长江水生生物多样性保护系列丛书
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海洋馆中的中华鲟保护研究

CONSERVATION RESEARCH OF CHINESE STURGEON IN AQUARIUM



危起伟　主编

科学出版社

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Edited by Wei Qiwei

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内 容 简 介

中华鲟在水族馆内的养殖、保护与展示具有很大的应用前景。本书总结了中华鲟养殖与保护工作中与海洋馆相结合的养殖、展示、保护等方面的研究成果，具有较高的学术价值；主要收录了与水族馆养殖中华鲟相关的论文，包括繁殖学、行为学、疾病学、营养学、生理生化等方面的研究成果。

本书主要供中华鲟保护相关的人士、科研人员、学生、水族馆技术人员等参考使用。

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《海洋馆中的中华鲟保护研究》编委会

Editorial Board of "Conservation Research of Chinese Sturgeon in Aquarium"

序

（PREFACE）

中华鲟为国家一级重点保护野生动物，是长江的旗舰保护物种，受到国际社会和我国政府的高度关注。中华鲟生长在我国东部沿海，在长江、珠江产卵繁殖，其自然种群兴衰与水域环境变化息息相关。随着我国经济的快速发展，其自然种群日趋衰退，并有灭绝风险。易地保护是中华鲟保护的重要手段，在目前长江经济带建设、“共抓大保护，不搞大开发”的背景下，积极探索中华鲟易地保护的技术与方法显得尤为重要。

中国水产科学研究院长江水产研究所长期致力于中华鲟的保护研究工作，取得了丰硕的成果。2007 年“中华鲟物种保护技术研究”获得了国家科技进步二等奖。在易地保护和人工种群建设方面，先后突破了中华鲟野生个体的人工繁殖、苗种培育、子一代亲本培育等技术瓶颈，实现了中华鲟亲本的规模化驯养与保种，2012 年突破了中华鲟的全人工繁殖，从而取得了中华鲟在全人工环境中的保种成功，为实施大规模中华鲟增殖养护提供了基础。

我在中国水产科学研究院及长江水产研究所任职期间，有幸见证并直接参与了一些中华鲟的保护研究工作。2005 年 1 月，长江水产研究所与北京海洋馆达成协议，启动科企联合方式开展中华鲟驯养展示及保护相关的科学研究。利用长江水产研究所的技术优势和北京海洋馆的设施条件与展示平台，最大程度上实现了国宝中华鲟的保育宣传，提高了公众认知和环保意识。经过 12 年持续合作与研究，先后突破了野生中华鲟的开口摄食、产后亲本的康复和再发育、子一代中华鲟的批量性成熟、子一代亲本的产后再发育等技术难题；建立了中华鲟驯养技术规范；初步建立了中华鲟健康养殖生理生化指标监测体系等。中华鲟在北京海洋馆中的养殖与保护效果证明，通过科企合作开展中华鲟的养殖与科研，是实施中华鲟保护的有效途径。

本书是海洋馆养殖条件下中华鲟易地保护相关研究的系统总结，不仅具有较高的科学意义，而且可为中华鲟在其他水族馆中的驯养、展示与保护工作提供参考借鉴。

农业部渔业渔政管理局　局长　张显良

2016 年 9 月 15 日

前　言

（FOREWORD）

中华鲟作为国家一级保护动物和大型洄游性鱼类，一直备受科研工作者和社会公众关注。然而，在长江及近海水域生态环境持续衰退的背景下，其自然种群数量急剧下降。在自然种群的保护尚未取得显著效果的同时，易地保护成为物种保护的有效手段。2005 年 4 月 22 日，首批 26 尾中华鲟从湖北荆州踏上旅程到达北京海洋馆。十多年来，北京海洋馆、香港海洋公园与长江水产研究所进行了多次中华鲟的交换、养殖和中华鲟在海洋馆的保护性公众展示。海洋馆在中华鲟的养殖与展示方面投入了大量的物力与精力，取得了良好的社会宣传效果。同时，海洋馆在保护性养殖方面也取得了丰硕的成果，开启了中华鲟易地保护的新篇章。

中华鲟在水族馆养殖的成功，离不开一系列研究工作的支撑。本文集收录了 2006 年以来公开发表或在学术会议上宣读的 28 篇论文。文集中，既有海洋馆养殖系统及设施的设计，也有鱼体在海洋馆环境下的生物学、生态学、行为学等方面的观察与研究；既有中华鲟成体的养殖与繁殖技术的研究，也有对幼鱼培育方法的探索。因此，本文集是目前为止中华鲟海洋馆养殖相关成果的最新、最全的总结，希望文集的出版能为中华鲟在各地海洋馆中的养殖提供技术指导，同时也为中华鲟的易地保护提供参考和借鉴。

由于我们水平有限，书中难免存在一些不妥之处，敬请广大读者批评指正。

编　者

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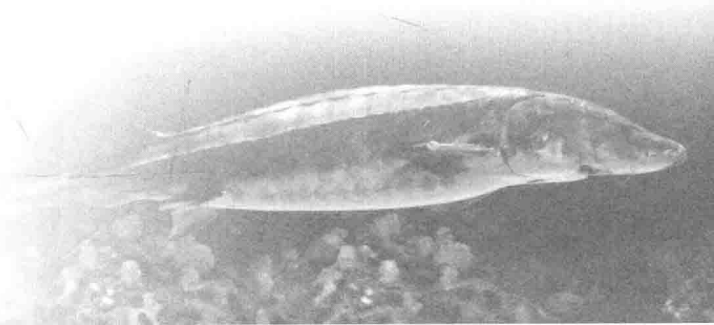

中华鲟水族馆迁地驯养的适应性研究

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摘 要 于2005年4月到2007年8月,观测了5尾野生中华鲟(W)和323尾子一代中华鲟(F_1)在水族馆中的存活、生长发育以及行为。W全部存活,F_1存活超过86%。W的体质量月增长率介于0.55%~10%,1尾雌性W在驯养28个月后性腺再次发育至Ⅳ期初期。子一代中华鲟体质量和全长月最低增长率为1.39%(F_1-1997)和4.28%(F_1-2001),最高为35.70%和29.35%(F_1-2005)。W主动摄食前后游泳行为变化明显,对食物具选择性,喜摄食鲜活饵料,对5种鲜饵有较好选择性,对其余8种选择性差。中华鲟可以适应水族馆环境,获得较好的生长发育效果表明,水族馆可作为中华鲟易地保护的栖息地之一。

关键词 中华鲟 行为 食物选择 生长 性腺发育 适应 水族馆

Acclimating and Maintaining Chinese Sturgeons (*Acipenser sinensis*) in the Captive Environment of a Large Aquarium

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Abstract In this study, the 5 wild Chinese sturgeons which were captured from the Yichang section of the Yangtze River, and the 323 offsprings of the Chinese sturgeons, were studied as to their survival, development and behaviour under aquarium conditions between 2005 and 2007 in the captive environment of an aquarium. All 5 wild caught females survived, with weight gains per month raging from 0.55% (Specimen W1#: Arrival: 220.00 kg, Final: 252.50 kg; across 27 months) to 10.00% of original body weight (Specimen W32#: Onset:

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125.00 kg, Final: 175.00 kg; across 4 months). In addition, the gonads of one captured fish redeveloped to the stage IV by August 2007. The changes of the depth in the tank were observed before, during and after active food intake. Furthermore, the fish formed strong feeding associations with live food items, such as *Hypophthalmichthys molitrix*, *Cyprinus carpio* and *Paralichthys lethostigma*, while rarely feeding on *Hexagrammos otakii* and *Epinephelus awoara*, occasionally on *Monopterus albus*, *Penaeus vannamei*, *Leiocassis longirostris*, and never on *Eriocheir sinensis* H. Milne-Edwards, *Misgurnus anguillicaudatus*, *Silurus asotus* Linnaeus, *Octopus Variabilis*, *Anadara uropygimelana*. The development of food preferences in the captive environment suggest that theses Chinese sturgeon successfully acclimated to the large aquarium, in addition, the survival rate of the filial generation of offspring was above 86 %. Across the study period, for the older captive bred offspring (1997 and 2001 stocks) minimum weight increase per month was 4.28 % (F_1-2001: Onset: (12.24 ± 1.11) kg, Final: (25.35 ± 2.10) kg; over 25 months) and the minimum lengthwise growth rate per month was 1.39 % (F_1-1997: Onset: (187.32 ± 1.32) cm, Final: 260.00 cm; across 28 months). However, the youngest (the 2005 offspring), had the highest weight gain of 35.70 % per month (Onset: (16.50 ± 1.92) g, Final: (8733.33 ± 739.80) g; across 18 months) and lengthwise growth rate 29.35 % per month (Onset: (15.53 ± 0.77) cm, Final: (115.33 ± 4.14) cm; across 18 months) respectively.

Key words *Acipenser sinensis* Gray Behaviour Food predisposed Growth Gonad development Adaptability Aquarium

1 Introduction

The Chinese sturgeon (*Acipenser sinensis* Gray) is a typical anadromous fish that matures in the East China Sea and Yellow Sea, and spawns in the Zhu River and Yangtze River (Wei et al., 1997). However, the construction of the Gezhouba Dam in the 1980s and the Three Gorges Dam in 2000s in the Yangtze River block the migration of the sturgeons to their natural spawning grounds, contributing to the decline and changes in stock structure of this critically endangered population (Wei et al., 2005) which is further exacerbated by females only breeding three to four times during the course of a life cycle, with < 1 % of offspring surviving due to high predation rates (Chen, 2007). It has been calculated that juveniles were further reduced by 80 %-90 % between 1981 and 1991, despite already being at critical levels (Ke, 1999). In response to the anthropogenic changes to the river structure, some breeding cohorts that are still functional have formed new spawning grounds below the Gezhouba Dam (Wei et al., 2004).

Due to the loss of natural habitats which are critical for reproduction, *ex-situ* conservation studies (i. e. outside of the natural environment) of Chinese sturgeon are required to safeguard population numbers and prevent the genetic diversity from becoming extinct. One of the primary problems of *ex-situ* conservation is the construction of suitable artificial environments that replicate sufficiently the natural environmental features to foster feeding and breeding activity by wild caught fish (Li et al., 1994). Due to the large size of sturgeon (with adults reaching up to 4 m in total length), Beijing aquarium is considered to be one of the few units in China that are equipped with advanced technical skills and large enough aquaria tanks suitable to identify the conditions required for the acclimation of sturgeons while serving species protection needs (Liu et al., 2006). In the wild, adult sturgeon usually stop food intake on initiation of the upstream migration to spawning grounds. Fish will start feeding again only after returning to the sea following spawning (The Yangtze Aquatic Resources Survey Group, 1988). Since the 1970s, several captive breeding programmes have been initiated to boost population numbers. However, the reintroduction of captive bred sturgeon to the Yangtze River, following

spawning, has so far resulted in extremely low survival rates (Wei et al., 2004). Therefore, to improve both *ex-situ* captive conditions and reintroduction success, it is necessary to develop an understanding of the feeding behaviour, and understand recovery needs after spawning, while also identifying the conditions required for gonad redevelopment of wild sturgeon that are housed in controlled environments. Such data are urgently needed to safeguard the critically endangered Chinese sturgeon.

Based on these requirements, the current study investigated the behaviour, growth and food preference of wild caught adult female Chinese sturgeon and their offsprings derived from three different captive stocks. The capacity of the wild caught sturgeon to acclimatize to the aquarium environment was also studied to identify parameters, which may be used to indicate performance and hence optimal conditions for welfare. Furthermore, the changes in the behaviour and morphology of one adult female were recorded during gonad re-development in captivity. We apply the findings of this study to identify parameters which can contribute to the successful acclimation of wild caught Chinese sturgeon. The implications of these findings will assist in the long-term captive breeding and re-introduction programmes.

2 Materials and methods

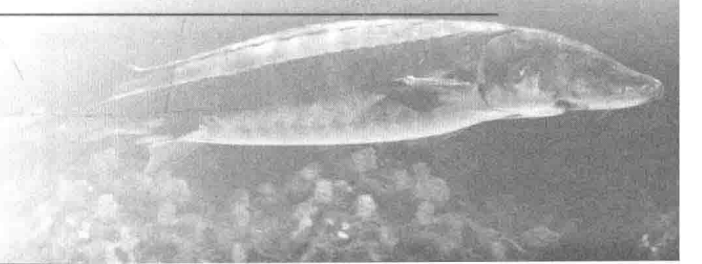
2.1 Fish stock

Between 2005 and 2006, five wild gravid female Chinese sturgeon were captured from the Yichang section of the Yangtze River, due to breed. The sturgeon were initially held at the Yangtze River Fisheries Research Institute of the Chinese Academy of Fisheries Sciences in Jingzhou city of Hubei Province, China. After 1 or 2 weeks in captivity the fish produced filial sturgeons and were held for a further 2 months at this site before transfer by ambulance to Beijing Aquarium. The origin of the wild caught fish, and accompanying basic measurement data are given in Table 1.

Table 1 Parameters of the wild caught adult female Chinese sturgeon that were housed at the Beijing Aquarium

Specimen identification	*N*	Origin of the fish	Age at arrival	Starting date (yyyy/mm/dd)
W1#	1	Capture in Yichang section of Yangtze River on 12th Oct, 2004, post mature, not propagated	Not determined	2005/04/03
W28#	1	Capture in Yichang section of Yangtze River on 5th Nov, 2005, post mature, not propagated	Not determined	2005/12/29
W29#	1	Capture in Yichang section of Yangtze River on 9th Nov, 2005, artificial propagation	Not determined	2006/01/13
W31#	1	Capture in Yichang section of Yangtze river on 30th Oct, 2006, artificial propagation	Not determined	2006/12/15
W32#	1	Capture in Yichang section of Yangtze river on 30th Oct, 2006, artificial propagation	Not determined	2006/12/19
F1-1997	2	Controlled propagation in 1997	7 +	2005/04/16
F1-2001	23	Controlled propagation in 2001	3 +	2005/03/25
F1-2005	298	Controlled propagation in 2005	0 +	2005/12/29

N, number of fish.



In addition, filial sturgeons from captive bred Chinese sturgeon stocks were assessed. These comprised two fish that were produced in 1997 (F1-1997), 23 fish that were produced in 2001 (F1-2001), and 298 fish that originated from the 2005 (F1-2005) reproduction. The F1-2005 sturgeons came from one of the experimental wild females (W29#), however, the F1-1997 and F1-2001 sturgeons did not originate from any of these females.

2.2 Housing conditions

The five wild caught adult females were accommodated in a square tank together with captive bred juveniles from the filial generation stock that were >1 m in total length (juvenile length ranged from 148 to 200 cm). The tank size was 29.0 m (length) ×11.0 m (width) ×4.4 m (height), with an exhibition-window on one side of the tank (20 m in length; 3.0 m height). The tank held a maximum water volume of 1 200 m^3. The stocking density was 2.2 kg/m^3.

F1-2005 generation from the wild caught females (also <1 m) were housed in two connected circular tanks, with two observation-windows (20 cm ×20 cm). The diameter and height of each tank were 3.5 and 1.4 m, respectively, which when combined held 25 m^3 water volume. The stocking density was maintained below 2.2 kg/m^3.

All tanks were equipped with advanced life support systems, which automatically control water quality to set specifications. For example, several key water parameters are controlled continuously, including water temperature at 21-24℃, oxygen content to be between 7 and 10 mg/L, while pH values were maintained at 7.5-8.0, and ionized ammonia [NH_4^+] concentrations leveled at 0.01-0.05 mg/L, and [NO_2^-] concentrations remained low (0-0.1 mg/L). The main water quality parameters were determined daily, and tanks were cleaned at fixed times twice weekly.

2.3 Feeding information

Both natural food (i.e. fish) and artificial dry pelleted commercial sturgeon diets were used for all four fish groups. The natural food was purchased from the market, and included a range of fish species of size range 5-40 cm; *Hypophthalmichthys molitrix*, *Cyprinus carpio*, *Paralichthys lethostigma*, *Hexagrammos otakii*, *Epinephelus awoar*, *Monopterus albus*, *Leiocassis longirostris*, *Penaeus vannamei*, *Eriocheir sinensis* H. Milne-Edwards, *Misgurnus anguillicaudatus*, *Silurus asotus* Linnaeus, *Octopus variabilis* and *Anadara uropygimelana*. The natural food was offered in three different forms; including frozen, fresh but dead, and live.

In the first tank, containing the wild caught sturgeon and F1-1997 and F1-2001 generation fish of >1 m, the fish were individually hand-fed by a diver. Hence all food intake was documented. Generally, after 2 weeks, force feeding of wild fish that had been recently caught except for W1# was required on arrival, and continued until active feeding was initiated, which individually varied between 20 days and 10 months (Zhang et al., 2007). Fish were fed once a day at fixed location. In the second tank, containing F1-2005 stock of <1 m, prepared commercial feed and natural food were offered by hand at the same location (tank surface) once daily.

2.4 Data collection

Growth measurements. Four different growth measurements were obtained during the course of

the study: (i) body circumference, (ii) waist girth, (iii) total body length (head to the end of vertebra), and (iv) body weight. The 'body circumference' was measured at the highest point of the third dorsal bony plate. The 'waist girth' was measured at the highest point of the fifth dorsal bony plate. For the wild caught sturgeon, these two measurements were obtained monthly by a diver using a tape measure under water while swimming with the fish. The total body length was measured using a tape measure, and the body weight was recorded after the fish removed from the water. For juvenile stock of >1 m the same procedure was followed. For juvenile stock of <1 m the fish were removed from the water to acquire all measurements every 3 months. Each measurement was repeated three times on each occasion for each fish. The means of these three measurements were used in the results.

Measurements were taken underwater due to the large size of the fish, a validation test was run to determine the degree of error that might exist by the same individual and by different individuals measuring the same fish. A total of three people made measurements on separate occasions during the course of 1 day. We found that measurement error was on average 0.5 cm (range 0-1; (0.5 ±0.32) cm) for repeated measurements by one person, and on average 1.5 (range 0-2.5 cm; (1.5 ±0.41) cm) for repeated measurements by different people. Based on these findings, during the main experiment only one person conducted all measurements to keep measurement error to a minimum.

Gonad development. The oocytes of one wild caught adult Chinese sturgeon (W1#) were removed by a veterinarian by biopsy and photographed on 4 August 2007. The diameter of the most of the oocytes was measured.

Behavior observations. Opportunistic sampling of the behavior of the wild caught sturgeon and the three different juvenile age groups was conducted. Behaviour was observed and documented for three times per day between 8:30 and 17:30 (total 90 min of observation period). In addition, feeding behavior was observed and documented daily. Food preference calculations followed the methodology of Liang (1995). The wild sturgeons feeding behaviours of 13 live baits were recorded and observed lasting for 1 month. Calculations on feeding behaviour was referred to the rate of special behaviour after Liang (1995). Each bait was given 10 days, three times per day, and 6-7 baits were given simultaneously and randomly in the 10 days, and the response of fish to the food item was recorded. The results are presented as percentage of observations.

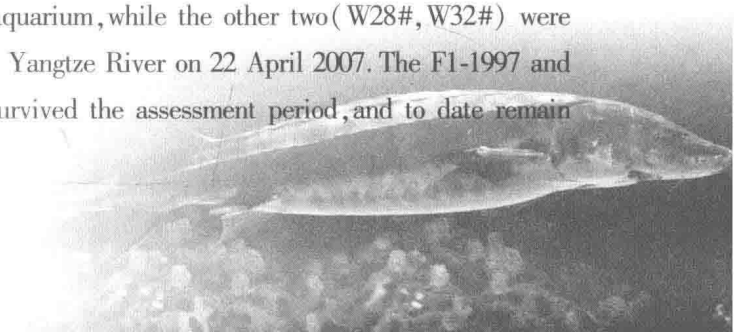
2.5 Data processing

The selection of different food items by the wild caught sturgeon were analyzed for differences using the Kruskal-Wallis Test and Mann-Whitney Test.

3 Results

3.1 Survival

All five wild caught Chinese sturgeon survived the assessment period. After the study, three of the individuals (W1#, W29#, W31#) remained at Beijing Aquarium, while the other two (W28#, W32#) were released back into the wild in the Jinzhou region of the Yangtze River on 22 April 2007. The F1-1997 and F1-2001 captive bred filial generation juvenile stock survived the assessment period, and to date remain



housed at Beijing Aquarium. Out of the 298 offspring in F1-2005 stock, 257 survived the assessment period, which is an 86 % survival rate. Of these, 148 were released into the Jinzhou region of the Yangtze River on 22 April 2006, while the rest of the fish remained housed at Beijing Aquarium.

3.2 Growth and development

Wild Chinese sturgeon. The first wild caught female (W1#) was initially captured on 12 October 2004 and admitted to the aquarium on 3 April 2005. The fish initiated active food intake from 7 April 2005 until suddenly stopping feeding on 20 August 2006. As a result, an increase followed by a declining trend in body circumference was recorded, as shown in Fig. 1. On the removal of gonad tissue by biopsy indicated the presence of brown and elliptic oocytes, with an average diameter of 3.2 mm. The polar spot was vague on the animal pole of oocyte.

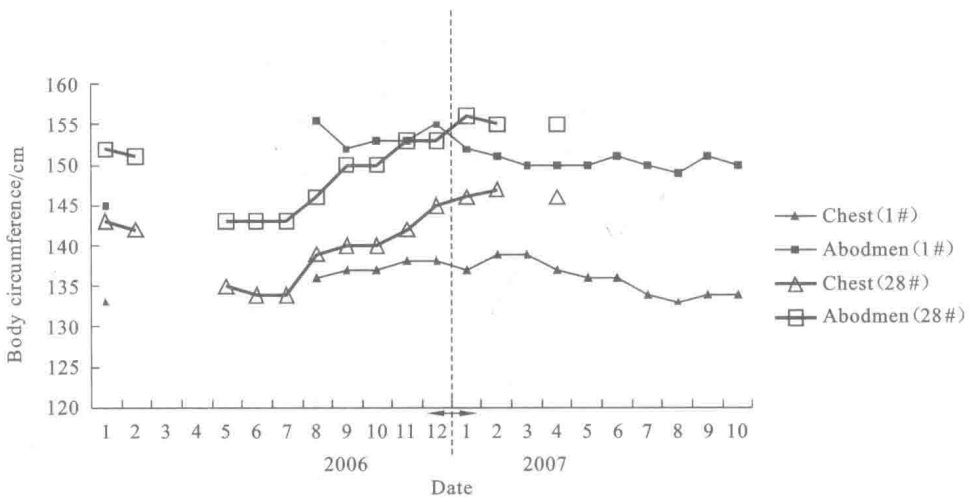


Fig. 1 Change in body circumference of W1#(female) and W28#(female) wild caught Chinese sturgeon during 2006-2007

The second female (W28#) was initially captured on 5 November 2005 and admitted to the aquarium on 29 December, 2005. The body circumference parameters declined from arrival until August 2006. At this point force feeding was initiated, and after 21 days the fish began active feeding, at which point body circumference measurements showed a steady increase (Fig. 1).

The third female (W29#) was initially captured on 9 November 2005 and admitted to the aquarium on 13 January 2006. The body circumference measurements declined after arrival. Force feeding was initiated on 29 May 2006 and began active feeding on 17 June 2006, after which the body circumference measurements steadily increased (Fig. 2).

The fourth female (W31#) was initially captured on 30 October 2006 and admitted to the aquarium on 15 December 2006. Force feeding was initiated on 18 June 2007, and at the end of the study period (October 2007) active feeding had not been initiated. The body circumference measurements are shown in Fig. 3.

The fifth female (W32#) was initially captured on 30 October 2006 and admitted to the aquarium on 19 December 2006. Force feeding was initiated on 9 January 2007, while active feeding commenced on 1 February 2007. Subsequently, body circumference measurements increased steadily (Fig. 3).

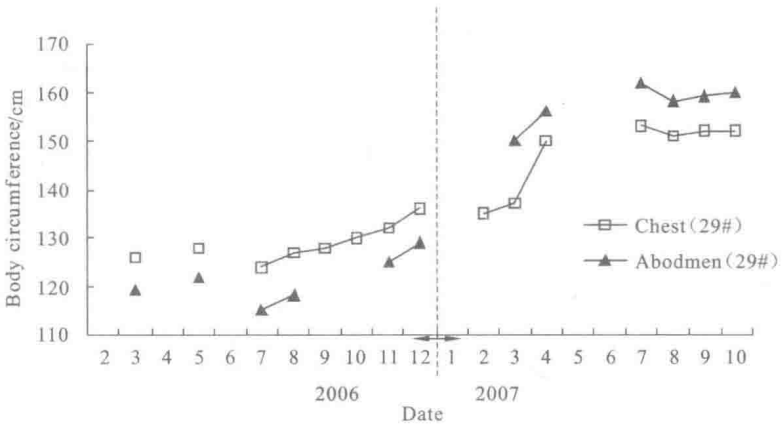


Fig. 2 Change in body circumference of W29#(female) wild caught Chinese sturgeon during 2006-2007

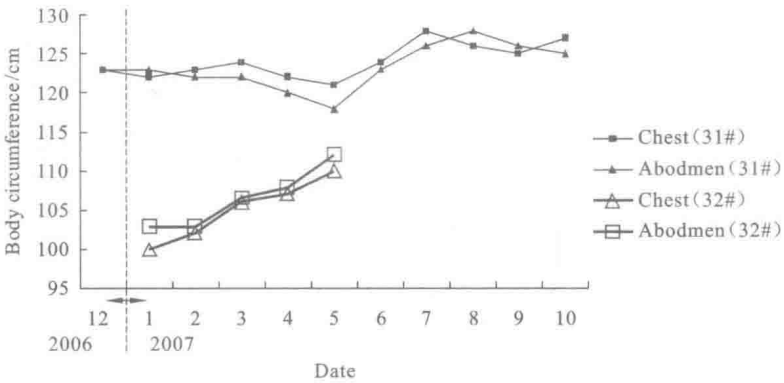


Fig. 3 Change in body circumference of W31#(female) and W32#(female) wild caught Chinese sturgeon during 2006-2007

Figures 4 and 5 show the variation of total length and body weight respectively for the five wild captured female Chinese sturgeon.

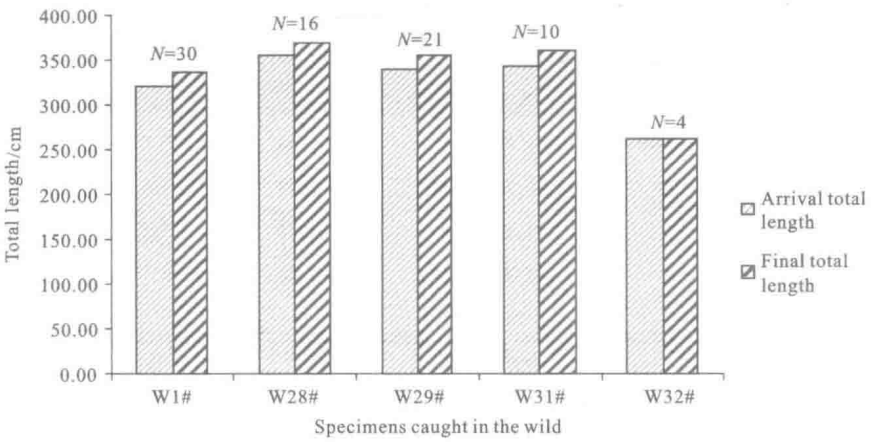


Fig. 4 Variation in total length measurements of wild Chinese sturgeon($n = 5$) during the study period in captivity(N = number of months in captivity)

First generation Chinese sturgeon. For the three different age groups of juvenile stock (F1-