

Individual variations in growth, food intake and activity in juvenile Chinese sturgeon *Acipenser sinensis* Gray

By X. Qian^{1,2}, Y. Cui¹, S. Xie¹, W. Lei¹, X. Zhu¹, B. Xiong² and Y. Yang¹

¹State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, the Chinese Academy of Sciences; Wuhan, Hubei, P. R. China; ²Fisheries College, Huazhong Agricultural University, Wuhan, Hubei, P. R. China

Summary

A 24-day trial was conducted to investigate the individual variations in growth, food intake and activity in 16 juvenile Chinese sturgeon (*Acipenser sinensis* Gray) (initial weight: 8.9–14.9 g) reared individually at 25°C. Fish were fed to satiation on tubificid worms (mainly *Limnodrilus* spp.) twice daily. Specific growth rate, food intake, digestibility, growth efficiency, and activity level were determined. Pronounced individual variations (CV = 31.7%) existed in the specific growth rate. Individual growth rate was positively correlated to food intake, growth efficiency and time spent on swimming but was not correlated with digestibility and distance moved. Food intake was positively correlated with distance moved and time spent on swimming. Our results did not support the hypothesis that less active sturgeon had a higher growth efficiency and, hence, higher growth rate.

Introduction

The Chinese sturgeon, *Acipenser sinensis* Gray, an anadromous fish, is classified as a class I endangered species by the Chinese government (Wei et al., 1997). Juveniles hatched in the Yangtze River migrate to the sea and return to spawn at the age of 8–10 years (CARSGS, 1988). Historical spawning areas in the upper reach of the Yangtze River at Yibin City will be greatly affected when the Three-Gorge Dam is built across the Yangtze River at Sandouping, about 1000 km below Yibin City. The conservation of this species may depend on artificial propagation.

Artificial spawning and larval rearing of *A. sinensis* have been partially successful. But their survival rates often fluctuate because of individual growth differences when the larval and fingerling culture of this species are conducted on a large scale (unpublished data). Therefore, investigation of the reasons for individual growth difference is important for successful culture of larvae and juveniles.

Most studies on individual differences in the growth of fish have been on fish held in groups, with emphasis on the effects of social interactions (Wickins, 1987; Kamstra, 1993; Jobling and Baardvik, 1994; Koskela et al., 1997). Information on the differences in growth by fish held in isolation has been limited (Cui and Liu, 1990; Kneib and Parker, 1991; Jobling and Baardvik, 1994). Based on studies on the individual differences in growth and energy budget in six fish species, Cui and Liu (1990) proposed three patterns in the physiological mechanism of individual growth differences. The differences could be caused by variations in food intake, growth efficiency or a combination of both. Since variations in growth efficiency may play an important role in determining individual growth

differences in fish, it can be postulated that individuals with a low level of activity may have a relatively low rate of metabolic expenditure, and hence a high growth rate.

The purpose of the present study was to test the above hypothesis by examining the individual differences in growth, feeding and activity in juvenile Chinese sturgeon *A. sinensis* held in isolation.

Materials and methods

Chinese sturgeon were obtained from the Institute of Sturgeon Researches in Yichang, China as yolk-sac larvae produced by induced spawning of wild fish. The fish were transferred to the constant temperature room 2 weeks prior to the trial, when they were 5 months old. Water temperature was gradually adjusted to 25°C (1–2°C day⁻¹) and the fish were acclimated at this temperature for 1 week before the experiment started. Fluorescent lights (105 lux) were used between 08.00 and 20.00 hours, and red lights (0.5 lux) used between 20.00 and 08.00 hours. During the acclimation period, fish were fed on tubificid worms to satiation twice a day.

Following 2 days of feed deprivation, 16 fish (initial weight: 8.9–14.9 g) were weighed and individually stocked into 16 Plexiglas tanks (40 × 20 × 20 cm; water depth 11–12 cm). Six fish from the same stock were sampled, killed and frozen for measurement of initial energy content. Excess weight of live tubificid worms (mainly *Limnodrilus* spp.) were fed to each fish twice a day at 09.00 and 15.00 hours. Uneaten food was collected by siphoning 1 h after feeding and reweighed. Weight loss in the worms was determined daily from a control tank without fish. The percentage loss ranged from 8.8 ± 1.89% (mean ± SE) to 17.8 ± 1.15% per day. The weight of the uneaten food was correlated with the weight loss in the worms. The worm mass was spread on a piece of filter paper for 2 minutes to remove excess water before weighing. A subsample of worms was weighed and dried at 70°C to determine the dry matter content every day.

All feces produced by each fish were collected twice a day by siphoning, dried at 70°C and then frozen at –20°C until analyzed. Activity of fish was monitored using the system described in Qian et al. (2000) on 5 days for each tank. Activity was recorded by an activity monitoring system (Videomex V, Columbus Corporation, Ohio, USA) through a videocamera mounted above the tanks. Horizontal distance moved per unit time and percent time moving were monitored continuously for four fishes each day from 09.00 to 20.00 hours and 21.00 to 08.00 hours, and the camera was moved to record another four fish the next day. One-third of the water in each tank was

replenished each day. Water quality were measured and dissolved oxygen ranged 6–9 mg L⁻¹, pH 7–9 and NH₄-N < 0.5 mg L⁻¹.

At the end of the 24-day experiment, fish were starved for 2 days and weighed individually. Each fish was killed and dried to constant weight at 70°C. The energy content of tubificid worms and each fish was determined using a Phillipson micro-bomb calorimeter (Gentry Instruments Inc., Aiken, USA).

The following parameters of growth performance were calculated:

Specific growth rate in wet weight (SGR_w) = 100 (ln W_t - ln W_o)/ t

Specific growth rate in energy (SGR_e) = 100 (ln W_{Et} - ln W_{Eo})/ t

Growth efficiency in energy (GE_e) = 100 (W_{Et} - W_{Eo})/ I_{TE}

Food intake = 100 $I_{TE}/(2 \times t \times (W_t + W_o))$

Where W_t is final and W_o initial wet weight of the fish, W_{Et} is final and W_{Eo} the initial body energy content, t is the duration of the experiment (24 days), and I_{TE} is total energy intake.

Digestibility of energy was estimated as: 100 (food consumed × energy in food × feces produced × energy in feces)/(food consumed × energy in food). Averages of the distance moved and time spent on swimming per day for each fish over 5 days were used to represent activity level. Coefficients of determination (R^2) were calculated using least squares regression for linear relationships between pairs of variables.

Results and discussion

One fish died during the experiment. Values and variations in the variables related to the growth performance and activity in individual sturgeon are presented in Table 1. Coefficients of variation were relatively high for SGR; growth efficiency in energy and indices of activity were moderate for initial body weight, final body weight and food intake, but low for digestibility.

SGR, either in wet weight or energy, was not significantly correlated with initial body weight of the fish (Fig. 1a and b). Both SGR in wet weight and energy were significantly correlated with food intake (Fig. 1c and d), but the variations in SGR accounted for by GE_e (R^2) were high (90% for SGR in energy) (Fig. 1e). This suggests that variations in growth efficiency were important in determining growth rate. In the larvae of *Fundulus heteroclitus*, growth was positively correlated with growth efficiency, but not with food intake. However, in *F. luciae*, growth was not correlated with growth efficiency, but increased with food intake (Kneib and Parker, 1991). In grass carp *Ctenopharyngodon idella* held in a group,

food intake accounted for a high proportion of variability in individual growth rate ($R^2=88.8\%$; Carter et al., 1992). Similar results were obtained for Arctic charr *Salvelinus alpinus* held in isolation (Jobling and Baardvik, 1994). Among six fish species held in isolation, growth rate in only one species was mainly determined by variations in food intake; in the other five species, growth efficiency played an important role in determining growth rate (Cui and Liu, 1990). These above results suggest that there are inter-species differences in the physiological mechanism underlying individual growth variations in fish.

The low variation in digestibility (Table 1), and the lack of correlation between SGR and digestibility (Fig. 1f), suggested that these variations were not important in determining individual growth differences in juvenile Chinese sturgeon. Thus, variations in growth efficiency may not be accounted for by individual digestibility differences. This suggests that variation in the metabolic rate could be the cause for individual differences in growth efficiency.

Metabolic rate in fish can be divided into standard metabolism, specific dynamic action or activity metabolism (Brett and Groves, 1979). SGR and growth efficiency in juvenile Chinese sturgeon were not correlated with distance moved per day (Fig. 1g and i) and increased significantly with increases in time spent swimming (Fig. 1h and j), suggesting that variations in standard metabolic rate and/or specific dynamic action (SDA) may be important in determining individual growth differences. There were marked differences in standard metabolism in Atlantic salmon *Salmo salar* (Cutts et al., 1998), but individuals with a higher standard metabolism were usually dominant fish that showed stronger aggression. Individuals of Atlantic salmon with enhanced growth rate also showed a lower protein turnover (Morgan et al., 2000). A lower protein turnover is expected to be associated with a lower SDA, since the cost of protein synthesis is supposed to be a major cause for SDA (Jobling, 1983).

Food intake was positively correlated with both indices of activity (Fig. 1k and l), the correlation being stronger between food intake and time spent swimming than that between food intake and distance moved. The results suggest that individuals that were more active, especially those that spent more time swimming, had a higher appetite.

In conclusion, both variations in food intake and growth efficiency were important in causing individual differences in the juvenile Chinese sturgeon growth rates. The more active individuals tended to have a higher food intake. The results of this study did not support the hypothesis that less active sturgeon had a higher growth efficiency and, hence, a higher growth rate.

Table 1

Variations in variables related to growth performance and activity in individually held juvenile Chinese sturgeon *Acipenser sinensis* Gray (n = 15). CV: coefficient of variation (%)

Variable	Mean ± SE	CV	Minimum	Maximum
Initial weight (g)	11.6 ± 0.5	15.7	8.9	14.9
Final weight (g)	18.0 ± 0.9	19.6	10.5	24.1
SGR _w (% day ⁻¹)	1.78 ± 0.15	31.7	0.70	2.93
SGR _e (% day ⁻¹)	3.25 ± 0.32	38.5	0.89	4.88
Food intake (kJ g ⁻¹ day ⁻¹)	0.296 ± 0.008	11.1	0.233	0.340
Energy digestibility (%)	92.1 ± 0.5	1.9	88.7	96.4
Growth efficiency in energy (%)	14.5 ± 1.7	44.2	3.9	25.0
Distance moved (m day ⁻¹)	785 ± 81.7	40.3	280.1	1445.7
Time spent swimming (h day ⁻¹)	19.2 ± 0.9	17.3	10.8	22.0

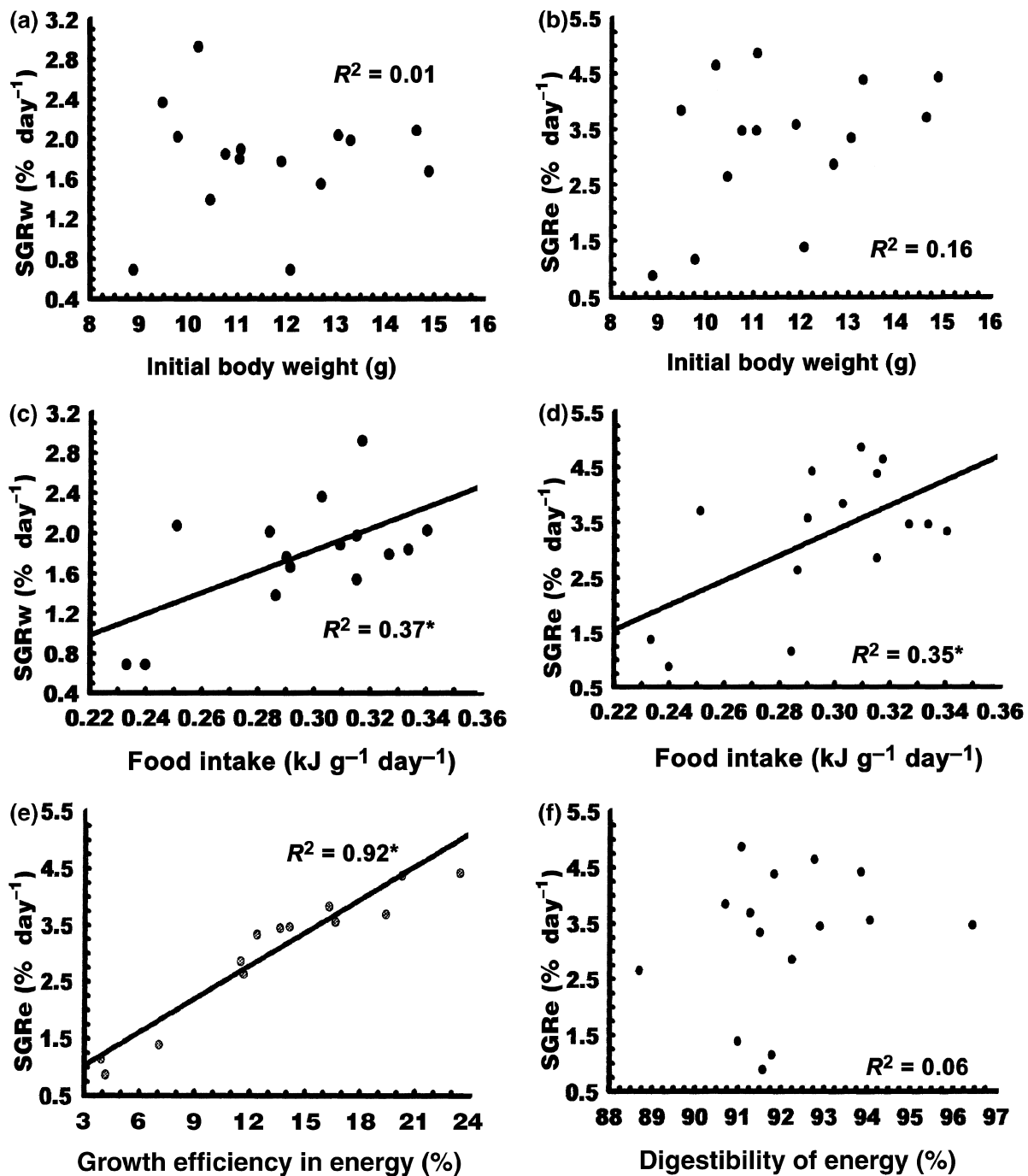


Fig. 1. Relationships between variables related to growth performance and activity in individual juvenile Chinese sturgeon *Acipenser sinensis* Gray. R^2 with * were significantly different from 0 ($P < 0.05$)

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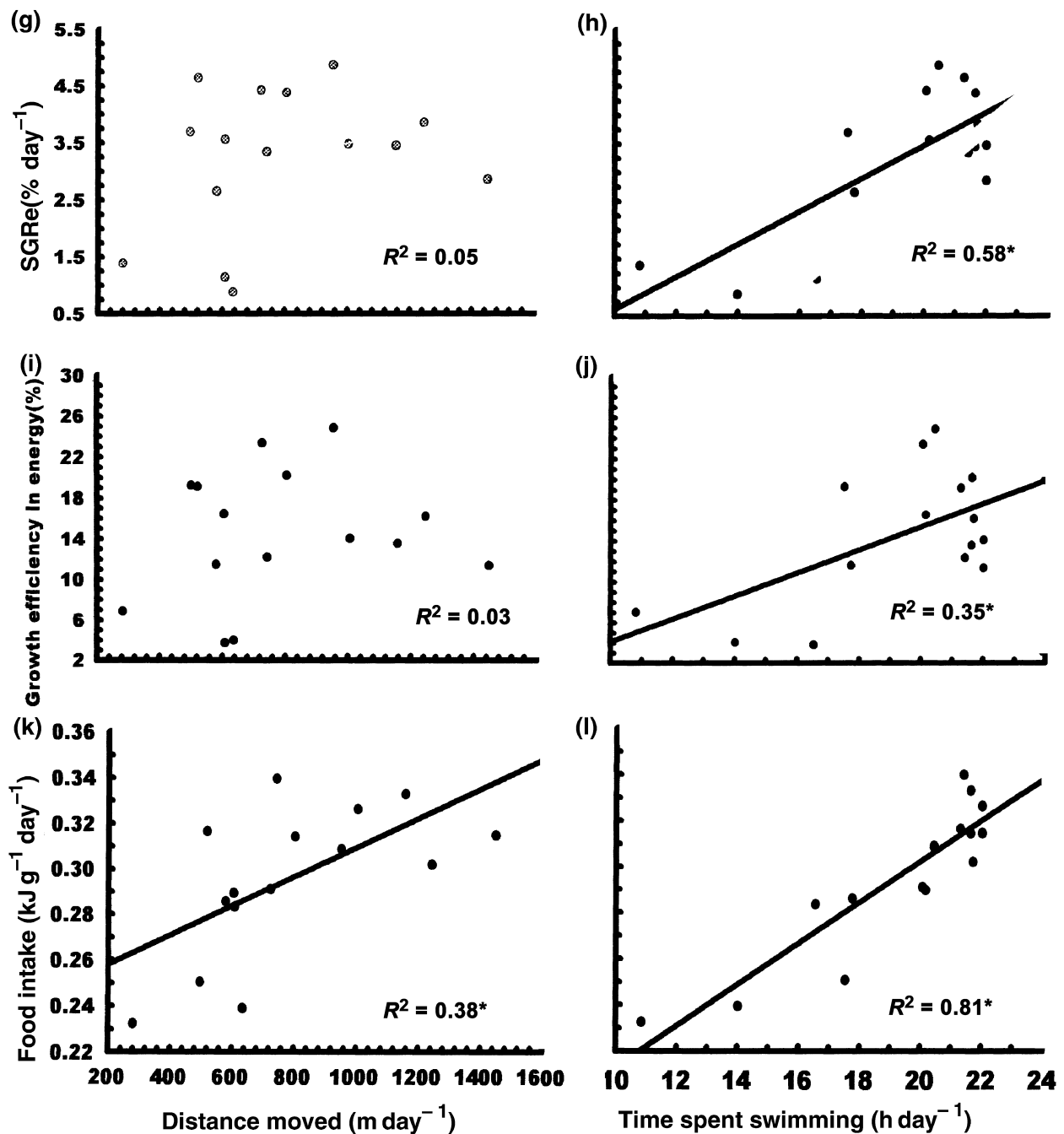


Fig. 1. (continued)

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Author's address: Shouqi Xie, State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, the Chinese Academy of Sciences, Wuhan, Hubei 430072, P. R. China.
E-mail: sqxie@ihb.ac.cn