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Temperature Modulation of Growth and Physiology of Juvenile Guadalupe Bass

Mario L. Sullivan [a] , Yixin Zhang [a] , Timothy H. Bonner [a] & Joseph R. Tomasso [a]

[a] Department of Biology, Aquatic Station, Texas State University-San Marcos, 601 University Drive , San Marcos , Texas , 78666 , USA

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NOTE

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Mario L. Sullivan,* Yixin Zhang, Timothy H. Bonner, and Joseph R. Tomasso
Department of Biology, Aquatic Station, Texas State University–San Marcos, 601 University Drive, San Marcos, Texas 78666, USA

Abstract
Fingerling Guadalupe Bass *Micropterus treculii* were cultured in 18, 21, 24, 27, or 30°C water for 6 weeks. Temperature affected the growth of the Guadalupe Bass when it was measured by increases in TL but not when measured by increase in mass. The optimal temperature for growth of Guadalupe Bass was 27–28°C. Condition factor increased linearly with temperature, indicating that the fish were plumper at warmer temperatures. The mean hematocrit was 37 and not significantly affected by temperature, although a trend of increasing hematocrit with increasing temperature was apparent. The liver index varied significantly with temperature, and the maximum index was at 24°C. The results of this study provide basic thermal information and some base line hematological values for hatchery production and management of Guadalupe Bass.

The Guadalupe Bass *Micropterus treculii* is a stream-dwelling black bass native to the Edwards Plateau region of southcentral Texas. It is a species of special concern in Texas due to limited natural distribution and genetic introgression with introduced black bass, particularly the Smallmouth Bass *Micropterus dolomieu* (Whitmore 1983; Warren et al. 2000; Littrell et al. 2007; Bonner and Bean 2008). The stocking of hatchery-produced Guadalupe Bass fingerlings is a part of the recovery effort for this species. Beyond some information on spawning and hatching conditions (Carmichael and Williamson 1986) and toxicity of nitrogenous wastes (Tomasso and Carmichael 1986), little is known of the environmental requirements of Guadalupe Bass. To develop a broader base of environmental information for hatchery managers, this study determined the effects of temperature on growth and body condition of Guadalupe Bass. We also observed the effect of rearing temperature on hematocrit, liver index, and body condition, which are indicators of general fish health (Barton et al. 2002).

METHODS

Approximately 400 Guadalupe Bass fingerlings (59–108 mm TL) were obtained from the A.E. Wood Fish Hatchery (Texas Parks and Wildlife Department) in May 2011. The fish were trained to consume prepared feed by generally following Carmichael and Williamson (1986). Briefly, fish were held in indoor fiberglass tanks receiving constantly flowing spring water (22°C). Initially, fish were offered a mixture of dried, crushed krill and silverside and a prepared pellet (BioDiet Grower©; Bio-Oregon, Longview, Washington: 43% protein, 14% oil, 1% fiber). During training, feed was offered at least 10 times/d, and the proportion of prepared pellet was increased as fish began to feed consistently. During training, approximately 5% of the fish died. Fish were transferred to experimental systems after they had been readily taking prepared pellets for at least 2 weeks.

Thirty individuals were stocked into each of six 300-L water recirculating systems (Living Streams, Frigid Units, Toledo, Ohio), and then water temperatures were adjusted at a rate of approximately ±0.5°C per day (starting water temperature was approximately 22°C) until temperatures in Living Streams were nominal 18, 21, 24 (two Living Streams), 27, or 30°C with a thermostat resolution of ±1.0°C. After all Living Streams reached their nominal temperatures, fish in each were anesthetized with tricaine methanesulfonate at 2 g/L of water, weighed individually, and returned to the Living Stream from which they were collected. Averaged fish weight was 4.7 g (SD, 1.47). Mean fish weight varied significantly (analysis of variance [ANOVA]; $P <$ 0.001) among Living Streams; means ranged from 3.9 to 5.3 g, being higher in the warmer tanks, which was due to thermally controlled differential growth during the acclimation period. After weighing, fish were exposed to experimental temperatures for 6 weeks and were fed to satiation once per day. During the

*Corresponding author: ms1667@txstate.edu
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6-week study, 6% of the fish died: seven fish in the 18°C treatment and three fish in the 21°C treatment.

Temperature and dissolved oxygen were monitored daily using a YSI 85-10 m (YSI, Inc., Yellow Springs, Ohio). The mean temperature for each Living Stream was the same as the nominal temperature with a maximum coefficient of variation of 2.1%. Mean oxygen concentrations ranged from 87% of saturation in the highest temperature treatment to 96% of saturation in the lowest temperature treatment, the maximum coefficient of variation being 3.8%. Total ammonia nitrogen (TAN) was measured by direct Nesslerization (APHA 1989) three times during the experimental period and fell below detectable limits (0.01 mg/L) each time. The pH was measured using an Accumet 15 pH meter (Fisher Scientific, Pittsburgh, Pennsylvania) three times during the experimental period and ranged from 8.5 to 8.6. Artificial sea salt was added to the culture water to maintain adequate ions and buffering capacity. It was measured daily using the YSI 85-10 and was 1.2 (±0.2) during the course of the study.

After a 6-week exposure to experimental temperatures, fish were anesthetized as described previously, weighed and measured (TL), and liver and blood samples were collected. For both length and mass, growth was calculated as percent gain. Blood was collected into a heparinized capillary tube from the hemal arch after severing the caudal peduncle. Capillary tubes were immediately centrifuged and hematocrit determined. After fish were weighed, livers were removed and weighed separately. Liver index was expressed as a percent of body mass represented by the liver. Fulton's condition factor (K) was calculated according to Anderson and Neumann (1996).

Regression analysis was applied to all data sets, and significance was set at $\alpha = 0.05$. Based on previous experience defining thermal–growth relationships in fishes (e.g., Atwood et al. 2003; Sullivan and Tomasso 2010), we fitted a second-degree polynomial to the growth data. Mean responses of individuals in each Living Stream were entered into analyses, resulting in an N of six in each analysis.

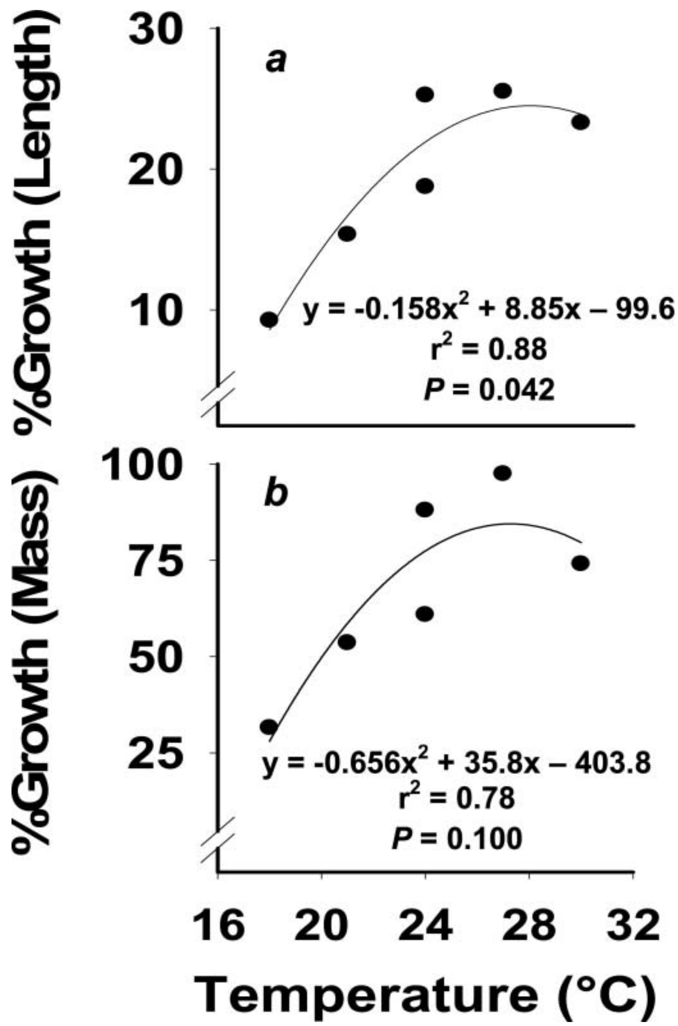

FIGURE 1. The effect of temperature on growth **(a)** TL and **(b)** wet weight of Guadalupe Bass after 6 weeks of exposure to five discrete experimental temperatures.

RESULTS AND DISCUSSION

Temperature affected the growth of the Guadalupe Bass as measured by increases in TL (Figure 1a). However, a significant treatment effect was not observed when growth was measured by mass (Figure 1b). The polynomials used to describe the temperature and growth relationship described 88% of the variability in the length observations and 78% of the mass observations. The optimal temperature for growth of Guadalupe Bass was estimated to be 28°C for length and 27°C for mass. Decreases in growth rates were observed at 30°C, indicating that the bass were in a thermal environment that was beyond their maximum metabolic scope (Neill and Bryan 1991). Estimated optimal growth temperature for Guadalupe Bass was similar to that reported for Largemouth Bass *Micropterus salmoides* (26–30°C; Jobling 1981) but differed from that of Smallmouth Bass (22°C; Whitledge et al. 2006). The low N (6) may be responsible for the failure to observe a significant treatment effect for mass and creates some uncertainty with regard to our estimate of optimal temperature.

Condition factor increased linearly with temperature (Figure 2), indicating that the fish were plumper at warmer temperatures. This is similar to results of Largemouth Bass where significantly greater condition factors were observed at 26°C and 32°C versus 20°C (Tidwell et al. 2003). To try and understand why K was different across treatments, we plotted mass versus length for all fish at the end of the study. The relationship was continuous ($\text{mass} = 0.000009 \cdot \text{length}^{3.004}$) and consistent ($r^2 = 0.95$), indicating that warmer (faster-growing) fish and cooler (slower-growing) fish will have the same K at a given mass. Hence, the differences we detected in K may be attributed to normal allometric growth rather than a thermal effect.

The mean hematocrit was 37 and not significantly affected by temperature, although a trend of increasing hematocrit with

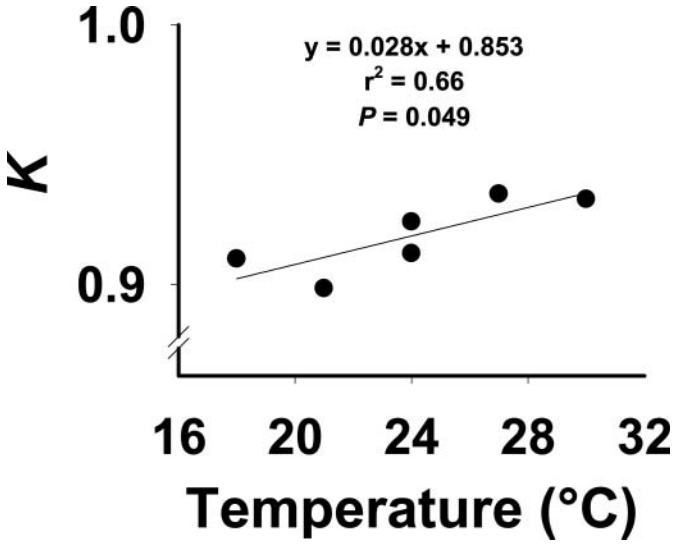

FIGURE 2. The effect of temperature on body condition (*K*) of Guadalupe Bass after 6 weeks of exposure to five discrete experimental temperatures.

increasing temperature was apparent. As temperature increases, oxygen demand by fish will increase while the solubility of oxygen in water and plasma decreases. Any increase in hematocrit under these conditions is probably directed toward increasing the ability of the animal to deliver oxygen to the tissues (reviewed in Nikinmaa 2006). However, diet and activity may also play a role in variability in hematocrit (Denton and Yousef 1975).

The liver index varied significantly with temperature with a maximum index at 24°C (Figure 3b). During periods of surplus energy intake, fish store energy in muscle and liver leading to changes in liver size relative to fish body size (Busacker et al. 1990). As stored energy is used, liver size decreases. In this study, relative liver size increased in fish reared at lower temperatures, peaked, and declined in fish reared at the higher temperatures. Relative liver size peaked at temperatures 3–4°C below the temperature for maximum growth. Perhaps the earlier decline in relative liver size represents a period when energy stored as liver fat and glycogen supplemented daily rations to support thermally controlled increases of metabolic rate and growth. The temperature at which fish growth decreases represents the point where metabolic scope is decreasing due to the rapid increase of standard metabolism (Neill and Bryan 1991). Similar peaks in relative liver size have been reported for Largemouth Bass (Heidinger and Crawford 1977; Brown and Murphy 2004).

Current recovery efforts are focused on the South Llano River (Texas) Guadalupe Bass population, which is 3% hybridized with Smallmouth Bass (Bean et al. 2013). Recovery efforts include capturing of broodstock from the South Llano River and subsequent back-stocking of hatchery-produced fingerlings. The results of this study provide basic thermal information for use during hatchery production of Guadalupe Bass and management of populations in the field.

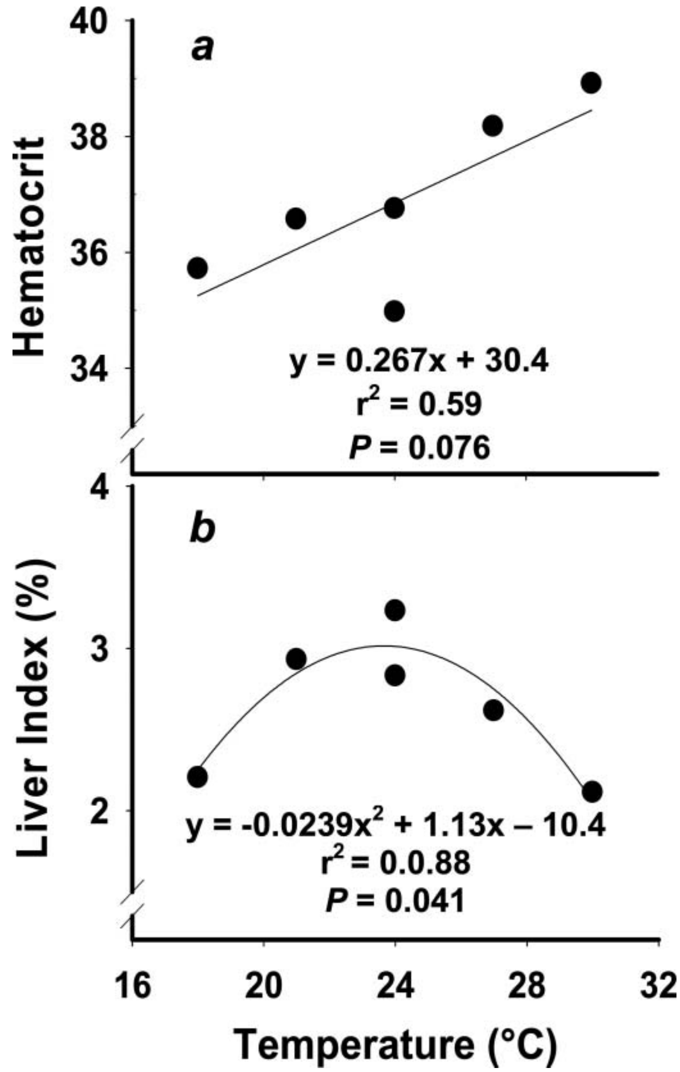

FIGURE 3. The effect of temperature on **(a)** hematocrit and **(b)** liver index in Guadalupe Bass after 6 weeks of exposure to five discrete experimental temperatures.

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