The Influence of Temperature on the Rate of Oxygen Consumption of Harvester Ants from Two Different Species and Climates

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Introduction

Ants are one of the most dominant animal groups in the world. Their dominance means that they have a significant influence over terrestrial environments in that they are involved in symbiotic relationships with plants, are sources of food for other animals, are predators for other insects, and aid in mixing nutrients. (Keck Science Department, 2018). With their importance in mind, it is important to address how the current issue of global warming may be affecting ants whose small bodies can be easily affected by temperature. Research has been done to determine how temperature affects ants’ metabolic rates by analyzing their oxygen consumption at various temperatures (Vogt & Appel, 1998). Interestingly, research has found that the *P. californicus* forages at hotter temperatures than *P. rugosus*, which forages at cooler temperatures, suggesting that different species of harvester ants are active at different temperatures (Lighton & Turner, 2004).

Harvester ants, specifically *P. barbatus*, are native to southwestern US (Gordon et al., 2011). Harvester ants are highly active, as they must individually forage scattered food sources (seeds) (Gordon et al., 2011). Temperature influences respiration, a physiological characteristic that is key when ants must perform active work, such as foraging (Vogt & Appel, 1998). Research has shown that as temperature increases, the oxygen consumption of *P. rugosus* does too, suggesting that harvester ants are able to metabolize and actively work in hot temperatures (Lighton & Bartholomew, 1988). However, it is vital that harvester ants reside in regions with climate that allow them to achieve their optimal performance, as it is important for not only the ants ability to forage and survive, but also the survival of the colony as a whole. For this reason, it is key that attention is being paid to changes in climate that may result from global warming.
In this experiment, we investigated the effect of various temperatures on the metabolic rates of ants from different species (but same genus: *Pogonomyrmex*—harvester ants). We hypothesized that ants from a hotter on average region will have a higher optimal performance temperature, and thus rate of oxygen consumption at higher temperatures, than ants from cooler regions. This indicates that ants from hotter regions will reach their peak in performance activity at higher temperatures. Because we know that the *Pogonomyrmex barbatus*, from Utah, live in temperatures ranging from 18°C to 22°C (Gordon et al., 2011) and ants from the BFS live in temperatures ranging from 25.5°C to 28.0°C, a temperature range found using after collecting above ground temperatures at the BFS for a week, we predicted that ants from the BFS will have achieve optimal performance temperature at hotter temperatures than *P. barbatus* due to ants from the BFS being from a hotter climate.

The literature shows that between two species of harvester ants (*P. californicus* and *P. rugosus*), the ant which forages at hotter temperatures (*P. californicus*) has a higher optimal performance temperature, meaning its optimal performance temperature is greater than the ant which forages at cooler temperatures (*P. rugosus*) (Lighton & Turner, 2004). Metabolic rates of our ants will be determined using a closed-system respirometry. We ran the respirometry test on the two different species at four different temperatures to calculate their oxygen consumption. These measurements will determine whether ants from the different locations and thus habitats have different temperatures in which they experience optimal metabolic rates due to their different temperate origins. This may possibly suggest an ants optimal temperature for activity and suggest how an ant may be affected by global warming.
Methods

Organisms Studied

The Harvester ants collected were from two different locations and thus climates. The harvester ants from the Bernard Field Station were *P. californicus* and the ants from Utah were *P. barbatus*.

Experimental Set Up

We collected *P. californicus* from the BFS which had a nest just off the main trail in an area that received no shade and had little plant life. In the location where the nest was found, a data logger was inserted into the soil to determine the average temperature of the general region around the nest. A week later, the data logger and 40 ants were collected from the nest and a respirometry experiment was performed on the ants.

For the respirometry experiment, a closed-system respirometer was used, as seen in Figure 1. KOH was used in one vial to precipitate out CO₂ and only measure oxygen consumption.

10 ants were placed in one of the two vials. The apparatus was placed in a water bath at a specific temperature with water levels at the top of the vial. Respirometers were allowed to equilibrate for 10 minutes in the bath before taking measurements. Every ten minutes the water level was recorded for each tube.

This process was done in water baths at four different temperatures (10°C, 20°C, 35°C, and 40°C) for ants from BFS and the ants from Utah (*P. barbatus*). At 10°C and 35°C water levels were recorded for 30 minutes. For 20°C and 40°C water levels were recorded for 40 minutes.
Data Collection and Analysis

To determine the temperature of the general region of the nest at the BFS, the data logger was collected after a week and maximum and min surface temperature was calculated as well as the maximum and minimum soil temperature.

To test the effect of temperature (independent variable) on the oxygen consumption of ants (dependent variable), the total oxygen consumed per minute per ant was calculated for each temperature. This was done by recording the water levels in the ant chamber and control chamber, calculating the total movement after 30 or 40 minutes, and dividing the movement by the number of ants times the number of minutes. From this, a performance curve was created for each ant species and a linear regression was fit to the curve. These curves were compared to see the difference in the rate of oxygen consumption of different species of ants at different temperatures. Previous research has shown that the curves provide the pejus, critical, and optimal temperatures for each ant (Miller and Stillman 2012). The pejus temperatures are temperature at which performance declines. Critical temperatures are temperatures at which ants cannot perform and face the risk of death. Optimal temperatures are temperatures at which the ant is most active and is consuming the most oxygen.

Results

The rate of oxygen consumption per ant for each temperature for both the *P. rugosus* and *P. californicus* exhibited behavior that allowed for a performance curve to be fit to the data points. This performance curve indicated the critical temperatures, the pejus temperatures, and the optimal performance temperature.

As seen in Figure 2 the *P. californicus*, the performance curve for these ants are incomplete because the temperature range that was used did not likely allow the ant to reach its optimal performance temperature. Their rate of oxygen consumption exhibits logarithmic
behavior. When looking at the performance curve, the ants from the BFS are estimated to have critical temperatures below 10°C and above 45°C. Their optimal temperature was can be estimated to be about 40-45°C. Their lower pejus temperatures could be estimated to be 35°C, but the incomplete curve makes it difficult to estimate the upper pejus temperature. The fit polynomial curve provides an R² value of 0.189, which indicates that about 18.9% of the variability in the rate of oxygen consumption at different temperatures was due to the temperature.

![Graph](image)

**Figure 2.** The effect that temperature has on amount of oxygen consumed (mL) per ant per minute for *P. californicus* \((y=45\times10^{-5}\ln(x)-2\times10^{-5}, \ R^2=0.189)\).

In Figure 3 it is seen that the *P. barbatus* from Utah had an lower critical temperature of 10°C and an upper critical temperature of 30°C. Their optimal performance temperature was about 25°C. Their lower pejus temperature was about 18°C and their upper was about 30°C. The fit polynomial curve for this the *P. barbatus* gives an R² value of 0.6701 which indicates that 67.01% of the variability in the rate of oxygen consumption at different temperatures was due to the temperature.
**Figure 3.** The effect that temperature has on amount of oxygen consumed (mL) per ant per minute for *P. barbatus* ($y=2\times10^{-6}x^2 + 8\times10^{-5}-0.0005$, $R^2=0.6701$).

**Discussion**

It was hypothesized that ants from hotter environments, *P. californicus*, would have a higher optimal performance temperature than ants from cooler regions, *P. barbatus*. The data supports this hypothesis. The results show that the *P. californicus*, which has an estimated optimal performance temperature of about 40-45°C, has a higher optimal performance temperature than the *P. barbatus*, which has an optimal performance temperature of about 25°C. This is supported by the figures, which show the relationship between oxygen consumption rate and temperature to be shifted right for the *P. californicus*. Additionally, the *P. californicus* rate of oxygen consumption was stable at temperatures at which the *P. barbatus* reached its critical limit, suggesting that the *P. californicus* can be active at a broader range of temperatures. Additionally the data shows that the *P. barbatus* had a greater maximum rate of oxygen consumption than *P. californicus*, however at cooler temperatures. This difference in the rate of oxygen consumption could be due to differences in mass between the two species, but further research would need to be done to confirm this.
Additionally, the data supports the conclusion of a study which indicated that increasing temperatures causes an increase in the oxygen consumption of *P. rugosus*, which implies that harvester ants are able to work in hot temperatures (Lighton & Bartholomew, 1988). Our conclusion aligns with this, as the oxygen consumption increased with temperature for both species of harvester ants. Our data specifically supports the present literature which found that between two different species of harvester ants, *P. californicus*, which forages at hotter temperatures, and *P. rugosus*, which forages at cooler temperatures, the *P. californicus* has a higher optimal performance temperatures (Lighton & Turner, 2004). The data from the data logger, as seen in Table 1, indicates that the average temperatures at which the *P. californicus* lives (25.5°C - 28°C) is hotter than temperature at which the *P. barbatus* lives (18°C to 22°C). This indicates that the temperature at which the *P. californicus* forages would be hotter than the temperature at which the *P. barbatus* forages. Thus, the *P. californicus*’s right shifted performance curve aligns with present research.

**Table 1.** Average minimum and maximum surface and underground temperatures per day at the *P. Californicus* nest site at the Bernard Field Station.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Max of Underground (°C)</th>
<th>Min of Underground (°C)</th>
<th>Max of Surface (°C)</th>
<th>Min of Surface (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Apr</td>
<td>23</td>
<td>21</td>
<td>23.5</td>
<td>21</td>
</tr>
<tr>
<td>4-Apr</td>
<td>22</td>
<td>18.5</td>
<td>22.5</td>
<td>18.5</td>
</tr>
<tr>
<td>5-Apr</td>
<td>31.5</td>
<td>18.5</td>
<td>34</td>
<td>11.5</td>
</tr>
<tr>
<td>6-Apr</td>
<td>30.5</td>
<td>14</td>
<td>34.5</td>
<td>8.5</td>
</tr>
<tr>
<td>7-Apr</td>
<td>33</td>
<td>15</td>
<td>39</td>
<td>9.5</td>
</tr>
<tr>
<td>8-Apr</td>
<td>34</td>
<td>18</td>
<td>41</td>
<td>9.5</td>
</tr>
<tr>
<td>9-Apr</td>
<td>36</td>
<td>14.5</td>
<td>48.5</td>
<td>7.5</td>
</tr>
<tr>
<td>10-Apr</td>
<td>37</td>
<td>17</td>
<td>47.5</td>
<td>10</td>
</tr>
<tr>
<td>11-Apr</td>
<td>36.5</td>
<td>17</td>
<td>42.5</td>
<td>8.5</td>
</tr>
<tr>
<td>12-Apr</td>
<td>33</td>
<td>17</td>
<td>35.5</td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>37</strong></td>
<td><strong>14</strong></td>
<td><strong>48.5</strong></td>
<td><strong>7.5</strong></td>
</tr>
</tbody>
</table>
From the data we can see that harvester ant species, *P. californicus*, from hotter habitats have both higher optimal temperature and a broader range of temperatures at which they can be active and do work, whereas the *P. barbatus* could perform work at a smaller range of temperatures, as seen by its pejus temperatures (18°C-30°C). This suggests that ants from cooler habitats may be at a greater risk with regard to climate change because the temperatures at which they can do work are much more narrow than that of *P. californicus*, which can do work at higher temperatures and a broader range of temperatures.

Future investigation should carry out more trials at each temperature. This would potentially improve the $R^2$ values. Additionally, to eliminate the influence of mass on oxygen consumption and isolate the influence of habitat temperature, a study should be done on the same species, but from two different temperate regions. For example testing the rate of oxygen consumption of *P. californicus* from a more southern, hotter region to *P. californicus* in the BFS.


