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## Conservation strategies for the Chinese sturgeon, *Acipenser sinensis*: an overview on 30 years of practices and future needs

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### Summary

Chinese sturgeon (Acipenser sinensis Gray), a species with important scientific and economic values, has been listed as a First Class Protected Animal by the China Government in 1989. Due to the effects of human activities, the wild population of A. sinensis has declined drastically in the past 30 years. Though a series of policies and protective measures have been implemented, the number of A. sinensis continues to drop. Considering the declining trend of A. sinensis population resource, some new conservation strategies are presented. On the one hand, some measures should be taken on the management side: (i) fishing should be prohibited in the Yangtze River, (ii) a solid plan on A. sinensis resources conservation should be identified based on scientific criteria for which research should be completed, and (iii) management of the water environment in the Yangtze River system should be enhanced. On the other hand, a lot of emphasis should be placed on studies of the natural population, including the existing and remaining core natural spawning grounds and habitats of A. sinensis. Additionly, cryopreservation of gametes for gene banking and constructing aritificial spawning grounds for broodstock management are highly necessary, while also the establishment of closed-cycle systems for maintaining captive broodstock is needed in order to provide the quality control needed for the foundation of sustainable farming while at the same time serving as a tool for the preservation of the gene pool of A. sinensis species.

### Introduction

Chinese sturgeon (Acipenser sinensis Gray) is a large and typically anadromous species, which is mainly distributed in the Yangtze River system and along the continental shelf areas of the East China Sea and Yellow Sea (YARSG, 1988). It was also listed as a Critical Endangered species in the IUCN Red List (IUCN, 2010). In the late 20th century, due to increased human activities, such as hydroelectric projects, overfishing, water pollution, heavy shipping, dredging of navigation channels and quarrying have altered the river system, blocked the migration route, changed the spwaning grounds, altered the river bed morphology and substrate types of the habitats for A. sinensis. Meanwhile, thèse human activities have also changed the hydrogeology, and the water quality as well as spatial distribution of natural runoff of the Yangtze River (Hu et al., 1985). All of these changes have failed to satisfy the conditions (habitats and hydrologic and water quality) needed for natural reproduction of *A. sinensis* (Hu et al., 1992; Yang et al., 2006; Zhang et al., 2007). It was reported that the spawning grounds have been limited to < 5 km of the river reaches below the Gezhouba Dam, which is < 1% of the length of the original 600 km upstream spawning reaches this species historically used in the Yangtze River. Particularly, the length of its core spawning area is now being restricted to only about 3 km (Kynard et al., 1995; Wei et al., 1998; Yang et al., 2007; Tao et al., 2009), and as a consequence, the wild population of the *A. sinensis* has continuously become smaller.

In order to protect the population resources, the government has worked out a series of policies to strengthen legislation and publicized these accordingly. Further, the government has also established a natural reserve and rescue stations for *A. sinensis*, where controlled propagation is performed and releasing programmes are implemented, while prohibiting commercial fishing, implementing a fishing permit system, and limiting fishing for scientific research as well as establishing closed fishing areas and seasons.

However, the number of *A. sinensis* specimens in the population as well as the quantity of eggs and the spawning frequency have significantly declined since (Xiao et al., 2006; Hu et al., 2009). The numbers involved in the broodstock population of *A. sinensis* (from downstream of the Gezhouba Dam to Gulaobei; 30 km) has been located in the natural reserve established for *A. sinensis* and were determined by Bisonics DT-X Echosounder (200 kHz) between 2004 and 2005 with the following results: 1, 453 and 789 individuals in 2004 and 2005, respectively (Zhang et al., 2007). It was deduced that if all factors are maintained at the same level in the next 20 years, the natural broodstock population of *A. sinensis* may reach a minimum by 2019, with about 402 individuals being left (Chang, 1999).

Therefore, it is necessary and urgent to analysis the reasons why the number of *A. sinensis* population has become alarmingly smaller and smaller, while also research must focus on determining effective ways to protect and restore the *A. sinensis* resources.

### Reasons for continuous decline of the A. sinensis population

Though the government has taken a series of protective measures, which has certainly slowed down the process of decline of the *A. sinensis* population in some ways, the population is still continuing to decline, and the reasons are as follows.

#### Human activities intensified more than ever before

Due to human impact, the *A. sinensis* is now rarely found in the Pearl River, and the Yangtze River is probably its last refuge (Wei et al., 1997). The construction of the Gezhouba Dam across the Yangtze River has blocked the migration of *A. sinensis* to their historic spawning grounds causing a significant decline of the entire population (Hu et al., 2009). This has significant consequences for fragmentation of habitats, blocking migration routes, and destroying spawning grounds, causing loss of biodiversity (Baxter, 1977).

Though a new spawning ground have been found below the Dam, it appears to be the only existing spawning ground and habitat for mature *A. sinensis* specimens (YARSG, 1988; Wei et al., 1998; Wei et al., 2009). The results of the various human activities (such as bridges construction, dredging of navigation channels, quarrying and sand-digging), the hydrogeology and water quality have changed, and the spawning area and habitats available for the spawners has become smaller (Yang et al., 2007; Zhang et al., 2007).

In particular, water pollution has been adversely affecting this endangered species. According to statistics, the pollution level at present is about 35 times higher than it has been in the past 30 years' in the Yangtze River (Hu et al., 2009). Water pollution not only directly influences the migration, growth, development, breeding and germplasm of *A. sinensis* (Hu et al., 2009), but also create a hazard to food organisms, destroys the food-web, and thereby affects indirectly the resources of *A. sinensis*. The serious eutrophication of the estuary causes sturgeons to die because of lack of oxygen.

There is a total of 2873 km of main waterways in the Yangtze River (Chen and Huang, 2008). There is a lot of construction such as piers in ports, while also many more boats are sailing on the river today. Shipping has become very heavy after the construction of the Three Gorges Dam, the number of shipments in 2009 were 12.5 times higher than in the 1980' (Chen, 2007). In addition, many boats have brought about serious noise pollution which frightens to broodstock of A. sinensis, as well as influence the behaviour of spawners; accidental kills and damages of adult sturgeons by ship propellers have increased greatly during the past 5 years (Wei et al., 2005). According to the statistics from the Departments of fishery administration of the Yichang City, the number of A. sinensis killed by propellers was 78 individuals between 1984 and 1985, however the average number now added up to 160 individuals in 2008.

Other reasons for the drastic population decline originate from the fact that a large number is removed by illegal fishing and 'accidental' captures made by fishermen (estimated 5000 individuals per year) as well as by the use of a great number of illegal fishing gears, leading to overfishing of mature and young fish (Cheng et al., 2005). The simulations by the 'whirlpool model' provided indications that the population is significantly reduced in size (136  $\pm$  56 ind.) and its population growth rate declined (5.3%) (Gao, 2007).

## Effective coordination between economic development, watershed management and *A. sinensis* resource conservation still lacking

In accordance with the regulations for The Natural Reserve of China human activities such as construction measures are prohibited in the core area and buffer zone (Wei, 2003; Zhang et al., 2007). However, human activities such as many shipping, quarrying, sand-digging, channel dredging, river adjustment projects, continuous pollution as well as fishing have become more and more frequent in the natural reserve of *A. sinensis* (Chen and Huang, 2008), indicating that some laws and their enforcement did not match the needs set by the regulations for the reserve. The operation of the Water Control Project still entails great contradiction between the comprehensive and ecological controls on the management of the river basin, while environmental impact assessments within the river basin are not done. Therefore, different functional departments cannot communicate and coordinate well with each others measures and activities. It is for these reasons that some urgently needed protective measures for *A. sinensis* are difficult to implement.

## A holistic approach for *A. sinensis* protection (serving all stakeholder needs) still missing

The A. sinensis resources should be recovered through an integrated implementation approach where many of the rescue measures include simultaneously the needs and duties of all stakeholders. Therefore, an integrated protection plan, accompanied by scientific verification of criteria and conditions that make these measures effective, should be formulated to give sound and well-planned guidance. The lack of a uniform planning process is obvious and leads to incomplete and unsatisfactory conservation management steps. As a result, poor coordination of sturgeon conservation measures occur; so far the research institutions have selected the scientific research projects by themselves, trying to do everything at once with little coordinated efforts to set priorities, leading to either much repetition or insufficient (inadequate) research. The resources are not shared in a concerted manner, thereby leading to inefficient resource utilization and this needs to be changed in the future through better coordination and cooperation.

## The effects of controlled reproduction and releasing of *A. sinensis* juveniles are unknown

Releasing of juveniles of A. sinensis has been a major measure for enhancement of this valuable resource. Although a large number of A. sinensis from controlled reproduction have been released into the Yangtze River in the past 20 years, the numbers of the natural spawning population of A. sinensis below the Gezhouba Dam has still dropped drastically in recent years (Yu et al., 1986; Wei et al., 2005; Yang et al., 2005). The possible reasons for the undesirable results are listed as: (i) relatively late releasing of large-size juvenile of A. sinensis which exhibit a higher survival rate (most of juvenile of A. sinensis < 10 cm have been released to Yangtze River; Wei, 2003), These released fish are apparently not yet fit enough to starting their long-distance migration, resulting in most of the juveniles to die so that the population enhancement objectives will not be achieved, (ii) the quality of the 'living environment' for A. sinensis gets worse day by day, most of A. sinensis face difficulties to adapt the changed environmental conditions, reducing the survival probability, and (iii) potentially, the quality the fry of A. sinensis resulting from controlled breeding, incubation, larval rearing, may lead partly to juvenile domestication effects, lacking the natural biological characteristics (morphology, feeding and behaviour) needed for good survival. Actually, physical and biochemical properties in the culture environment might differ from the natural habitat, leading to degrading adaptability of the A. sinensis juveniles when released to the natural environment. These above mentioned problems may lead to low survival rates in nature, requiring a thorough assessment of the subsequent releasing results for the development of improved procedures. Additional effects of the early alterations of fitness for this long-lived species may be the late sexual maturity, lower survival probability and a reduced return rate.

# Strengthening Chinese conservation needs through improving legislature, regulations and their enforcement as well as through better public awareness

Most of the relevant laws and regulations do not foresee provisions for any adequate penalties in case of violations and this leads to vague enforcement measures against any unit or individual who destructs natural resources and harms the ecology of critical environments essential for sturgeons. The after-the-event remedial measures are usually taken but no effective preventive actions are in place also when considering 'in-process' control. The lack of preferential policies results in insufficient attention and unsatisfactory law enforcement. Particularly, for the germplasm resource management, China has still not the relevant regulations and management systems in place to act adequately, and the research base on this subject needs urgently to be supported to gain the required improvements necessary for rapid improvements.

Because present publicity campaigns and educational measures to promote the enforcement of the laws, regulations and to enhance the basic knowledge on *A. sinensis* conservation issues are not satisfactory, the awareness for sturgeon conservation in the public at large is still relatively weak and needs to be substantially promoted. The phenomenon of paying attention to development and paying no attention to conservation still exists in some departments. Consuming secretly wild and endangered animals is still prevailing, including the consumption of *A. sinensis* and caviar is still occurring at significant scale. Somehow, some competent departments and law enforcement personnel seem not yet to have a full understanding of the importance of *A. sinensis* conservation, and a stronger sense of responsibility to act effectively is urgently needed.

## Deficiencies in research support to develop *A. sinensis* conservation methodologies

Conservation of *A. sinensis* is highly technical as it concerns spawning habitat restructuring and controlled reproduction for release, both aspects need effective management. In order to carry out an effective conservation programme, detailed research projects need to be carried out on the living habits, ecological environment and protective measures for *A. sinensis*, however, the research is at presently not adequate and insufficient to reach the objectives. The species conservation is also a social public welfare undertaking and needs substantial investment. The present insufficient funding will affect the effectiveness of recovery programmes and the needed implementation of protection measures as well as the enforcement capabilities (Wei et al., 1997).

### Chinese sturgeon germplasm resource conservation failed to attract the needed attention

Sturgeon aquaculture development and native sturgeon species conservation can become a critical issue for conservation, contaminating the native genetic resources through interactions with escaped cultured specimens. There are many net cages in various tributaries of the Yangtze River, raising various sturgeon species such as Amur, Siberian and Russian sturgeon. Various sturgeons have escaped and have been captured at different locations of the Yangtze River since. These escapees are a potential threat to the native genetic resources, but the invasion of exterior species may also lead to exclusion (replacement) of *A. sinensis* by a successful exotic species. At the same time risking 'pollution' of the native germplasm, thereby reducing the genetic power of *A. sinensis* (Zhu et al., 2002; Li et al., 2009).

### Countermeasures to improve mitigation strategies

### Focus on improvement-oriented, pre-cautionary management approaches

Whenever there is a contradiction between the wanted economic development and the needed environmental protection, the destruction of ecologically important environments and the species resource needs are always losing out because of poor management. Therefore, ways for an effective coordination mechanism needs to be established that permits the execution of a cohesive management procedure and operational mechanisms which can effectively coordinate and communicate between resources development and environmental protection needs, creating win-win situations. In case of the Chinese sturgeon the scientific pre-requisites need to be established to complete an Action Plan for A. sinensis resources protection, strengthening the environmental assessment, paying greater attention to forecast prevention success and controlling the progress during the implementation of measures. Specifically, the measures mainly include the following:

- 1 A sound science-based and feasible Action Plan for full protection and recovery of the *A. sinensis* must be developed in order to guide further implementation steps and ensure the survival of the currently surviving critically small population. The ultimate goal will be to increase its population size while comprehensively assessing the effectiveness of conservation measures.
- 2 To change operational mechanism on technological approaches, while establishing a coordinating committee for *A. sinensis* resources management, in order to effectively communicate and coordinate all efforts on sturgeon conservation between all relevant departments, while also guiding the government on priority setting, and advise companies scientists and the public at large on their rôle as partner in protection measures. Especially, various sources of pollution, shipping and hydro construction projects, which have effected the habitats and spawning grounds of *A. sinensis* should be supervised within the dedicated natural reserve of *A. sinensis*.
- **3** To build a comprehensive river basin management strategy. In particular, the environmental impact assessment must be strengthened, strictly implementing its assessment methodologies which should include the so-called 'Three Simultaneous Steps' in a systems approach, to be set up by the EIA of the Yangtze River Basin Planning Programme and incorporate project linkage mechanisms from the start, so as to prevent disorderly development, thereby avoiding any project congenitally EIA deficiencies by pre-cautionary principles and 'in-process' control. Thus promoting adjustments between needed industrial and economic structure and environmental protection.

- **4** *A. sinensis* research project management must be strengthened as part of an integrated sector resource concept with the aim to define clear research priorities, avoid duplication of efforts, and share the needed resources between institutions who can provided the concerted expertise needed.
- 5 An *A. sinensis* ecological benefit compensation and incentive mechanisms should be established, setting up special funds to support those units and individuals which actively participate in the *A. sinensis* conservation and its ecoenvironmental protection programme, including pollution abatement measures, with appropriate funding from relevant beneficiaries and social contributions.
- **6** The nature reserve construction and management activities for *A. sinensis* need to be urgently strengthened through various measures, including (i) limitations on shipping in certain core areas which are critical to successful spawning during the natural breeding season of *A. sinensis*, and (ii) strengthen the fishery control measures by expanding the capabilities and means for law enforcement. Fishing bans should be established and enforced in the Yangtze River while noticably increasing the penalties for illegal operators, strictly enforcing to reduce sturgeon by-catch and poaching.
- 7 Full support should be given to the role of Sturgeon Associations, assisting the aquatic wildlife authorities of the Government engaged in sturgeon protection, in order to better implement protection measures, while also fostering the development of industry self-discipline and self-protection rules.
- 8 There should be strong public awareness measures developed on *A. sinensis* conservation to further enhance the protection awareness throughout the public at large, thereby improving the consciousness and initiative of people to widely participate the protection measures for *A. sinensis*.

## Strengthening research on protection technologies to increase effectiveness of conservation measures

Species restoration requires a variety of protective measures, many of them are of technical nature. Therefore, research on such technical measures should focus with high priority on the following issues:

- 1 Fully protect the remaining spawning grounds and habitats of natural reserves, mainly through strengthen the protection of the existent natural parental fish appearing on the spawning ground with conservation of the genetic resources in mind (Zhu et al., 2008).
- 2 Strengthen the investigations on the conditions for natural spawning at remaining sites and identify habitat requirements needed by *A. sinensis*, while trying to construct new alternative habitat and spawning grounds to assist survival of the remaining population. We should perform studies on artificial spawning grounds and *ex-situ* conservation programmes, leading to confederate control between The Three Gorges Dam and Gezhouba Dam authorities. Further, cryo-preservation studies on gametes and perhaps on embryonic cells of *A. Sinensis* should promoted to allow gene mapping, and establish a gene library.
- **3** Monitoring population dynamics of *A. sinensis* must be continued and research intensified while water quality and ecological conditions be included into these monitoring efforts. Natural reproduction and the effect of the artifical

releasing programmes must be more comprehensively investigated to reveal the variables regulating a selfsustaining population under environmental change. An indicator system should be established that even utilizes GIS to monitor and document these alterations.

- **4** The conservation of native species resources must be more vigorously promoted, establishing also a management system for germplasm conservation of sturgeons, preventing hybridization with exotic sturgeon species in the Yangtze River Basin (Weiet al., 2011). Controlled release programmes need to support best the wild parental fish while broodstock technology needs to assure to maintain the genetic integrity of the species. The optimum time-size-release window for fry and fingerling need to be determined, avoiding domestication (Li et al., 2009).
- 5 Exchange and cooperation with countries experienced in conservation technology should be strengthened, making full use of international cooperation through appropriate means (e.g. organizations such as WSCS, World Sturgeon Conservation Society), to learn and master advanced research techniques and tools for a better conservation of *A. sinensis*.

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