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The Stability of Standard Metabolic Rate and its Relationship to Growth Performance Variation in Southern Catfish, *Silurus meridionalis* Chen

Shi-Jian Fu, Zhen-Dong Cao and Jian-Lan Peng
Laboratory of Evolutionary Physiology and Behaviour, College of Life Sciences,
Chongqing Normal University, Chongqing, 400047, China

Abstract: Southern catfish *Silurus meridionalis* Chen, a sit-and-wait fish, was selected as experimental model to identify the relationship between Standard Metabolic Rate (SMR) and growth by measure growth performance variables of a three week growth experiment and SMR at the start and end of experiment. The results showed that relative SMR (rSMR) at the start and end of experiment was repeatable. The rSMR at the start of experiment had no correlation with any growth performance variable. But rSMR at the end of experiment was positive correlated with Specific Growth Rate (SGR) and Feed Efficiency (FE). The results suggested in southern catfish, higher SMR of fast growth individual might due to the costly energy expenditure of issue biosynthesis. The high SMR was consequence but not the cause of fast growth.

Key words: Standard metabolic rate, growth, *Silurus meridionalis* Chen

INTRODUCTION

Standard Metabolic Rate (SMR) is the minimal maintenance or resting metabolic rate of unfed animals. It represents the costs of organismal maintenance, including protein turnover, ion pumping, blooding circulation and ventilation (Bennett, 1988). The allocation of energy to various components of an individual's energy is often viewed as a competitive process. As such, a tradeoff may exist between growth and maintenance metabolism (SMR) (Sears, 2005), consequently, individual with higher standard metabolic rate tended to have low growth rates as demonstrate in turtle (*Chelydra serpentina*) (Steyermark, 2002). But Leggatt *et al*. (2003) suggests a positive relationship between growth and maintenance because growth is costly in terms of tissue production (high SMR is the consequence of fast growth). Lahti *et al*. (2002) suggests a high SMR in fish may produce a large metabolic scope leading to a greater potential for growth (high SMR is the cause of fast growth). The growth benefits associated with a high SMR may be the reasons for the evolution of animals with increasingly high SMRs. More data in different kinds of animals should be documented before we can give a reasonable explanation about the relationship between maintenance metabolism and growth.

Recent study suggests ectotherms may provide an excellent model for investigations into the relationship between growth and maintenance metabolism due to a lower maintenance metabolism compared to endotherms (Steyemark, 2002). Southern catfish (*Silurus meridionalis* Chen), a sit-and-wait fish, usually consumes large meals and lies motionless at the most of time (Fu and Xie, 2004). It was selected as experimental model because its fasting growth and easily measurement of metabolic rate. Furthermore, previous study in southern catfish show there is considerable variation in growth rate, SMR and maximal metabolic rate during feeding or immediately after locomotion (Fu *et al*., 2005a). The aim of this study was to identify the relationship between SMR and growth in southern catfish. We also give a primary investigation on stability of standard metabolic rate.

Corresponding Author: Shi-Jian Fu, Laboratory of Evolutionary Physiology and Behaviour, College of Life Sciences, Chongqing Normal University, Chongqing, 400047, China Tel /Fax: 862365363633

MATERIALS AND METHODS

Experimental Animals

Experiment was conducted in Laboratory of Evolutionary Physiology and Behaviour, Chongqing Normal University from March to June, 2005. Experimental juvenile southern catfish were obtained from the local hatchery. They were acclimated to the experimental rearing system for four weeks prior to the experiment. During this period the fish were fed at about 2% body weight daily on cutlets of freshly killed loach, *Misgurnus anguillicaudatus*. Water temperature was maintained at 27.5°C, range±0.2°C and oxygen content was kept >5 mg L^{-1}.

Experimental Facility and Measure of Metabolic Rate

Oxygen consumption for individual fish was measured by using a 40-chamber (0.1 or 0.2 L), continuous flow respirometer (Fu *et al*., 2005b, c). Experimental fish were used in any given experiment and one chamber without a fish acted as background oxygen consumption. The following formula was used to calculate oxygen consumption (mg O_2h^{-1}) of individual fish:

$$\text{Oxygen consumption} = \Delta O_2 \times v \quad (1)$$

where ΔO_2 is the difference (mg O_2L^{-1}) in oxygen concentration between an experimental chamber and the control chamber, v is the velocity of water flow in a chamber (L h^{-1}).

Dissolved oxygen concentration was measured at the outlet of the chamber by an oxymeter (HQ20, Hach Company, Loveland, Colorado, U.S.A.). The flow rate of water through the respirometer chamber was measured by collecting the water outflow from each tube into a beaker over a 2 min period.

Experimental Protocol

After 24 h fasting and measurement of body weight, 130 juvenile southern catfish (11.58-61.90 g) were placed in respirometer chamber and allowed to acclimate for 48 h. Oxygen consumption rate was measured four times at 4 h intervals and used as SMR. Then 40 juvenile with similar weight (12.12-17.32 g) was screened for growth experiment for three weeks. Fish were held individually and fed to satiation on cutlets (1.0, range±0.1 g) of freshly killed loach, *Misgurnus anguillicaudatus*, once daily (18:00). Five individual was died during growth experiment. Fish were weighted after 24 h starvation at the end of experiment and placed in respirometer chamber for measurement of SMR (identical operation as at the start of experiment).

Data Handling and Analysis

The STATISTICA 4.5 (StatSoft Inc) was used for data analysis. AP-value lowers than 0.05 was considered statistically significant.

A standard relationship between oxygen consumption and body size was calculated by regressing the natural log of the oxygen consumption against the natural log of their body weight before fish was screened for growth experiment. Then this equation was used to calculate the expected oxygen consumption levels for a fish of a given weight both at the start and end of growth experiment. By subtracting the expected oxygen consumption values from the observed values, the residual or relative SMR (rSMR) of each fish was calculated (Metcalfe *et al*., 1995). Fish with oxygen consumption rates greater than would be expected for a fish of that size had positive values of rSMR and were said to have high rSMRs and those with negative rSMR values had low rSMR s. All analysis of metabolic rates are based on these rSMR values.

The growth performance variables were calculated as following: (1) Specific growth rate (SGR,%. day^{-1}) = (ln(final wet body mass)-ln(initial wet body mass)) ×100%/duration of experimental days (2) Ration level (% g^{-1}. day^{-1}) = diet intake ×100% /(mean wet body mass×duration of experimental days) (3) Feed efficiency = 100%×weight gain/feed consumed.

RESULTS

Standard Metabolic Rates and Stability of Individual Relative Standard Metabolic Rate

A standard relationship between oxygen consumption and body size was calculated by regressing the natural log of the oxygen consumption against the natural log of their body weight before fish was screened for growth experiment as Fig. 1

$$y = 0.80x\text{-}1.52\ r^2 = 0.929,\ n = 130,\ p<0.001 \quad (2)$$

where y is natural log of the oxygen consumption, x is natural log of their body weight.

Use Eq. 2 to calculate expected standard metabolic rates for fish of a given weight and hence rSMR, the relationship between rSMR at the start and end of growth experiment could be described as Fig. 2.

$$Y = 0.702x+0.008\ \ r^2 = 0.240,\ n = 35,\ p = 0.003 \quad (3)$$

where y is rSMR at the end of growth experiment, x is rSMR at the start of growth experiment.

The Relationship Between Relative Standard Metabolic Rate and Growth Performance

rSMR at the start of growth experiment has no significant correlation with SGR (Specific growth rate, 4.88±0.14% day^{-1}), FE (Feed efficiency, 56.00±0.93%) and RL (Ration level, 8.02±0.12%. day^{-1}) ($p>0.05$). rSMR at the end of experiment also was not significantly relative to RL. But it was significantly related with SGR, the relationship could be described as Fig. 3.

$$y = 2.43x+4.62\ \ r^2 = 0.188,\ n = 35,\ p = 0.011 \quad (4)$$

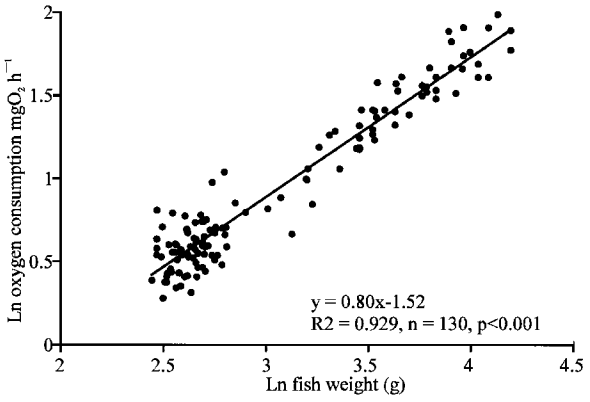

Fig. 1: Double-logarithmic plot of oxygen consumption against fish weight for juvenile southern catfish, based on initial measurements of 130 fish at the start of experiment. The regression equation (y = 0.80lnx-1.52) was used to calculate expected standard metabolic rates for fish of a given weight and hence relative SMR

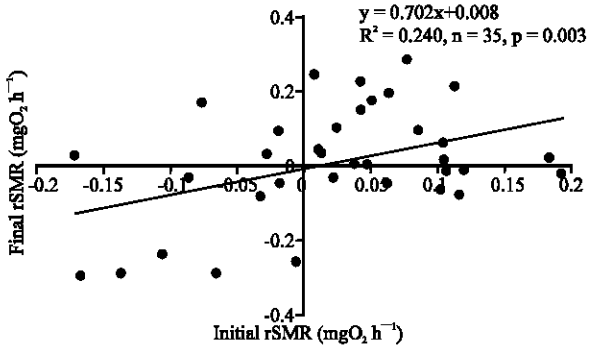

Fig. 2: The correlation between two relative standard metabolic rate (rSMR) status values ($mgO_2\ h^{-1}$) for 35 surviving fish at the beginning and end of growth experiment

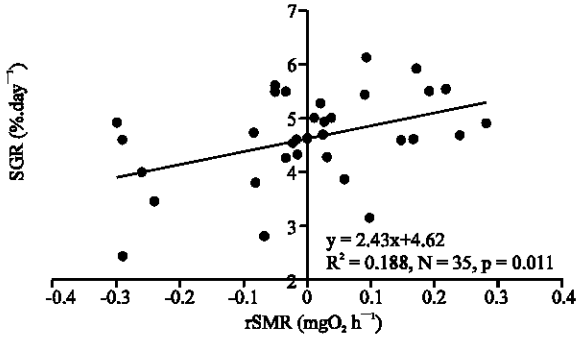

Fig. 3: The correlation between SGR ($\%.d^{-1}$) and relative standard metabolic rate (rSMR) ($mgO_2\ h^{-1}$) for 35 surviving fish at the end of growth experiment

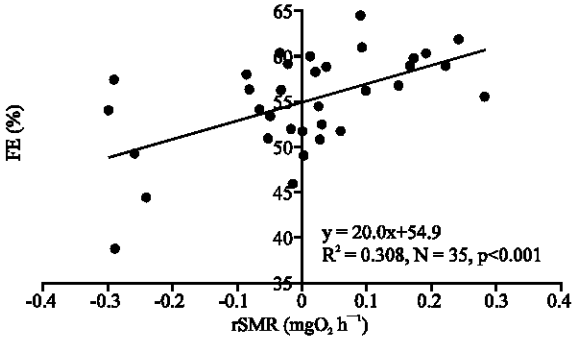

Fig. 4: The correlation between FE (%) and relative standard metabolic rate (rSMR) ($mgO_2\ h^{-1}$) for 35 surviving fish at the end of growth experiment

where y is SGR, x is rSMR at the end of growth experiment.

rSMR at the end of experiment was also significantly related with FE, the relationship could be described as Fig. 4.

$$y = 20.0x+54.9 \quad r^2 = 0.308,\ n = 35,\ p<0.001 \tag{5}$$

SGR was positive correlated with FE ($r^2 = 0.365$, $p<0.001$) and RL ($r^2 = 0.640$, $p<0.001$)

DISCUSSION

Studies of the causes and consequences of individual variation in physiological performance are becoming an important part of physiological ecology (Hayes and Jenkins, 1997). Understanding the proximate physiological factors that contribute to individual performance and quantifying the ecological and evolutionary consequences of this observed variation is one major goals of physiological ecology (Metcalfe, 1998; McCarthy, 2000). In this study, we investigated the relationship between SMR (at the start and end of growth experiment) and growth performance.

Study on relationship between performance and his physiological determinants were conduct on the assumption that such physiological determinants were relatively stability, i.e., must be repeatable. SMR was found to be a repeatable trait in Arctic char (*Salvelinus apinus*, L.) (Cutts *et al*., 2001), Atlantic salmon (*Salmo salar* L.) (McCarthy, 2000; O'Connor *et al*., 2000). In this study, the SMR in southern catfish at the start and end of growth experiment was also positive associated Fig. 1.

Whether metabolic rate a reliable indicator as growth rate in fish has been investigated recently (Alvarez and Nicieza, 2005; Blake and Chan, 2006). Two questions must be answered before the trying of using metabolic rate as a predictor of growth: whether SMR correlated with growth? If so, does SMR positive or negative relate with growth rate? Previous study in Arctic char and some salmonids suggest fish with higher SMR usually more aggressive and dominance, hence preferential access to resources such as food (McCarthy, 2001; Lahti *et al*., 2002). So it seems to be a positive correlation between SMR and growth, at least when fish growth in low-complexity habitats. But recent study in reptile such as turtle and sagegrush lizard suggest individuals with higher standard metabolic rates tend to have low growth rate. It suggested selection for faster growing fish will favour more aggressive and competitive fish, rather than those that maximize the efficiency of growth. That is, there might be a tradeoff between growth and energy efficiency but not growth and maintenance energy. Higher SMR individual could offset the increased maintenance energy expenditure by ingest more energy. The SMR in southern catfish at the start of growth experiment was neither positive nor negative correlated with growth rate (and FE, RL). It was perhaps because experimental southern catfish was held individually, hence the higher SMR gain no benefit as to preferential access to food. But not like salmonides, southern catfish was lives single in natural habitat. Such food competition might also not usually happen in nature. Also as a sit-and wait forager, the SMR of southern catfish was lower than most of other fish (Fu *et al*., 2005a-c). So the difference in maintenance metabolism might not have profound effect on energy deposit on growth. The SMR at the end of experiment was positive correlated with growth rate (Fig. 2), which suggest higher SMR of fast growth individual might due to the costly energy expenditure of issue biosynthesis (Leggatt *et al*., 2003). That is, the high SMR was consequence but not the cause of fast growth. Further more, the feed efficiency was also positive correlated with growth rate and SMR. That means individual with high SMR gain more deposited structure with equal ingested food. It suggests in southern catfish, neither tradeoff between growth and maintenance metabolism nor tradeoff between growth and energy efficiency does exist. The fitness cost of higher growth rate individual might lies otherwise. Since total energy budget of juvenile comprise SMR, feeding metabolism and activity metabolism. So energy expended on feeding and (or) activity was lower in high SMR individual. Further study needs conduct before we can give a satisfied explanation.

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