Stoeckel Lab Mussel Research Updates for the 2022 Alabama Mollusk and Crayfish Working Group Annual Meeting

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A review of lethal thermal tolerance among freshwater mussels (Bivalvia: Unionida) within the North American faunal region

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Freshwater mussels of the order Unionida are currently one of the most imperiled groups of organisms in the North American faunal region. Accurate risk assessments and development of effective management strategies for remaining populations require knowledge of thermal limits in the face of increasing surface water temperature due to climate change and various anthropogenic factors. We conducted a systematic literature review of unionid mussels (order Unionida, families Margaritiferidae and Unionidae) in the North American faunal region to (1) summarize lethal thermal tolerance data by life stage and taxonomy, (2) discuss ecological and climate change implications of existing lethal tolerance data, and (3) identify needs for future research. We identified lethal tolerance estimates for only 28 of 302 species in the families Unionidae and Margaritiferidae. The mean acute median lethal temperatures were 32.8°C for glochidia (19 species), 35.0°C for juveniles (13 species), and 36.3°C for adults (4 species). Generally, glochidia were less tolerant than juveniles or adults of the same species – but there were several exceptions. Generally, Amblemini had the highest acute and chronic thermal tolerance of all tribes followed by Anodontini, Pleurobemini, Lampsilini, and Quadrilini. Acclimation temperature affected lethal tolerance endpoints in less than half (52 of 145) of comparisons within species. Lethal tolerance data for additional species, combined with a comprehensive database of in situ surface water temperatures would be useful for modeling the frequency and duration of lethal limit exceedance in North America and identifying populations currently living at or near their upper lethal limits.

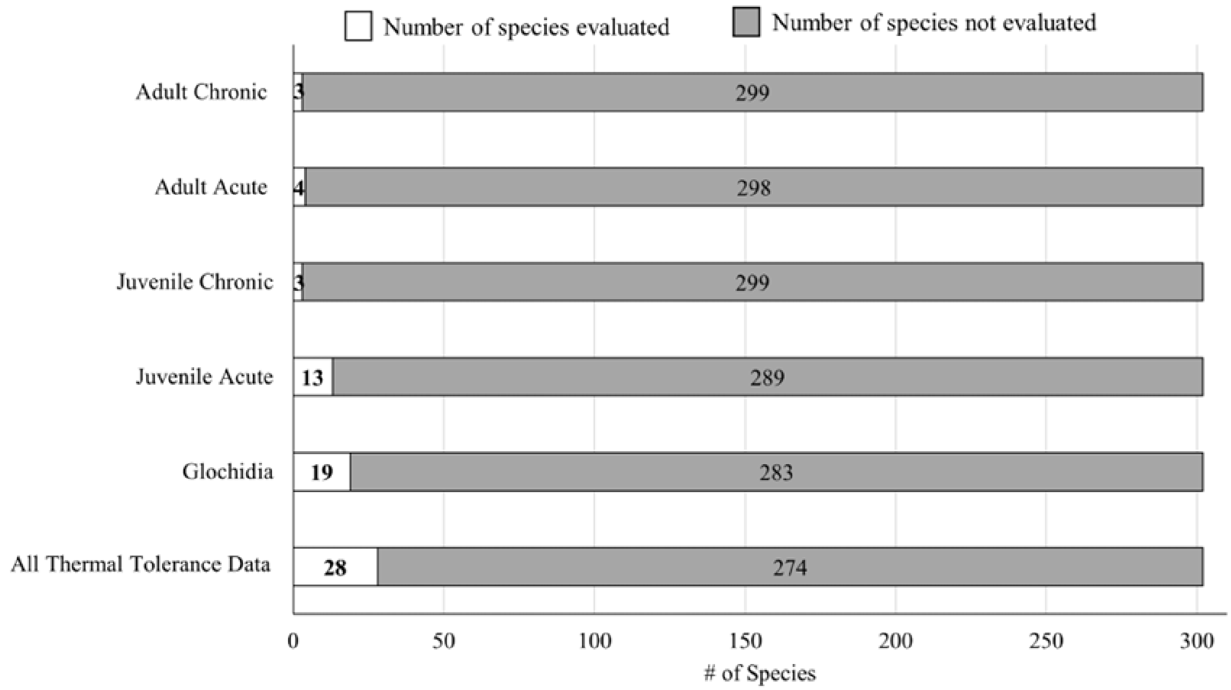

Figure 1 The total number of North American unionid species that have had upper thermal tolerance limits evaluated compared to the number of species that remain to have upper thermal tolerance measured as determined through a literature review.

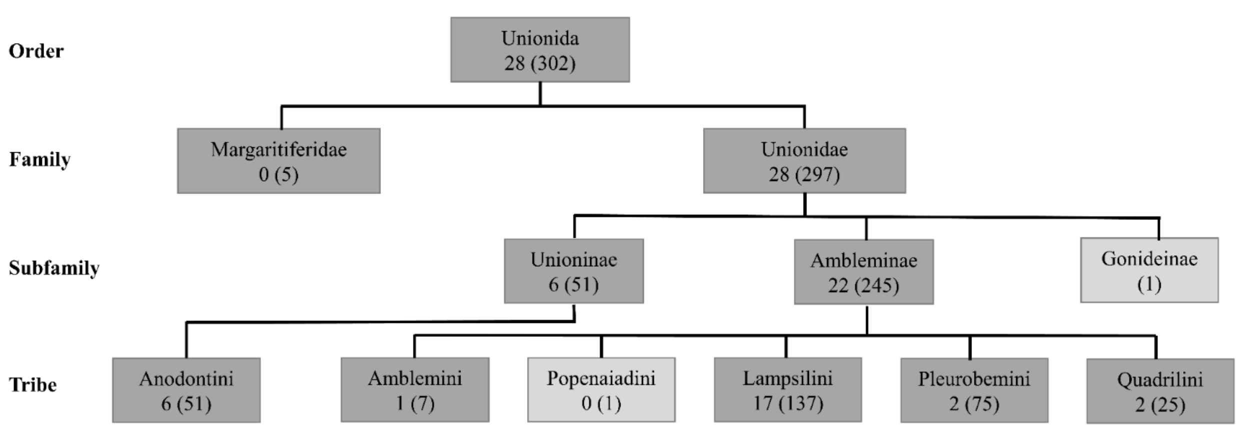

Figure 2 Twenty-eight Unionida species were represented in the lethal thermal literature, shown here by taxonomic group, compared to species richness in the North American faunal region (listed in parentheses).

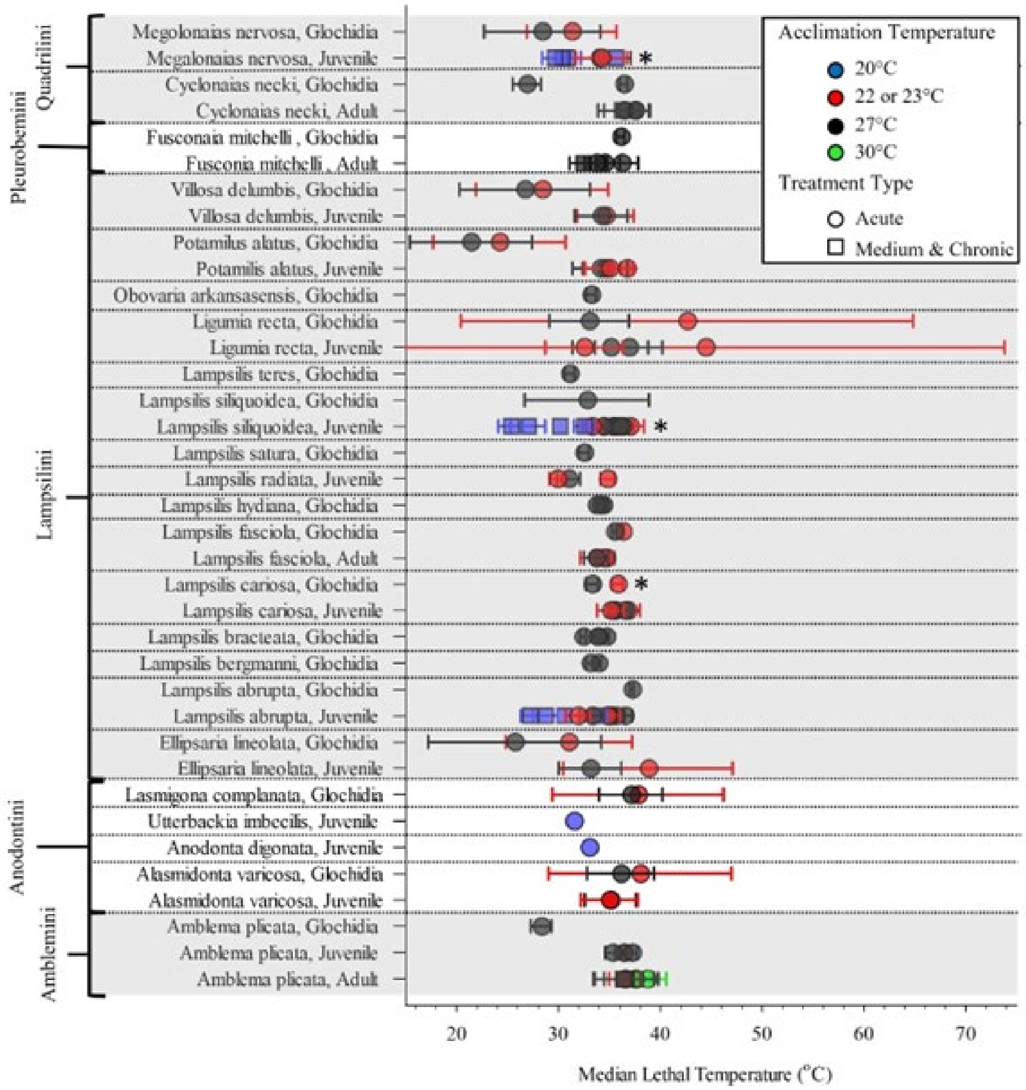

Figure 3 Median lethal temperatures (LT50) and corresponding 95% confidence intervals from static thermal exposures conducted on glochidia, juvenile, and adult Unionid mussels under a range of conditions [i.e., exposure duration (acute/chronic), acclimation temperature (20-30°C), or exposure type (water-only or with sediment)]. LT50 values represent the temperature expected to cause mortality in 50% of an exposed population in a specified time. LT50s ranged from 21.4 to 44.4°C (mean = 34.2°C) among all species, life stages, and test conditions (n = 130). Species are arranged by decreasing LT50 values within tribes. Acclimation temperature is signified by color (20°C = blue, 22 or 23°C = red, 27°C = black, 30°C = green). Treatments are signified by symbol shape (● = acute exposure and ■ = chronic exposure. Asterisk (*) denotes when there were significant differences in mean LT50s across acclimation temperatures (determined by 95% CI's not overlapping). Data are from a review of the thermal literature for Unionid mussels. See text for details.

Various Approaches to Evaluate Thermal, Hypoxia, and Desiccation Tolerance of Mussels

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We used various approaches to evaluate thermal, hypoxia, and desiccation tolerances of the federally endangered Texas Hornshell in 2022. Experimental animals were collected in October 2021 from the Black River, New Mexico under Permit # **TE78507C-0**.

We completed a series of Scope for Growth (SFG) experiments where we measured the metabolic energy that a mussel needs for basic maintenance, filtration, and feeding. We subtracted energy needs from the energy the mussel is acquiring from the food (i.e. algae) that it ingests. The net energy (energy spent – energy acquired) represents Scope for Growth: energy left over for growth, reproduction, burrowing, etc. We have collected data to calculate SFG for mussels acclimated to five temperatures (16, 20, 24, 28, and 32 °C). Data is currently being analyzed. Main findings thus far are described below:

<u>*Clearance rate*</u> is the volume of water completely cleared of particles per gram of mussel per hour. Because we kept food concentration relatively constant in the water, an increase in clearance rate represents an increase in the number of algal cells removed from the water column. We found that clearance rate of THS remains fairly constant from 16-24°C, but increases rapidly as temperatures increase above 24°C (Fig. 1).

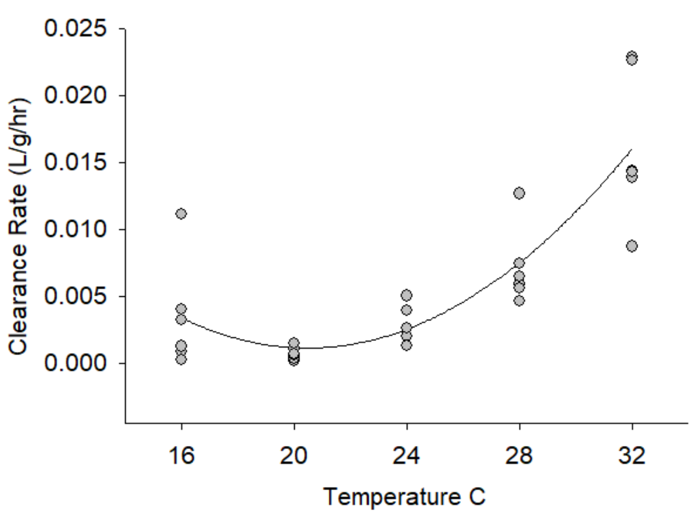

Figure 1. Relationship between clearance rate and temperature for THS acclimated to each temperature for ~2 weeks.

Absorption efficiency represents the proportion of food (i.e. organic carbon) cleared from the water column and ingested by the mussel that is incorporated into the mussel tissues and not egested as feces. We found a unimodal relationship between absorption efficiency and temperature where absorption efficiency peaks at ~24°C and then declines at higher temperatures (Fig. 2).

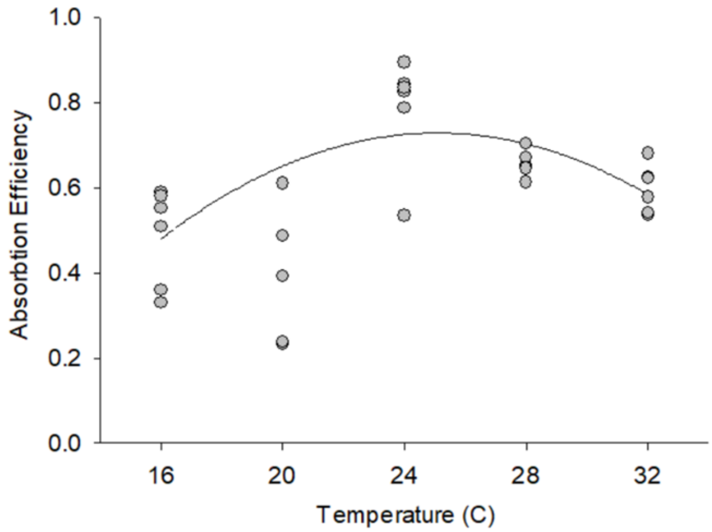

Figure 2. Relationship between absorption efficiency and temperature for THS acclimated to each temperature for ~2 weeks.

Respiration rate represents the energetic costs required for basic maintenance plus filtration plus digestion. We found that energy costs increased exponentially with increasing temperature (Fig. 3).

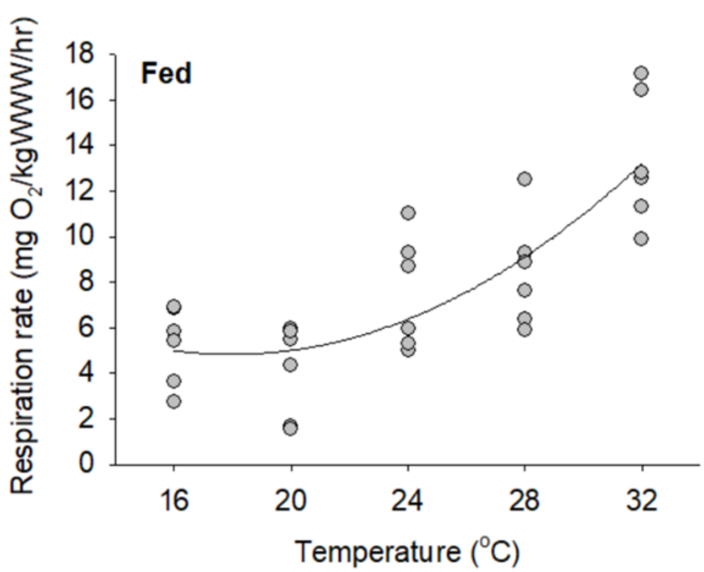

Figure 3. Relationship between respiration rate and temperature for actively feeding THS acclimated to each temperature for ~2 weeks.

Scope For Growth (SFG) represents the energy surplus available for growth and reproduction after energetic costs (i.e. respiration) have been subtracted from energy intake (assimilated food). In the case of THS the increase in clearance rate was counterbalanced by the decrease in assimilation efficiency and the increase in energy costs with increasing temperature. This led to a peak in SFG at ~28 °C followed by a decline with further increases in temperature (Fig. 4).

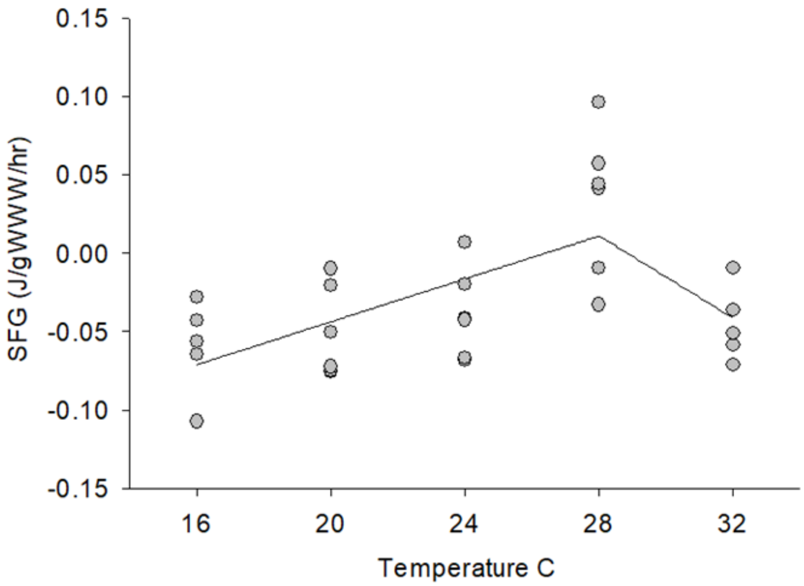

Figure 4. Relationship between scope for growth (SFG) and temperature for THS acclimated to each temperature for ~2 weeks. Each data point represents and individual mussel.

Acute thermal tolerance

We conducted sublethal and lethal, acute thermal tolerance experiments where temperature was increased at a rate of 2°C/hr until mussels reach their critical thermal maximum (CTmax). Mussels began showing the first behavioral signs of acute thermal stress (full extension of foot outside of shell) at 39.31°C ± 0.25 SE. All mussels reached their CTmax at 43.1°C as evidenced by gaping behavior, retraction of mantle tissue, and non-reponsiveness to probing. Respiration data is still being analyzed but preliminary results indicate that metabolic depression (i.e. inability to obtain sufficient oxygen due to thermal stress) occurred at ~40°C. Texas Hornshell mussels from the Black River (this report) exhibited nearly identical temperatures at metabolic depression and CTmax as the six mussels previously collected from the Delaware River and subjected to identical acute thermal tolerance assays in 2020. However, foot extension occurred ~2°C earlier in the Delaware River compared to the Black River mussels.

Hypoxia tolerance

Critical dissolved oxygen concentration (DOcrit) represents the dissolved oxygen threshold below which organisms cannot obtain sufficient oxygen from the surrounding waters and begin transitioning from aerobic respiration to less efficient, and presumably more stressful, anaerobic respiration. An increase in DOcrit with increasing temperature is generally interpreted as indicating a decrease in hypoxia tolerance (Fig 5).

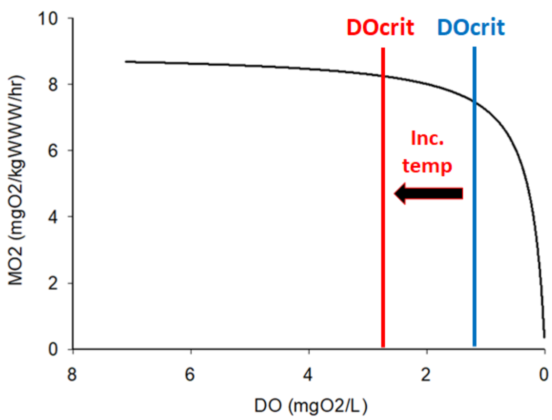

Figure 5. Relationship between aerobic respiration rate (MO_2) and dissolved oxygen (DO). The blue DO_{crit} represents the dissolved oxygen concentration threshold below which aerobic respiration rapidly declines. A hypothetical increase in DO_{crit} with increasing temperature (red line) would indicate a decrease in hypoxia tolerance.

In our experiments, we observed a significant increase in DO_{crit} with increasing temperature, indicating that the ability of Texas Hornshell mussels to obtain sufficient oxygen from surrounding waters decreases as temperatures increase (ANOVA; $F_{2,12} = 23.579$, $p < 0.001$).

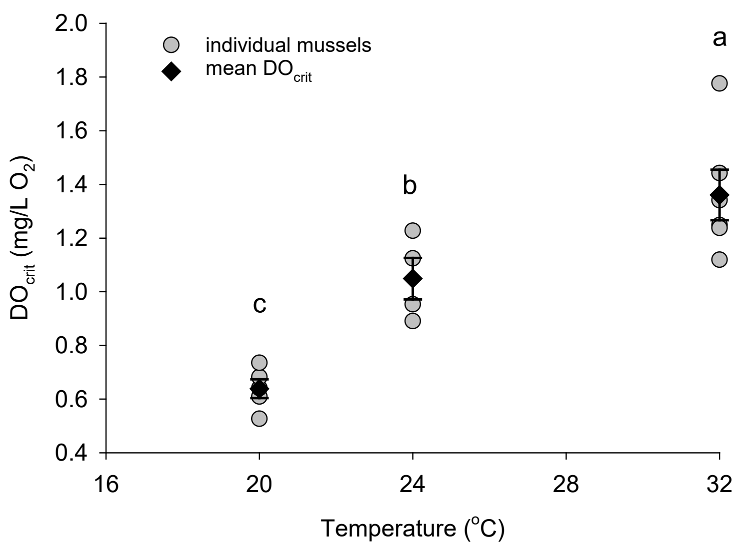

Figure 6. Relationship between DOcrit and temperature for THS acclimated for ~2 weeks to each temperature. Error bars represent ± 1 SE. Letters indicate significant differences.

Emersion Tolerance

We conducted laboratory 7-day emersion tolerance experiments under a scenario of high temperature (30 °C) and high humidity to simulate potential midsummer conditions in dewatered undercut banks. During the emersion trials, 12 of 12 mussels survived five days and 11 of 12 mussels survived seven days of complete emersion. The 11 surviving mussels exhibited 82% survival over two weeks following resubmersion on day 8. Control mussels that remained submerged at 30°C exhibited 92% survival over the entire four-week experimental period.