

A new approach to estimate arthropods biodiversity in orchards

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Abstract

Traditional methods of monitoring arthropod biodiversity are generally labor-intensive, invasive, and limited in temporal coverage. Moreover, environmental conditions such as temperature, humidity, and wind can influence insect activity, indirectly affecting monitoring results. Here, we evaluated a new automated, continuous monitoring system (FaunaPhotonics, now Evolito) in organic apple and raspberry plantations. The device detects atmospheric electric field modulations caused by flying insects and uses convolutional neural networks for detection and wing-beat frequency analysis, enabling the calculation of standard biodiversity indices. An algorithm estimates taxon-specific weights, which can be used to calculate total biomass. Data from two seasons are presented, with observations also related to landscape features.

Keywords: biodiversity monitoring, artificial intelligence, automated insect detection.

Introduction

Insects represent the largest share of global biodiversity (Bánki *et al.*, 2024) and support key ecosystem functions such as pollination, nutrient cycling, and natural pest regulation (Dangles *et al.*, 2019). Their rapid responses to environmental change make them valuable indicators in conservation and sustainable agriculture (Samways *et al.*, 2020).

However, traditional insect monitoring still relies heavily on trapping and specimen processing, which provide only brief temporal snapshots that are sensitive to weather-driven fluctuations in insect activity. These limitations highlight the need for automated, continuous, and non-invasive monitoring approaches.

The FaunaPhotonics (now Evolito) system offers such a solution by detecting the electrical disturbances generated by flying insects. Machine-learning algorithms classify flight events, extract wing-beat frequencies, and estimate biomass and diversity metrics. Recent field validation demonstrated strong agreement with traditional trapping methods (Odgaard *et al.*, 2025), supporting its suitability for evaluating insect biodiversity patterns in orchards.

Material and Methods

Monitoring was conducted in apple orchards (Nowy Kłopotczyn, Central Poland) and raspberry plantations (Karczmiska Pierwsze and Brzostówka, Eastern Poland) using automated FaunaPhotonics (now Evolito) sensors (Fig. 1). The system is solar-powered and operates continuously from one hour before sunrise until one hour after sunset, detecting flying insects through infrared light and electric field modulations. It is non-invasive, allowing assessment of insect activity, abundance, biomass, and community composition without physical trapping.

Study sites:

- Apple orchards: Orchard 1 (organic farming) and Orchard 2 (conventional farming), separated by 400 m. A nearby control garden was included for comparison.
- Raspberry plantations: Brzostówka (two plantations under organic farming) and Karczmiska Pierwsze (conventional farming).

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In-field sensors collected detailed flight event data, which were processed using a proprietary system using convolutional neural networks and species-specific biomass algorithms. Processed data were transmitted to a cloud platform and made accessible through a user interface for analysis. While the system can capture wing-beat frequency and other traits, this study focused on temporal and spatial patterns of insect biodiversity under different management conditions. Diversity and abundance were calculated by continuous collection of the wing-beat during daily hours. The sensors record data in 1-minute intervals, producing 16-bit signals sampled at a frequency of 4 kHz, which are first used to identify insect species and then to estimate their body mass using a proprietary algorithm referenced to literature data (Odgaard et al. 2025). Cumulative abundance is the total daily insect count in the monitored area. Cumulative biodiversity (i.e. an index based on the Shannon Entropy of the wing beat frequency distribution divergence from a homogeneous distribution – Torelli and Kjærbo 2025) was calculated on weekly basis. The aggregated values of both parameters as “accumulated” data summed from the start of the recording to the specific day (end of recording).



Figure 1: The method of deployment of the Fauna Photonics (now Evolito) sensors in the two crops: (A) apple orchards and (B) raspberry fields.

Results and Discussion

The FaunaPhotonics (now Evolito) system revealed clear differences in insect community structure across both seasons and all study sites.

In the apple orchards, accumulated diversity values were relatively consistent across orchards, whereas accumulated abundance varied notably (Figure 2A). The control, a garden, had the highest insect abundance, while the organic orchard (1) and conventional orchard (2) had a lower abundance compared to the garden. However, the organic apple orchard showed a higher diversity level compared to the conventional one, similar to the garden.

In the raspberry plantations, diversity patterns across locations and management types were broadly overlapping. The organic plantation 1 in Brzostówka exhibited slightly higher accumulated abundance than the other sites, while diversity remained comparable (Figure 2B).

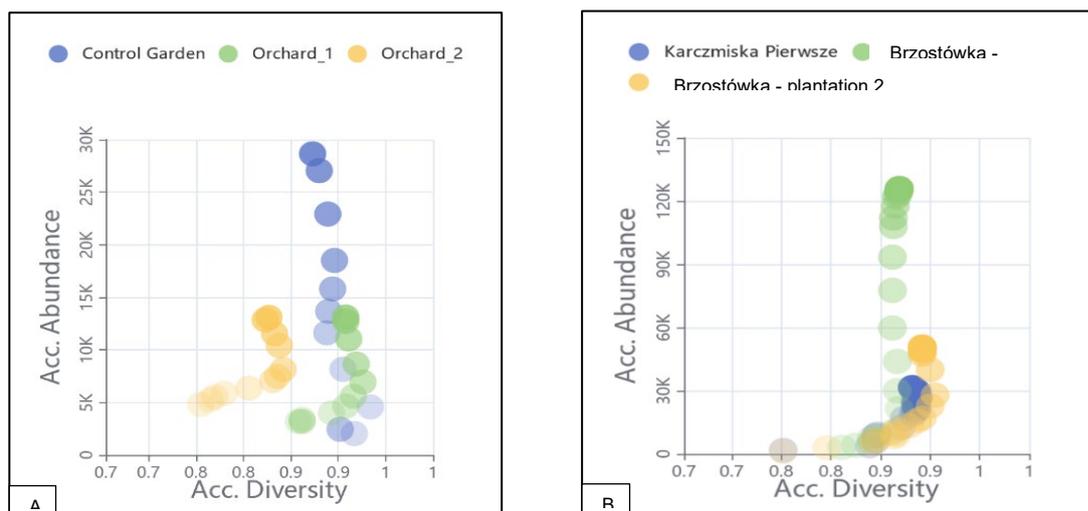


Figure 2: Insect diversity-abundance patterns in (A) the apple orchard and (B) the raspberry fields.

Organic management of fruit orchards may increase biodiversity. However, it was shown that changes in population dynamics of beneficial insect taxa followed the changes of pest insect taxa and were related to food availability and climatic conditions, with high diversity expressed in organic apple orchards (Popov et al. 2018). Moreover, even though organic farming showed some benefits for biodiversity compared to conventional apple orchards managed according to IPM, its effects were inconsistent across taxa, with stronger positive effects on species abundance rather than on species diversity, leading to consider the presence of semi-natural habitats more important for biodiversity conservation (Daelemans et al. 2025). Nevertheless, these studies were relying on common methods of biodiversity assessment, and thus not fully comparable to the results of the trials presented here. It shall also be highlighted that studies on insect biodiversity in raspberry crops are limited, thus making the findings of the present study suitable for further analyses.

Conclusion

The FaunaPhotonics system effectively captured insect biodiversity in apple and raspberry plantations, revealing clear patterns in abundance and diversity. Reducing dependence on traditional trapping can allow capturing subtle spatial and temporal variations in insect communities that might be overlooked by traditional, trap-based methods. Continued testing in a wider range of habitats in comparison with traditional insect monitoring results will be essential to refine system performance and broaden its usefulness for biodiversity monitoring.

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