Changes in growth and osmoregulation during acclimation to saltwater in juvenile Amur sturgeon Acipenser schrenckii*

ZHAO Feng (赵峰), ZHUANG Ping (庄平)**, ZHANG Longzhen (章龙珍), HOU Junli (侯俊利)

Key and Open Laboratory of Marine and Estuarine Fisheries Resource and Ecology, Ministry of Agriculture, East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200090, China

Received Feb. 24, 2009; revision accepted Oct. 10, 2009

© Chinese Society for Oceanology and Limnology, Science Press, and Springer-Verlag Berlin Heidelberg 2010

Abstract We evaluated the ability of juvenile Amur sturgeon (Acipenser schrenckii) to osmoregulate and grow in saltwater. Hatchery-reared juveniles (mean weight 106.8 g, 5-month old) were transferred from freshwater to 10, 20, and 25 salinity saltwater over a period of 20 d. We measured the growth, serum osmolality, ion concentrations, and Na+/K+-ATPase activity. In addition, we prepared samples of gill tissue to quantify morphological changes in gill ultrastructure. Rearing in up to 25 saltwater for 30 d had no significant effect on growth. Similarly, serum osmolality and ion concentrations were similar to levels reported in other teleosts following acclimation to saltwater. Serum osmolality and Na+, Cl- concentrations increased significantly with the initial increase in salinity. Afterwards, levels tended to stabilize and then decrease. Serum K+ levels did not change during acclimation to saltwater. Gill Na+/K+-ATPase activity increased initially as salinity was increased. However, the activity later decreased and, finally stabilized at 3.7±0.1 μmol Pi/mg prot·h in 25 saltwater (1.6 times higher than the level in those in freshwater). In fish that were held only in freshwater, the chloride cells were located in the interlamellar regions of the filament and at the base of the lamella. Following acclimation to 25 saltwater for 30 d, the number and size of chloride cells increased significantly. Our results suggest that juvenile Amur sturgeon is able to tolerate, and grow in, relatively high concentrations of saltwater.

Keyword: sturgeon; serum osmolality; ion concentration; Na+/K+-ATPase activity; chloride cells

1 INTRODUCTION

Amur sturgeon (Acipenser schrenckii) is distributed throughout the Amur River (Heilongjiang in Chinese) basin and in the Ussuri and Sungari (Songhuajiang, in Chinese) rivers. This species accounts for 50% of the total sturgeon production in China (Zhuang et al., 2002). Recently, it was revealed that Amur sturgeon often undertake long distance anadromous migrations (Omoto et al., 2004). This discovery suggests that Amur sturgeon may be cultured in brackish water, or even full strength seawater. However, despite their importance as a commodity, little is known about the salinity tolerance and osmoregulatory capacity of this species.

Many species of sturgeon are able to adapt to high levels of salinity. The mechanisms controlling this adaptation are similar to those described in other teleosts. These include changes in branchial ionoregulatory capacity as a result of morphological and physiological changes (Hoar, 1988; Evans, 1993). When fish are transferred from fresh water to salinity water, they lose water and dehydrate. Differences in ion concentrations cause sodium (Na+) and chloride (Cl-) ions to enter the body through diffusion or drinking. Elevated plasma Na+ and Cl- levels stimulate ion extrusion mechanisms and induce an increase in Na+/K+-ATPase activity. Increased Na+/K+-ATPase activity is accompanied by lowered serum Na+ and Cl- levels and adaptation to saline conditions.

* Supported by the National High Technology Research and Development Program of China (863 Program) (Nos. 2004AA603110 and 2008AA10Z227) and the National Natural Science Foundation of China (No. 30490234).

** Corresponding author: pzhuang@online.sh.cn
A number of studies have focused on the salinity tolerance and osmoregulatory capacity of sturgeon (Natochin et al., 1985; McEnroe et al., 1985; Cataldi et al., 1995; Altinok et al., 1998; LeBreton et al., 1998; Krayushkina, 1998; Mckenzie et al., 1999, 2001a, b; Jarvis et al., 2003), but none have studied the Amur sturgeon. To address this, we evaluated the effect of rearing in saltwater on growth, serum osmolality and ion concentrations, gill structure, and Na+/K+-ATPase activity in juvenile Amur sturgeon. Our data is likely to be useful for determining the suitability of this species for culture in salt water environments.

2 MATERIALS AND METHODS

2.1 Fish and maintenance

We cultured juvenile Amur sturgeon from eggs and sperm that were collected from wild adults caught in the mid reaches of the Amur River (near the town of Fuyuan) during April, 2004. We reared the juvenile sturgeon indoors in circular fiberglass tanks (600 L) supplied with dechlorinated tap water (28±0.2°C) at the Key and Open Laboratory of Marine and Estuarine Fisheries Resource and Ecology, Ministry of Agriculture of China, Shanghai. The fish were fed with a dry commercial pellet to satiation every other day. The oxygen, pH, and ammonia nitrogen levels were maintained at 6.5±0.5 mg/L, 7.9±0.2, and 0.02±0.01 mg/L, respectively. The tanks were covered with black mesh to prevent fish from jumping out and to shield fish from visual disturbance.

2.2 Experimental design

We used 120 fish (age: 5 months, total length: 31.28±2.18 cm, body mass: 106.8±28.31 g) in the experiments. Twenty individuals were transferred into each of six circular fiberglass tanks (600 L) that were supplied with re-circulated water. The six tanks were divided into two groups: 1) a control group that was reared in freshwater, and 2) a treatment group that were reared in 10 saltwater for 10 d, transferred into 20 saltwater and reared for another 10 d, then transferred into 25 saltwater and reared for 30 d. The control group was transferred from freshwater to freshwater following the schedule outlined above.

2.3 Sampling schedule

At the end of each 10-d period (freshwater, 10, 20, and 25 saltwater), we collected five fish from each of the three tanks. In addition, we sampled the fish after 30 d rearing in 25 saltwater. The fish were euthanized by an overdose of anesthetic (MS-222). We then collected approximately 1.5–2.0 ml blood from the caudal vessels using a syringe. In addition, we collected samples of the gill filament tissue taken from the second gill arch on the right side of the fish. The blood serum was separated by centrifugation at 3 220 × g for 10 min.

2.4 Analytical methods

We evaluated the effect of salinity transfer on fish growth by measuring the final body weight, total length, and the specific growth rate (SGR). The SGR was approximated in accordance with Rodríguez et al. (2002):

\[
SGR (% \text{ day}^{-1}) = 100 \times \frac{\ln W_t - \ln W_0}{t}
\]

where \(W_t\) and \(W_0\) represent the final and initial mean body weights and \(t\) is the growth period in days.

We measured serum osmolality using a Wescor 5520 vapor pressure osmometer (Wescor, Logan, UT, USA). The serum ion composition (Na+, K+, Cl-) was determined using a Xunda XD-683 electrolyte analyzer (Xunda, Shanghai, China). We measured gill Na+/K+-ATPase activity following the methods described by Hwang et al. (1989). Each sample was assayed in triplicate.

The gill tissue was also examined by light microscopy. We collected three fish (one per tank) that were reared in freshwater or in 25 saltwater for 30 d. These fish were euthanized by an excess dose of MS-222 and the gill filaments were excised as described above. The gill tissue was fixed by immersion in Bouin’s fluid for 24 h, embedded in paraffin, and serially sectioned (7 μm). The sections were dried for 24 h and stained with haematoxylin and cosin. We used computer image analysis (Image-Pro Plus 5.1, Media Cybernetics, Inc.) to count the number of chloride cell and calculate the maximum diameter of the cells in each histological section.

2.5 Statistical analysis

Data are presented as means±SD. We tested for differences among the acclimation periods using one-way analysis of variance (ANOVA) followed by Fisher’s least significant difference (LSD) test for multiple pair-wise comparisons. \(P<0.05\) was considered significant.

3 RESULTS

3.1 Growth

There was no significant difference in body weight