The Effects of Elevated Temperature on Oxygen Consumption, Swimming Direction, and Survival of Caribbean King Crab Larvae

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Introduction

In the Florida Keys, coral habitats have been in decline since the 1970s due to multiple stressors including coral bleaching, disease outbreaks, hurricanes, and cold snaps. As a result, once coral-dominated communities are now becoming increasingly dominated by macroalgae, which are associated with lower economic, ecological, and aesthetic value. Herbivory, or the grazing of macroalgae, is a key process on coral reefs that helps maintain coral-dominated states and can potentially reverse macroalgal shifts on degraded reefs. The Caribbean king crab, *Maguimithrax spinosissimus,* is a noted voracious algae consumer with natural physiological resilience to stressful environmental conditions, making them a promising coral restoration candidate. However, their ability to tolerate stressful environmental conditions, such as warmer seawater temperatures, remains unknown. This study determined the larval survival (%), oxygen consumption (mg/L), and geotactic swimming behavior under a control temperature (28°C) and an elevated temperature (32°C) scenario.

We hypothesized that larvae exposed to the elevated temperature treatment (32°C) would experience higher mortality, reduced oxygen consumption, and exhibit increased downward swimming behavior relative to the control.

Methodology and Experimental Design

Larval Survival

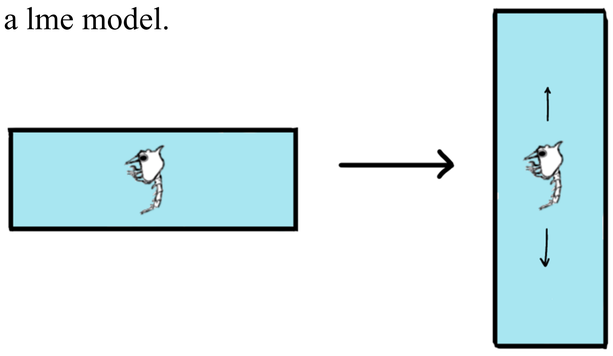
To monitor the effects of temperature (28°C or 32°C) on larval survival, individual larvae were checked for molts every 12 hours until molting to juveniles or death occurred. The time to molt and/or die into a certain life-stage was recorded at each time check. Data was analyzed with a Cox Hazard Model.

Oxygen Consumption

Larval oxygen consumption at each experimental temperature (28°C or 32°C) was measured using microrespirometry (FirestingO2) at each larval stage. Two individual larvae for both larval stages were used during microrespirometry trials (4mL vial). All microrespirometry trials were conducted in a dark room and the water bath was digitally controlled at the larvae's respective experimental temperature treatment. Each trail also included a "blank" control chamber, which was filled with only treatment seawater to account for any respiration from microorganisms. All trials were then corrected for O_2 drawdown using the blank chamber. Microrespirometry trials were performed for 1 hr and oxygen was recorded every 2 minutes. Total O_2 consumption was analyzed using a lme model with temperature and larval stage as fixed factors and brood as a random factor.

Geotaxis

To measure the vertical swimming ability of king crab larave at different temperatures individual larvae that were raised in each temperature treatment were randomly selected and dark-acclimated in a horizontal geotaxis chamber (below). After acclimation, the chamber was gently rotated to a vertical position. The directional swimming of each larva was then recorded for the 10 seconds following rotation using a digital video camera (Graftek). Larval vertical movements were categorized as upward, downward, or neutral movement. Neutral responses consisted of individuals that did not change position after rotation. Directional responses were analyzed using a lme model.



Results

Oxygen Consumption

- Linear mixed effects model:
  - Temperature: $p = 0.645$ → no significant effect of temperature on oxygen consumption.
  - Larval stage: $p = 0.203$ → no significant difference between larval stage 1 and 2.
  - Interaction: $p = 0.687$ → the effect of temperature does not differ between larval stages.

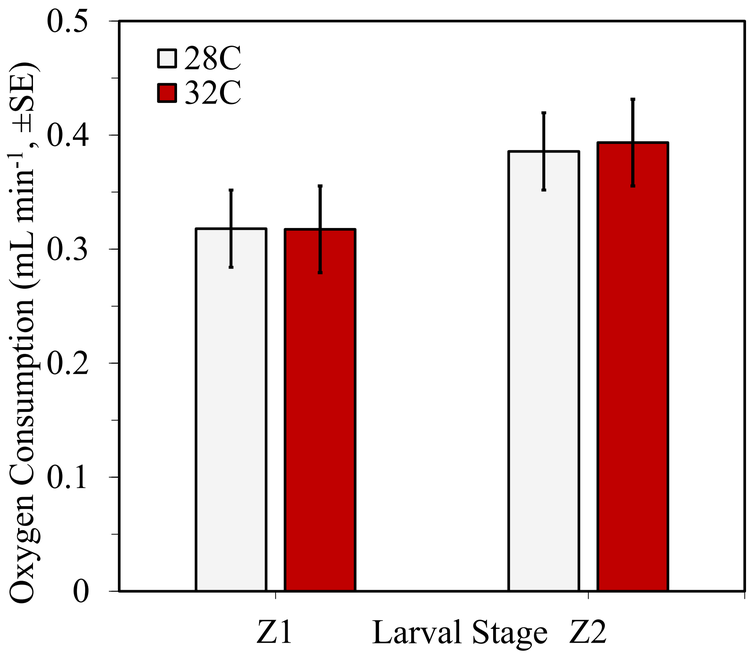


Figure 1. Oxygen consumption (mL min^{-1}, ±SE) for larval stage 1 and 2 in 28°C and 32°C treatments (Z1: 28°C n=52, 32°C n=53; Z2: 28°C n=19, 32°C n=6). Oxygen consumption was not significantly significant across treatments ($p = 0.64$) or stages ($p = 0.20$).

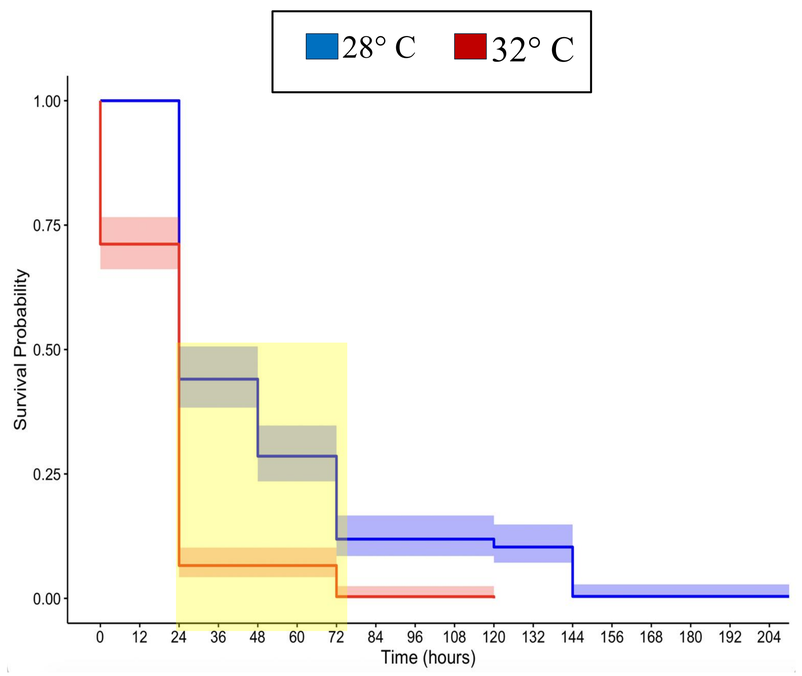


Figure 3. Larval survival (hours) in each treatment (28°C n=251, 32°C n=287).

Swimming Behavior

- Z1 larvae: significant changes in swimming direction.
  - Control (28°C): high tendency to swim up (~81%; $p < 0.001$)
  - Elevated (32°C): upward swimming was reduced and only 53% swam up (Figure 2; post hoc: $t = -3.2$, $p = 0.02$)
- Z2 larvae: most swam down.
  - Control (28°C): low tendency to swim up (~12%)
  - Elevated (32°C): slightly lower (~8%), but effect not statistically significant (Figure 2).

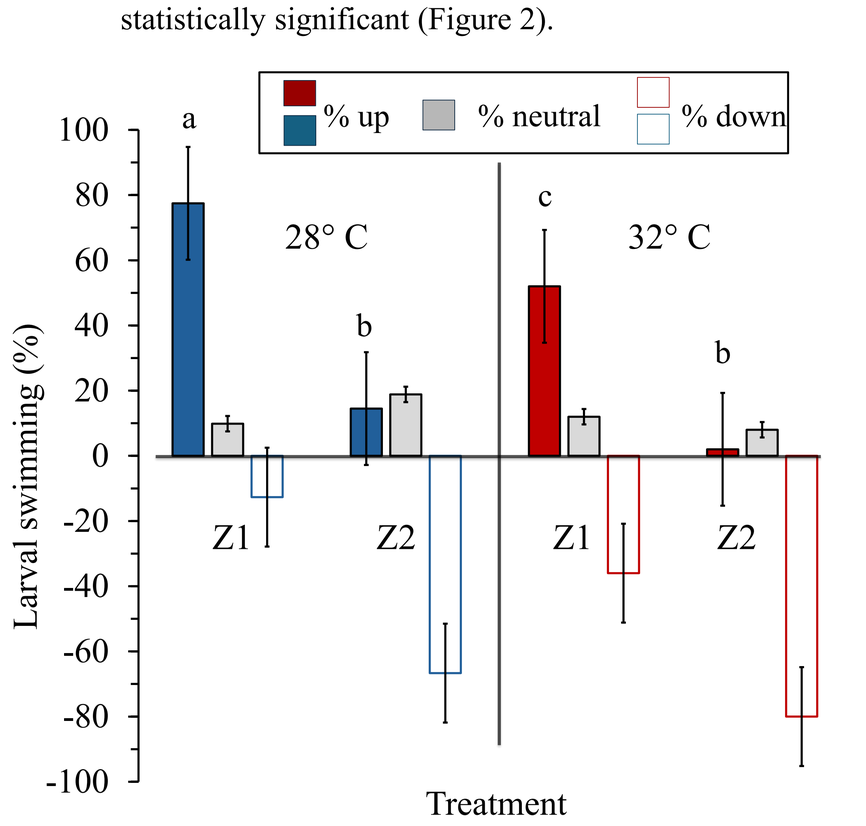


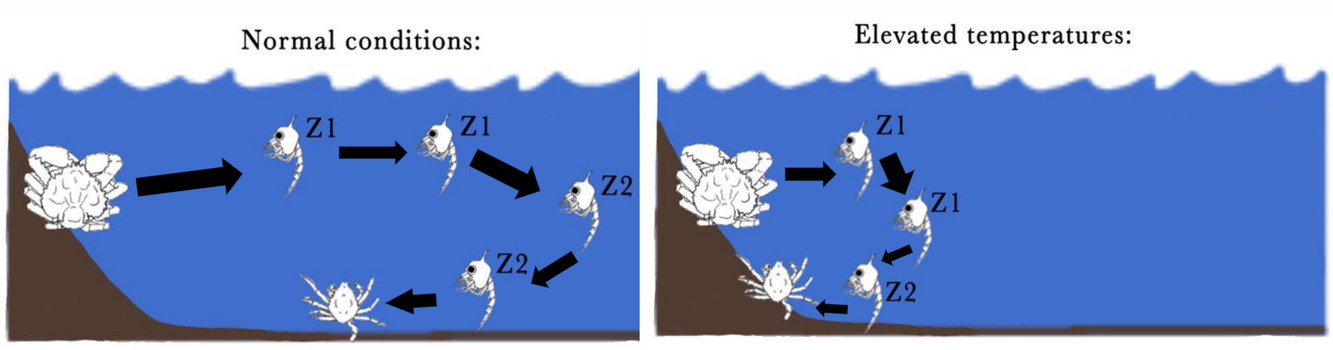
Figure 2. Percent of larvae swimming up, down, or eliciting a neutral response at 28°C and 32°C for both larval stages (Z1:28°C n= 70; Z2: 28°C n= 69; Z1:32°C n=50; Z2: 32°C n=50). Different variables (a, b, or c) indicate significant differences between stages or treatments.

Larval Survival

- Survival was lower in the elevated temperature treatment ($z = -6.5$, $p < 0.0001$) but this was dependent on time ($z = -5.1$, $p < 0.001$.
- Mean survival time was higher at 28°C for the first 72 hours of exposure compared to 32°C ($p_{24\text{-}48} = 0.01$; $p_{48\text{-}72} < 0.001$)
- Larvae at 28°C survived, on average, ~24–36 hours longer than those at 32°C
- Larvae in the elevated treatment were 1.3x more likely to die than cohorts in the control.
- There were no differences in survival among the treatments after 72 hrs.

Discussion and Conclusions

Our results indicate that elevated temperatures significantly reduce larval survival and upward swimming behavior, particularly in early-stage larvae (Z1), while later-stage larvae (Z2) are less responsive to temperature changes. Reduced survival and impaired swimming could limit larval dispersal and settlement success, which are critical for population replenishment. For management and restoration efforts, such as NOAA's *Mission: Iconic Reefs* project, these findings suggest that timing and site selection should consider local temperature regimes to maximize larval survival and recruitment. Specifically, outplanting during cooler periods or in areas with lower thermal stress may enhance larval retention and connectivity, ultimately improving the success of restoration initiatives. Additionally, monitoring larval behavior and survival under projected warming scenarios could inform adaptive management strategies to ensure long-term population resilience.



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