The silver lining in rewilding the vanished sturgeon in the Yangtze River

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On April 6th, 2024, researchers from the Yangtze River Fisheries Research Institute of the Chinese Academy of Fishery Sciences achieved remarkable success in their habitat creation experiment conducted in the Yangtze River. After a 23-year hiatus, they successfully triggered the spontaneous spawning of the once *wild extinct* Yangtze sturgeon in its natural habitat by reconstructing suitable spawning areas in the Yangtze River, resulting in the production of fertilized eggs and hatched fry. This achievement represents further research into recreating spawning areas in a wider area of the river, following a successful reproduction test conducted in an artificial spawning cage in 2023. This marks a significant milestone in the Yangtze sturgeon rewilding effort and highlights the immense potential of active habitat restoration to revitalize fish populations in the Yangtze River. The success of these experiments not only offers hope for the rewilding of this endangered giant fish in the Yangtze River but also serves as an encouraging precedent for the conservation of other threatened fish species worldwide.

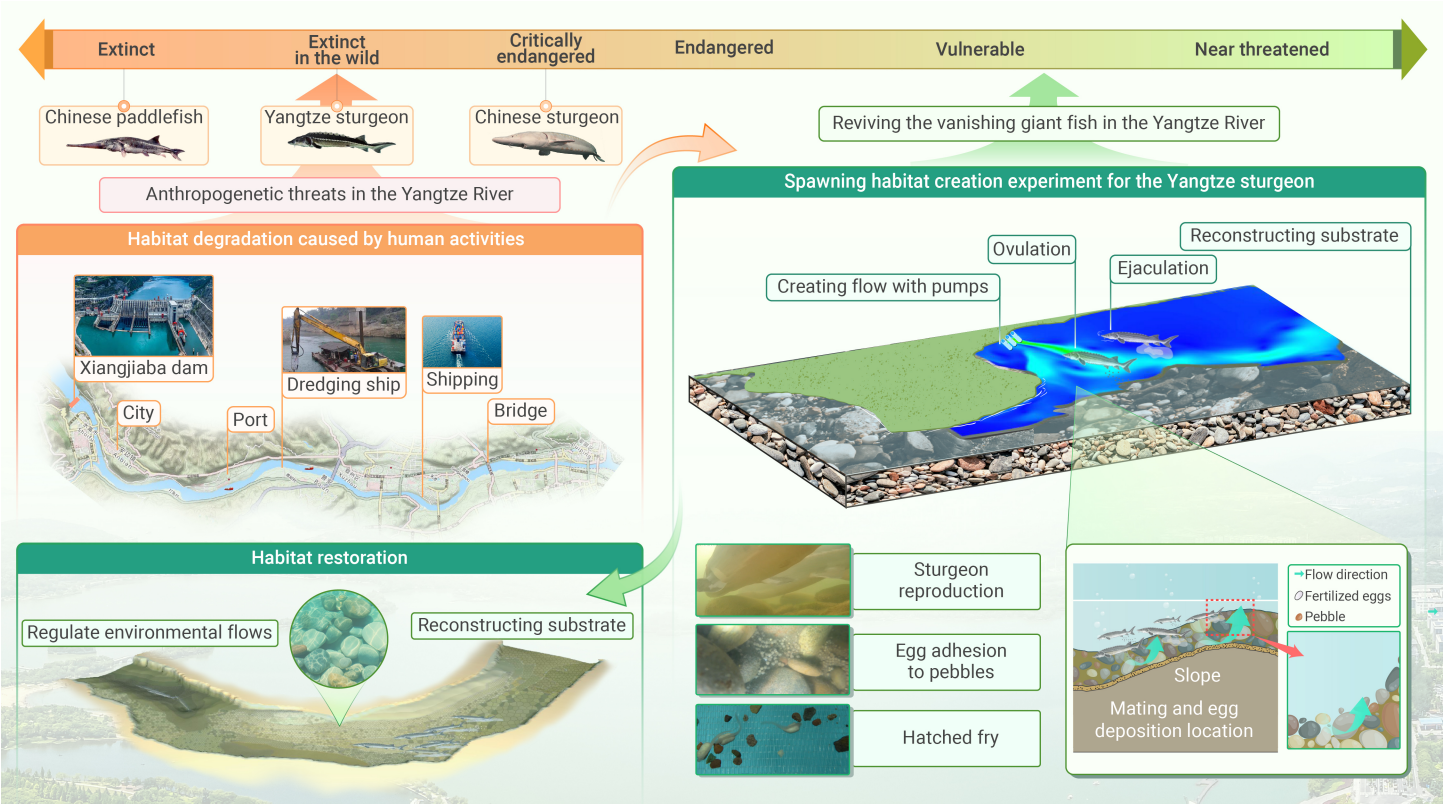

Figure 1. Background of spawning habitat degradation and diagram of spawning habitat creation experiment for the Yangtze sturgeon.

BACKGROUND

Biodiversity loss is a critical threat to vital ecosystem services and human well-being. The ongoing extinction crisis of numerous species worldwide, particularly in freshwater ecosystems, is predominantly attributed to anthropogenic activities that result in habitat loss, fragmentation, and degradation.[1] Among these activities, dam construction, dredging, and shipping have a profound effect on the survival and reproduction of aquatic organisms.[2]

The Yangtze River, the world's third-longest river and a hotspot for fish diversity has suffered extensive anthropogenic interventions. Construction of over 50,000 dams and the frequent dredging affecting 70% of the Yangtze River's length has fragmented and degraded aquatic habitats, leading to severe fish depletion.[3] A recent survey showed a sharp decline in fish species in the Yangtze River, with over 130 (including ~100 benthic fish) vanishing. This contrasts sharply with historical records of over 400 species. The anthropogenic impact on the river is underestimated, especially for species sensitive to riverbed and hydrodynamic changes.[4] Fortunately, conservation measures such as fishing bans, the establishment of nature reserves, and artificial stocking have been implemented, with a recent 10-year fishing ban playing a pivotal role. These measures have led to a gradual recovery of aquatic biodiversity in the Yangtze River. However, the recovery of some rare and endangered giant fish species has been slower than that of other aquatic life due to their long life cycles and the continued destruction of their habitats.

The situation of sturgeons is particularly serious. These ancient giants of freshwater fish have existed for 200 million years, occupy a crucial phylogenetic position in fish evolution, and have immense economic and cultural importance. All 27 Acipenseriformes are either extinct or critically endangered worldwide. Habitat loss and degradation, leading to natural reproduction failure, are the main threats to their sustainability. In the Yangtze River, following the extinction of the world's largest Chinese paddlefish (*Psephurus gladius*) in 2022, the last two surviving species, the Chinese sturgeon (*Acipenser sinensis*) and the Yangtze sturgeon (*Acipenser dabryanus*) are on the verge of extinction with signs of ceased natural reproduction since 2000

and 2013, respectively. The situation is particularly alarming for the Yangtze sturgeon, which no longer exists naturally in its original habitat and is only found in captivity. It was declared "Extinct in the wild" by the IUCN in 2022.[5] Despite significant conservation efforts, including the establishment of a nature reserve and the release of millions of cultured juveniles and adult fish into the Yangtze River since 2007, the Yangtze sturgeon has shown no signs of natural reproduction. This highlights the need for a more comprehensive approach to understanding the ecological and biological barriers to its reproduction.

Habitat restoration holds the promise of long-term protection for threatened species, but global efforts are limited by politics, funding, and uncertainty. Despite progress in understanding sturgeon reproduction, we still lack a comprehensive framework for restoration. This hampers effective habitat creation [5]. Innovative approaches are urgently needed to address these challenges. Failure to act swiftly could result in the loss of vital opportunities and the tragic extinction of these precious endangered species.

Therefore, the restoration of suitable spawning habitats is crucial for reviving sturgeon reproduction. We used eco-hydraulic modelling and habitat recreation experiments to identify optimal spawning conditions for the Yangtze sturgeon. This led to the successful creation of an artificial spawning cage in 2023 and the reconstruction of spawning areas in 2024 (Figure 1). These experiments confirm that sturgeon can be attracted to suitable habitats and spawn naturally. These achievements provide valuable support for future efforts to restore and rebuild sturgeon populations in the wild.

HOW TO CREATE THE SUITABLE SPAWNING AREAS

Our research analyzed the habitat requirements for the natural reproduction of the Yangtze sturgeon by modelling the eco-hydraulic conditions in its historical habitat over 600 km of the upper Yangtze River. We found that the critical spawning conditions are determined by a combination of flow field, bottom substrate, and river topography, rather than by any single factor. Spawning grounds are typically found in pool-riffle sequences with steep slopes that generate high flow and macro-scale vortex structures. The high flow efficiently removes fine sediments to expose coarse substrates such as pebble and cobble, which are essential for sturgeon reproduction. Their eggs adhere securely to these substrates during incubation, and hatching in crevices minimizes the risk of predation by other fish. Macro-scale vortex improves sperm-egg mixing during spawning and provides sufficient dissolved oxygen for embryonic development.

Based on our theoretical study, we successfully induced sturgeon spawning in indoor experiments from 2016 to 2021 by precisely adjusting various environmental conditions. The suitable spawning condition included setting the bottom slope at a stoss side angle of -5° to -2°, maintaining the flow field at a velocity of 0.6 – 0 .8 m/s, and piling the substrates with pebbles with a medium grain size of 10-20 cm. This achievement was followed by the validation of our habitat creation technique for Yangtze sturgeon reproduction in its natural habitat. In March 2023, we placed 10 adult males and 10 adult females, all at the IV stage of gonad development, into a specially designed 45 m^3 spawning cage in the Jiang'an section of the upper Yangtze River. This cage was designed with adjustable flow rates, pebble substrates, and optimized slopes to mimic natural spawning conditions. After four days of observation, we were thrilled to witness mating behaviors and recorded a remarkable fertilization rate of 54.6%. In April 2024, we took our research to the next level by releasing 31 male and 31 female sturgeons into a newly recreated 150 m^2 spawning area in a 20,000 m^2 natural water body at the fork of the upper Yangtze River near Jiang'an Bamboo Island, Yibin City. The experimental area has a low flow rate to facilitate the control of flow generation. The experiment lasted 27 days, from 21st March to 16th April, with water temperatures ranging from 18 to 25°C. This spawning area was carefully reconstructed using techniques such as flow control and modification of the bottom substrate with pebble to create an optimal spawning condition. After placing the Yangtze sturgeon in the experimental area for 15 days, we were delighted to observe the reproductive behavior and detect fertilized eggs in the spawning area. The fertilization rate was 83.4%, resulting in over 480,000 eggs being laid, of which 10% hatched successfully. This confirms the successful reproduction of sturgeon in their natural habitat using the habitat creation technique (Figure 1).

These remarkable results clearly demonstrate that captive-bred sturgeon can be able to seek suitable spawning areas and reproduce in the Yangtze River. Our achievement not only confirms the effectiveness of our habitat creation technique based on our eco-hydraulic model of spawning grounds but also holds significant implications for the conservation and restoration of this endangered ancient giant fish.

FUTURE IMPLEMENTATION

In China, there have been many successful cases of restoring the wild populations of terrestrial animals, notably pandas and Tibetan antelopes. Nevertheless, restoring wild populations of aquatic animals remains a challenge due to the complexity of underwater experiments. Our recent experimental success marks a milestone in the pursuit of bringing endangered aquatic animals back to their natural habitats.

Our research underscores the pivotal role of flow velocity, substrate, and riverbed morphology in stimulating reproductive activity in Yangtze sturgeon during the spawning season at a suitable temperature. Insights from small-scale habitat creation experiments can greatly inform large-scale restoration efforts in the Yangtze River. Furthermore, environmental flow assessments are crucial for optimizing hydropower operations and creating appropriate eco-hydraulic conditions. Our study highlights the urgent need to adapt conservation policies and prioritize the preservation of sturgeon spawning habitats, combining active habitat restoration with optimized hydropower operation to rewild this giant fish and safeguard the biodiversity of the Yangtze River.

Currently, the implementation of active habitat restoration in nature reserves poses significant challenges. Concerns arise that such efforts might introduce further disturbance to the released sturgeon populations. Additionally, policymakers and others remain unconvinced due to the limited empirical evidence available. However, our research provides unequivocal evidence that active habitat restoration holds immense potential for the revival of sturgeon species in the Yangtze River. These strategies require coordinated collaboration among scientists, policymakers, conservation practitioners and the media to facilitate the uptake of research findings into policy frameworks and ensure the effective conservation of the Yangtze River's rich ecological heritage for future generations.

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DECLARATION OF INTERESTS

The authors declare no competing interests.