

SHORT COMMUNICATION
THE SWIMMING PERFORMANCES OF INDIVIDUAL
LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*) ARE
REPEATABLE

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Previous studies have shown that the critical swimming speed (U_{crit}) of largemouth bass, *Micropterus salmoides* Lacépède, is significantly influenced by a number of factors including body mass (Beamish, 1970), training (Farlinger and Beamish, 1978), water temperature (Hocutt, 1973; Kolok, 1991) and photoperiod (Kolok, 1991). These studies share a common approach in that they were primarily concerned with comparing mean values of U_{crit} of fish from different treatment groups, and individual variation within the groups was treated as statistical noise. While this approach is valid, it may overlook a significant source of performance variation – the variation found among individuals.

Recent research (for a review, see Bennett, 1987) into the locomotor performance of amphibians and reptiles has suggested that individual variation is substantial and repeatable (i.e. performance variation of an individual forced to perform multiple times will be minor compared to the variation found when a number of individuals are forced to perform once). This research has been conducted on animals at a constant temperature, and also before and after an acute temperature change. No study has been done to determine whether performance repeatability is maintained following a chronic change in temperature. This may be particularly important with respect to fishes because many fish undergo physiological and morphological changes when subjected to chronic changes in water temperature. In the current study, variations in the U_{crit} of individual bass were quantified, and performance repeatability was established at 11 and 22°C and after an acute and chronic decrease in water temperature from 20 to 10°C.

Juvenile largemouth bass were obtained from the Wray Fish Hatchery, Colorado Division of Wildlife, during November and August. The fish used during November ($N=7$) varied from 7.8 to 9.8 cm (mean 9.0 cm) in fork length and from

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6.2 to 12.2 g (mean 9.0 g) in body mass. The fish used during August ($N=21$) varied from 8.7 to 11.0 cm (mean 9.4 cm) in fork length and from 8.2 to 17.2 g (mean 11.4 g) in body mass. Correlations between U_{crit} (when expressed in terms of body lengths per second, BLs^{-1}) and fork length and body mass were not significant for the fish in either season.

The bass were collected from holding ponds, then transported to Boulder where they were held at field water temperatures and photoperiods (November 11°C, 12 h:12 h light:dark; August 20–22°C, 14 h:10 h light:dark). All fish were fed commercial fish pellets *ad libitum* once per week, a feeding regime at which the fish maintained their body mass but did not grow. The fish were fasted for a minimum of 48 h before they were challenged with a bout of swimming.

U_{crit} was determined using the swim chamber previously described by Kolok (1991). Water continually circulated from a 200 l reservoir into a 250 l trough holding the submersed swim chamber. Water in the trough was chilled to the desired temperature using a chiller unit partially immersed in the reservoir. A 0.5 horsepower (373 W) water pump was used to generate water flow within the swim chamber. Water flows within the chamber were measured using an on-line pitot-type flowmeter and the water flow was straightened using two flow straighteners located 20 and 40 cm from the pump discharge region. The fish swam in a 7.7 cm inner diameter 55 cm long clear acrylic tube attached downstream from the flow straighteners. Black plastic shaded the middle 35 cm portion of the swim chamber and fish generally remained in the shaded area until they were close to fatigue.

The on-line flowmeter was calibrated using a Marsh-McBirney electronic flow meter and direct volume displacement. Water flow patterns within the chamber were analyzed using a 20 MHz pulsed Doppler system and a Doppler probe consisting of a 20 MHz ultrasonic crystal mounted in an 8 mm diameter plastic tube. Water flow was determined at 13 positions within the chamber at water velocities of 20 and 50 cm s^{-1} , and was found to be essentially rectilinear at both velocities.

U_{crit} values were generated using a protocol modified from that of Kolok (1991). Individuals were placed into the swim chamber and given 1.5 h to habituate to a water velocity of 15 cm s^{-1} . The 1.5 h habituation period was much shorter than the 24 h period recommended by Beamish (1978). However, Kolok (1991) found that there were no significant differences between the performances of largemouth bass habituated to the chamber for 1.5 or 24 h at either 5 or 20°C. At the end of the habituation period, the fish were subjected to a swimming challenge in which water velocity was increased by 5 cm s^{-1} every 20 min until fatigue. The fish used in this study were approximately 10 cm in fork length; therefore, the velocity increment used was approximately 0.5 BLs^{-1} . A fish was assumed to be fatigued when it could no longer be encouraged, by gentle prodding, to swim off the flow straighteners at the rear of the chamber.

For the repeatability tests at a constant temperature, seven fish during November (11°C) and nine fish during August (22°C) were challenged with two bouts of swimming. The fish were given at least 4 days post-capture to habituate to the laboratory environment before their first swimming challenge. Immediately

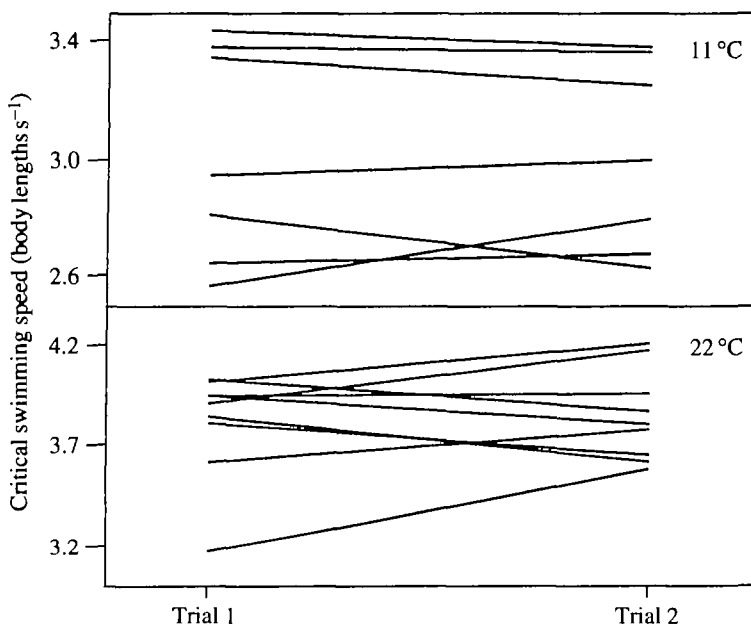


Fig. 1. The critical swimming speeds of seven largemouth bass at 11°C and nine largemouth bass at 22°C. Each individual was challenged with two bouts of swimming 4 days apart. There were significant correlations between the rank order performance of the fish between trials 1 and 2 at both temperatures.

following recovery from the first bout of swimming, each fish was weighed, measured for fork length and uniquely freeze-branded. The fish were then given 4 days to recover from the first swimming challenge (the fish were offered food on the second day after the challenge) before the performance challenge was repeated.

The mean U_{crit} of the fish swimming at 22°C was 3.81 BL s⁻¹ during the first trial and 3.84 BL s⁻¹ during the second. The mean U_{crit} of the fish swimming at 11°C was 3.02 BL s⁻¹ during the first trial and 3.01 BL s⁻¹ during the second trial. These U_{crit} values are consistent with previous findings on nonbranded juvenile largemouth bass at similar temperatures; Farlinger and Beamish (1978) obtained a U_{crit} of 3.41 BL s⁻¹ at 25°C, while Kolok (1991) found it to be 3.60 BL s⁻¹ at 22°C and 2.91 BL s⁻¹ at 10°C.

Variation in the individual values of U_{crit} of fish at 11 and 22°C were substantial and repeatable. U_{crit} values of individual fish from trial 1 varied from 2.56 to 3.44 BL s⁻¹ at 11°C, while at 22°C they varied from 3.17 to 4.03 BL s⁻¹ (Fig. 1). This degree of variation was substantial enough that the best performers at 11°C had higher U_{crit} values than the worst performer at 22°C. Correlations between the rank order performance of the fish in trial 1 and 2 were significant at 11°C (Spearman rank correlation coefficient, $N=7$, $\rho=0.86$, $P=0.036$) and 22°C ($N=9$, $\rho=0.77$, $P=0.030$), suggesting repeatability of performance. These results are

consistent with the results from other ectothermic vertebrates, specifically lizards, snakes and toads (Bennett, 1987).

For the repeatability tests in which water temperature varied, 12 fish were challenged with a bout of swimming at 20°C. Immediately following recovery from the first bout of swimming, each fish was weighed, measured for fork length and uniquely freeze-branded. Four days after the last fish had swum, the water temperature in the holding tanks was decreased to 10°C over 2 days. This rate of change was chosen because preliminary data suggested that a more rapid transfer would lead to significant mortality.

The fish were then challenged with two bouts of swimming at 10°C, the first bout starting 48 h after the temperature drop and the second bout approximately 4 weeks after the drop in temperature. Because there was only one swim chamber available, there was a 48 h variation in the exposure time to the cold water between the first and last fish challenged with a bout of swimming. Variation in the amount of time the fish were subjected to cold water, however, was not significantly correlated with swimming performance in either the acute ($N=12$, $r^2=0.015$, $P=0.70$) or chronic ($N=12$, $r^2=0.0002$, $P=0.96$) challenge. At the end of the experiment, the fish were weighed and measured for fork length a second time. Neither body mass nor fork length changed significantly (t -test, $P=0.7$ and 0.9 , respectively) during the 4 week acclimation period.

There were significant differences (Kruskal Wallis, $P<0.05$) in the swimming performance of the fish acclimated to 20°C, 10°C (acute) and 10°C (chronic). The mean U_{crit} of the fish decreased significantly (nonparametric multiple comparison, Zar, 1984) from 3.77 BL s^{-1} to 2.43 BL s^{-1} when they were exposed to a drop in water temperature from 20 to 10°C over 48 h. After 4 weeks at 10°C, the mean U_{crit} of these fish increased from 2.43 to 2.63 BL s^{-1} , but this increase was not statistically significant. The performance of individual largemouth bass within the three treatment conditions was quite variable, with the difference between the best and worst performer being 0.97 BL s^{-1} at 20°C, 1.48 BL s^{-1} at 10°C (acute) and 0.88 BL s^{-1} at 10°C (chronic) (Fig. 2). When these performances were ranked, there was a significant correlation between the rank order performances of the fish in the three groups (Kendall correlation of concordance, $N=12$, $W=0.75$, $P<0.025$).

Significant correlations between the rank order performance of a number of individuals before and after an acute temperature change have been shown for a number of lizard species (Bennett, 1980; Huey and Hertz, 1984), for yearling rainbow trout (J. E. Keen and A. P. Farrell, personal communication) and now for juvenile largemouth bass. These results suggest that in fish, as well as in other ectothermic vertebrates, individuals do not specialize at being good performers at either cold or warm temperatures. It appears, however, that the best performers remain so regardless of the temperature at which they perform.

Fish acclimated to cold water frequently have elevated swimming performances compared to fish acutely exposed to the same water temperature (Roots and Prosser, 1962; Griffiths and Alderdice, 1972). Prior to the current study on

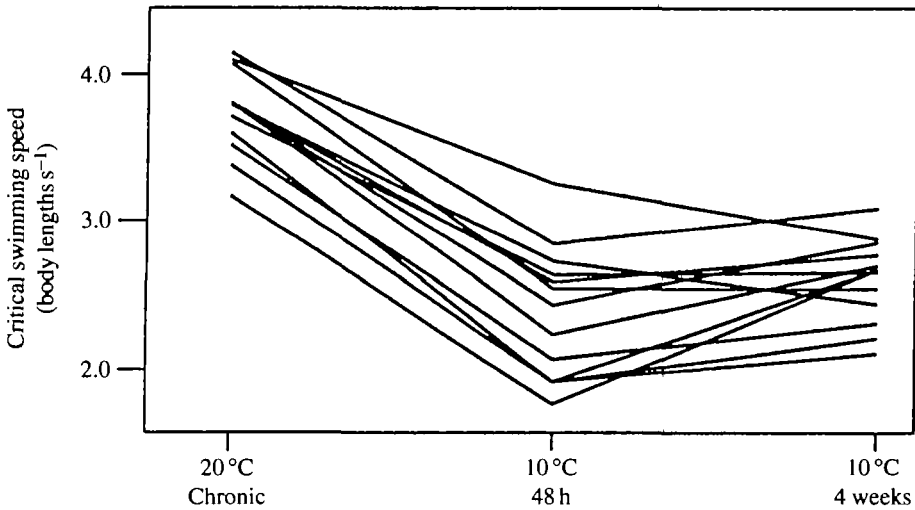


Fig. 2. The critical swimming speeds of twelve juvenile largemouth bass seasonally acclimatized to 20°C, acutely exposed to 10°C for 48 h, and acclimated to 10°C for 4 weeks. Each individual was challenged with three bouts of swimming. A positive correlation exists between the rank order performance of the fish across the three treatment groups.

largemouth bass, it was unknown whether an acclimatory response to cold water would significantly alter the rank order performance of the acclimated fish. This was not the case for the largemouth bass acclimated to 10°C for 4 weeks. While the rank order of one or two largemouth bass changed dramatically after the acclimation period, the significant correlation among the rank order performances of the fish at 20°C, 10°C (acute) and 10°C (chronic) was maintained (Fig. 2). This result suggests that the effect of acclimation to cold water was consistent from individual to individual, and that the best-performing fish would remain so even after acclimation to a different water temperature.

The results of this study suggest that variation in the swimming performance of individual juvenile largemouth bass is substantial and repeatable for fish tested twice at one temperature, tested at different temperatures, or tested after a 4 week acclimation to a different temperature. These results strongly suggest that individual variation in U_{crit} is more than statistical noise and that it is a source of variation that can be exploited when designing future experiments.

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