12-10-2014

The Non-Lethal Effects of Climate Change on the Territoriality of Lottia gigantea

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The non-lethal effects of climate change on the territoriality of *Lottia gigantea*

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Introduction

The intertidal zone has been described as ground zero for global warming (Harley et. al, 2006). Here, organisms, such as the owl limpet, *Lottia gigantea,* adapted to the cool ocean temperatures, must withstand a few hours of baking sun during day-time low tides, a hardship that is predicted to increase in frequency and severity in the future (Diffenbaugh & Giorgi, 2012). Although there is a growing literature on the cellular responses of intertidal invertebrates to such heat events, relatively little is known about more holistic effects on natural behavior and ecology.

Background & Hypothesis

The territorial behavior of *Lottia gigantea* provides individual limpets with an exclusive garden of algae (Stimson, 1970). This behavior is surprisingly complex (Wright, 1985), raising the possibility that it may be vulnerable to heat events. Our research investigates the sub-lethal role of heat events on territorial behavior of *Lottia gigantea*. We hypothesize that heat events compromise territorial behavior.

Materials and Methods

All observations and experiments were performed at Inspiration Point (33.590519° , -117.870750°) near Newport Beach California. Limpets were labeled using epoxy glue and numbered tags. We measured radiant heat from these limpets during day-time low tides using a field-calibrated infrared "thermogun". We also measured shell length to the nearest mm.

We observed behavior of labeled limpets during high-low tides (0.5-0.6m). We staged territorial encounters using "bait limpets", removed from a different location, placed in front of tagged foraging subject limpets (Wright, 1985). We recorded the following responses:

- Territorial- movement (> 1 shell length) toward the bait limpet,
- Retreat – movement (> 1 shell length) away from the bait limpet,
- No Response- movement of less than 1 shell length. We also recorded the speed of the response.

We first identified pairs of limpets of similar shell length, location, and past behavior. We then randomly assigned one of each pair to be the experimental and the other to be the control. During day-time low tides, radiant temperatures of experimental limpets were amplified by 7-12°C above ambient temperatures using the heat of the sun reflected off of 4 to 8 hand mirrors. Control limpets were not heated. The radiant temperatures of both limpets were monitored every 10-15 min during the experiment. During the next high-low tide following (>6 h) the heat experiment, both limpets were tested for territorial behavior.

Figure 1. Baiting a limpet to induce a response (territorial, retreat, or no response) from a moving subject limpet. The bait limpet (upper left) is held in front of the subject limpet (lower right).

Figure 2. A single limpet-heating experiment. The experimental subject limpet is illuminated (bottom right) with 8 hand mirrors (upper left). The control limpet remains in the shadow of the adjacent substratum.

Results

Heat-Behavior Correlation.

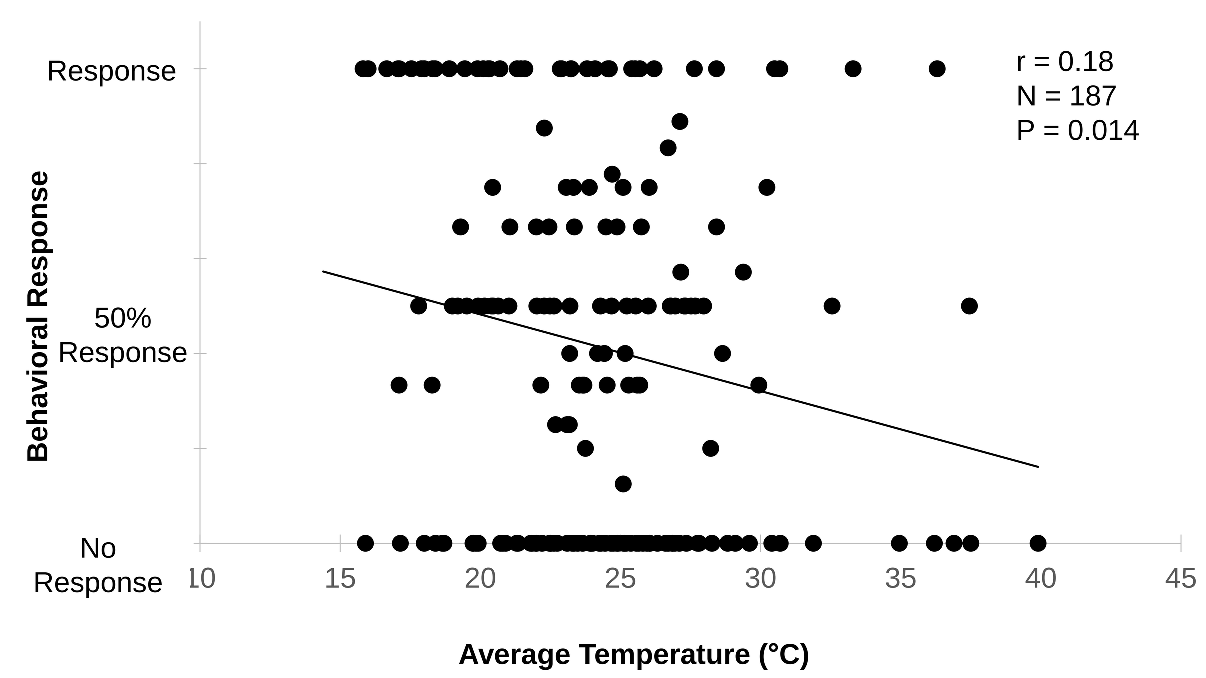

Figure 3. Behavioral responsiveness (Territorial or Retreat behavior) of individual limpets (N = 187) decreases as limpet temperature (averaged across 8 months, November-July; P = 0.014) increases.

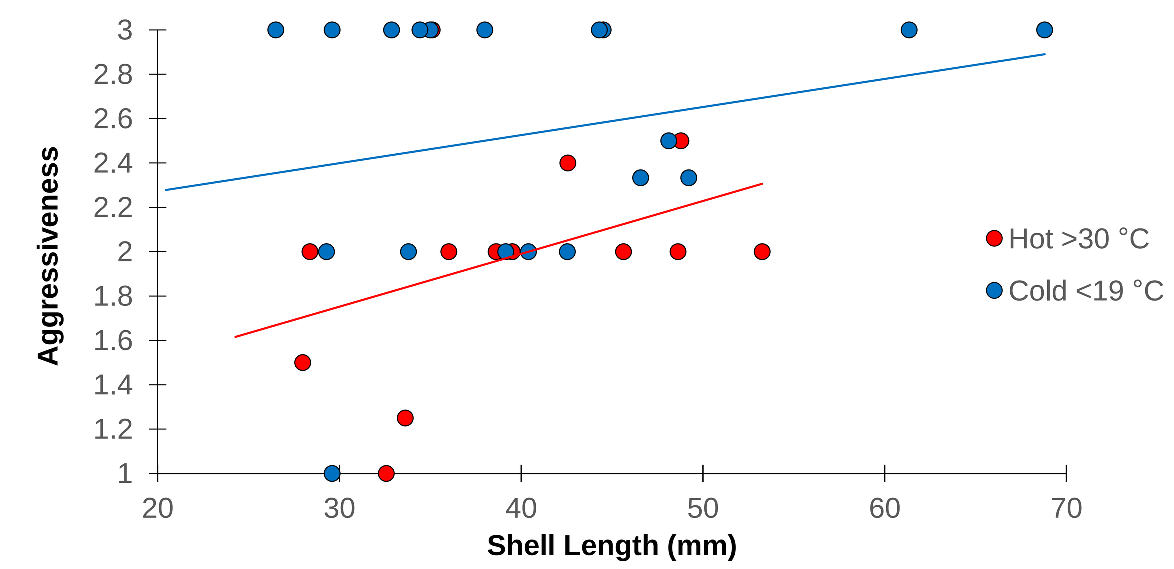

Figure 4. Aggressive behavior (Territorial = 3, No Response = 2, Retreat = 1) increases with increasing size. Cold limpets (N =18, blue symbols; average temperature <19°C) are significantly more aggressive (P = 0.022) than warm limpets (N = 13, red symbols; average temperature > 30°C).

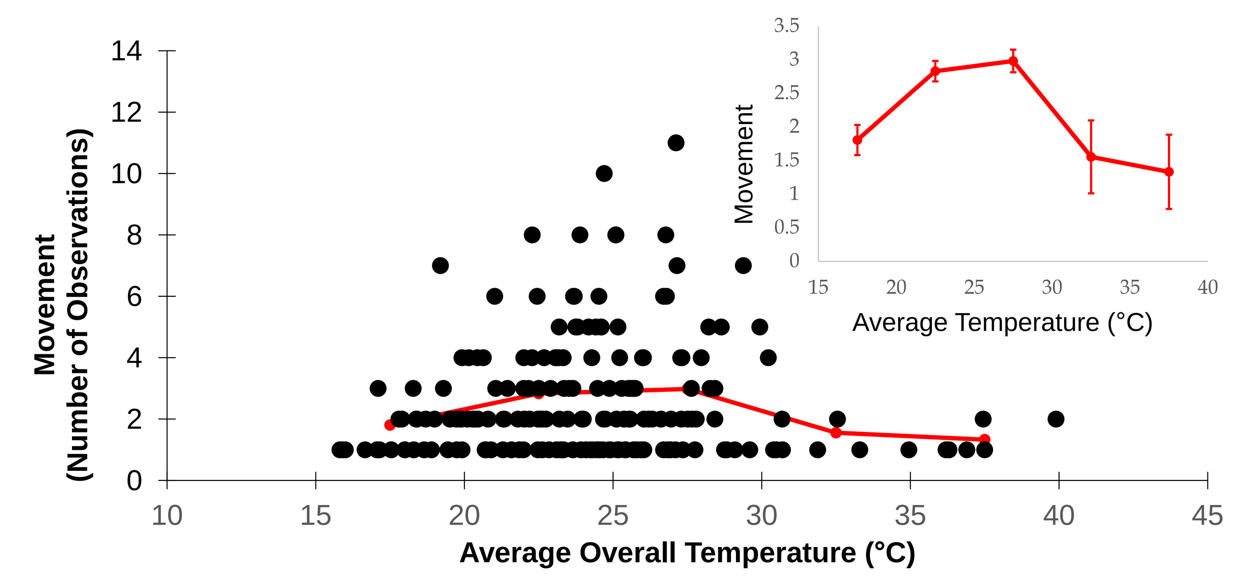

Figure 5. Movement frequency peaks between 25°C and 30°C (N = 177). The insert on the right plots the average movement frequency (± standard error of mean) at 5-degree intervals.

Heat Amplification Experiments. The heat experiments began during sunny day-time low tides and ended when the limpets were wetted by the incoming tides (40-100 minutes).

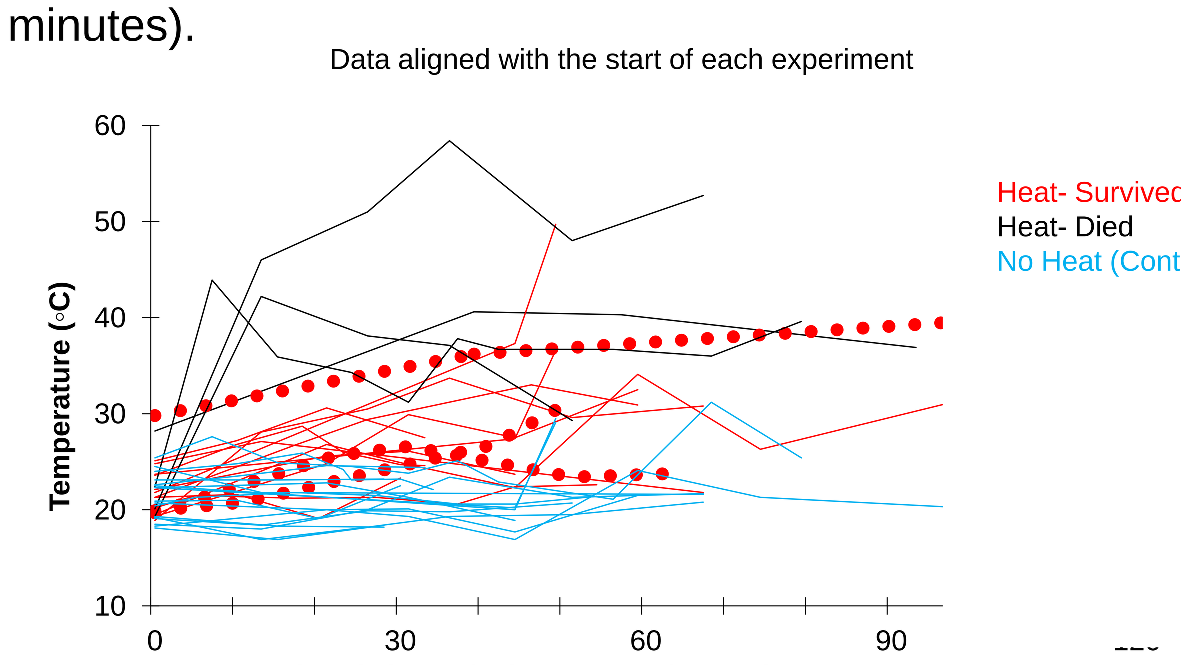

Figure 6. Of the experimentally heated limpets, the warmest (maximum radiant temperature > 40°C, black lines), limpets died or went missing. Of the experimental limpets that did not die (red lines), only three (dotted lines) demonstrated a decrease in territoriality.

Discussion

The natural correlation shown in Figure 3 suggests that increased temperature can decrease behavioral responsiveness of an owl limpet. Furthermore, the fact that cool limpets were significantly more territorial than warm limpets (Figure 4) suggests that warm temperatures may reduce aggressiveness. However, the experimental test of elevated temperature on limpet behavior gave little support to the temperature-behavior hypothesis (Figure 6). These experiments successfully amplified experimental limpet temperatures above that of controls, but these amplified temperatures failed to significantly reduce territorial behavior. In future experiments, temperatures will be amplified at a constant rate and for a longer period of time.

Conclusions

1. **There is a negative correlation between temperature and behavioral responsiveness *L. gigantea* (Figure 3)**
2. **Warm limpets were consistently less aggressive across size than were cool limpets (Figure 4)**
3. **Experimental evidence of high temperatures reducing territoriality was lacking, likely because of the short time span of heat amplification (Figure 5)**

Significance

Lottia gigantea is a *bona fide* "ecosystem engineer" (Jones, 1994): its territorial behavior shapes the rocky intertidal community (Stimson, 1970). If, as hypothesized here, more frequent heat events, predicted by climate-change biologists reduce territorial behavior of *L. gigantea*, this could significantly alter the community structure of the rocky intertidal.

Acknowledgements

We'd like to thank Dr. John Yules, Ryan Kabala, Bishoi Nassef, Jeremy Feck, Alex Williams, Amelia Cunningham, John Berriman, Alex Hall, and Max Suonoo for helping with data collection and the Chapman Office of Undergraduate Research for funding this project.

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