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Recent Progress and Future Directions for Conservation of the Yangtze Finless Porpoise (*Neophocaena asiaorientalis asiaorientalis*)

Fortschritte und zukünftige Maßnahmen zur Erhaltung des Jangtse-Schweinswals (*Neophocaena asiaeorientalis asiaorientalis*)

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Abstract

With the functional extinction of the Yangtze River dolphin or baiji (*Lipotes vexillifer*) based on the survey conducted in 2006, the Yangtze finless porpoise (*Neophocaena asiaorientalis*) is now the only surviving freshwater cetacean species in the Yangtze River. Due to similar threats from various anthropogenic activities in the Yangtze region, the natural population of the Yangtze finless porpoise (YFP) has been experiencing a drastic decline in the past few decades. Various conservation activities have been implemented to prevent the YFP from suffering the same fate as the baiji. Significant progress has been made recently, including natural habitat restoration, increasing the *ex-situ* population, and captive breeding success. Although there is a glimmer of hope, there are still some scientific and technical issues that need to be addressed to further improve the effectiveness and efficiency of the program through integrative planning for the whole conservation practice, which may include: 1) managing the *ex-situ* reserves as metapopulations; 2) replanning and managing the natural reserves and key habitats; 3) further improving research on the conservation biology of small cetaceans; 4) further encouraging public involvement. In general, this paper aims to review the implemented measures and re-

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cent progress achieved for the conservation of the critically endangered YFP and addresses the existing questions for further conservation practice of this species. Furthermore, we hope that this work will shed light on the conservation of other endangered small cetaceans in the world.

Keywords: Yangtze finless porpoise, small cetacean, conservation biology, *ex-situ,* Yangtze River

Introduction

In July 2020, there were 131 recognised cetacean species and subspecies in the world, with 22 listed as critically endangered (CR) and 20 as endangered (EN), according to the IUCN – SSC Cetacean Specialist Group. It has been widely realised that biodiversity in freshwater systems is at more risk than other systems (Allan & Flecker, 1993; Nabi et al., 2021a). Therefore, it is not surprising that, among the seven dolphin and porpoise species and subspecies living in freshwater habitats, three are recognised as critically endangered and four as endangered (Wang et al., 2013; Minton et al., 2017; da Silva et al., 2018; Braulik et al., 2019; da Silva et al., 2020). The Yangtze River, also called the Mother River of China, is the largest river in China. It originates in Qinghai, crosses through 9 provinces and two cities, and finally empties into the East China Sea at Shanghai City (Bergmann et al., 2012; Xia et al., 2021). The river is also famous for being one of the two big rivers in the world that harbour two cetacean species (Wang, 2009). Due to the effects of various human activities, however, the Yangtze River dolphin, or baiji (*Lipotes vexillifer*), was driven to functional extinction in 2007 (Turvey et al., 2007). Thus, the Yangtze finless porpoise (*Neophocaena asiaorientalis asiaorientalis*, YFP) is now the only freshwater cetacean species in this river.

The YFP is the only freshwater species or subspecies in the family Phocoenidae. It is exclusively endemic to the middle and lower reaches of the Yangtze River and its two adjoining lakes – Poyang Lake and Dongting Lake (Gao & Zhou, 1993). Since the late 1980s, several studies have reported a continuous decline in the number of YFPs (Zhang et al., 1993; Wang et al., 1998; Wang et al., 2000; Zhao et al., 2008). For example, in the early 1990s, the total number of YFPs was reported to be about 2,600 (Zhang et al., 1993), but by 2006 it has reduced drastically to approximately 1,800 individuals (Zhao et al., 2008) and only 1,045 individuals in 2012. The annual decline rate of this population in the river's main stem increased from about 6% to nearly 14%, which means that half of the YFP population in the main stem was lost in the six years from 2006 to 2012 (Mei et al., 2012). Consequently, the status of the YFP was re-evaluated as Critically Endangered in 2013 from its previous classification of Endangered on the IUCN's Red List of Threatened Species (Wang et al., 2013; Mei et al., 2012).

To protect the baiji and the YFP, the Chinese government launched a series of conservation actions beginning in the late 1980s that have been reviewed in detail by the Institute of Hydrobiology of the Chinese Academy of Sciences (Wang, 2009, 2015). Its actions fall into three main activity categories: *in-situ* conservation, *ex-situ* management, and a captive breeding program. Since the early 1990s, some hot spots have been recognised and established as *in-situ* nature reserves to protect the baiji and YFP's key habitats. Eight YFP nature reserves have been established, including three national, four provincial, and one municipal reserve. Over an extended period, however, its natural habitat in the Yangtze basin has continuously deteriorated due to the pressure of economic development despite the establishment of nature reserves (Wang, 2009). *Ex-situ* conservation practice was therefore recognised as an urgent and indispensable measure to protect a 'seed population' amid the quick decline of the wild population of the YFP. The first *ex-situ* population of YFPs was established in 1990 at Tian-E-Zhou Oxbow in Hubei Province,

where an *ex-situ* attempt was planned for the highly endangered baiji. Although the *ex-situ* population of the baiji was not established for various reasons at that time, the YFP population in this oxbow developed very well, which established a model of *ex-situ* conservation for YFP (Wang, 2015) and led to the establishment of two other *ex-situ* reserves, in He-Wang-Miao Oxbow in Hubei Province and Xi-Jiang in Anhui Province, respectively. Captive breeding has also been considered an important complementary conservation strategy (Wang et al., 2005). Since the first captive population was established in 1996 in the Baiji Dolphinarium or Yangtze Cetacean Breeding and Research Centre (YCBRC), four calves have been born under human care. In addition, two more captive breeding populations have been established in commercial aquariums, despite some controversies.

Although the integrative strategy for protecting the Yangtze River cetaceans was proposed as early as the mid-1980s, only some progress was achieved until recent years. According to the survey conducted in 2017, the declining rate of the YFP population has been reversed for the first time, and the estimated number of individuals in 2017 was 1,012, which is not statistically different from the number in 2012 (Huang et al., 2020). According to a statement by the Ministry of Agriculture and Rural Affairs, the rapidly declining population trend of the YFP has been successfully curtailed. More encouragingly, a newly completed whole-range survey in September and October in 2022 revealed that the YFP population just bottomed out with a statistic number of 1249 (unpublished data). In addition, the three *ex-situ* reserve populations have also increased significantly in the past several years. The dire trajectory of the YFP seems to have eased considerably in only the past few years. The interesting question is: what led to this significant change after the YFP had suffered such a long period of population decline? Compared to the baiji, why is the YFP so fortunate as to be able to grasp this last straw of hope? There is no doubt that this potential recovery of the YFP population convincingly suggests the effectiveness of present conservation measures, even though they made people lose confidence for many years (Wang, 2015). Therefore, we want to review the recent progress achieved and provide some suggestions on future directions to further improve the effectiveness of these measures. Moreover, we also want to take the YFP as an example to be used in protecting or saving other endangered small cetaceans from the brink of extinction.

Progress in *ex-situ* protection

Worried about the tremendous population decline of the baiji in the 1980s, Chinese researchers suggested establishing *ex-situ* populations for the Yangtze cetaceans and initiated this practice in the early 1990s. Tian-E-Zhou Oxbow in Shishou County, in Hubei Province, was finally selected as an ideal place to introduce the baiji and Yangtze finless porpoise. This oxbow was initially a part of the mainstream of the Yangtze River but was cut off by currents in 1972. It is an old course of the Yangtze River about 21 km long and 1–2 km wide, with a habitat quite similar to that of the mainstream (Zhang et al., 2003). For security, five porpoises were captured and introduced into the oxbow in 1990 as a pre-test for the introduction of baiji (Wang, 2009). Several additional introductions were conducted over the following years. Although it has been proved that the YFP can live and reproduce well in the oxbow, the population fluctuated until 2010 due to various problems, including poor infrastructure and management. Since 2010, the reserve has managed the fishing activity well, and the YFP population has begun to increase quickly. According to the 2015 survey, the 2015 population exceeded more than 60 individuals (from 25 animals in 2010), a net increase of 108% (Wang, 2015). This population further increased to 100 individuals, according to the latest capture survey conducted in April 2021

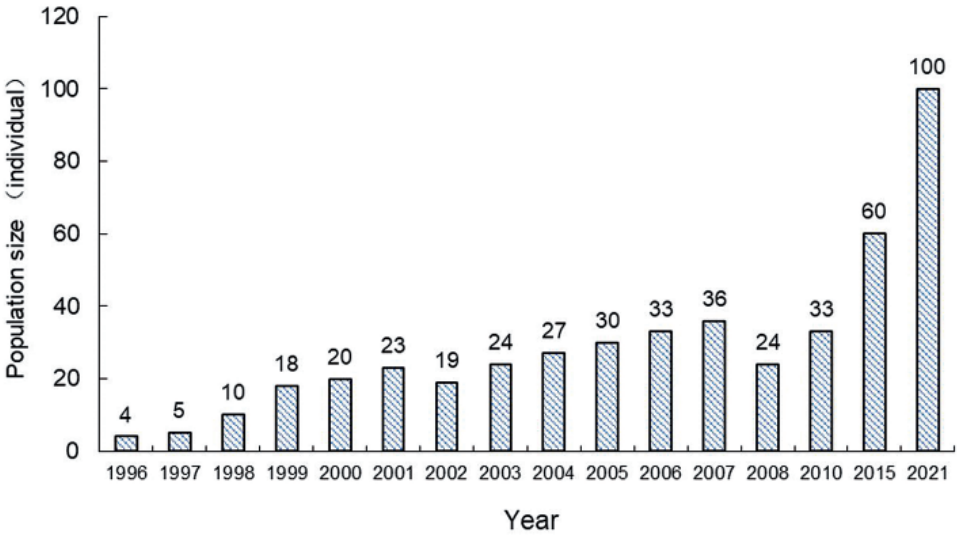

Fig. 1: YFP population increase in the Tian-E-Zhou Oxbow

(unpublished data) (Fig. 1).

Inspired by the success of the Tian-E-Zhou population, in 2015 the Ministry of Agriculture (MOA) established the second *ex-situ* reserve for the YFP in He-Wang-Miao Oxbow in Jianli County of Hubei Province, with technical support from the Institute of Hydrobiology at the Chinese Academy of Sciences (IHB). Twelve animals were introduced from Poyang Lake (8) and Tian-E-Zhou Oxbow (4) through three translocations in 2015 and 2017, respectively. The He-Wang-Miao Oxbow is about 30 km long, and its lower mouth is still connected to the Yangtze River; therefore, its water quality and fish resources are even better than the Tian-E-Zhou oxbow's. The carrying capacity is estimated to sustain about 110 YFPs, much higher than the Tian-E-Zhou Oxbow. Encouragingly, since 2016, new babies have been sighted every year. With the introduction of another eight and six animals from Tian-E-Zhou Oxbow in 2021 and 2022 respectively, the present population is estimated to be around 40, which will undoubtedly be the largest potential *ex-situ* YFP population.

In 2015, with the combined efforts of local fishery administrations and the Ministry of Agriculture and Rural Affairs (the present name of MOA), the third *ex-situ* reserve was established in Xijiang Oxbow, Anqing, in Anhui Province. This is a smaller oxbow with the capacity to hold about 20 animals. Eighteen animals had been introduced into this oxbow, and two new-born calves have been reported. Besides the three natural *ex-situ* reserves for the YFPs, another small seminatural *ex-situ* population was established in 1993 in a small channel between two islets in the Tongling section of the Yangtze River (Xian et al., 2010). This channel is about 1.6 km long and 80-220 m wide, with about ten animals living here. Although the YFPs can forage naturally, they must be fed twice a day due to the limited amount of fish resources in the channel (Xian et al., 2010). Therefore, considering its small size and need for extensive human intervention, it is not consensually recommended as an appropriate method for *ex-situ* conserving the YFPs.

The YFPs in the *ex-situ* reserves total around 130 animals, which has set a solid foundation for restoring its natural population in the Yangtze River. *Ex-situ* management actions to conserve YFPs provided the first positive example of *ex-situ* management for small cetaceans, which was seen as the Dawn of Hope for the conservation of the endangered small cetaceans in the world,

according to the IUCN Report of the 2018 workshop on *ex-situ* options for cetacean conservation (IUCN, 2018). In November 2019, the IUCN cetacean specialist group organised another symposium to investigate Chinese researchers' *ex-situ* achievements in YFPs. Inspired by the progress on the YFP *ex-situ* conservation work, the IUCN cetacean specialist group proposed introducing the One Plan Approach (see von Fersen and Miller in this special issue) methodology, including *ex-situ* options to conserve other endangered or threatened small cetacean species.

Efforts on Habitat Protection

Habitat protection is a fundamental measure for the conservation of wild animals, which benefits not just a single species but the entire ecosystem (Schelle, 2010), and, in the case of the YFP, through improved natural water flow, increased fish resources, and improved habitat quality. Therefore, since the mid-1980s, *in-situ* conservation has been suggested as one of the three major measures for Yangtze River cetaceans. Currently, a total of eight natural reserves have been established near the Yangtze River and its appended lakes (Fig. 2). The sum of the total length of the six reserves in the Yangtze River is approximately 494.5 km, accounting for nearly 30% of the area of the middle and lower reaches of the Yangtze River. For example, the Dongting YFP reserve accounts for about 26% of the size of Dong Lake. In comparison, the Poyang YFP reserve only accounts for a small proportion of the size of the lake (1.6%), even though it is the most important habitat for the wild YFP population (Zhao et al., 2008; Mei et al., 2012; Huang et al., 2020). The establishment of reserves, however, cannot protect the habitat of the YFPs without strong enforcement.

Although scientists have desperately called for immediate actions to protect the Yangtze cetaceans (Wang et al., 2000; Wang, 2009, 2015), due to continuous and extended developmental pressure in the Yangtze region, conservation measures have not been able to be fully implemented, even in the reserve regions. Human activities, such as shipping, fishing, hydro-project construction, sand-dredging, and urbanisation, are vital for developing the local economy and communities, so excluding or mitigating their impacts is difficult. Although the impacts of the individual anthropogenic activities were not quantitatively assessed, it is widely accepted that the cumulative effects of these activities are responsible for deteriorating the habitat of the YFP and other aquatic animals. Among these impacts, overfishing is seen as the major contributor to

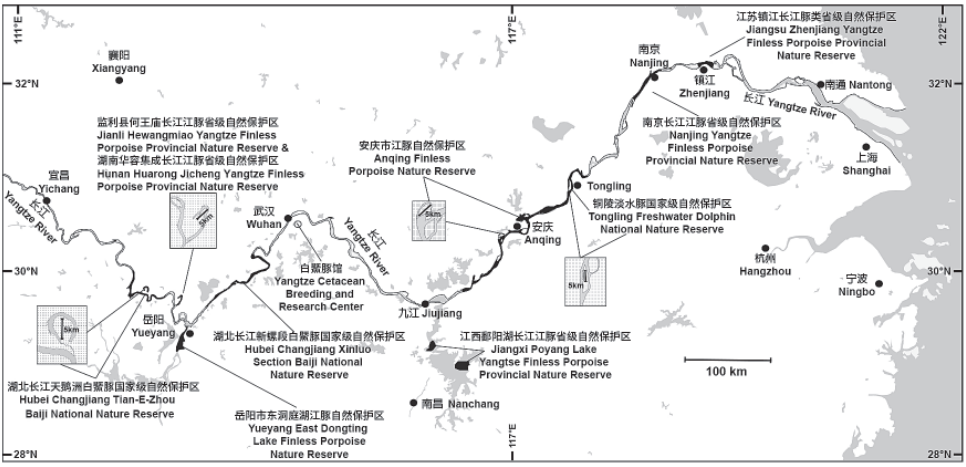

Fig. 2: YFP nature reserves in the Yangtze (by Frank).

the serious collapse of fish resources (Chen et al., 2002; Wei et al., 2007; Chen et al., 2009) and consequently destroys the foundation for a prosperous population of YFPs. In addition, food scarcity can cause detrimental nutrition stress in top predators (Wang, 2009; Schelle, 2010), which can fundamentally compromise the immunity, reproduction, and ultimately survival of the animals (Rosen, 2009; Nabi et al., 2017a, 2020a, 2020b). Moreover, various non-selective, illegal, and harmful fishing methods, such as electrofishing (Smith & Reeves, 2000), rolling hooks, and gill nets (Schelle, 2010), have been widely used in the Yangtze River and its adjoining lakes, even in some reserve sections. Like other small cetaceans, YFPs are prone to becoming entangled in fishing nets, which can cause severe injuries and predispose them to various infections and ultimately death by drowning (Schelle, 2010). Based on our preliminary investigation of the carcasses of YFPs collected in the Yangtze River, nearly one third of the identified causes of death were related to fishing activities (unpublished data).

To protect the fish resources, the Ministry of Agriculture and Rural Affairs, the major authority for freshwater biodiversity conservation in China, has implemented a seasonal fishing ban or spring fishing moratorium on the Yangtze River since 2002. It seems, however, that the three- or four-month seasonal fishing ban has not effectively protected the fish resources in the Yangtze River. As a result, the fish resources have declined continuously even after the implementation of the fishing ban, and it was announced that the biodiversity integrity index of the Yangtze River had reached the worst 'fish-free' level (People, 2018). Although the fishing ban was strictly enforced and the spawning and hatching of various fish species were well protected during the spring fishing ban period, fishing activities always increased immediately after the ban lifted. Controlling and enforcing fishing gear and methods during the fishing season is much more difficult than completely stopping fishing activity during the no-fishing period. Increased illegal fishing at night has been reported during the fishing season, with detrimental fishing practices on Poyang Lake and other water regions (Mei et al., 2020). With the continuous decline of fish stocks in the whole ecosystem, sustaining enough prey for the YFPs living in the reserves in a flowing riverine system is impossible, even with the strictest enforcement in the reserve sections. Despite the nearly 20-year seasonal fishing ban, however, it seems that the biodiversity integrity of the Yangtze River was still on the track to collapse, as shown by the stunning evidence of the likely extinction of baiji and the Chinese paddlefish (*Psephurus gladius*) and the quick decline of the YFP population and many other aquatic animals during this period (Turvey et al., 2007; Mei et al., 2012; Zhang et al., 2020).

An ichthyologist at the Institute of Hydrobiology proposed a complete fishing ban in 2006, when the shortcomings of the seasonal fishing ban were recognised. Still, more than 230,000 fishermen depend on fishing in the Yangtze basin. The trade-off between biodiversity protection and fishing livelihoods has long been negotiated. In the face of deteriorating environmental conditions and a booming economy, the 10-year fishing ban was finally implemented in all protected areas in early 2020 and throughout the entire Yangtze basin on 1 January 2021 (Mei et al., 2020). The central and local governments along the Yangtze have provided special funds for the retraining of fishers in new jobs by teaching them new skills and providing them with benefits, like social security. With the help of some NGOs, some fishers have been trained and appointed as fisheries wardens. They still live on the boats and do not fish but assist law-enforcement agencies in regulating fishing activities. Although there remains a lack of solid scientific data, it has been reported that the fish stocks have shown obvious signs of recovery, at least in some regions. In Lake Poyang, for example, the largest freshwater lake in China and the most important habitat for YFP, fish stocks increased significantly despite having a complete fishing ban for less than two years in this region. According to the Jiangxi Provincial Fisheries and Research Institute, the fish community structure in Poyang Lake is improving, and the fish resources have been replenished (People, 2021). Moreover, some rare or endangered fish species, such as

the common sucker (*Myxocyprinus asiaticus*) and (*Ochetobius elongatus* Kner, 1867), also re-emerged in Poyang Lake, according to the latest survey conducted by the local institute.

The waterfront zone is an important wetland, flood-storage area, and detention area of the Yangtze River and plays important roles in economic, social, and ecological functions (Duan et al., 2020). Several surveys of the YFP have shown that these animals are more frequently sighted in sections with more natural waterfront zones (Mei et al., 2012; Huang et al., 2020, Chen et al., 2020). Anthropogenic activities, however, have significantly occupied and disturbed this vital component of the Yangtze ecosystem. The ecologically sensitive waterfront of the Yangtze River measures 3,943.2 km, accounting for 49.9% of the total length of the Yangtze River, among which about 1,625 km were artificially disturbed, accounting for 41.2% of the total length of the ecologically sensitive waterfront. This is even higher than the overall development and use rate of the main stem of the Yangtze River (36.7%), indicating that the existing protection areas played only a limited role in conserving the natural coastlines of the Yangtze River (Duan et al., 2020). The Ministry of Water Resources launched a campaign on cleaning and restoration actions for the coastline of the Yangtze River in 2016 based on the Guidelines for Development Along the Yangtze Economic Belt approved by the Political Bureau of the Central Committee of the CPC in 2016. According to the MWR, by October 2020, 2,441 projects suspected of violating laws and regulations had been cleaned up and remedied, accounting for 98.9% of the total. Furthermore, 158 km of the Yangtze River coastline had been restored, and 121,300 m^2 of beaches and banks were rehabilitated. This campaign has been significantly changing the Yangtze River's waterfront zone, thus rehabilitating the Yangtze ecosystem's ecological functions.

Water pollution is seen as another important factor in the deterioration of the habitat of the YFP (Wang, 2009, 2015). Another major cause is the reduction of fish resources, since fish are more vulnerable to various pollutants in water and tend to accumulate pollutants in their bodies (Jia et al., 2017). Previous studies have reported the bioaccumulation of toxic chemical pollutants in different fish and other aquatic species endemic to the Yangtze River (Shao et al., 2005; Xian et al., 2008; Su et al., 2010). YFPs are at the top of the food chain and can, therefore, bio-accumulate various toxic pollutants by ingesting polluted prey (Schelle, 2010). Dong et al. (2006) reported the deaths of five YFPs in Dongting Lake from pesticide exposure. More recently, Xiong et al. (2019) and Zhang et al. (2020) reported several organic pollutants in blubber and trace elements in various tissues. Although acute mortality caused by pollutants is rare, accumulated toxins in animals can cause multiple problems, such as reproductive failure, an imbalance in biochemical homeostasis, and cardiovascular, hepatic, and renal problems (Willett et al., 1998; Stahl et al., 2011; Nabi et al., 2019, 2021b), which can compromise the animals' survival.

As one of China's most important economic belts, the Yangtze River has long suffered from tremendous amounts of industrial wastewater, agricultural effluents, ship navigation wastes, and urban sewage (Floehr et al., 2013). The deteriorated water quality poses a grave threat to public health (Lu et al., 2008) and aquatic biodiversity (Ullah et al., 2021a, b). The Yangtze River was even rated as one of the top ten 'risk rivers' globally by the World Wildlife Fund in 2007 (Wong et al., 2007). Although actions on pollution prevention have long been continuously conducted along the Yangtze basin, a systematic and thorough campaign on water-pollution control in the Yangtze basin has been overwhelmingly implemented throughout the whole basin under the supervision of the Ministry of Ecology and Environment since 2016. According to the Ministry of Economy and Labour, 228 chemical enterprises along the Yangtze River have been relocated or renovated, including all the outdated chemical enterprises within one km of the Yangtze River. At the same time, pollution from non-point agricultural sources has been significantly reduced by, for instance, decreasing the use of and increasing the efficiency of chemical fertilisers

and pesticides and applying green crop disease and insect prevention and control technology. Furthermore, centralised sewage-treatment facilities in all cities along the mainstream of the Yangtze River have been established, and nearly 24,000 sewage outlets in total from the cities along the river have been eliminated. Moreover, 33,872 pollutant reception facilities for ships were completed in the Yangtze Economic Belt to reduce pollution from the ports and piers. As a result of these measures, remarkable improvements have been achieved, with the good water quality sections (grade I to grade III) increasing to 96.7% of the Yangtze River basin, 14.9% higher than that in 2015. Moreover, in 2020, for the first time, the water quality of the whole mainstream reached Grade II (News China, 2022).

Acoustic pollution, particularly from ships, is another potent stressor for all cetaceans of any age (Wright et al., 2007). A sudden loud noise can kill nearly any cetacean (Claridge, 2006), but, more commonly, it causes damage to their external and internal organs (Cox et al., 2006). Chronic acoustic pollution can cause hearing loss (Finneran et al., 2002) and mask their vocalisations essential for foraging, mother-offspring bonding, navigation, and escape from predators (Marine Mammals Commission, 2007). Furthermore, exposure to chronic acoustic pollution can directly suppress the Hypothalamic-pituitary-gonadal (HPG) axis and compromise fertility (Nabi et al., 2018a). Additionally, daily social behavioural patterns, such as group cohesion (Nowacek et al., 2001), travel direction, behavioural state (Miller et al., 2008), dive duration, and breathing synchrony, can be negatively compromised by acoustic pollution (Nabi et al., 2018b). Acoustic pollution can also directly reduce the foraging efficiency of cetaceans (IWC, 2007), which can consequently compromise their survival (Wright et al., 2007). Many cases have been reported of YFPs' being killed or severely injured by propeller strikes (Zhou & Zhang, 1991; Chen et al., 1997). Therefore, scientists have long petitioned to regulate shipping or navigation in the Yangtze River (Wang et al., 1998, 2000; Wang et al., 2006; Wang, 2009, 2015).

The Yangtze River is the major artery of China's inland water transportation, which is called the Golden Channel of the Chinese economy (Schelle, 2010; Fu et al., 2010). According to the Ministry of Transport (MOT), shipping along the Yangtze River contributes more than 200 billion yuan directly and 4.3 trillion yuan indirectly to economic and social development along the river every year (MOT, 2020). It is impossible to reduce the Yangtze River's shipping ability due to its function as a backbone of the economy. Thus, it is not easy to regulate the huge shipping industry. The MOT has issued regulations and standards for preventing and controlling noise pollution from ships in the Yangtze River and strengthened on-site supervision. Moreover, it has pledged to investigate further technical measures, such as new and green energy engines, to control noise pollution in the river. In some reserve sections, boat-speed control has been proposed and is notified automatically by radio when a boat or ship enters the reserve section, which might help mitigate the effects of noise pollution and shipping on the animals in the region.

Although it is impossible to solve all problems at once, with the implementation of a series of campaigns by various departments, particularly the complete 10-year fishing ban and waterfront zone-cleaning and restoration actions, the environment and ecology of the Yangtze River have been changing significantly. In general, the habitat of the YFPs is gradually improved by the evidence of frequent sightings and reports of YFPs from different regions. For instance, the Nanjing Provincial YFP Natural Reserve now can be seen as a successful example of an *in situ* nature reserve of YFPs in the urban section of the busy channel of the Yangtze River although it is the latest natural reserve established in October 2014. Thanks to strict enforcement of all fishing controls, including recreational fishing, and the restoration of the river's natural shorelines, the YFP population has increased significantly, from 20 to 50 animals, since its establishment in 2014, and the population continues to grow steadily. In addition to management by the Nanjing local authorities, the participation of the local population, including NGOs and volunteers, has also contributed significantly to the recovery of the YFP in this section. The

Yichang section, just down to the Gezhou Dam, is another encouraging example. Historically, it was not a traditional hotspot of the YFP but a provincial nature reserve for the threatened Chinese sturgeon. With the environmental improvement of this region, a small group of YFPs explored it in 2015 and now dwell in the reserve. The present number of residents is estimated at 15 to 20 animals, and they have now become a famous symbol of this city, attracting many local photographers every day. The Poyang and Dongting Lakes are the two most important habitats for YFPs (Zhao et al., 2008; Mei et al., 2013) and have been seen as the last refuge of the YFPs. In addition to the intensive fishing activities, illegal sand dredging was another threat contributing to the deteriorating habitat of the YFP and the survival of other aquatic animals in the two lakes (Jing, 2008; Wang, 2015). Due to the local economy's dependence on sand-dredging, the sand-dredging ban has faced imaginable difficulties in these regions. Thanks to the strong implementation of the Great Conservation Project for the Yangtze River proposed by the central government, sand-dredging has been strictly suppressed and regulated. As a result, the former muddy lakes are now becoming clean and calm. Regional surveys conducted by the local institutes have shown that the population of the YFP is increasing, which has been confirmed by the 2022 survey (unpublished data).

Progress in the Captive Breeding Programme

As early as 1986, at the first symposium on Biology and conservation of Freshwater Cetaceans in the World, Chinese researchers identified captive breeding as the last of the three major conservation measures for the Yangtze River dolphins. A male baiji named Qi-Qi was rescued on 11 January 1980 and raised in captivity in the Baiji dolphinarium for 22 years and 186 days, making him one of the longest-lived freshwater dolphins under human care. Although attempts were made to find a breeding partner for him, the captive breeding program for baiji finally failed with the death of Qi-Qi on 14 July 2002 (Wang, 2009).

The long-time husbandry of Qi-Qi, however, led to important knowledge about and experience in the care of small freshwater dolphins that is now helping Chinese researchers and trainers to keep YFPs under human care. The first group of YFPs, two females and one male, was successfully introduced to the Baiji dolphinarium or the Yangtze Cetacean Breeding and Research Centre in 1996. The first calf, named Tao-Tao, was born on 5 July 2005 (Wang et al., 2005). Although several other calves were born in captivity in the following years, however, all calves died prematurely, possibly due to the old facility, maternal problems, or poor nutritional management. The rearing pools in the Baiji dolphinarium were reconstructed in 2008, and three young females from Poyang Lake were introduced in 2009 (Yang-Yang) and 2011 (F7 and F9), respectively. Moreover, Chinese researchers have investigated and improved the husbandry and management of captive animals, including grouping, monitoring, and nutritional adjustment during the females' different physiological stages. In 2018, the second male calf, 'E-Bo', was born successfully and has now fully matured. Furthermore, the male second-generation baby YYC (Yang-Yang's calf) was born in 2020, which is named Han-Bao later and now is fully independent of his mother. In 2022, the first female second-generation baby was born, which further enhances the reproductive success of this captive population. Presently, it has totally 11 animals in this captive population and provides a dependable research platform for the small cetacean biology.

Although captive breeding of YFPs remains challenging, the whole process, including pregnancy, delivery, and nursing, is now common and natural in the Baiji dolphinarium. The protocols and procedures for the management and husbandry of captive YFPs have been significantly improved (Hao et al., 2019), and the experiences in keeping and breeding YFPs in human care made at the Baiji dolphinarium have also been applied to a net cage project in the Tian-E-Zhou

oxbow. In recent years, two calves were born in the net cage in 2016 and 2020. The first calf was released to the oxbow in 2020 after she was confirmed to be fully matured, and the second calf is now also already completely independent.

Although it remains controversial to use captive breeding as a conservation measure, there is no doubt that keeping even a small group of animals can build a significant amount of knowledge and experience in handling and caring for the animals, which is in turn important for wild animal rescue and handling. Moreover, it provides an exclusive opportunity for the public to know more about this species, significantly inspiring their concern, love, and care for these unique small cetaceans in the Yangtze River. However, in the case of the YFP, the contribution of captive breeding programs to enhancing the wild populations in the Yangtze River or in the oxbow river reserves remains to be seen. Even though, and amid suspicious public opinions, two captive populations were established in two commercial aquaria in 2019 and 2020, respectively, with individuals taken from the two of the YFP ex-situ reserves. Considering the difficulties of reintroducing animals born under human care back into the wild, the effect of these commercial breeding programs to the endangered YFP wild population is still uncertian compared to the promising network of natural ex-situ reserves along the Yangtze River.

Future direction for the conservation of the YFP

After decades of efforts by Chinese researchers, conservationists, governmental authorities, and NGOs, a systematic conservation strategy has been established, and the terminal trajectory of the YFPs has been fundamentally changed. Despite this success, more scientific and conservation issues still need to be addressed to further strengthen the foundation of the progress and restore the natural population of YFPs in the Yangtze River.

Managing the *ex-situ* populations as a metapopulation

The *ex-situ* reserves are relatively small areas for a large population of YFPs. For example, the carrying capacity of the Tian-E-Zhou oxbow is estimated at only 89 animals total, according to the Ecopath Model (Li, 2017). Using the same model, the carrying capacity of the He-Wang-Miao oxbow is estimated at 110 animals (unpublished data), while the carrying capacity of the Anqing Xi-Jiang oxbow is much smaller, at less than 30 animals. Using a stable population model, the threshold for the population size to persist for 100 years requires 113 animals, and 472 animals are needed to persist for 500 years (Mei et al., 2021). Based on this data, it is evident that none of the present *ex-situ* reserves can sustain the progress of the YFP population for long. It is, therefore, important to manage the *ex-situ* populations as a metapopulation. Moreover, in small and fragmented populations, the loss of the population's genetic structure and genetic diversity may alter the species' demography and increase its risk of extinction (Frankham et al., 2002). The population decline, combined with the restricted gene flow, can cause a serious loss of genetic diversity and result in genetically fragmented populations (Chen et al., 2014). Therefore, the artificial exchange of individuals among the *ex-situ* populations is critical to maintaining genetic diversity and a self-sustaining *ex-situ* population. According to a model simulation, for the Tian-E-Zhou population, at least two animals each year need to be exchanged with other *ex-situ* populations or natural populations to maintain their genetic diversity.

A genetic-diversity management program has been implemented for *ex-situ* populations. The Institute of Hydrobiology, supervised by the SFAO, introduced four animals from Poyang Lake into the Tian-E-Zhou Oxbow in 2015 and 2018. In return, in 2015 and 2020, four and eight animals, respectively, were translocated to the newly established He-Wang-Miao population.

Moreover, two males were translocated from the Tian-E-Zhou Oxbow to the Anqing Xijiang Oxbow. The preliminary genetic evaluation demonstrated that, with these movements, the genetic diversity of the Tian-E-Zhou population has significantly improved (Wang Ding, personal communication). In the long run, functional connectivity through artificial exchanges among *ex-situ* populations is required to maintain the genetic biodiversity and population dynamics.

With the population reaching or even surpassing the carrying capacity of the Tian-E-Zhou oxbow, it is now urgent to evaluate the optimum sustainable population (OSP) to maintain healthy population development. With the increase in the *ex-situ* population, the animal's net reproductive rate and nutritional status, as indicated by body mass index (BMI), has shown an obvious decline in the Tian-E-Zhou population (unpublished data). Therefore, it is now a reality that determines how many animals need to be translocated out each year to maintain an optimal sustainable population. Moreover, sewage discharge, the allocation of water resources, fishery management, carrying capacity improvement, and water quality control are some new issues in managing *ex-situ* reserves. Therefore, further investigation is needed to develop the categories required for establishing and manipulating the *ex-situ* reserves, including criteria for location, size, topography, water quality, fish availability, wetlands, climate, and the surrounding communities. Another important question is how to re-evaluate the role of *ex-situ* populations for the recovery of the natural population of YFPs in the Yangtze River.

Boosting habitat restoration and natural population recovery

Decades of environmental degradation on the Yangtze River due to rapid and unregulated development had almost driven the YFP into the vortex of extinction, prompting even conservationists to ponder its future (Wang, 2015). The change in China's development philosophy gives the YFP a chance to grasp the last straw of hope. The significant changes in the Yangtze ecosystem reignited the hope that the natural habitats of the YFP and other aquatic animals in the Yangtze could be restored. In the context of the greater protection of the Yangtze River and the 10-year fishing ban, the following measures are proposed to further boost the recovery of the natural population of YFPs.

Re-establish the connection of some tributaries and lakes to the main stem of the Yangtze River to reconstruct its ecological function

Historically, the Yangtze River was connected with numerous lakes and tributaries that were disconnected from the main stem of the Yangtze for, among other purposes, flood control and irrigation projects. Only a few lakes remain directly connected with the main stem, like Dongting and Poyang Lakes. These barriers significantly reduced the ecological function and biomass of the ecosystem by impeding the breeding or foraging migration of some fish species and curtailing the free movements and gene flow of aquatic organisms (Morita et al., 2009). The construction of the Three Gorges Dam significantly reduced the probability of a major flood in the Yangtze River to one in 100 years. It, therefore, provides the possibility to reconnect the main stem of the Yangtze to some of its tributaries and lakes through a thorough and objective ecological evaluation.

Readjust the nature reserves according to hotspot or habitat changes of the YFPs

Eight natural protected areas are presently established for the YFP. Due to various anthropogenic activities, however, the habitats and distribution of the YFP differ from decades ago, when the reserves were established. It is necessary to readjust the reserve areas according to the present results from the series of surveys (Zhao et al., 2008; Mei et al., 2013;

Huang et al., 2020). Some important habitats of the YFP, e.g., the Balijiang section or the mouth of Poyang Lake, the Jingjiangmen section or the mouth of Dongting Lake (Huang et al., 2020), should be designated as protected areas for the YFPs. Previous YFP population surveys have also shown that the distribution of the YFP in the mainstream of the Yangtze River is highly correlated with the characteristics of the river shoreline. This suggests that protecting the nature shoreline of the Yangtze River is key to the protection of the natural habitat of the YFP. Therefore, it is highly recommended that the functional zoning adjustment of the YFP reserve in the main stem of the Yangtze River should focus on protecting the river coastline environment, which should be designated as the core protection area of the reserves (Liu et al., 2020).

Continue regular surveys across the range to monitor population trends and assess the level of threat

With the implementation of the Greater Protection of the Yangtze River, it is optimistic to expect that the natural population will increase gradually in the foreseeable future. Therefore, it is recommended to conduct a population viability analysis according to the recent data from the surveys to project the population trajectory, which can be used to assess the effectiveness of conservation strategies. Moreover, with the *ex-situ* population reaching carrying capacity, it is time to evaluate the possibility of releasing some of the animals from the *ex-situ* reserves, such as Tian-E-Zhou Oxbow, to certain natural habitats to restore the wild populations.

Improve research on the conservation biology of small cetaceans

The recovery of the YFP population is a good example of how species can be conserved and can thus serve as a model species for the conservation of small cetaceans. Advanced technologies can be tested in natural, *ex-situ,* and captive populations of YFPs to conserve other threatened small cetaceans worldwide. Although integrated conservation activities have improved the status of the YFP, many knowledge gaps still exist that would allow us to refine the conservation system and technologies further. For example, the traditional population survey is relatively laborious and time-consuming, and its result is prone to be affected or even biased by the visual differences of individual observers. Moreover, the fast-developing drone (i.e., unmanned aerial vehicle) technology allows for the establishment of drone-based survey technology, which could be more efficient and accurate. Furthermore, remote-sensing technology is highly recommended for habitat investigation, planning, and management.

Genetic diversity (Zheng et al., 2005), divergence (Yang et al., 2002), correlation between environmental factors and genome size (Bo et al., 2006), adaptation to the environment (Ruan et al., 2016), renal transcriptome sequencing (Ruan et al., 2015), and basic information about the finless porpoise biology (Zeng et al., 2017a, 2017b; Xiao et al., 2018; Ji et al., 2019; Zeng et al., 2019) have been studied. Additional studies are needed to investigate inbreeding depression-related loci, gene-environment interactions, overdominance, epistasis, and genetic susceptibility, which are important for animal conservation (Khan et al., 2016). Historical information related to the origin, speciation time, ancestral effective population size, and microevolution of the YFPs needs to be collected.

The *ex-situ* reserves for the YFP can serve as a model for the Yangtze River ecosystem. A series of scientific or technological issues can be investigated on this platform: e.g., the energy flow and balance in the closed ecosystem, the function and interaction of the top predator, the YFP, with its prey and other aquatic organisms, and the biodiversity varia-

tion and gene flow in the closed population with changes in the population size. Moreover, changes in population dynamics and the reproductive performance of the population with the population size approaching the carrying capacity of the closed reserve ecosystem can also be studied.

For the captive breeding population of YFPs, artificial insemination (AI) technology can be a useful tool in conserving endangered species. Improving the genetic material, increasing the overall population, and enabling breeding at different times and different geographical locations can be achieved by AI. AI also ensures breeding in the presence of behavioural, physiological, and physical abnormalities after a male's death (Jane, 2011). Current research is in progress to investigate the ovulation period through hormones and ultrasound in captive female YFPs. Training male YFPs for semen collection has also been started. There are still various challenges regarding AI, however, including gamete preservation and the development of a protocol for AI. Thus, combined contributions from various field experts are needed to overcome and establish a sustainable captive population.

Advanced molecular techniques can help explain how different toxicants, pathogens, and other parasites can disrupt the cellular machinery of YFPs. Furthermore, there is also a need to develop viable cell lines and improve medical husbandry techniques to understand the cellular and physiological responses of YFPs to various anthropogenic stressors. When using advanced molecular and other physiological methods, criteria are needed for animal translocations and release practices considering the genetic diversity and richness, disease risk assessment, and health screening of the YFPs. Post-release assessments via satellite-linked telemetry are also needed to understand whether the animal can re-adapt to its natural environment.

Further encourage public involvement

Public involvement is a key factor in conservation, especially for the protection of flagship species that act as ambassadors for the entire ecosystem. The giant panda is a good example of this model, where conservation action is focused on this charismatic species to achieve conservation success for other species as well. The YFP is also an intriguing species that could act as a symbol for the conservation of the Yangtse River in general. It was not well protected before, partly because it was not well known by the public due to its evasive behaviour. The activities conducted to educate the public coordinated by the Chinese government, media, and NGOs over the last few years, however, have informed the public about the status of the YFP. The Baiji Dolphinarium of IHB has played a key role in this campaign by providing pictures, videos, and TV programmes. With the YFP becoming more popular, more and more people have become concerned and even joined forces to protect this species. Every year, many visitors of different ages and nationwide volunteers come to see the porpoise. Ten delegates of the Chinese People's Political Consultative Conference (CPPCC) submitted a joint proposal to upgrade the YFP to a First Grade National Protected Animal during the fifth meeting of the 12th session of its 2017 conference, which contributed significantly to its upgrading in 2020 and is a clear indication of public awareness. Wuhan Baiji Conservation Foundation (WBCF) was the first NGO established in 1996 for the conservation of the Yangtze River cetaceans. Recently, however, over 20 organisations have been directly involved in the conservation of the YFP in different regions, such as Poyang Lake and Dongting Lake, and the Wuhan, Anqing, Nanjing, and Zhenjiang sections. These NGOs organise various public educational events, conduct surveys, report illegal activities, and report stranding events of YFPs, which have contributed and will continue to contribute to the restoration of the natural population of YFPs in the Yangtze River.

Conclusions

Since the extinction of the Yangtze River dolphin in 2006, the YFP is now the only freshwater cetacean endemic to the Yangtze River. Unfortunately, like the baiji, the YFP also faced tremendous pressures resulting from various anthropogenic activities. As a result, YFPs have been on an accelerated path to extinction for the last few decades. Different measures, such as promoting public awareness, a fishing ban, *in-situ* conservation, *ex-situ* conservation, captive breeding, and various biological research programmes have been carried out to conserve YFPs. Only recently fruitful results have been achieved through the integrative use of these conservation tools, as shown by the quickly increasing population in *ex-situ* reserves, significantly slowing the decline rate of the natural population and making progress on captive breeding and public education projects. By comparing the conservation process of the baiji and YFPs, an integrated conservation plan, including *ex-situ* options, is important to draw a threatened cetacean species out of the extinction vortex. *Ex-situ* measures should be implemented early enough to ensure that one or more seed populations can be established without significantly affecting the natural population. The protection of the natural habitat is the fundamental measure for restoring the wild population of endangered cetacean species. Therefore, significant conservation measures should be implemented to mitigate or eliminate the major threats from the species' hotspots (e.g., fishing). Natural habitat protection, however, always conflicts with the livelihoods and economy of local communities. Therefore, it needs the strong support of political and legitimate enforcement, which also needs to be backed up by the nation's strong economy, such as implementing the 10-year fishing ban in the Yangtze River. Captive breeding can support filling the knowledge gap and educating the public about the protection of the cetacean species. Still, it seems costly and inefficient to save a cetacean species by reproducing many animals in captivity. From our experience with YFP, we suggest using integrated conservation tools to protect endangered small cetacean species by considering *ex-situ* options as early as possible to establish seed populations, protect natural habitats as much as possible, and fill the knowledge gap as quickly as possible by all means possible, including through a small-scale captive breeding program. If these measures could be implemented properly, changing the fate of any endangered cetacean species is highly possible.

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Zusammenfassung

Mit dem Aussterben des Jangtse-Delfins oder Baiji (*Lipotes vexillifer*) auf Grundlage der im Jahr 2006 durchgeführten Erhebung ist der Jangtse-Schweinswal (*Neophocaena asiaorientalis*) nun die einzige überlebende Süßwasser-Cetacea-Art im Jangtse-Fluss. Aufgrund ähnlicher Bedrohungen durch verschiedene anthropogene Aktivitäten in der Jangtse-Region hat die natürliche Population des Jangtse-Schweinswals (YFP) in den letzten Jahrzehnten einen drastischen Rückgang erlebt. Um zu verhindern, dass dem YFP das gleiche Schicksal wie dem Baiji widerfährt, wurden verschiedene Schutzmaßnahmen ergriffen. In letzter Zeit wurden erhebliche Fortschritte erzielt, darunter die Wiederherstellung natürlicher Lebensräume, die Vergrößerung

der Ex-situ-Population und die erfolgreiche Zucht in Menschenobhut. Obwohl es einen Hoffnungsschimmer gibt, müssen noch einige wissenschaftliche und technische Fragen geklärt werden, um die Effektivität und Effizienz des Programms durch eine integrative Planung für die gesamte Erhaltungspraxis weiter zu verbessern, die Folgendes umfassen kann 1) Management der Ex-situ-Reservate als Metapopulationen; 2) Neuplanung und Management der natürlichen Reservate und der wichtigsten Lebensräume; 3) weitere Verbesserung der Forschung über die Erhaltungsbiologie von Kleinwalen; 4) weitere Förderung der Beteiligung der Öffentlichkeit. Im Allgemeinen zielt dieser Beitrag darauf ab, einen Überblick über die durchgeführten Maßnahmen und die jüngsten Fortschritte bei der Erhaltung der stark gefährdeten YFP zu geben und die bestehenden Fragen für die weitere Erhaltungspraxis für diese Art zu erörtern. Darüber hinaus hoffen wir, dass diese Arbeit Licht auf die Erhaltung anderer gefährdeter Kleinwale in der Welt werfen wird.

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