) and other fish species (Table 1) [10]; and (d) net loss of biodiversity due to extinctions of other terrestrial and aquatic organisms including plants, invertebrates, and migratory birds [11].

2. Key stressors and ecological and environmental deteriorations in different river reaches

2.1. The headwater reach

The headwater reach of the Yangtze River has the least human disturbance of anywhere in the basin. Major stressors are climate-driven hydrological modifications, especially due to increased snow-melt, which increases water levels in the flows of headwater streams and their associated lakes [7]. The riparian area of the headwater reach typically contains low vegetation cover and/or

Table 1
Status and stressors of major aquatic biota in the Yangtze River Basin.

Species or group	Endangered status	Abundance	Distribution	Stressors or reasons of decline/extinct
Yangtze River dolphin Baiji *Lipotes vexillifer*	Critically endangered	200 individuals in 1990, <100 individuals in 1995, and no evidence of its continued existence since 2006	Middle and lower reaches	Overfishing and illegal fishing of their prey, heavy boating traffic, sand mining, construction projects in or near the water, and pollution
Yangtze finless porpoise *Neophocaena asiaeorientalisis asiaeorientalisis*	Critically endangered	2700 individuals in 1991, 1800 individuals in 2006, and 1000 individuals in 2012	Middle and lower reaches, largely in Poyang and Dongting lakes	Overfishing and illegal fishing of their prey, heavy boating traffic, sand mining, construction projects in or near the water, and pollution
Chinese paddlefish *Psephurus gladius*	Critically endangered	60 individuals during 1986–1993, 2 observed individuals during 2002–2003, and now functionally extinct	Entire river reach	Overfishing, habitat degradation due to dams, sand mining, and others
Chinese sturgeon *Acipenser sinensis*	Critically endangered	No natural spawn in 2013 and 2014, maintained through stocking	Entire river reach	Overfishing, habitat degradation due to dams, sand mining, and others
Yangtze sturgeon *Acipenser dabryanus*	Critically endangered	No natural spawn since 2000, maintained through stocking	Entire river reach	Overfishing, habitat degradation due to dams, sand mining, and others
Bigheaded carps: Silver carp *Hypophthalmichthys molitrix* Bighead carp *Hypophthalmichthys nobilis*	NA, important food fishes for human consumption and prey for endangered aquatic animals	Annual larval production decreased over 90% due to dams, maintained through stocking	Entire river reach	Habitat degradation due to dams, sand mining, and others, and overfishing

Source: modified from [10] and also Chinese Academy of Sciences.

consists of barren land, leading to reduced capacity of source water storage and increased erosion along the river banks (Fig. S3). Variations of the hydrological condition in concert with eroded sediments are suspected to affect the aquatic communities in streams and rivers in this region. Scattered animal grazing in the hills along this river reach also may have some limited impacts on the river ecosystem though they are suspected to be of limited scale (Fig. S3).

2.2. The upper reach

The upper reach of the Yangtze River has been experiencing the greatest anthropogenic hydrological modifications due to serially-built cascade dams. These dams include the previously built Gezhouba Dam and Three Gorges Dam in the mainstem near Yichang city, the recently built Xiangjiaba Dam and Xiluodu Dam in the upper reach mainstem (called Jinshajiang), and numerous smaller tributary dams. In addition, there are many more dams under construction or planned for the future in the Jinshajiang (Figs. 1, S3). Although these dams have created many large reservoirs that serve other purposes, they blocked river channels for fish migration and disrupted riverine food webs. Ecological and environmental conditions in the upper reach include: (a) increased sediment accumulation above the dams, and reduced sediment transport and altered flow regimes below the dams (Table S1; Figs. S3 and S4); (b) blocked migration routes which has limited some fishes from completing their life history processes [10]; and (c) loss of riverine fish species that require more lotic habitats [10]. Overall, these dams were not only affecting the Yangtze River upper reach, but also fisheries and ecological processes in downstream reaches and the estuary [10].

2.3. The middle reach

The middle reach of the Yangtze River has been experiencing the highest level of sand mining in the entire basin, especially in the areas of Dongting and Poyang lakes (Fig. S3). Many sand mining vessels in the Dongting and Poyang lake areas operate on constant 24 h per day/7 days per week schedules, which removes the only substrate and habitat for aquatic animals in the lakes and adjacent river channels. In addition, dams or hydraulic sluices were built in most lakes to impede connections between the Yangtze River and the lakes. River channels were deepened and widened to meet navigation purposes (Fig. S3). Overfishing in the Dongting and Poyang lake areas also induces a large stress on fishery resources. Ecological and environmental conditions in the middle reach include: (a) habitat degradation in the river channel and associated lakes due to sand mining and reduced upstream flows from reservoir operations; (b) reduced fish diversity due to habitat losses and channelization; and (c) the creation of land-locked aquatic species resulting from the loss of river-lake connections.

2.4. The lower reach

The lower reach of the Yangtze River has experienced the most severe channelization and river bank construction (e.g., construction of harbors) throughout the entire basin (Fig. S3). For instance, there were 3893 active docks along the Yangtze River mainstem by the end of 2013, with 360 of them can hold over 10,000 tons of cargos [11]. In addition, this reach is by far the most urbanized and industrialized in the basin. Ecological and environmental conditions in the Yangtze River lower reach include: (a) habitat degradation; (b) widespread chemical pollution; and (c) reduced biodiversity due to habitat losses.

2.5. The estuary

The estuary has experienced pollution from upstream sources [11]. Ecological and environmental conditions in the Estuary include: (a) chemical pollution from upstream; (b) hypoxia; and (c) reduced biodiversity as loss of habitat and water quality stress [11].

3. Basin wide and reach based ecological and environmental conservation strategies and policy recommendations

3.1. Basin wide

Based on the current situation in the Yangtze River basin, we recommend the following actions for the whole basin:

(1) Adapt to natural climate change and air pollution control;

Here, we want to emphasize and suggest large-scale (i.e., not small or local scale) and continuous (i.e., not seasonal or event-based) control of air pollution emissions.

(2) Water pollution control and watershed restorations;

A good template for Yangtze River tributaries and their watersheds is the Mississippi River Basin Healthy Watersheds Initiative (MRBI), which focuses on reducing, controlling, and removing pollutants from watersheds and conducting watershed restorations [10]. A good model for Yangtze River mainstem restoration would be habitat restorations that have occurred throughout the Mississippi River, which focus on increasing the habitat complexity of the river channel [10].

(3) Enforcing management regulations and/or bans on commercial fishing throughout the Yangtze River basin. This emergent strategy should potentially restore the already degraded aquatic biodiversity in major areas of the basin. Compared to the total fishery output contribution from aquaculture, the commercial fisheries of freshwater including rivers, lakes, and reservoirs in China is actually very small. For instance, commercial fishing contributes only 7% of the total freshwater fishery production (i.e. freshwater commercial catches and aquaculture combined) and only 8% of the total freshwater fishery economic return [13]. Thus, we feel this component of freshwater fisheries production and economic return can be easily replaced by developing environmentally sustainable aquaculture. An example would be the extensive fishery production (i.e., fish is cultured with a very low density and no external feeding) in lakes [10].

We feel by adopting taking the above actions, priorities should be given to tributaries and their watersheds, especially those located in environmentally sensitive areas or in areas receiving high levels of pollution.

3.2. Reach based

Based on reach characteristics and challenges, we provide the following recommendations for each Yangtze River reach:

(1) Control erosion by maintaining vegetation and establishing buffer zones along the river corridor and adapt to and/or mitigate the effects of climate change (e.g., stabilize the river banks to reduce high flow impacts) in the headwater region;

(2) Establish a maximum limit for dam development, conduct on-site restoration for dam-impacted areas, and regulate flows ecologically in the Yangtze River upper reach;

(3) Better control and more effective regulation of sand mining and restore river-lake connections in the Yangtze River middle reach;

(4) Adjust and manage riparian development and urban/industry processes in the Yangtze River lower reach;

(5) Develop more effective methods to treat polluted water and adapt to seawater intrusion into the Yangtze River estuary.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.scib.2017.04.009.

References

[1] The State Council of the People's Republic of China. The State Council's Advisory Recommendations on Promoting the Yangtze River Economic Belt Development Based on the Golden Watercourse; 2014. [in Chinese]; http://www.gov.cn/zhengce/content/2014-09/25/content_9092.htm.

[2] Liu J, Diamond J. China's environment in a globalizing world, how China and the rest of the world affect each other. Nature 2005;435:1179–86.

[3] Fang J, Wang Z, Zhao S, et al. Biodiversity changes in the lakes of the Central Yangtze. Front Econ Environ 2006;4:369–77.

[4] Dudgeon D. Asian river fishes in the anthropocene: threats and conservation challenges in an era of rapid environmental change. J Fish Biol 2011;79:1487–524.

[5] Xinhua News Agency. The Release of the Yangtze River Economic Belt Development Framework; 2016. [in Chinese]; http://news.xinhuanet.com/mrdx/2016-09/12/c_135680690.htm.

[6] National Flood and Drought Control Office; 2016. http://fxkh.mwr.gov.cn/.

[7] Wang X, Siegert F, Zhou A, et al. Glacier and glacial lake changes and their relationship in the context of climate change, Central Tibetan Plateau 1972–2010. Glob Planet Change 2013;111:246–57.

[8] Ren W, Tian H, Tao B, et al. Impacts of tropospheric ozone and climate change on net primary productivity and net carbon exchange of China's forest ecosystems. Global Ecol Biogeogr 2011;20:391–406.

[9] The State Council of the People's Republic of China. The National New Urbanization Plan for 2014–2020; 2014. [in Chinese]; http://www.gov.cn/gongbao/content/2014/content_2644805.htm.

[10] Chen Y, Chapman D, Jackson J et al., editors. Fisheries resources, environment, and conservation in the Mississippi and Yangtze (Changjiang) River basins. American Fisheries Society, Symposium 84, Bethesda, Maryland.

[11] China Association of Science and Technology. The 2016 Yangtze River Basin Ecological Investigation Report; 2016. [in Chinese].

[12] Ministry of Environmental Protection (MEP). China Environmental Status and Condition Bulletin. Ministry of Environmental Protection, People's Republic of China, Beijing, China; 2016. [in Chinese].

[13] Ministry of Agriculture (MOA). China Fishery Statistical Yearbook. Fishery Bureau, Ministry of Agriculture, People's Republic of China, China Agriculture Press, Beijing, China; 2015. [In Chinese].