Emerging threats and opportunities for conservation of global pollinators

A rapid assessment for Bee:wild

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bee:wild

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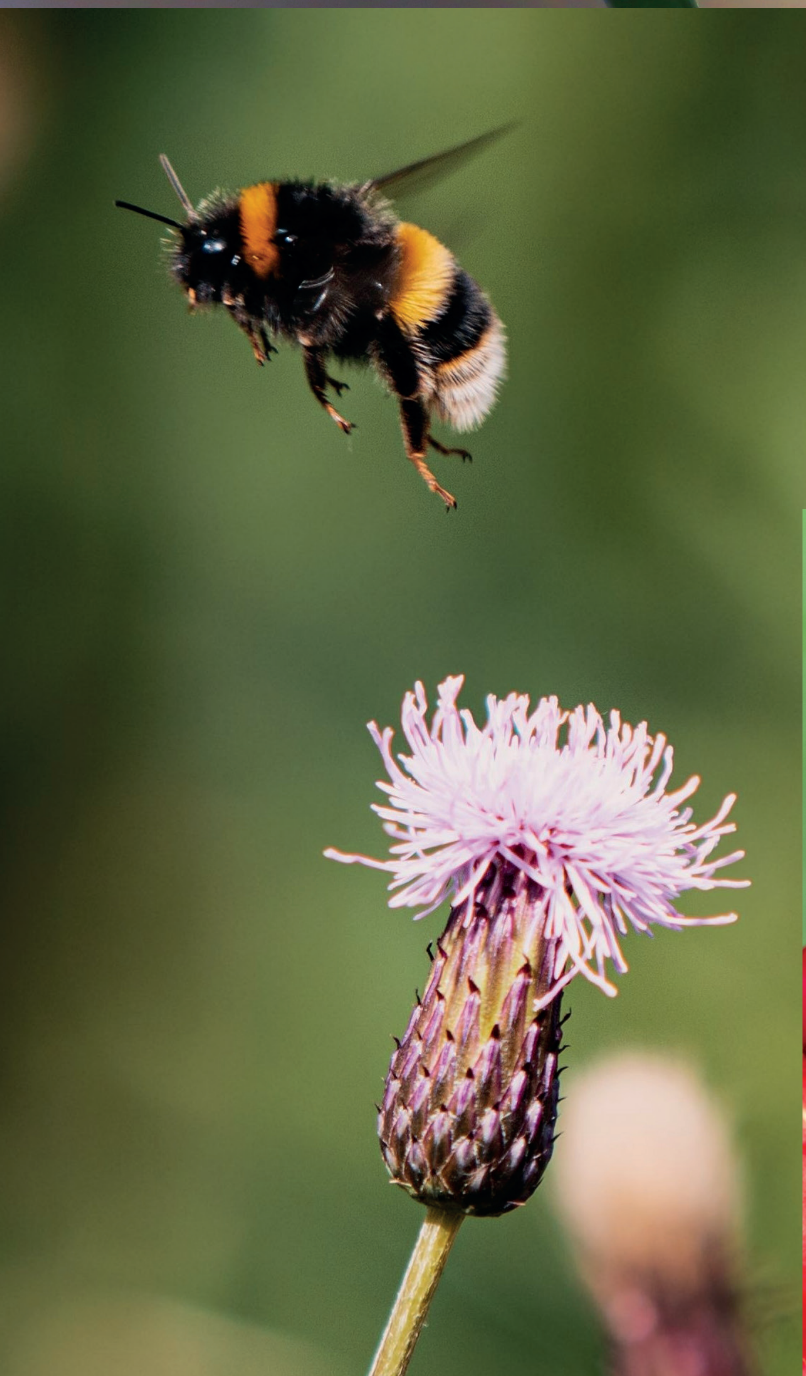


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"The choices we make today will shape the future – not only for pollinators, but for all life on Earth."

Razan Khalif

Razan Khalifa Al Mubarak,
President of the International Union for Conservation of Nature (IUCN) and Board Member of Re:wild

Nature's most extraordinary work often happens quietly. As we go about our lives, an incredible community of pollinators – bees, butterflies, moths, birds, bats, and others – sustains the ecosystems that feed and nourish us.

Their invisible care supports the vast majority of wild flowering plants and much of the food we depend on. Pollinators are not only essential to biodiversity; they are vital to our food security, our economies, and our wellbeing.

Yet today, these vital species face growing challenges – from habitat loss and pesticide use to climate shifts and invasive species. Emerging pressures, such as microplastics and light pollution, add new urgency to our efforts.

If we lose pollinators, the consequences will ripple far beyond nature itself. The services they provide are fundamental to human survival – supporting everything from the food on our plates to the health of ecosystems that regulate our climate and clean our air and water. Their decline is a warning signal that we cannot afford to ignore.

The good news is that solutions are within reach. Through stronger policies, sustainable farming practices, technological innovation, and local and global action, we can safeguard pollinators and the ecosystems they sustain.

Bee:wild's work shines a light on these solutions. By planting for pollinators, reducing light pollution, supporting regenerative food systems, and encouraging sustainable business practices, each of us can contribute to a healthier, more resilient planet.

The choices we make today will shape the future – not only for pollinators, but for all life on Earth. Together, we can ensure that these remarkable species continue their vital work, sustaining the natural world that sustains us all.

ACKNOWLEDGEMENTS

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Project partners

Bee:wild is a science-led, non-profit civil society movement, powered by brands, that aims to increase pollinator numbers for the benefit of nature and healthier people.

Bee:wild is a campaign of Re:wild, a leading nature conservation organization focused on the most effective solution to the interconnected climate, biodiversity and human wellbeing crises; protecting and restoring the wild.

Learn more at beewild.org

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SUMMARY

Pollinators like bees, hoverflies, butterflies, moths, and some birds and bats, are vital to nature and our food supply. Nearly 90% of flowering plants and over 75% of the world's main food crop types depend on them.

Yet pollinators are facing an ongoing crisis from many well-established and overlapping threats. In addition, it is becoming clear that there are many new and emerging risks which are multiplying the negative impacts of these established threats. This report highlights not only these well-known risks, but also emerging opportunities for early, coordinated action to protect pollinators before it is too late.

The ongoing drivers of global decline

The biggest pressures on pollinators today are not new, but they are intensifying, and include:

- **Habitat loss** driven by intensive farming, urbanisation, and infrastructure development, reducing food and nesting resources for pollinators.
- **Pesticides** like insecticides, herbicides, and fungicides, which can kill pollinators or affect their health, behaviour and ability to navigate.
- **Climate change** altering habitats, flowering times and pollinator activity periods as well as causing extreme weather like heat stress and drought.
- **Pests and pathogens** including a wide variety of harmful microorganisms.
- **Invasive species** like introduced managed bee species, which can compete with, and transmit diseases to native pollinators.

These threats interact in dangerous ways to produce a lethal cocktail of threats, making it harder for pollinators to survive and recover.

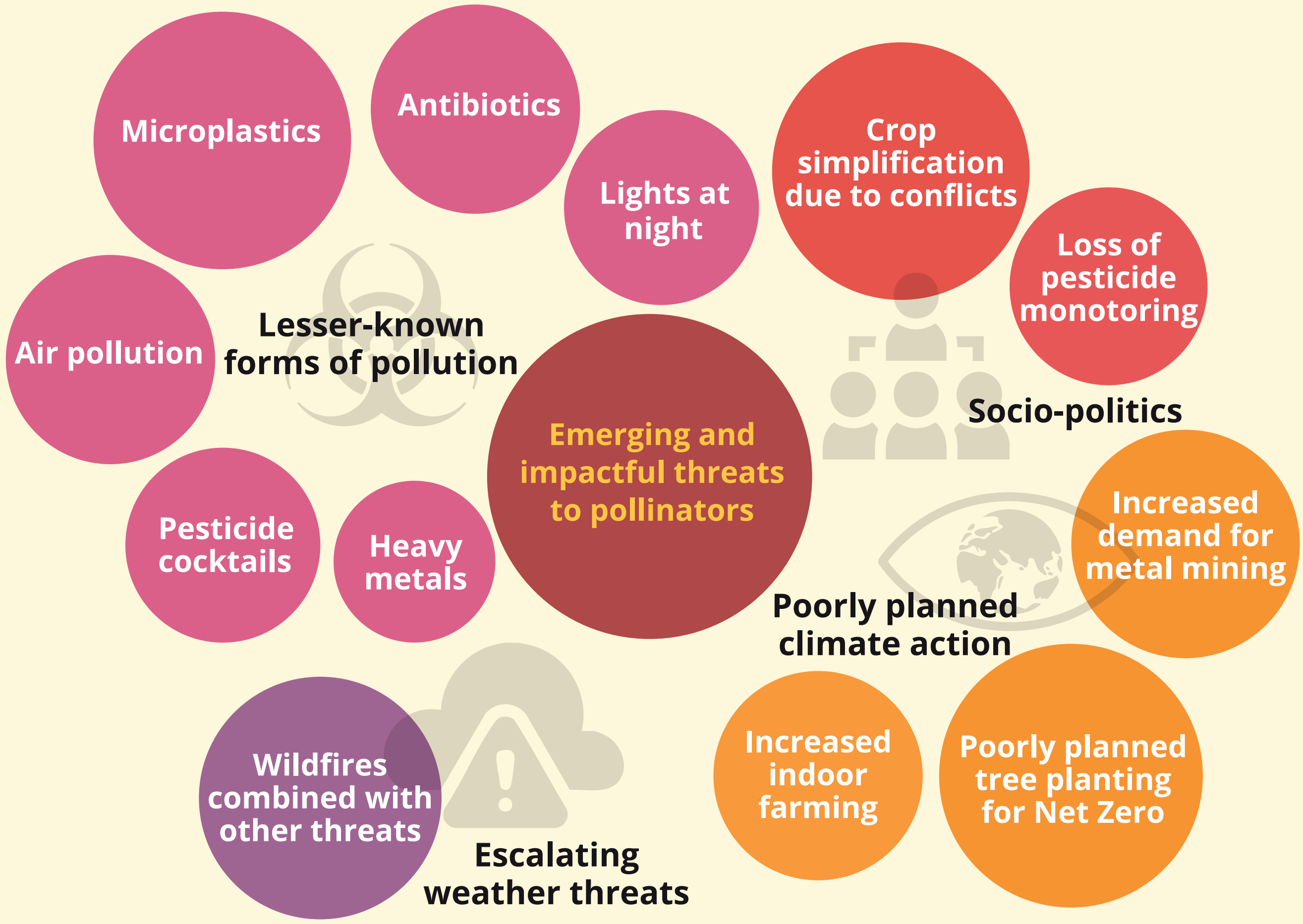
New and emerging threats to watch

Pollinators are increasingly challenged by a rapidly changing world shaped by new and emerging threats. We highlight four major themes that capture the breadth of the most novel and impactful emerging threats likely to accelerate in the next 5-15 years (Figure 1):

- **Lesser-known forms of pollution**: Microplastics, antibiotics, air pollution, heavy metals, and artificial light at night are harming pollinators in ways we are only beginning to understand, and mixtures of pesticides may be more dangerous together than previously thought.
- **Poorly planned climate action**: Some efforts to fight climate change, like large-scale tree planting, increased demand for mining for for e-batteries, or indoor farming, may backfire if not planned well. The wrong trees in the wrong places can harm pollinators by replacing wildflowers, and indoor farms often remove habitat while relying on managed bees that may compete with wild ones.
- **Socio-political effects on the environment**: Conflict-driven crop simplification and reduced pesticide monitoring are leaving pollinators with fewer resources and protections.
- **Escalating weather threats**: Wildfires made worse by climate change are burning fragmented habitats, leaving pollinators with fewer places to feed and nest.

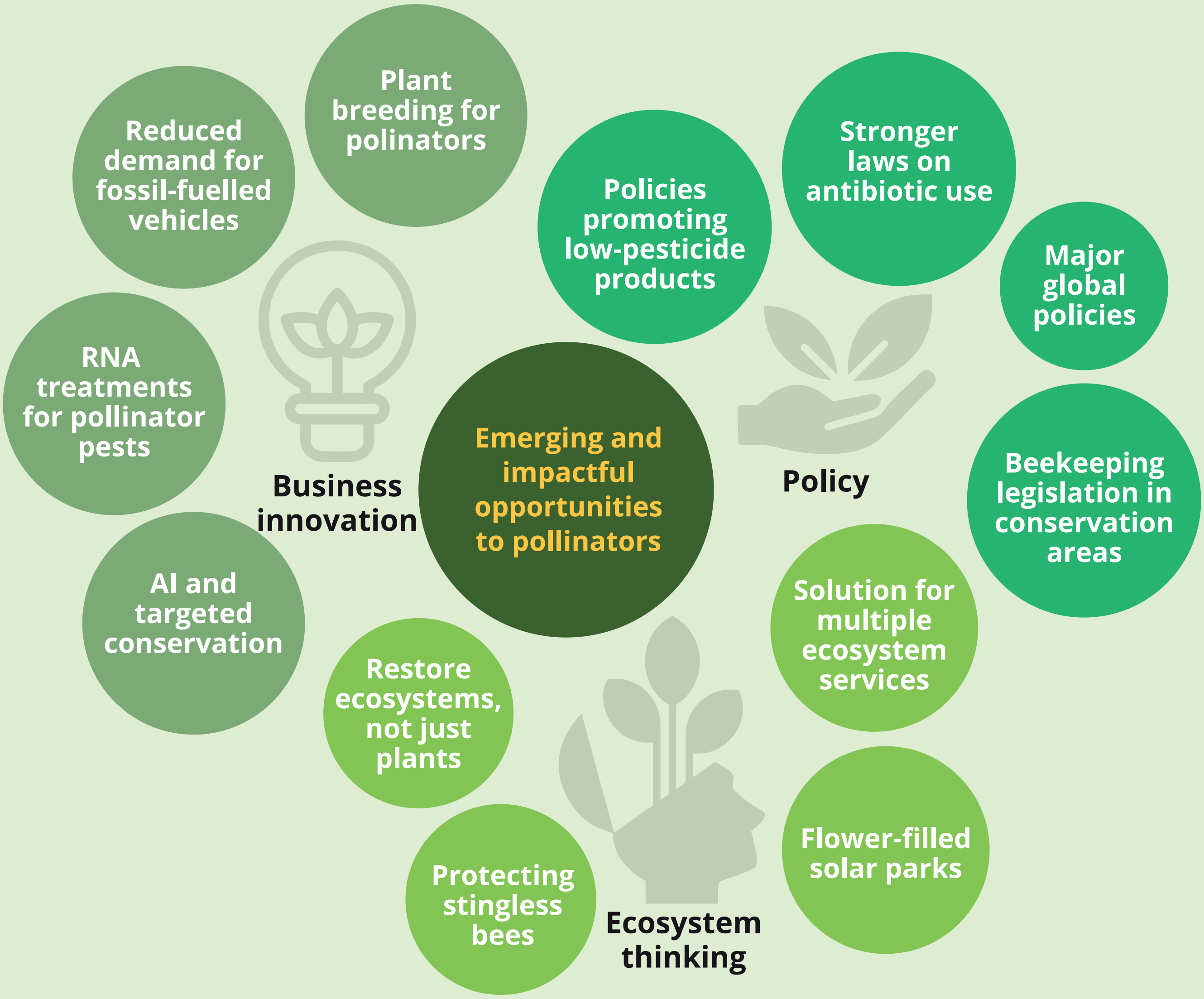
These threats must be met by new avenues for protection and recovery.

Figure 1: Emerging threats to pollinators at regional to global levels, scaled by novelty and impact (bigger circles indicate higher novelty and greater negative impact).



Microplastics are more widespread than previously thought. They likely pose a serious threat to wild pollinators as well.

Figure 2: Emerging opportunities for pollinators at regional to global levels, scaled by novelty and impact (bigger circles indicate higher novelty and greater positive impact).



This is not just a biodiversity issue: pollinators are central to our food systems, climate resilience, and economic security.

New and emerging opportunities to safeguard pollinators

We identified three major avenues of emerging and impactful opportunities that can help to prevent future pollinator declines (Figure 2):

More effective policies, laws and global frameworks: Stronger regulations, like responsible antibiotic use, reforming trade to favour low-pesticide products, and controlling beekeeping in conservation areas, could all reduce major threats to pollinators. International agreements, such as the EU Nature Restoration Regulation and the United Nations Convention on Biological Diversity (CBD) and Food and Agriculture Organization (FAO)'s global initiatives, are driving coordinated efforts to restore habitats and promote pollinator-friendly farming.

Business innovation - Technology and smarter practices: Advances in electric batteries, new innovations in pest control (e.g. using RNAi), plant breeding, and AI monitoring could offer new tools to support pollinators. These advances can help reduce chemical use, target threats more precisely, and improve habitat management, but require careful oversight to avoid unintended harms to pollinators.

Ecosystems thinking - Multifunctional and resilient landscapes: Creating pollinator habitats within solar parks, protecting stingless bees, and restoring full ecosystem functions, with careful consideration of what is planted and where, will support broader biodiversity. Nature-based solutions that link pollination with soil health, water retention, and carbon storage offer win-win approaches for people and the planet.

Rising threats, emerging opportunities

The themes identified in this report reflect both the escalating complexity of pressures on pollinators and the growing diversity of tools and opportunities available to help reverse their decline.

The top 12 threats and top 12 opportunities identified in this report, in order of a) novelty and b) impact, can be found on pages 10 and 11.

This report offers important insights we need right now to inform and guide governments, farmers, businesses, NGOs and civil society in supporting pollinators.

These vital species face more challenges than ever before, including some that are just starting to be understood, but we still have time to act. By recognising these emerging threats and opportunities, and working together, we can better protect pollinators and the vital role they play in sustaining ecosystems and the services they provide, including pollination of the food we rely on.

This is not just a biodiversity issue: pollinators are central to our food systems, climate resilience, and economic security. Protecting them means protecting ourselves.

TOP 12 THREATS

Emerging threats to pollinators (regional to global) ranked from highest to lowest by novelty, then impact

1. **Crop simplification due to conflicts** – War and conflict affects how land is used, reducing crop variety, which could harm wild pollinators.
2. **Microplastic pollution** – Tiny plastic particles are everywhere and can reduce pollinator health and lifespan.
3. **Poorly planned tree planting for Net Zero** – Planting lots of trees can help or hurt nature, depending on the type of trees planted, and where.
4. **Antibiotic pollution** – Antibiotics pollute the environment and may change bee behaviour.
5. **Air pollution** – Polluted air with gases like ozone and nitrogen oxides makes it harder for insects to survive and reproduce.
6. **Increased indoor farming** – Growing crops in enclosed spaces reduces natural habitats for wild pollinators and may spread disease through the introduction of managed pollinators.
7. **Increased demand for mining of metals** – Mining for materials like lithium and cobalt, used in batteries, damages land and water, which may harm pollinators.
8. **Pesticide cocktails** – Mixing different pesticides can weaken pollinators, and their use is increasing, particularly in some regions like Africa and South America.
9. **Light pollution** – Bright artificial lights at night confuse pollinators like moths and can reduce pollination.
10. **Heavy metal pollution** – Toxic metals like cadmium and mercury can harm pollinators' health, behaviour, and survival.
11. **Wildfires combined with other threats** – More frequent large wildfires destroy pollinator habitats, making recovery harder.
12. **Regional loss of pesticide monitoring** – Without proper tracking, harmful pesticides may be overused, killing pollinators and removing floral resources, as well as making pests resistant and damaging the environment.

TOP 12 OPPORTUNITIES

Emerging opportunities for pollinators (regional to global) ranked from highest to lowest by novelty, then impact

1. **Stronger laws on antibiotic use** – Better regulations could limit antibiotic pollution, especially in areas where there are no restrictions.
2. **Reduced demand for fossil-fuelled vehicles** – Electric vehicles can reduce air pollution that can be harmful to pollinators.
3. **Plant breeding for pollinators** – Crops can be designed for pollinators by providing more pollen and nectar, but more research is needed to ensure safety.
4. **Flower-filled solar parks** – Solar farms can serve as pollinator-friendly habitats if located well and designed properly.
5. **RNAi treatments for pests of pollinators** – New pest control methods using RNAi technology could protect bees while reducing pesticide use.
6. **AI and targeted conservatio**n – AI can track pollinators, detect pests, and help improve conservation efforts.
7. **Trade and agricultural policies promoting low-pesticide products** – Regulations could encourage farming with fewer pesticides, protecting pollinators and their habitats.
8. **Beekeeping legislation in conservation area**s – Implementing regulations could help minimise competition between managed bees and wild pollinators for essential resources.
9. **Restore full ecosystem function, not just plants** – Conservation should focus on rebuilding whole ecosystems, not just planting trees.
10. **Protecting stingless bees** – Efforts should focus on saving native stingless bees, which play a key role in pollination in the tropics.
11. **More effective global policies** – International regulations and laws, like the EU Nature Restoration Regulation, support pollinator protection and create groundswell support for pollinator conservation.
12. **Solutions benefiting multiple ecosystem services** – Protecting pollinators can also simultaneously improve soil health, water storage, and carbon capture.

INTRODUCTION

The importance of pollinators

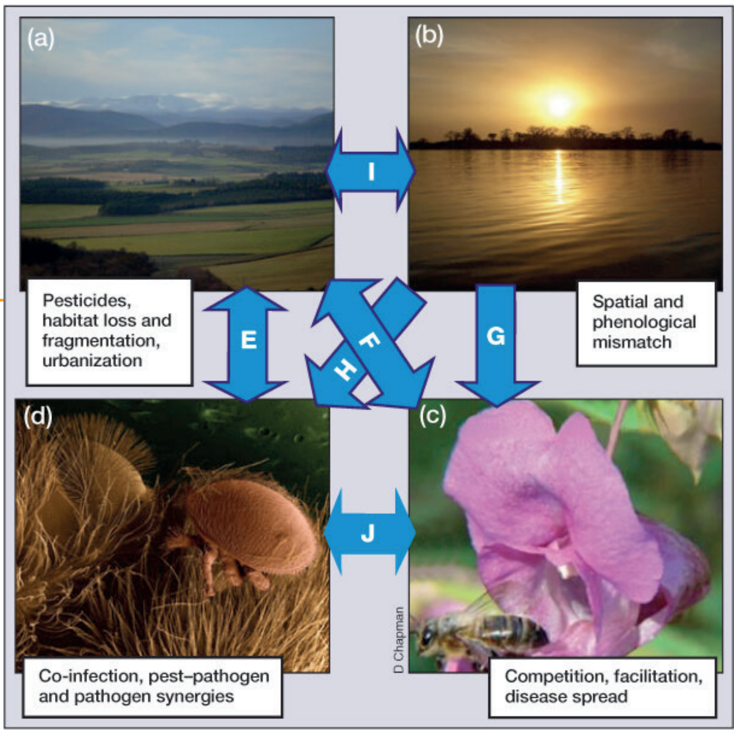
Pollinators are vital for global food security, biodiversity, and healthy ecosystems. This diverse group, including managed honey bees, native wild bees, butterflies, flies, moths, birds, bats, and other animals, plays a critical role in moving pollen between flowers, enabling plants to produce fruits, seeds, and the next generation of vegetation. Almost 90% of flowering plant species (Ollerton et al., 2011) and more than three-quarters of the world's key food crops (Klein et al., 2007) rely on animal pollinators to reproduce. Pollination services sustain the crops that support rural economies and the habitats that provide clean air, water, and climate regulation. A decline in pollinator populations threatens not only what we eat (fruits, vegetables, nuts, and more) but also the health of the natural systems that underpin life on Earth (IPBES, 2016).

Managed bees and wild pollinators

It is important to recognise the distinct but interconnected roles of industrial pollinators, like managed honey bees used in agriculture, and wild pollinators which can include a huge diversity of native insects, birds, bats and mammals. In many parts of the world, managed bees are essential for large-scale farming, especially monoculture crops, but they are not a replacement for the diversity and resilience that wild pollinators bring in supporting wild plants and broader ecosystems. All pollinators are vital to global crop and plant pollination (IPBES, 2016) and each face unique yet overlapping threats (Siviter et al., 2023).

Current known and well-established threats

Even though pollinators are essential, their populations are under serious threat. Some of the biggest dangers they face include habitat loss, pesticides, climate change, parasites, disease, and invasive species (Figure 3) (Brown et al., 2016; IPBES, 2016; Dicks et al., 2021; Vanbergen et al., 2013; Goulson et al., 2015). As farms and cities expand, many pollinators lose access to the flowers and nesting places they need to survive. Pesticides can harm pollinators by affecting their survival, health and ability to navigate. Pollinators such as bees are also at risk from diseases, such as those caused by the Varroa mite in managed honey bees, and harmful microorganisms like bacteria and viruses which can affect all pollinators. Invasive pollinator species can add to the problem by competing with native pollinators for food or bringing new diseases that can spread quickly. Invasive plants can draw native pollinators away from native plants threatening wild plant communities. Climate change makes things worse by driving changes in the distribution of pollinators and their habitats (which can become disconnected), causing disruptions such as changing when flowers bloom and how much nectar they produce (Gallagher and Campbell, 2017; Frigero et al., 2025). Extreme weather events, including severe droughts and floods, are becoming worse and more frequent across continents (IPCC, 2023). A single extreme weather event can seriously harm nature, suddenly wiping out large numbers of diverse plant and animal species, including pollinators (Dorey et al., 2021). All these threats are acting in parallel and often interacting to severely undermine pollinator populations.



By bringing attention to these issues and related conservation opportunities, this report aims to galvanise and inform early action to reduce risks and strengthen global efforts to protect pollinators.

Figure 3: Arrows representing interactions between known threats to pollinators; (a) Land-use intensification, (b) climate change, (c) alien species, (d) and pests and pathogens (Vanbergen et al., 2013).

Multiple threats interact

The combined effect of multiple stressors can be far worse than any single threat alone. For example, habitat loss may leave pollinators with fewer resources, making them more vulnerable to pesticide exposure or disease. Likewise, climate change can alter flower availability, forcing pollinators to forage in areas where they are more likely to encounter harmful chemicals or invasive species. These overlapping pressures create a threat multiplier, where each new challenge intensifies the impact of the others, pushing pollinator populations toward even steeper declines.

New emerging threats

On top of the well-known and well-established threats, new challenges are further amplifying the problems for pollinators. Changes in land use and the rise of new technologies, may be adding emerging threats, but we do not yet fully understand their effects. As these problems build up, the situation for pollinators is becoming increasingly serious. As we have learned from the impacts of well-established threats in the past, such as broad-spectrum pesticides and loss of natural habitats, early actions when these threats are first recognised can greatly help reduce the extent of their negative impacts.

Purpose of the report

Identifying new threats and finding ways to protect pollinators early is key to preventing further major declines. If we identify risks in advance, governments, scientists, farmers, conservationists, businesses, and civil society can act before it is too late. This could involve restoring or creating habitats, or changing farming practices, laws, and land-use approaches. By acting early, we can reduce harm and help pollinators continue their important work in nature and food production.

This report highlights emerging threats and opportunities for pollinators that may appear across the globe in the next 5 to 15 years. By bringing attention to these issues and related conservation opportunities, it aims to galvanise and inform early action to reduce risks and strengthen global efforts to protect pollinators.






METHODS

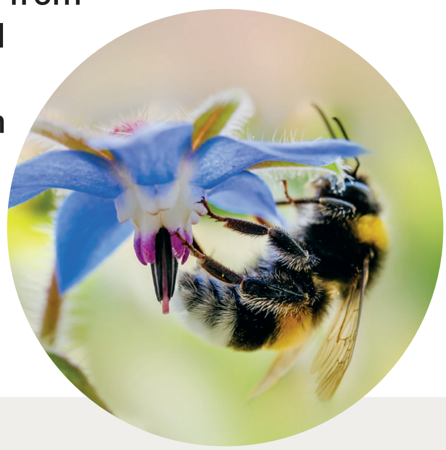
We used an expert elicitation process with ten internationally recognised experts from across the globe, with a broad knowledge of different pollinator groups, to identify emerging and under-researched threats and opportunities for pollinators that are likely to emerge over the next 5 to 15 years. Experts scored these issues based on their novelty*, potential impact to pollinators, geographical coverage, and confidence in their assessment. For the full description of the methods, please refer to Annex 1. In some cases, the emerging threats and emerging opportunities are opposing aspects of the same issue, which we indicate in our report with a + for positive aspects, and – for negative aspects. In other cases the threats and opportunities are not linked.

*Novel = without substantial evidence, little studied or reported, that adds value or insight to the field.

RESULTS

In this report, we present the results of an expert review highlighting 44 emerging threats and 36 opportunities for pollinators (Annex 2-3).

While all of these are emerging according to experts, this section focuses on those identified as the top 12 most novel and impactful threats and top 12 opportunities, from regional to global scales. The full scores are shown in Annex 4.



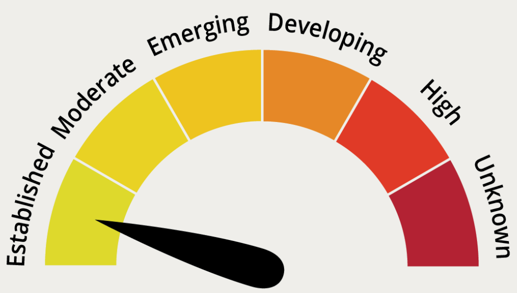
KEY

Two-sided issues

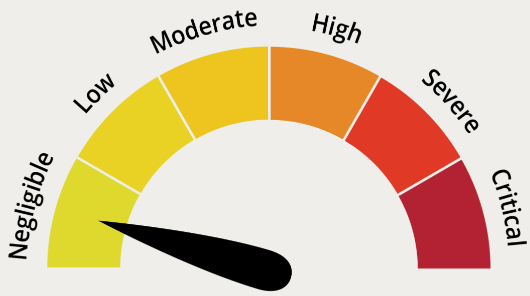
Examples where there are both positives and drawbacks are marked with + and – for the relevant case.

What size area could it cover?

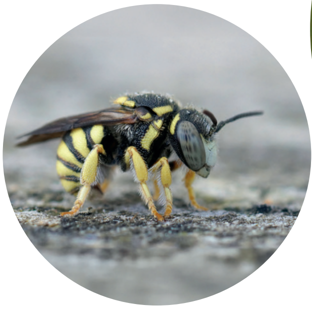
How new is it?



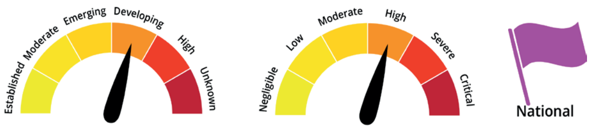
How impactful could it be?



THREATS

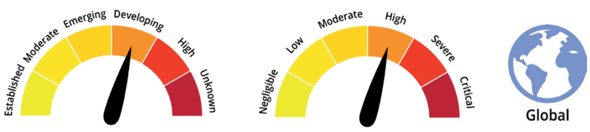


1. Crop simplification due to conflicts



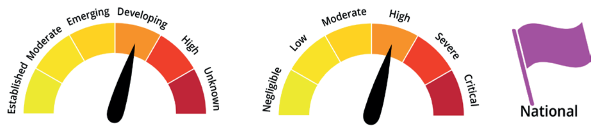
War and conflict can change how land is used and how farmers grow food (Zhang et al., 2023a; Dinc and Eklund, 2024). For example, countries affected by war or that depend on imported food may instead focus on self-dependency and transform more land into agricultural land to ensure enough food for their people. This can lead to loss of natural habitat and reduction in habitat diversity and quality. These simplified landscapes can harm wild pollinators by limiting the variety and timing of food resources and can also increase pest outbreaks, driving up pesticide use. In simpler farming systems, flowers that pollinators rely on may only be available for a short time, leaving them without food for the remainder of the season (Kovács Hostyánszki et al., 2017).

2. Microplastic pollution



Microplastics are tiny plastic particles, smaller than 5 mm, that have been shown to harm honey bees by impacting their growth, affecting their gut health, and shortening their lives (Al Naggar et al., 2024). Whilst studies have so far mainly focused on honey bees (Willcox et al., 2023), since microplastics are so common, they could also pose a growing threat to other pollinators (Anbumani & Kakkar, 2018). Recent research from the **INSIGNIA project** found that microplastics are more widespread than previously thought. Tests on honey bee colonies in 27 EU countries showed that almost all were contaminated, with most plastic coming from synthetic materials like PET (polyethylene terephthalate). Since microplastics are everywhere and research suggests they can be harmful, they likely pose a serious risk to wild pollinators as well.

3. Poorly planned tree planting for Net Zero (+-)



- With growing momentum around Net Zero (NZ), numerous policies, initiatives, and guidelines support large-scale tree planting. The European Commission, for example, aims to plant 3 billion trees by 2030 (EC 2024). While this focuses on reducing carbon emissions, its effect on biodiversity, particularly pollinators, strongly depends on the types of trees planted. Fast-growing trees like Eucalyptus absorb a lot of carbon but can harm wildlife in non-native ranges (Goded et al., 2019), especially if they replace flower-rich areas.

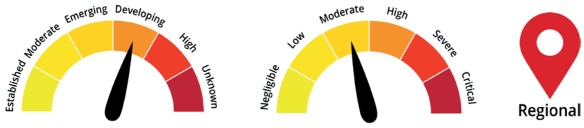
+ On the other hand, a mix of native species like wild cherry and willow supports more biodiversity (Bożek et al., 2023). There are good guidelines for planting the right trees in the right places, for example the UK Tree species Guide (Beauchamp and Broome, 2024), but to date consideration of biodiversity implications of planting trees for net zero are often overlooked.

As large-scale tree planting spreads across regions, it can either benefit nature (choosing species good for carbon and good for wildlife) or cause unintended harm (species good for

We highlight the most novel and impactful emerging threats to pollinators, at a regional to global scale, that are likely to emerge in the next 5-15 years.

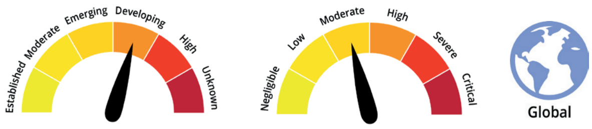
carbon but poor for wildlife).

4. Antibiotic pollution



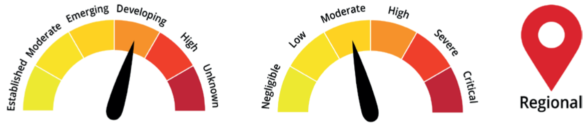
Antibiotics can enter the environment in different ways, such as when they are given to farm animals (Lyu et al., 2020) or sprayed on crops to prevent bacterial diseases (Avila et al., 2024). There is growing concern for leftover (i.e., residual) antibiotics in the environment since they can harm natural ecosystems (Ashworth et al., 2023; Zhang et al., 2023b). Antibiotics used to treat plant and human diseases can contaminate honey bee hives and honey. Although research is limited, laboratory tests suggest that antibiotics could affect behaviour of honey bees and other pollinators, for example by reducing their foraging or visits to flowers (Avila et al., 2024).

5. Air pollution



Human activities can increase air pollution by releasing substances like ozone, sulphur dioxide, nitrogen oxides, and tiny particles into the air (Ryalls et al., 2024). This pollution can harm insects, including pollinators, by affecting their survival, reproduction, and growth. Even moderate pollution levels can negatively impact insect health (Ryalls et al., 2024). Honey bees may have an increased risk of death in areas with poor air quality, particularly in areas with fewer plants (Coallier et al., 2025). Diesel exhaust and ozone (O3) can also affect pollination services, for example reducing the number of visits to flowers by insect pollinators (Ryalls et al., 2022).

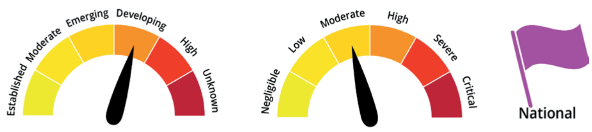
6. Increased indoor farming (+-)



\+ In many parts of the world, there is a move towards using more closed systems for growing food, like glasshouses and polytunnels. This change is mainly driven by a drive to use resources like water, fertilisers, and soil more efficiently, protect crops from bad weather, and reduce the risk of pests and diseases (Ortiz et al., 2021). While using fewer resources and using less land for farming could be good for the environment, allowing more space for wild pollinators, there are some downsides.

\- One problem is that these systems take away flowers and habitat that wild pollinators need for food and nesting. Also, many crops in these systems rely on pollinators, so managed bees are often introduced. These bees can sometimes escape, become competitors of wild pollinators, and may even spread diseases to local bee populations (Kendall et al., 2021).

7. Increased demand for mining of metals (+-)



\- Lithium and cobalt are two examples of key materials for renewable energy technologies like electric cars, wind turbines, and solar panels. Increased use of electric batteries reduces air pollution from fossil fuelled vehicles which has

Our findings provide a robust basis for the development of specific calls to action for a wide range of stakeholders.

clear environmental benefits. However, as the demand grows, the need for lithium and cobalt is expected to increase significantly by 2030 (Melchor-Martínez et al., 2021), and the mining process itself can have serious negative impacts on biodiversity, especially if mining occurs in areas rich in pollinator and plant diversity, including regions with endemic species. Mining also uses a lot of energy, can pollute the air and water, damage land, and even contaminate groundwater (Paz et al., 2023; Chaves et al., 2021). These effects can cause serious harm to pollinators.

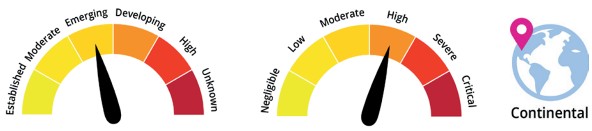
+ However, it is also important to consider the wider benefits of reduced air pollution from using electric vehicles, as well as recognising that mining lithium and cobalt has a relatively smaller environmental impact than using and drilling for oil or gas.

8. Pesticide cocktails

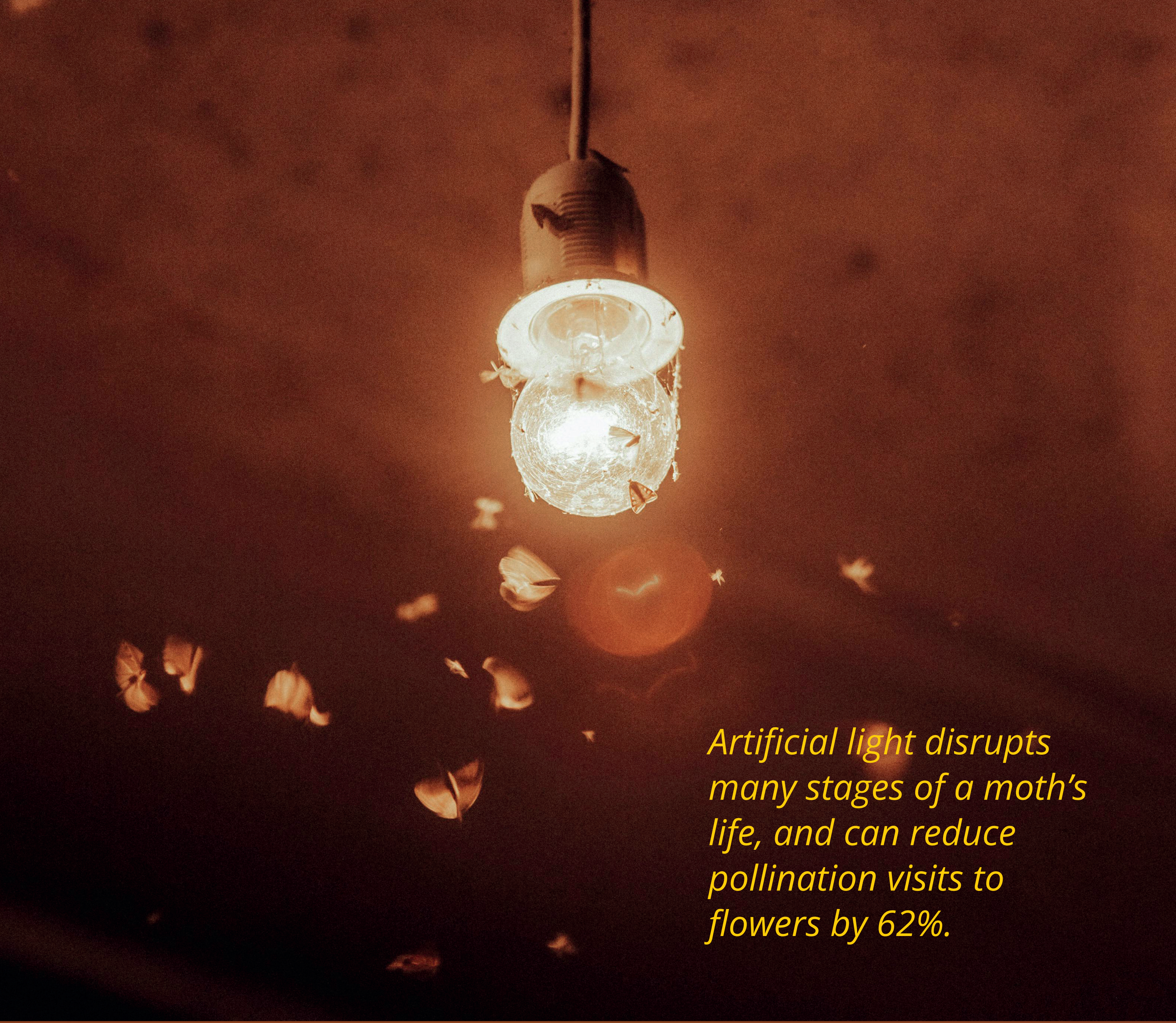
During their life, pollinators can encounter a cocktail of different types of pesticides, including herbicides, insecticides, and fungicides. Some pesticides can directly kill pollinators or cause sublethal effects that impact their ability to nest, reproduce, forage, and survive. The combined effects of different types of pesticides are being increasingly studied but the extent of negative impacts of various combinations of pesticides on the full range of wild pollinators is still being established. Some research shows that when fungicides are used in combination with insecticides, they can interfere with how bumblebees break down toxins, affecting their health (Basu et al., 2024). The combined effects of different types of pesticides could be especially dangerous in developing countries, where many people depend on pollinator-dependent crops for food security and exports (Murphy et al., 2022). A global study by Basu et al. (2024) examined pesticide use trends from 1995 to 2020 and reviewed research since the 2016 IPBES report, and found that:

- Insecticides, herbicides and fungicides types are increasing in Africa and South America.
- Herbicide use is rising in North America and Central Asia.
- Fungicide use is growing across all Asian regions.

9. Artificial light pollution

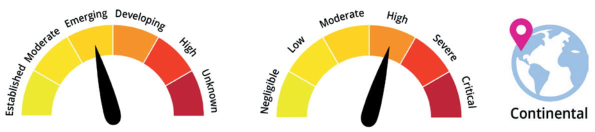


Moths and other insects that are active at night have not had as much research attention as pollinators that are active during the day, but they may play a much bigger role in pollinating crops and wildflowers than previously thought (Fijen et al., 2023). We still do not fully understand what has shaped moth populations over time, but urban development often leads to fewer moths and less diversity among them (Wagner et al., 2021). Light pollution is now recognised as a major threat to species that are active at night (Barentine, 2023). Studies show that artificial light disrupts many stages of a moth's life, affects key behaviours (Boyes et al., 2021), and can reduce pollination visits to flowers by 62% (Knop et al., 2017).



Artificial light disrupts many stages of a moth's life, and can reduce pollination visits to flowers by 62%.

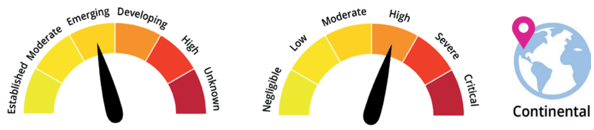
10. Heavy metal pollution



Although heavy metals are naturally occurring elements, some can be harmful to animals depending on the amounts they are exposed to. Heavy metals can enter the environment through a range of processes, including natural, agricultural, industrial and domestic. Different activities release varying types and amounts of heavy metals into the environment, making their impact hard to predict. These metals can contaminate dust, soil, air, water, and even pollen and nectar, increasing the chances that pollinators will be exposed (Monchanin et al., 2023).

Most research on heavy metal pollution and pollinators has focused on honey bees and a few wild bee species. Studies have found several harmful effects, for example, cadmium can weaken the immune system, affect learning (Polykretis et al., 2016; Li et al., 2022) and unbalance the bee gut microbiome (Li et al., 2024). Mercury can harm brain function, making it harder for bees to forage and start new nests (Provase et al., 2021), and lead can reduce a bee's ability to learn from smells, which can impact how they find food (Monchanin et al., 2021). These findings show that heavy metal pollution can seriously harm insect pollinators by affecting their health, behaviour, ability to reproduce, and overall survival. Once released, heavy metals persist in the environment and continue to accumulate over time (Monchanin et al., 2023).

11. Wildfires combined with other threats

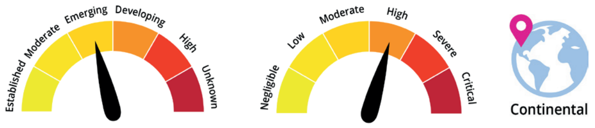


Fire is a natural part of many ecosystems and plays an important role in shaping habitats. Although fire can initially kill insects and plants, ecosystems adapted to fire can recover quickly which, in the long-term, can help maintain insect pollinator and wild plant communities.

However, due to climate change, fires across the world are becoming larger, more severe, over larger areas, more frequent, longer lasting, and earlier in the season. Whilst not yet fully researched, these are likely to have more pronounced negative effects on pollinators than historical fire regimes (Hogendoorn et al., 2021, Dorey et al., 2021; Latty and Forster, 2025). Excessive wildfires may leave pollinators with fewer places to feed, making it harder for them to survive, with greater distances from unburnt areas to cross in order to return to good quality habitats.

When habitats are already broken up into smaller patches, it is even harder for pollinators to find safe places to survive and recover after a fire, or serve as refuges to allow them to recolonise burnt sites (Dorey et al., 2021). Some pollinators, especially those that depend on specific plants, struggle the most because their resources may be wiped out locally (Latty and Forster, 2025).

12. Regional loss of pesticide monitoring

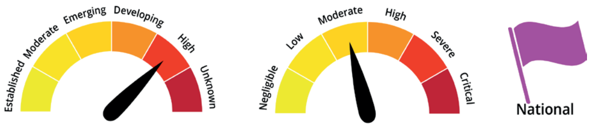


Some regions have stopped or reduced the monitoring of pesticide use due to budget cuts or system failures. This can lead to more toxic insecticides being used repeatedly, even when pests develop resistance. For example, to fight a rise in malaria in the mid-2000s, which was likely due to climate change and resistance developed by the mosquito vector to pyrethroid insecticides, South Africa brought back the use of DDT (dichlorodiphenyltrichloroethane) with the aim of reducing the mosquito population (Mulamba et al., 2014). However, without regular monitoring, there is no way to know if mosquitoes are becoming resistant, which could make the pesticide ineffective. Meanwhile, the pesticide can cause serious environmental and human health effects (Wells and Leonard, 2006).

Trade rules can encourage farmers to use fewer pesticides by limiting the sale of high-pesticide products and giving preference to products with lower pesticide levels in national and international markets.

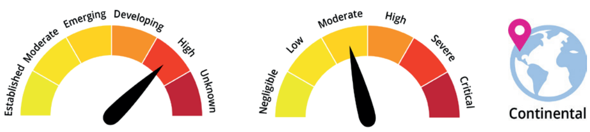
OPPORTUNITIES

1. Stronger laws on antibiotic use



When used responsibly, antibiotics are vital for plant, animal and human health. In regions with strong regulations and monitoring, effective laws and safe practices have helped to limit antibiotic pollution, protecting ecosystems (Kraemer et al., 2019; Thakur et al., 2025). Contrastingly, in areas where regulations are still developing, antibiotic residues from livestock and crops can enter the environment, contaminate beehives, and potentially affect pollinators (page 18, Antibiotic pollution). Some early studies suggest that even low levels of exposure may influence bee behaviour, such as foraging activity (Lyu et al., 2020; Avila et al., 2024). Expanding proven policy models, and strengthening regulations globally for antibiotic use and disposal, could help reduce environmental contamination and create healthier environments for pollinators and other wildlife (Ashworth et al., 2023; Zhang et al., 2023b).

2. Reduced demand for fossil-fuelled vehicles (+-)



+ Using more electric vehicles could help to reduce the threat of air pollution from substances like ozone, sulphur dioxide, and tiny particles to the air. This pollution can harm insects, including pollinators, by affecting how well they survive, grow, and reproduce (Ryalls et al., 2024) (Page18, Air pollution). By cutting emissions from fossil-fuelled transport, cleaner technology could help restore air quality and improve habitat conditions. Mining for the materials required to produce electric batteries is vastly less harmful than fossil fuel extraction.

– However, it must be noted that mining for these materials for electric batteries still uses a lot of energy and can threaten pollinators by pollution, land damage, and water contamination depending on the extent and location (Paz et al., 2023; Chaves et al., 2021) (Page 18, Increased demand for mining of metals).

3. Plant breeding crops for pollinators (+-)

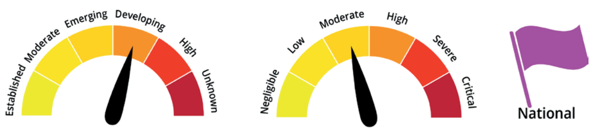
+ Plant breeding allows scientists and industry to develop new crop varieties with specific traits. This process can be achieved through traditional breeding methods and also by genetically modifying (GM) crops. Whichever method is used, there are potentially both benefits and risks. For example, some GM crops are designed to resist insect pests (Insect Resistant crops), which can reduce the need for harmful chemical insecticides that also affect pollinators (IPBES, 2016). Certain plant traits, like nectar and pollen content or the timing of flowering, influence how beneficial a plant is for pollinators (Tscharntke et al., 2024). In future applications, plant breeding could be used more widely to enhance these traits to better support pollinators.

– However, the potential risks of GM crops, both direct and indirect, need careful assessment and monitoring (Arpaia et al., 2021). The use of GM crops is a highly debated

Our findings provide a robust basis for the development of specific calls to action for a wide range of stakeholders including civil society, NGOs, businesses as well as governments.

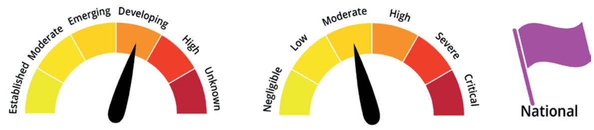
topic, with strong public concerns in some regions and wider adoption in others. More research is needed to fully understand how GM crops affect pollinators and to find ways to reduce any risks while maximising potential benefits. It is important to note that some forms of genetic modification of crops can have negative effects on pollinators. For instance, the development of herbicide-tolerant crops has contributed to increased use of weedkillers, making glyphosate the most widely used agrochemical globally. Glyphosate reduces the abundance of weed species, which are valuable resources for pollinators, and has also been shown to negatively impact bee health, learning, navigation, immunity, and survival (Siviter et al., 2023).

4. Flower-filled solar parks in strategic places



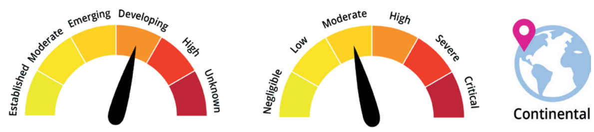
More solar parks are being built around the world due to the shift to renewable energy, and these can provide good habitats for pollinators if located and managed properly. Many solar parks are located on low-quality agricultural land, and adding flower-rich habitats within the parks can improve resources for pollinators. However, if solar parks replace already high-quality habitats this could have a negative impact. There is strong scientific evidence showing that solar parks can support pollinators (Blaydes et al., 2021 and 2024). With the right management, and in the right locations, solar parks can significantly help increase pollinator biodiversity by reducing some of the main factors causing pollinator decline (Wit and Biesmeijer, 2019).

5. RNAi treatments for pollinators' pests



Pest control by RNA interference (RNAi) is a process that uses double-stranded RNA to silence genes essential for the survival and reproduction of pests. This technology has been studied as a potential method for managing pests while also protecting beneficial insects like pollinators. One promising application is controlling Varroa mites, a major threat to managed honey bee colonies. RNAi can precisely target and reduce Varroa populations, causing less harm to managed bees, making it a safer alternative to conventional and organic miticides (McGruddy et al., 2024; Zotti et al., 2015). RNA treatments can be applied as a spray or incorporated into plants through genetic modification, providing a highly selective pest control tool (Arpaia et al., 2021). Because RNAi targets specific pests, it has the potential to be less harmful to non-target organisms, including pollinators, compared to broad-spectrum pesticides. However, further research is needed to fully understand the long-term risks and benefits.

6. AI and targeted conservation

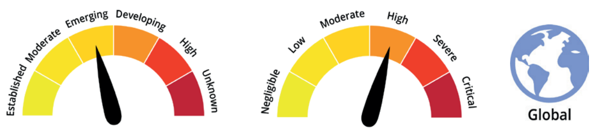


The rapid rise of AI technology in recent years is transforming how we monitor pollinators and biodiversity, offering opportunities alongside some challenges (Pringle et al., 2023). One major benefit is the improved ability to collect high-



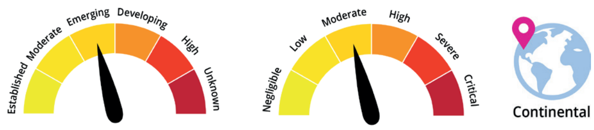
quality data on pollinators and their habitats using tools such as camera traps, audio sensors, remote sensing, and mobile apps, all of which can inform better management practices (Pringle et al., 2023). In addition, technologies like hive sensors not only help detect threats to honey bee colonies but may also provide early warnings about risks facing wild pollinators. AI is also being used to improve pest detection and make pesticide use more targeted, potentially reducing harm to beneficial insects (Willcox et al., 2023). Meanwhile, citizen science platforms are increasingly engaging the public in monitoring efforts and encouraging interest in pollinators and their food sources, while at the same time reducing the need for lethal sampling techniques (Persson et al., 2023). Finally, AI is helping researchers predict areas most at risk of pollinator decline, supporting more strategic conservation planning (Chaplin-Kramer et al., 2019).

7. Trade and agricultural policies to promote low-pesticide products



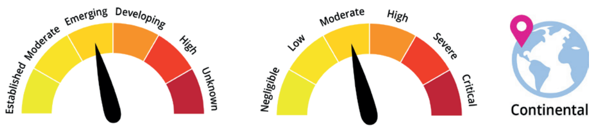
Trade rules can encourage farmers to use fewer pesticides by limiting the sale of high-pesticide products and giving preference to products with lower pesticide levels in national and international markets. Preferred products might include those grown using organic farming, regenerative agriculture, or integrated pest management (IPM) practices, all of which aim to minimise or eliminate the use of synthetic pesticides. Organic farming prohibits most synthetic chemical inputs, regenerative agriculture focuses on soil health and ecological balance which naturally reduces pest pressure, and IPM uses a combination of biological, physical, and chemical tools to manage pests in the most targeted and least harmful way possible. By prioritising these methods in trade and agricultural policies, markets can incentivise production systems that reduce pesticide use to create safer environments for pollinators, supporting healthier populations and improving biodiversity. This could limit pesticide-related pollinator deaths and sublethal effects like reduced ability to nest and forage (Page 20, Pesticide cocktails and Page 24, Regional loss of pesticide monitoring).

8. Beekeeping legislation, particularly in conservation areas



Managed honey bees play a valuable role in agriculture and honey production, and the strong interest in beekeeping presents a potential opportunity to engage more people in pollinator conservation. With clear understanding and thoughtful planning, beekeeping can complement broader ecosystem goals (Beaurepaire et al. 2025). Well-designed legislation could help to ensure that beekeeping does not put unintended pressures on wild pollinators, such as competition for resources or disease spread (Iwasaki & Hogendoorn, 2022). By recognising the diversity of wild pollinators and creating guidelines that protect their unique roles, it should be possible to support both managed and wild species in thriving ecosystems. Instead of moving honey bees inside protected areas, creating valuable pollinator habitats outside of conservation areas is one solution to achieve this.

9. Restore full ecosystem function, not just the plants

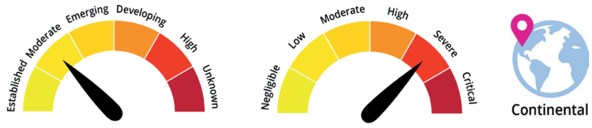


In countries such as Brazil, restoration efforts focus on replanting trees and plants for specific ecosystem services and functions like carbon capture. A more complete approach that aims to restore all ecosystem services and functions, including pollination, would make habitat recovery more successful and is a great opportunity for improved long-term environmental and pollinator health (Mori and Isbell, 2024). Adopting this principle globally in all efforts to create and restore natural ecosystems could help leverage multiple co-benefits for pollinators, wider biodiversity, climate mitigation, soil health and water quality.

10. Protecting stingless bees across urban, semi-natural, and wild habitats

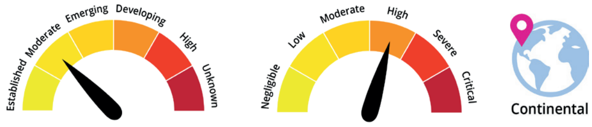
In tropical regions, some native plants have depended on stingless bees (Meliponini) for pollination long before managed honey bees *(Apis mellifera)* were introduced. There are about 500 species of stingless bees worldwide, with 80% living in the Western Hemisphere. They thrive in many environments, from rainforests to drylands, and at altitudes ranging from sea level to 4000m above sea level. Stingless bees are essential for pollinating native plants and many crops. They also produce honey and geopropolis, a powerful medicinal resin (Bąk-Badowska et al., 2019; Seabrooks and Hu, 2017). Threats to stingless bees could lead to a decline in both the bees and the plants they pollinated, but the issue has received much less attention then it has for honey bees. Protecting natural habitats, restoring damaged areas, and creating urban gardens with food sources for these bees could help prevent their decline and extinction (Toledo-Hernández et al., 2022).

11. Major global policies



Governments and international organisations are increasingly committed to protecting pollinators. Global initiatives are leading conservation efforts, such as those from the UN Convention on Biological Diversity (CBD), the Food and Agriculture Organization of the United Nations (FAO), regional economic blocks like the European Union (EU) and individual countries such as Brazil, UK and Mexico. One major step forward is the EU Nature Restoration Regulation, passed in June 2024. This law requires all 27 EU Member States to implement restoration actions to meet the legally binding target to reverse the decline of pollinators by 2030 (EU, 2024).At the same time, the CBD and FAO are developing the International Initiative on the Conservation and Sustainable Use of Pollinators and its Plan of Action promotes farming practices that support pollinators. This encourages countries to work together and share knowledge to protect these essential species more effectively (FAO & CBD, 2022). These global initiatives offer real opportunities to restore ecosystems, create groundswell support for carbon capture and groundswell support to strengthen pollinator conservation worldwide.

12. Exploring solutions that benefit multiple ecosystem services



Nature-based solutions are "actions to protect, conserve, restore, sustainably use and manage... ecosystems which address social, economic and environmental challenges effectively...while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits" (UNEA, 2022, 5.2 Resolution 5). One example is pollinator conservation, which not only helps beneficial insects but also improves soil health, stores carbon, cleans the air, and helps retain water and nutrients in the soil. At the same time, healthy soils and clean water can support pollinators, showing how these natural systems are connected and reciprocally beneficial (Belaire et al., 2022; Seppelt et al., 2011; Schulte et al., 2024). Understanding these connections further could help make nature-based solutions even more effective. As this is a new and emerging concept, only about 3% of research studies to date on nature-based solutions (such as urban green spaces, urban farming, and agroforestry) consider pollinators, even when the plants involved rely on them for pollination (Rafferty and Cosma, 2024). Addressing biodiversity loss requires recognising how different ecosystem services are linked. Using a more interconnected approach and the consideration of pollinators could help make these solutions stronger and more resilient (Rafferty and Cosma, 2024).

One way to achieve this is by planting native species in areas dominated by crops. For example, in US corn and soybean fields, researchers found that adding native perennial plants improved biodiversity, increased pollinator populations, and provided multiple other benefits. These benefits included 40% less water runoff, 20 times better soil retention, and 4.3 times more phosphorus remaining in the soil (Schulte et al., 2024). By designing conservation strategies that serve multiple purposes, we can better protect biodiversity while also creating healthier, more sustainable environments for both nature and people.

DISCUSSION

Pollinators already face serious threats, including habitat destruction, climate change, and pesticide use. This report highlights a wide range of new and emerging risks, as well as potential opportunities, that could strongly affect pollinators over the next 5 to 15 years. These threats and opportunities could affect a wide range of pollinators across the world. Without rapid action from a range of stakeholders, these newly identified threats could worsen the situation. However, with quick conservation action and through taking advantage of novel opportunities, these threats could be addressed to protect pollinators.

Emerging pollutants

Many of the issues we found build on and amplify existing problems, but some introduce entirely new risks and opportunities. For example, pesticides have long been known to harm pollinators (Brown et al., 2016). However, we identified an emerging development on this issue where types of pesticides (herbicides, insecticides, and fungicides) may interact in complex ways, making them even more dangerous. Other pollution threats are also emerging, including microplastics, antibiotics, ozone, sulphur dioxide, nitrogen oxides, heavy metals, and artificial light.

New land-use and replanting opportunities

Another major theme is that these emerging issues can be seen as threats or opportunities depending on how they are addressed, particularly when considering how land is used and replanted, and choosing plant species with consideration for their role in the ecosystem. Examples include the expansion of solar farms, large-scale greenhouse use, net-zero tree planting, and nature-based solutions. Although these new land-use strategies may help offset habitat loss or sequester carbon, they also come with their own risks and uncertainties. Although there is some guidance on how to use land in ways that support pollinators, opportunities for conservation could be missed if pollinators or broader ecosystem services are overlooked.

Rapid assessment

To ensure a broad perspective and to reduce bias, we consulted experts with knowledge of different pollinator species and regions. However, we acknowledge that a different group of experts might have identified different issues or ranked them differently in terms of how novel, impactful, widespread, or well-supported they perceive them to be. By definition these threats and opportunities are emerging, and therefore there is currently a paucity of available evidence, therefore a rapid assessment using the collective knowledge of 10 internationally recognised experts is a pragmatic and efficient way to gain important and timely insights. A larger group and a full "horizon scanning" approach (a structured method used in government and business to predict future challenges (Brown et al., 2016)) would further build on and expand our study.

Consensus between experts

Despite these limitations, experts mostly agreed on the key threats and opportunities, as shown by their consistent ratings. However, there were two main exceptions. Firstly, there was more variation in the perception of the geographic coverage of some opportunities. This might be because the rating scale did not fully capture all details, for example, whether an opportunity had small, local effects in many countries or a



weaker but more widespread effect in just a few places. Second, there was less agreement on the novelty of two ideas: trade policies that promote low-pesticide products and exploring solutions that benefit multiple ecosystem services. These ideas may have stood out because they take a broader, more interdisciplinary and system-level approach compared to others. Because these threats and opportunities are so new, evidence is still building, which led to expert confidence levels generally ranging from very low to moderate.

Outlook

Despite the limitations, this report provides critical and timely insights to support pollinator conservation in the period between major horizon scans. We believe the emerging issues identified here should be a priority for concerted actions to help protect pollinators worldwide. In the face of complex, interacting and compounding threats, we urgently need a holistic approach to pollinator conservation involving all levels; individual, industry, policy, academia, and charity. Our findings provide a robust basis for the development of specific calls to action for a wide range of stakeholders including civil society, NGOs, businesses as well as governments.

Conclusion

Pollinators continue to face serious and evolving threats, and this report highlights emerging threats and opportunities that could substantially reshape their status over the next 5 to 15 years. Most emerging threats build on well-established, continuing, serious issues and others introduce entirely new concerns; in either case the emerging threats could significantly multiply the impacts of well-established threats.

Although this study was based on a rapid assessment with a small group of experts, given the urgency of pollinator declines, this report serves as a valuable and timely resource to guide continued pollinator conservation by individuals, communities and institutions alike.

Taken together, these findings underscore how pollinator conservation is deeply connected to larger environmental, technological, and societal systems.

From land-use change and novel pollutants to agricultural shifts, trade policy, and cutting-edge biotechnologies, the future of pollinators is being shaped by complex, multi-layered factors. This complexity presents both serious risks and transformative opportunities. Policies that promote sustainability, advances in technology, smart land management, responsible beekeeping, and global treaties, all have the potential to safeguard pollinators if designed and implemented with care. Importantly, many of these interventions serve not only pollinators but also support climate goals, biodiversity protection, and ecosystem resilience. Viewing pollinator conservation through this broader lens is essential for creating lasting, scalable solutions. While the challenges are significant, the diversity of emerging responses gives real cause for hope.

The next decade will be pivotal and the choices made now will determine whether pollinator populations continue to decline or become part of a more sustainable future for nature and people.

ANNEX

Annex 1: Full technical description of methods

We contacted 23 pollinator experts, balanced across taxa of expertise and geographic knowledge. Of those, 10 experts participated in the survey process overall, 9 in questionnaire 2. Table A1 shows how the group maps on to the two criteria, taxonomic and geographical expertise, and demonstrates strong coverage.

We used a structured questionnaire to elicit a longlist of emerging and under-researched threats and opportunities for pollinators over the next 5-15 years, particularly those novel issues that were only beginning to gain attention. They were encouraged to give any evidence for their argument. A long list of 44 threats and 36 opportunities, with associated references, was compiled using results of an initial questionnaire (Annex 2). These were collated to remove redundancies and distributed in alphabetical order in a second questionnaire (Annex 3). The experts were asked to score each item based on its novelty, geographical coverage, potential impact on pollinator populations, and their confidence of their assessment according to the criteria overleaf.

Table A1: The number of experts participating in the study within each geographic and taxonomic area of expertise.

	South America	North America	Europe	Africa	Asia	Oceania	Australia
Birds	1	1	1	2	1	1	1
Bats	1	1	1	1	1	1	1
Moths/ Butterfly	3	4	3	3	3	3	3
Flies	3	3	3	3	3	3	3
Wild bees	4	5	4	5	4	4	5
Managed bees	1	1	1	2	1	1	1
Wasps	1	1	1	1	1	1	1
Other	1	1	1	1	1	1	1

Criteria for expert scoring process

Novelty

1. Well-Established (Long-recognised, well-studied, and widely understood)
2. Moderately Established (Recognised for some time, but still evolving in understanding)
3. Emerging Concern (Recently identified as important, with growing evidence)
4. New and Developing (Very recent, with early research indicating significance)
5. Highly Novel (Previously unknown, little research, potential major impact)
6. Completely Unknown (No prior evidence, highly uncertain but potentially significant)

Level of Impact

1. Negligible Impact (No noticeable effect on pollinator populations or ecosystems)
2. Low Impact (Affects some pollinators but with minimal or localised consequences)
3. Moderate Impact (Noticeable effects on specific pollinator species or habitats)
4. High Impact (Significant effects on pollinator populations or ecosystems, but not widespread)
5. Severe Impact (Widespread, major consequences for pollinators and ecosystem services)
6. Critical Impact (Threatens pollinator survival or causes irreversible ecosystem disruption)

Level of Geographical Coverage

1. Very Localised (Affects a single site, farm, or small habitat)
2. Local (Affects a town, city, or small ecological region)
3. Regional (Impacts multiple regions or an entire country)
4. Widespread National (Affects pollinators across a whole country)
5. Continental (Affects pollinators across multiple countries or ecosystems)
6. Global (Worldwide impact on pollinators)

Confidence in Assessment

1. Low Confidence (Limited or unreliable data, significant uncertainty)
2. Moderate Confidence (Some supporting evidence, but notable gaps remain)
3. High Confidence (Strong, well-supported evidence with minor uncertainty)
4. Near-Certain (Extensive, reliable data with minimal uncertainty)

An even number of rankings were used to reduce fence-sitting. The highest-ranked threats and opportunities were then used to guide a review of scientific and grey literature.

Annex 2: The compiled longlist of threats and opportunities, with associated references, generated from Questionnaire 1.

Threats

1. Air pollution by ozone, nitrogen oxides, sulphur dioxide and particulate matter
2. Pesticide synergism (Herbicide, insecticide and fungicide) particularly in developing countries
3. Beneficial invertebrates have been overlooked when investigating (and perhaps mitigating) biotic homogenization
4. Climate change impacts and its synergistic impacts with all current drivers
5. Robotic bees
6. Weak pesticide regulations
7. Net zero tree planting
8. Shift to glasshouse systems
9. Food security over sustainability
10. Light pollution
11. Longer drought spells reduce resources
12. Bushfire destruction of nesting substrate
13. Habitat fragmentation synergy with bushfires
14. Competition from urban beekeeping
15. Public awareness of wild bee species importance and confusion with the term "pollinators"
16. Honey production in conservation areas
17. Heavy metal pollution
18. Changing crop production patterns due to protectionism/war / conflicts
19. Artificial snow on ski slopes affecting plant-pollinator interactions
20. EV battery mining operations
21. Loss of monitoring programmes of pesticide effects and evolved resistance in countries with competing needs for funding and/or just a break down of systems; OR use of more severe insecticides where resistance has been found
22. Beehive pressure in protected areas
23. Fire regime changes and large fires
24. Lack of pollinator monitoring in Global South
25. Pesticide dumping - pesticides or their ingredients dumped on countries with less strict laws
26. Microplastic pollution
27. Loss of natural land to agriculture
28. Habitat degradation
29. Climate change
30. Environmental eutrophication driven by fertilizers and Nox emissions
31. Pesticide use and other intensive farming practices
32. Land use change
33. Agro-chemicals (especially pesticides)
34. Antibiotic pollution
35. Competition of wild and managed bees
36. Cash crops over subsistence crops due to lack of subsidy
37. Disruption to plant-pollinator mutualisms by spatial and phenological mismatch, physiological stress
38. Loss of food resources due to habitat alteration
39. Synergistic impact of multiple stressors (pesticide exposure, habitat loss, climate change, diseases)

40. Diseases exacerbated by human activity, often from managed sources
41. Habitat alteration due to loss of natural disturbance regimes
42. Air pollution (in Bogor city)
43. Bat consumption as part of traditional bushmeat and medicine
44. Songbird trafficking

Opportunities

1. Global mechanism for international, regional and national (perhaps subnational) coordination on pollinator conservation issues including research and monitoring
2. Opportunities for academia to use AI and more scenarios and models to predict areas with the greatest vulnerability of pollinator loss (and loss of pollinator services)
3. Major global policies
4. Adoption of monitoring technology
5. Expansion of solar parks
6. Designing new GM crops to better support pollinators
7. Promote real action on climate change, start talking about real, rather than net zero
8. Quick large response to bushfires
9. Planting for specialists
10. Urban beekeeping legislation
11. New terminology for pollinators for public awareness of wild bee species importance
12. Reduce/limit honey production in conservation areas
13. Emerging technology including AI and citizen science technology for biodiversity monitoring
14. Increasing use of EV vehicles leading to reduced air pollution including diesel exhaust fumes that disrupt plant-pollinator interactions
15. Changing crop production patterns due to protectionism/war / conflicts
16. Use of supplementary feeding in gardens for avian pollinators can support nectivorous birds in times of scarcity following fire
17. Use of AI to detect pests and ensure more targeted approaches to pesticide use may reduce pesticide prevalence
18. Citizen science platforms increase interest in pollinators and their forage species
19. RNA treatments for pollinators' pests
20. Laws banning pesticide in cities
21. Investigate attitudes towards pollinator gardening
22. Invest in restoration
23. Trade policy to favour low-pesticide products
24. Payments for ecosystem services
25. Actions towards the recognition of pollinators as bio-input in agriculture
26. Laws requiring the conservation of specific natural areas for maintenance of ecosystem services (water quality, landslide control)
27. Strengthened policy for landuse change
28. Replacement of agrochemicals using agroecological methods, biological control and strengthened policies for pesticide regulation (e.g., approval, continuation on markets)
29. Strengthened/implementation of legislation on antibiotic use

30. Promoting wild bees for enhanced pollination and yield for professional horticulture and developmental projects as well (in the framework of environmental conservation)
31. Agricultural subsidies to promote agrocecological methods
32. Incentivise conservation that can boost yield in agroecological systems
33. Promote habitat conservation and reduced pesticide usage in urban systems
34. Explore coupled-ecosystem service solutions
35. Promoting conservation of urban stingless bees in Bogor areas
36. Increased uptake of citizen science technology

Annex 3: Collated list of novel threats and opportunities to pollinators without redundancies for use in Questionnaire 2.

THREATS	SUMMARY
Adoption of novel technologies	The adoption of pollinator and biodiversity monitoring technologies has surged in recent years, presenting both opportunities and risks. For example, there are concerns about the technology's applicability to certain taxa and an overemphasis on some species at the expense of others (Pringle et al. 2023).
Air pollution by tropospheric ozone, nitrogen oxides, sulphur dioxide and particulate matter	Human activity can increase the incidence of air pollutants, including ozone, sulphur dioxide, nitrogen oxides and particulates (Ryalls et al., 2024). Air pollution can reduce the performance of beneficial invertebrates, including pollinators, for example by affecting survival, reproduction and development. Moderate levels of air pollution can adversely affect invertebrate fitness, and these effects varying little with pollutant concentration (Ryalls et al., 2024).
Antibiotic pollution	Antibiotics used for plant and human pathogens have been identified as contaminates in honey bee hives. While there have been few studies, laboratory evidence suggests that antibiotics could have sublethal effects on bee foraging behaviour and colony health (Avila et al., 2024).
Artificial snow and plant-pollinator interactions	Temperatures are rising worldwide and in the European Alps even at a faster rate than the average. To continue skiing activities in highly touristic areas in the European Alps and Pre-Alps, artificial snow is increasingly used. Artificial snow possesses different physical and chemical properties than natural snow, leading to both denser and deeper snow cover on ski runs. Changes in vegetation composition have been observed where artificial snow is used, favouring nutrient- and moisture-demanding species (Rixen et al., 2003). These changes might affect alpine pollinator insects through changes in their communities and in the interactions with plants.

Bat consumption as part of traditional bushmeat and medicine	In certain regions of Indonesia, particularly North Sulawesi, consuming wildlife, including bats, is a long-standing tradition. Bats are commonly prepared as bushmeat and are also used in traditional medicine. This practice is widely recognized as part of the local culinary and cultural heritage in North Sulawesi. Multiple bat species are threatened which has led to calls for bat conservation (Sheherazade at al., 2019).
Bushfire synergies	The increasing frequency and size of bushfires, combined with habitat fragmentation, poses a significant threat to pollinators by destroying food and nesting resources (Hogendoorn et al., 2021). Fragmented habitats may limit the availability of refuges and hinder recolonisation after fires, especially for specialists relying on specific resources. Changes in fire regimes, including larger and more frequent fires, also exacerbate these threats by making it harder for pollinators to access forage in central fire zones, further disrupting their survival and recovery.
Cash crops over subsistence crops due to lack of subsidy leads to more land given to agriculture	The lack of agricultural subsidies to incentivise growing subsistence crops is resulting in an ever-growing amount of cash crops. This results in less space dedicated to agroecological practices such as crop rotation, intercropping. For example, cocoa and coffee production have increased globally, particularly since 2017 (FAOstat).
Competition for pollen from urban beekeeping	Urban beekeeping, (i.e. keeping bees in, of, or for the city), continues to be highly popular, for example in the Unites States. Managed bees in urban areas may create competition in an area with already reduced resources compared to natural habitat and may also introduce diseases, but this has been little studied.

Crop changes due to conflicts/ protectionism	Armed conflicts can influence land use and farming (Zhang et al., 2023; Dinc and Eklund, 2024). For example, countries impacted by war or reliant on imports may prioritize domestic production of staple crops (e.g., wheat, rice, maize) to enhance food security, potentially reducing the diversity of crops grown. This reduced crop diversity may detrimentally impact wild bee populations. With the exception of a switch to hardier, low-maintenance crops that require fewer inputs or are less risky to cultivate, this could pose a threat to wild bee populations since in simplified systems, floral food resources may be abundant only for a short period, leaving pollinators without sustenance during the rest of the season.
E-battery mining	Lithium and cobalt are essential materials for renewable energy technologies, for example, electric vehicles, wind turbines, and solar panels. With the increasing demand for electric cars and consumer electronics, their global consumption is expected to rise significantly by 2030. While mining these metals has a low-er environmental impact compared to fossil fuel extraction, and their use comes with positives effects such as reduced air pollution, the mining process remains energy-intensive and can lead to pollution, land degradation, and potential groundwater contamination, all of which could potentially threaten pollinators.
Eutrophication by ferti-lizers and Nox	Atmospheric nitrogen deposition and other forms of environ-mental eutrophication have risen significantly worldwide over the past century, despite recent declines in Europe. While the vulnerability of plants to eutrophication is well-documented, relatively few studies have examined how these impacts extend to pollinators (David et al., 2019; Hoover et al., 2012; Carvalheiro et al., 2020). For example, the level of nitrophily of plant species affects overall patterns of plant richness, which could affect pollinators based on their ability to adjust their diet (i.e. on the level of specialization) (Carvalheiro et al., 2020).

Food security over sustainability	Globally, there is ongoing tension between food security and environmental sustainability, intensified by geopolitical shifts, conflicts, food tariffs, and extreme weather affecting agriculture. As a result, food production is often prioritized over environmental policies, undermining efforts to integrate sustainability into agriculture (Talebian et al., 2024; Vanbergen et al., 2020; Berry et al., 2015). Despite strong scientific evidence sup-porting the need for biodiversity in resilient food systems, policies have instead favoured intensive pesticide use and habitat reduction – both harmful to pollinators. Conversely, reducing pollution and preserving high-quality habitats could enhance biodiversity, strengthening agriculture against future shocks.
Heavy metal pollution	Research on the effects of heavy metal pollution on pollinators has primarily focused on honey bees and a few Bombus species. Documented negative impacts include effects on foraging efficiency, gut microbiota, metabolism and immune response (cadmium); neurotoxic effects and impaired reproductive fitness (lead and mercury); reduced survival rates of larvae (chromium), and impaired motor functions and foraging efficiency (arsenic) (Polykretis et al., 2016, Li et al., 2022, Monchanin et al., 2021, Provase et al., 2021, Shi et al., 2023). These findings suggest that heavy metal contamination poses significant risks to bee populations, affecting their health, behaviour, and survival.
Light Pollution	Moths and other night active insects are under-researched organisms within the wider pollinator community and their role as crop and wildflower pollinators has recently been revealed to be much greater than previously thought (Fijen et al. 2023). Historic and current drivers of moth community trends are poorly understood, and light pollution is fast emerging as having a significant negative impact on nocturnal species (Barentine 2023). New evidence shows diverse impacts of artificial light across most life stages and key behaviours of moths (Boyes et al. 2021), with light pollution reducing nocturnal pollinator visits to flowers by 62% (Knop et al. 2017).

Loss of pesticide monitoring in some regions	The loss of pesticide monitoring programs, either due to competing financial priorities or systemic failures, poses a significant challenge. In some cases, the absence of monitoring leads to the continued use of increasingly potent insecticides where resistance has developed. For example, South Africa reintroduced DDT to combat a resurgence of malaria in the mid-2000s (Mulamba et al., 2014), likely driven by climate change. However, there is no ongoing monitoring to assess whether mosquito populations are developing resistance, raising concerns about long-term effectiveness and potential environmental consequences (Wells and Leonard, 2006).
Microplastic pollution	Microplastics, synthetic polymers under 5 mm in diameter, may harm honey bees by increasing mortality, reducing body mass, and altering gut biota (Al Naggar et al., 2024). Though research is limited to honey bees (Willcox et al., 2023), their widespread presence suggests a potential emerging threat (Anbumani & Kakkar, 2018). Recent findings from the INSIGNIA project (final meeting, 05/12/2024) reveal microplastics are more prevalent than previously thought. Samples from 315 sentinel honey bee colonies across 27 EU Member States showed near-universal contamination, with 44% of fibers and 94% of particles being synthetic, mainly PET. Given their ubiquity and emerging evidence of harm, microplastics likely pose a severe threat to wild pollinators.
Pesticide dumping	Banned and restricted pesticides or their ingredients can be 'dumped' on countries with less stringent laws (Dowler and Hofmeister, 2024). Their use raises environmental concerns and highlights the complexities of international pesticide regulation. This includes fipronil, which has been linked to the recent poisoning of thousands of bee hives in Brazil.

Pesticide syngergism	Herbicide, insecticide and fungicide may have synergistic impacts on pollinator populations. Basu et al., (2024) conducted a long-term, global analysis of inter-regional trends in the use of different classes of pesticide between 1995 and 2020 (FAO-STAT) and a review of literature since the IPBES pollination assessment (2016). The use of all three pesticide classes is to in-crease in Africa and South America, herbicide use is to increase in North America and Central Asia and Fungicide use is to in-crease across all Asian regions. Whilst results have been mixed, synergistic effects of pesticide classes can have physiological consequences and can interfere with the detoxifying mechanisms in bumble bees (Basu et al., 2024). This may cause a particular threat to developing countries and regions where pollinator-dependent food production is high (for export) and food security is most vulnerable for people (Murphy et al., 2022).
Pollinating songbird trafficking	The illegal bird trade is contributing to, and perhaps driving, the decline in songbird populations in Indonesia's forests, particularly due to high demand in bird markets, and includes pollinating species. This is especially prominent among the Javanese, who are well known for their tradition of keeping songbirds.
Reduced avian pollination services due to garden bird feeders	The use of supplementary feeding in gardens can help support nectarivorous birds during periods of nectar scarcity following wildfires. While this can aid their survival and recovery, it may also lead to a preference for feeders over natural flowering plants, potentially reducing visits to wild species and impacting seed set. For example, in a study by du Plessis et al., (2021) one bird-pollinated species showed no change in visitation, whereas another species experienced a decline.
Robotic bees	There has been a continued push by engineering researchers and start-ups, promoting robotic bees to replace wild pollinators (Potts et al. 2018). There are strong ecological, economic, and ethical reasons why replacing pollinator by diversity with robotic bees is a major threat (Potts et al. 2018).

Shift to glasshouse systems	In many places in the world there is a shift to more closed systems for food production, such as glass houses and Polytunnels. This is often driven by the need to a) more efficiently use inputs such as water, fertiliser and soil, b) reduce the exposure to unfavourable climatic conditions; and c) reduce the risk of pests and diseases on crops (Ortiz et al., 2021). While the more efficient use of inputs, and potentially smaller area of land used for production, could have some benefits on the wider landscape in terms of less total area being used, thereby leaving more uncultivated area for pollinators, there are some negative aspects. These include removing crop floral resources from being available to wild pollinators. Additionally, many of these close systems have crops which are dependent on pollinators and so will introduce managed pollinators such as bumblebees, which can escape and outcompete local wild pollinators and or result in gene introgression and the spillover of pathogens.
Solar parks on previously high-quality habitat	Solar parks are often placed on lowgrade agricultural land, which with proper management can improve the quality of pollinator habitat (Blaydes et al., 2021). However, should solar parks instead replace existing high-quality habitats then the effect could be detrimental overall.
Unguided net zero tree planting	With growing momentum around Net Zero (NZ), numerous policies, initiatives, and guidelines support large-scale tree planting. The European Commission, for example, aims to plant 3 billion trees by 2030 (EC 2024). While this aids NZ goals, its impact on biodiversity, including pollinators, varies. Planting fast-growing, carbon-sequestering species like Eucalyptus spp. often harms wildlife, especially if replacing flower-rich habitats. In contrast, diverse species like wild cherry and willow can provide significant ecological benefits. Though well-established guidance exists (e.g., Tree Species Guide for UK Agroforestry Systems), it is often overlooked. As tree-planting efforts expand across Europe, they present both a major opportunity and a potential risk.

Weak pesticide regulations	Despite strong evidence of pesticides' harm to pollinators and biodiversity, regulations in Europe and globally remain weak. In 2022, the European Commission proposed the Regulation on the Sustainable Use of Plant Protection Products (RSUPPP) under the Green Deal, aiming to cut pesticide use and risk by 50% by 2030. This could have significantly benefited biodiversity, but opposition from farmers and the pesticide industry led to its withdrawal in 2024 (EC 2024 https://eur-lex.europa.eu/eli/C/2024/3117/oj). As a result, most EU Mem-ber States have not addressed regulatory gaps, failing to set strong targets for reducing pesticide risks and dependence. Without stricter regulations like RSUPPP, pesticide threats to pollinators remain high (Nicholson et al., 2024), with little prospect of improvement. Weak regulations persist worldwide.

OPPORTUNITIES	SUMMARY
Beekeeping legislation, particularly in conservation areas	Due to habitat loss and fragmentation, and the misconception that even managed pollinators are threatened, beekeepers in Australia are increasingly demanding access to conservation areas for honey production. This leads to competition with native insects, with consequences for insectivores, and the introduction of plant diseases and pollination of weed species (Iwasaki and Hogendoorn, 2022).
Designing GM crops for pollinators	Modern plant breeding technologies allow new traits to be ex-pressed in new crop varieties. For instance, nectar, pollen con-tent, and flowering periods can influence the benefit of plants to pollinators (Tscharntke et al., 2024), so perhaps these traits could be enhanced using genetic modification.
EV vehicle uptake to reduce air pollution (yet consider mining operations)	Increasing use of EV vehicles could to reduced air pollution including diesel exhaust fumes that disrupt plant-pollinator inter-actions. Common air pollutants, such as nitrogen oxides (NOx), emitted in diesel exhaust can impact learning and memory in bees, disrupt pollinator foraging efficiency and detrimentally impact pollination services (Ryalls et al., 2022). As such, in-creased uptake of EV vehicles could be an opportunity for protection of pollinators, provided that mining operations for EV batteries do not cause habitat destruction and fragmentation.
Explore coupled-ecosystem service solutions	Many pollinator conservation opportunities also benefit soil quality, carbon sequestration, other ecosystem services (Belaire et al., 2022; Seppelt et al., 2011). This is an area which could be explored further in order to optimise nature-based solutions.
Garden bird feeders following fire	The use of supplementary feeding in gardens can help support nectarivorous birds during periods of nectar scarcity following wildfires. While this can aid their survival and recovery, it may also lead to a preference for feeders over natural flowering plants, potentially reducing visits to wild species and impacting seed set. For example, in a study by du Plessis et al., (2021) one bird-pollinated species showed no change in visitation, whereas another species experienced a decline.

Incentivise conservation that can boost yield in agroecological systems	Farm management schemes and ecological intensification such as plant diversification can mitigate potential ecological harm by increasing species richness and boosting related ecosystem services to agroecosystems (Kennedy et al., 2013; Lichtenberg et al., 2017). Focus could be placed on incentivising those conservation efforts which can both boost pollinator populations and improve crop yield.
Invest in restoration with a focus on restoring function, not just vegetation.	In many regions worldwide, such as Brazil, restoration efforts still prioritize vegetation over the recovery of ecosystem functions. There is significant room for improvement in achieving a more holistic approach.
Increased uptake in AI technology, including vulnerability prediction for targeted conservation to the most vulnerable	The adoption of pollinator and biodiversity monitoring technolgies has surged in recent years, presenting both opportunities and risks (Pringle et al. 2023). Key benefits include: (i) high-quality data on crop pollinators and habitats via camera traps, audio sensors, remote sensing, and identification apps, aiding management practices (Pringle et al. 2023); (ii) omics technologies and hive sensors to detect chemical and biological threats in honey bee colonies, serving as an early warning for wild pollinators (Willcox et al. 2023). AI can enhance pest detection, enabling targeted pesticide use and potentially reducing pesticide prevalence. Expanding citizen science platforms and uptake fosters interest in pollinators and their forage species while minimizing destructive sampling and promoting biodiversity awareness.
Major global policies	There are examples of strong political willingness to support pollinators at the regional and global scale, including efforts from the CBD, FAO and EU. For instance, the EU's Nature Restoration Regulation (NNR) has recently passed into primary legislation (June 2024), and is almost certainly the most significant piece of environmental law for the EU over the last few decades.

New terminology for pollinators for public awareness of wild bee species importance	While growing awareness of local honey bee declines has elevated the importance of pollinators, public attention remains disproportionately focused on honey bees. It is crucial to extend this attention to a broader range of pollinators, particularly those that are the most threatened or critically endangered. To prevent further extinctions, decision-makers must implement policies and actions that support the conservation of all pollinators, beyond just crop pollinators. Association of the term pollinators with only managed bees leads to misunderstanding of the species that need conservation, which species to plant, and which habitat to plant them in (Iwasaki and Hogendoorn, 2021).
Planting for specialists	Provision of vegetative resources for specialist pollinators which rely on more specific species for resources than generalists.
Promoting conservation of urban stingless bees, for example in Bogor areas	With their increasing local commercial use, sustainable management of stingless bees can support both ecological health and economic opportunities.
Promoting wild bees for horticulture and developmental projects	There is an opportunity for promoting wild bees to enhance pollination and yield in professional horticulture and development projects, within the framework of environmental conservation. For example incorporating wild bee-friendly practices into urban planning, landscaping, and agricultural development to support biodiversity and ecosystem services e.g. designing projects that include native plantings, nesting sites, and reduced pesticide use to support wild bee populations. Some urban land uses can support substantial pollinator populations (Baldock et al., 2019). Habitat conservation and reduced pesticide use in urban environments could be promoted through sustainable design incentives that enhance public awareness, engagement, and pollinator protection. Urban conservation could be better aligned with views on the ecological importance of urban landscapes (Hall et al., 2017).

Quick large response to bushfires to reduce the negative impacts	The largest negative impacts of extreme wildfires on plants and animals, including pollinators, may occur in areas with frequent or recent past fires and within extensively burnt areas (Driscoll et al., 2024). To improve resilience to wildfire in flammable ecosystems could depend on reducing fire recurrence, including rapid wildfire suppression in areas frequently burnt. Quick wild-fire suppression efforts may be increasingly necessary to pre-vent the same areas from burning too frequently.
Recognition of the services of pollinators	Recognising the full ecosystem services provided by pollinators, beyond crop pollination, to include biodiversity support and ecosystem stability may strengthen conservation efforts by high-lighting their broader ecological and economic value. While growing awareness of local honey bee declines has elevated the importance of pollinators, public attention remains disproportionately focused on honey bees. It is crucial to extend this attention to a broader range of pollinators, particularly those that are the most threatened or critically endangered. To prevent further extinctions, decision-makers must implement policies and actions that support the conservation of all pollinators, beyond just crop pollinators. Association of the term pollinators with only managed bees leads to misunderstanding of the species that need conservation, which species to plant, and which habitat to plant them in (Iwasaki and Hogendoorn, 2021).
RNA treatments for pollinators' pests	Targeted silencing of genes essential for the survival and reproductive processes of pest species using double-stranded RNA (dsRNA), a process termed RNA interference (RNAi), has been investigated for the treatment and prevention of diseases in beneficial insects such as pollinators. For example, this tool could be used for highly targeted reductions in pest populations such as varroa mite (McGruddy et al., 2024; Zotti et al., 2015).

Solar parks on low grade agricultural land with flower rich habitats	Solar parks are projected to hugely increase in number and area as there is a global shift towards renewable energy production. Solar parks have the potential to provide high quality habitat for pollinators if they are managed in a pollinator positive manner. Solar parks are often cited on low grade agricultural land and so the inclusion of flower rich habitats will improve the quality of the land relative to the baseline. In contrast should solar parks be placed on existing high-quality habitats then the effect would be detrimental overall. There's substantial scientific evidence demonstrating the potential of solar parks to support pollinators (Blaydes et al., 2021 and 2024).
Strengthened legislation on antibiotic use	Antibiotics used for plant and human pathogens have been identified as contaminates in honey bee hives. While there have been few studies, laboratory evidence suggests that antibiotics could have sub-lethal effects on bee foraging behaviour and colony health (Avila et al., 2024). There is a need for stronger policies or better policy implementation, as no maximum residue limits (MRLs) for antibiotics currently exist in some countries such as Africa.
Trade policy to favour low-pesticide products	Policies to promote reduction of pesticide applications based on national and international markets (e.g. not buying products with high levels of pesticides).

Annex 4: The median ranks and interquartile range of A) threats and B) opportunities for global pollinators according to a survey of nine experts for novelty, impact, geographical coverage, and their confidence in their assessment.

Threats	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range
Crop changes due to conflicts	4	2	4	1	4	2	2	1
Microplastic pollution	4	1	4	1	6	1	2	0
Unguided NZ tree planting	4	1	4	1	4	2	2	1
Antibiotic pollution	4	1	3	1	3	3	2	1
Air pollution	4	2	3	1	6	1	2	0
Shift to glasshouse systems	4	1	3	0	3	1	2	1
E-battery mining	4	2	3	1	4	2	2	2
Pesticide synergism	3	1	5	0	5	1	2	1
Light Pollution	3	2	4	2	5	1	2	1
Heavy metal pollution	3	1	4	1	5	2	2	1
Bushfire synergies	3	1	4	1	5	2	2	1
Regional loss of pesticide monitoring	3	2	4	2	5	1	3	1

Opportunities	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range	Median Rank	Inter-quartile range
Strengthened legislation on antibiotics	5	1	3	1	3	2	2	1
EV vehicle uptake	5	1	3	0	5	1	2	1
GM crops for pollinators	5	1	3	1	3	3	1	1
Solar parks on low grade land	4	1	3	0	3	1	2	0
RNA treatments for pollinators' pests	4	1	3	1	3	3	2	1
Increased uptake in AI	4	2	3	1	5	3	2	1
Trade policy to favour low-pesticide products	3	3	4	0	6	1	3	2
Beekeeping legislation	3	2	3	1	5	2	2	0
Restoring function, not just vegetation	3	1	3	1	5	3	2	0
Conservation of urban stingless bees	3	2	3	0	4	2	2	1
Major global policies	2	2	5	1	5	2	2	1
Coupled-ecosystem service solutions	2	3	4	1	5	1	2	1

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We urgently need a holistic approach to pollinator conservation involving all levels – individual, industry, policy academia, and charity.

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