

Communication

# Fish Biodiversity Conservation and Restoration, Yangtze River Basin, China, Urgently Needs ‘Scientific’ and ‘Ecological’ Action

Jianhua Li <sup>1</sup>, Xiaochen Chen <sup>2,\*</sup> , Xinliang Zhang <sup>3</sup>, Zhenjia Huang <sup>2</sup>, Liang Xiao <sup>2</sup>, Liangliang Huang <sup>4</sup> , Yuichi Kano <sup>5</sup> , Tatsuro Sato <sup>5</sup>, Yukihiro Shimatani <sup>5</sup> and Chunpeng Zhang <sup>6</sup> 

<sup>1</sup> Key Laboratory of Yangtze Water Environment, Ministry of Education, Tongji University, Shanghai 200092, China; leejianhua@tongji.edu.cn

<sup>2</sup> Fujian Provincial Engineering Research Center of Rural Waste Recycling Technology, College of Environment and Resources, Fuzhou University, Fuzhou 350108, China; zhuang@fzu.edu.cn (Z.H.); n190627056@fzu.edu.cn (L.X.)

<sup>3</sup> Crawford School of Public Policy, Australian National University, Canberra, ACT 2601, Australia; adam.zhang@alumni.anu.edu.au

<sup>4</sup> College of Environmental Science and Engineering, Guilin University of Technology, Guilin 541004, China; llhuang@glut.edu.cn

<sup>5</sup> Department of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, Fukuoka 819-0395, Japan; kano@species.jp (Y.K.); sato@civil.kyushu-u.ac.jp (T.S.); shimatani@civil.kyushu-u.ac.jp (Y.S.)

<sup>6</sup> Key Laboratory of Groundwater Resources and Environment (Ministry of Education), Jilin University, Changchun 130021, China; zhang\_cp@jlu.edu.cn

\* Correspondence: chenxiaochen@fzu.edu.cn

Received: 23 September 2020; Accepted: 27 October 2020; Published: 29 October 2020



**Abstract:** Although many significant policies and legislation have been put forth by the Chinese government aiming toward “ecological civilization” for the aquatic environment, in practice, the situation is still undesirable. A pioneering multi-year study has since been conducted on the East Tiaoxi River (a major tributary of the renowned Yangtze River), focusing on fish distribution, influencing factors and habitat requirements, and river health as well. This revealed certain key species, hotspot protection areas, negative impacts of local anthropogenic activities, and inappropriate perceptions and practices of conservation and restoration. We found that not all fish species were equally conserved and that the supposedly ecological engineering measures were initiated without regard for ecological integrity. Our exemplary study appreciates scientific basis and truly ecological notion, and urgently advocates comprehensive and continuous basin-scale scientific investigation of fish biodiversity, and “ecological river”-oriented conservation and restoration action for the Yangtze River Basin and broader areas of China.

**Keywords:** conservation; ecological integrity; fish biodiversity; restoration; river basin management; Yangtze River

## 1. Introduction

The number and biodiversity of fish are the most significant indicators of the health of a waterbody. In China, there are more than 1100 species of freshwater fish, 70% of which inhabit the rivers [1,2]. Although the total number is notable among worldwide statistics, the biodiversity has been continuously declining with increasing anthropogenic and economic development. In fact, as early as 1998, 92 species

of the freshwater fish were listed in the China Red Data Book of Endangered Animals: Pisces [3], which shows that four species unfortunately have gone extinct and 28 species have become endangered. The loss of biodiversity greatly exceeds the world average [4]. It is the adverse anthropogenic impacts on the freshwater ecosystem that must first be to blame. Both notorious industrialisation and urbanisation are major hindrances to sustainable development in China. Against the background of abrupt population expansion, many irrational activities associated with urbanisation have led to deterioration of the aquatic environment, such as unsustainable exploitation of water resources, improper river modification, pollutant discharge and exotic species invasion.

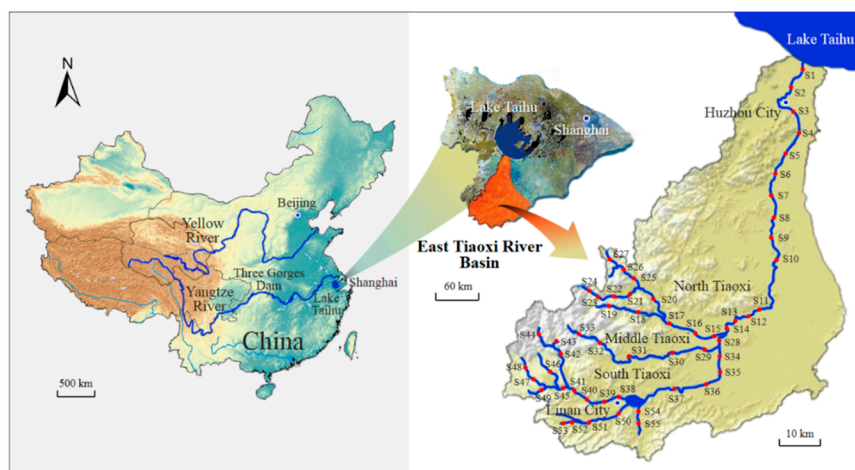
In 2018, China's 13th National People's Congress inserted the term "ecological civilization" into the country's constitution for the very first time, indicating that the notion has now been raised up to the national strategy level as a main focus paralleling economic and social development [5]. In the field of aquatic environment, Chinese government has established a series of policies aimed toward balanced water resources exploitation and aquatic ecosystem protection and restoration. In April 2015, the State Council of China promoted the "Action Plan for Prevention and Control of Water Pollution," a milestone also known as the "Ten-point Water Plan," the primary objective of which was to substantially improve the country's water quality and aquatic ecological situation by the year 2020 [6]. More recently, legislation also has been enhanced. In 2018, the revised Water Pollution Prevention and Control Law came into force, aiming at boosting aquatic environmental protection and restoration from a legal standpoint [7]. The effects of water quality on aquatic biodiversity have been comprehensively reviewed, and accordingly a series of protection areas have been established throughout the country. All these actions demonstrate that the priority of public policy has shifted from mainly social and economic progress to also include environmental conservation for healthy aquatic ecosystems and sustainable hydrologic cycles.

However, the practical situation suggests an aquatic ecological deficit would remain. What is worse, knowledge of the ecosystemic constitution of freshwater fish (including migratory fish) of river basins over much broader areas of China, as well as specific factors influencing the biodiversity, is far from sufficient. The reported monitoring data over the past few decades were either not comprehensive or lacked continuity. As a result, the conservation and restoration of aquatic ecosystems have been performed nationwide without a reliable scientific basis and have even tended to be too formalistic and/or disorganised. To make contributions for sound river basin management in China, a pioneering study on the ecological situation (especially the fish biodiversity) was initiated in the Yangtze River Basin. The necessity and significance of the scientific basis and the truly ecological notion would be emphasized. Besides, the comprehensive and continuous basin-scale scientific investigation, as well as the "ecological river" concept-oriented conservation and restoration action, would be timely advocated.

## 2. Materials and Methods

As shown in Figure 1, the Yangtze River originates from glaciers on the Qinghai–Tibet Plateau at its westernmost point, heads toward the East China Sea and eventually enters the Pacific Ocean. Along the way, it flows across the southwestern and central parts of China before reaching its outlet in Shanghai (the economic centre of the country). With a length of 6300 km and a catchment area of 1.8 million km<sup>2</sup>, the Yangtze River is the third largest river in the world. Having the biggest discharge volume, it also supports the world's largest hydroelectric power station, i.e., the Three Gorges Dam. Designated as part of the latest national development strategies, the Yangtze River Economic Belt includes about 40% of the country's population and aggregate economy and is on the way of high-speed development. In its development planning outline issued in 2016, "ecology first" and "green development" form basic principles. Unfortunately, the Yangtze River Basin had long been sustaining extremely severe destruction of aquatic habitats [8]. In a multi-year study undertaken by the China Europe Water Platform (CEWP) project, a China–Austria cooperating project, etc., representative tributaries of the lower basin of the Yangtze River were thoroughly and continuously investigated. The main study area was the East Tiaoxi River Basin, one of the best epitomes of the

environmental issues of the Yangtze River Basin (Figure 1). With a mainstream length of 152 km and a catchment area of 2267 km<sup>2</sup>, the East Tiaoxi River is the largest river flowing into Lake Taihu, the third largest freshwater lake in the Yangtze River Basin. This lake with scenic beauty has been drawing focuses of worldwide researchers, ironically due to its notorious chronic water pollution problems such as eutrophication [9].



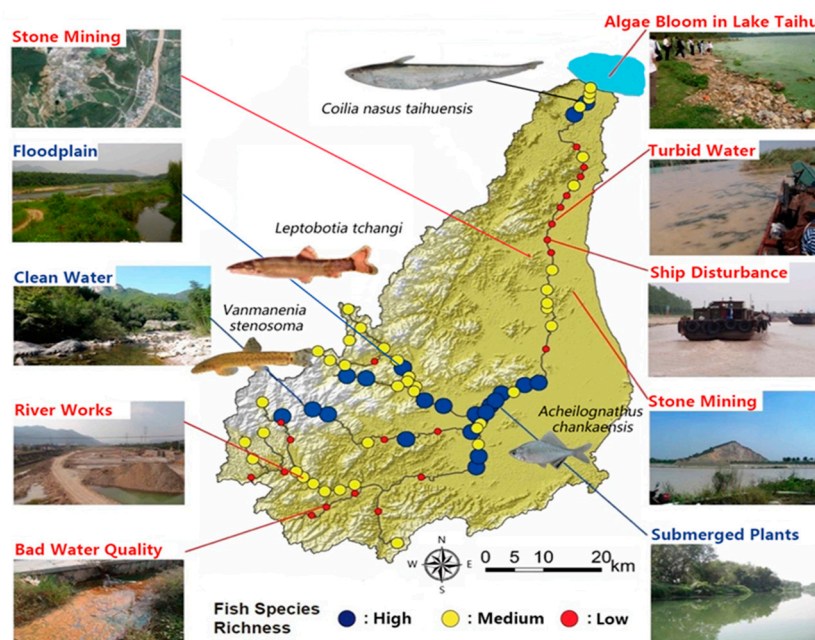
**Figure 1.** Study area and sampling sites.

Regarding fish species and communities, the joint research focused primarily on the following: (1) spatiotemporal distribution, (2) natural and anthropogenic influences, (3) habitat requirements of certain key species and (4) river health assessment based on fish-based index of biological integrity (FIBI). Regarding FIBI system development, 24 metrics were selected as candidate metrics, which covered five attributes of fish assemblage, i.e., species richness and composition, trophic composition, tolerance/intolerance, reproductive guilds, and fish abundance and health condition. Two FIBI systems were then established for the upper reaches (eco-zone of evergreen broad-leaf forest) and middle-lower reaches (eco-zone of urban and suburban agricultural areas), respectively. The detailed system composition, as well as the criteria of metric scoring and assessment, was described by Huang et al. [10]. Geographic Information System (GIS) was one of the major tools used to facilitate the entire research. Detailed field investigation was carried out at 55 sampling sites of the East Tiaoxi River Basin (Figure 1), by wading in the upper reaches (reservoirs excluded) and by boat in the middle-lower reaches, respectively. In the shallow reaches fish were sampled using specific backpack electrofisher at the main habitat units such as riffle, glide and pool, while in the middle-lower reaches local boat electrofisher was used. The samples were identified to species level, followed by data processing using methods such as sample-based rarefaction curve and cluster analysis to reveal fish distribution patterns [11–13]. The spatiotemporal variation of fish communities and the associations of fish density and richness with environmental variables (influencing factors) were also investigated using methods such as non-metric multidimensional scaling and canonical correspondence analysis based on fish abundance data [11,13–15]. Note that the major natural factors focused on included distance to source, altitude, stream width, stream velocity, stream depth and pH, and the major anthropogenic factors covered residential area, revetment, farmland and factory.

### 3. Results

In this study, we recorded 84 species of fish, 35 of which were endemic. The main results are presented in Table S1, Figures S1 and S2. Inspiringly, certain endangered species in the neighbouring country Japan were found to be locally flourishing (Figure 2). Owing to the devastation of habitats as well as the blockage of breeding migration routes, the once common *Leptobotia tchangii* Fang, 1936 has almost disappeared and hence was called a “natural monument” by the Japanese Ministry of the Environment.

For similar anthropogenic reasons, *Vanmanenia stenosoma* Boulenger, 1901 and *Acheilognathus chankaensis* Dybowski, 1872 are both at risk of extinction in Japan. The detailed investigation of their habitat requirements (stream depth, stream velocity, pebble size, etc.) provided valuable information for further protection and restoration initiatives in both China and Japan. Taking *Leptobotia tchangi* for instance, it was found that its density had positive correlation with stream velocity, while its body size positively correlated with pebble size (see Figures S3 and S4). On the other hand, the once-famous *Coilia ectenes* Jordan & Seale, 1905 of high culinary and economic value now can rarely be observed, as the deterioration of water quality, devastation of habitats and overharvesting in the Yangtze River led to the drastic decline of this diadromous fish in the past few decades [16]. Meanwhile, another variety featuring freshwater migration—*Coilia nasus taihuensis* Yuan, Lin, Liu & Qin, 1977—has emerged in Lake Taihu and tributaries of the East Tiaoxi (Figure 2), reminding people of the dramatic ecological change induced by human activities. Furthermore, according to the results of river health assessment (Tables S2 and S3), 24 out of 45 monitoring sites were determined to be “healthy” or “fair,” while the rest were either “poor,” “very poor” or “null.” Based on the strategy of identifying conservation priority areas first, 21 locations with high fish biodiversity were determined to be hotspot protection areas, including the habitats of all the above-mentioned key species (see Figure 2). GIS-based tools significantly increased the accuracy of protection activities.



**Figure 2.** Map of fish biodiversity hotspots and influencing factors for East Tiaoxi River.

By comprehensively researching the influences on the richness of fish species, natural factors were identified, including distance to source, altitude, stream width, stream velocity, stream depth and pH (Table S4, Figure S5). More importantly, the study also revealed the impacts of anthropogenic activities (Figure S6, Table S5), especially the negative influences (Figure 2). In addition to common adverse effects such as from water pollution and ship disturbance, we found the impact of local privatised stone mining to be non-negligible. With no regard for the aquatic environment, the stone powder and other residuals from mining and transportation freely entered the adjacent waterbodies, which seriously suffocated the fish by getting stuck in their gills. Besides, other ubiquitous practices such as river training works and water pollution control projects have been continuously converting river environments from their original states to artificial states, thereby causing serious loss of the basic ecological functions of the rivers. The entire study area has locally been subjected to various negative impacts by human activities, such as the expansion of floodways, constrictions caused by bridge crossings, river realignments due to cutoffs and restoration activities, changes in resistance



of dikes, weirs and riprap, river diversion for water intakes, dams and grade control structures, sediment supply from deforestation, increased runoff due to impervious cover, increased nutrient loads and aggravated bank erosion (see Figure 3 for examples). From one October to the next, engineering construction had degraded a hotspot with 15 fish species and 216 individuals to a silent-spot with only 6 species and 20 individuals in just a year. Only where the aquatic habitats were maintained in a good state and rich with hydrophytes was satisfactory fish biodiversity observed (Figure 2). Ironically, the “submerged plants” area would have been reclaimed without this study at river basin scale. The flora presents relevant ecological significance, including the ability to mitigate negative impacts resulting from stone mining. However, it was completely neglected in previous conservation and restoration schemes, as regular surveys on water quality and fish biodiversity were conducted randomly and only at the local level, thus failing to draw the whole picture.



**Figure 3.** Threat to riverine fish biodiversity of Yangtze River posed by engineering construction.

We have also noticed inappropriate perceptions and practices of protection and restoration, which require urgent correction. For example, only fish regarded as flagship species and/or included in the national protection list draw broad attention, such as *Acipenser sinensis* Gray, 1835 and *Neophocaena* Palmer, 1899. Normal fish species, including ones presented in Figure 2, are usually ignored. However, based on the theory of a healthy ecosystem as well as the experience and lessons of many developed countries, all the species within a specific ecosystem must be equally conserved, as they all interrelate and interdepend. Swayed by the impractical expectation of instant effects as well as influenced by the urbanisation tendency in river basin planning, various kinds of supposedly ecological engineering measures are prevailing in riparian areas. Energy-consuming modes of wastewater treatment plants and facilities have been transplanted to the riparian areas. Since they fulfil the dream of ameliorating water pollution overnight, such palliatives make it seem to be quite desirable for local government to handle the inspection and assessment based on directives from higher authorities. Also, popular artificial wetlands have been constructed here and there, with the main focus being on water purification and aesthetics rather than biodiversity conservation. Even worse, a large amount of money has been invested to the artificial landscape projects with no true ecological idea involved, such as a hydrophilic platform (Figure 4). These supposedly ecological measures swiftly satisfy human desires but go against the laws of nature. With dramatically changed land cover and land use in the riparian areas, the vulnerable habitats for fish and other living creatures are apt to be even further degraded. According to the theory of ecological integrity, it is a natural and undisturbed state with physical, chemical and biological integrity that should be the right goal of ecological restoration [17].



**Figure 4.** Hydrophilic platform, an example of supposedly ecological measures.

#### 4. Discussion

The master plan for the development of the Yangtze River Economic Belt has become one of China's principal national strategies. Because the primary goal of water-related environmental policies in China has fundamentally changed as conservation and restoration gain top priority, some measures have been taken as essential, such as a 10-year ban on fishing in the Yangtze River starting in 2020. However, this case study revealed that current practices apparently fail to keep pace with the central government's directives. The present situation in the Yangtze River Basin is still sounding the alarm and causing critical concern among the public. As the biodiversity of freshwater fish keeps on decreasing mainly due to anthropogenic impacts, it is apparent that there has been a serious lack of scientific basis and truly ecological action for sound river basin management.

Comprehensive and continuous scientific investigation at river basin scale is proposed to track riverine fish biodiversity and to further understand the influencing factors. We believe that accurate identification of ecological protection red lines and relevant hotspot protection areas, more targeted action plans and technical guidelines for normalising conservation and restoration activities would be achieved only on the basis of data from scientific study in accordance with the theory of ecological integrity. The results of this exemplary study reveal significant insight into the highly anticipated nationwide practices. To support the initiative, we recommend that the relevant government bodies—such as the Ministry of Science and Technology and the affiliated National Natural Science Foundation of China—set up special funds for long-term fundamental research on the ecological environment and biological resources of the Yangtze River Basin. All involved local authorities should also take responsibility for routine environmental monitoring and assessment. Further, we advise that the supposedly ecological engineering measures for conservation and restoration, together with the destructive pollution control and treatment practices, be strictly prohibited by policy and institutional means [18], which recently have received positive reply from the prime minister. Meanwhile, scientific data and the know-how for effective environmental conservation and restoration must be delivered to and shared among all the stakeholders, especially the government decision-makers in this Chinese case. From the viewpoint of ecological integrity, the real concept of “ecological river” needs to be advocated and put into practice, which aims at recovering the original structure and ecological functions of a river and hence make it regain the resilience and stability in order to maintain acceptable quality under long-term or sudden disturbance [13]. Last but not least, to ensure the success of the whole cause, more stringent legislation and regulations must be enacted and enforced.

Water resources management is the epitome of China's environmental issues, and significant aquatic biodiversity loss in the major river basin shows the severity of the challenges. Heading toward sustainable development, China must make its great power accountable and lead the way by taking “scientific” and “ecological” action.

**Supplementary Materials:** The following are available online at <http://www.mdpi.com/2073-4441/12/11/3043/s1>, Figure S1: Fish species composition in the East Tiaoxi River [13], Figure S2: Fish species richness in each stream order of the East Tiaoxi River [13], Figure S3: The relation between *Leptobotia tchangii*'s density and stream velocity at different sampling sites [11], Figure S4: The relation between *Leptobotia tchangii*'s body size and pebble size at different sampling sites [11], Figure S5: Canonical Correspondence Analysis (CCA) of environmental factors and fish assemblage [11], Figure S6: Impacts of anthropogenic activities to non-parametric multidimensional scaling (NMDS) ordination of fish assemblages [11], Table S1: The list of fish species and their distribution in the East Tiaoxi River [13], Table S2: Criteria for river health assessment based on ecological integrity of fish in the East Tiaoxi River [11], Table S3: River health condition based on Fish Integrated Biotic Index [11], Table S4: Matrix of Spearman  $r_s$  correlation coefficients of environmental variables [11], Table S5: One-way ANOSIM for analysing the impacts of human activities on fish communities [11].

**Author Contributions:** Conceptualization, J.L.; methodology, J.L.; formal analysis, L.H., Y.K., T.S. and Y.S.; investigation, L.H., Y.K., T.S. and Y.S.; writing—original draft preparation, X.C. and X.Z.; writing—review and editing, J.L., X.C., Z.H., L.X. and C.Z.; supervision, J.L. and X.C.; project administration, J.L. and X.C.; funding acquisition, J.L. and X.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by China Europe Water Platform (CEWP) project; China–Austria Joint Innovative and Technological Research Project, grant number 2016YFE0115800; Japanese Global COE Program (Center of Excellence for Asian Conservation Ecology as a Basis of Human-Nature Mutualism); China Major Science and Technology Program for Water Pollution Control and Treatment, grant number 2017ZX07205; Shanghai Institute of Pollution Control and Ecological Security; CSC-DAAD PPP Programmes for Project-Related Personal Exchange, grant number [2019]12039; and Research Funds of Jinjiang Fuzhou University Science Park, grant number 2019-JJFDKY-07.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

## References

- Xing, Y.; Zhang, C.; Fan, E.; Zhao, Y. Freshwater fishes of China: Species richness, endemism, threatened species and conservation. *Divers. Distrib.* **2016**, *22*, 358–370. [[CrossRef](#)]
- Dudgeon, D. Asian river fishes in the Anthropocene: Threats and conservation challenges in an era of rapid environmental change. *J. Fish Biol.* **2011**, *79*, 1487–1524. [[CrossRef](#)] [[PubMed](#)]
- Yue, P.; Chen, Y. *China Red Data Book of Endangered Animals: Pisces*; Science Press: Beijing, China; Hong Kong, China; New York, NY, USA, 1998.
- Chang, N.; Shiao, J.; Gong, G. Diversity of demersal fish in the East China Sea: Implication of eutrophication and fishery. *Cont. Shelf Res.* **2012**, *47*, 42–54. [[CrossRef](#)]
- National People's Congress of China. *Constitution of the People's Republic of China (2018 Amendment)*; National People's Congress of China: Beijing, China, 2018.
- Notice of the State Council on Issuing the Action Plan for Prevention and Control of Water Pollution. Available online: [http://www.mee.gov.cn/zcwj/gwywj/201811/t20181129\\_676575.shtml](http://www.mee.gov.cn/zcwj/gwywj/201811/t20181129_676575.shtml) (accessed on 23 September 2020).
- National People's Congress of China. *Water Pollution Prevention and Control Law of the People's Republic of China 2017*; National People's Congress of China: Beijing, China, 2017.
- Zhu, C.; Pan, J.; Pancost, R.D. Anthropogenic pollution and oxygen depletion in the lower Yangtze River as revealed by sedimentary biomarkers. *Org. Geochem.* **2012**, *53*, 95–98. [[CrossRef](#)]
- Wu, Z.; Wang, X.; Chen, Y.; Cai, Y.; Deng, J. Assessing river water quality using water quality index in Lake Taihu Basin, China. *Sci. Total Environ.* **2018**, *612*, 914–922. [[CrossRef](#)] [[PubMed](#)]
- Huang, L.; Wu, Z.; Jiang, K.; Sato, T.; Kano, Y.; Li, J. Development and application of IBI based on fish to assess the river's health in the East Tiaoxi River. *China Environ. Sci.* **2013**, *33*, 1280–1289.
- Huang, L. Study on the Environmental Biology of Fishes and Assessment Index System of River Health in the East Tiaoxi River. Ph.D. Thesis, Tongji University, Shanghai, China, 2012.
- Huang, L.; Wu, Z.; Li, J. Fish fauna, biogeography and conservation of freshwater fish in Poyang Lake Basin, China. *Environ. Biol. Fish.* **2013**, *96*, 1229–1243. [[CrossRef](#)]
- Li, J.; Huang, L.; Sato, T.; Zou, L.; Jiang, K.; Yahara, T.; Kano, Y. Distribution pattern, threats and conservation of fish biodiversity in the East Tiaoxi, China. *Environ. Biol. Fish.* **2013**, *96*, 519–533. [[CrossRef](#)]
- Jiang, K. Study on River Habitat Types and Their Fish Community Dissimilarity in North Tiaoxi River. Master's Thesis, Tongji University, Shanghai, China, 2013.

15. Li, J.; Huang, L.; Zou, L.; Kano, Y.; Sato, T.; Yahara, T. Spatial and temporal variation of fish assemblages and their association to habitat variables in a mountain stream of north Tiaoxi River, China. *Environ. Biol. Fish.* **2012**, *93*, 403–417. [[CrossRef](#)]
16. Shen, H.; Gu, R.; Xu, G.; Xu, P.; Nie, Z.; Hu, Y. In-depth transcriptome analysis of *Coilia ectenes*, an important fish resource in the Yangtze River: De novo assembly, gene annotation. *Mar. Genom.* **2015**, *23*, 15–17. [[CrossRef](#)] [[PubMed](#)]
17. Ecological Integrity. Available online: <https://archive.epa.gov/aed/research/web/html/ecoint.html> (accessed on 23 September 2020).
18. Wu, L.; Li, J.; Li, S. Destructive pollution control and treatment is aggravating riverine ecological degradation. *China Comment* **2019**, *2*, 44–46.

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).