

Monitoring the response of honeybee colonies to external stressors WITH INTELLIGENT SENSORS

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Background

The biological characteristics of honeybees date back to antiquity, a fact that is often overlooked in modern beekeeping. Beekeeper intervention in the colony, inadequate food sources, environmental pollutants, climate change, high colony density, pathogens and pests all cause stress in bees. To improve the well-being of bee colonies in the future, a newly developed intelligent multi-sensory system has been developed that monitors the bees' response to various stress factors and provides insights into the colony without the need for manual intervention.

Methods

Twenty Carniolan honeybee colonies (*Apis mellifera carnica*) were placed at four sites with different impact of stressors, five at each site. Newly developed multi-sensors were installed in the colonies to measure **temperature, relative humidity, air pressure and VOC, beehive mass, sound inside the beehive and to detect rainfall**. The health status of the colonies were monitored and various bee-related samples for chemical analysis of pesticides and toxic metals were collected and analyzed.

Results

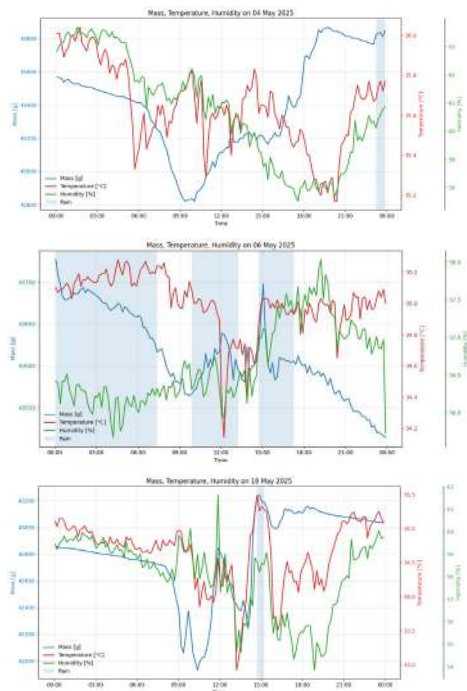


Figure 4: Results of measurements with intelligent sensors: mass, temperature, humidity and rain on 4, 6 and 18 May 2025



Figure 1: Multi-sensory system installed in a honeycomb



Figure 2: Beehives with installed sensors and pollen traps



Figure 3: The analytical procedure for determining total element concentrations

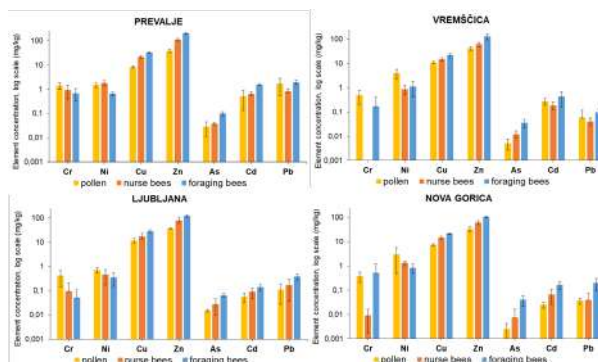


Figure 5: Concentrations of elements in pollen, nurse honeybees and foraging honeybees sampled at four locations in Slovenia in June and July 2025. Data are presented as mean $\pm$ standard deviation of five colonies at each location, expressed on a dry weight basis.

At all sites, foraging honeybees generally accumulated higher concentrations of most metals (especially Cu, Zn, As, Cd, Pb) compared to nurse honeybees and pollen, reflecting their exposure during foraging. Pollen showed relatively high Cr and Ni concentrations, but generally lower concentrations of other metals, suggesting selective accumulation of certain elements. Depending on the sampling location, there were remarkable variation in the element concentrations of foraging honeybees. Prevalje (industrial and mining area) consistently showed elevated concentrations of Cr, Cu, Zn, As, Cd and Pb, while Nova Gorica (intensive agricultural area), Ljubljana (urban environment) and Vremščica (pristine site) generally exhibited lower concentrations.

Conclusions

With the current analysis of the sensor readings with artificial intelligence methods, we can determine the degree of stress to which the bees are exposed due to various external factors. Through further measurements and analyses of the measured data, we will try to determine the correlations with the identified stress factors that have affected the bee colonies. By analysing the sensor data, beekeepers will be able to track and predict various colony activities more accurately than with a single investigation. At the same time, the bees will be less exposed to certain stress factors, which will have an impact on their well-being, health and productivity. The results of the chemical analyses show that honeybees and hive products, such as pollen, serve as both bioindicators and passive bioaccumulators of heavy metals, making them effective tools for monitoring environmental pollution.

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BACKGROUND/PURPOSE: The biological characteristics of honeybees date back to ancient times, which is often overlooked in modern beekeeping, and bee colonies are exposed to various stressors. To improve the well-being of bee colonies in the future, a newly developed intelligent multi-sensors in combination with AI will provide new knowledge for bee protection.

PROBLEM DESCRIPTION: Beekeeper intervention in the colony, insufficient food sources, environmental pollutants, climate change, a high density of bee colonies in a particular location, pathogens and pests, all these factors cause stress in bees. A multi-sensory system has been developed to monitor the bees' response to various stressors and gain insight into the colony without the need for manual intervention. This will make beekeeping more efficient in terms of bee welfare.

METHODOLOGY: Twenty Carniolan honeybee colonies (*Apis mellifera carnica*) were placed at four sites with different impact of stressors, five at each site. Newly developed multi-sensors were installed in the colonies to measure temperature, relative humidity, air pressure and VOC (both inside and outside of a beehive), beehive mass, sound inside the beehive and to detect rainfall. We monitored the health status of the colonies and collected various bee-related samples for chemical analysis of pesticides and toxic metals. The bee colonies were exposed to varying degrees of beekeeper manipulation.

RESULTS AND CONCLUSION: By analysing sensor data using artificial intelligence methods, we were able to track events in a beehive more accurately than with just a single investigation. The analysis also included monitoring the harvest or lack of food and bee deaths during the winter. The sound analysis enabled the early detection of swarming and queenless colonies. With the current analysis of the sensor readings, we determine the degree of stress to which the bees are exposed due to various external factors.

PRACTICAL IMPLICATIONS FOR BEEKEEPERS: By using smart technology, beekeepers will be able to monitor and predict various activities of bee colonies with a lower level of human intervention. At the same time, bees will be less exposed to certain stress factors, which will have an impact on their well-being, health and productivity.