THERMAL TOLERANCE, SWIMMING PERFORMANCE, AND METABOLIC PHYSIOLOGY OF WILD SALMONIDS – LESSONS FROM REDBAND TROUT IN SOUTHEASTERN OREGON

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EXTENDED ABSTRACT ONLY- DO NOT CITE

Introduction

Redband trout (*Oncorhynchus mykiss ssp.*) inhabit high elevation streams in southeastern Oregon, with extreme variability in seasonal flow and periods of high stream temperatures during midsummer. Given the strong influence and potential limitations exerted by temperature on fish metabolic demands and management interests in this subspecies, the objective of this study was to determine how acute temperature change, thermal history, and geographic separation affect the physiological capabilities and biochemical characteristics of these trout.

Study Sites, Experimental Animals, and Methods

During July and August of 2000, we conducted streamside measurements of critical swimming speed (U_{crit}), critical thermal maximum (CTM), and oxygen consumption at environmentally relevant temperatures for wild redband trout in Bridge, Rock, and 12-mile Creeks. These 3 streams contain genetically distinct populations (Gamperl et al. submitted), and both Rock and 12-mile Creeks are much warmer in the summer months than Bridge Creek. We also collected samples for subsequent measurements of morphometrics, genetic variability, and biochemical indices of energy metabolism in the heart (ventricle), axial white skeletal muscle, and blood. To minimize capture stress and injury, fish were collected by anglers using dry flies and barbless hooks. All fish were held for 2-5 days prior to metabolic studies or sampling of tissue.

U_{crit} and metabolic capacity was determined by swimming fish in Blazka swim tunnel respirometers at increasing water velocities until they reached exhaustion. For CTM, water temperature in respirometers was initially set to 14°C and increased by 2°C h^{-1} until the fish lost equilibrium and was unable to swim. This rate of temperature increase approximated the maximum rate of heating that redband trout experience during a diurnal temperature cycle. Water velocity was maintained at approx. 0.5 bl sec^{-1}. We also measured swimming performance of fish at 24°C. Metabolic Power was calculated as maximum MO_2 (MO_2max; measured at maximum swimming speed) minus routine MO_2 (RMO_2 at 0.5 bl sec^{-1}).

Additional trout were anesthetized and blood samples were drawn for measurement of plasma osmolality, electrolytes, hemoglobin and circulating lipid substrates. We weighed the cardiac ventricle and excised epaxial white muscle for measurement of maximal activities of citrate synthase (aerobic capacity) and lactate dehydrogenase (anaerobic capacity). ANOVAs (one-way and repeated measures) plus ANCOVAs were used to examine whether variables differed between trout within and between streams. Differences were considered significant when $P<0.05$.

Results and Discussion

Adult versus Juvenile: Bridge Creek

RMO_2, MO_2 max, and metabolic power all scaled allometrically with body mass at 24°C and there was no significant difference in relative U_{crit} values between adult (400-1400 g, 3.2 bl s^{-1}) and juvenile (40-100 g, 3.9 bl s^{-1}) redband trout. However, adult trout swam more efficiently than juveniles. RMO_2 in adult and juvenile redband trout increased at similar rates as water temperature was raised from 14° to 22°C, however, the metabolic response of these two groups between 22° and 26°C suggests that only adults have a high thermal sensitivity and may not withstand environmental challenges at temperatures above 24°C (Fig. 1). Surprisingly, the CTM of both size classes at Bridge Creek, and the other populations of redband trout was approximately 29°C.

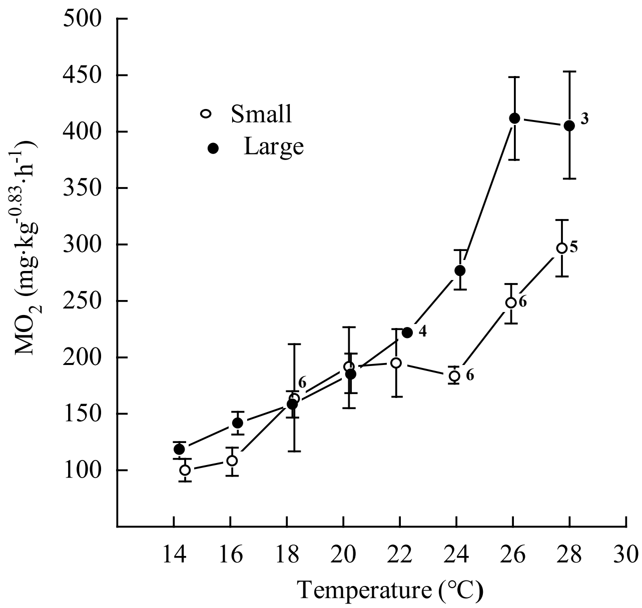

Fig. 1. Routine metabolic rate (MO_2) vs. water temperature for large (400-1400 g; n = 5) and small (40-140 g; n = 7) redband trout as measured during critical thermal maximum (CTM) tests at Bridge Creek. Vertical bars show ± 1 SE Numbers next to the symbols indicate reduced sample size due to variability in the CTM or exclusion of trout exhibiting high activity levels.

Comparisons Between Populations: Juveniles

RMO_2, MO_2 max., metabolic power and U_{crit} at 24°C were not significantly different between juvenile trout in Bridge, Rock, and 12-mile Creeks. However, analysis of the relationship between COT and swimming speed revealed that Bridge Creek trout swam more efficiently than those from 12-mile or Rock Creeks (Fig. 1). The minimum COT of Bridge Creek trout was 30% lower than for trout from the other two locations, and the COT of these fish was markedly lower at swimming speeds in excess of 40 cm s^{-1}.

Bridge Creek redband trout had 20% smaller ventricles than the other populations. Animals from 12-mile Creek, the warmest stream, were hyperkalemic and had significantly lower levels of plasma triglyceride and free fatty acids compared to Bridge Creek trout. These data provide evidence that the health and nutritional status of redband trout from 12-mile Creek were compromised. Other hematological variables were identical between populations. Lactate dehydogenase activity in white skeletal muscle scaled with animal size and we did not see interpopulation differences in muscle enzyme activities. In summary, redband trout in southeastern Oregon display differences in thermal sensitivity and swimming efficiency according to body size and stream population, respectively. It is noteworthy that redband trout were capable swimmers at even 24°C, although their CTM values were similar to those in the literature. The take-home message is that redband trout in southeastern Oregon are not uniquely thermally-tolerant compared with other salmonids, but they may display phenotypic variability that promotes performance at warmer temperatures.

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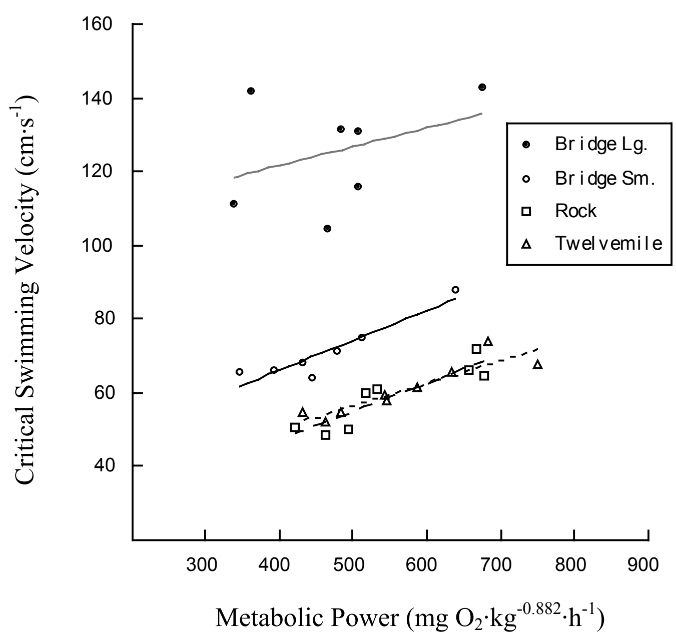

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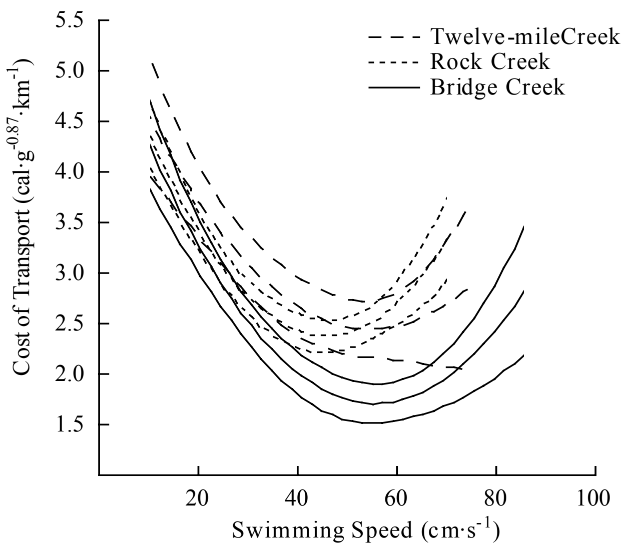

Figure 2. (**A**) Absolute critical swimming velocity vs. metabolic power for redband trout as measured at 24°C. The regression lines and the 95% confidence intervals for the relationships are shown. (**B**) Total cost of transport vs. swimming velocity for small redband trout from Bridge, Rock, and Twelve-mile Creeks at 24°C. Lines show fitted least-squares regression curves with 95% confidence intervals.

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