PERSPECTIVE

A new window for conservation biogeography

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Classic biogeography provides the context for understanding why large-scale patterns of biodiversity occur where they do. However, over the past half century, human activities have greatly changed biogeographic patterns and caused accelerating loss of biodiversity on the earth. In spite of the Launch of Conservation Biogeography a couple of decades ago, there has been no concerted effort to implement conservation practices for regional biodiversity by integrating ecology and evolution over geographical space and time. This paper presents lessons and experiences from biodiversity protection of the Yangtze River, demonstrating an urgent need for biogeography-based solutions that cannot be easily deduced from current conservation biogeography. We aim to open a new window for conservation biogeography by providing a new cross-level paradigm and a new definition, seeking for biogeographic strategies for the long-lasting preservation of regional biodiversity. We believe that this paper makes a concise conceptual advance in conservation biogeography.

The earth is currently in an unprecedented period of changes due to increasing human activities that have greatly changed biogeographic patterns and caused an accelerating loss of biodiversity. Biogeography is vital in understanding the patterns of biodiversity across space and time; yet these patterns need to be combined with ecological and evolutionary processes. A couple of decades ago, conservation began to be deeply rooted in biogeography, resulting in the emergence of conservation biogeography defined as "the application of biogeographical principles, theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity".[1] It is needed to spark a paradigmatic shift from a focus on the final stages of collapse to the inclusion of cross-time scale and cross-level patterns, processes, and mechanisms associated with initial decline and trajectories towards extinction.[2] Lessons from biodiversity protection of the Yangtze (Figure 1B) demonstrate an urgent need for biogeography-based solutions under a scientific paradigm.

BIOGEOGRAPHIC EVOLUTION

The Yangtze River, the third longest river in the world, is one of the world's hotspots of global biodiversity. It has 424 fish species, of which 183 are endemic. It is home to ancient flagship species: two freshwater mammals, the Baiji dolphin (*Lipotes vexillifer*) and finless porpoise (*Neophocaena asiaeorientalis*), and three sturgeons, the Chinese sturgeon (*Acipenser sinensis*), Yangtze sturgeon (*A. dabryanus*), and Chinese paddlefish (*Psephurus gladius*).

The birth of the Qinghai-Tibet Plateau can be traced back to 50 -55 Mya when a collision between the Indian and Eurasian Plates occurred, leading to a gradual uplift of this plateau. The rising plateau then changed the climate from a planetary wind-driven to a monsoon climate, resulting in the evolution of large rivers in South and East Asia. The Yangtze was a cradle for the evolution of many endemic cyprinids and the home of "living fossil" animals.

The Eocene fossil fish in China included species of Cyprinidae in Cypriniformes, Catostomidae, Bagridae, and Perciformes, which all went extinct.[3] Extant fish evolved later, adapting to large rivers under a monsoon climate, notably forming the endemic East Asian cyprinids. Especially, key egg attributes may function as "magic traits" in the adaptive radiation of these cyprinids,[4] i.e., the ancestors were benthic and spawned with adhesive eggs in southern East Asia before ca. 23 Mya when the palaeo-Jinshajiang flowed southwards, and then dispersed eastwards to lay semibuoyant eggs by ca. 18 Mya, a time for the formation of the current Yangtze River. Some cyprinids began laying adhesive eggs again by ca. 15 Mya, a time for the formation of a productive potamo-lacustrine ecosystem.[5]

The ancestors of the Baiji Dolphin appeared 20 Mya, while the earliest fossils of sturgeon date back to 200 Mya. *P. gladius* in the Yangtze River and *Polyodon spathula* in the Mississippi River are the only two species of Polyodontidae in the world, and their divergence occurred approximately 68 Mya. *A. schrenckii* in the Heilongjiang, Songhua, and Wusuli Rivers and *A. sinensis* and *A. dabryanus* in the Yangtze River diverged approximately 70 Mya. Divergence between *A. sinensis* and *A. dabryanus* occurred approximately 10.5 Mya within the current Yangtze.[6]

The Yangtze is low in productivity due to extremely turbid water influenced by strong erosion in the rainy season; in contrast, the adjacent lakes where the sand sinks rapidly are very productive. For example, phytoplankton productivity in the river is only 14% of that in the lakes.[7] Many endemic species evolved and maintained in the Yangtze biogeographic unit characterized by a vast flood plain in the middle-lower reaches but a turbulent environment in the upper reaches, e.g. four fish ecotypes have appeared: those living solely in lakes, those migrating between rivers and lakes (laying semibuoyant eggs in rivers and fattening in lakes), those living solely in rivers, and those migrating between oceans and rivers. The former two types dominate total fish production and provide essential food for top predators in the food chain, the Baiji and finless porpoise.

BIOGEOGRAPHIC FRAGMENTATION

Over the past half century, the Yangtze biogeographic unit has been seriously fragmented and the number of threatened fish in the Yangtze is the largest among large Chinese rivers. To prevent floods, lakes in the middle and lower reaches have been almost completely disconnected from the river, causing an 85% decline in river fish resources since the 1950s,[7] and to obtain hydropower, large water conservancy hubs have been constructed on the main river (e.g., Gezhouba Dam and Three Gorges Dam), cutting off the migration pathways of sturgeons (Figure 1B). In addition, more than 24,000 smaller hydropower stations have been built in the branches, having significantly changed the upstream turbulent environments. Gates between rivers and lakes have greatly decreased fish resources in the river through worsening food availability, thereby threatening mammalian predators. The number of Baiji dropped from 400 in 1980 to fewer than 50 by the end of the 20th century. The estimated number of finless porpoise decreased from over 2,500 in 1991 to 1,800 in 2006 and to 1,012 in 2020. In the past few decades, the population sizes of both the Baiji and finless porpoise decreased almost proportionally with those of fish resources.[7] Compared with the finless porpoise, the Baiji was much more vulnerable to the decline in food availability, partially due to the smaller size of its base population.

Young Chinese sturgeons feed and grow near the sea and when mature, they migrate more than 3200 km up the river for reproduction, guided by inherent biogeographic signals. This is the longest migration of any sturgeon in the world. They were believed to be able to form new spawning grounds downstream after the completion of the Gezhouba Dam but failed to do so as

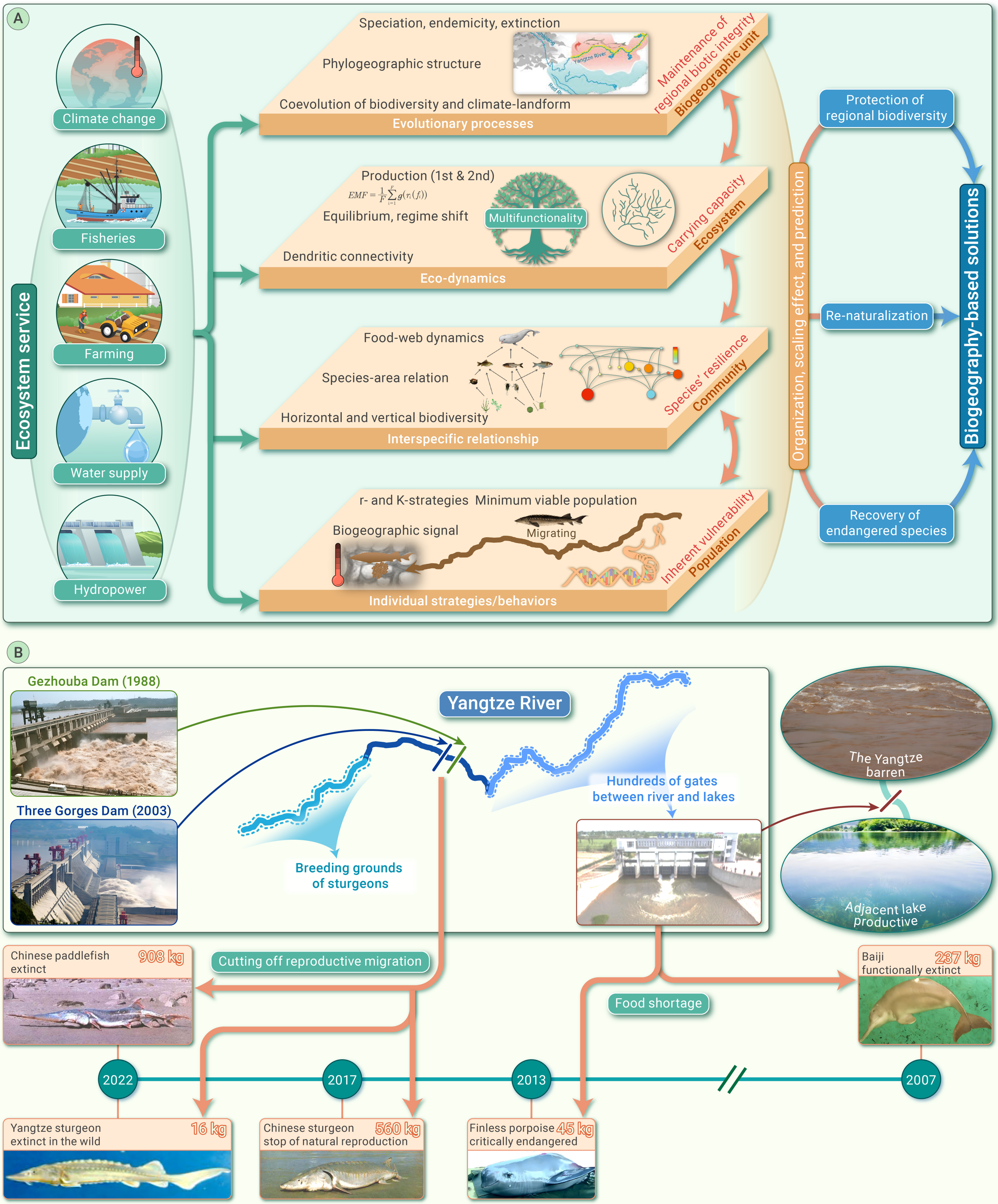

Figure 1. A sketch of new paradigm for conservation biogeography, inspired by unsuccessful rescue of biodiversity in the Yangtze River during the past decades (A) A hierarchical integration of cross-time scale and cross-level studies for effective conservation planning and interventions to halt regional extinction. (B) A chronicle of events for the loss of flagship species in the Yangtze, China, driven by dams or gates. Baiji has not been recorded since 2006 and was declared functionally extinct in 2007, thereby holding the unenviable record of being the first dolphin species driven to extinction by humans. In 2022, the IUCN confirmed the extinction of the Chinese paddlefish, whereas Yangtze sturgeon moved from "critically endangered" to "extinct in the wild".

predicted.[8] In the 1970s, an estimated 2,000 Chinese sturgeons spawned every year, but since 2013 (except for 2014 and 2016) no new spawning activity has been detected, indicating a critically endangered state. Apparently, molecular and neurological bases underlying the key behaviour (e.g. reproductive migration) of a species can shape the resilience through their interactions with a/biotic environments.

UNSUCCESSFUL RESCUE

One prominent contribution of biogeography to conservation biology has been the use of island biogeography theory, and protected areas are expected to be the only effective and efficient conservation tool. A threshold of 50,000 km^2 has been widely adopted in conservation prioritization analyses.[9]To rescue Chinese sturgeon, the government established three reserves and released millions of young, yet not capable of halting their ongoing collapse, suggesting that reserve is less applicable to aquatic ecosystems than to terestrial ecosystems; i.e., it is perhaps more effective to restore continuity (re-naturalization) than to establish protected areas in the Yangtze. However, the large water conservancy hubs could not be easily demolished in the short term. A bypass channel around the dam has been suggested to save the extremely endangered Chinese sturgeon.[10] Small dams in the branches should be dismantled as much as possible to restore the continuity of the river and the rapids-adapted fish.

China enacted the Yangtze River Conservation Law in 2021, which bans fishing in the Yangtze and its tributaries for 10 years. However, as overfishing contributed only approximately 30% of the total decline and habitat degradation of the remaining 70%, a fishing ban alone can only eliminate the top-down factor (humans) affecting fish but does not increase the food resources of the fish.[7] Therefore, the free-flowing channels between feeding and breeding locations need to be reconnected to restore the natural rhythm of the river to improve conditions for river-lake migratory fish, which may facilitate the recovery of the finless porpoise population in the Yangtze.[7]

NEW PARADIGM AND REDEFINITION

The above lessons from the Yangtze ask for biogeography-based solutions. For the sake of this, a new cross-level paradigm for conservation biogeography is outlined below as well as in Figure 1A.

At the population level, foci should be on minimum viable populations, r- and k-strategies, and biogeographical signals that guide the key individual behavior of flagship species, to understand the inherent vulnerability of species and to look for possible behavioral or eco-physiological regulation to rescue endangered species.

At the community level, emphasis should be placed on horizontal and vertical biodiversity, species-area relationships and their scale dependence, and most importantly, the spatiotemporal dynamics of food webs, to understand species resilience and to clarify which species are susceptible to disturbances of the food web.

At the ecosystem level, the core topics should include elementary cycling, primary and secondary production, resource utilization, equilibria, regime shifts, and the connectivity of (sub)systems, to determine how much biodiversity the current ecosystem processes can support.

At the biogeographical level, efforts should target speciation, extinction, phylogenetic geographic structure, as well as taxonomic distinctiveness, rarity, endemicity, and lineage-specific traits to reveal the coevolution of regional biodiversity and climate-landform, to understand how current biogeographic integrity has been formed and maintained, eventually providing biogeography-based solutions.

It is surely important to put theory into practice and to initiate conservation actions on the ground. Accordingly, from a more practical point of view, conservation biogeography is here redefined as an academic endeavor that (a) addresses biodiversity problems at geographic scales; (b) constructs predictable models of species loss by scaling up the behavior of individuals and the organization and interaction of populations, communities, and ecosystems; and (c) advances biogeographic strategies for the re-naturalization (not necessarily entirely pristine) of mega-ecosystems to enhance both the recovery of endangered species and the long-lasting preservation of regional biodiversity under current conditions and future scenarios.

REFERENCES

1. Whittaker, R.J., Araújo, M.B., Jepson, P., et al. (2005). Conservation biogeography: assessment and prospect. Divers. Distrib. 11: 3–23. DOI: 10.1111/j.1366-9516.2005.00143.x.
2. Lomolino, M.V. (2023). The ecological and geographic dynamics of extinction: Niche modeling and ecological marginalization. Proc. Natl. Acad. Sci. 120: e2220467120. DOI: 10.1073/pnas.2220467120.
3. Chang, M. M., and Zhou, J. (1993). A brief survey of the Chinese Eocene ichthyofauna. Kaupia. 2: 157–162. http://www.irgrid.ac.cn/handle/1471x/246803?mode=full.
4. Chen, F., Wang, Y., He, J., et al. (2022). Molecular mechanisms of spawning habits for the adaptive radiation of endemic East Asian cyprinid fishes. Research. 2022: 9827986. DOI: 10.34133/2022/9827986.
5. Chen, F., Xue, G., Wang, Y., et al. (2023). Evolution of the Yangtze River and its biodiversity. The Innovation. 4: 100417. DOI: 10.1016/j.xinn.2023.100417.
6. Peng, Z. G., Ludwig, A., Wang, D., et al. (2007). Age and biogeography of major clades in sturgeons and paddlefishes (Pisces: Acipenseriformes). Mol. Phylogenet. Evol. 42: 854–862. DOI: 10.1016/j.ympev.2006.09.008.
7. Wang, H. J., Wang, P., Xu C, et al. (2022). Can the "10-year fishing ban" rescue biodiversity of the Yangtze River. The Innovation. 3: 100235. DOI: 10.1016/j.xinn.2022.100235.
8. Xie, P. (2003). Three-Gorges Dam: risk to ancient fish. Science. 302: 1149. DOI: 10.1126/science.302.5648.1149b.
9. Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., et al. (2004). Effectiveness of the global protected area network in representing species diversity. Nature, 428: 640–643. DOI: 10.1038/nature02422.
10. Zhang, L., Wang, H., Gessner, J., et al. (2023). To save sturgeons, we need river channels around hydropower dams[J]. Proc. Natl. Acad. Sci. 120: e2217386120. DOI: 10.1073/pnas.2217386120.

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DECLARATION OF INTERESTS

The authors declare no competing interests.