Journal of Applied Ichthyology

J. Appl. Ichthyol. 25 (2009), 632–639

ISSN 0175–8659

Received: March 10, 2009
Accepted: August 25, 2009
doi: 10.1111/j.1439-0426.2009.01366.x

Sturgeon aquaculture in China: status of current difficulties as well as future strategies based on 2002–2006 / 2007 surveys in eleven provinces

By R. Li[1], Y. Zou[2,3] and Q. Wei[2,3,4]

[1]*Ocean University of China, Qingdao, China;* [2]*Key Laboratory of Freshwater Biodiversity Conservation and Utilization, Ministry of Agriculture, Yangtze River Fisheries Research Institute, Chinese Academy of Fisheries Science, Jingzhou, Hubei, China;* [3]*Fisheries College, Huangzhong Agricultural University, Wuhan, China;* [4]*Freshwater Fisheries Research Center, Chinese Academy of Fishery Science, Wuxi, Jiangsu, China*

Summary

A nationwide survey in July and August 2007 employed a representative sample of Chinese sturgeon farms from 2002–2006 / 2007, including data from previous surveys and official statistics dating back to 1998, showing that the development of China's sturgeon aquaculture has progressed steadily in the past few years. *Acipenser baerii* and Amur hybrids (*Acipenser schrenckii* × *Huso dauricus)* have become the dominant cultured species, accounting for 80% of total production. Production centers moved from the southeastern coast towards the midwestern inland provinces, where cold freshwater resources are available in abundance. The paper presents production trends as well as the price structure for commercial fish / meat and juveniles in the various provinces and also considers import and export data for products, fertilized eggs and fingerlings. Results show that: (i) production of juveniles in hatcheries has risen only slightly during the survey period; (ii) the number of larvae obtained from the wild gradually declines each year; (iii) the price for commercial fish / meat drastically declined between 1998 to 2002, but remained stable from 2002 to 2007; and (iv) total production from the 83 surveyed farms was almost stable from 2002 to 2007. Major problems influencing sustainable development of sturgeon aquaculture were identified, including: (i) insufficient domestic supply of larvae and the ban for commercial use of *A. sinensis*; (ii) disorganized hybridization; (iii) the potential threat to the genetics of natural stocks in the Yangtze River; (iv) diseases originating from environmental pollution and poor-quality fish feed; (v) limited domestic markets; (vi) low volume of sturgeon export due to lack of intensive processing; and (vii) lack of organizational structure in the industry.

Introduction

Since 2000, China has been the world's largest producer of sturgeon (Wei and Yang, 2003; Wei et al., 2004). The 2006 total production of cultured sturgeon in China was 17 424 tonnes (t), whereas the total world production (including wild-caught and fish produced through aquaculture) excluding China was estimated to be only 4835 t (FAO Fishstat Database, 2007). Thus, sturgeon aquaculture and its development in China is an important issue, not only within China but also in relationship to global developments.

In addition to supplying fish for the market, the culture of sturgeon is believed to help greatly mitigate pressures on natural sturgeon stocks. However, this is more a fisheries management and regulatory enforcement issue rather than a strictly aquaculture-dependent conservation issue. Prior to the 1990s, commercial sturgeon fishery in the Amur River focused primarily on caviar. From the beginning of the 21st century *A. schrenckii* and *H. dauricus* have also been caught for controlled breeding and release. In 2007, China received approval for caviar export quotas of 1337 kg for wild-caught *A. schrenckii* and 1595 kg for wild-caught *H. dauricus* from the Amur River. However, this quota could not be filled because the sturgeon population in the Amur River declined drastically and thus the resource must be considered as exhausted. One objective of sturgeon aquaculture development should be the strong encouragement to raise sturgeons from captive broodstock, without reliance on wild breeders, and thereby supporting a more sustainable development. The Chinese fisheries administration should enact stricter measures to halt sturgeon fishing in the Amur River, while also supporting rearing programmes for stock rehabilitation along the principles outlined in the Ramsar Declaration on Global Sturgeon Conservation (Rosenthal et al., 2006).

One Chinese sturgeon company has successfully exported caviar from farmed sturgeon since 2006, and it is anticipated that sturgeon meat products will also be exported to Europe in the near future. However, the sustainable development of sturgeon aquaculture is uncertain, as opportunistic involvement is growing while a realistic assessment of the marketing opportunities and options as well its limitations have still to be explored. This study was therefore initiated to assess the status of sturgeon culture in China and determine the main difficulties that arise while discussing the potential counter-measures in China's sturgeon aquaculture development and conservation programmes that may need to be taken to reach sustainability.

Materials and methods

This article is based chiefly on the results of an independent survey: the authors surveyed 83 large (more than 200 t production) and mid-size (50–200 t production) sturgeon farms by conducting telephone interviews, questionnaires by fax and on-site visits in the eleven most important sturgeon aquaculture provinces (Beijing, Fujian, Guangdong, Guizhou, Hebei, Heilongjiang, Hubei, Jiangsu, Shandong, Sichuan, and Zhejiang). Twelve live-fish wholesale markets in selected large cities (Beijing, Tianjin, Shanghai, Hangzhou, Guanzhou, Chongqing, Chengdu, Wuhan, Shijiazhuang, Jinan, Shenyang,

and Harbin) were also included in the survey. The number of wholesale markets varies among cities (as indicated in Fig. 1). The results of this survey are analyzed together with statistical data from the Ministry of Agriculture and Department of Aquatic Wild Animals and Plants Protection, Bureau of Fisheries of the Ministry of Agriculture (MoA).

Current status of sturgeon aquaculture in China

Production trend

With the development of aquaculture and the importation of fertilized eggs of exotic sturgeon species, sturgeon aquaculture in China had experienced tremendous growth between 1998 and 2007 (Fig. 2). The production of farmed sturgeon leapt from 100 t in 1998 to 2000 t in the year 2000. China sturgeon farming continues to achieve new records, as documented by official statistics: 10 871 t in 2003, 11 269 t in 2004, 15 407 t in 2005, 17 424 t in 2006 and 12 862 t in 2007 (FAO Fishstat Database, 2007; Department of Aquatic Wild Animals and Plants Protection, Bureau of Fisheries of MoA, 2008).

Farmed species

Based on our survey results, *A. baerii* has been the dominant farmed species since 2002 – and perhaps even earlier (Wei and Yang, 2003), at present accounting for 40% of total sturgeon production by weight. The species is well known for its rapid growth and endurance during transport and resistance to diseases. The Amur hybrid (*A. schrenckii* × *H. dauricus)* is known for tolerance of very high water temperatures during the hot summers in the southern part of China (e.g. in areas such as Hubei and Guangdong provinces). This hybrid accounts for nearly 40% of total production by weight. *A. schrenckii* accounts for 15% with the remaining 5% of total production coming from other species. Earlier imported species, such as *A. gueldenstaedtii* and *A. ruthenus,* have largely disappeared from culture programmes because the former was not acceptable to consumers and the latter grew too slowly for acceptance by the farmers. Culture of the domestic *A. schrenckii* has gradually been phased out because of some unsolved diseases problems during the fingerling stage (Gulyas and Li, 2006).

Main production areas

The main production areas identified in this study are listed in Table 1. Beijing, Guangdong, Sichuan (including Chongqing), Hubei, and Shandong are the five areas contributing the most to sturgeon production in China. Sturgeon production has evidently increased in some inland provinces such as Sichuan, Chongqing and Hubei, which have abundant cold freshwater resources; production in Guangdong, where pond water is too hot in summer for sturgeon, is in decline (Liu et al., 2004).

Type of farming

Concrete ponds and floating cages remain the two principal production systems for sturgeon farming in China. In Beijing and Shandong, the typical method to raise sturgeons is in concrete ponds filled with spring water (a means of farming widely accepted in most provinces). In Fujian, farmers raise sturgeons in concrete ponds filled with water pumped from wells; these ponds were originally designed for eels, whereby the farmers will be able to return to eel farming once the culturing of sturgeon is no longer profitable (Li et al., 2007). Floating cages are much more popular in the provinces of Hubei, Sichuan, and Guangdong. Figure 3 shows the surface areas dedicated to concrete ponds or floating cages in various provinces.

Supply and origin of fertilized eggs or larvae

The total supply of domestically farmed and wild broodstock and of imported fertilized eggs and larvae remained roughly stable between 1998 and 2006 (Fig. 4). Although the proportion from wild stock declined, it still represented almost half of the total in 2006. The seedlings from the artificial breeding stocks began in 2004 when the first batch of farmed *A. schrenckii* matured. At present, half of the larvae originate from the wild and from controlled reproduction, and larvae

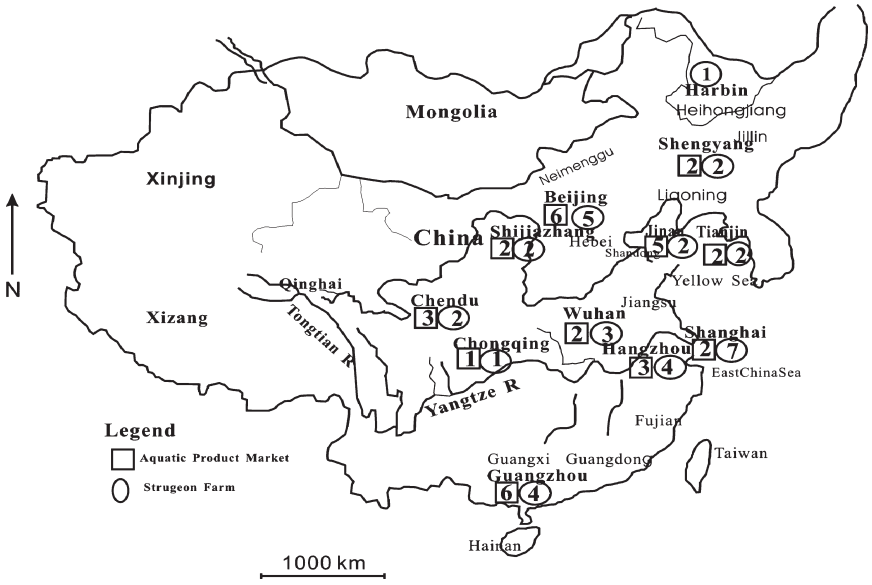

Fig. 1. Map showing the geographical distribution of the Sturgeon Farms and Fish Markets of the 12 key cities in China where the survey was carried out. ○ = Number of Fish Markets; □ = Number of Sturgeon Farms

○ = Number of fish markets; □ = Number of sturgeon farms

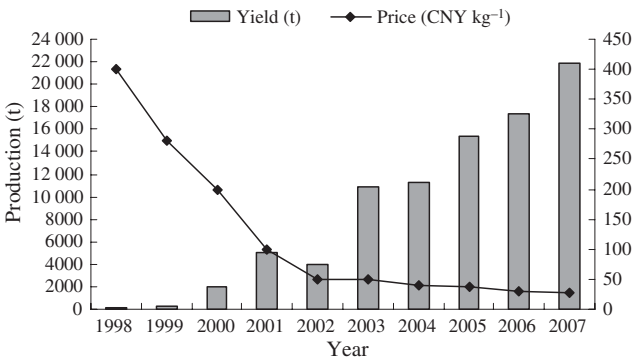

Fig. 2. Trends in production(wet weight) and market prices of cultured sturgeon in China from 1998 to 2007. (Source: Data from 2003 are from FAO Fishstat Database, 2007. Fisheries Bureau of Ministry of Agriculture (MoA), 2008,) 1 USD = about 8.23 CNY from 2002 to 2006, and about 7.36 CNY at the end of 2007

shows no differences in price between the northern and southern parts of China, thanks to the diffusion of sturgeon farming technology (Feng et al., 2004) and because the markets in these key cities can be supplied by farmers in the suburbs, with no need for large-scale air transport as in past years (Cao, 2007). The wholesale price remained roughly stable from 2001 to 2007, although production was quite different. The mean farm-gate prices from 2002 to 2006 of fingerlings and commercial sturgeon in the 83 surveyed farms were roughly stable (Table 2), matching the wholesale price trends. The wholesale price is usually based on the farm-gate price, transport cost and benefit to the wholesaler. Transportation costs (by water-tank truck) were about 6.0 CNY kg^{-1} in 2006, but prices increased to about 8.0 CNY kg^{-1} after 2006.

Table 1
The production (t) of main sturgeon culture areas in China from 2004 to 2006

Province	2004	2005	2006	Total
Beijing	2678 ± 100	2761 ± 98	2556 ± 25	7995 ± 80
Guangdong	2386 ± 35	3251 ± 55	1791 ± 25	7428 ± 75
Sichuan & Chongqing	1537 ± 25	3256 ± 30	3277 ± 25	8070 ± 80
Hubei	1508 ± 10	1274 ± 15	2470 ± 22	5252 ± 50
Shandong	701 ± 5	1045 ± 13	2061 ± 20	3807 ± 35
Fujian	582 ± 3	932 ± 8	746 ± 9	2260 ± 25
Hebei	353 ± 2	1068 ± 10	1592 ± 16	3013 ± 30
Jiangsu	330 ± 2	582 ± 4	563 ± 4	1475 ± 20
Others	1203 ± 20	1238 ± 20	1210 ± 22	3651 ± 25

Each value represents the mean ± SD

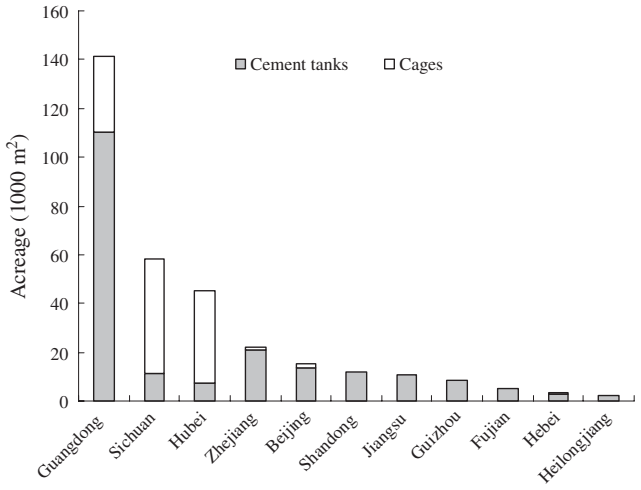

Fig. 3. Total areas of concrete ponds and floating cages devoted to sturgeon farming in the 83 surveyed sturgeon farms cumulated by province

import has declined considerably. Since 2000, fertilized eggs and larvae of *A. baerii* are mostly imported; almost no fertilized eggs from other sturgeon species were acquired from abroad in 2005. In the 83 farms surveyed, *A. baerii* and the Amur hybrids were dominant species (Fig. 5).

Prices

Figure 2 also shows the price trends of cultured sturgeon trade in China from 1998 to 2007. Our survey (July 2007)

Discussion and conclusions

Differing production results between the official data and the survey

There are no official statistics available on sturgeon farms in China. The authors estimate that the production of commercial fish and fingerlings in the 83 surveyed sturgeon farms accounts for almost 10% of the national total production, while the quantity of broodstocks accounts for almost 50% of the national total sturgeon stocks on farms.

According to the MoA, production markedly increased from 2002 to 2007 (Fig. 2); however, total production of the 83 surveyed farms remained almost stable during the same period (Fig. 6). Considering that the total larvae supplies (both domestic and imported) were almost stable, the annual total

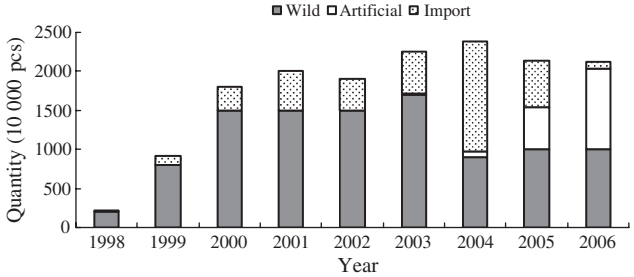

Fig. 4. Larvae from three different sources, wild, artificial reproduction and import, from 1998 to 2006 (Source: The report of Sun Dajiang: Sturgeon Culture in China for 15 years (unpublished data), 2006)

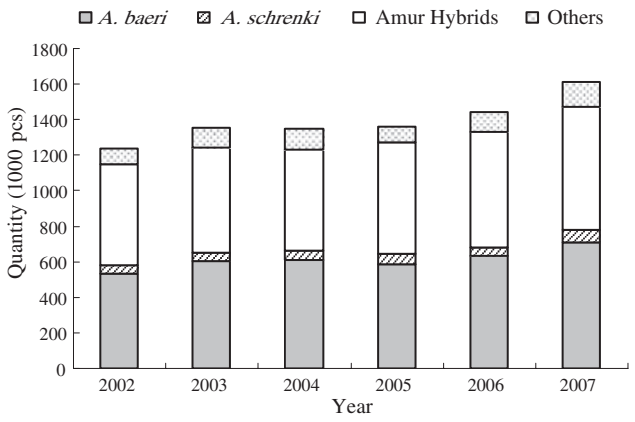

Fig. 5. Quantity of hatched larvae for different species in the 83 surveyed sturgeon farms from 2002 to 2007. Others: *A. gueldenstaedtii, H. dauricus, A. ruthenus, Polyodon spathula*

Problems facing sturgeon aquaculture in China

The main difficulties limiting the sustainable development of sturgeon aquaculture in China are:

Insufficient supply of domestic larvae and the ban on the commercial use of *A. sinensis* The annual need of domestic sturgeon seedlings is 100–200 million eggs. Before 2004, all seedlings were raised from wild-caught broodstocks in the Amur River (Lu et al., 2000; Hua and Wang, 2005). After 2004, a growing portion of larvae came from cultured broodstocks. However, the supply of domestic sturgeon seedlings never satisfied demand, thus there was the need to import fertilized eggs (as well as larvae in the early years). The quantity of imported fertilized sturgeon eggs increased from 1999, reaching a peak in 2004 (Fig. 7). Russia was the first and biggest source of imported fertilized eggs, but more expensive and with the need to be prepaid; thus, Chinese importers

Table 2
Farm-gate price of fingerling and marketable size sturgeon (1–3 kg) in the surveyed 83 farms from 2002 to 2006

	2002		2003		2004		2005		2006	
Province	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Beijing	7 ± 0.5	30 ± 5	6 ± 0.4	34 ± 3	4 ± 1	30 ± 4	5 ± 0.8	32 ± 3	6 ± 1	32 ± 5
Guangdong	6 ± 1	34 ± 2	5 ± 0.3	32 ± 2	3 ± 2	26 ± 5	4 ± 1.2	28 ± 4	5 ± 1.5	28 ± 4
Guizhou	7 ± 0.8	40 ± 5	6 ± 1	36 ± 4	5 ± 1	32 ± 3	6 ± 1	34 ± 6	6 ± 0.7	34 ± 2
Hebei	6 ± 0.5	36 ± 4	5 ± 1	32 ± 4	4 ± 1	28 ± 2	5 ± 1	32 ± 3	5 ± 1	32 ± 3
Hubei	7 ± 1	34 ± 4	5 ± 0.8	30 ± 5	4 ± 1	24 ± 5	4 ± 1.5	28 ± 4	4 ± 1	30 ± 5
Jiangsu	7 ± 1	36 ± 3	6 ± 1	32 ± 3	5 ± 1	28 ± 3	6 ± 1	30 ± 2	4 ± 3	32 ± 3
Shandong	7 ± 0.6	38 ± 2	5 ± 0.9	34 ± 4	4 ± 1	26 ± 4	5 ± 0.8	30 ± 3	6 ± 0.5	34 ± 2
Sichuan	7 ± 1	40 ± 4	6 ± 1	36 ± 3	4±	30 ± 2	5 ± 1	34 ± 2	5 ± 1	36 ± 3
Zhejiang	7 ± 0.8	34 ± 5	5 ± 1	30 ± 5	4 ± 1	26 ± 4	4 ± 1.5	28 ± 4	5 ± 0.5	30 ± 4
Heilongjiang	6 ± 1	34 ± 2	6 ± 0.5	32 ± 3	5 ± 1	28 ± 3	5 ± 1	30 ± 5	5 ± 0.8	32 ± 3
Fujian	6 ± 1	32 ± 4	6 ± 0.8	34 ± 2	5 ± 1	30 ± 5	5 ± 1.3	34 ± 3	6 ± 1	34 ± 2

P1 = farm-gate mean price of sturgeon fingerling (CNY per pc fingerling); P2 = farm-gate mean price of commercial sturgeon (CNY kg^{-1}); CNY = Chinese Yuan; 1 USD = about 8.23 CNY from 2002 to 2006, and about 7.36 CNY at the end of 2007.
Each value represents the mean ± SD.

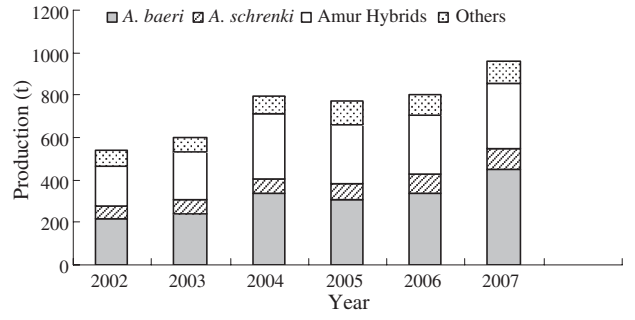

Fig. 6. Production by main sturgeon species from 2002 to 2007 in the surveyed 83 farms. Others: *A. gueldenstaedtii, H. dauricus, A. ruthenus, Polyodon spathula*.

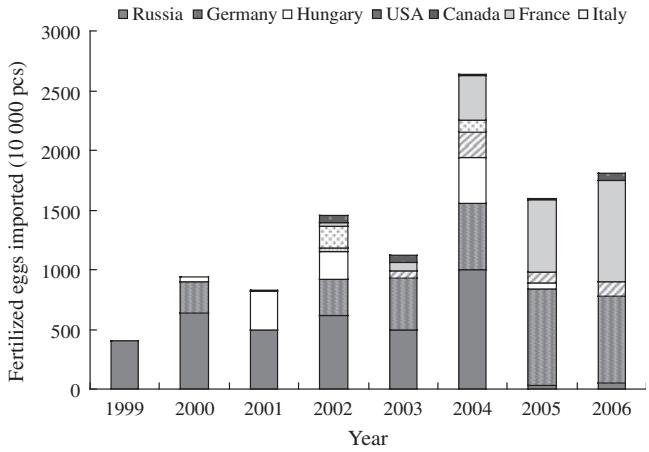

Fig. 7. Quantities of imported sturgeon fertilized eggs from 1999 to 2006 from different countries (Source: Fisheries Bureau of Ministry of Agriculture)

production in China should be almost stable at around 12 000 t in 2004 and 2006. As for the reasons why the figures of MoA were much higher, the authors believe that there could be an error in the official statistics in that the small fish are sold to other farms for on-growing where they appear in biomass counting with their whole weight. Thus, multiple sellings between farms add to a production level which is actually not there.

turned to Germany and France because of their stable supplies and the means of payment after the eggs had hatched.

According to our survey, the 83 large farms have at present in their rearing facilities 40 220 unsexed 5- to 7-year-old sturgeons. The species are *A. baerii*, *A. schrenckii*, and Amur

Table 3
Quantity(pcs) of captive brood stock maintained in the surveyed 83 sturgeon farms according to unsexed species

Province	Number of farms surveyed	*A. baerii*	Amur hybrids	*A. schrencki*	Others
Beijing	10	5500 ± 80	–	3000 ± 40	2500 ± 38
Guangdong	10	500 ± 20	1200 ± 25	–	200 ± 15
Guizhou	5	1000 ± 35	–	500 ± 25	300 ± 18
Hebei	3	1350 ± 32	–	500 ± 24	250 ± 15
Hubei	17	1000 ± 35	2000 ± 50	1500 ± 28	1000 ± 20
Jiangsu	4	–	1300 ± 29	1000 ± 20	300 ± 15
Shandong	10	1300 ± 24	500 ± 20	200 ± 12	150 ± 10
Sichuan	10	1000 ± 22	500 ± 20	300 ± 15	120 ± 10
Zhejiang	7	3000 ± 38	2000 ± 30	1500 ± 30	500 ± 35
Heilongjiang	2	–	1500 ± 35	1200 ± 25	200 ± 35
Fujian	5	1000 ± 20	–	250 ± 18	100 ± 30
Total	83	15 650 ± 100	9000 ± 80	9950 ± 85	5620 ± 55

Others: *A. gueldenstaedtii, H. dauricus, A. ruthenus, Polyodon spathula.*
Each value represents the mean ± SD.

hybrids (Table 3). Including farms not surveyed, the estimated total quantity of 5- to 7-year-old unsexed sturgeon should be about 80 000 animals.

Based on current propagation techniques and quantities of captive broodstocks, Chinese breeders will not be able to fulfill the growing need for sturgeon larvae in the immediate future. Meanwhile, the natural domestic broodstock resources in the Amur River are dissipating; concerns on the potential threat of genetic pollution by exotic species to native sturgeon populations in the Yangtze River may finally bring about some restrictions on the import of sturgeon seedlings. The insufficient supply of domestic larvae will become a hindrance, restricting the further development of sturgeon aquaculture in China. On the other hand, the endangered native species, *A. sinensis,* has not yet been permitted for commercial used. If the ban is lifted, it would greatly alleviate the issue of insufficient domestic seedling supplies. In fact, for years a large quantity of *A. sinensis* has been illegally farmed in South China, whereby the propagation technique has been improved and consolidated.

Disorganized hybridization As with many other aquaculture species, there is neither a native-strain farm nor a fine-strain farm for sturgeons in China. In the early years of sturgeon aquaculture, larvae were taken from wild-caught females, which died when the fishermen removed their ovaries (Lu et al., 2000). It was impossible to keep the fish alive for further breeding use. Nowadays, mature farmed sturgeons are used for artificial reproduction. However, the government has yet to approve a plan for generalized fine-strain identification and for native-strains broodstock conservation. This may lead to future germplasm degeneration. Meanwhile, in fact, with no breeding guidelines, farmers are cross-breeding the sturgeon with any sturgeon species available.

This uncontrolled hybridization worsened in the spring of 2006, when *A. baerii* eggs were in very short supply. The farmers crossbred *A. baerii, A. gueldenstaedtii, A. ruthenus, A. schrenckii,* and Amur hybrids to produce larvae. This confusing, complex hybridization continued in 2007, when some farmers obtained hot-water-tolerating hybrids and fast-growing hybrids, as well as sickly hybrids and slow-growing hybrids. The farmers did not care which kind of hybrid they were farming because they thought that all hybrids had cross-breeding superiority.

Uncontrolled hybridization has already caused – and will continue to cause – serious problems, such as:

1 Not all hybrids have cross-breeding superiority. Some types of hybrids are sickly and have a low survival rate, and some grow very slowly. Considering that the total quantity of hybrids was almost half of the total sturgeon production in 2007, the overall loss caused by disorganized hybridization is probably considerable.
2 With the growth of the sturgeon aquaculture enterprise in China, sturgeon will need to be exported in the future. However, these disorganized, unclear strains of sturgeons will face difficulties from the CITES.

Exotic sturgeon species Exotic species pose a potential threat of genetic pollution to the native sturgeon in the Yangtze River. The threat of genetic pollution may be one of the most serious impacts on sturgeon aquaculture. Only three sturgeon species are native to China, all in the Yangtze River: *A. sinensis*, *A. dabryanus*, and *Psephurus gladius*. All are endangered species with extremely valuable gene pools. Since the end of the 1990s, farmers began cage-farming many exotic sturgeon species in the Yangtze River (Wei et al., 1997; Shi et al., 2002). All of these legally farmed sturgeons (including the native *A. schrenckii*, *Huso dauricus*, and the Amur hybrids) are, in fact, exotic species to the Yangtze River. At present, cage farming of sturgeon occurs in almost all branches of the Yangtze River, with many reports of sturgeon escapes. In 2006 the *A. sinensis* Emergency Center (Changshu City, Jiangsu Province) collected a total of 221 young sturgeon from their fishery resources monitoring nets in the Yangtze River. Among these, 153 were hybrids, accounting for 69.9%, while only 68 were *A. sinensis* (Chen, 2007). Although genetic pollution of the native Yangtze River sturgeon by these escaped exotic sturgeons has not yet been studied, the potential impacts are anticipated to be very serious.

Disease Diseases originating from environmental pollution and poor-quality fishfeed pose another problem, and there have been some reports of fatal epidemic diseases in mature Chinese sturgeon. However, the most common diseases are those syndromes that originate from environmental pollution and poor-quality fishfeed (Bemis and Kynard, 1997).

With the development of industrialization, the waters used in aquaculture, especially in the suburbs of cities, have been polluted by sewage, aggregation of heavy metals, and residuals from fertilizer and pesticides. Most of the waters in highly populated areas are rich in nutrients. Of the 1200 rivers with water quality inspection, 850 are reported to be polluted. In the rivers heavily populated with fishfarm cages, self-pollution by aquaculture should not be overlooked. Many sturgeon farms are located in the suburbs of cities for easy transport of live fish. Therefore, pathologies originating from environmental pollution readily occur and cause sturgeon mortality.

Poor-quality fishfeed is the key factor leading to fatty liver disease in sturgeon. This may not be a serious problem when fish are consumed in small amounts. However, for large fish used in propagation or production of caviar, we have found fatty gonad syndrome in females, which renders them unable to ovulate because of these fatty ovaries, whereby the eggs cannot leave the follicular envelope and thus remain inside the gonad tissue (Gulyas and Li, 2006).

Limited domestic market In contrast to Europeans, Chinese prefer to eat fish that they can see and choose live from a tank, rather than as fish fillets. The sturgeon is not a fish traditionally consumed by most Chinese and it is also difficult to process at home. Most Chinese consumers eat sturgeon by choosing a fish swimming in a tank, for preparation in a restaurant. Thus, fewer sturgeon are sold compared to carp, which are bought by housewives every day in open markets. Live fish consumption not only limits the market for sturgeon but also wastes sturgeon resources, as the popular size of live fish is only 1.0–1.5 kg, which represents the juvenile fish stage of a sturgeon (Xin, 2005).

Another key reason for the limited market is that the sturgeon processing industry is undeveloped. Although processors know that large sturgeon have a higher percentage of edible parts (65% in fish of 6–7 kg) than any other freshwater fish (e.g. carp), they cannot find a proper supply because farmers do not raise sturgeons to this size as they are afraid that no one will buy them.

Undeveloped export In recent years, the Chinese have tried to export sturgeon to Hong Kong, Japan, South Korea, Singapore, United States, and Taiwan, but the export volume has never reached a notable level. Maximum export of over 100 t was in 2001; in other years this has varied from 30 to 70 t.

One reason for this low level of export may have to do with how the fish are processed. Only Russian consumers accept individual quick-frozen sturgeon; other European consumers prefer to import smoked products, which are not familiar to the Chinese. Another reason may be the lack of large fish for fillets. The CITES regulations might also be a restrictive factor, as very few farmers ask for CITES certificates when buying eggs/larvae, hence it is impossible for them to receive CITES permits for export.

Because the natural resources were becoming exhausted, the Chinese government gradually forbid the capture of wild sturgeon in the Amur River, and the production and export of caviar declined (Fig. 8). A symbolic event in 2006 was a Chinese-American joint venture company that exported its first batch of caviar from farmed sturgeon. However, Chinese caviar production will require much more time to reach the 1980s level (26 000 kg from the Amur River in 1987), because

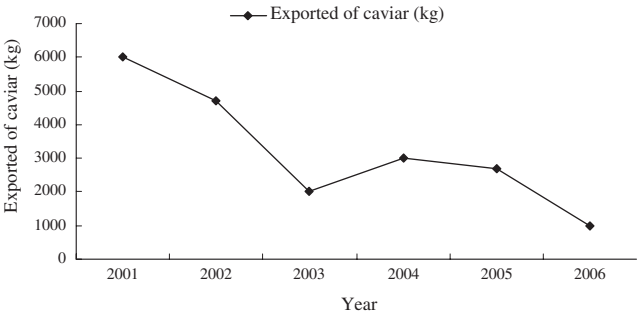

Fig. 8. Quantity of China's export of caviar (from both wild caught and aquaculture) from 1999 to 2006 (Source: Fisheries Bureau of Ministry of Agriculture

fewer than five companies farm large sturgeon for caviar production purposes.

Inappropriate industrial organization mode Currently the most popular industrial mode of aquaculture in China is the 'company + farmers' mode, which can expand production very quickly. The company and farmers sign a contract stating that the company supplies fingerlings, feed, and technology to the farmers and buys all the products at a fixed price. In this way, the company can save capital and the farmers do not have to worry about marketing. However, this mode is no longer appropriate for the following reasons:

1 Although medicinal residues are of serious concern to the public at present, it is really uneconomical and not feasible for the companies to check each batch of fish from every small farmer. If the farmers use contraband chemicals, the companies would be the sole bearers of the loss and punishment, because it is difficult to trace the farmers. The Chinese government has announced plans to implement a food tracing system in the near future because food security problems occur frequently. Thus, the 'company + farmers' mode will no longer be in existence in the Chinese food industry.
2 The codes of CITES require that all sturgeon products for international trade be verified. Under the 'company + farmers' mode, the legal resources and course of aquaculture are difficult to record and trace and thus this mode is not fit for future use.

Strategies

To ensure the sustainable development of sturgeon aquaculture in China, the following key policies should be implemented:

Allow commercial use of *A. sinensis* The MoA should take action to change the law and allow commercial farming of *A. sinensis* as soon as possible. Based on the current technology and artificial breeding capability of *A. sinensis*, larvae demand can be satisfied. This will help greatly to solve larvae shortage. The government could ask for donations from *A. sinensis* larvae sales to support the restocking and rehabilitation research programmes for this endangered species.

Prohibit farming of exotic sturgeon species in the Yangtze River The Bureau of Fisheries of the MoA, which is responsible for the protection of aquatic species and production of

fisheries, should invest in studying the threat of genetic pollution by exotic species in the native Yangtze River sturgeon as well as prohibit the cage farming of any allochthonous sturgeons. Effective measures to prevent the escape of exotic species should be required before water can be released into the Yangtze River from land-based sturgeon farms.

Regulate the cross-breeding and supply of sturgeon larvae The Bureau of Fisheries of the MoA should regulate cross-breeding and sales of larvae by the registration and supervision of hatcheries (Gray, 2002; Bound and Voulvoulis, 2004). Research should be conducted to assess hybrids and determine the best cross-breeding for farming. Cross-breeding trials with the endangered native sturgeon of the Yangtze River should be strictly prohibited. MoA should invest in plans for generalized fine-strain identification to help farmers receive fine-strain seedlings. MoA should also prepare plans for native-strain broodstocks, to protect and preserve the natural resources and gene pools of native species.

Implement a 'dual-purpose labeling system' The MoA should cooperate with the Ministry of Commerce (MoC) to set up a 'dual-purpose labeling system' for sturgeons. For sturgeon bound for domestic sale, labels could be in a less expensive form, but useful for tracing for public food security purposes. This would also help to build up a healthy aquaculture system by establishing a database with records of fish development from larvae to commercial size. Fishfeed and medicinal treatment would also be included in the database.

For fish destined for the international market, a RFID (Radio Frequency Identification) labeling system should be used to meet the requirements of CITES (Miranda and Zemelman, 2002). One of the feasible labeling techniques available for sturgeon to date, RFID is very expensive, but the sturgeon meat and caviar export will be able to support this cost. Within China, RFID-labeled sturgeon products will be acknowledged by the CITES authority: the Import and Export Food Safety Bureau of AQSIQ, and Customs.

Implement a 'minimum sales size regulation' MoA should cooperate with MoC to set up a 'minimum sales size regulation' for sturgeon, following the key points:

1 A 'resources fee' will be levied on the sale of pure species weighing < 1.5 or 2.0 kg, to encourage farmers and companies to raise them to larger sizes for processing and export.
2 Hybrids weighing < 1.5 or 2.0 kg can be sold without levy. This will fulfill the traditional request for live fish consumption in restaurants, as hybrids grow faster but are difficult to export.

Induce and encourage the setting of a new industrial organization mode The Regulation of Farmers Cooperative Unions of the PRC, which became effective on 1 July 2007, encourages peasants to organize a new economic 'specialized cooperative' organization, which is somewhat like a company. Members of the specialized cooperatives will share the benefits and the losses. This will make them more responsible for the cooperative and cause them to monitor each other, thereby limiting irregular aquaculture modes. It would be the cooperatives, not individual farmers, who sign the contracts with the companies to supply traceable food, and the cooperatives would be responsible for any problems concerning the quality of materials (Xiao, 2004; Sun, 2007).

At the same time, the role of the Sturgeon Guild (an organization that guides and manages sturgeon farmers' specialized cooperatives and sturgeon aquaculture enterprises to sell sturgeons to domestic and foreign markets) should be emphasized. The government should transfer some of the administrative functions to this guild to help the guild control the industry. The key points of this mode are:

1 The farmers do not sell their fish directly to the companies. They will deal with the specialized cooperatives, or join the specialized cooperatives. This will help the farmers to gain as much profit as possible and keep the enterprises from purchasing fish with potential problems from any irresponsible individual farmers.
2 For the domestic market, the specialized cooperatives can sell sturgeons farmed by their members. The enterprises (companies) can also sell sturgeons that they farmed themselves or that they bought from the specialized cooperatives.
3 Only sturgeons (and sturgeon products such as caviar) farmed by the registered and product-traceable enterprises are allowed to be exported in order to meet the product-traceable requirements of the CITES.

Acknowledgements

We greatly appreciate the review and many subsequent editorial suggestions of Harald Rosenthal (World Sturgeon Conservation Society, Germany) and Prof. Paolocomment (World Sturgeon expert, Italy). We also thank the staff of Sturgeon Ltd. of Qiandao Lake for their assistance.

References

Bemis, W. E.; Kynard, B., 1997: Sturgeon rivers: an introduction to Acipenseriform biogeography and life history. Environ. Biol. Fish **48,** 167–183.

Bound, J. P.; Voulvoulis, N., 2004: Pharmaceuticals in the aquaticenvironment - a comparison of risk assessment strategies. Chemosphere **56,** 1143–1155.

Cao, C., 2007: The decline reasons and the measures for sustainable development of fisheries resources. Hebei Fish. **2,** 4–6 (in Chinese).

Chen, X. 2007: Biological characteristics and current situation of resource of species of Acipenseriformes. Ocean Publishing House, Beijing. (in Chinese).

Department of Aquatic Wild Animals and Plants Protection, Bureau of Fisheries of MoA, 2008: China Fisheries Yearbook. Beijing, China.

FAO Fishstat Database, 2007: FAO, Rome, Italy.

Feng, G..; Zhuang, P.; Zhang, L.; Zhang, T.; Huang, X.; Zhao, F., 2004: Status quo and prospects of sturgeon aquaculture in China. Mar. Fish. **26,** 317–319 (in Chinese).

Gray, J. S., 2002: Biomagnification in marine systems: the perspective of an ecologist. Mar. Pollut. Bull. **45,** 46–52.

Gulyas, T.; Li, R., 2006: The several common question of sturgeon aquaculture. J. China Fish. **11,** 47–49 (in Chinese).

Hua, Y.; Wang, D., 2005: A review of sturgeon virosis. J. Fore. Res. **16,** 79–82 (in Chinese).

Li, R.; Zou, Y.; Wang, R., 2007: Current status and countermeasures on sturgeon aquaculture industry in China. Chinese Fish Ecol **29,** 16–19 (in Chinese).

Liu, S.; Sun, Y.; Zhang, C., 2004: Production of gynogenetic progeny from allotetraploid hybrids of red crucian carp x common carp. Aquaculture **236,** 193–200.

Lu, M.; Huan, G.; Zhang, H.; Xiao, X.; Wu, R., 2000: Biology of some sturgeons and paddlefish and prospects for aquaculture. J. Dalian Fish Univ. **15,** 280–283 (in Chinese).

Miranda, A. D.; Zemelman, R., 2002: Antimicrobial multiresistance in bacteria isolated from freshwater Chilean salmon farms. Sci. Total Environ. **293,** 207–218.

Rosenthal, H.; Pourkazemi, M.; Bruch, R. 2006: 5th Internat. Symp. on Sturgeons: a conference with major emphasis on conservation, environmental mitigation and sustainable use of the sturgeon resources. J. Appl. Ichthyol. **22,** (Suppl. 1), 1–11.

Shi, Z.; Wang, Y.; Li, W.; Zhu, C.; Chen, Z., 2002: The resource, protection and utilization of sturgeons in China. J. Shanghai Fish Univ. **11,** 317–319 (in Chinese).

Sun, C. 2007: The operational mode of company and farmers cooperative unions and farmers. China Academic Journal Electronic Publishing House. 2pp. (in Chinese).

Wei, Q.; Yang, D., 2003: Conservation and management of sturgeons and paddlefishes in China and their industrialization. Fresh. Fish. **33,** 3–7 (in Chinese).

Wei, Q.; Ke, F.; Zhang, J.; Zhuang, P.; Luo, J.; Zhou, R.; Yang, W., 1997: Biology, fisheries, and conservation of sturgeons and paddlefish in China. Environ. Biol. Fish **56,** 241–255.

Wei, Q.; He, J.; Yang, D.; Zheng, W.; Li, L., 2004: Status of sturgeon aquaculture and sturgeon trade in China: a review based on two recent nationwide surveys. J. Appl. Ichthyol. **20,** 321–330.

Xiao, J. 2004: Discussion of the industry development mode of company and farmers' cooperative unions. Feed Review. 21pp. (in Chinese).

Xin, Y. 2005: Present situation and developmental counter measures of China sturgeon industrialization. J. Beijing Fish 30pp. (in Chinese).

Author's address: Qiwei Wei, Yangtze River Fisheries Research Institute, Chinese Academy of Fisheries Science, No.41 Jianghan Road, Shashi District, Jingzhou City, Hubei 434000 China.
E-mail: weiqw@yfi.ac.cn