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Using Technology to Monitor Honey Bee (Apis mellifera) Winter Clusters: A Study in Comparative Advantages of Thermal Imaging and Temperature/Humidity Sensing Technologies

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Using Technology to Monitor Honey Bee (*Apis mellifera*) Winter Clusters:
A Study in Comparative Advantages of Thermal Imaging and Temperature/Humidity Sensing Technologies

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Introduction: Wintertime is difficult for many beekeepers, as honey bees must keep themselves warm and dry while surviving on food stores from previous seasons [4]. Honey bees are able to survive such cold temperatures by vibrating their bodies in a cluster, which moves throughout the hive, to keep themselves and the queen warm and dry [4]. Outside temperatures greatly influence the efficiency of the internal cluster of the hive [4]. Honey bee colonies have the most efficient (i.e. least amount of energy spent and least amount of food stores used) clusters when the outside temperature is between 40-50°F; the efficiency of this cluster greatly breaks down when the outside temperature rises slightly above 50°F [4]. At this temperature the mechanics of the cluster change drastically; this is the point at which most energy is expended and the highest amounts of food stores are consumed [4]. Newly available technologies may be useful for beekeepers to improve management techniques during the winter season [1,2,3,4,5,6,7,8,9]. This study used an infrared (IR) smartphone camera accessory (FLIR One Thermal Imager), temperature, and relative humidity sensors (from BroodMinder™). The goal was to determine practical uses of these technologies in winter management.

Methods: In order to collect data, temperature and relative humidity sensors (8 temperature and relative humidity sensors, 15 temperature only sensors) were placed in various locations inside 8 hives and 1 nucleus colony at the Grand Valley State University Apiary in Holland, MI. The hives used for this study were comprised of unwrapped standard 8 wooden hives. Temperature and relative humidity sensors were placed directly under the covers of the hives, and 1 or 2 temperature only sensors were placed under the first and second boxes. The FLIR One IR smartphone accessory (Fig. 5) was used to take 11 sets of weekly pictures before 8am and within an hour before sunrise. This timing was used in order to achieve the best thermal contrast between the hives and the background (sparse woods). At this time hourly temperature and relative humidity data was synced from the BroodMinder™ (Fig. 4, Fig. 6) sensors to the beekeeping.io web portal (Fig. 7).

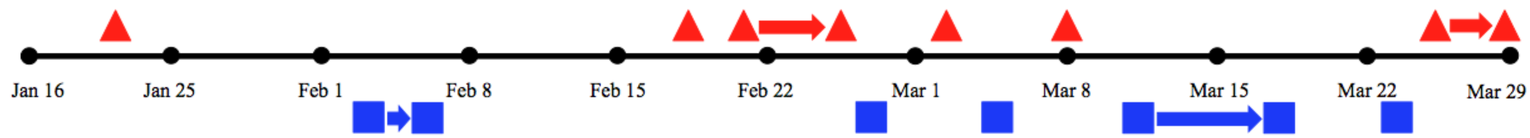


Figure 1: Timeline of warm and cold days Black dots represent dates on which IR photos were taken, ▲ represent "warm" days (temperature reached at least 45°F), ■ and represent "cold" days (temperature dropped below 25°F)

Warm Days: above 45°F, ▲

Figure 2: Representative pictures 2/22 Hive 1 (left), Hive 5 (right)

Figure 3: Representative pictures 3/8 Hive 1 (left), Hive 2 (center), Hive 5 (right)

Cold Days: below 25°F, ■

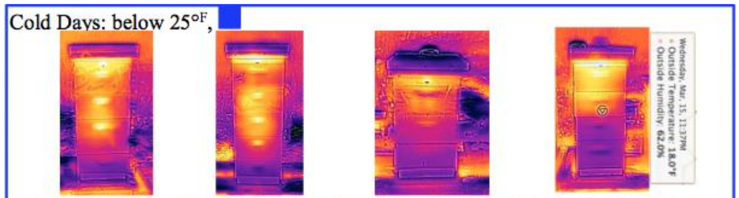
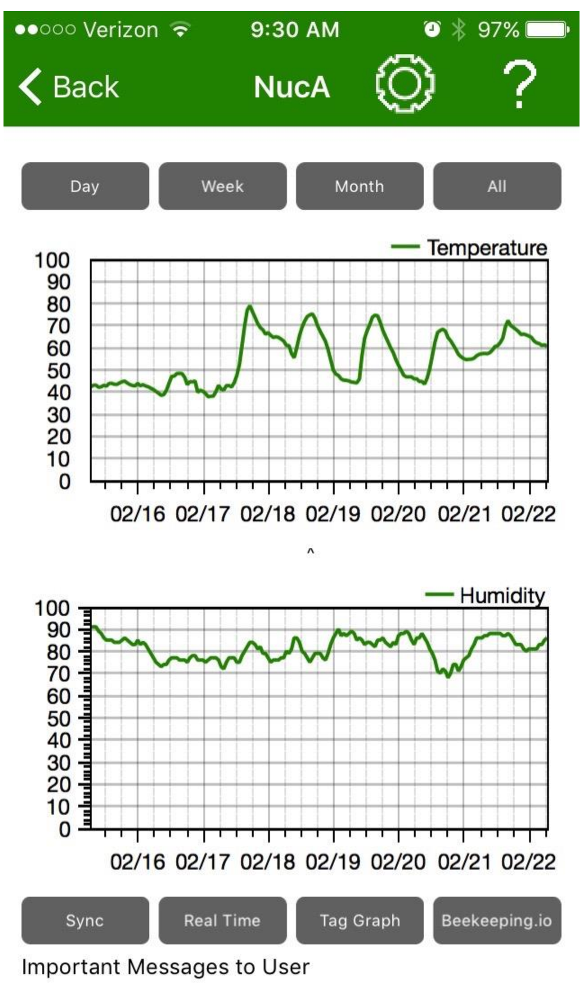


Figure 4: Representative pictures 3/15 In order from left to right: Hive 1, Hive 2, Hive 5, Hive 6

Figure 4: Image of BroodMinder™ sensors used in study

Figure 5: Left: FLIR One Thermal Imager device used. Right: FLIR One Thermal Imager when attached to mobile device.



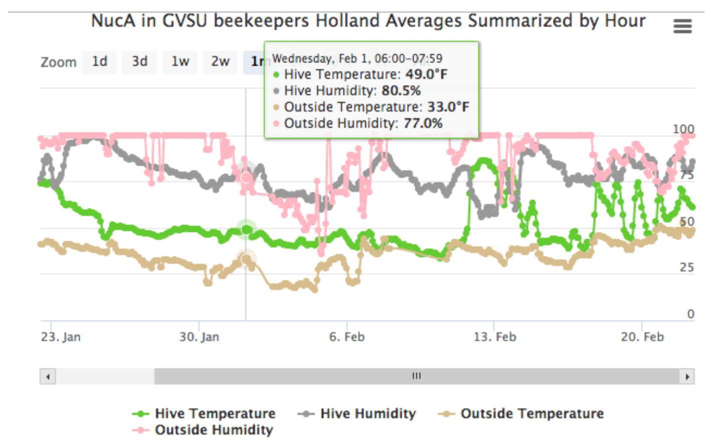


Figure 6 (Left): Screenshot of synced data from BroodMinder™ sensors in nucleus colony.

Figure 7(Above): Sample graph of compiled hive temperature, hive relative humidity, outside temperature, and outside relative humidity from beekeeping.io.

Results: The data from this study show that the technologies are able to roughly determine the position and viability of the cluster within the hive. A timeline shows outside temperature differences (Fig. 1). The temperature and relative humidity readings from inside the hives, as well as local weather conditions from Weather Underground, were combined into graphs via Beekeeping.io. In the IR photos, the lightest yellow areas are the warmest areas, and the darkest purple areas are the coldest areas (Figs. 2 & 3).

Discussion: The FLIR camera seems to provide better "practically" useful information than the BroodMinder™ sensors alone. The main use of the IR images for this study was determining if a hive was still alive throughout the winter and the relative position of the cluster within the hive, all while the hives remained safely closed [2,5]. In situations where the vibrations of the bees may not be able to be heard through the wood or plastic of the hive, the only alternative to determining whether or not a hive is alive is to open the hive. New methods could be useful for beekeepers, or experienced beekeepers that may be concerned about the survival of their hives over the winter season. Also knowing when during the winter a hive died could also be useful with improving management techniques for a given apiary. Compared to other available IR camera accessories (i.e. the Seek Thermal Imager) and point-and-shoot IR cameras, the FLIR image quality and resolution is superior and the cost is much less [7]. A temperature sensing setting is also available on the FLIR One camera, though the accuracy of this setting was not evaluated in this study. The FLIR camera's rechargeable battery lasts a significant amount of time on a single charge (after the initial charge the FLIR camera only needed to be charged once during the study), and the free FLIR smartphone application was easy to use [7].

In combination with the FLIR camera, the BroodMinder™ sensors provided some interesting information. Perhaps the design of the temperature sensors could be improved so that the electronic components remained in the current plastic housing, but a temperature sensor could drop down several inches in order to be closer to the main cluster of honey bees [2,5]. The warmest part of the cluster is in the center, with temperatures dropping several degrees only a few inches away from the buzzing core [2,5]. With a more accurate cluster temperature reading, beekeepers may be able to know when the honey bees begin rearing brood. Little is known about the overall hardiness of the sensors, as well, since the technology is relatively new. However the battery life seems to be extremely long lasting, as hardly any charge was used during the 11-week duration of this study. The current setup of the BroodMinder™ sensors and smartphone application allow for quick syncing of data via Bluetooth LE to a mobile device and submission to beekeeping.io. Temperature and moisture in the air seem to influence the syncing time of the BroodMinder™ sensors. On colder days, the sensors seemed to take longer to connect with the BroodMinder™ smartphone application than on warmer days. Sensors connect with the application

even when signal strength is as low as 4%. Once connected, data syncing time does not seem to be affected by temperature or moisture.

With multiple winters' worth of data collected (photographs, hive temperatures, local temperatures, etc.), patterns could be observed in the temperature and cluster movement patterns of the hives. The winter season of 2017 was also warmer, and had greater temperature fluctuations, compared to recent west-Michigan winters, with maximum temperatures rising approximately 10°F [10]. In the current environment of a warming climate, understanding the temperature and relative humidity patterns of a hive could allow beekeepers to better manage their apiaries through the winter. Continuation of this research could reveal local patterns of hive temperature related to outside temperature.

Honey bees are the most important pollinators worldwide, and are declining at an alarming rate. The devices discussed could be useful for electronically monitoring hives during the winter, when opening the hives may be detrimental.

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