

## FISHERIES

# Fishing ban halts seven decades of biodiversity decline in the Yangtze River

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China's rapid economic development has triggered an unparalleled freshwater biodiversity crisis since the 1950s. To restore fisheries resources, the Yangtze River Fishing Ban was implemented in 2021 to cease all basin-wide commercial fishing. We evaluate the effectiveness of this large-scale conservation action by assessing fish communities across mainstem habitats before and after the ban (2018 to 2023). The seven-decadal biodiversity loss was halted with improvements in fish biomass, body condition, species diversity, and initial recovery of threatened species. Eliminating fishing pressure was likely key to this recovery, in addition to actions targeting water quality improvement, hydrological and riparian habitat restoration, and vessel traffic reduction. Ambitious conservation actions can halt biodiversity loss in the Yangtze River, bringing hope for biodiversity recovery in other large rivers.

Freshwater biodiversity, essential for ecosystem function and human well-being (1–3), is facing a global crisis (4) driven by multiple threats (5, 6). Although large-scale restoration and management efforts are recognized as increasingly necessary (7–11), securing long-term political and financial support remains difficult owing to uncertainties about their effectiveness (12, 13). These challenges are particularly evident in rapidly developing regions, such as China. Over the past four decades, China has emerged as the world's second-largest economy, yet the costs of this achievement are reflected in marked ecological and environmental degradation in some regions (12, 14). The Yangtze River is emblematic of these trade-offs. Supporting ~30% of the Chinese human population and generating ~40% of the nation's gross domestic product, the Yangtze River basin is also in the midst of a severe biodiversity crisis. Several endemic and culturally valued species have been driven to extinction, including the Yangtze River dolphin (*Lipotes vexillifer*) and the Chinese paddlefish (*Psephurus gladius*), and many others are critically endangered (12). Since the 1950s, the yield from the Yangtze River fisheries has collapsed to a quarter of the historical peak (15), and 135 fish species from historical surveys were no longer found in recent records (16). Among the primary contributors to the biodiversity crisis are the multiple interactive impacts of fishery overexploitation, dams causing flow regulation and fragmentation, habitat degradation and water pollution from sand mining, industries, navigation activities, and land conversion for agriculture and urbanization (17–19).

Dedicated conservation efforts have involved establishing a network of protected areas (20, 21) and investing more than 300 billion USD in management and restoration actions during the past 10 years (22), leading to marked improvement of surface water quality (23).

Despite this, biodiversity continues to decline (12, 15, 16). More effective, dedicated, and durable conservation actions were apparently necessary to bend the curve of biodiversity loss in the Yangtze River (24). Protected areas with enforced fish harvest restrictions and habitat restoration efforts have been widely tested and embraced in marine ecosystems. However, their effectiveness in promoting the recovery of freshwater biodiversity has received less attention (25, 26), especially in large rivers that have a lower extent of protection (27). Such questions are valid given that freshwater protected areas often yield positive outcomes but can, in some cases, be ineffective owing to limited law enforcement or environmental threats originating from upstream, unprotected reaches (26, 28). Collectively, this draws attention to the potential protective effects of the Yangtze River Protection Law of the People's Republic of China, which implemented a 10-year full fishing ban over the whole river basin, managing river habitats (by regulating sand mining, riparian development, chemical industries, and navigation), ensuring flow management from dam operations and water quality by improving wastewater treatment, and reducing agricultural pollution (12, 29, 30).

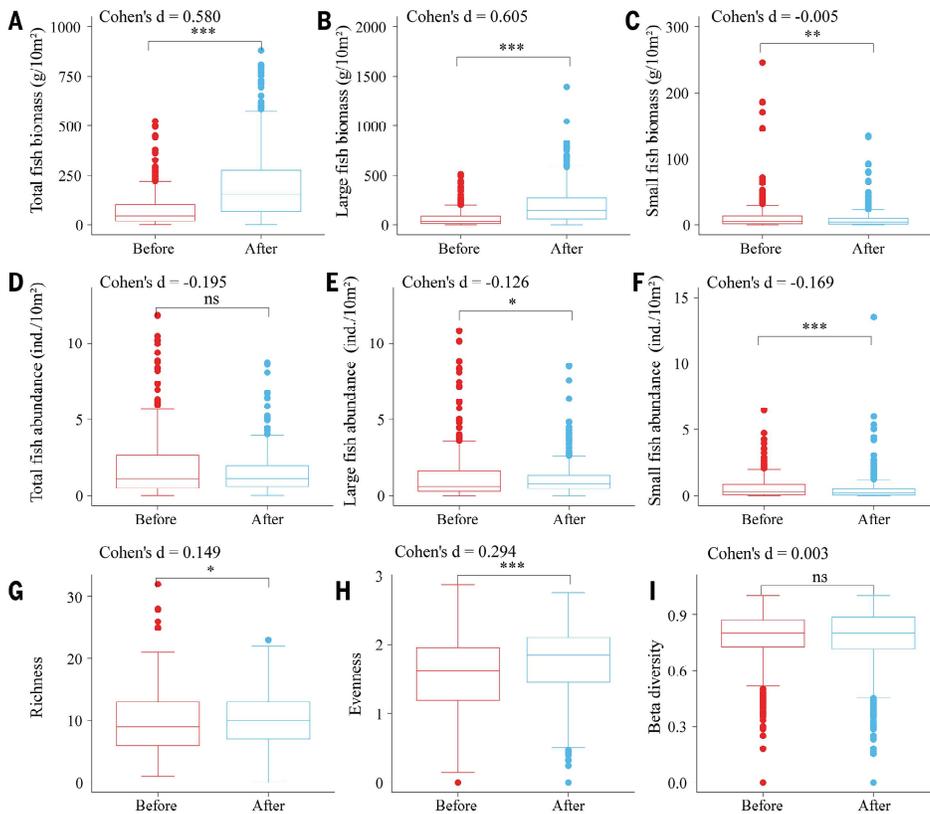
Establishing the 10-year full fishing ban required tremendous coordination and resources, involving the recall of 111,000 fishing boats and resettling 231,000 fishers by investing more than 2.74 billion USD across 11 provinces and municipalities in the Yangtze River basin (31). The fishing ban halted commercial fisheries, including illegal and destructive fishing practices that use fine-meshed nets, electricity, poisons, and explosives. Compliance with the fishing ban has been achieved in part due to strict penalties and river police enforcement. During this time, stocking of Chinese major carps to sustain commercial fish stocks and stocking of Chinese sturgeon (*Acipenser sinensis*) to promote recovery remained. The fishing ban entered its fifth year of implementation in 2025. This study evaluates the effectiveness of this ambitious restoration project on the Yangtze River by reporting the outcomes across 57 river reaches over a 6-year period that spans both before and after the full fishing ban (fig. S1).

## Evidence of initial recovery of fish stocks and biodiversity

In this study, we show evidence for a trajectory toward initial recovery of fish stocks after implementation of the fishing ban (Fig. 1, fig. S2, and table S2). The postban period demonstrated a more than twofold increase (median = +209%, Wilcoxon  $P < 0.001$ , Cohen's  $d = 0.580$ ,  $n = 57$ ) in overall fish biomass and an increase of +13% in species richness (Wilcoxon  $P = 0.011$ , Cohen's  $d = 0.149$ ,  $n = 57$ ) compared with those of the preban period. Fish abundance changed little but was more evenly distributed among species (Evenness median = +7%, Wilcoxon  $P < 0.001$ , Cohen's  $d = 0.294$ ,  $n = 57$ ) in the postban period (Fig. 1H, fig. S2, and table S2). Compositional changes occurring after the fishing ban did not lead to significant increases in species dissimilarity among sites (i.e.,  $\beta$  diversity; Fig. 1I, fig. S2, and table S2), suggesting that longer-term protection may be required to support greater local habitat diversity (32).

The fishing ban was also associated with changing fish body size distributions. Larger-bodied species (i.e., maximum body length larger than 200 mm,  $n = 16$  species) benefited greatly from the fishing ban, showing significant increases in biomass (median = +232%, Wilcoxon  $P < 0.001$ , Cohen's  $d = 0.605$ ,  $n = 57$ ) (Fig. 1B, fig. S2, and table S2). By contrast, biomass of smaller-bodied species (i.e., maximum body length smaller than 200 mm,  $n = 4$  species) decreased by 18% (Wilcoxon  $P = 0.007$ , Cohen's  $d = -0.005$ ,  $n = 57$ ; Fig. 1C, fig. S2, and table S2). These

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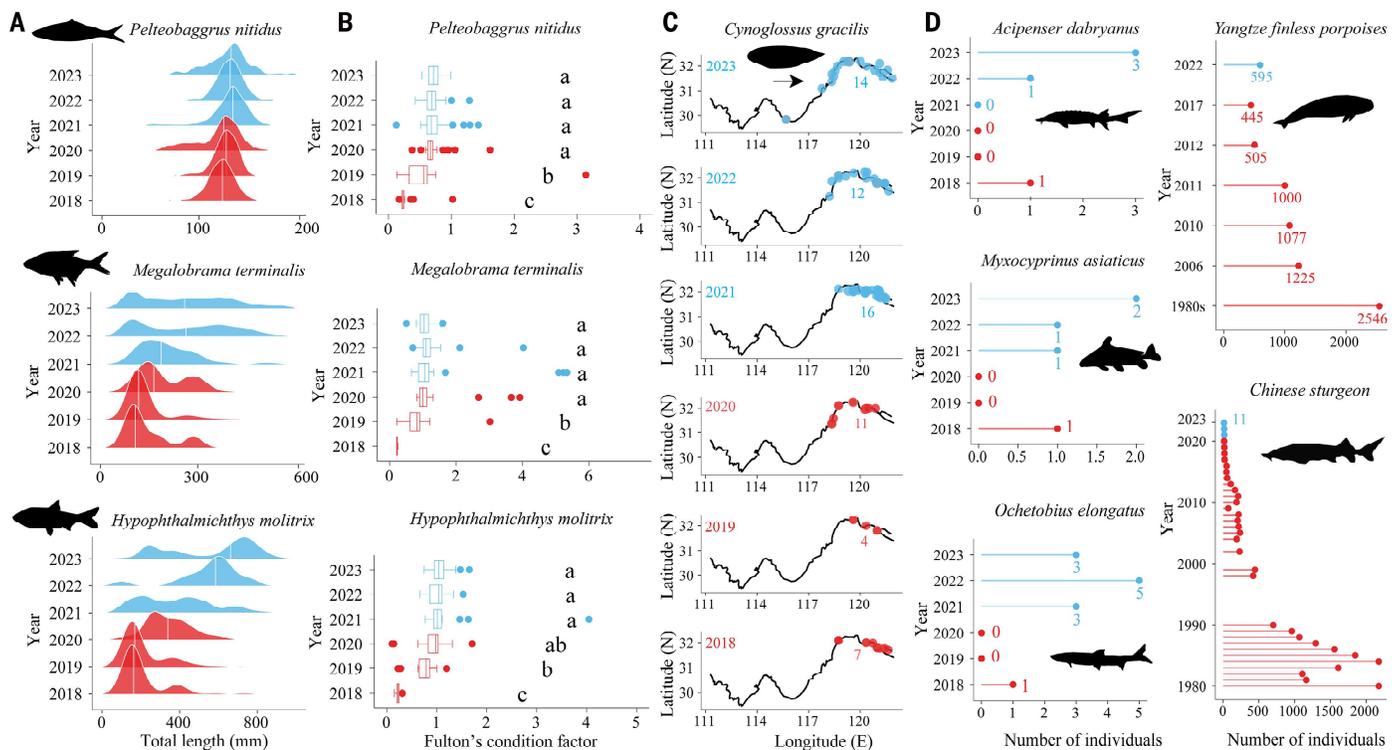
**Fig. 1. Overall changes of fish biomass, abundance, and biodiversity indices before and after the full fishing ban.**

The preban period (2018 to 2020, before) is represented in red ( $n = 258$ ), and the post-ban period (2021 to 2023, after) is represented in blue ( $n = 312$ ). The Wilcoxon signed rank test was used to detect differences between pre- and postban periods with significance levels of  $*P < 0.05$ ,  $**P < 0.01$ , and  $***P < 0.001$ . ns, not significant. Cohen's  $d$  refers to effect size, with 0.2, 0.5, and 0.8 indicating small, medium, and large effect sizes, respectively. Parameters (table S1) include (A) total fish biomass (total catch per unit effort in weight,  $g/10m^2$ ), (B) large fish biomass (larger-bodied fish catch per unit effort in weight,  $g/10m^2$ ), (C) small fish biomass (smaller-bodied fish catch per unit effort in weight,  $g/10m^2$ ), (D) total fish abundance (total catch per unit effort in number,  $ind./10m^2$ ), (E) large fish abundance (larger-bodied fish catch per unit effort in number,  $ind./10m^2$ ), (F) small fish abundance (smaller-bodied fish catch per unit effort in number,  $ind./10m^2$ ), (G) richness (species richness), (H) evenness (Shannon index), and (I)  $\beta$  diversity (fish fauna dissimilarity between localities, Jaccard index).

Outcomes align with previous studies showing that biological responses to fishing bans are often differentially expressed across species and their ecological traits (33–35). In this case, larger-bodied organisms occupying higher trophic positions, but also large detritivores responded positively to the implementation of the fishing ban (Fig. 2A and figs. S3 and S4). This included increasing the chances of survival and growth for larger-bodied fishes, such as economically valuable black Amur bream (*Megalobrama terminalis*) and white Amur bream (*Parabramis pekinensis*) (figs. S5 and S6). Notably, the overall abundance of larger- and smaller-bodied species decreased, indicating that larger individuals are more represented than before the fishing ban. Further evidence is provided by an increase of fish condition factor for both larger- and smaller-bodied species ( $P < 0.001$ ; Fig. 2B and fig. S7), suggesting that factors other than fishing pressure, such as system productivity, may have been improved by concurrent efforts to improve water quality and habitat (30, 36). The durability of the changes we report between the pre- and postban periods remain uncertain given the relatively short duration of the study when compared with the history of commercial fishing. Despite this, results were minimally influenced by the specific year of comparison, supporting the rapid and key role of the fishing ban and associated conservation measures in contributing to the observed initial recovery of the Yangtze ecosystem (fig. S8).

Our results also point to signs of initial recovery for migratory and endangered species. For example, slender tongue sole (*Cynoglossus gracilis*) populations increased after the ban, and its freshwater migration extended further upstream (Fig. 2C). This outcome may have resulted from a shift in species' life history (e.g., migratory routes, distance traveled, and spawning sites) to exploit habitats improved by restoration measures and the elimination of harvest practices that intercept migratory species, making it difficult for them to reach critical habitats (37). Endangered fish species, such as the Yangtze sturgeon (*Acipenser dabryanus*), Chinese sucker (*Myxocyprinus asiaticus*), and tube fish (*Ochetobius elongatus*), although still rare, also showed signs of initial recovery after implementation of the fishing ban (Fig. 2D). It is important to note that the fishing ban appears to benefit not only the species directly targeted by supplemental conservation stocking programs (Yangtze sturgeon and Chinese sucker) but also other endangered taxa that are not currently the focus of specific conservation actions, such as the tube fish. Although derived from a limited sample size and short time series, these findings suggest that numerous threatened species could potentially benefit from the implementation of the fishing ban. Another notable positive outcome of the fishing ban was the short-term recovery trajectory of the only extant freshwater mammal in the Yangtze River, the Yangtze finless porpoise (*Neophocaena asiaorientalis asiaorientalis*), whose population increased by one-third from 445 in 2017 to 595 in 2022 (Fig. 2D). Such initial recovery was probably due to increased survival because of enhanced availability of prey (i.e., mainly fish), reduced mortality from fishing (e.g., bycatch mortality) and vessel strikes, and positive outcomes from the mitigation of other stressors, such as underwater noise from vessel propellers that negatively affected porpoise populations (38).

The trajectory toward initial recovery of the Yangtze ecosystem is consistent with trends observed in smaller rivers, such as the Chishui River, a tributary of the upper Yangtze (30). Extending large-scale fishing bans to the whole Yangtze basin offers important insight into restoring other large rivers across the world. Despite this, the fishing ban and associated conservation measures should not overlook the detrimental effects of river fragmentation caused by dams, which continue to threaten certain endangered migratory species. This is the case for the Chinese sturgeon (Fig. 2D), which continues to face an uncertain future (39). Other migratory species can no longer reach their primary spawning sites mainly distributed in the upper reaches owing to the Gezhouba and Three Gorges dams located on the middle reaches of the Yangtze (40). This is, for example, the case for the Yangtze sturgeon and the Chinese sucker. For these species, although the fishing ban improves individual survival, they remain unable to access their historical spawning grounds. Additional conservation measures, such as assisted translocations, construction of effective fish passage facilities, or creation of alternative spawning habitats (39), may be needed to ensure their long-term recovery. What remains uncertain is whether



**Fig. 2. Annual changes in fish total length (A), Fulton's condition factor (B), occurrence of migratory fish species (C), and abundance of endangered species (D) in the Yangtze River.** The preban period (2018 to 2020) is represented in red, and the postban period (2021 to 2023) is represented in blue. Fulton's condition factor measures the physiological status and nutritional condition of fish based on total length and weight, different letters in (B) represent significant differences ( $P < 0.05$ ) from an analysis of variance. The black curve in (C) represents the Yangtze mainstem, with estuary on the right side. The black arrow indicates flow direction, and dots and numbers represent migratory fish species occurrence and their total abundance, respectively. The fish species presented in (A) and (B) are the shiny yellow catfish *Pelteobagrus nitidus*, black Amur bream *M. terminalis*, and silver carp *Hypophthalmichthys molitrix*. The migratory fish species presented in (C) is the slender tongue sole *C. gracilis*. Population trends (number of individuals collected or observed per year) of endangered fish species are shown in (D) are *A. dabryanus*, *M. asiaticus*, *O. elongatus*, Yangtze finless porpoise *N. asiaeorientalis asiaeorientalis*, and Chinese sturgeon *A. sinensis*.

the short-term fish biodiversity trends reported in this study are an indication of long-term recovery, or whether they are perhaps merely transient in nature. Other existing stressors, such as hydrological changes due to dams, habitat degradation, and pollution, might easily reverse the initial recovery that we report. Particular attention should thus be given to control and reduce these other stressors to maintain the trajectory toward biodiversity recovery.

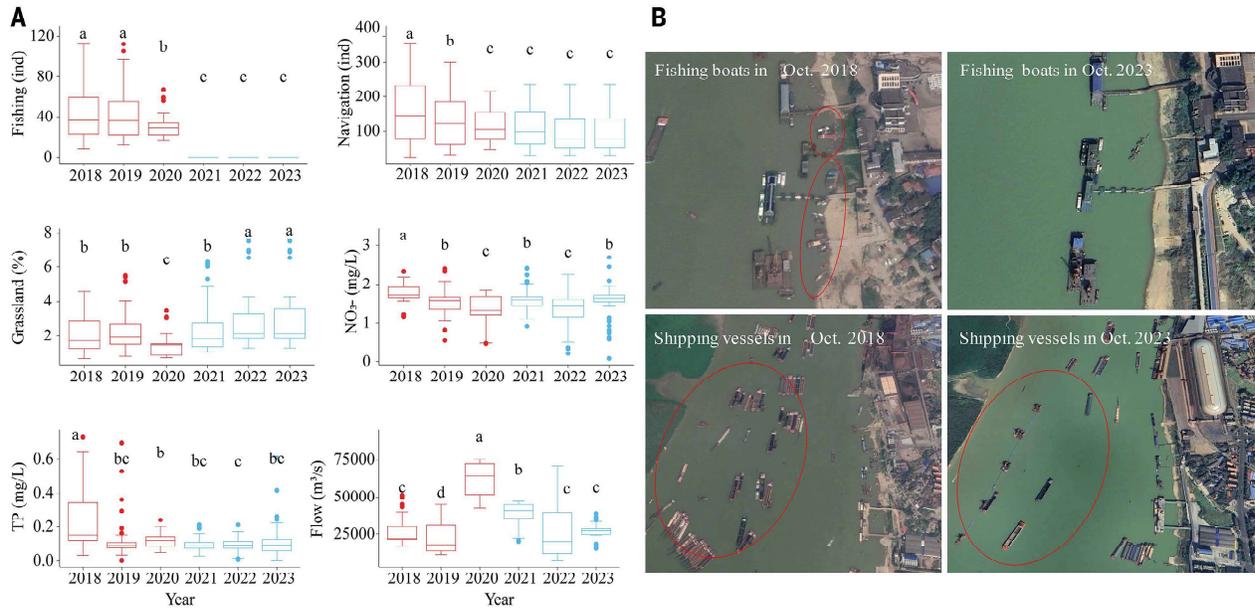
### Fishing pressure removal is a key contributor to initial recovery

Many anthropogenic threats were reduced, and indicators of overall system health improved from 2018 to 2023 in the Yangtze River. Fishing pressure was completely eliminated along with reduced vessel traffic, and riparian vegetation buffers were also created, which contributed to improved water quality (Fig. 3 and fig. S9). For example, we report reduced nitrogen ( $\text{NO}_3^-$ ) and phosphorus (TP) loads during the study period (Fig. 3A).

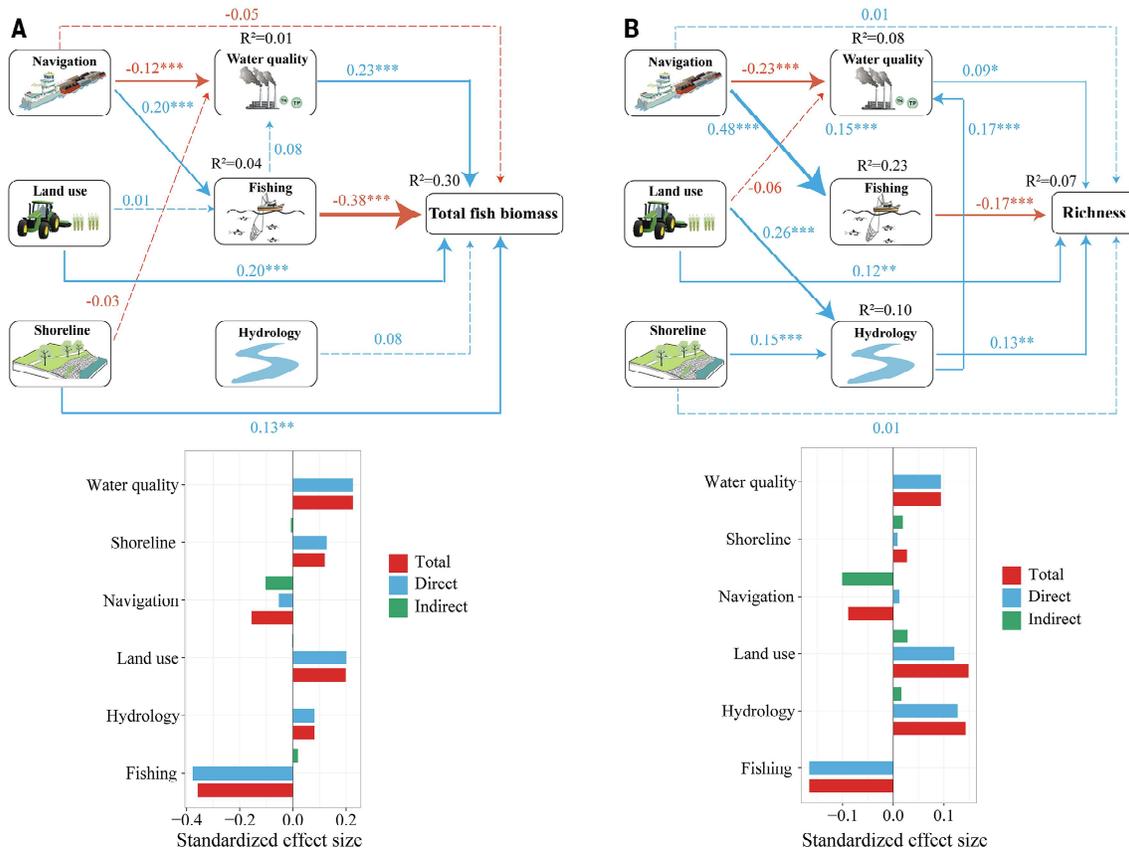
Measuring the links between conservation measures and biodiversity trends using generalized least-squares (GLS)-based structural equation models (SEMs) that account for spatial and temporal effects revealed that the fishing ban is the primary driver of the trajectory of initial recovery of the Yangtze ecosystem. Specifically, the fishing ban was the main driver of increases in fish biomass, along with contributions of other conservation measures, including water quality improvement (Fig. 4A). Similarly, increases in local richness in fish species were primarily related to the fishing ban. However, improving water quality, applying natural hydrological regimes, and regulating land uses also contributed to restoring natural habitats and thus promoted an initial

recovery in fish species richness (Fig. 4B). Furthermore, GLS-SEM results confirmed the substantial contributions of water quality, hydrology, and land use to improvements in fish populations and diversity (figs. S10 to S12). For example, enhancing water quality and restoring hydrological regimes can promote fish spawning success by optimizing sediment transport dynamics and the spatial configuration of thermal refugia (41). However, although high-quality habitat is the foundation for healthy and productive fisheries (42), there are instances when dramatic reductions in fishing pressure are needed to allow systems to recover (43). In addition, regulating navigation can reduce bank erosion by wave actions, promote riparian vegetation recovery, and decrease physical disturbance of fish nursery habitats (44). Concurrently, habitat heterogeneity generated by land-use diversification might provide critical reproductive refugia for niche-specialist fishes, thus supporting greater spatial diversity in fish biodiversity (fig. S12). Our results support the need for large-scale integrated watershed management strategies that goes beyond single-policy interventions when seeking to bend the curve of diversity loss (45).

Despite the trajectory toward initial biodiversity recovery, the future of the Yangtze River biodiversity remains uncertain and sensitive to emerging threats, such as changes in water management and dam infrastructure, which are imminent with mounting pressures associated with ongoing climate change (46). Additional challenges include other cooccurring stressors, such as emerging micropollutants, including pharmaceuticals and microplastics (47), that represent a further threat to biodiversity in rivers flowing through highly populated areas. This is of particular concern in China, where the use of pharmaceutical and



**Fig. 3. Changes of (A) fishing, navigation, grassland, NO<sub>3</sub><sup>-</sup>, TP, and flow during the 2018-to-2020 (red) and 2021-to-2023 (blue) periods and (B) aerial photos showing fishing boats and shipping vessels in a typical river reach (Yueyang, 29°26'11.02"N, 113°8'13.07"E) in 2018 and 2023. Fishing and navigation pressures were quantified by counting the number of fishing boats and shipping vessels in each river reach, respectively. Different letters in (A) represent significant differences ( $P < 0.05$ ) from analysis of variance.**



**Fig. 4. Relationships among total fish biomass and richness and environmental and anthropic conditions. (A)** GLS-based SEM of land use, water quality, shoreline, fishing, navigation, climate, and hydrology on total fish biomass (Akaike information criterion, AIC = -1300.31, Fisher's  $C = 8.369$ ,  $P = 0.756$ ). **(B)** GLS-based SEM of fish species richness (AIC = -642.15, Fisher's  $C = 8.738$ ,  $P = 0.725$ ). In GLS-SEM, the numbers are the standardized path coefficients ( $P < 0.05$  for all);  $R^2$  is the explained variance of the corresponding variable. Temporal and spatial effects were considered in these models. Solid lines indicate significant paths ( $*P < 0.05$ ;  $**P < 0.01$ ;  $***P < 0.001$ ). Dotted lines indicate nonsignificant paths. Blue and red lines indicate positive and negative paths, respectively. Total, direct, and indirect standardized effect sizes of each driver on fish indices are presented on the bottom. The direct effect reflects the degree of standard deviation change in dependent variables, with each one standard deviation change in a directly linked predictive variable, and the indirect effect reflects the magnitude of associated change through an indirect link.

personal care products is among the most notable per capita on Earth (48, 49). These stressors continue to impact the potential for long-term biodiversity recovery.

## Conclusions

The Yangtze River Protection Law provided a large-scale whole-river experiment wherein a complete fishing ban has contributed to the halt of a seven-decadal period of biodiversity loss. Additional monitoring and research will be needed in the future, but the short-term trends reported in this study are promising. Although the fishing ban will not be sufficient to completely recover species threatened by a host of other human stressors, evidence suggests that it has contributed to a trajectory toward initial recovery of fish biomass, diversity, growth, migration distance, and abundance of some of the most endangered and emblematic species (e.g., tube fish and the Yangtze finless porpoise) in the Yangtze River. It has been 19 years since the first spring seasonal fishing ban was implemented in 2002 to protect spawning fish. Now, the ban extends to prohibit all fishing activities for a decade (2021 to 2030) and is thus a bold strategy to slow the loss of and ultimately restore freshwater biodiversity in the Yangtze River (12, 17).

In the meantime, we remain cautiously optimistic that this short-term biodiversity recovery will be durable, yet we also caution that this progress could easily be reversed by reinitiating commercial fishing operations or in response to continuing stressors that compromise habitat condition, connectivity, water quality, and the flow regimes upon which fish species depend. Although longer time series would offer insight into the durability of the biodiversity recovery patterns reported here, the 10-year full fishing ban provides a hopeful example of the potential effectiveness of large-scale biodiversity conservation to meet the goals of the United Nations Decade on Ecosystem Restoration (11).

Similar conservation measures could be implemented on rivers such as the Mekong and the Amazon, where increases in sustainable aquaculture production might help offset concerns regarding human protein requirements (50). Instituting full fishing bans may help restore river ecosystems, but it concurrently requires subsequent effort to support recovery of sustainable fisheries. This also includes reducing other stressors that impair habitat condition, connectivity, water quality, flow regimes, and other key river attributes. The results reported in this study for the Yangtze River provide hope that in an era of global biodiversity decline (51), ambitious political decisions that support large-scale restoration efforts can help reverse the ecosystem damages of the past and lead to a brighter future for nature and people.

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## SUPPLEMENTARY MATERIALS

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Materials and Methods; Figs. S1 to S20; Tables S1 to S3; References (53–69);  
MDAR Reproducibility Checklist; Data S1 and S2  
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## Fishing ban halts seven decades of biodiversity decline in the Yangtze River

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### Editor's summary

The Yangtze River was once wild and biodiverse. But rapid economic development since the middle of the 20th century has led to overfishing, and the abundance and diversity of aquatic life has plummeted. In response, the Chinese government implemented in 2021 a 10-year ban on all commercial fishing in the river basin. Xiong *et al.* examined fish abundance and diversity before and after the ban and found promising signs of initial recovery in biomass, diversity, body condition, and even threatened species. They conclude that cessation of fishing was responsible but emphasize that other threats remain and that such a recovery would not withstand a return to fishing.  
—Sacha Vignieri

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