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Effects of Ecologically Realistic Heating Profiles on Feeding in the Intertidal Hermit Crab, Pagurus sameulis

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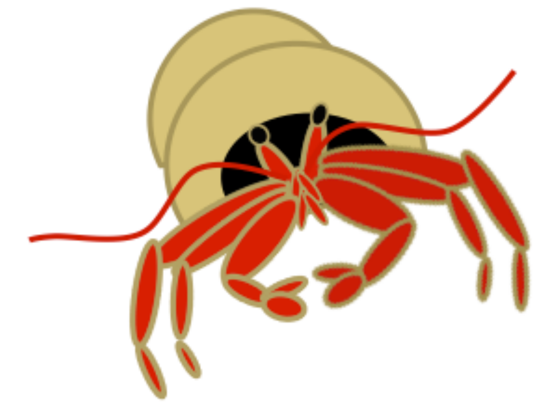

Effects of ecologically realistic heating profiles on feeding in the intertidal hermit crab, *Pagurus samuelis*

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Introduction

The intertidal zone is an ideal habitat to investigate effects of global warming because species living in it are existing very close to their physiological limits (Stillman, 2002). Work on the physiology (Tomanek and Somero, 2002) and behavior (James, 2013) of these species has generally involved rapidly warming individuals and measuring the consequences. However, these studies heat individuals much faster than observed in nature. In the present study, we applied a slower heat treatment to *Pagurus samuelis*, the blue banded hermit crab. These crabs are omnivorous detritivores, commonly found in tide pools on the west coast on North America.

Previous studies in the Wright lab and elsewhere have shown that feeding in this species is inhibited by an abrupt increase in temperature (James, 2013). Here we study the effects of three different rates of heating—Fast, Medium, and Slow—on hermit crab feeding. Fast repeats the James protocol while Medium and Slow utilize a different technique to create a constant and more gradual rate of temperature change. We hypothesize that this more gradual temperature increase (Medium, Slow) will have a more moderate effect on behavior than the abrupt temperature increase.

Experimental Methods

We collected hermit crabs from Little Corona, Newport Beach, CA (33°35'30.46" N 117°52'18.00" W). We also measured temperature (±0.2°C) increases in two tide pools on a foggy day (10/17/14).

Temperature Profile

We first replicated the abrupt heating method used by James (2013; Fast trial, Figure 2). We placed a hermit crab into a single cup with seawater at ambient temperature (18°C) and placed the cup directly into a water bath set at 29°C.

In contrast to the James protocol, in the Medium and Slow protocols we sought to create a slower and more constant temperature increase. To do so, we stacked three (Medium) and five (Slow) plastic cups together and placed them into a large (2000 mL) Tupperware container. Water in the cups (60 mL) and large Tupperware container was initially 18°C. We then placed the Tupperware container with the cups inside into a water bath set to 50°C. The water inside the cups was heated until 29°C was reached. At this time, the system was transferred to a 29°C water bath for the duration of the remaining experiment to maintain constant temperature. See below for temperature profiles.

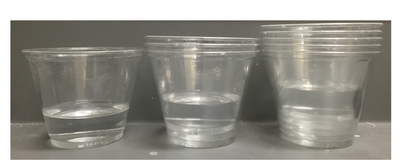

Figure 1: 1, 3, and 5 stacked cups with 60 mL of water within them

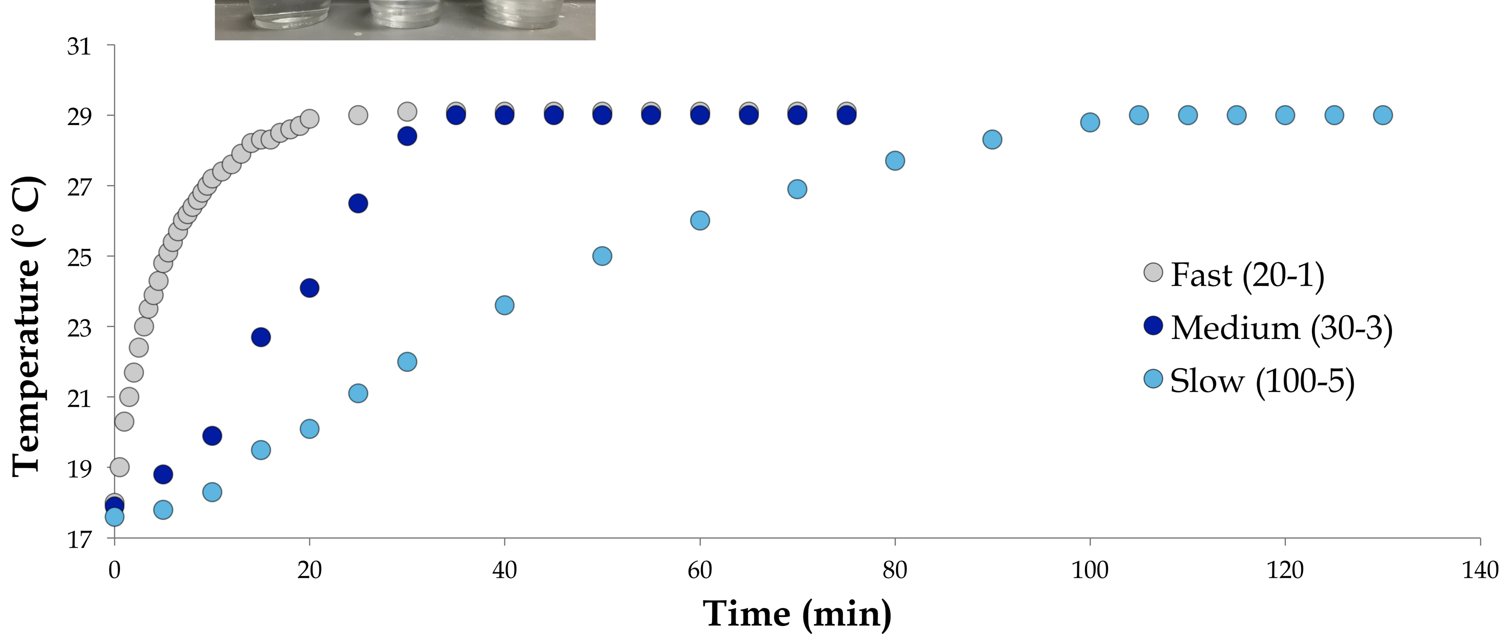

Figure 2: Previous experimental manipulations (James, 2013) causes rapid and non-linear increase in temperature (Fast) compared to methods of the present study, which produces constant and slow rate of temperature change (Medium, Slow).

Methods (Continued)

Feeding Experiment

In each experiment, 16 hermit crabs were selected and tested for feeding. Crabs were divided into experimental (Fast, Medium, or Slow) or control, each with 8 crabs and 3 blank cups (no hermit crab) for each of the 4 treatments. Heating began at time zero. We introduced a pre-weighed standardized squid pellet (Takagi et al. 2010) 45, 45, and 100 minutes after heating began in the Fast, Medium, and Slow trials, respectively. Crabs were allowed to consume the pellet for 30 minutes. We removed the crabs and weighed the pellets following the feeding. We calculated "Consumption" as change in pellet weight minus average change in weight of blanks. Each crab's "standardized pellet consumption" was calculated as Consumption divided by the average Consumption of crabs held in ambient (18°C) water temperature.

Results

1) Tide pool temperature

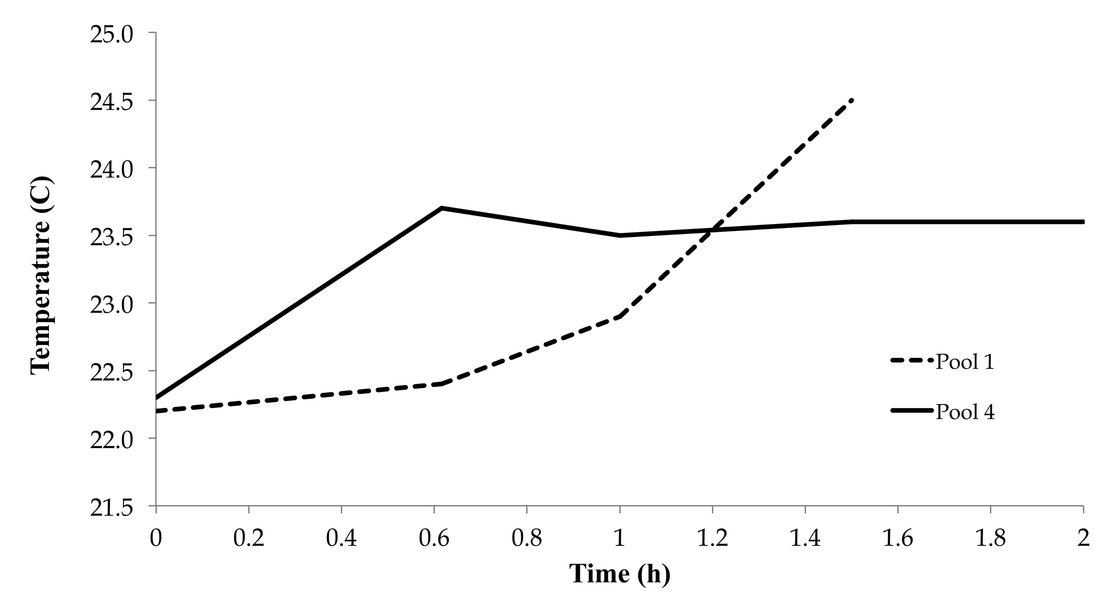

Figure 3: Heating rate of two selected tide pools at Little Corona, Newport, on a foggy day (10/17/14). We collected temperature beginning at 2:00PM (time 0, x axis). Largest temperature increase occurred between 3:00PM and 3:30 PM (1-1.5 h; 3.2°C•h^{-1}; cf., Figure 2, 6.8°C•h^{-1} for Slow).

2) Consumption in each trial

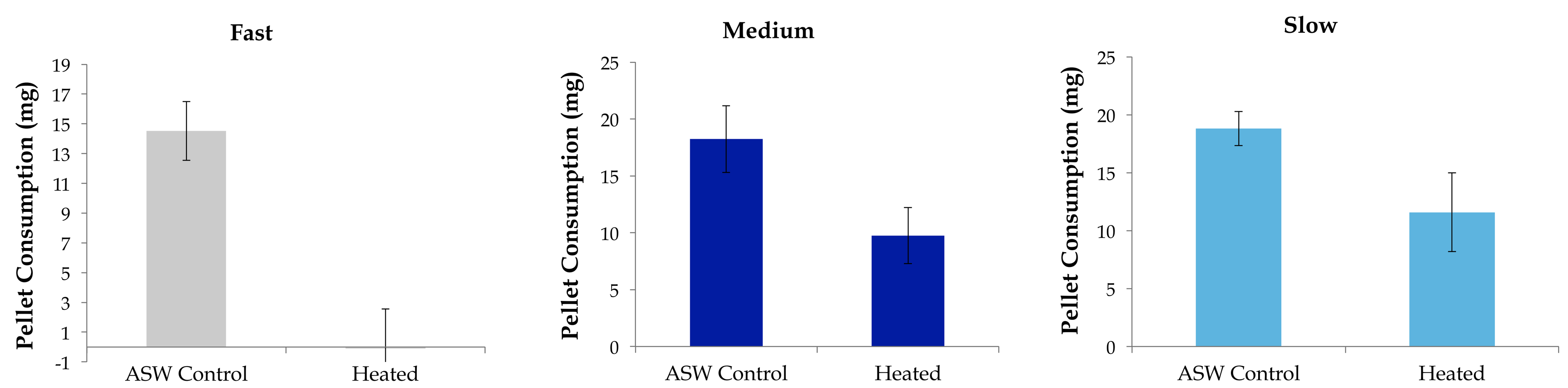

Figure 4: Slower rate of change to 29°C mitigates the inhibitory effect of hot temperature on pellet consumption. Shown is pellet consumption (mg) in three different heating rates (Fast-20 min, Medium-30 min, and Slow-100 min). See Figure 5 for statistical comparisons.

3) Standardized pellet consumption

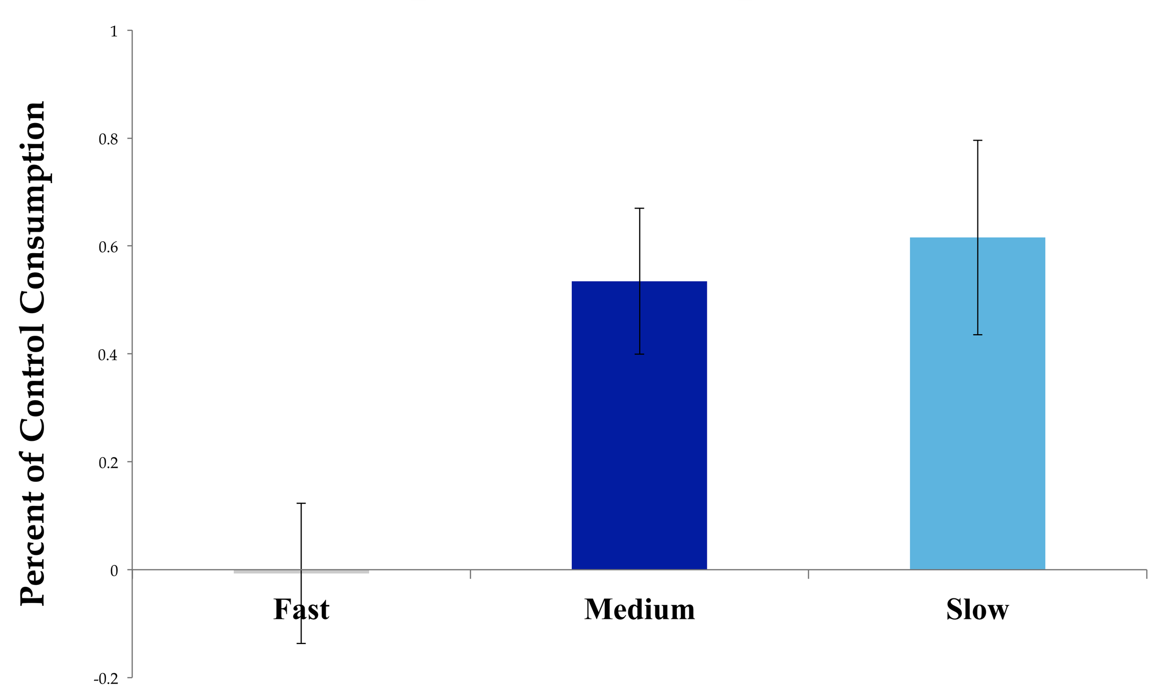

Figure 5: Pellet consumption was significantly increased by decreasing rates of heating. Shown is consumption standardized by each experiment's average control (ANOVA, $F_{2, 21} = 5.39$, $P = 0.013$). Individual t-tests with a Bonferroni correction showed significance at $\alpha=0.05$ between Fast and Medium trials, and a trend ($0.05 < P < 0.10$) between Fast and Slow trials.

Discussion

These experiments showed that rapid temperature rise to identical maximum temperatures inhibits food consumption in *Pagurus samuelis*, whereas more gradual and realistic temperature increases do not. Thus, previous studies at the biochemical (Tomanek and Somero, 2002) and behavioral (James, 2013) levels likely overestimated the effects of heating on organisms. These data demonstrate the value of an intertidal invertebrate model system to help us predict the consequences of global warming on organisms in their natural habitat.

Climate scientists predict that Southern California will likely have hotter and longer heat waves in the future (Tamrazian et al. 2008). We suggest that our approach will help us understand the consequences of such heat waves.

Finally, these data are important at a more specific ecological level because hermit crabs, *Pagurus samuelis*, are among the most abundant species in the intertidal zone. Thus, heat induced changes could have significant consequences on the intertidal community.

Acknowledgments

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