Dynamical Thermoregulation of Honey Bees Colonies

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CISA Student Showcase

Background Information

- Honey bees play an extremely **important role in ecosystem** stability and diversity and in the production of bee-pollinated crops [1].
- Honey bees are **under threat** from the combined effects of parasites, diseases, poor nutrition, pesticides, and **climate changes** that impact the timing, duration, and variability of seasonal events [2].
- Abiotic factors (**temperature** and relative humidity) affect honey bee **internal activities** (brood rearing, food storing, social homeostasis, adjusting internal colony temperature to a suitable range) and **external activities** (worker foraging and flight activity of queens and drones).
- Beekeepers reported several **consequences related to severe weather events** (weakening or loss of colonies; scarcity of nectar, pollen, and honeydew; decrease or lack of honey and other bee products; greater infestation by varroa; decline in pollination), **making it necessary to provide** supplemental sugar feeding, intensive transhumance, more effective and sustainable techniques for varroa control, and increased production of nuclei.
- Previous modeling work highlighted that seasonality is important for hive survival [2,3]. Climate change shifts the timing of season events, and seasonality changes cause hives to collapse.

Research Question

How can a graphical model of the temperature of 5 different locations inside a honey bee colony provide insight into the effect of extreme temperatures on honey bees?

Hypothesis

If a graphical model of the temperature of 5 different locations inside a honey bee colony is determined, the temperature of the brood center will be higher than that of the outer edge because of the honeybees' attempts to mitigate the extreme heat conditions.

Methods

- The temperature inside the honeybee colony is examined by placing temperature data loggers at different locations inside the colony
- There are **5 loggers** in each honeybee colony (Fig1): 2 out edge (OE), 2 brood edge (BE), and 1 brood center (BC)
- The temperature is recorded every **30 minutes**
- The data collection period of 1 year is split up into 5 sessions
- Temperature vs. time for each logger is graphed based on the session
  - Calculate the maximum, minimum, and average temperature by date.
  - Compare airport temperature with same-day in-hive temperature.
  - Use a linear regression model to quantify the relationship between environmental and in-hive temperatures. Y indicates in-hive temperature, X indicates environmental temperature, a indicates the slope , and b indicates intercept.

$$Y = aX + b$$

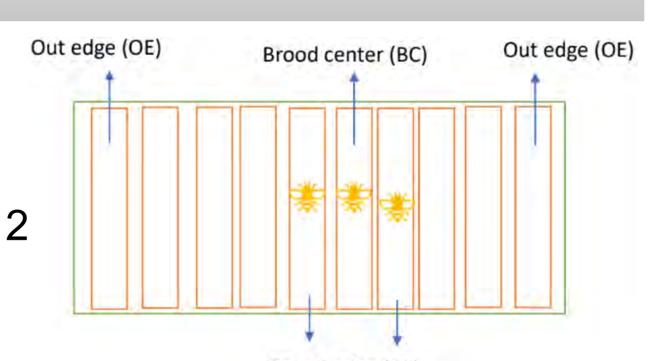

Fig1: logger position in the hive. The honey bee icon means brood frames

Results

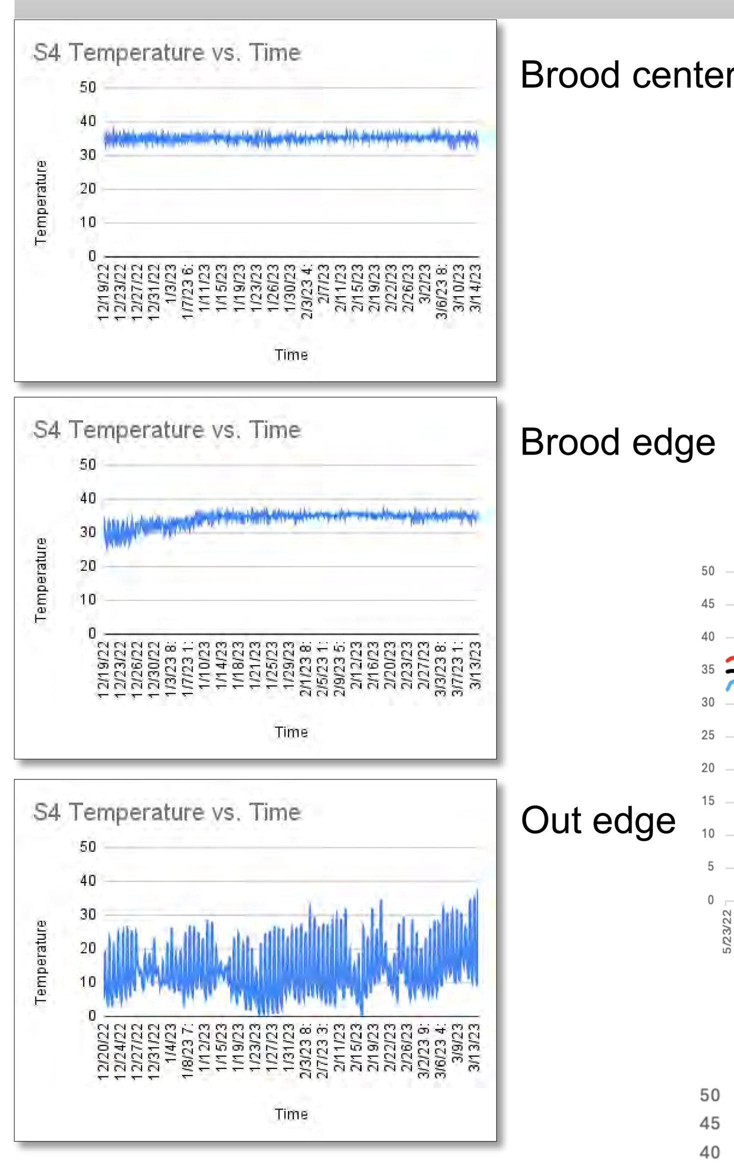

Fig2: Temperature in bee hive by time series

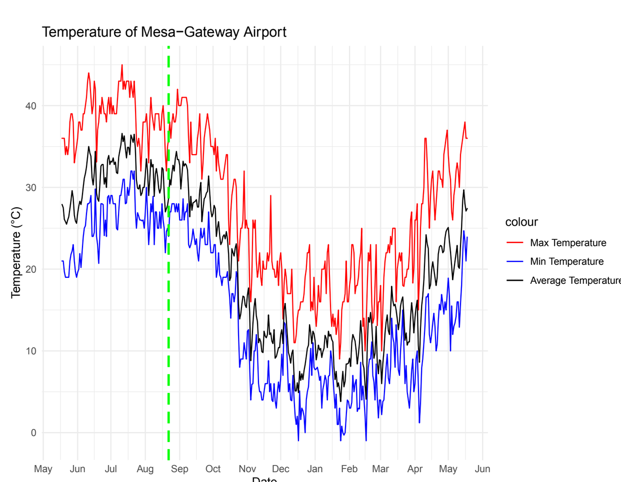

Fig3: Environmental temperature by time series. Green is Aug 22nd

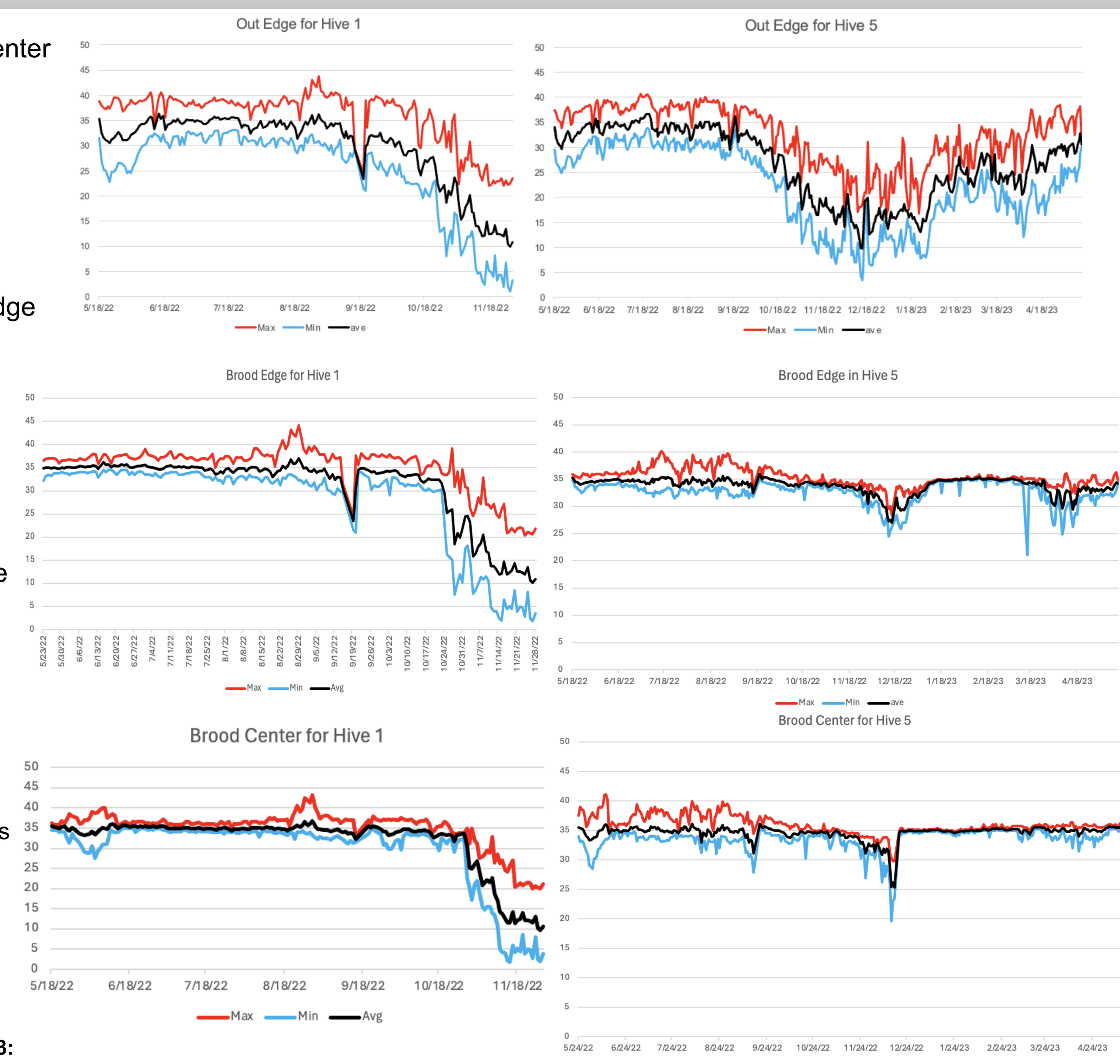

Fig4: Temperature (maximum, average, and minimum) in bee hive (BE,BC and OE) by time series

Fig5: Relationship between airport temperature and in-hive temperatures (OE, BE, and BC). Linear regression model for data.

- The temperature of the hive fluctuates more on the outer edge than on the brood center and brood edge (Fig 2).
- The environmental temperature varies greatly daily in AZ, and summer is over 40 ℃ (Fig 3).
- The brood center averaged nearly 35℃ throughout all of the year except for winter (Fig 4).
- The collapsing hive (hive 1) has thermoregulation until October. Out Edge is the first to lose thermoregulation, then the brood edge, and last is the brood center (Fig 4).
- The survival hive (hive 5) has better thermoregulation in the brood edge and brood center for a whole year. However, the out edge has a lower temperature in the winter and rises back in spring (Fig 4).
- The temperature thermoregulation of the brood edge and brood center of the survival hive is very stable regardless of the environmental temperature, but the collapsing hive did not (Fig 5).
- When faced with environmental temperatures, the collapsing hive has worse thermoregulation (higher slope) than the survival hive (Fig 5).
- In the collapsing hive, the brood center has the smallest slope, and the out edge has the largest slope (Fig 5). When faced with environmental temperatures, honey bees do the best thermoregulation in the brood center.

Conclusions

- **Honey bees do the best thermoregulation in the brood center at around 35℃.**
- **Thermoregulation is the key to survival.**
- **It is more difficult to thermoregulate in winter than in summer.**

Literature Cited & Acknowledgement

[1] Kristine M Smith, Elizabeth H Loh, Melinda K Rostal, Carlos M Zambrana-Torrelio, Luciana Mendiola, and Peter Daszak. Pathogens, pests, and economics: drivers of honey bee colony declines and losses. EcoHealth, 10(4):434–445, 2013.

[2] Chen, Jun, Gloria DeGrandi-Hoffman, Vardayani Ratti, and Yun Kang. "Review on mathematical modeling of honeybee population dynamics." *Mathematical Biosciences and Engineering* 18, no. 6 (2021).

[3] Chen, Jun, Jordy O. Rodriguez Rincon, Gloria DeGrandi-Hoffman, Jennifer Fewell, Jon Harrison, and Yun Kang. "Impacts of seasonality and parasitism on honey bee population dynamics." *Journal of Mathematical Biology* 87, no. 1 (2023): 19.

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