POLICY BRIEF

Integration of novel technology in pollinator monitoring

Toke T. Høye, Mario Balzan, Simon G. Potts, Oliver Schweiger, Pavel Stoev

INTRODUCTION

Pollinators are critical to Europe's biodiversity, food security, and ecosystem resilience. Yet, their populations are declining due to habitat loss, climate change, and pesticide use. Under Article 10(2) of the Nature Restoration Regulation, Member States must improve pollinator diversity and reverse the decline of pollinator populations at the latest by 2030 and thereafter achieve an increasing trend of pollinator populations, measured at least every six years from 2030, until satisfactory levels are achieved. In order to be able to assess Member State progress it is therefore necessary to have a robust and standardised monitoring method which provides high quality species abundance data; this will be provided by the EU Pollinator Monitoring Scheme (EU PoMS, Potts et al. 2024). EU PoMS will generate huge numbers of specimens which need to be identified to species level, and so significant increases in taxonomic capacity are needed across the whole of Europe. While significant capacity building and training efforts are currently underway, there is considerable scope for the inclusion and adoption of emerging technologies to help reduce the taxonomic burden.

The MAMBO project (Modern Approaches to the Monitoring of Biodiversity) can potentially contribute to this goal through its development and demonstration of cutting-edge technologies, including artificial intelligence (AI) and insect camera traps, that can support how pollinators are monitored across Europe. This brief outlines MAMBO's innovations, highlights emerging opportunities, and recommends actions for integrating these tools into EU PoMS.

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MAMBO INNONNAVATIONS FOR POLLINATOR MONITORING

Context

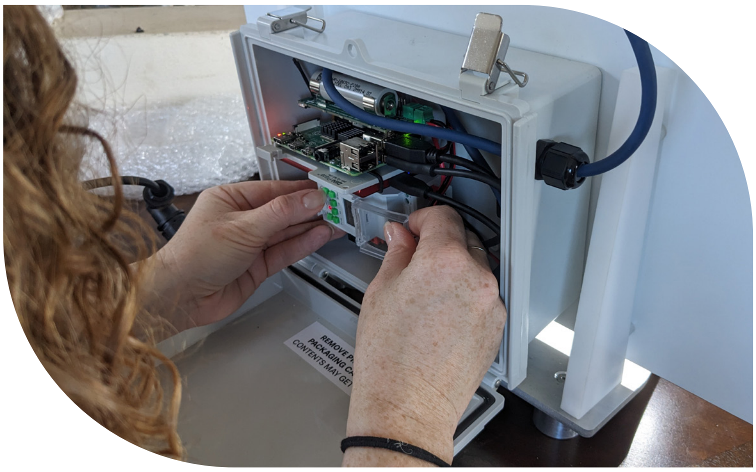
The revised EU Pollinators Initiative (A New Deal for Pollinators) and more recently the Nature Restoration Regulation (NRR) has driven the development and implementation of an EU Pollinator Monitoring Scheme (EU PoMS). The NRR requires the collection of data on the abundance and diversity of pollinator species across ecosystems. This necessitates the identification of observed and caught specimens to the species level.

While pollinator monitoring could include all groups, the current available capacity limits EU PoMS to wild bees, hoverflies, butterflies and moths (excluding micro-moths). EU PoMS will include two main approaches for collecting species-level data:

1. **For day-active pollinators (i.e. bees, hoverflies, butterflies and day-active moths) transect walks will be used.**
2. **For night-active moths, light traps will be used.**

These two methods will be rolled out across multiple sites within each Member State and provide a standardised replicated approach to monitor common species of wild bees, hoverflies, butterflies and moths. However, these standardised methods are not appropriate for monitoring rare species and so these will be monitored by targeted field visits on known locations where the survey method is selected to be the most appropriate for the target rare species.

Since EU PoMS metrics and indicators are all based on species level data, the contribution of MAMBO to EU PoMS has to match this. However, there are many other opportunities for employing pollinator monitoring technology outside of EU PoMS. Below, we focus on two main contributions from MAMBO to pollinator monitoring across Europe (insect camera traps and AI powered species recognition tools in citizen science apps) and highlight how they can support EU PoMS.



Light trap (AMI-trap) in the field

INSECT CAMERA TRAPS

MAMBO is advancing insect camera technologies to monitor both nocturnal and diurnal pollinators in a nonlethal, automated, and scalable manner. Insect camera traps offer a promising avenue for enhancing the EU Pollinator Monitoring Scheme (EU PoMS), particularly as part of its complementary modules. These automated, non-lethal devices—ranging from LED-based moth traps to image recognition systems for diurnal pollinators—enable scalable, standardised, and high-frequency data collection with minimal field expertise (Høye et al. 2025). While current insect camera traps primarily yield presence-absence data, they complement core methods like reinforced transects by capturing nocturnal or cryptic taxa and expanding spatial-temporal coverage. Integration with AI and centralised data workflows ensures harmonisation and validation across Member States.

Due to resource limitations, EU PoMS currently relies on a limited number of sites appropriate for the detection of broader trends. This might require considerable restoration efforts to be reflected in increasing trends across the respective MS. Thus, there is great potential for camera traps to complement the transect walks and thus increase the number of sites and power to detect even smaller changes in trends.

For the rare species, it may be possible to detect morphological distinct species with insect camera traps already and upscaling can be done based on ecological niche models obtained from a limited number of camera traps to identify candidate areas for additional monitoring. However, there are still limitations to the capabilities of image recognition based classification models and further investment is needed to reach the aim of reliable species-level identification.

For applications, where species-level data is not required, insect camera traps already deliver continuous monitoring of the broader taxonomic groups of moths attracted to light and bees, butterflies, and hoverflies attracted to flowers during the day. The high-frequency imaging delivers information on phenology, behaviour, and abundance proxies. Through edge computing, where the camera directly runs image-recognition pipelines, these systems can deliver real-time monitoring data on pollinators.

These systems reduce reliance on manual fieldwork. They may reduce the need for expert taxonomists on trivial tasks while creating new opportunities for their involvement with validation of rare species detections. Insect camera traps enable monitoring in remote and under-sampled regions and support biodiversity assessments aligned with the EU Habitats Directive and IUCN Red List. The unique contribution from MAMBO is the demonstration, testing and codevelopment of insect camera traps across EU demonstration sites, coordinated with EU PoMS and the STING expert group and other stakeholders.

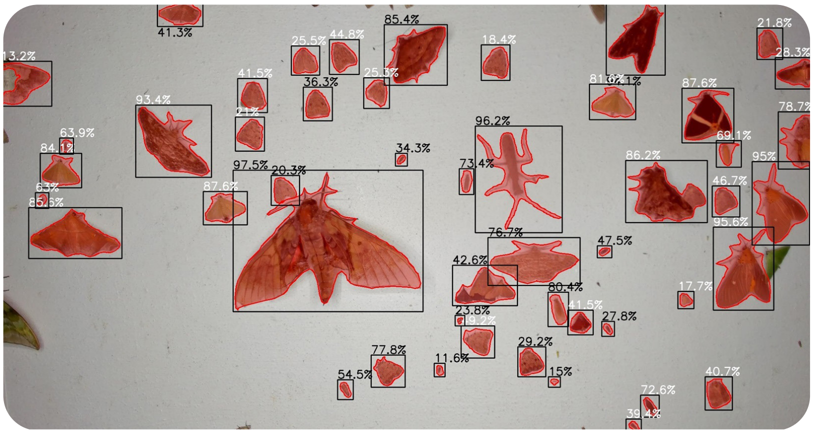
Pollinator camera in the field

ARTIFICIAL INTELLIGENCE FOR SPECIES IDENTIFICATION

Within EU PoMS, image-based methods have already demonstrated success in moth monitoring, where the SPRING project trials across five countries recorded over 69,000 moths from 1,500+ species using volunteer-friendly protocols and mobile apps. This approach supports citizen science engagement, reduces taxonomic bottlenecks, and provides robust phenological data. MAMBO actively contributes to enhancing species recognition capabilities of European species observation portals by increasing the number of species that can be reliably determined from AI-powered image recognition tools and integrating them into national biodiversity portals.

AI tools for species recognition are central to the scaling and for sustaining the EU Pollinator Monitoring Scheme (EU PoMS). Specifically, they offer solutions to overcome taxonomic bottlenecks and to support standardised, cost-effective biodiversity monitoring across Member States. Mobile apps such as ObsIdentify enable rapid, non-lethal identification of pollinators like moths, butterflies, bees, and hoverflies, even by non-experts. These tools have already demonstrated success in SPRING project trials, where LED light traps paired with AI apps achieved 94% identification accuracy for macro-moths in NW Europe. AI integration reduces reliance on scarce taxonomists —especially in Southern and Eastern Europe, where 70% of countries face poor or eroded taxonomic capacity—and empowers citizen scientists to contribute meaningfully. Within EU PoMS, AI tools support transect walks, moth monitoring with LED bucket traps and the monitoring of easily recognisable rare and threatened species.

Despite challenges—such as incomplete reference databases and lower accuracy for rare taxa—ongoing investment in AI infrastructure, training, and expert validation networks is recommended. By harmonizing protocols, expanding multilingual apps, and integrating with citizen science platforms, AI tools will be an important element in EU PoMS's long-term strategy for inclusive, scalable, and policy-relevant pollinator monitoring.



Identifying species using the Light trap (AMI-trap)

OPPORTUNITIES FOR THE EUROPEAN COMMISSION

Scalable monitoring across Europe

MAMBO's tools enable high-resolution, automated monitoring of insects including pollinators that can be scaled across Member States, including remote and biodiversity-rich areas with large data gaps.

Enhanced citizen science participation

By embedding AI into user-friendly mobile apps, MAMBO empowers citizens to contribute to pollinator monitoring, increasing data volume and public engagement.

Integration with existing infrastructure

MAMBO's technologies are designed to interface with existing research infrastructures (e.g. eLTER, LifeWatch and DiSSCo), facilitating seamless data integration and interoperability.

Cost-effective monitoring solutions

Automated tools reduce long-term monitoring costs by minimising labour and enabling continuous data collection. MAMBO's cost-benefit analyses help identify optimal tool combinations for different contexts.

Policy alignment and reporting support

MAMBO tools support reporting under the EU Biodiversity Strategy 2030, Birds and Habitats Directives, and the Nature Restoration Regulation by providing standardised, high-quality data and indicators.

POLICY RECOMMENDATIONS

Support MAMBO technologies for future adoption into transnational monitoring

Insect camera traps could support EU PoMS and other insect monitoring activities in the future if implemented as part of sensor networks e.g at eLTER sites or other research infrastructures. Likewise, MAMBO's open-source frameworks for image and sound recognition could be implemented in EU-wide monitoring.

1

Expand reference databases and benchmark data sets

Support MAMBO's efforts to link image, sound, and other data sources for pollinator monitoring. Fund initiatives to establish reference databases to benchmark image and sound recognition models of relevance to pollinator monitoring.

2

Develop infrastructure for scalable monitoring

Image-based sensors create vast amounts of data. There is a need for EU-wide solutions to data storage challenges. Similarly, investments are needed for cloud-based virtual labs for processing sensor data and support for the standardisation of data formats and workflows across Member States.

3

CONCLUSIONS

The MAMBO project offers transformative tools to potentially enhance pollinator monitoring across Europe. By integrating AI and insect camera traps into parts of EU PoMS, the European Commission can achieve more accurate, scalable, and inclusive biodiversity assessments—supporting the EU Biodiversity Strategy 2030, the Green Deal, and the Nature Restoration Regulation. By enabling high-frequency data collection and real-time monitoring, they complement traditional methods like transect walks and expand coverage of nocturnal and cryptic taxa. MAMBO's coordinated development and testing of insect camera traps across EU demonstration sites, alongside integration with citizen science platforms and national biodiversity portals, exemplifies the potential for inclusive and cost-effective monitoring. While current limitations—such as incomplete reference databases and lower accuracy for rare species—require continued investment in AI infrastructure, training, and validation networks, the benefits are substantial. These innovations not only improve ecological data collection but also foster public engagement and cost-effective conservation. They do, however, require investment beyond those provided to individual projects, such as MAMBO, for the benefits and full impact potential to be harvested.

PROJECT OBJECTIVES AND METHODOLOGY

EU policies, such as the EU biodiversity strategy 2030 and the Birds and Habitats Directives, demand unbiased, integrated and regularly updated biodiversity and ecosystem service data. However, efforts to monitor wildlife and other species groups are spatially and temporally fragmented, taxonomically biased, and lack integration in Europe. To bridge this gap, the MAMBO project will develop, test and implement enabling tools for monitoring the conservation status and ecological requirements of species and habitats for which knowledge gaps still exist. MAMBO brings together the technical expertise of computer science, remote sensing, social science expertise on human-technology interactions, environmental economy, and citizen science, with biological expertise on species, ecology, and conservation biology. MAMBO is built around stakeholder engagement and knowledge exchange (WP1) and the integration of new technology with existing research infrastructures (WP2).

MAMBO will develop, test, and demonstrate new tools for monitoring species (WP3) and habitats (WP4) in a co-design process to create novel standards for species and habitat monitoring across the EU and beyond. MAMBO will work with stakeholders to identify user and policy needs for biodiversity monitoring and investigate the requirements for setting up a virtual lab to automate workflow deployment and efficient computing of the vast data streams (from on-the-ground sensors, and remote sensing) required to improve monitoring activities across Europe (WP4). Together with stakeholders, MAMBO will assess these new tools at demonstration sites distributed across Europe (WP5) to identify bottlenecks, analyse the cost-effectiveness of different tools, integrate data streams and upscale results (WP6). This will feed into the co-design of future, improved and more cost-effective monitoring schemes for species and habitats using novel technologies (WP7), and thus lead to a better management of protected sites and species.

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
API	Application Programming Interface
EU	European Union
EU PoMS	EU Pollinator Monitoring Scheme
IUCN	International Union for Conservation of Nature
MS	Member States
NRR	EU Nature Restoration Regulation

REFERENCES

Høye TT, Montagna M, Oteman B, Roy DB (2025) Emerging technologies for pollinator monitoring. Current Opinion in Insect Science 69:101367. doi: 10.1016/j.cois.2025.101367

Hogeweg L, Yan N, Brunink D, Ezzaki-Chokri K, Gerritsen W, Pucci R, Ghani B, Stowell D, Kalkman VJ (2024) AI Species Identification Using Image and Sound Recognition for Citizen Science, Collection Management and Biomonitoring: From Training Pipeline to Large-Scale Models. Biodiversity Information Science and Standards 8: e136839. https://doi.org/10.3897/biss.8.136839

Potts, S.G., Bartomeus, I., Biesmeijer, K., Breeze, T., Casino, A., Dauber, J., Dieker, P., Hochkirch, A., Høye, T., Isaac, N., Kleijn, D., Laikre, L., Mandelik, Y., Montagna, M., Montero Castaño, A., Öckinger, E., Oteman, B., Pardo Valle, A., Polce, C., Povellato, A., Quaranta, M., Roy, D., Schweiger, O., Settele, J., Ståhls-Mäkelä, G., Tamborra, M., Troost, G., van der Wal, R., Vujić, A., Zhang, J. (2024) Refined proposal for an EU Pollinator Monitoring Scheme, Publications Office of the European Union, Luxembourg https://data.europa.eu/doi/10.2760/2005545, JRC138660.

Roy DB, Alison J, August TA, Bélisle M, Bjerge K, Bowden JJ, Bunsen MJ, Cunha F, Geissmann Q, Goldmann K, Gomez-Segura A, Jain A, Huijbers C, Larrivée M, Lawson JL, Mann HM, Mazerolle MJ, McFarland KP, Pasi L, Peters S, Pinoy N, Rolnick D, Skinner GL, Strickson OT, Svenning A, Teagle S and Høye TT (2024) Towards a standardized framework for AI-assisted, image-based monitoring of nocturnal insects. Philosophical transactions of the Royal Society B 37920230108 http://doi.org/10.1098/rstb.2023.0108

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COORDINATOR

Toke Thomas Høye, Aarhus University, Aarhus, Denmark;
e-mail: tth@ecos.au.dk

PROJECT DURATION

September 2022 – August 2026 (48 months)