Title: Biodiversity Conservation Policy Unintentionally Boosted Science Research

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Abstract:
The implementation of the seasonal fishing ban along the Yangtze River since 2003 has successfully preserved fishery resources as originally intended, yet their broader implications remain poorly understood. Using a difference-in-differences design, we provide the earliest causal evidence of how local biodiversity conservation policies affect science and innovation, in unintended and serendipitous ways. The analysis reveals that the ban spurred more quality research inquiries about Yangtze River fish: Funded programs doubled and funding amounts more than tripled. Scientific output grew dramatically, with publications more than tripled, citations augmented more than five-fold, and related books, patents, awards, and public influence significantly increased. We attribute these increases to the enhanced availability of biological research materials (in both quantity and diversity), rather than other attention-based or policy-based channels. We conclude that preserving nature is not only an ecological duty but also potentially a strategic investment in the future of science and innovation.

Main Text:

Biodiversity is the cornerstone of Earth's ecosystems and the sustainable development of humanity[1-5]. However, the accelerating loss of biodiversity has emerged as a major global environmental crisis[6]; the global population of wild animals has declined by an average of 73% since 1970, with freshwater populations having plummeted by 85%[7]. In response, the international community has undertaken a series of actions over the past half century to promote the sustainable use of natural resources and strike a balance between economic development and ecological preservation. For example, the Convention on Biological Diversity has provided a legal framework for global conservation efforts and many nations have implemented measures such as the establishment of nature reserves and the delineation of ecological protection redlines.

Empirical evidence indicates that conservation efforts can effectively facilitate the recovery of biological populations[8,9] and further generate substantial ecological and economic impacts[10-16]. It is widely acknowledged that scientific breakthroughs significantly depend on the availability of diverse wild flora and fauna. For instance, the diversity of Darwin's finches in the Galápagos Islands enabled scientists to observe the real-time effects of natural selection in the wild for the first time, a discovery that catalyzed major advancements in modern evolutionary theory[17]. Although theoretical research has explored the scientific value of biodiversity[18-20], quantitative empirical evidence on the effects of biodiversity conservation efforts on scientific research remains relatively scarce. Using econometric techniques, this paper offers one of the first studies to identify the effect of biodiversity conservation policies on scientific research, quantify its economic magnitude, and examine the plausible underlying mechanisms.

Freshwater ecosystems are recognized as critical biodiversity loss hotspots[21]. The Yangtze River, China's longest and the world's third longest river, has long been hailed as a biodiverse haven[22,23]. However, overfishing and climate change have severely depleted its fishery resources by the turn of the century[24,25]. To restore the fishery resources and biodiversity of the Yangtze River, the Chinese government initiated an annual spring fishing ban in 2003. Previous studies have shown that such fishing management or catch limits positively impact fish species richness and abundance[8,13,26]. This fishing ban in China was primarily designed for the sustainable development of fishery resources[27], rather than intentionally targeting scientific objectives. This makes it an exogenous policy intervention to study the impact of biodiversity conservation on scientific research, primarily through its effect on the availability and diversity of biological materials for research purposes.

We construct a species-year panel dataset covering 1,562 fish species, including 320 Yangtze River fish (YRF) species and 1,242 non-YRF species, and compute the scientific research intensity associated with each fish species for each year. To achieve this, we manually collected micro-level grant data on China's most important

research funding system—the National Natural Science Foundation of China (NSFC)—between 1995 and 2014. Using natural language processing techniques based on a corpus of fish species taxonomic systems, we match funded programs with specific fish species. Our approach to assessing scientific research has three key advantages over existing literature that primarily relies on published papers and citation data: First, the NSFC grants are highly competitive, with an approval rate of around 15%, and therefore, research program funded by NSFC is more likely to serve as a proxy variable for the capability of conducting high-quality scientific research. Second, the NSFC's annual centralized applications and peer reviews, similar to the U.S. National Science Foundation (NSF), ensure the timeliness and objectivity of our research metrics. Third, the requirement for funded programs to submit progress reports at various stages allows us to comprehensively track their outcomes and build a complete fish-related research database, including funding, subsequent publications, and impact.

Integrating databases with comprehensive information on fish species attributes and funded programs, we compare the differences in the number of funded programs, total funding amounts, publications per program, and citation counts per paper between YRF and non-YRF before and after the 2003 fishing ban. This difference-in-differences (DiD) empirical strategy detects a significant surge in scientific inquiry, output, and citations related to YRF following the ban, compared to non-YRF. The ban also increased related books, patents, awards, and public influence---indications of broader societal impact. We further examine various economic mechanisms through which the ban potentially affects scientific research: (1) policies (the ban and other ones) targeting spurring YRF research, (2) increased public attention on YRF, and (3) greater availability of biological research materials due to the ban. The evidence is most consistent with the third channel that the fishing ban stimulates scientific research by preserving or adding research materials, both in quantity and variety. Compared with the factors influencing scientific research identified in the literature, such as workforce, data, and research methods and tools[28-31], our study underscores the importance of biodiversity as a foundational source of research materials for scientific research.

Results

Fishing ban and scientific research

Table 1 presents the results from estimating the DiD model (Eq. 1 in Methods). Columns 1-4 display the number of funded programs, total funding amount (thousand RMB), average number of papers generated from these programs, and average citations per paper five years post-publication. The statistically significant point estimates reveal that other things being equal, the ban led to an additional increase of 97% in the number of funded YRF programs and a 230% increase in funding amounts for YRF compared to pre-ban levels, and relative to non-YRF programs. Moreover, YRF is also associated with a 273% differential increase in publications and a 458% increase in citations compared to pre-ban levels. Our approach for estimating these

economic impacts is explained in the Methods section. Robustness checks in Table S2, which include additional fixed effects and alternative citation metrics, corroborate these findings. The effects grow over time and easily double when using alternative metrics of research impact and excluding fish species with no funded research.

We next estimate the event study regressions (outlined in Eq. 2 in Methods) and summarize the results in Fig. 1. The conditional differences in Fig. 1 between YRF and non-YRF funding, publications and citations are small in magnitude and statistically insignificant before the introduction of the fishing ban. This fact validates the critical parallel trends assumption. There is a lag of approximately three years before the impact on funding becomes statistically significant, likely attributable to the time required for the fish populations to recover, proliferate, and then yield more potential research materials (Fig. 1a,b). Due to the exponential path of fish reproduction, the magnitude of the effects becomes ever larger over time. The average number of eventual publications increases right after the fishing ban in part because our publication measure includes all future publications from a program funded in any particular year (Fig. 1c). Note also that these publications are supported by the cumulative increase in fish research materials following the ban. The average citations to the research publications also increase after the fishing ban (Fig. 1d).

To dispel concerns that the increase in research funding due to fishing bans might "crowd out" the funding that non-YRF programs should have received, we verify in the data that research on non-YRF also received greater funding, witnessed an increase in publications, and garnered more citations than what the pre-ban trend would project. This is shown in table S3 Panel A and B. As such, we infer that the ban did not simply divert funding from non-YRF to YRF programs.

We also investigate whether fish programs divert funding or talent from other disciplines (see Fig. S1). First, we confirm that most fish programs (both YRF and non-YRF programs) are categorized under the Fisheries Science discipline within the Life Sciences field (Fig. S1a). Second, we analyze the disciplinary distribution of all fish programs within Life Sciences, categorizing them into Fisheries Science programs and non-Fisheries Science programs. We find that, after the fishing ban, the proportion of fish research conducted by non-Fisheries Science does not increase. This implies that fish programs become more concentrated within Fisheries Science after the YRF ban and they do so without attracting resources away from non-Fisheries Science disciplines (Fig. S1b). Third, we investigate whether Life Sciences divert funding from other fields. Time series graphs for the proportions of programs across eight fields including Life Sciences are in Fig. S1c. The shares of Life Sciences programs slightly decrease after the ban, further reinforcing that they do not crowd out programs in other fields. In the end, even if there were any crowding-out as a market outcome, it is unlikely welfare-reducing, absent salient market frictions.

It is important to ascertain whether the fishing ban affects other types of scientific output. We investigate patents, awards, and books related to funded programs and show the fishing ban also leads to an increase in these other types of YRF research outputs. These results are presented in Columns 1-3 of Table 2. Public influence on YRF research also increases following the fishing ban. Here, we use news reports related to fish research to construct the public influence of research each year for each type of fish. More reports typically mean more research activity, as findings are often shared with the public through the media. We classify news reports as "fish research" if they mention a fish species from our catalog and include research-related terms in Table S7. The result in Column 4 of Table 2 shows that there was a significant rise in news reports about YRF research compared to non-YRF research after the fishing ban, indicating increased public influence of YRF research post-ban.

Potential explanations

Government research policies concerning YRF programs

One explanation for our main finding may be that more government policies arise related to, contemporaneous with, or even after, the fishing ban to encourage YRF-related scientific research. To investigate this possibility, we first collect all policy documents in the 1995-2014 period from several major Chinese ministries and conduct a textual analysis to test this mechanism. We segment the documents into words and create a word cloud of the 50 most frequent terms (Fig. 2a). None of the top words pertain to scientific research, implying that these policies are unlikely to target scientific research directly. Second, the main goal of the fishing ban is to protect fish resources in the Yangtze River, which could target research focusing on "Yangtze River" or "fish protection." To test this, we remove funded programs related to "Yangtze River" and "fish protection" from our sample. The main results remain, further invalidating the alternative channel (Table S4). Third, following the fishing ban, the NSFC committee might have boosted Yangtze River-related research funding by increasing support for such studies. If this mechanism were in place, the committee would have discussed its support for Yangtze River research through media statements. Therefore, we also collect all news reports from the NSFC official website and tag those related to the Yangtze River by year. The result shows no significant change in the support in these news reports post-ban, ruling out this possible channel (Fig. 2b). In summary, policies directly increasing support for research on the Yangtze River and its fish species following the fishing ban appear absent and, even if present, cannot be the primary driver for our findings.

Increase in public attention to the fishing ban

Another possible mechanism through which the fishing ban boosts scientific research is increasing attention in both the public and academic spheres paid to the fishing ban and YRF. We examine the time trend of such attention using the annual ratio of the number of news reports on the "Yangtze River fishing ban" to the number of news reports on the "Yangtze River." We find that public interest peaks when the ban was implemented in 2003 but decreases afterward, suggesting only a transient surge in

attention (Fig. 2c). However, our baseline regression results show that YRF-related scientific research steadily increases over time. This contrast suggests that the rise in scientific research is unlikely to have been driven by public attention to the fishing ban policy.

Furthermore, critically-rare fish species—characterized by low population numbers but still with a chance of recovery through conservation efforts—are most likely to capture the attention of researchers among different fish species[32]. Studying rare species may attract more funding and foster more collaboration opportunities and career advancement. The high academic value and research difficulty of these species often lead to publications in high-impact journals, bringing researchers greater achievement and recognition. Thus, if the mechanism of "heightened researcher attention" were in effect, we expect a surge in research focused on these rarer fish species over others. We classify "rare" fish species as those that are categorized as either "critically endangered (*CR*)," "endangered (*EN*)" or "vulnerable (*VU*)." Contrary to what this channel would imply, the results reveal that research related to rare fish species does not receive a stronger effect than other fish species after the fishing ban (Fig. 2d and Table S5).

Increase in research materials

The third explanation for our main finding, and arguably the most intuitive ex post, is that the implementation of the fishing ban increased the fish population, thus providing a richer biological resource base for scientific study. Note that rigorous scientific research often requires extensive and repeated experimentation to get real and accurate conclusions, a process for which an ample supply of research subjects is indispensable[33-36]. For instance, differential therapeutic effects may arise from varying concentrations of fish oil. High concentrations enhance brain function and address cardiovascular issues, while lower concentrations may contain components increasing cardiovascular risk. Researchers using different amounts of research materials (i.e., fish) may yield divergent conclusions, so the abundance of fish species would be critical for reconciling findings that emerge across different studies[37,38].

The ideal approach to evaluating this mechanism would be to examine directly whether the populations of each YRF species increased following the fishing ban. However, there are no official observational records documenting temporal changes in fish populations. Despite these methodological challenges, we attempt to employ three heterogeneity-based indirect approaches to disentangle the potential role of research materials.

First, we consider potential heterogeneity in the access to research materials. In the early 2000s, China's inter-provincial transport infrastructure was underdeveloped, posing significant obstacles for scientists traveling across provinces for research. Given limited mobility, the scholars near the Yangtze River had an inherent advantage in studying the river's fish species. This proximity reduced the logistical

and financial costs associated with research, potentially increasing the productivity of local institutions. As a result, we would expect the fishing ban to have a greater impact on scientific research conducted by institutions within the Yangtze River basin than those outside it due to the differential ease of access to research materials.

Second, we consider the potential heterogeneity in the availability of different types of fishery materials to help us verify this mechanism. Intuitively, the fishing ban would have a less noticeable effect on research related to extinct fish. This is because even the strictest fishing policies cannot bring back extinct fish, thus eliminating the availability of corresponding materials for researchers to study. Consequently, the fishing ban is expected to have a greater impact on research concerning non-extinct fish species than on research of extinct species.

Third, we examine the potential heterogeneity among fish populations in the upstream and non-upstream sections of the Yangtze River. The upstream region harbors approximately 90% of the river basin's hydropower infrastructure. Extensive cascade development and river channelization have resulted in significant habitat fragmentation. Due to these challenging environmental conditions, the recovery effect of the fishing ban on fish populations in the upstream section is likely to have been weaker. Therefore, if the proposed research material mechanism holds, the impact of the fishing ban on research related to fish species in the non-upstream areas of the Yangtze River is more pronounced compared to those in the upstream regions.

For the aforementioned heterogeneity analyses, we construct three variables: (1) whether the institution conducting the research in a funded program is located in a province within the Yangtze River Basin; (2) whether the fish species is extinct; and, (3) whether the fish species is an endemic fish from the upstream of the Yangtze River. We use a triple-difference regression model (listed as Eq. 5, Eq. 6, and Eq. 7 in Methods), interacting each variable with the baseline DiD term. The point estimates of the coefficients and the 95% confidence intervals are presented in Fig. 3. The coefficients are primarily positive, indicating that the mechanism of increased research materials leads to an increase in scientific research (Fig. 3 and Table S6). These heterogeneity results would not have arisen if the ban had not increased fish species as research materials because neither government policies nor private incentives at the time of the ban specifically targeted researchers in the Yangtze River basin. Additionally, non-extinct or non-upstream fish species were not prioritized by such policies or incentives.

We also document evidence of the effect of the increased diversity of fish species after the fishing ban on funded programs. First, we describe in Fig. 4a how the reported number of fish species in the Yangtze River declined prior to the ban, but exhibit a gradual increase after the ban, including that for the Hejiang reach, an important part of the Yangtze River. Furthermore, we record the natural fishery catch

in the Three Gorges Reservoir area of the Yangtze River, which see a notable increase following the ban. These findings corroborate an increase in fishery resources.

Next, the increase in fish diversity, as seen in Fig. 4a, should also increase research diversity if fish species are used in scientific research. We document the patterns in the annual numbers of fish species mentioned in funded programs' published papers affiliated with YRF and non-YRF. As shown in Fig. 4b, YRF programs' papers mention more fish species than non-YRF programs' papers following the fishing ban.

Discussion

In this study, we examined the unintended spillover effect on scientific research of a sweeping fishing ban in the Yangtze River since 2003. Utilizing a unique dataset on NSFC programs and corresponding papers and citations from 1995 to 2014, we find evidence that the implementation of the fishing ban significantly increased the activity, output, and quality of scientific research related to fish species in the Yangtze River. The evidence is most consistent with one explanation—the research boost arose from the increase in the availability of biological research materials (and their diversity across species) brought about by the fishing ban. Our findings augment the understanding of the benefits[39,40] and costs[14,15,41] of biodiversity conservation and of the implications of natural resources conservation on science in particular.

Our study has several implications. First, effective biodiversity conservation policies, such as a fishing ban, may yield positive externalities on science. This finding underscores the idea that sustainability initiatives may facilitate knowledge creation and dissemination. When assessing the benefits and costs of natural resources conservation policies, we recommend that decision-makers consider its broader effects on research and innovation, because they constitute not only matters of ecological responsibility but also strategic investments in future science and technology. Our estimates likely prove useful when forecasting the impacts of similar conservation policies, such as the 2021 intensification by the Chinese government of the seasonal ban along the Yangtze River to a year-round prohibition for a minimum of ten years. Absent our study, it is difficult to anticipate or quantify how the new initiative can advance quality scientific inquiries and outputs beyond serving as a catalyst for bolstering greater biodiversity and species abundance in the Yangtze River.

Second, our study offers insights concerning the underlying factors driving scientific advancement. In addition to substantial financial investment in research[42] and demographic considerations[29], accessible, abundant, and diverse research materials are equally important for the development of modern science[8], because they enable researchers to conduct experiments, validate hypotheses, and ultimately advance the frontiers of scientific knowledge. This is documented empirically for the first time in the "science of science" field.

In closing, we acknowledge certain limitations of our study and suggest future research directions. Our measurement of scientific inquiries focuses on NSFC, arguably the most important funding program in China. However, other research funding and activities exist, which could render our results an understatement of the effects of the fishing ban on scientific research. Moreover, our analyses regarding the effect of the fishing ban on scientific impact can be extended to examine how the research translates into commercial products and technologies with practical applications. Finally, while fish studies are crucial in biology and ecology, research on other biological groups can be equally informative about the potential effects of conservation and research involving these organisms on allocating research funding and scientific outputs and quality. Our findings hopefully serve as an anchor for promising future research along these lines.

Methods

Data

Fish species

Data on fish species is merged from four different sources. First, we manually collected all the information about freshwater and freshwater/saltwater fish in China from Cnfishbase[43], a comprehensive database of Chinese fish species. This database integrates data from multiple trusted sources, including regional fish monographs, relevant journals and books, and other scientific literature. By synthesizing these diverse inputs, the database Cnfishbase ensures reliability in ichthyological taxonomy through meticulous data verification and comparison. This database includes information about each fish's order, family, species (according to the biological classification system), and habitat (the descriptive statistics are shown in Table S1 Panel C). Second, we determine whether a certain fish is distributed in the river according to the Yangtze River Fish List[44]. Third, based on China's Red List of Biodiversity (2004), we construct a categorical variable (Threatened Level) indicating seven ranked endangered levels: extinct (*EX*), extinct in the wild (*EW*), critically endangered (*CR*), endangered (*EN*), vulnerable (*VU*), least concern (*LC*), and not evaluated (*NE*). Fourth, we also define whether a fish species is endemic to the upstream of the Yangtze River from the literature[45].

Research program funding

Data on all funded programs are retrieved from the NSFC website, which provides information on successful applications. For each program, information is obtained on its unique ID, its affiliated institution, the title of the program, summary and keywords, research field, year of application, amount of grant, and type of fund. We identify programs related to each fish species per year based on whether the species is mentioned in the title, summary, or keywords. We then aggregate the number of programs and funding amounts at the species-year level. Information is obtained from the papers published by these programs and their corresponding citations, which are similarly aggregated at the fish species-year level. Due to data limitations, the quality of the NSFC data after 2014 is not so reliable. Additionally, significant changes in

fishing ban policies occurred after 2015. Consequently, our sample period is restricted to the year 2014 and earlier. According to the sub-sample statistics in Table S1 Panel B, the total number of funds related to YRF is about 0.11 per year per fish species on average, with a total amount of about 51,240 RMB. The average number of papers generated by YRF-related funded programs is 0.26 and the average citation within five years post-publication for those papers is 0.16.

Model

We begin examining the impact of the fishing ban in the Yangtze River on project funding in the following standard DiD framework. Specifically, we run the following regression:

$$Scientific\ Research_{f,t} = \alpha + \beta_1 YRF_f \times Post_t + \delta_f + \gamma_t + \varepsilon_{f,t} \ (\text{Eq.1}) \cdot$$

where *f* indexes fish species, and *t* indexes years. The outcomes of interest, denoted $Scientific\ Research_{f,t}$, include four metrics: the number of funded programs, the amount of funding (thousand RMB), publications per fund, and citations per paper related to fish *f* in year *t*. YRF_f is a dummy variable that equals one if fish *f* is included in the list of YRF. $Post_t$ is a dummy variable that equals one for the years in and after 2003, the start year of the fishing ban. The equation also contains controls for fish species and year-fixed effects, δ_f and γ_t. $\varepsilon_{f,t}$ is the error term. The fish species fixed effects, δ_f, which are a set of fish-specific dummy variables, can control for time-invariant confounders specific to each fish, such as the family and habitat. The year fixed effects, γ_t, are a set of dummy variables that account for shocks common to all fishes in a given year, such as a national policy. We cluster the standard errors at fish order × year level to account for possible correlations in the residual. The coefficient of interest in Eq. 1 is β_1, the estimated impact of the fishing ban on scientific research. We expect the coefficient to be positive, suggesting a greater increase in the scientific research related to YRF.

We also estimate a fully flexible year-by-year specification taking the following form:

$$Scientific\ Research_{f,t} = \alpha + \sum_{\tau \neq 2002} \beta_\tau YRF_f \times Year_\tau + \delta_f + \gamma_t + \varepsilon_{f,t} \ (\text{Eq.2})$$

In Eq. 2, instead of interacting YRF_f with a post-reform indicator variable, we interact the treatment variable with each year relative to 2002. The estimated vectors of β_τ reveal the differences between the treated and control groups in each year. If, for example, the fishing ban increased scientific research, then we would expect the estimate β_τ to be constant over time for years before the fishing ban and then to increase as the ban began.

To investigate whether the increase in fund applications is closely related to the increase in Yangtze River-related policy support of the fund's supply side, we evaluate the changes in the probability of news articles from the NSFC website being classified as "Yangtze River research." The specification is set as follows:

$$1\left(News\ on\ Yangtze\ River\ Research\right)_{i,t} = \alpha + \sum_{t=2001}^{2014} \beta_{i,t} Year_t + \varepsilon_{i,t} \quad \text{(Eq.3)}$$

where $1\left(News\ on\ Yangtze\ River\ Research\right)_{i,t}$ equals one if the news i contains the term "Yangtze River" along with a list of associated research-related terms in table S7, zero otherwise. $Year_t$ equals one in year t and zero otherwise. Each observation is a piece of news from the NSFC website. The coefficient $\beta_{i,t}$ captures the change in NSFC's support on the Yangtze River research year by year.

To test the mechanism that the fishing ban has led to heightened attention from researchers, we run the following regression:

$$\begin{aligned} Scientific\ Research_{f,t} &= \alpha + \beta_1 YRF_f \times Post_t \times Rare_f \\ &+ \beta_2 YRF_f \times Post_t + \beta_3 Rare_f \times Post_t + \delta_f + \gamma_t + \varepsilon_{f,t} \quad \text{(Eq.4)} \end{aligned}$$

where $Rare_f$ equals one if a fish species is classified as vulnerable (*VU*) or endangered (*EN*) or critically endangered (*CR*), according to the threatened level of fish in Table S1 Panel C, and zero otherwise.

To provide further evidence to support the claim that the fishing ban has led to an increase in research materials and thus YRF research, we further run the following three regressions:

$$\begin{aligned} Scientific\ Research_{f,p,t} &= \alpha + \beta_1 YRF_f \times Post_t \times YR\ Prov_p \\ &+ \beta_2 YRF_f \times Post_t + \beta_3 YR\ Prov_p \times Post_t + \beta_4 YRF_f \times YR\ Prov_p + \delta_f + \mu_p + \gamma_t + \varepsilon_{f,p,t} \quad \text{(Eq.5)} \end{aligned}$$

where $YR\ Prov_p$ represents whether a province is geographically proximate to the Yangtze River basin, including 19 provincial-level administrative units: Qinghai, Tibet, Sichuan, Yunnan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, Shanghai, Guizhou, Gansu, Shaanxi, Henan, Zhejiang, Guangxi, Guangdong, and Fujian. The interest coefficient in the equation, β_1, is anticipated to display a statistically significant positive effect.

$$\begin{aligned} Scientific\ Research_{f,t} &= \alpha + \beta_1 YRF_f \times Post_t \times Non-Extinct_f \\ &+ \beta_2 YRF_f \times Post_t + \beta_3 Non-Extinct_f \times Post_t + \delta_f + \gamma_t + \varepsilon_{f,t} \quad \text{(Eq.6)} \end{aligned}$$

where $Non-Extinct_f$ equals one if a fish species is not classified as extinct (*EX*) or extinct in the wild (*EW*) according to the threatened level of fish in Table S1 Panel C, zero otherwise.

$$Scientific\ Research_{f,t} = \alpha + \beta_1 YRF_f \times Post_t \times Non-Upstream_f + \beta_2 YRF_f \times Post_t + \beta_3 Non-Upstream_f \times Post_t + \delta_f + \gamma_t + \varepsilon_{f,t} \quad (\text{Eq.7})$$

where $Non-Upstream_f$ equals one if a fish species is classified as being found in the Yangtze River but not endemic to the upstream of the Yangtze River according to the distribution of fish in Table S1 Panel C.

Furthermore, we examine whether the public influence on YRF research has increased following the fishing ban. We utilize news reports related to fish research to construct a measure of the public's impact on research for each type of fish each year. The specification of the event study is set as follows:

$$News\ report\ on\ fish\ research_{f,t} = \alpha + \sum_{\tau=2000}^{2014} \beta_\tau YRF_f \times Year_\tau + \delta_f + \gamma_t + \varepsilon_{f,t} \quad (\text{Eq.8}).$$

where $News\ report\ on\ fish\ research_{f,t}$ equals the number of news related to research on fish *f* in year *t.* A news report is identified as research-related if it includes both the name of a fish species and a set of research-related terms in Table S7. The other terms remain unchanged from Eq. 1.

Method for quantifying economic impact

When calculating the economic impact, it is essential to compare the counterfactual scenario with the actual situation. We can simulate the absence of the fishing ban by setting YRF to zero in Eq.1 following the established protocols[46]. By doing so, we estimate the overall scientific research outcomes (including the number of funded programs, funding amounts, publications, and citations) related to YRF under the counterfactual scenario where the fishing ban does not exist, other things being equal. Comparing this hypothetical scenario with the actual situation allows us to quantify the increase in scientific research attributed to the fishing ban.

The back-of-the-envelope calculation goes as follows. First, based on the DiD coefficient estimated from Eq.1, we subtract this coefficient from the actual scientific research values for YRF. This provides us with the estimated scientific research values under the counterfactual scenario. We then calculate the difference between the actual and counterfactual situations. Summing up these differences, we obtain the overall impact on scientific research resulting from the ban.

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Figures and tables

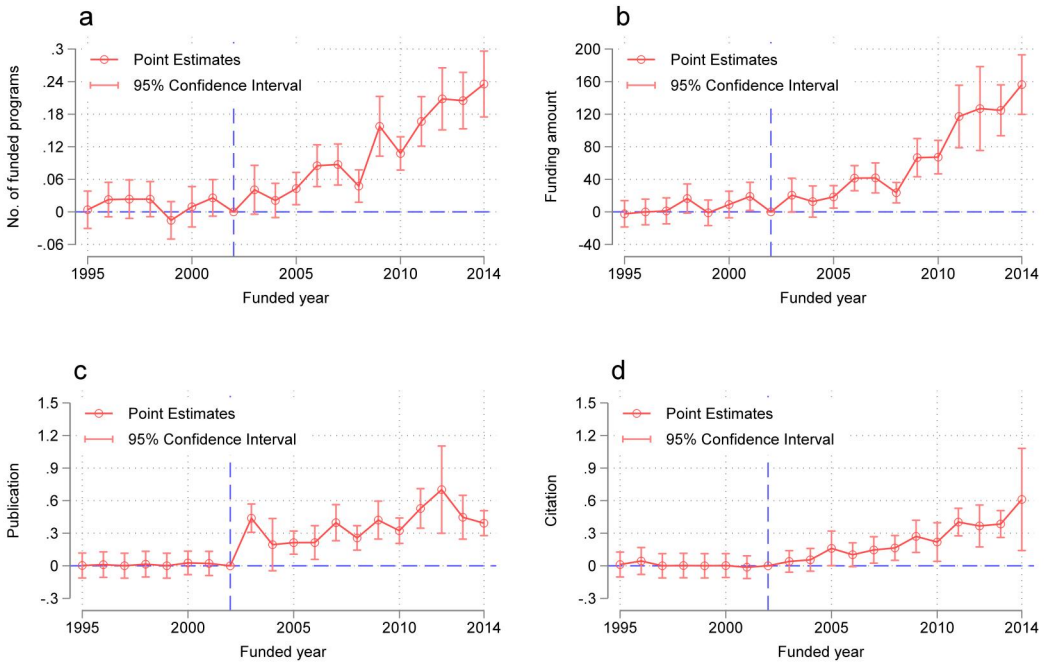


Fig. 1: Effect of fishing regulation on scientific research. This figure illustrates the estimated differences in various metrics between Yangtze River fish species and non-Yangtze River fish species before and after the fishing ban, as calculated using Eq. 2. Specifically, it examines differences in the number of funded programs (**a**), the amount of funding (thousand RMB) (**b**), eventual publications per funded program (**c**), and citations per published paper (**d**). The markers and capped spikes represent the OLS estimators and 95% confidence intervals. The sample period covers from 1995 to 2014. The dashed vertical line indicates the time point one year prior to the initiation of the fishing ban. The regression includes fish species fixed effects and year fixed effects. The standard errors are clustered at the fish order × year level.

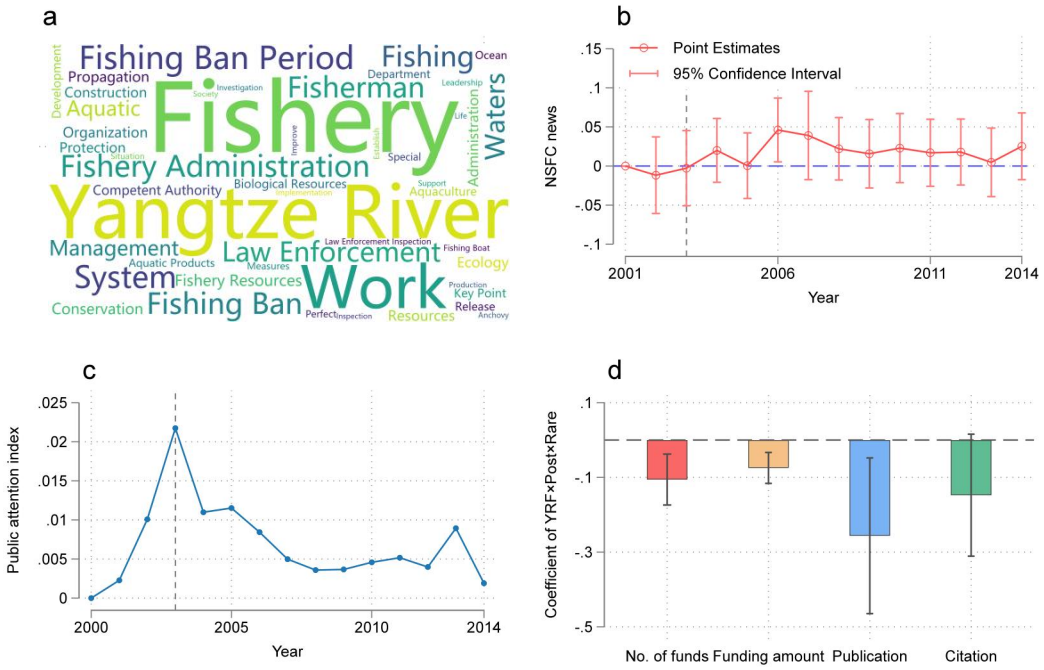


Fig. 2: Direct policy support for YRF scientific research. a, A word cloud of fishing ban policy documents, where the size of the word indicates its frequency of occurrence. We select the top 50 most frequent words. The fishing ban-related policies were collected from the websites of the Ministry of Agriculture, Ministry of Science and Technology, Ministry of Finance, the State Council, Ministry of Ecology and Environment, and the National Development and Reform Commission for "fishing ban" related policy documents. **b,** Changes in support from NSFC towards research on the Yangtze River (see Eq. 3 in Methods for details). This is depicted through the estimated changes in the probability of news articles being classified as "Yangtze River research" news. The classification is based on the occurrence of the term "Yangtze River," along with a list of associated research-related terms on the NSFC website (Table S7). **c,** Change in the public's attention regarding the Yangtze River fishing ban. We calculate the Public Attention Index by dividing the number of news reports mentioning the theme "Yangtze River fishing ban" by the total number of news reports mentioning the "Yangtze River" for that particular year. **d,** Heterogeneous effects of fishing ban on research pertaining to rare fish species (see Eq. 4 in Methods for details). Rare fish species are classified as vulnerable (*VU*) or endangered (*EN*) or critically endangered (*CR*). The dependent variables are the number of funded programs, funding amount (million RMB), publications per fund, and citations per paper. The regression includes fish species fixed effects and year fixed effects. The standard errors are clustered at the fish order × year level.

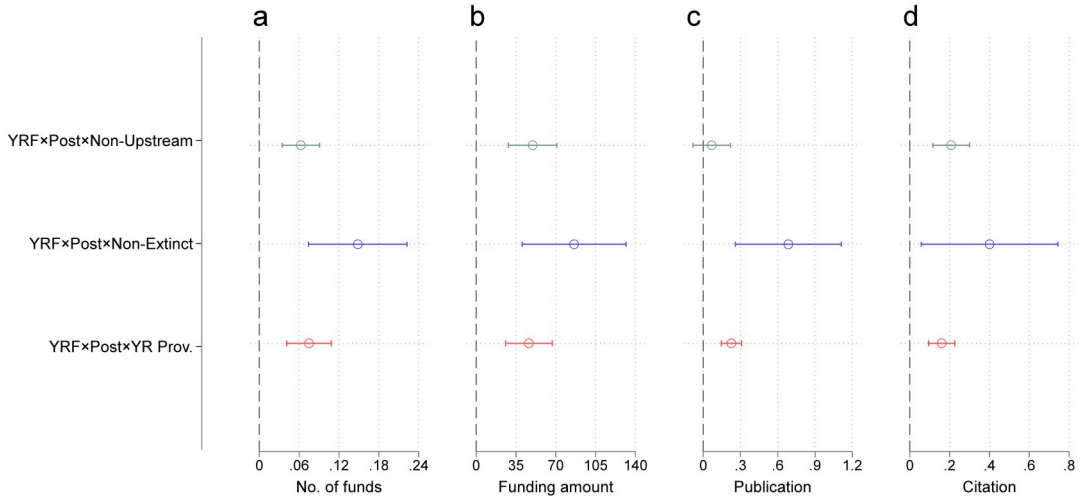
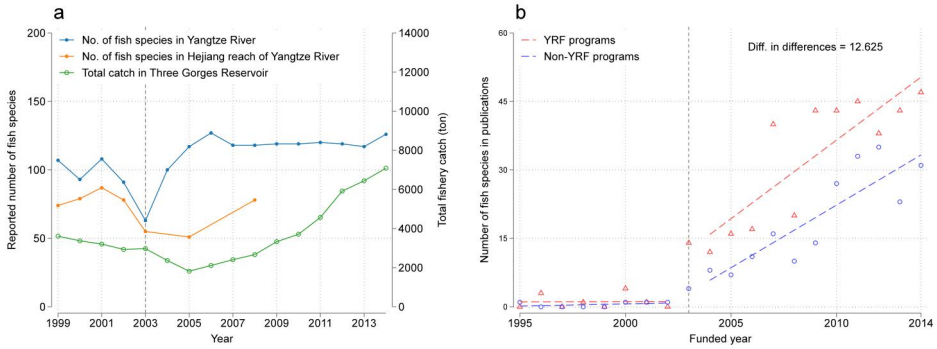


Fig. 3: Increase in biological materials for scientific research. This figure presents the heterogeneity of the impact of fishing regulations on scientific research across different groups. The groups include: (1) Whether the institution to which the fund belongs is located in a province in the Yangtze River Basin, (2) Whether the fish species have become extinct (*EX*) or extinct in the wild (*EW*), and (3) Whether the fish species are endemic to the upstream of the Yangtze River. This figure presents the point estimates and 95% confidence intervals of the effects on the number of funds, funding amount (thousand RMB), publications per fund, and citations per paper. The regression includes fish species fixed effects and year fixed effects. The standard errors are clustered at the fish order × year level.



642

643 **Fig. 4: Increase in biological materials for scientific research. a,** Annual reported number
644 of fish species in the Yangtze River and the Hejiang reach of the Yangtze River. The
645 statistical data is from the *Bulletin on the Ecological and Environmental Monitoring Results*
646 *of the Three Gorges Project* issued by the Ministry of Environmental Protection from 2000 to
647 2015. The blue and orange solid lines represent the trend in the reported number of fish
648 species in the Yangtze River and the Hejiang reach of the Yangtze River. The green solid line
649 represents the trend in total fishery catch in the Three Gorges Reservoir area. The black
650 vertical dashed line indicates the year when the fishing ban started. Due to the major flood
651 that occurred on the Yangtze River in 1998, we are only displaying data from 1999 onwards.
652 **b,** Number of fish species in the YRF and non-YRF programs' corresponding publications.
653 The red dashed line represents the YRF programs' associated publications, while the blue
654 dashed line represents the non-YRF programs' associated publications. The black dashed
655 vertical line indicates the time when the fishing ban was implemented.

Table 1: Effect of fishing regulation on scientific research

	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post	0.105***	62.848***	0.368***	0.238***
	(0.018)	(11.503)	(0.034)	(0.038)
Observations	31240	31240	31240	31240
Adjusted R^2	0.521	0.349	0.193	0.163
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: The table presents the DiD estimation of the impact of fishing regulations on scientific research outcomes, evaluated from both short-term and long-term perspectives. In the short term, the analysis examines two independent variables: the number of funded programs (Column 1) and the amount of funding (Column 2). From a long-term perspective, the analysis examines publications per fund (Column 3) and citations per paper (Column 4). The sample covers the period from 1995 to 2014. "YRF" is a binary indicator that equals one if a fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and after 2003. The regression includes fish species fixed effects and year fixed effects. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 2: Effect of fishing regulation on other scientific outputs and public influence

	Patents	Books	Awards	Public Influence
	(1)	(2)	(3)	(4)
YRF×Post	0.012***	0.003***	0.008***	0.020***
	(0.003)	(0.001)	(0.002)	(0.003)
Observations	31240	31240	31240	23415
Adjusted R^2	0.041	0.050	0.079	0.642
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: This table replaces the dependent variable with other outcomes of the fund, including patents, books, awards (also divided by the number of funds) and news related to fish research. The sample covers the period from 1995 to 2014 for Columns 1-3, and 2000 to 2014 for Column 4. "YRF" is a binary indicator that equals one if a fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and after 2003. The regression includes fish species fixed effects and year fixed effects. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Supplementary Materials

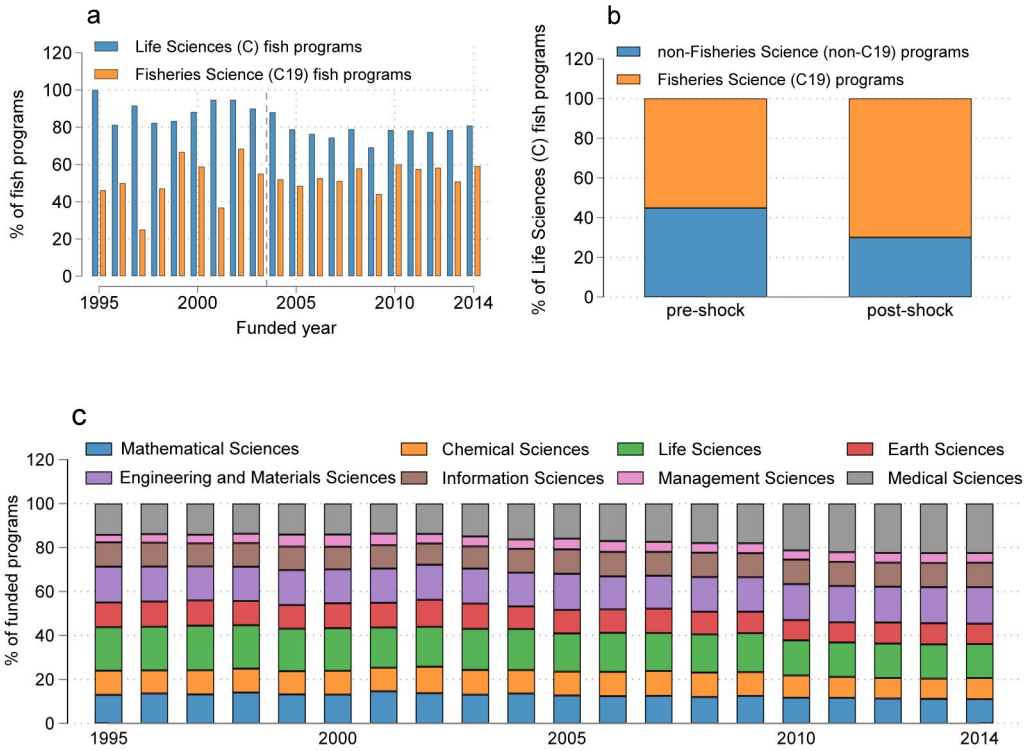


Fig. S1: Excluding inter-disciplinary crowding out. a, The percentage of fish programs in the discipline of Fisheries Science (code C19) out of all fish programs, and the percentage of fish programs in the discipline of Life Sciences (code C) out of all fish programs. **b**, The percentage of Fisheries Science fish programs out of all Life Sciences fish programs before and after the fishing ban. **c**, The percentage of funded programs by each field out of all programs over time.

684 **Table S1: Variable definitions and summary statistics**

Panel A: Variable definitions and summary statistics

Variable	Definition	Number of obs.	Mean	Std. Dev.
Outcome				
Number	Total number of fish-related funded programs	31240	0.03	0.38
Amount	Total amount of fish-related funded programs (thousand RMB)	31240	12.99	224.98
Publication	Average number of papers published by funded programs	31240	0.08	0.96
Citation	Average citation within five years following publication for papers out of funded programs	31240	0.05	0.79
Treatment				
Yangtze	Takes one if it is included in the list of Yangtze River fish, zero otherwise	31240	0.20	0.40

Panel B: Subsample statistics: funded programs information

Variable	Sample	Number of obs.	Mean	Std. Dev.
Number	Yangtze	6400	0.11	0.79
	Non-Yangtze	24840	0.01	0.15
Amount	Yangtze	6400	51.24	463.29
	Non-Yangtze	24840	3.13	87.44
Publication	Yangtze	6400	0.26	1.73
	Non-Yangtze	24840	0.03	0.61
Citation	Yangtze	6400	0.16	1.51
	Non-Yangtze	24840	0.02	0.43

685

686 **Table S1: Variable definitions and summary statistics (continued)**

Panel C: Subsample statistics: Fish information

Variable	Sample	Number of obs./Category	Unique number
Species	Yangtze	6400	320
	Non-Yangtze	24840	1242
Family	Yangtze	6400	33
	Non-Yangtze	24840	86
Order	Yangtze	6400	16
	Non-Yangtze	24840	33
Habitat	Yangtze	freshwater	303
		freshwater/saltwater	17
	Non-Yangtze	freshwater	1169
		freshwater/saltwater	73
Threatened level	Yangtze	not evaluated (*NE*)	276
		least concern (*LC*)	2
		vulnerable (*VU*)	16
		critically endangered (*CR*)	4
		endangered (*EN*)	19
		extinct (*EX*)	1
		extinct in the wild (*EW*)	2
	Non-Yangtze	not evaluated (*NE*)	1166
		least concern (*LC*)	1
		vulnerable (*VU*)	46
		critically endangered (*CR*)	3
		endangered (*EN*)	22
		extinct (*EX*)	2
		extinct in the wild (*EW*)	2
Distribution	Yangtze	fish species endemic to the upstream of the Yangtze	46
		other fish in the Yangtze River	274
	Non-Yangtze	non-Yangtze River fish	1242

687 Notes: This table presents the descriptive statistics of the main variables. **Panel A** reports the
688 number of funds and the corresponding funding amounts. **Panel B** categorizes these statistics
689 by whether the funds and funding amounts are related to Yangtze River fish or non-Yangtze
690 River fish. **Panel C** provides a detailed breakdown of the descriptive statistics for each type
691 of fish, organizing the data by species, family, order (according to the biological classification
692 system), habitat, threatened level, and distribution.

693 **Table S2: Robustness of baseline results**

Panel A

	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post	0.104***	62.872***	0.335***	0.218***
	(0.021)	(13.460)	(0.037)	(0.042)
Observations	31240	31240	31240	31240
Adjusted R^2	0.539	0.362	0.213	0.184
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Family×Post FE	YES	YES	YES	YES

Panel B

	Alternative citation measurement: average citation within N years post-publication				Citations after excluding fish species with no funded research
	N=5	N=6	N=7	N=8	
	(1)	(2)	(3)	(4)	(5)
YRF×Post	0.238***	0.280***	0.300***	0.306***	0.610***
	(0.038)	(0.045)	(0.047)	(0.048)	(0.183)
Observations	31240	31240	31240	31240	2000
Adjusted R^2	0.163	0.162	0.167	0.155	0.175
Species FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES

694 Notes: This table presents additional results as well as robustness checks. **Panel A** further
695 includes Family × Post fixed effects based on the baseline regression. **Panel B** considers the
696 citation counts in the 6th, 7th, and 8th years following the publication of the paper (Columns
697 1-4) and excludes fish samples that have never been funded by the program (Column 5). The
698 sample covers the period from 1995 to 2014. "YRF" is a binary indicator that equals one if a
699 fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and
700 after 2003. Standard errors in parentheses are clustered at the fish order × year level. ***, **,
701 and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table S3: Changes in scientific research on YRF and non-YRF after the fishing ban

Panel A: Sample = YRF				
	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
Post	0.113***	67.061***	0.415***	0.262***
	(0.019)	(12.076)	(0.038)	(0.041)
Observations	6400	6400	6400	6400
Adjusted R^2	0.542	0.361	0.213	0.157
Species FE	YES	YES	YES	YES
Panel B: Sample = non-YRF				
	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
Post	0.008***	4.214***	0.047***	0.024***
	(0.002)	(1.018)	(0.008)	(0.005)
Observations	24840	24840	24840	24840
Adjusted R^2	0.296	0.206	0.125	0.156
Species FE	YES	YES	YES	YES

Notes: This table shows the changes in scientific research on Yangtze River fish and non-Yangtze River fish after the fishing ban. **Panel A** restricts the sample to Yangtze River fish, and **Panel B** restricts the sample to non-Yangtze River fish. Throughout the analysis, fish species fixed effects are controlled for, and the dependent variables encompass four key indicators of scientific research: the number of funded programs (Column 1), the amount of funding (Column 2), publications per fund (Column 3), and citations per paper (Column 4). The variable "Post" is assigned a value of 1 if the year is 2003 or later and 0 otherwise. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table S4: Excluding programs related to Yangtze River and fish protection

	Excluding "YR" related programs	Excluding "protection" related programs					
			at least X times (10 times in total) the program is judged to be "protection" related by the large model				
			X=6	X=7	X=8	X=9	X=10
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
YRF×Post	0.095***	0.081***	0.077***	0.079***	0.082***	0.082***	0.087***
	(0.016)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)
Observations	31240	31240	31240	31240	31240	31240	31240
Adjusted R^2	0.521	0.520	0.506	0.513	0.519	0.522	0.522
Species FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Notes: This table presents the regression results at the fish-year level after excluding programs related to the "Yangtze River" or "fish protection." Column 1 shows the regression results after removing programs related to the "Yangtze River," defined as programs with the term "Yangtze" in their titles, abstracts, or keywords. Column 2 shows the regression results after removing programs related to "fish protection," defined as programs with the term "protection" in their titles, abstracts, or keywords. Columns 3 to 7 use a prominent large language model (GPT 4o) to determine whether a program is related to "fish protection." The sample covers the period from 1995 to 2014. "YRF" is a binary indicator that equals one if a fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and after 2003. The regression includes fish species fixed effects and year fixed effects. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table S5: Heterogeneous effect on research related to rare fish species

	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post×Rare	-0.106***	-0.075***	-0.256**	-0.148*
	(0.035)	(0.021)	(0.106)	(0.083)
Observations	31240	31240	31240	31240
Adjusted R^2	0.521	0.349	0.194	0.163
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: The table presents the triple difference estimation of the impact of fishing regulations on scientific research outcomes, evaluated from both short-term and long-term perspectives. In the short term, the analysis examines two independent variables: the number of funded programs (Column 1) and the amount of funding (Column 2). From a long-term perspective, the analysis examines publications per fund (Column 3) and citations per paper (Column 4). The sample covers the period from 1995 to 2014. "YRF" is a binary indicator that equals one if a fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and after 2003. "Rare" is a binary indicator that equals one if a fish species is classified as vulnerable or endangered or critically endangered. The regression includes fish species fixed effects and year fixed effects. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table S6: Heterogeneous effect on research

Panel A: Heterogeneous effect on research in Yangtze River Basin institutions				
	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post×YR Prov	0.077***	47.904***	0.245***	0.159***
	(0.017)	(10.724)	(0.043)	(0.033)
Observations	62480	62480	62480	62480
Adjusted R^2	0.317	0.200	0.140	0.086
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Panel B: Heterogeneous effect on research related to extinct fish species				
	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post×Non-Extinct	0.148***	86.041***	0.685***	0.400**
	(0.038)	(23.244)	(0.217)	(0.175)
Observations	31240	31240	31240	31240
Adjusted R^2	0.521	0.349	0.193	0.163
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Panel C: Heterogeneous effect on research related to fish species native to upstream of Yangtze River				
	Short-term		Long-term	
	Number of funds	Funding amount	Publication	Citation
	(1)	(2)	(3)	(4)
YRF×Post×Non-Upstream	0.063***	49.630***	0.068	0.208***
	(0.014)	(10.863)	(0.077)	(0.047)
Observations	31240	31240	31240	31240
Adjusted R^2	0.521	0.349	0.193	0.163
Species FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Notes: The table presents the triple difference estimation of the impact of fishing regulations on scientific research outcomes, evaluated from both short-term and long-term perspectives. In the short term, the analysis examines two independent variables: the number of funded programs (Column 1) and the amount of funding (Column 2). From a long-term perspective, the analysis examines publications per fund (Column 3) and citations per paper (Column 4). The sample covers the period from 1995 to 2014. "YRF" is a binary indicator that equals one if a fish species belongs to the Yangtze River. "Post" is a binary indicator that equals one in and after 2003. In **Panel A**, "YR Prov" is a binary indicator that equals one if a funded

program is hosted by an institution located in one of the provinces within the Yangtze River Basin. In **Panel B**, Non-Extinct is a binary indicator that equals one if a fish species is classified as *not* extinct. In **Panel C**, Non-Upstream is a binary indicator that equals one if a fish species is classified as *not* endemic to the upstream region of the Yangtze River. The regression includes fish species fixed effects and year fixed effects. Standard errors in parentheses are clustered at the fish order × year level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table S7: List of vocabulary related to scientific research

Chinese words	English translation
研究	Research
科研	Scientific research
实验	Experiment
试验	Test
创新	Innovation
突破	Breakthrough
论文	Paper
专利	Patent
学术	Academic
理论	Theory

Notes: This table presents a set of vocabulary related to scientific research. We use this vocabulary to determine whether the news on the NSFC website (Eq. 3) and the impact of fish research (Eq. 8) are research-related.