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GHOTI

Basin-scale approach needed for Yangtze River fisheries restoration

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Abstract

The Yangtze River contains the highest fish diversity and most important inland fishery resources in China, but its biota and ecosystem services face an uncertain future. The river and its basin have undergone vast changes from centuries of human impacts, and fish stocks are in a particularly dire situation. A complete 10-year moratorium on commercial fishing within the entire Yangtze River was implemented starting in January 2021. By itself, the ban on fishing will unlikely guarantee full recovery. We conclude that multiple human impacts to the basin and its fish stocks require multidisciplinary strategies implemented at the whole basin scale for effective conservation.

KEYWORDS
basin scale, dams, fisheries policy, flow alteration, inland fishery, overfishing

Ghoti papers

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Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

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1 | INTRODUCTION

Chinese folklore characterizes the Yangtze River as the mother of the country, an appropriate metaphor given the river's important role in the nation's social and economic development. Scientists, environmentalist and an increasing number of policymakers perceive that the river is at a critical crossroads (Stone, 2010; Xie, 2003; Zhang et al., 2020). In an address given on 26 April 2018, before a forum to promote the development of the Yangtze River Economic Belt, President Xi Jinping stated that 'the Yangtze falls sick, and it is very sick' (Xi, 2018). Historically, the Yangtze Basin supported 416 fish species, with 178 endemic; 145 amphibians species, with 49 endemic; and two unique cetacean mammals, the Baiji (*Lipotes vexillifer*, Lipotidae) and Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*, Phocoenidae) (Zhang et al., 2020). In the 1950s, yields from wild capture fisheries in the Yangtze River accounted for approximately 60% of national inland fish production and 6.83% of the global catch (FAO, 2020). Decline in fish stocks and extirpation of aquatic species from China's rivers have increased over recent decades (Chen et al., 2020; Guo et al., 2019; Zhang et al., 2020). President Xi Jinping described the Yangtze River as almost a 'fish desert' (Xi, 2018).

The Yangtze Basin is home to nearly one-third of China's population and for more than half a century has been the epicentre of a struggle between social-economic development and environmental protection. Fishery resources have been adversely affected by overfishing, hydropower development, pollution, sand mining and other impacts (Zhang et al., 2020). The Chinese government imposed a complete moratorium on all commercial fishing in the Yangtze River and its tributaries starting in January 2021 (Mei et al., 2020). This ban is being implemented in stages, with commercial fishing banned within 332 conservation areas in 2020, when at least 230,000 registered fishermen had to find other means for a livelihood. During the fishing moratorium, scientific assessments have been performed for water quality, fish stocks and economic and social indicators. The Yangtze River Protection Law also was enacted in 2021 to further restore the river; however, it lacks coordination of regulatory authority and activities among agencies (Qiu et al., 2021).

2 | MULTIPLE STRESSORS CONTRIBUTING TO THE DEPLETION OF FISHERIES

Rivers worldwide are stressed by multiple impacts, including dams, water diversion, pollution, fishing, mining, invasive species and climate change (Allan et al., 2005; Winemiller et al., 2016), impacts that must be addressed to restore fisheries and conserve native biodiversity. Fisheries yields in the Yangtze mainstem began to decline during the years following the record catch of 450,000 tonnes in 1954, and by 2019, the catch was less than 100,000 tonnes, a decline of nearly 80%, with a notable depletion of migratory species (Zhang et al., 2020).

More than 43,000 dams and dikes have been constructed in the Yangtze Basin (Yang & Lu, 2014) (Figure 1), and their effects on fish stocks have been studied extensively (Cheng et al., 2015; Young et al., 2011). Upstream of dams and reservoirs alters river habitat from lotic to lentic, increasing the risk of extinction of habitat specialists and invasion by exotic species (Gao et al., 2019). Dams block fish migration, gene flow, and access spawning and nursery habitats (Liu et al., 2020; Wei et al., 1997; Zhai et al., 2019). Dam operations alter the natural flow regime, which disrupts fish feeding, growth and reproduction (Yao et al., 2021; Young et al., 2011). The Three Gorges, Gezhouba and other major dams on the Yangtze mainstem block spawning migrations, for example threatened Chinese sturgeon (*Acipenser sinensis*, Acipenseridae) and recently extinct Chinese paddlefish (*Psephurus gladius*, Polyodontidae), and fragment populations, for example Yangtze sturgeon (*Acipenser dabryanus*, Acipenseridae) (Wei et al., 1997). An environmental impact assessment is required for new dams in China; but there is no assessment of cumulative effects from cascades of dams that now exist on many river reaches (Cheng et al., 2015; Wang et al., 2018). For example, the distance between the Gezhou and Three Gorges dams is less than 40 km. These dams and associated reservoirs destroyed critical habitats for 46 endemic species, fragmented populations of 134 species and blocked migration routes for 35 potamodromous fishes (Cheng et al., 2015). Construction of small hydropower plants in tributaries is often considered a less harmful alternative; however, their cumulative impact can be significant (Kibler & Tullos, 2013; Williams-Subiza & Epele, 2021). Research from the Upper Salween Basin in China revealed that many small dams (installed capacity ≤50 MW) produced greater cumulative effects on hydrology and habitat than fewer large dams (Kibler & Tullos, 2013).

Aquatic habitats in the vast floodplains of the Yangtze's middle and lower reaches supported major fisheries for centuries (Figure 2). During the 1940s, the total area of floodplain lakes was 25,828 km^2; today, it is estimated to be 15,770 km^2 (Wang et al., 2016). Many floodplain lakes now lack periodic connections with the river channel that support lateral fish migrations. Following completion of the Three Gorges Dam, water levels dropped in the Poyang Lake system in the middle Yangtze floodplain, and the aquatic vegetation community underwent a regime shift (Feng et al., 2016). Since the

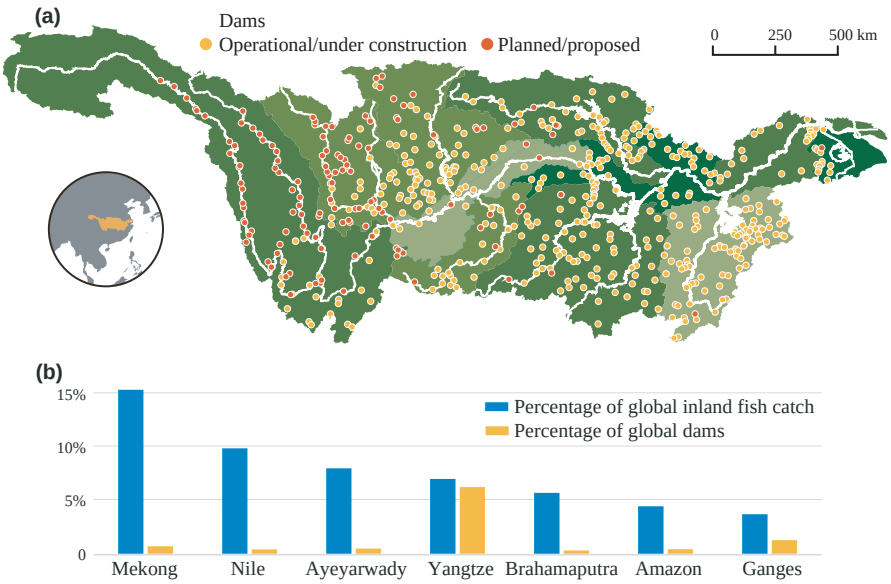

FIGURE 1 Yangtze Basin has experienced an unprecedented boom in construction of hydropower (a). The basin not only accounts for 6.83% of global inland capture fisheries yield, but also has an alarmingly high proportion of dams globally (6%) (b). Basin-scale planning was lacking, and dams often were approved without adequate environmental impact assessment. Dam information was taken from two global dam datasets: Global Reservori and Dam Database (dam volume ≥0.1 km^3; Lehner et al., 2011) and Future Hydropower Reservoirs and Dams (installed capacity ≥1 MW; Zarfl et al., 2015). Half of total global catch can be attributed to 7 basins: Mekong, Nile, Irrawaddy, Yangtze, Brahamaputra, Amazon and Ganges (FAO, 2020)

1960s, the Yangtze experienced a major decline in annual sediment flux. Reduction in sediment delivery to downstream reaches impacts water quality, nutrient dynamics, fluvial geomorphology and fish habitat (including spawning grounds for the Chinese sturgeon) as well as saltwater intrusion in reaches near the coast (Zhang et al., 2016; Zhou et al., 2021).

Over 45% of China's GDP is produced in Yangtze Basin. Water has been polluted with excessive nutrients, metals, and agricultural and industrial chemicals (Dudgeon, 2010). Whereas it is fairly straightforward to measure contaminant concentrations, it is difficult to estimate biological responses (Jensen, 2019). In Japan, introduction of neonicotinoid pesticides to rice paddies resulted in the collapse of plankton, insects, Japanese smelt (*Hypomesus nipponensis*, Osmeridae) and Japanese eel (*Anguilla japonica*, Anguillidae) in a nearby lake (Yamamuro et al., 2019). Over the past two decades, neonicotinoid insecticides have been used extensively in China, especially within the Yangtze Basin where levels in water were higher than those reported in Japan (Chen et al., 2019).

Invasive exotic species pose an additional threat and were estimated to have contributed to the endangerment of 27.7% of Yangtze fishes (Ye et al., 2011). The number of native species in Lake Dianchi within the Upper Yangtze Basin declined from 25 in the 1940s to 8 in 1982 (Fu et al., 2003). This trend followed the introduction of native carps (*Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idellus* and *Mylopharyngodon piceus*, Cyprinidae), icefish (*Salangichthys tangkahkeii*, Salangidae) and other fishes from middle and lower reaches of basin to enhance fishery production in the plateau lakes (Ye et al., 2011). The red swamp crayfish (*Procambarus clarkii*, Cambaridae), one of the world's most successful aquatic invaders, is now common throughout the middle and lower basin. Ponds for crayfish aquaculture now cover 12,860 km^2, with annual production exceeding 2.09 million tonnes in 2019 and economic output over 411 billion yuan (65 billion USD) (Anonymous, 2020). Despite the magnitude of the problem, damage to native biodiversity and ecosystems from exotic species has not gained much public attention in China (Xie et al., 2001).

Inland fisheries in China are mostly indiscriminate; although certain species are sought because of high market value, almost all fish species are harvested. Indiscriminate fishing reduces populations of apex predators and other large, slow-growing species and may increase the relative abundance of small, rapidly maturing species. These impacts reduce functional diversity and leave ecosystems vulnerable to changing environmental conditions (McCann et al., 2016). Research on impacts of climate change on Chinese inland fisheries and aquatic biodiversity is lacking (Kang et al., 2017), but a recent study (Guo et al., 2019) suggested fish distributions in China will shift in response to anticipated changes in environmental conditions.

3 | CURRENT MANAGEMENT IS INADEQUATE

Inland fisheries are crucial for food security, environmental health and economic development throughout much of the world (Lynch et al., 2020). Capture fisheries have small environmental footprints compared with other means of acquiring animal protein (FAO, 2020).

FIGURE 2 Overfishing and land-use change in the Poyang Lake floodplain in the Middle Yangtze Basin. The fish catch is being dried next to a construction site on the lakeshore. Multiple human actions, together with uncertainty about future environmental conditions under climate change, make prospects for rebuilding Yangtze fisheries uncertain

China's fisheries management has involved a gradual process of policy evolution in response to political, economic, social and environmental developments. Since 1986, China has enacted a series of regulations aimed to protect the viability of inland fisheries, including the *Fishery Law*, *Law on the Protection of Wildlife* and *Water Quality Standard for Fisheries*. However, these regulations have failed to conserve fisheries and aquatic ecosystems during recent decades (Zhang et al., 2020). Since 2002, fishing regulations have been different for sections of the Yangtze River above and below the Gezhouba Dam. After 15 years of fishing under these regulations, stocks have not recovered, and catch per unit effort has fallen to an historic low (Kang et al., 2017). Experts estimate that many of the most valuable commercial species require 3–4 years to reach maturity, and therefore, 10 years allow just two or three generations to reproduce (Kang, 2020). In January 2015, the Ministry of Agriculture expanded fishing regulations to the Yangtze's main tributaries and floodplains and extended the prohibition of fishing from 3 to 4 months. The new fishing moratorium will result in the decommissioning of 111,000 fishing boats and resettlement of fishing families with provisions for vocational training.

The precipitous decline in Yangtze fisheries was caused by adverse effects from multiple stressors and their interactions. China has adopted separate regulations for natural resources and the environment (e.g. *Water Act*, *Forestry Act*, *Land Management Law and Environmental Protection Act*), most of which do not directly address aquatic habitat while also lacking full implementation. Water management in the Yangtze Basin is governed by more than 30 laws, with authority divided among 15 central and 19 provincial entities (Lv, 2020). For example, water conservation departments manage water resources and hydropower, while environmental protection departments manage water quality and pollution, and municipal departments manage urban water supplies and drainage. Currently, the legislation that influences rivers and fisheries is decentralized and disconnected, with limited coordination between departments.

4 | BASIN-SCALE AND MULTIDISCIPLINARY APPROACHES ARE NEEDED

The Yangtze is at a critical crossroads with an uncertain future. Without an ecosystem-based strategy that addresses habitat connectivity, hydrology, land use, urbanization, pollution and climate change, the current fishing moratorium can only partially recover fish stocks. The first complete fishing ban was taken place in the Chishui River, but so far fish assemblage has not shown significant recovery in the middle and lower reaches, where fish populations are threatened by more intensive human activities (Liu et al., 2021). Given the enormous size of the Yangtze Basin, policies at the national level must coordinate with those formulated under regional and local jurisdictions. Currently, China's national Fisheries Law regulates both inland and marine fisheries, realms with different landscapes, habitats and biota impacted by different stressors. Management strategies and policies are needed to address features unique to inland fisheries.

To restore China's freshwater fish stocks, several key issues need to be addressed immediately. Current monitoring and assessment of fishery resources are insufficient to assess effectiveness of the fishing ban (Chen et al., 2020). What is required is an adaptive management approach, whereby fish stocks and critical habitats are assessed using standardized methodologies in long-term monitoring programmes. Only in this manner will we have data suitable for teasing apart effects and interactions from multiple impacts on stock dynamics. An integrated, basin-wide assessment of impacts from multiple stressors is needed for the development of coordinated policies and strategies. Greater effort is needed in ecological modelling, so that when fishing is re-established, effective policies can be developed for sustainable fisheries and biodiversity conservation. Fisheries restoration needs to be based on approaches that integrate freshwater conservation priorities into larger landscape conservation strategies (Abell & Harrison, 2020).

Hydropower planning and dam management need to integrate biological and socioeconomic perspectives (Xu & Pittock, 2021). To restore river network connectivity, the Ministry of Water Resources in conjunction with other departments recently

embarked on a programme to remove 241,000 small hydropower dams (installed capacity ≤50,000 KW) in the Yangtze Basin. Top-down, technocratic decision-making not only has its advantages, but can also cause problems. A 'one-size-fits-all' approach to dam removal affects multiple functions, such as flood control and water supplies for irrigation, municipalities and industry. More research is needed to determine which dams should be removed and in what order. New mega-hydropower dams are planned for upper reaches of the Yangtze. Consequently, there exists an opportunity to apply spatial optimization models at the watershed scale (Couto et al., 2021). Protection of fish stocks within reserves could help mitigate unavoidable negative effects from dams (Xu & Pittock, 2021). Strategies for locating new dams should be combined with strategies for removal of existing dams to maximize benefits for hydropower, fisheries and biodiversity conservation. China's plans for environmental management have not historically focused on watersheds. In December 2021, the Ministry of Water Resources proposed the idea of unified watershed management, involving planning, governance and management. Research is urgently needed to establish environmental flow standards to aid policymakers and managers as they attempt to balance economic, social and environmental needs. Current understanding of fish migration in Yangtze Basin is limited and deserves urgent attention from fisheries biologists and funding sources. Migratory fish, such as the Chinese sturgeon, cannot complete their life cycles in the fragmented system, and it will be necessary to increase hatchery production for long-term survival.

Pollution remains a big problem in China. Laws to curtail water and air pollution need to be just as aggressive as the new law that prohibits fishing. Water pollution obviously has a direct impact on the health of aquatic organisms, but air pollution also affects watersheds and aquatic ecosystems. For example, deposition of nitrogen from air pollution causes nutrient loading and alters nutrient and production dynamics in aquatic ecosystems. Whereas it is conceivable that some fish stocks could recover in the absence of fishing, their flesh may pose significant risks for human health. Exotic invasive species are a growing threat to China's freshwater ecosystems, yet their direct and indirect impacts on native fishes are largely undocumented. Finally, we note that recreational fishing in China also can impact fish stocks but lacks monitoring data for evaluation of its effects relative to commercial fishing (Zhang et al., 2020).

Entire riverscapes and associated watersheds must be managed to restore aquatic habitats that support fish stocks. The Yangtze and its fisheries are on life support. We are encouraged the Chinese government has taken the first step with the fishing moratorium; however, fisheries will only be restored if this measure is accompanied by efforts to rehabilitate the river and associated watersheds. China is preparing to release a new 5-year economic and social development plan for 2021–2025, and a longer-term plan, *Vision 2035*, is under development, and inland fisheries need to be included along with the more traditional and visible sectors (FAO, 2020). Given the cultural and economic importance of the Yangtze River, 'the mother of China', even moderate success in the rehabilitation of the river and its fisheries would significantly enhance the nation's social, economic and environmental future.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available from the Global Dam Watch (https://globaldamwatch.org) and the FAO (https://doi.org/10.4060/ca9229en).

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