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Biodiversity and Conservation of Freshwater Fishes in the Yujiang River, China

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Key words
Aquatic conservation, Biodiversity, Freshwater fish, Inventory, Indo-Burma biodiversity, Yujiang River

ABSTRACT

The Yujiang River lies within the Indo-Burma biodiversity hotspot, a large conservation international-designated biodiversity hotspot in tropical Asia that supports some of the most diverse and unique ecosystems on the planet. Despite the extraordinary endemism in its 33 terrestrial ecoregions, there is little information about its freshwater fish biodiversity. Based on our field investigations and an extensive review of the literatures, we identified 137 fish species (including two non-native species), representing 9 orders, 26 families and 88 genera, that are distributed in the Yujiang River and its drainage basin. According to the International Union for Conservation of Nature (IUCN) criteria, six of these species (*Anguilla japonica*, *Cyprinus carpio*, *Luciocyprinus langsoni*, *Pseudohemiculter dispar*, *Ptychidio jordani*, and *Cranoglanis bouderius*), qualify for recognition as Threatened Species. Overfishing, water flow diversions and modifications, and the impacts of non-native species are the greatest threats to freshwater fish biodiversity in the Yujiang River. We recommend the adoption and enforcement of additional protected areas, improvement in approaches to sustainable fishery management, much better control of non-native species, and an improvement in and the expansion of fish life-history research. Our study contributes recommendations for the better protection of freshwater fish biodiversity and the development of sustainable fisheries in the Yujiang River.

INTRODUCTION

Freshwater ecosystems support extremely high levels of aquatic biodiversity and endemism when compared to other ecosystem categories (Strayer and Dudgeon, 2010). They occupy less than 1% surface of earth, yet they support nearly 10% of the earth's biodiversity (Dudgeon *et al*., 2006). Freshwater ecosystems are also the most endangered of the ecosystems in the world (Gleick, 2003). Among all aquatic organisms, freshwater fishes are considered the second most threatened animal group (Bruton, 1995). For this reason, freshwater fishes have received particular attention by conservation biologists and environmental organizations (Olden *et al*., 2010).

China is one of the countries with the greatest biodiversity in the world, including both in marine and freshwater ecosystems (Cao *et al*., 2016). Its vast territory, the varied natural and geographical conditions, and abundance of waterbodies make China one of the most biodiverse countries in its freshwater species diversity (He *et al*., 2020). Many researchers have focused on freshwater fishes in adjacent biodiversity hotspots, such as the Yangtze River (Fu *et al*., 2003) and the Mekong River (Kang *et al*., 2009). Information about freshwater biodiversity in other regions within the Indo-Burma, such as the Yujiang River, is scarce. Indo-Burma is an important biodiversity hotspot region including Cambodia, Laos, Burma, Thailand,

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Vietnam, and South China (Myers *et al*., 2000).

The Yujiang River is located in the Indo-Burma, which is one of biodiversity hotspots with the richest biodiversity on the planet (Myers *et al*., 2000). Although the investigations have reported the freshwater fish biodiversity in regions of Indo-Burma, such as Hainan Island (Xiong *et al*., 2018) and Leizhou Peninsula (Xiong *et al*., 2019), information about freshwater biodiversity in Yujiang River Basin, is scarce.

The aims of this study are (1) to compile a list of the freshwater fish fauna of Yujiang River; (2) to summarize the main threats to freshwater fish biodiversity; and (3) to advance recommendations for fish biodiversity conservation in the Yujiang River ecosystem.

MATERIALS AND METHODS

Study area

The Yujiang River is the largest tributary of the Xijiang River system in the Pearl River Basin, and it is also the boundary between the Xujiang River and the Qianjiang River. It originates near the village of Guangnan, County of Liancheng in Yunnan Province. The upper reaches of the Yujiang River are referred to as the Daliang River. It flows northeast into the Guangxi Province. The Yujiang River crosses the southwestern part of the Guangxi Autonomous region of China. It flows through Guanglian, Baise, Tianyang, Tiandong, Pingguo, Longan, Nanning, Hengxian, Guigang, and ends in Guiping where it converges with the Qianjiang River. The Yujiang River has a length of 1,179 km and a total drop in elevation of 1,655 meters. The average slope is 1.4% and the average annual runoff is 47.9 billion m^3. The drainage area is 90656 km^2, and it passes through 7007 km^2 in Guangxi, accounting for 34.5% of the total area of the Xijiang River system.

Sources of freshwater fish information

Based on both field surveys and literature reviews, we compiled information about the freshwater fish species in Yujiang River (Fig. 1). About twenty ichthyological surveys have been conducted in the Yujiang River during different seasons between 1985 and 2017. Fish samples were collected using gillnets (20×10 m, mesh size 0.5 cm), cage nets (200×10×15 cm, mesh size 0.5 cm), and electrofishing (CWB-2000P, 12V, 250HZ). For a detailed description of the sampling methods, see Xiong *et al*. (2017). We searched for literature that contained the following combination of words: The Yujiang River and freshwater fish or freshwater ichthyo* in the title, abstract, or keywords using the Thomson Institute for Scientific Information (ISI, http://www.isiknoledge.com) and CNKI (http://www.cnki.net). We also collected information from Chinese books, such as The freshwater fishes of Guangdong Province (Pearl River Fishes Research Institute, 1991). The scientific names were used as found in the catalog of fishes (http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp).

To identify the freshwater fishes in the Yujiang River that are at a risk of extinction, we determined if the species were assigned a designation in the red list category system (www.iucnlist.org). Fish species assessed as critically endangered (CR), endangered (EN) or vulnerable (VU) are referred as threatened in this study.

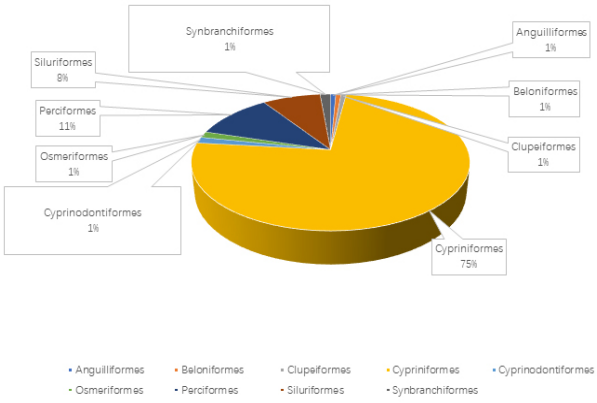

Fig. 1. Fish composition in the Yujiang River.

RESULTS

We identified 137 fish species (including to two non-native species), within 9 orders, 26 families, and 88 genera, distributed in the Yujiang River (Table I). Cyprinidae are the most species-rich of the families represented (83 species, 60.5%). Eight species, one Balitoridae (*Balitora ludongensis*), one Gastromyzontidae (*Vanmanenia lineata*), one Cobitidae (*Cobitis australis*), and five Cyprinidae (*Bangana decora*, *Bangana wui*, *Hemibarbus umbrifer*, *Ptychidio jordani*, and *Ptychidio macrops*) are endemic to the Yujiang River. Thus, the Yujiang River, though accounting for less than 1% of total land area of China, contains 135 native freshwater species (nearly 10% of the total number of Chinese freshwater fish), with eight species being endemic to it. Because of the remarkable species richness and diversity in its fishes, the Yujiang River is one of the most important freshwater fish biodiversity conservation priorities in China.

The result showed that a total of six species (*Anguilla japonica*, *Cyprinus carpio*, *Luciocyprinus langsoni*, *Pseudohemiculter dispar*, *Ptychidio jordani*, and *Cranoglanis bouderius*) were listed as threatened species according to IUCN red list criteria (Table I).

Table I. Freshwater fishes in the Yujiang River.

Orders/ Family	Scientific name	IUCN
Order: Anguilliformes		Endangered
Family: Anguillidae	1. *Anguilla japonica* Temminck and Schlegel, 1846	
Order: Beloniformes		Not evaluated
Family: Hemiramphidae	2. *Hyporhamphus intermedius* (Cantor, 1842)	
Order: Clupeiformes		Not evaluated
Family: Clupeidae	3. *Tenualosa reevesii* (Richardson, 1846)	
Order: Cypriniformes		Least concern
Family: Balitoridae	4. *Balitora kwangsiensis* (Fang, 1930)	
	5. *Balitora ludongensis* Liu and Chen, 2012a	Not evaluated
	6. *Sinogastromyzon wui* Fang, 1930	Least concern
Family: Gastromyzontidae	7. *Vanmanenia lineata* (Fang, 1935)a	Not evaluated
	8. *Vanmanenia pingchowensis* (Fang, 1935)	Least concern
Family: Catostomidae	9. *Myxocyprinus asiaticus* (Bleeker, 1864)	Not evaluated
Family: Botiidae	10. *Leptobotia pellegrini* Fang, 1936	Least concern
	11. *Parabotia banarescui* Nalbant, 1965	Data deficient
	12. *Parabotia fasciatus* Dabry de Thiersant, 1872	Not evaluated
	13. *Sinibotia pulchra* Wu 1939	Data deficient
	14. *Sinibotia reevesae* (Chang, 1944)	Not evaluated
	15. *Sinibotia robusta* (Wu, 1939)	Data deficient
Family: Cobitidae	16. *Cobitis arenae* (Lin, 1934)	Data deficient
	17. *Cobitis australis* Chen, Chen and He,2013a	Not evaluated
	18. *Cobitis sinensis* Sauvage and Dabry de Thiersant, 1874	Least concern
	19. *Misgurnus anguillicaudatus* (Cantor, 1842)	Least concern
Family: Cyprinidae	20. *Abbottina rivularis* (Basilewsky, 1855)	Not evaluated
	21. *Acheilognathus barbatulus* Günther, 1873	Least concern
	22. *Acheilognathus barbatus* Nichols, 1926	Not evaluated
	23. *Acheilognathus tonkinensis* (Vaillant, 1892)	Data deficient
	24. *Acrossocheilus longipinnis* (Wu, 1939)	Not evaluated
	25. *Ancherythroculter daovantieni* (Bănărescu, 1967)	Data deficient
	26. *Aphyocypris arcus* (Lin, 1931)	Not evaluated
	27. *Bangana decora* (Peters, 1881)a	Not evaluated
	28. *Bangana wui* (Zheng and Chen, 1983)a	Data deficient
	29. *Carassioides acuminatus* (Richardson, 1846)	Least concern
	30. *Carassius auratus* (Linnaeus, 1758)	Least concern
	31. *Chanodichthys dabryi* (Bleeker, 1871)	Least concern
	32. *Chanodichthys erythropterus* (Basilewsky, 1855)	Least concern
	33. *Chanodichthys mongolicus mongolicus* (Basilewsky, 1855)	Not evaluated
	34. *Chanodichthys recurviceps* (Richardson, 1846)	Not evaluated
	35. *Cirrhinus molitorella* (Valenciennes, 1844)	Near threatened
	36. *Ctenopharyngodon idella* (Valenciennes, 1844)	Not evaluated
	37. *Culter alburnus* Basilewsky, 1855	Not evaluated

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Orders/ Family	Scientific name	IUCN
	38. *Cyprinus carpio* Linnaeus, 1758	Vulnerable
	39. *Cyprinus multitaeniata* Pellegrin and Chevey 1936	Near threatened
	40. *Discogobio tetrabarbatus* Lin, 1931	Least concern
	41. *Elopichthys bambusa* (Richardson, 1845)	Data deficient
	42. *Folifer brevifilis* (Peters, 1881)	Data deficient
	43. *Garra orientalis* Nichols, 1925	Least concern
	44. *Gobiobotia kolleri* Bănărescu and Nalbant, 1966	Data deficient
	45. *Gobiobotia meridionalis* Chen and Cao, 1977	Data deficient
	46. *Hemibarbus labeo* (Pallas, 1776)	Not evaluated
	47. *Hemibarbus macracanthus* Lu, Luo and Chen, 1977	Data deficient
	48. *Hemibarbus maculatus* Bleeker, 1871	Not evaluated
	49. *Hemibarbus medius* Yue, 1995	Not evaluated
	50. *Hemibarbus umbrifer* (Lin, 1931)a	Least concern
	51. *Hemiculter leucisculus* (Basilewsky, 1855)	Least concern
	52. *Hemiculterella wui* (Wang, 1935)	Not evaluated
	53. *Hypophthalmichthys molitrix* (Valenciennes, 1844)	Near threatened
	54. *Hypophthalmichthys nobilis* (Richardson, 1845)	Data deficient
	55. *Luciobrama macrocephalus* (Lacepède, 1803)	Data deficient
	56. *Luciocyprinus langsoni* Vaillant, 1904	Vulnerable
	57. *Megalobrama terminalis* (Richardson, 1846)	Not evaluated
	58. *Metzia formosae* (Oshima, 1920)	Least concern
	59. *Metzia lineata* (Pellegrin, 1907)	Least concern
	60. *Microphysogobio elongatus* (Yao and Yang, 1977)	Not evaluated
	61. *Microphysogobio fukiensis* (Nichols, 1926)	Least concern
	62. *Microphysogobio kiatingensis* (Wu, 1930)	Least concern
	63. *Mylopharyngodon piceus* (Richardson, 1846)	Data deficient
	64. *Ochetobius elongatus* (Kner, 1867)	Least concern
	65. *Onychostoma barbatum* (Lin, 1931)	Data deficient
	66. *Onychostoma gerlachi* (Peters, 1881)	Near threatened
	67. *Onychostoma leptura* (Boulenger, 1900)	Not evaluated
	68. *Onychostoma ovalis rhomboides* Tang 1947	Not evaluated
	69. *Onychostoma rarum* (Lin, 1933)	Data deficient
	70. *Onychostoma simum* (Sauvage and Dabry de Thiersant, 1874)	Data deficient
	71. *Opsariichthys bidens* Günther, 1873	Least concern
	72. *Osteochilus salsburyi* Nichols and Pope, 1927	Least concern
	73. *Parabramis pekinensis* (Basilewsky, 1855)	Not evaluated
	74. *Parator zonatus* (Lin, 1935)	Not evaluated
	75. *Procypris mera* Lin, 1933	Data deficient
	76. *Pseudohemiculter dispar* (Peters, 1881)	Vulnerable
	77. *Pseudohemiculter hainanensis* (Boulenger, 1900)	Least concern
	78. *Pseudolaubuca engraulis* (Nichols, 1925)	Least concern
	79. *Pseudolaubuca sinensis* Bleeker, 1864	Least concern

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Orders/ Family	Scientific name	IUCN
	80. *Pseudorasbora parva* (Temminck and Schlegel, 1846)	Least concern
	81. *Ptychidio jordani* Myers, 1930a	Critically endangered
	82. *Ptychidio macrops* Fang, 1981a	Data deficient
	83. *Puntius semifasciolatus* (Günther, 1868)	Least concern
	84. *Rectoris posehensis* Lin, 1935	Not evaluated
	85. *Rhodeus lighti* (Wu, 1931)	Least concern
	86. *Rhodeus ocellatus ocellatus* Kner, 1866	Not evaluated
	87. *Rhodeus sinensis* Günther, 1868	Least concern
	88. *Rhodeus spinalis* Oshima, 1926	Least concern
	89. *Sarcocheilichthys parvus* Nichols, 1930	Least concern
	90. *Saurogobio dabryi dabryi* Bleeker 1871	Not evaluated
	91. *Semilabeo notabilis* Peters, 1881	Data deficient
	92. *Sinibrama macrops* (Günther, 1868)	Least concern
	93. *Sinibrama melrosei* (Nichols and Pope, 1927)	Data deficient
	94. *Spinibarbus denticulatus* Oshima, 1926	Least concern
	95. *Spinibarbus hollandi* Oshima, 1919	Data deficient
	96. *Squalidus argentatus* (Sauvage and Dabry de Thiersant, 1874)	Data deficient
	97. *Squalidus wolterstorffi* (Regan, 1908)	Least concern
	98. *Squaliobarbus curriculus* (Richardson, 1846)	Data deficient
	99. *Toxabramis houdemeri* Pellegrin, 1932	Least concern
	100. *Xenocypris davidi* Bleeker, 1871	Not evaluated
	101. *Xenocypris macrolepis* Bleeker, 1871	Least concern
	102. *Zacco platypus* (Temminck and Schlegel, 1846)	Not evaluated
Family: Nemacheilidae	103. *Schistura fasciolata* (Nichols and Pope, 1927)	Data deficient
	104. *Schistura incerta* (Nichols, 1931)	Data deficient
	105. *Traccatichthys pulcher* (Nichols and Pope, 1927)	Least concern
Order: Cyprinodontiformes		Not evaluated
Family: Adrianichthyidae	106. *Oryzias latipes* (Temminck and Schlegel, 1846)	
Family: Poeciliidae	107. *Gambusia affinis* (Baird and Girard,1853)b	Least concern
Order: Osmeriformes		Least concern
Family: Salangidae	108. *Neosalanx tangkahkeii* (Wu, 1931)	
	109. *Salanx reevesii* (Gray, 1831)	Data deficient
Order: Perciformes		Least concern
Family: Channidae	110. *Channa asiatica* (Linnaeus, 1758)	
	111. *Channa gachua* (Hamilton, 1822)	Least concern
	112. *Channa maculata* (Lacepède, 1801)	Least concern
Family: Gobiidae	113. *Mugilogobius myxodermus* (Herre, 1935)	Not evaluated
	114. *Rhinogobius brunneus* (Temminck and Schlegel, 1845)	Data deficient
	115. *Rhinogobius giurinus* Rutter, 1897	Least concern
Family: Odontobutidae	116. *Micropercops compressocephalus* Chen, 1985	Not evaluated
	117. *Odontobutis obscura* (Temminck and Schlegel, 1845)	Not evaluated
	118. *Odontobutis sinensis* Wu, Chen and Chong, 2002	Not evaluated
Family: Osphronemidae	119. *Macropodus opercularis* (Linnaeus, 1758)	Least concern

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Orders/ Family	Scientific name	IUCN
Family: Sinipercidae	120. *Siniperca chuatsi* (Basilewsky, 1855)	Data deficient
	121. *Siniperca knerii* Garman, 1912	Not evaluated
	122. *Siniperca scherzeri* Steindachner, 1892	Data deficient
	123. *Siniperca undulata* Fang and Chong, 1932	Near threatened
Family: Cichlidae	124. *Oreochromis niloticus* (Linnaeus, 1758)b	Not evaluated
Order: Siluriformes		Data deficient
Family: Bagridae	125. *Hemibagrus guttatus* (Lacepède, 1803)	
	126. *Hemibagrus macropterus* Bleeker, 1870	Least concern
	127. *Tachysurus fulvidraco* (Richardson, 1846)	Least concern
	128. *Tachysurus intermedius* (Nichols and Pope, 1927)	Least concern
	129. *Tachysurus vachellii* (Richardson, 1846)	Data deficient
	130. *Tachysurus crassilabris* (Günther, 1864)	Not evaluated
	131. *Tachysurus argentivittatus* (Regan, 1905)	Not evaluated
Family: Clariidae	132. *Clarias fuscus* (Lacepède 1803)	Least concern
Family: Cranoglanididae	133. *Cranoglanis bouderius* (Richardson, 1846)	Vulnerable
Family: Sisoridae	134. *Glyptothorax fokiensis* (Rendahl, 1925)	Least concern
Family: Siluridae	135. *Silurus asotus* Linnaeus, 1758	Least concern
Order: Synbranchiformes		Least concern
Family: Mastacembelidae	136. *Mastacembelus armatus* (Lacepède, 1800)	
Family: Synbranchidae	137. *Monopterus albus* (Zuiew, 1793)	Least concern

a, endemic to the Yujiang River; b, non-native species.

These threatened fish species occur primarily in the mountain streams of Yunnan and Guangxi (Wang and Xie, 2004).

Threats to freshwater fish biodiversity

Freshwater ecosystems, including lakes, reservoirs, rivers, and wetlands, cover about 5% of the global land surface area, but support nearly 10% of the planet's described animal species (Reid *et al*., 2018). Freshwater ecosystems are considered to have a higher proportion of species that are threatened with extinction than their terrestrial and marine counterparts (Vörösmarty *et al*., 2010). The main threats to freshwater fish biodiversity in the Yujiang River include overfishing, flow modification, and the impacts of non-native species (Xiong *et al*., 2018, 2019; He *et al*., 2020).

Overfishing is an important threat to Chinese freshwater fish biodiversity (Xing *et al*., 2016). Most of the areas through which the Yujiang River passes are in extremely economically poor regions of China. More than 20 million people living in the Yujiang River Basin, and fishes are the most important source of animal protein for local residents (GXBS, 2021). Many kinds of illegal fishing equipment, such as traps, gill nets, electrofishing, and poisons are widely used to harvest fish from the Yujiang River system (Xiong *et al*., 2018, 2019). A number of small fish taxa, such as *Oryzias latipes*, *Rhodeus lighti*, *Rhodeus ocellatus*, *Rhodeus sinensis*, *Rhodeus spinalis*, *Mugilogobius myxodermus*, *Rhinogobius brunneus*, *Rhinogobius giurinus* and tilapia species (Xiong *et al*., 2019, 2023), are wild-caught for the aquarium trade. Thus, overfishing is the greatest threat to native fish abundance and biodiversity.

Some water conservation projects can cause degradation of habitat and restrict the functioning of river ecosystems (Dudgeon, 2000; Dudgeon *et al*., 2006). Since the 1950s, many dams, irrigation projects, and hydropower projects have been constructed in the Yujiang River system (Miao *et al*., 2015). For example, the Guangxi Basin water conservation project, considered to be one of the top ten projects in China, was built between 2001 and 2006. The construction of these water conservation projects altered fast flowing streams to slow, pooled flow conditions, making habitat unsuitable for many endangered or endemic species such as *Balitora ludongensis*, *Vanmanenia lineata*, and *Cobitis australis*.

China has become known as world's most notorious hotspot for the introduction of non-native aquatic species (Xiong *et al*., 2015, 2017). Fortunately, only two non-native fish species we identified were introduced in Yujiang River. These two non-native fish are the worst of the invasive species and have caused great negative ecological

and economic impacts in China (Cheng *et al*., 2018; Gu *et al*., 2019). Nile tilapia (*Oreochromis niloticus*) is the most important non-native species used for aquaculture (Xiong *et al*., 2015), and Guangxi and Yunnan (the main regions of the Yujiang River watershed) are China's top two tilapia producers (Xiong *et al*., 2023). Inevitably, a great number of tilapia have escaped and established feral populations and even over 80% of total fisheries capture (Gu *et al*., 2016; Xiong *et al*., 2023) causing the sharp decline of native aquatic biodiversity (Gu *et al*., 2015; 2019). The omnivorous tilapia increases the turbidity and nutrient levels of water, which has made it difficult for some native fishes to survive (Zhang *et al*., 2017). The western mosquitofish (*Gambusia affinis*) is the most popular non-native freshwater fish species in China (Cheng *et al*., 2018). We found that mosquitofish have widely spread in rivers, lakes, ponds, reservoirs, canals, and paddy fields of the Yujiang River Basin. Mosquitofish chase small or young native fish and prey on large quantities of their eggs, larvae and immature individuals (Cheng *et al*., 2018; Xiong *et al*., 2019). Nile tilapia and mosquitofish have contributed significantly to the sharp decline of native freshwater fish in the Yujiang River.

Conservation of freshwater fish biodiversity

Freshwater fish are regarded as the second most threatened animal group of all animal categories (Bruton, 1995) and they are the most important animal group in terms of providing food and protein to humans (Wang *et al*., 2015). Therefore, it is important to protect freshwater fish for both ecological and economic seasons.

The establishment of protected areas is one of the most effective ways to assist in the conservation of freshwater fish (Xiong *et al*., 2018, 2019). Although over 300 protected areas have been established for the conservation of forests, mangroves, birds, and karst ecosystems in Yunnan and Guangxi, there are no protected areas established specifically for freshwater fish. It would be a strong and likely effective measure to designate protected areas for freshwater fish and add protected lists of fish species in already established protected area in the Yujiang River, especially in the mountain streams which are important spawning grounds and habitats for a number of threatened fish, such as *Balitora ludongensis*, *Vanmanenia lineata*, *Cobitis australis*, and *Ptychidio jordani*.

Designating seasonal fishing times or terminating fishing altogether in certain areas is another important means of conserving fish biodiversity and fisheries resources (He *et al*., 2020). Recently, some river reaches have been designated as closed to fishing in China. For example, the mainstem of the Yangtze River has been closed to fishing between April 1 to June 30. Local governments should forbid fishing in designated spawning habitats as a protective measure for some endangered or endemic species. Illegal fishing gear, especially electrofishing and the use of poisons, should be strictly prohibited in the Yujiang River.

Finally, the prevention of additional introductions of non-native aquatic species would be an excellent manner of halting additional impacts by newly introduced non-native species (Xiong *et al*., 2015). The Yujiang River Basin is an important region for aquaculture, which uses non-native species to raise and sell commercially (Xiong *et al*., 2023). Some non-native species were and continue to be introduced solely for aquaculture. Researchers and environmental organizations should dedicate more effort to monitoring, studying life-history traits, and gaining a better understanding the ecological and economic impacts of potentially invasive aquatic species (Xiong *et al*., 2015; Cheng *et al*., 2018).

CONCLUSION

The Yujiang River supports a high freshwater fish biodiversity, with some species recognized as endangered or endemic. Many fish species are play an important role in providing food for local residents. Overfishing, flow modification, and non-native species are the primary threats to native fish biodiversity. To better protect native freshwater fish biodiversity and maintain the development of sustainable fisheries, local governments should enforce effective measures including the establishment of additional protected areas, the provision of selective bans on fishing, better control of the use of illegal fishing gear, and the prevention of new introductions or further invasion by extant non-native species.

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IRB approval and ethical approval

This research was conducted in accordance with ethics committee procedures of animal experiments.

Sampling and field studies

All necessary permits for sampling and observational

field studies have been obtained by the authors from the competent authorities and are mentioned in the acknowledgements, if applicable.

Data availability

All data generated or analyzed during this study are included in this article.

Statement of conflict of interest

The authors have declared no conflict of interest.

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