INSIGNIA-EU

Preparatory action for monitoring of environmental pollution using honey bees

LEGACY BROCHURE

INSIGNIA-EU receives funding from the European Union under project No 09.200200/2021.864096/SER/ENV.D.2.

THE INSIGNIA-EU CONSORTIUM

The INSIGNIA-EU consortium comprises thirteen organisations from ten countries:

- Alveus AB Consultancy, Netherlands
- University of Graz, Austria
- Ellinikos Georgikos Organismos DIMITRA, Greece
- Carreck Consultancy Ltd, UK
- University of Strathclyde, UK
- Instituto Politécnico de Bragança, Portugal
- Wageningen Environmental Research, Netherlands
- Istituto Zooprofilattico Sperimentale del Lazio e della Toscana "M.Aleandri", Italy
- Benaki Phytopathological Institute, Greece
- Universidad de Almeria, Spain
- Danmarks Biavlerforening, Denmark
- Latvian Beekeepers' Association, Latvia
- Ghent University, Belgium

SUMMARY

The INSIGNIA-EU project "Preparatory action for monitoring of environmental pollution using honey bees" has shown that honey bees provide an effective mechanism for environmental monitoring across all 27 EU Member States.

Project objectives were delivered efficiently through streamlined processes, and strong communications ensured all teams worked effectively and kept the Citizen Scientist (CS) beekeepers well-informed and highly motivated.

Novel and non-invasive sampling standard techniques were developed to minimise harm to the bees whilst gathering samples for further analysis and interpretation.

The sampling programme provided detailed spatial and temporal information about the incidence of a number of environmental pollutants including polar (water soluble), semi and non-polar pesticides, heavy metals, microplastics, Volatile Organic Compounds (VOCs) and PolyAromatic Hydrocarbons (PAHs).

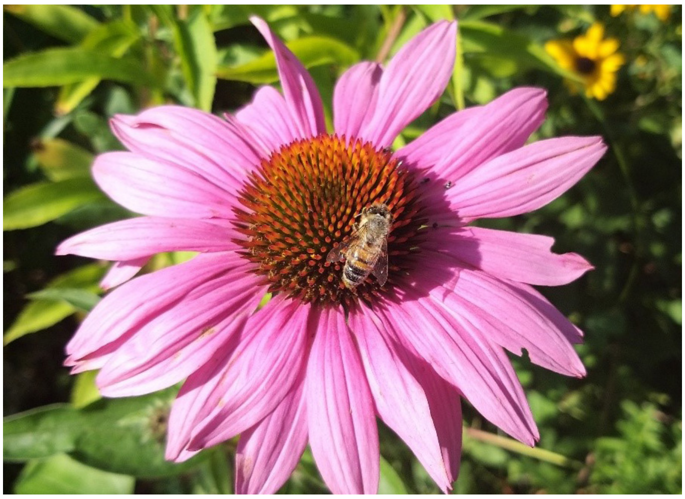
INSIGNIA-EU evolved from the COLOSS CSI Pollen Project (2014 to 2016) which used CS beekeepers across Europe to collect pollen samples from bee hives to assess the diversity of pollen collected by honey bees over the season[1]. It was followed by the EU-funded INSIGNIA Project (2018 to 2020) which expanded the concept to sample pollen and monitor for pesticides using plastic ApiStrips[2] in nine European countries.

The current INSIGNIA-EU Project started in 2021 to monitor for a wider range of pollutants using honey bees. Pilot studies (2022) determined new methods to study the additional pollutants. In 2023, the full sampling programme was carried out in 315 apiaries in all 27 EU Member States over nine sampling rounds.

The project has been a great success and a wide range of pollutants identified across the EU. To date, 14 scientific papers have been published (with more to follow) together with a range of popular articles, and presentations made at conferences.

[1]Brodschneider, R. *et al*. (2021) CSI Pollen: Diversity of honey bee collected pollen studied by citizen scientists. Insects, 12(11): 987. https://doi.org/10.3390/insects12110987

[2]Murcia-Morales, M. *et al*. (2020) APIStrip, a new tool for environmental contaminant sampling through honey bee colonies. Science of the Total Environment, 729: 138948. https://doi.org/10.1016/j.scitotenv.2020.138948

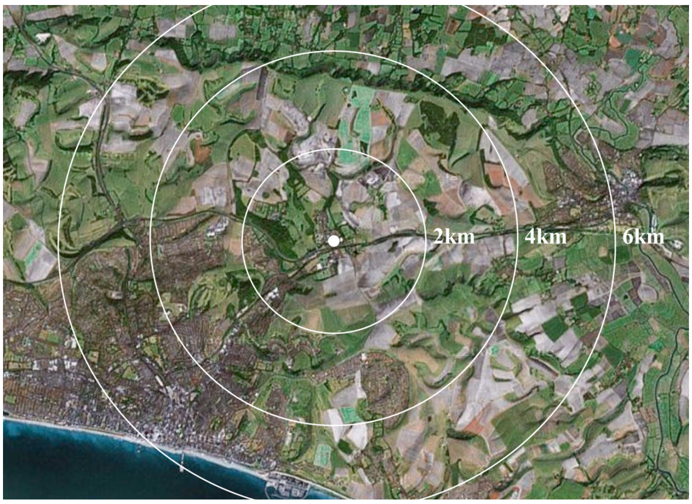


WHY HONEY BEES?

Honey bees live in a colony with a queen, thousands of female workers, and several hundred male drones. They feed themselves with nectar (carbohydrates), pollen (proteins, minerals and fatty acids), and water (minerals and hydration). In addition, they collect resins from plant buds to cover the inside of their nest with propolis, which has antibiotic properties.

They usually forage within a 1-1.5 km radius of the colony; a 3 km radius covers the majority of the foraging area, but good locations further away may also be explored. The colony can focus on the most profitable food sources in terms of energy. If a forager's flight uses more energy than is brought back as food the source will be abandoned, but bees will fly long distances for nectar with a high sugar concentration.

Honey bees have a great preference for large areas of mass flowering crops. They show "flower constancy", meaning that during a foraging flight bees will only visit flowers of one species. Scout bees are constantly searching for new sources of nectar, pollen, water and propolis. When they find a good source, they share a sample of the food they have found, and communicate its location to the colony using dances in the hive. Foragers do not divide themselves evenly over the area, but may focus on just one part, whilst others may forage elsewhere, with some overlapping. In a diverse landscape with few mass flowering crops, the foragers will collect their food from a wide range of less profitable sources.



The honey bee colony is an excellent biomonitoring tool for airborne pollutants and systemic pesticides mainly because they can easily be managed by humans, but also because:

1. They collect nectar and pollen from flowers and simultaneously unintentionally pick up contaminants that have been deposited on flowers and water sources.

2. There is intense in-hive exchange of food and materials that bees carry on their body and in their honey stomachs by auto- and allogrooming (physical contact) and by trophallaxis (direct bee-to-bee) food exchange.

3. The collected food and contaminants are all accumulated in a central location - the hive.

4. The foraging area of a colony ranges from 7 - 28 km^2.

5. The number of food-collecting foragers is 30 - 40% of the total number of bees in the colony, which ranges from 30,000 to 50,000 bees.

6. The constant conditions in the brood nest (Temperature 34.5 ^{o}C to 36^{o}C and Relative Humidity of 90 - 95%, make the results of in-hive passive samplers directly comparable, and independent from local weather conditions.

7. To maintain these constant conditions, bees fan out stale air which has relatively high CO_2 and low O_2 concentrations and let fresh air enter passively.

WHY BEEKEEPER CITIZEN SCIENTISTS?

Honey bee colonies are managed all over the world, so can easily be used for biomonitoring in any country. In terms of biomonitoring, the honey bees do the sampling, and subsequently, a beekeeper acting as a "Citizen Scientist" (CS) can subsample the colony to collect the accumulated information. In other words, the honey bees do the major part of the work for free, and it can takes the beekeeper only a short time to do the subsampling by exchanging carefully designed in-hive samplers.

Beekeepers form a very varied group, ranging from the amateur with one or two colonies in their back garden, or the balcony of their urban apartment, to commercial beekeepers with hundreds or thousands of colonies. For many, beekeeping is a hobby, for others it is a means of supplementing their income, whilst for others it can be a large business providing most or all of their income.

Large or small, however, the principles of beekeeping remain the same, and whilst traditions of, for example, design of the hives, may vary from country, as do climatic conditions, the skills of beekeepers from different countries are remarkably constant.

Most beekeepers find honey bees fascinating insects, and in studying their biology, develop an interest in the natural world and environmental matters. They are thus an ideal group from whom to recruit citizen scientists to take part in an environmental monitoring project such as INSIGNIA-EU.

Although beekeepers already have a high degree of skill in bee husbandry, a project such as INSIGNIA-EU requires them to develop new skills to collect samples, and a commitment to exert great care in collecting, storing and shipping the

samples to the scientists running the project.

Through questionnaires and interviews with beekeepers throughout INSIGNIA-EU, it has been found that beekeeper CSs participate because of their own interest in their bees and a desire to help understand both theirs and the honey bee's environment.

Further reading

Bieszczad, S.R. *et al.* (2023) How Citizen Scientists see their own role and expertise: An explorative study of the perspectives of beekeepers in a Citizen Science project. *Citizen Science: Theory and Practice*, 8(1): 26, pp. 1–12. https://dx.doi.org/10.5334/cstp.501

Gratzer, K., Brodschneider, R. (2021) How and why beekeepers participate in the INSIGNIA citizen science honey bee environmental monitoring project. *Environmental Science and Pollution Research*, 28: 37995-38006. https://doi.org/10.1007/s11356-021-13379-7

THE INSIGNIA-EU PROJECT

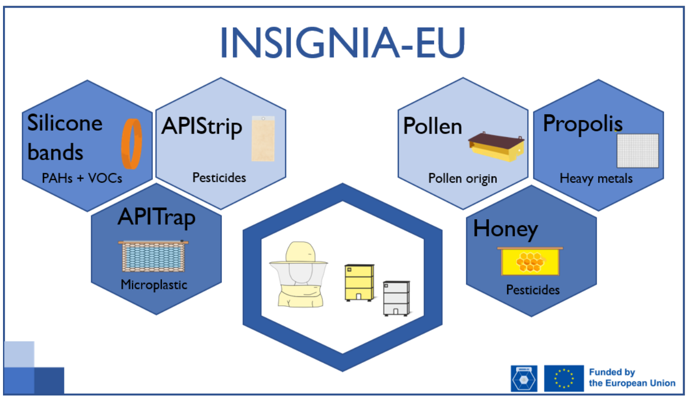
INSIGNIA-EU was commissioned by the European Commission DG Environment as "Preparatory action for monitoring of environmental pollution" (Project No 09.200200/2021.864096/SER/ENV.D.2).

The aims of INSIGNIA-EU are to provide a guideline for providing information on environmental pollution on a pan-European scale covering all EU Member States, using a network of beekeeping Citizen Scientists (CS)

The INSIGNIA-EU consortium comprises thirteen organisations from ten countries forming a multi-disciplinary team with specialist skills covering bee science, environmental science, citizen science, analytical chemistry, molecular biology, statistics, modelling, beekeeping extension and dissemination.

The project is coordinated by Alveus AB Consultancy, Netherlands with project financial management by Ghent University, Belgium.

Since the remit of the project covered a much wider range of pollutants than the previous INSIGNIA study, the first year of the project (2022) comprised a pilot project carried out by a limited number of CS beekeepers and research scientists in Austria, Denmark and Greece and led by Ellinikos Georgikos Organismos DIMITRA, Greece with contributions from many partners.



The pilot studies primarily tested a range of different media to collect samples for analysis of the full range of pollutants. Crucially they needed to test whether such methods were reliable in the range of different climatic conditions experienced in these three countries.

A number of additional side studies took place, such as testing a wide range of different plastic grids for propolis collection in Latvia and Greece.

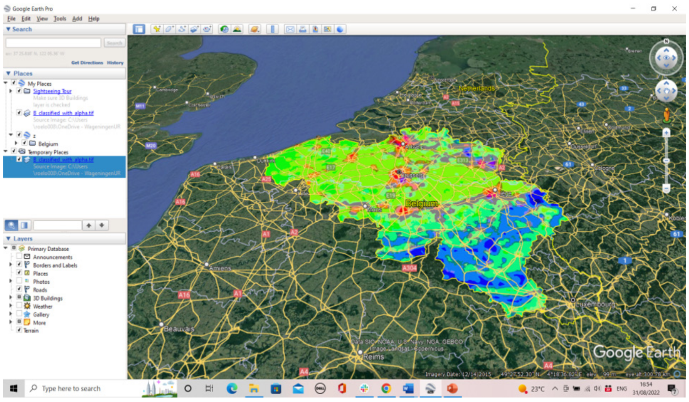
One concern was that the smokers used by beekeepers could introduce pollutants to the hive and therefore confound studies of external pollution such as Volatile Organic Compounds (VOCs). A batch of brand new smokers were purchased and tested with a wide range of different fuels in Denmark.

Since some samples such as pollen are very prone to decay, a number of studies were carried out into a range of methods for sample storage, preservation and efficient and cost effective transport.

The results of these pilot studies were carefully discussed, and weighted on a number of factors such as practicability and quality of the results, and it was pleasing that the final combination of sampling matrices were all non invasive to the honey bee colony.

SELECTING THE SITES

Sentinel honey bee colonies can be placed anywhere where nectar, pollen, and water are available and accessible. The worldwide network of beekeepers and honey bee colonies provides the ultimate means to use these colonies for bio-sampling, both for large-scale overview monitoring, and also for detailed small-scale monitoring.



Bio-monitoring means structured repeated bio-sampling of the same colonies. Focusing on large-scale studies, the land use and colony density determine the “region” and not the national borders. Sampling points should be spread over the region, depending on the study objective.

Selection of sites for INSIGNIA-EU took into account a number of factors. Firstly, it was necessary to ensure coverage over the area of the entire European Union, which meant decisions had to be made over very small countries like Malta, Cyprus and Luxemburg, which were allocated 5 apiaries, and very large countries such as France and Poland which had 20 apiaries, with the others on a sliding scale, giving 315 apiaries in total in the study.

The apiary locations were chosen using to provide a balanced range of sites from agricultural, artificial (i.e. urban or industrial) and forest / natural sites, and sites having a low, medium and high diversity of land uses. Suitable areas were identified using the CORINE land use database and suitable modelling techniques.

Once suitable target areas had been identified, the National Coordinator (NatCo) in each country was tasked with finding a sufficient number of suitable beekeeper Citizen Scientists (CS).

This required considerable planning, as beekeepers may be clustered in certain locations, but equally they may be very few in areas where there is little bee forage available. Eventually, a good distribution of apiaries was obtained.

At each apiary, the CS provided two honey bee colonies of suitable size, with a backup colony should any problems occur during the season. The beekeepers maintained their colonies throughout the season using their normal apicultural practices.

Nine sampling rounds were planned in 2023 at fortnightly intervals, but deciding when to begin involved some compromise, respecting differences between countries, as, for example, in Spring, colonies in Mediteranean countries may be experiencing their first honey flows, and nearby farmers may be spraying pesticides on growing crops, whilst in Nordic countries hives may still be under a depth of snow...

CITIZEN SCIENTIST BEEKEEPERS

Overall responsibility for organising the INSIGNIA-EU Citizen Scientist (CS) protocol rested with the University of Graz, Austria, with central coordination of supplies of all sampling materials and equipment by Danmarks Biavlerforening, Denmark.

Responsibilty for organising the CSs in each of the 27 Member States was through a network of National Coordinators (NatCos). Some were members of the consortium and the remainder were bee scientists and bee extension specialists.

The Consortium communicated with NatCos through the medium of an initial training meeting held at Wageningen, Netherlands, and then through regular online "NatCo Cafés" where any queries could be raised.

The NatCos had responsibility for recruiting and training an appropriate number of beekeeper CSs. Communication with the CSs took place through a range of channels, including tutorial videos and a Picture Manual, which were produced by the consortium and then translated by the Nat Cos into 23 different languages.

Communication with individual CSs also took place in a number of ways which varied between countries and comprised a mix of face to face meetings, online meetings and then via email or phone.

With any citizen science project, especially one which requires a commitment over nine sampling rounds over a full beekeeping season, maintaining motivation and morale is a vital part of the work of the NatCos, and overcoming any inevitable problems due to illness or absence of the CSs. Regular communication between CSs, NatCos and the consortium allowed many minor problems to be rapidly resolved ensuring that a very large proprtion of the expected number of samples were collected, safely received by the various laboratories in four different countries, and successfully analysed.

The wide experience of the consortium in previous citizen science projects meant that many problems had been anticipated, but inevitably a number of unexpected problems, such as the destruction of hives by bears in Romania had not been anticipated!

APISTRIPS

The "APIStrip" is a passive in-hive sampler devised by the University of Almeria, Spain. It is a polystyrene strip covered with Tenax® (a porous absorbent polymer). It is placed between two combs in the centre of the honey bee colony. The Tenax® is very firmly bound to the plastic strip and binds non-polar (insoluble in water) and semi-polar pesticide molecules that circulate inside the colony on the bees' exterior, as loose particles and in gas form.

In INSIGNIA-EU in 2023 a total of 5,838 ApiStrips were received and analysed for a total of 430 compounds, including all pesticides licensed in each EU Member State, and other compounds thought likely to occur. The strips were cut into small pieces, extracted into a solvent and then centrifuged. Various analytical techniques were then used including GC-QqQ-MS/MS and LC-QqQ-MS/MS analysis.

In all, 202 different compounds were detected, and these included acaricides used to control varroa mites in the bee colonies, together with many agricultural compounds including insecticides and various fungicides. Azoxystrobin, boscalid and acetamiprid were the most commonly detected. The results showed that 14 compounds were each detected in more than 20 countries, and four compounds were detected in all 27 countries. On average, 48 different compounds were detected in each country, varying from 26 compounds in Denmark to 78 in Germany, and the number of total detections over the season varied from 132 in Luxembourg (with 5 apiaries) to 1,698 in Poland (with 20 Apiaries.)

The median number of compounds per APIStrip was four in agricultural, two in urban and two in semi-natural areas.

There were considerable variations in both the number of compounds detected and the actual compounds identified between apiaries within each country, between countries, and over the sampling season.

Further reading

Luna, A. *et al*. (2023) Comparison of APIStrip passive sampling with conventional sample techniques for the control of acaricide residues in honey bee hives. *Science of the Total Environment*, 905: 167205. https://doi.org/10.1016/j.scitotenv.2023.167205

Murcia-Morales, M. *et al.* (2020) APIStrip, a new tool for environmental contaminant sampling through honey bee colonies. *Science of the Total Environment*, 729: 138948. https://doi.org/10.1016/j.scitotenv.2020.138948

Murcia-Morales, M. *et al.* (2021) Dissipation and cross-contamination of miticides in apiculture. Evaluation by APIStrip-based sampling, *Chemosphere*, 280.130783. https://doi.org/10.1016/j.chemosphere.2021.130783

Murcia-Morales, M. *et al.* (2021) Environmental monitoring study of pesticide contamination in Denmark through honey bee colonies using APIStrip-based sampling. *Environmental Pollution*, 290, 117888. https://doi.org/10.1016/j.envpol.2021.117888

Murcia-Morales, M. *et al.* (2022) Presence and distribution of pesticides in apicultural products: A critical appraisal. *Trends in Analytical Chemistry*, 146: 116506 https://doi.org/10.1016/j.trac.2021.116506

Murcia-Morales, M. *et al*. (2023) Enhancing the environmental monitoring of pesticide residues through *Apis mellifera* colonies: Honey bees versus passive sampling. *Science of the Total Environment*, 884: 163847 http://dx.doi.org/10.1016/j.scitotenv.2023.163847

HONEY

Honey consists of a solution of various sugars collected as nectar by foraging honey bees. Nectar can contain water soluble pesticides which have been applied as a seed dressing, but honey in the hive can contain other water soluble substances such as herbicides which have been applied to the leaves of plants, and which bees pick up in their foraging activities, but which would not be absorbed onto the ApiStrips.

In 2023, a total of 1,164 honey samples were analysed by the Benaki Institute, Athens, Greece, and 73 were found to contain at least one compound.

Polar pesticides found in honey were glyphosate, AMPA (a metabolite of glyphosate), phosphonic acid or N-acetyl-glyphosate. The first two compounds were found to be predominant, and the others were less commonly detected.

SILICONE WRISTBANDS

Wristbands made of silicone plastic, the kind handed out at music festivals and other events, actually prove to be very good at absorbing Volatile Organic Compounds (VOCs) and PolyAromatic Hydrocarbons (PAHs). Preliminary tests in 2022 by the The Benaki Institute, Greece, showed that when placed on the bee hive frame tops for several weeks they were effective samplers for VOCs and PAHs in the bee hive.

In 2023, a total of 1,216 samples were analysed, and the results showed that nine VOCs were commonly found, with two others less common, whilst six PAHs were commonly found, with three less frequently, and one PAH which was tested for was not found at all. Isoprene followed by hexane and benzene were the most common VOCs, and of 35 target PAH compounds, 34 were detected, the dominant compounds being naphthalene, methylnaphthalenes and pyrene. Significant exceedance of the average values indicated locally increased emissions, but there were no clear trends in occurrence, and it will be difficult to attach the results to particular sources.

Further reading

Murcia-Morales, M. *et al*. (2024) Environmental assessment of PAHs through honey bee colonies – A matrix selection study. *Heliyon*, 10: e23564. https://doi.org/10.1016/j.heliyon.2023.e23564

APITRAPS

Microplastics (MPs) are tiny (<5 mm) plastic particles that result from both manufacturing and the breakdown of larger plastic items. They can be harmful to the environment, and never breakdown chemically but instead disintegrate into ever smaller particles. An important MP source is synthetic fibres in clothes. These MPs may enter the ambient air by the wearing of clothes, and their washing and drying. Part of the MPs load will enter the bee hive via airflow, part will be deposited on flying bees, or collected from flowers by the foragers. Honey bees are therefore exposed to MPs and can be used to sample them from their surroundings.

MPs can be collected in the hive using an "APITrap", a double sided sticky sheet contained in a mesh cage so that bees cannot touch it, placed in a frame inside the brood nest. Development by the Latvian Beekeepers' Association, Latvia, ensured that the APITrap is made to fit in the smallest commonly used frame so that results from all countries are directly comparable.

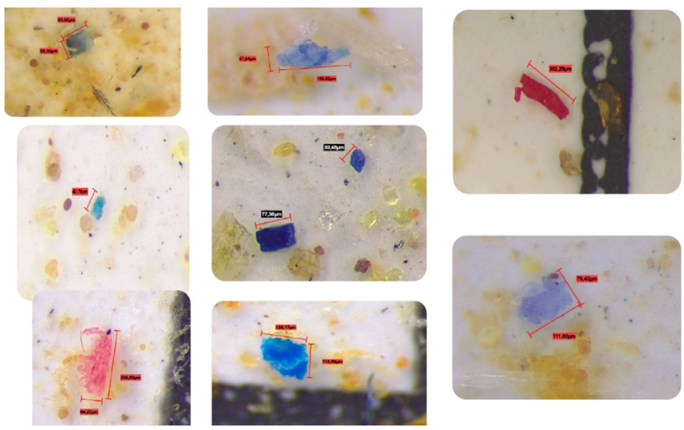
INSIGNIA-EU samples were analysed by the University of Almeria, Spain, and in 2023 a total of 2,390 samples were analysed. In order to retrieve the contaminants, each APITrap was put into a glass jar with solvent, placed in an ultrasonic bath, and then the liquid was filtered under vacuum. A stereomicroscope was then used to identify the number of MPs and classify them in terms of morphology, colour and type. After morphological identification, a micro-FTIR was used to characterize MPs and identify the polymer types.

The particles extracted were classified into fibres, fragments or films, and by colour and type of plastic. The results showed that fibres were 80% of all identifications, and those made of polyester (PET) were by far the most common. 52,099 synthetic polymer fibres and 7,244 synthetic polymer fragments and films were detected and analysed. Overall, polyester, polypropylene, and polyacrylonite were the most detected, and there was variation between countries; some were consistently above or below the average of all 27 EU Member States. There was little variation over the season, and on average, 40 fibres and five fragments and film particles were recovered from every ApiTrap. Blue, black and green were the most commonly occurring colours of particle.

Further reading

Cortés-Corrales, L. *et al*. (2024) Evaluation of microplastic pollution using bee colonies: An exploration of various sampling methodologies. *Environmental Pollution*, 350:124046. https://doi.org/10.1016/j.envpol.2024.124046

[1]Edo, C. *et al.* (2021) Honey bees as active samplers for microplastics. *Science of the Total Environment,* 767: 144481. https://doi.org/10.1016/j.



PROPOLIS GRIDS

Propolis is composed of plant resins collected by honey bees, mainly collected from plant sticky buds. As such it is very prone to contamination by air pollution, especially by heavy metals.

In 2023, propolis samples which were collected on plastic screens inserted over the combs were analysed by Wageningen University, Netherlands for heavy metals. Although there was a decline in the amounts of propolis collected in some countries as the season progressed, a large proportion of the expected samples were obtained.

Eleven individual metals were tested for, and the results showed that trends seem to be similar between apiaries and between countries, but on average, lower concentrations of metals were detected

in the northern countries compared to the southern countries. The analysis detected some point emission sources. It is to be expected that factors such as predominant soil type, climate, and the amount of propolis collected may influence the results.

POLLEN

Pollen is produced by the male parts of flowers for transport to the female parts for fertilisation to produce seeds and fruit. Although many plants such as cereals are pollinated by wind, most of the attractive flowers that we see, which produce the fruits, nuts and other products that we

like to eat, have evolved to be pollinated by insects. Bees form the most successful group of pollinators because they have evolved to collect pollen for their protein food source. Honey bees are well adapted with their hairy bodies and pollen baskets to collect pellets of pollen which they bring to the hive.

Beekeepers often use pollen traps at the entrance of hives to collect pollen as a human food, and these can easily be used to collect a pollen sample to find out which plants the bees have been visiting. The colour of the pollen load can be a guide, and examination under a light microscope can usually identify pollen grains to plant species. This however, is a very time consuming and skilled job. In recent years, various DNA techniques including metabarcoding have provided a

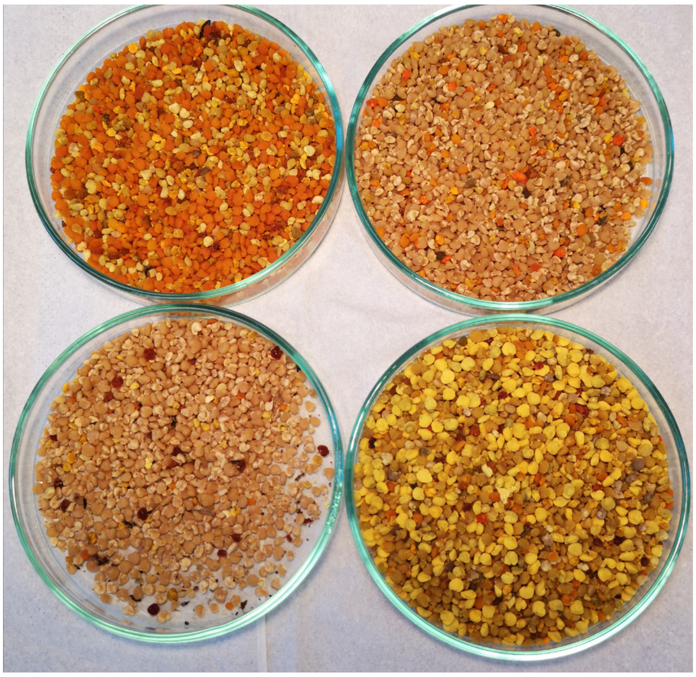
POLLEN

quick and reliable alternative method of pollen identification.
In the INSIGNIA-EU project it is important to identify the plants that the bees have been visiting, for example in order to tie the presence of an agricultural pesticide to a crop that was flowering at the time.

The Instituto Politécnico de Bragança, Portugal has developed ITS2 metabarcoding techniques to identify pollen collected from pollen traps by CS beekeepers to Family, Genus and Species level. In 2023, a total of 2,835 samples were received, of which 2,513 were successfully analysed. A few samples, particularly in the later sampling rounds were found to be insufficient in quantity for analysis, and a small number were contaminated by mould, to which pollen is very susceptible.

As expected, the pollen sources varied considerably over the season, and there was considerable variation between countries, with neighbouring countries tending to form regional groups, but Cyprus and Malta had very different pollen profiles from the other countries. In general there was greater diversity in the pollen sources of the southern countries, the Mediterranean region having the most differentiated bee-collected pollen in Europe, whilst the northern countries have the lowest.

There are clear variations between sites

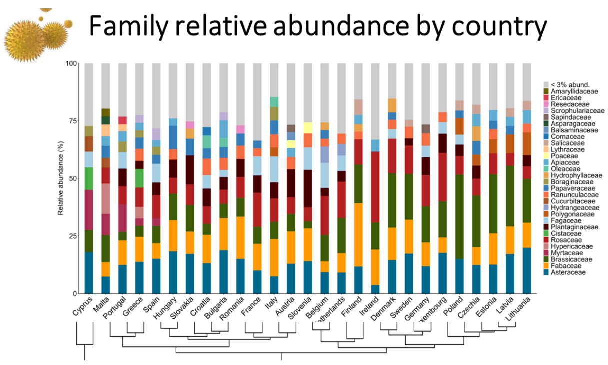


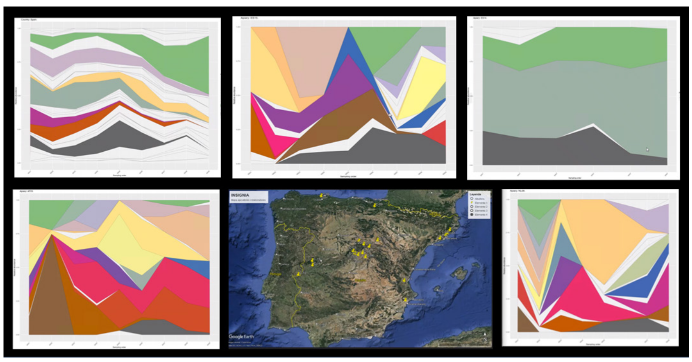
of different land use types; diversity was higher in urban and semi-natural areas than in agricultural areas. Overall, the most commonly occurring families were the Asteraceae, Brassicaceae, Fabaceae, Plantaginaceae, and Rosaceae, and no single genus was present over all 27 countries. Pollen of *Trifolium*, *Plantago*, *Brassica*, *Rubus*, and *Castanea* were most abundant.

Further reading

Quaresma, A. *et al*. (2021) Preservation methods of honey bee collected pollen are not a source of bias in ITS2 metabarcoding. *Environmental Monitoring and Assessment*, 193: 785. https://doi.org/10.1007/s10661-021-09563-4

Quaresma, A. *et al.* (2024). Semi-automated sequence curation for reliable reference datasets in ITS2 vascular plant DNA (meta-) barcoding. *Scientific Data*, 11(1): 129. https://doi.org/10.1038/s41597-024-02962-5





STATISTICS AND MODELLING

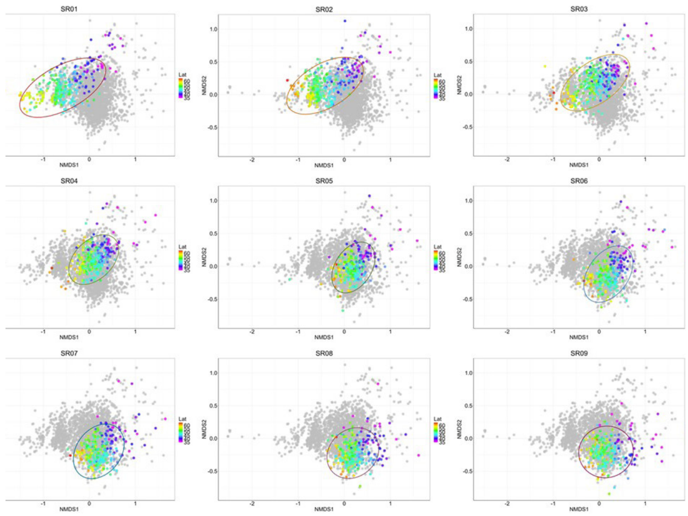
In INSIGNIA-EU, careful and safe storage of all data, whether information supplied by the beekeeper CSs or the NatCos, or analitical results produced by the laboratories is essential, so has been stored centrally by the Data Controller based at Wageningen Environmental Research, Netherlands, before being made available for statistical analysis and modelling.

Responsibilty for statistical analysis has been taken by the University of Strathclyde, UK. The main aim has been to assess, for example, differences between the numbers of pollutants recorded by sampling date, by the apiary within a country, and by country. If a large number of apiaries are participating within any one country, apiaries might be categorised by geography or landscape type and this could be used instead of apiary as an explanatory factor.

Summary statistics can be used to form an informal impression of the data overall for each country, and of any differences between sampling dates or apiaries within a country. Separate analyses for each country are appropriate. As the aim is to relate the number of pollutants to sampling date and apiary for any one country, study of the statistical significance of the effects on number of pesticides of sampling date and apiary, individually or simultaneously, can be accomplished through fitting generalised linear models (GLMs), generalised linear mixed models (GLMMs) and other techniques.

Heavy metals- PCA

Further modelling of the data is being carried out by Wageningen Environmental Research, Netherlands. As well as the data collected during INSIGNIA-EU, use



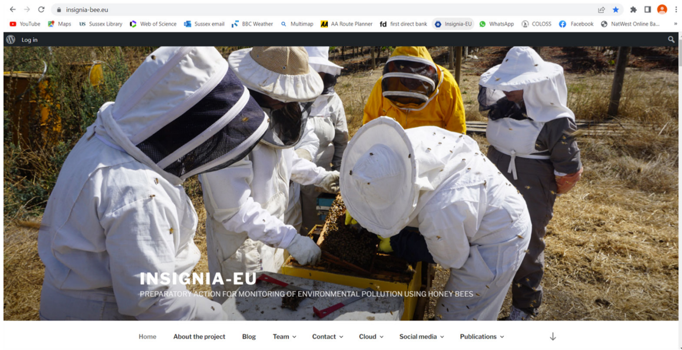
has been made of a number of European databases of weather, land use, physical geography to better interpret the results.

Analysis and modelling of the results is continuing, but raw results, including individual spectrum diagrams showing the botanical origin of the pollens from each hive over the season have been sent to the National Coordinators for distribution to their individual Citizen Scientist beekeepers.

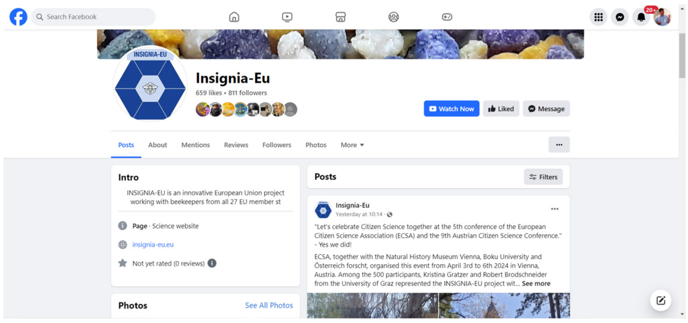
As a final outcome of INSIGNIA-EU, pollen diversity and the distribution of environmental pollution throught the entire European Union over the course of a complete bee season are now being visualized in spatially explicit models.

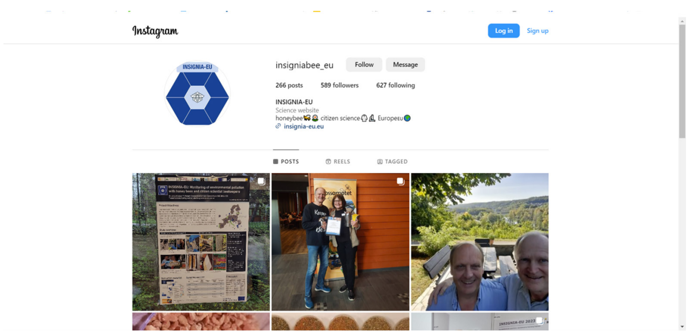
INSIGNIA-EU DISSEMINATION

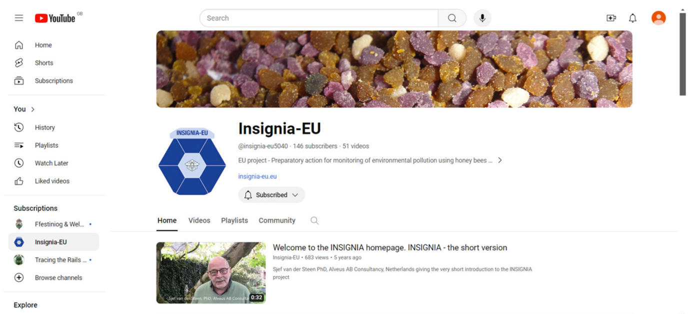
In any project involving citizen scientists, dissemination is extremely important. This is especially true of INSIGNIA-EU, as keeping the volunteer CS beekeepers fully informed and motivated through the season is vital. Dissemination has been led by Carreck Consultancy Ltd, UK, University of Graz, Austria and Danmarks Biavlerforening, Denmark, but all members of the consortium and the network of Nat Cos have contributed.



The INSIGNIA-EU website https://www.insignia-bee.eu/has been the core of the dissemination strategy. It has had regular blog posts, leading to social media outlets such as FaceBook, Instagram, and a YouTube channel which hosts regular videos giving training and updates. Regular newsletters have been produced and circulated to those signing up on the website.





Members of the consortium have given talks at international, national, regional and local meetings, to scientific audiences, and beekeeping groups and the general public.

A number of popular scientific articles have been written, translated into many different languages, and have appeared in many national and local beekeeping journals. Fourteen papers arising from the project have already been published in refereed scientific journals, with many more in preparation.

INSIGNIA-EU LEGACY

INSIGNIA-EU has been the first comprehensive pan-European environmental pollution monitoring study using Citizen Scientist beekeepers to sample honey bees.

It has sampled a wide range of pollutants over a complete season with a balanced distribution of apiaries, non-invasive sampling, high quality laboratory analysis, data analysis, spatial and temporal pesticide risk exposure model and pollen diversity modelling in pan-European cooperation with stakeholders and cooperation with other EU bee research projects and a comprehensive dissemination programme.

It has demonstrated the potential for a long term Pan-European monitoring programme using beekeeper Citizen Scientists.

We thank all of the beekeeper Citizen Scientists in all 27 EU Member States for their contribution to the project's successful outcome.

For more information see: https://www.insignia-bee.eu/

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