MISSION INSECTIBLE

Integrative Monitoring and Restoration of Insect Biodiversity in Europe

Call	HORIZON-CL6-2026-01-BIODIV-01 - Understanding and tackling the decline of insects
Project type	Research and Innovation Action concept note
Core focus	Underrepresented insects beyond pollinators: Carabidae, Scarabaeoidea and EPT taxa

1. Challenge and Rationale

Insects underpin ecosystem functions that are essential for biodiversity, climate resilience, agricultural productivity and human well-being. However, European insect decline remains insufficiently understood beyond pollinator-focused research. The call requires improved knowledge of insect diversity, status and trends; analysis of multiple drivers of decline; valuation of ecosystem functions and services; effective restoration strategies; and long-term monitoring schemes able to support biodiversity policy implementation.

MISSION INSECTIBLE will address these needs by focusing on three ecologically complementary and comparatively underrepresented insect groups: **ground beetles** (Coleoptera: Carabidae), **dung beetles** (Coleoptera: Scarabaeoidea), and **freshwater EPT taxa** (Ephemeroptera, Plecoptera and Trichoptera). Together, **they cover terrestrial, soil-associated and freshwater ecosystems and represent key functions beyond pollination**, including biological pest control, nutrient cycling, soil formation, decomposition, parasite suppression and freshwater ecosystem integrity.

2. Overall Objective and Specific Objectives

The overall objective is to develop an integrated European framework for understanding, monitoring, valuing and restoring underrepresented insect biodiversity, combining taxonomy, genomics, artificial intelligence, museum collections, soil bioindicators, ecosystem service valuation and nature-based restoration technologies.

- Improve identification and assessment of insect diversity through integrative taxonomy, museum collections, DNA barcoding, DNA metabarcoding, eDNA and population genomics.
- Assess the status, trends and vulnerability of Carabidae, Scarabaeoidea and EPT taxa across contrasting land-use, soil and freshwater contexts.
- Analyse multiple drivers of insect decline, including climate change, land-use intensification, habitat fragmentation, pesticides, veterinary pharmaceuticals, hydrological alteration, water pollution and light pollution.
- Quantify ecosystem functions and socioeconomic value delivered by target insects and associated soil arthropod communities.
- Develop and test resource-based restoration solutions, including habitat restoration, ecological connectivity, riparian restoration, grazing management and VOC-assisted bio-inspired restoration technologies.
- Establish scalable long-term monitoring and policy-support tools aligned with European biodiversity monitoring infrastructures and policy needs.

3. Scientific Pillars

1. **What biodiversity do we have**?	2. **Why is it declining**?	3. **Why does it matter**?	4. **How can it be restored**?	5. **How can recovery be monitored and embedded into policy?**
Understand and identify insect diversity and status using taxonomy, genomics, museums and AI.	Analyse multiple interacting pressures and produce risk and vulnerability models.	Quantify ecosystem functions and socioeconomic value beyond pollination.	Develop resource-based restoration, nature-based solutions and bio-inspired technologies.	Create long-term monitoring schemes, digital tools and policy support.

4. Methodological Approach and Innovation

4.1 Museums, taxonomy and digital biodiversity infrastructure

Natural history museums and taxonomic facilities will be core infrastructure partners. They will provide access to historical collections, type and reference material, taxonomic expertise, high-resolution imaging and DNA barcoding of reference specimens. These resources will support harmonised European reference libraries linking morphology, DNA barcodes, genomic data and images for Carabidae, Scarabaeoidea and EPT taxa. The project will seek interoperability with European biodiversity infrastructures such as CETAF, DiSSCo, GBIF and Biodiversa+ monitoring initiatives.

4.2 Genomics and integrative taxonomy

Morphological identification will be complemented by DNA barcoding, DNA metabarcoding, eDNA and population genomics. These approaches will enable the detection of cryptic species, rare taxa, early life stages and poorly known groups, while also supporting the assessment of population connectivity, genetic diversity, adaptive capacity and responses to environmental stressors.

4.3 Machine learning for all selected insect groups

Machine learning will be developed as a cross-cutting tool for all selected insect groups. For EPT taxa, existing evidence shows that convolutional neural networks can classify 90 taxa with very high accuracy, demonstrating strong feasibility for automated freshwater biomonitoring. The project will extend this logic to Carabidae and Scarabaeoidea using standardised dorsal images, museum specimens, newly collected field material and expert-validated labels. Models will be trained to support species identification, functional trait extraction, body-size estimation and monitoring workflows, reducing the taxonomic bottleneck while retaining expert validation.

4.4 Soil biological biodiversity

Soil biological quality will be assessed using the QBS-ar index (Soil Biological Quality), a standardised and widely adopted bioindicator method for evaluating soil health and ecosystem functionality. QBS-ar will be applied to compare soil biological quality across agricultural, forest, grassland, restored and urban environments. It will complement focal insect monitoring by capturing wider soil arthropod community responses to land management, restoration and environmental pressures.

4.5 Restoration and Eurecat bio-inspired technologies

Restoration will follow a resource-based framework, ensuring that insects are not merely attracted to sites but can complete their life cycles. Eurecat will explore biodegradable hydrogels and microencapsulation systems releasing ecologically relevant VOCs, potentially produced by safe microbial consortia acting as living microreactors. Dung-derived VOC profiles will be tested for dung beetles, while plant-associated semiochemicals linked to trophic interactions will be explored for ground beetles. For EPT taxa, restoration will focus on oviposition habitat and larval conditions, including flow heterogeneity, clean substrates, riparian vegetation, shading, oxygen levels and water quality. All cue-based approaches will be tested only where resources, breeding sites, shelter and connectivity are available, avoiding ecological traps.

5. Preliminary Work Package Structure

WP	Title	Main focus	Indicative outputs
WP1	Coordination and management (Eurecat)	Governance, ethics, data management, quality assurance and liaison with EU initiatives.	Management plan; data management plan; risk and quality framework.
WP2	Insect diversity, taxonomy, museums, genomics and AI	Integrative taxonomy, museum reference collections, image libraries, DNA barcoding, metabarcoding, eDNA, population genomics and AI models for all focal groups.	European reference libraries; AI identification tools; biodiversity baselines.
WP3	Drivers of insect decline	Climate, land use, habitat fragmentation, pesticides, veterinary pharmaceuticals, hydrology, water pollution and light pollution.	Driver-risk models; vulnerability maps; multi-driver scenarios.
WP4	Ecosystem functions, QBS-ar and socioeconomic value (CREA)	Pest control, nutrient cycling, soil formation, decomposition, freshwater ecosystem functioning and QBS-ar soil biological quality assessment.	Ecosystem service indicators; QBS-ar assessment; economic valuation framework.
WP5	Restoration and nature-based solutions	Habitat restoration, ecological corridors, grazing management, freshwater restoration, VOC-assisted restoration and hydrogel/microcapsule technologies.	Restoration toolbox; demonstration results; guidelines to avoid ecological traps.
WP6	Long-term monitoring, decision support and policy uptake	Monitoring protocols, digital tools, citizen science, biodiversity infrastructures and policy recommendations.	European insect monitoring framework; decision-support tools; policy briefs.
WP7	Communication, dissemination, exploitation and stakeholder engagement	Stakeholder engagement, training, Living Labs, exploitation and science-policy dialogue.	Stakeholder strategy; training materials; exploitation roadmap.

6. Consortium Needs

Expertise required	Expected role
Carabidae specialists	Ground beetle monitoring, functional traits and biological pest control.
Dung beetle specialists	Scarabaeoidea taxonomy, dung removal functions, grazing systems and veterinary pharmaceutical impacts.
Freshwater/EPT specialists	EPT monitoring, freshwater bioassessment, hydromorphology and restoration.
Museums and taxonomic infrastructures	Reference collections, imaging, DNA barcoding, CETAF/DiSSCo interoperability.

Machine-learning groups	Computer vision pipelines, CNN models, data curation and model validation for all selected insects.
Genomics laboratories	DNA barcoding, metabarcoding, eDNA and population genomics.
Soil ecology experts	QBS-ar, soil arthropod communities and soil functionality assessment.
Restoration and biomaterials partners	Nature-based solutions, VOC delivery systems, hydrogels and microencapsulation.
Policy and ecosystem service experts	Socioeconomic valuation, policy uptake and decision-support tools.

7. Expected Outcomes and Impact

- Researchers will gain improved knowledge of the status, trends, diversity and drivers of decline for underrepresented insect groups.
- Competent authorities will receive robust evidence, monitoring tools and ecosystem service valuation to support biodiversity, restoration and climate adaptation policies.
- Land managers, farmers, conservation bodies and society will receive practical tools to address drivers of decline and implement insect-friendly restoration.
- The project will support implementation of the EU Biodiversity Strategy for 2030, the Nature Restoration Regulation, the European Climate Law and the Kunming-Montreal Global Biodiversity Framework.
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