Written evidence submitted by the Cambridge Global Food Security Interdisciplinary Research Centre, Wolfson College Interdisciplinary Research Hub on Sustainability & Conservation, and the Cambridge Institute for Sustainability Leadership (INS0036)

We welcome the Science, Innovation and Technology Committee's call for evidence on insect decline and UK food security. Our response draws on two distinct perspectives. Firstly, a series of current and proposed field-based projects at Wolfson College, which, like other constituent colleges of the University, is a registered charity for education and research; Wolfson College is testing new ways of supporting insect populations on its nine-acre suburban campus and on Wildlife Trust sites. Secondly, we draw on a project we have undertaken expressly for this inquiry, updating earlier collaborative work undertaken through the Cambridge Conservation Initiative concerning the private sector; it assesses corporate responses to the insect decline. We describe unique findings from each project, as well as common conclusions that affect both sectors.

Summary findings

Findings from our field-based research in a non-profit setting

A.1. Insect population monitoring is very valuable as a biodiversity metric, and we need to bolster our data by monitoring additional species across different habitats. We recommend continuing investment in the UK Pollinators Monitoring Scheme (PoMS) for as long as possible, and providing funding support to help experts launch new monitoring projects, which will train new researchers and help experts mobilise a wide base of volunteers.

A.2. There are valuable opportunities to use urban and suburban spaces, particularly educational institutions with land, as test-beds for biodiversity initiatives, which can substantially defragment habitats. However, colleges and schools will require financial support to help implement these initiatives which sit outside their primary remit of education provision. We recommend setting up funding to assist schools in turning their grounds into biodiverse habitats and suitable testing-sites for new urban biodiversity interventions.

A.3. Successful centres of biodiversity researchers and advocates can catalyse important interventions in neighbouring spaces and wider communities. However, they need secure streams of funding to maximise their impact via multi-year efforts. Such funding would help these centres organise regular educational events like workshops, and provide for permanent staff who can grow and sustain ties to local residents and communities. We recommend encouraging the creation of centres of biodiversity innovation and knowledge via community funding, tax incentives, and/or research council funding that is specifically for sustaining such centres (potentially on the model of Leverhulme Centres).

A.4. A collection of educational sites with biodiversity actions plans in place can substantially defragment the natural habitat, but coordinating between institutions will be

key to creating a bigger overall benefit to biodiversity. We recommend creating a national map of high-quality grasslands that will identify gaps in pollinator connectivity, enhancing the work of Buglife's 'B-lines' project and helping to target resources into the local community.

For more details, please see our responses to topics 1 & 5 on monitoring schemes (beginning with D) and additional policy initiatives (beginning with G).

Findings from our review of private sector businesses along the food supply chain

B.1. Awareness of insect biodiversity initiatives throughout the food system is growing. However, we observe critical gaps in engagement, for example with food manufacturers and distributors. We recommend active engagement on biodiversity initiatives with stakeholders across the entire food supply chain, domestic and abroad.

B.2. According to our recent reassessment of public disclosures by companies first assessed for actions on pollinators in 2017, awareness of insect biodiversity among businesses has visibly improved. Several of the companies are implementing biodiversity initiatives at different points along their value chain. However, the impact of these initiatives is often not clear. Companies also seem unsure how to handle the complexity of biodiversity. We recommend supporting businesses in designing and implementing biodiversity initiatives of sufficiently large scale and effectiveness, and also in measuring the results of these projects.

B.3. We have further identified several distinct opportunities to engage with businesses: for example through guidance on agri-environmental measures and existing industry-wide certification schemes. Business engagement in biodiversity initiatives would likely also benefit from frameworks for assessment and tools to enable and support local collaborations, among several businesses and with researchers and other organisations.

For more details, please see our responses to topic 3 (beginning with F) on biodiversity initiatives and coordination with the UK food system.

Joint findings relevant to the non-profit and private sectors

C.1. Scientific knowledge and evidence is not being translated effectively into advice for practitioners, including companies (such as food manufacturers), local community organisations, gardeners and land managers of private lands (e.g. educational institutions). Many businesses and public institutions understand the importance of biodiversity and supporting insect populations, however they are unsure of how to approach this incredibly detailed and complex issue. We recommend providing local experts/researchers the tools to communicate their knowledge via workshops. We also recommend creating educational resources/guidance on supporting the most common pollinators, both wild and managed. The resources/guidance should be targeted at A) gardeners, and B) food manufacturers, illustrating basic steps and interventions, as well as more advanced interventions with practical information on individual species. Furthermore, we recommend the development of frameworks for businesses to assess their interrelations with biodiversity, in terms of ecosystem services and in terms of business impact on biodiversity more widely. Details can be found in paragraphs F.5-7, F.20-25 and G.17-20.

C.2. The main drivers of insect decline are habitat loss, agricultural intensification, pollution (especially pesticides), and climate change. It is possible that climate change poses a greater risk for insects than for other taxa, because of their small size and sensitivity to weather conditions. We recommend providing specific guidance for growers and land managers on the challenges (present and future) to insect populations caused by climate change, and the links between climate change and the biodiversity crisis. We also recommend supporting research and testing for new mitigation measures, facilitating engagement between researchers and land and business managers, including grants for start-up costs. Details can be found in paragraphs F.8-10 and G.1-6.

C.3. The terms ‘sustainable’ and ‘regenerative’ mean different things to different groups. Even within the same organisation people might disagree on the choice in metrics, targets, and how to operationalise concepts like ‘regenerative agriculture’. We recommend the adoption of evidence-based definitions and guidelines, potentially linked to the Sustainable Farming Incentive and also jointly with researchers and community biodiversity schemes. Details can be found in paragraphs F.14-16.

Organisations involved

The Cambridge Global Food Security Interdisciplinary Research Centre is a network of researchers across the University, from crop scientists and engineers to specialists in policy, economics and public health. It promotes interaction and knowledge sharing, and supports collaborative research to address the issues surrounding food security at local, national and international scales.

Wolfson College is one of thirty-one colleges in the University of Cambridge. It is home to the Interdisciplinary Research Hub on Sustainability & Conservation, a research and practitioner network of academics, students, alumni and College staff working together on solutions to environmental challenges, using the College and its grounds as a testbed for innovation and new ideas. The Hub’s projects and its members have been recognised under the international Green Impact environmental accreditation scheme with multiple awards for Impact Excellence, Social Impact, and Student Leadership.

The University of Cambridge Institute for Sustainability Leadership (CISL) partners with business and governments to develop leadership and solutions for a sustainable economy. We aim to achieve net zero, protect and restore nature, and build inclusive and resilient societies. For over three decades, we have built the leadership capacity and capabilities of individuals and organisations and created industry-leading collaborations to catalyse change and accelerate the path to a sustainable economy. Our interdisciplinary research engagement builds the evidence base for practical action.

About the response

All topics are shown below as they appear in the inquiry. Our response addresses only select topics. Topics to which we have not responded are shown in grey text.

1. The current evidence base for insect abundance in the UK, and the gaps in scientific understanding that require further research

D.1. The vast majority of insects are understudied but the UK has some of the best long-term records anywhere in the world and, of these, the best represented group are UK butterflies. Systematic data has been collected on the abundance and distribution of UK butterflies and moths since the 1970s, providing a hugely important evidence base for us to assess changes in insect populations across the country. The more long-term data we have, the better we can be at making informed decisions to protect insects. Ideally, this data collection should continue for as long as possible. Data from a diverse group of insects from different environments would be particularly useful (freshwater, terrestrial, flying insects etc). Good examples of these include the UK Pollinators Monitoring Scheme (formed as part of the National Pollinator Strategy), the UK Butterfly Monitoring Scheme and Butterflies for the New Millennium recording programmes.[1]

D.2. Recommendation: Continue to invest in the UK Pollinators Monitoring Scheme (PoMS) for as long as possible.

D.3. Recommendation: Provide funding via Biological Record Centres to help launch new monitoring schemes, based on academic and community interest, to be used for recruiting and training experts and to set up the infrastructure to reach a large volunteer base.

D.4. Butterflies numbers are indicative of general insect abundance, and 80% of butterfly species have declined over the last fifty years. Butterflies have a complex life cycle with multiple distinct life stages (egg, larva, pupa and adult). Each stage can have a different set of specific requirements, which means even a small change in the environment is likely to impact at least one part of the life cycle. This means butterflies are sensitive bioindicators and if you see their numbers falling it can be an early warning system for a wide range of other species. This makes butterfly declines particularly worrying. In the latest 'State of the UK's Butterflies Report' in 2022, it was found that 80% of species have declined over the last fifty years.[2] Future developments in England will be required to provide a 10% biodiversity net gain. However, this is hard to measure and is a very general target.

D.5. Recommendation: Create more clarity (specific targets) for industry and developers about measures to support insect populations.

D.6. Recommendation: Specifically review the Biodiversity Metric 4.0, which underpins the Biodiversity Net Gain requirement, to ensure that the scoring adds value for insect species, by retaining structural heterogeneity, and diverse floral resources, for example.

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[1] https://ukpoms.org.uk/, https://ukbms.org/ and https://butterfly-conservation.org/our-work/recording-and-monitoring/butterflies-for-the-new-millennium

[2] https://butterfly-conservation.org/state-of-uk-butterflies-2022

2. The effects of pesticides, such as neonicotinoids or other agricultural control methods on insects including pollinators and their impact on UK food security

E.1. Pesticides, particularly systemic insecticides,[3, 4, 5] but also herbicides,[6] have been shown to have potentially highly deleterious impacts on insect populations. These are often mediated through sublethal effects on foraging behaviour or reproductive success, which are not so easily picked up in the regulatory approval processes. These effects can influence pollination services directly (demonstrated for apple pollination by Stanley et al 2015[7]), and therefore have potential to reduce food production for pollinator-dependent crops in the UK.

E.2. Application of insecticides has been shown not to decrease pest densities over the long term, when natural enemies are present, which is almost everywhere.[8]

E.3. Insecticides can also reduce the positive impact of insect conservation measures.[9] For example, several studies have measured pesticide residues, including neonicotinoids and fipronil, in flowering plants sown or encouraged in field margins for insect conservation.[9]

3. The extent that biodiversity initiatives, such as creating reservoir populations, are addressing insect decline and whether there is sufficient coordination with the UK food system

F.1. While there are a number of progressive initiatives around biodiversity across Britain, and growing awareness of the new post-2020 Global Biodiversity Framework (GBF) (where pollination is explicitly mentioned in Target 11), there are still critical gaps in engagement and coordination with the UK food system. For instance, the 2014 *National Pollinator Strategy* mainly addressed private citizens, public and not for profit sectors, agricultural suppliers, horticultural or farming businesses, and food retailers. Much of the private sector

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[3] B.A. Woodcock *et al.* (2017) Country-specific effects of neonicotinoid pesticides on honey bees and wild bees. Science 356 (6345), pp. 1393-1395. https://doi.org/10.1126/science.aaa1190
H. Siviter *et al.* (2018) Sulfoxaflor exposure reduces bumblebee reproductive success. Nature 561 (7721), pp. 109-112. https://doi.org/10.1038/s41586-018-0430-6

[4] B.A. Woodcock *et al.* (2016) Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature Communications 7, 12459. https://doi.org/10.1038/ncomms12459

[5] H. Siviter *et al.* (2018) Sulfoxaflor exposure reduces bumblebee reproductive success. Nature 561 (7721), pp. 109-112. https://doi.org/10.1038/s41586-018-0430-6

[6] E.A. Straw *et al.* (2021) Roundup causes high levels of mortality following contact exposure in bumble bees. Journal of Applied Ecology 58 (6), pp. 1167-1176. https://doi.org/10.1111/1365-2664.13867

[7] D.A. Stanley *et al.* (2015). Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees. Nature 528 (7583), pp. 548–550. https://doi.org/10.1038/nature16167

[8] A. Janssen and PCJ van Rijn (2021). Pesticides do not significantly reduce arthropod pest densities in the presence of natural enemies. Ecology Letters 24 (9), pp. 2010-2024. https://doi.org/10.1111/ele.13819

[9] D. Alberoni *et al.* (2020). What do we currently know about the impacts of pesticide and fertiliser use in farmland on the effectiveness of adjacent pollinator conservation measures such as flower strips and hedgerows, and what additional research is needed? Report prepared by an EKLIPSE Expert Working Group. UK Centre for Ecology & Hydrology, Wallingford, United Kingdom. https://eklipse.eu/wp-content/uploads/website_db/Request/Pollinators/Pollinators_Report.pdf

is left out. Although actors like food manufacturers and distributors within the food supply chain might be less immediately visible, they hold considerable influence.

F.2. There has been little demonstrated attention or progress from these companies (food manufacturers and distributors) to consider how supply chains might be affected by pollinator decline. **We recommend closer government engagement and coordination with corporations across the entire food supply chain in support of pollinator biodiversity initiatives**.

F.3. Pollinators are essential to food security: 35-40% of global crop production and 75% of leading global food crop species rely on animal pollination,[10] and contribute especially to nutrition security that requires a varied diet. Furthermore, changes in pollinator-dependent crop production and food supply chains will likely have an oversized impact on the United Kingdom: in all scenarios of loss in pollination services analysed in a 2022 study, the United Kingdom was among the top ten countries suffering the greatest absolute economic losses, even if the crops were affected elsewhere.[11] **We recommend that coordination with the food system on biodiversity and insect decline take a global approach to crop production and the food supply chain.** Coordination efforts should and can be targeted at specific business groups, as reliance on pollinators varies substantially between businesses, depending on the relevant crop species; pollinator losses can prove much more significant to certain businesses compared to the impact at national level (details under F.4.). Finally, while our response focuses on pollination, insects also contribute substantially to the food system as biological pest control, mentioned in the *Plant biosecurity strategy for Great Britain (2023 to 2028)*, and insects are essential to soil quality and the function of ecosystems at large. **Business action for pollinators provides a case study that can illustrate businesses' understanding of nature and biodiversity initiatives, and relevant coordination with and within the UK food system more broadly.**

F.4. In 2017, members of the Cambridge Conservation Initiative (CCI) published a report on *supply chain resilience in the face of pollinator decline*[12] that included a review of 27 companies selected for their perceived dependence on pollination. For this inquiry, we have updated that review for 24 of the companies.[13] Our preliminary assessment provides insight

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[10] A.-M. Klein *et al.* (2007) Importance of pollinators in changing landscapes for world crops, Proceedings of the Royal Society 274, pp. 303-313. https://doi.org/10.1098/rspb.2006.3721

[11] J.T. Murphy *et al.*(2022) Globalisation and pollinators: Pollinator declines are an economic threat to global food systems, People and Nature 4 (3), pp. 773-785. https://doi.org/10.1002/pan3.10314

[12] Cambridge Institute for Sustainability Leadership, Fauna & Flora International, University of East Anglia, & UNEP-WCMC (2017) The pollination deficit: Towards supply chain resilience in the face of pollinator decline. UNEP-WCMC, Cambridge, UK. https://www.cisl.cam.ac.uk/system/files/documents/the-pollination-deficit.pdf

[13] **Notes on methodology**: Our update currently focuses on companies from the 2017 CCI report that process agricultural outputs; it set aside the three agricultural suppliers originally included. Whilst nearly all of the selected companies are based within the food sector, the selection also included a cosmetics company and a cosmetics brand; in addition to food production, pollination also contributes for instance to the production of certain fuels, fibres, cosmetics, and medicines.
Our desk-based review relied on information that is publicly available; results were not checked by the companies and may not reflect all activities under way. Nevertheless, there is incentive for companies to publish their sustainability activities, the information indicates what they are willing to discuss publicly, and this is the information accessible to potential customers for purchasing decisions.
We searched 1) the internet for updates on projects included in the relevant appendix 2 of the 2017 CCI report, 2) companies' annual reports, ESG (Environmental, Social, Governance) reports, and

into the development of biodiversity initiatives and respective coordination gaps with and within the UK food system.

- **F.5. Coordination gap**: While awareness of pollination among businesses has improved, knowledge and understanding of key concepts remains unclear. Unless leaders can discuss and understand the risks to their business of the pollination deficit, we cannot count on their invaluable power to invest in solutions. However, there is not enough information available for companies about the commodities that rely on pollination and which are integral to their business.

  F.6. Key insights: The number of businesses addressing pollination has increased in the last ten years. A 2014 review by financial group Schroders[14] identified 25 leading companies that had exposure to risk from pollinator decline, of which only five explicitly addressed pollinator decline. In the 2017 CCI report, about half of the 27 companies assessed addressed bees or pollination. In our recent review, this increased to 21 of the 24 companies assessed.

  While awareness of pollination among businesses has visibly improved, understanding of key concepts remains unclear. In our review, for example only thirteen companies specify managed pollinators and only twelve specify wild pollinators.[15] Few companies in our preliminary analysis demonstrated more detailed knowledge in publicly available documents, for example by specifying relevant wild pollinators, and in one instance identifying the honey bee as important to agriculture but invasive to the Americas.[16] Such knowledge is critical for maximising impact, and our findings demonstrate a potential need for improved access to information on crop vulnerability to pollinator decline. The companies surveyed in the 2017 CCI report themselves identified this information gap, which is now acknowledged by select governing bodies: for example, in 2020 the EU published guidelines on *action by the agri-food and beverage sector to protect wild pollinators*[17], a summary factsheet,[18] and other sector-specific publications to promote key knowledge necessary for the agri-food and beverage sectors to contribute towards stopping the decline of wild

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related documentation such as relevant policies, and 3) companies' websites, using both targeted search terms and standardised search filters. We did not generally consider activities on deforestation or rewilding; our review focused on activities concerning farms, and horticultural and field crops.

[14] R. Stathers (2014) The Bee and the Stockmarket. An overview of pollinator decline and its economic and corporate significance. Schroders. http://www.schroders.com/staticfiles/schroders/sites/global/pdf/the_bee_and_the_stockmarket.pdf

[15] This observation aligns with research on public awareness of pollinators, for example an analysis of public comments on pollinator conservation policy in Canada in 2020: A.A. Nicholls *et al.* (2020) Understanding public and stakeholder attitudes in pollinator conservation policy development, Environmental Science and Policy 111, pp. 27-34. https://doi.org/10.1016/j.envsci.2020.05.011

[16] On the conflict between managed and native bee species see for example L. Russo *et al.* (2021) The managed-to-invasive species continuum in social and solitary bees and impacts on native bee conservation, Current Opinion in Insect Science 46, pp. 43-49. https://doi.org/10.1016/j.cois.2021.01.001

[17] European Commission, Directorate-General for Environment, K. Driesen, H. Van Gossum (2020) Business and nature working together: action by the agri-food and beverage sector to protect wild pollinators. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/696869

[18] European Commission, Directorate-General for Environment (2020) Business and nature working together: action by the agri-food and beverage sector to protect wild pollinators. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/728348

pollinators.

F.7. Recommendation: Build business awareness of insects, including pollination, pest regulation, and other services provided by them. Survey businesses to identify key knowledge gaps, and provide required information in suitable formats. This could possibly be addressed under activities outlined in the *National Pollinator Strategy: Pollinator Action Plan, 2021 to 2024* Table 6: Knowledge exchange.

- **F.8. Coordination gap**: Despite growing awareness, biodiversity remains several years behind climate in terms of corporate understanding and action. To enable the necessary resilience of our food systems, businesses must tackle both the climate and nature crises.

F.9. Key insights: In 2016, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) published its global assessment of pollinators, pollination, and food production;[19] fourteen governments subsequently established *Promote Pollinators*, the *Coalition of the Willing on Pollinators* at the thirteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP13) in 2018. As growing membership of the coalition and increasing numbers of national initiatives for pollinators show,[20] these activities have since received considerable attention in the public sector. However, only two companies in our review reference IPBES, and only four the CBD. This remains the case even following the landmark signing of the Global Biodiversity Framework (GBF) in Montreal at CBD COP15.

By contrast, 23 out of 24 companies reference the Sustainable Development Goals (SDGs), and 21 out of 24 companies reference the Intergovernmental Panel on Climate Change (IPCC). The climate change and biodiversity crises are intertwined;[21] for example, research suggests that climate change is already affecting the synchronisation of pollinators, pollination, and plant communities.[22]

F.10. Recommendation: Capitalise on the private sector's interest in international sustainability initiatives. More actively encourage business contributions to such activities regarding biodiversity, e.g., to IPBES' ongoing Business and Biodiversity Assessment,[23] and support businesses in the uptake of relevant outputs, e.g., through the UK IPBES Stakeholder Network.[24]

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[19] IPBES (2016) The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. https://doi.org/10.5281/zenodo.3402856
[20] For further information see https://promotepollinators.org
[21] H.-O. Pörtner *et al.* (2023) Overcoming the coupled climate and biodiversity crises and their societal impacts, Science 380, eabl4881. https://doi.org/10.1126/science.abl4881
[22] F. Duchenne *et al.* (2020) Phenological shifts alter the seasonal structure of pollinator assemblages in Europe, Nature Ecology & Evolution 4, pp. 115–121. https://doi.org/10.1038/s41559-019-1062-4
[23] For further information see https://www.ipbes.net/business-impact
[24] https://jncc.gov.uk/our-work/intergovernmental-science-policy-platform-on-biodiversity-and-

- **F.11. Coordination gap**: Exposure to pesticides and other toxic pollutants plays a large role in pollinator declines. However, there is a lack of standardisation amongst businesses in their understanding of and approach to pest management, leading to varied implementation.

  F.12. Key insights: The 2014 National Pollinator Strategy, the 2016 IPBES assessment of pollinators, pollination, and food production, and multiple scientific publications[25, 26] have called for Integrated Pest Management (IPM) to reduce the use of pesticides. According to the 2017 CCI report, fewer than half of the companies assessed had pesticide reduction programmes in place at the time. According to our recent review, 17 out of 24 companies assessed now promote IPM, and a further two provide training on pest management to farmers in their supply chain.

  However, the measures included with companies' approaches to IPM vary widely, and implementation ranges from a general commitment to detailed guidance and requirements. Notably, while all five retailers included with our review were among the companies who already had pesticide reduction programmes in place in 2017, they have further developed their approaches to varying extent – sometimes explicitly in response to Pesticide Action Network UK's (PAN UK) ranking of supermarkets.[27]

  F.13. Recommendation: Continue to implement the *National Pollinator Strategy: Pollinator Action Plan, 2021 to 2024* on Pesticides and Integrated Pest Management. Consider expanding these activities to include experiences among companies on how to implement IPM along the entire supply chain, and potentially also draw on PAN UK's insights from scoring supermarkets.

- **F.14. Coordination gap**: Businesses frequently refer to "regenerative agriculture". However, it is unclear whether they truly understand the role this plays in addressing biodiversity, including pollinators, and the corresponding actions they need to take.

  F.15. Key insights: All companies reviewed referred to sustainable agriculture in the 2017 CCI report. While 'sustainable agriculture' remains the more common term among the wider public, and while some companies also referred to agroforestry (especially concerning coffee and cocoa), 18 out of 24 companies reviewed now refer to regenerative agriculture. The term 'regenerative agriculture' has been gaining popularity since 2018.[28] However, multiple reviews have concluded that there is no consensus definition of regenerative agriculture, and understanding of the term varies.[29, 30] Only one of the assessed companies acknowledges this, and only one

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ecosystem-services-ipbes

[25] L.V. Dicks *et al.* (2016) Ten policies for pollinators. Science 354, pp. 975-976. https://doi.org/10.1126/science.aai9226

[26] S.G. Potts *et al.* (2016) Safeguarding pollinators and their values to human well-being. Nature 540, pp. 220-229. https://doi.org/10.1038/nature20588

[27] https://www.pan-uk.org/supermarkets/

[28] See for example the search term 'regenerative agriculture' in Google Trends at https://trends.google.com

[29] P. Newton *et al.* (2020) What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes. Frontiers in Sustainable Food Systems 4, 577723. https://doi.org/10.3389/fsufs.2020.577723

other company quotes an external definition, from non-profit Regeneration International.

A 2020 systematic review that compiled and analysed various perspectives on regenerative agriculture ultimately proposed "a provisional definition of [regenerative agriculture] as an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple ecosystem services".[31] Taking action to improve soil conservation, however, is not necessarily efficient in improving biodiversity. Based on these findings, farming systems promoted for their sustainability can, but do not necessarily, provide more food and habitat for insects. In contrast to earlier studies, one publication from 2020 even concluded that farmland heterogeneity can have similar – and sometimes even larger – effects on farmland biodiversity than the farm management practices used in individual crop fields.[32] A current project at the University of Cambridge, H3 (www.h3.ac.uk) is testing this question in a large-scale field experiment co-designed with UK farmers. Results are expected in 2025-6. In a recently published study based on a survey of UK farmer soil management practices, we propose a scoring system based on the principles of regenerative agriculture, as a way to gain insight into the degree of systemic transformation taking place on farms claiming to be regenerative[33].

F.16. Recommendation: Sustainable farming systems differ widely in their approach and components, and they can prove beneficial in multiple ways. However, given the lack of consensus definitions, Government should lead by establishing the evidence benchmarks for labels like 'sustainable' or 'regenerative'. This should be done in consultation with experts and include specific references to the systems' ability to improve biodiversity, and their value for wildlife.

- **F.17. Coordination gap**: Certification schemes are a key tool for businesses to manage supply chain risks in response to insect declines. They can act as a stepping stone to ensure sustainable sourcing of key commodities and enable actionable commitments to pollinators. There is a clear role for policymakers and certification schemes to provide regulatory controls, incentives or guidance for pollinator-friendly practices.

  F.18. Key insights: In the 2017 CCI report, the vast majority of companies already used certification schemes, to help deliver targets within supply chain strategies and commitments on sustainable agriculture. In our recent review, all except one

[30] EASAC (2022) Regenerative agriculture in Europe. A critical analysis of contributions to European Union Farm to Fork and Biodiversity Strategies. EASAC policy report 44, ISBN: 978-3-8047-4372-4. https://easac.eu/publications/details/regenerative-agriculture-in-europe

[31] L. Schreefel *et al.* (2020) Regenerative agriculture – the soil is the base. Global Food Security 26, 100404. https://doi.org/10.1016/j.gfs.2020.100404

[32] A.E. Martin *et al.* (2020) Effects of farmland heterogeneity on biodiversity are similar to—or even larger than—the effects of farming practices. Agriculture, Ecosystems & Environment 288, 106698. https://doi.org/10.1016/j.agee.2019.106698

[33] C.C. Jaworski *et al.* (2023) Sustainable soil management in the UK: a survey of current practices and how they relate to the principles of regenerative agriculture. Soil Use and Management. https://doi.org/10.1111/sum.12908

company publicly communicated that they subscribe to a number of such schemes. Several companies now even ask their suppliers for certain certifications, or require them, at least in some contexts: nowadays, forgoing common certifications means potentially losing out on business. While we have not yet updated that separate assessment, the 2017 CCI report found that several widely used certifications either address pollinators directly or indirectly. Notably, while there are certifications that specialise in the support of pollinators, only one company we assessed seemed to subscribe to one of those.

F.19. Recommendations: Recognise how important certain certifications have become for an integrated food system. Whilst specialist certifications in support of pollinators may, for example, raise awareness and inspire projects, also consider working with existing major industry certifications in support of insects. We concur with the 2017 CCI report that suggested a guide for companies on the extent to which different certification schemes address insects. These certification schemes should also exclude agro-chemical companies and similar businesses, as their certification would be highly inappropriate.

- **F.20. Coordination gap**: Based on a range of projects in public disclosures, businesses seem more aware and willing to address pollinator declines; however, this has not been paired with targeted, meaningful and sustained action of the necessary extent. Biodiversity is getting more attention; however, the issue is detailed and complex, and companies are likely unsure how to handle that complexity.

F.21. Key insights: 20 out of 27 companies in the 2017 CCI report had projects in direct or indirect support of pollinators underway. For pollinators or bees, these projects were mostly related to community projects and to improving field margins for pollinator forage.

In our recent review, 22 out of the 24 companies assessed appeared to be running projects that directly, indirectly, or at least potentially support pollinators. The projects generally fall into four categories: 1) Projects that are fully integrated with the company's supply chain: for example, one company is looking to sell a bee-friendly certified product. 2) Projects adjacent to a company's supply chain: for example, farmers in several companies' projects keep bees alongside crop production, and sell the honey. 3) Projects outside the supply chain: for example, one company is restoring a forest habitat for an endangered, yet important, wild pollinator. 4) Projects that can potentially support pollinators: for example, several companies encourage cover crops on farms.

Among a range of measures, improving field margins remains popular. For example, at least one third of the companies' projects explicitly involve sowing wild flowers, and the activity is likely also included with several other companies' projects. While wildflower margins have proven beneficial to pollinators, they should be well-managed, the plant species included should be selected for the local environment – including seed mixes promoted by governmental agri-environment schemes[34, 35] –

and wild flower margins should be embedded among several activities in support of pollinators.[36] Overall, it is unclear to what effect companies are selecting, combining, and applying different activities. Furthermore, for example at least six companies explicitly encourage cover crops; the activity is likely encouraged by other companies, as well, for example under their regenerative agriculture schemes. However, it remains unclear whether these cover crops will support pollinators, and whether several company schemes for regenerative and/or sustainable agriculture will effectively address insects.

At least one third of the assessed companies support and encourage beekeeping, both in the UK and internationally. In the British Isles, honey-hunting and beekeeping have a history of several thousand years: as the appendix to this document shows, this history could prove informative to current pollinator management. Notably, while honey bee hive numbers in the UK declined over several decades,[37] colony numbers recorded with the National Bee Unit's BeeBase appear to have increased more recently.[38] While managed bees contribute substantial pollination services, some research suggests that the majority of crop pollination in the UK is provided by wild pollinators.[39, 40] Furthermore, even in this environment there are potential conflicts between managed and wild pollinators: for example, research suggests that competition from managed honeybees can harm bumblebees native to the UK,[41] and further research suggests that managed bumblebees and honeybees should be regulated and well-cared for to prevent the transmission of emerging infectious diseases to wild pollinators in the UK.[42] Internationally, managed and/or invasive bee populations seem to present an even greater potential threat to native pollinator species. Notably, honeybees (*Apis mellifera*) as a generalist, social bee species that reaches high population densities can pose enhanced risks; its impact may be further exacerbated in agricultural landscapes that favour it.[43] At the same time, the benefits

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[34] T.J. Wood *et al.* (2015) Pollinator-friendly management does not increase the diversity of farmland bees and wasps. Biological Conservation 187, pp. 120-126. https://doi.org/10.1016/j.biocon.2015.04.022

[35] R.N. Nichols *et al.* (2019) The best wildflowers for wild bees. Journal of Insect Conservation 23, pp. pages 819–830. https://doi.org/10.1007/s10841-019-00180-8

[36] D.J. Steele *et al.* (2019) Management and drivers of change of pollinating insects and pollination services. National Pollinator Strategy: for bees and other pollinators in England. Evidence statements and Summary of Evidence: National Pollinator Strategy: for bees and other pollinators in England. DEFRA, London, UK. https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectID=20277

[37] S.G. Potts *et al.* (2010) Declines of managed honey bees and beekeepers in Europe. Journal of Apicultural Research 49 (1), pp. 15-22. https://doi.org/10.3896/IBRA.1.49.1.02

[38] https://www.nationalbeeunit.com

[39] T.D. Breeze *at al.* (2011) Pollination services in the UK: How important are honeybees? Agriculture, Ecosystems & Environment 142 (3-4), pp. 137-143. https://doi.org/10.1016/j.agee.2011.03.020

[40] J. Ollerton *et al.* (2012) Overplaying the role of honey bees as pollinators: a comment on Aebi and Neumann (2011). Trends in Ecology & Evolution 27 (3), pp. 141-142. https://doi.org/10.1016/j.tree.2011.12.001

[41] D. Goulson and KR Sparrow (2009) Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size. Journal of Insect Conservation 13, pp. 177-181. https://doi.org/10.1007/s10841-008-9140-y

[42] M.A. Fürst *et al.* (2014) Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature 506, 364–366. https://doi.org/10.1038/nature12977

[43] L. Russo *et al.* (2021) The managed-to-invasive species continuum in social and solitary bees and impacts on native bee conservation, Current Opinion in Insect Science 46, pp. 43-49.

of beekeeping extend beyond local pollination, ranging from nature education to the availability of flexible pollination services and business diversification for farmers who sell bee products.

Reviewed companies typically described their biodiversity initiatives in absolute numbers, e.g., by financial investment or land area covered, or relative to their business. Overall, information published by companies on their biodiversity initiatives often proved fragmented and sparse, which hampered assessment. Impact assessment was rarely communicated. No company seemed to publish evaluations measured against environmental need, for example in terms of species conservation or the extent and characteristics of habitats required for effective conservation. Furthermore, research suggests that the '5 simple actions' promoted by the National Pollinator Strategy, or current guidance in agri-environment schemes are insufficient: wild pollinator species require action more closely tailored to their needs.[44] Accordingly, rare pollinators are suffering disproportionate losses.[45] Crucially, pollinator diversity is not merely critical to wild plant species; research shows that pollinator diversity is required for maintaining crop pollination in the long term.[46]

Notably, several companies we assessed are undertaking projects in support of pollinators on farms that do not require pollination services. For example, they pay farmers to make space for dedicated pollinator habitats alongside wheat and oat crops, or they encourage pollinator-friendly practices on dairy farms. These projects are encouraging in light of research which shows that a focus on crop pollination does not suffice to conserve wild pollinators.[47] Alongside an ecosystem services approach, protecting these species requires a moral imperative and a holistic view of biodiversity and conservation: these companies set an important example - and demonstrate that a holistic view of biodiversity has its place in successful business. That companies are taking this perspective is consistent with earlier findings in the 2014 review by financial group Schroders,[48] and also implicit in the 2017 CCI report. These companies' projects further illustrate that large areas of agricultural land are of little use to pollinators: we need more research, for example, into floral resources for pollinators in agricultural grasslands,[49] mixed cropping (in cereals) and agroforestry.

Finally, we noticed several co-operations among businesses for biodiversity

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https://doi.org/10.1016/j.cois.2021.01.001

[44] T.J. Wood *et al.* (2015) Pollinator-friendly management does not increase the diversity of farmland bees and wasps. Biological Conservation 187, pp. 120-126. https://doi.org/10.1016/j.biocon.2015.04.022

[45] G.D. Powney *et al.* (2019) Widespread losses of pollinating insects in Britain. Nature Communications 10, 1018. https://doi.org/10.1038/s41467-019-08974-9

[46] N.J. Lemanski *et al.* (2022) Greater bee diversity is needed to maintain crop pollination over time. Nat Ecol Evol 6, pp. 1516–1523. https://doi.org/10.1038/s41559-022-01847-3

[47] D. Kleijn *et al.* (2015) Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature Communications 6, 7414. https://doi.org/10.1038/ncomms8414

[48] R. Stathers (2014) The Bee and the Stockmarket. An overview of pollinator decline and its economic and corporate significance. Schroders. http://www.schroders.com/staticfiles/schroders/sites/global/pdf/the_bee_and_the_stockmarket.pdf

[49] B.A. Woodcock *et al.* (2014) Enhancing floral resources for pollinators in productive agricultural grasslands. Biological Conservation 171, pp. 44-51. https://doi.org/10.1016/j.biocon.2014.01.023

initiatives, including projects that benefit pollinators. Tools such as publicly available, high-resolution maps that are rich in information on pollinator species, habitats, types of agricultural lands, etc. – similar to the UN Biodiversity Lab[50], but on a national scale – might prove helpful for businesses, researchers, and other organisations to coordinate efforts; ideally, a map layer should allow users to display their projects. This tool can be combined with our recommendation in paragraph G.18.

F.22. Recommendation: Government should actively engage with businesses to ensure that they are equipped to meet key nature goals.
   - Survey and evaluate businesses' biodiversity initiatives; compare them against each other and against external measures. Identify best practices, benchmarks, and evidence-based targets. Encourage consistent ESG reporting that covers biodiversity initiatives in sufficient detail and depth.
   - Develop and publish frameworks for companies to assess their interaction with biodiversity throughout their supply chain, for example their reliance on pollinators. Incentivise businesses to undertake these assessments.
   - Develop and publish tools that support cooperation among businesses and other organisations, for example interactive high-resolution maps with relevant information on land use, other environmental factors, and (insect) biodiversity.
   - Publish more detailed practical guidance on insect biodiversity initiatives for businesses. Examples include advice on designing wildflower mixes that suit local insect populations, or selecting and implementing coordinated measures that support insects on farms. Harmonise this guidance with any frameworks and tools described above.

- **F.23. Recommendation:** Strive for optimum information underpinning biodiversity initiatives.
   - Evaluate agri-environmental schemes for fitness for purpose and impact, especially with regard to insects, including wild pollinators.
   - Clearly distinguish between managed and wild pollinators in all communications. Review regulation of managed pollinators, including for example on caring for bee colonies, and the placement of hives.
   - Invest in rigorous research on biodiversity and the food system; especially research in cooperation with practitioners on farms and in the food industry, and translational research. Interaction between agriculture and wild pollinators is an example for a key area of interest.

- **F.24. Recommendation**: The ecosystem services concept has its place; yet, it does not suffice to fully address conservation needs, as illustrated by the example of wild pollinators. Build on businesses' proven capacity to take a holistic view of biodiversity.

- **F.25. Recommendation:** Create a public online map resource for the UK with high-resolution maps that are rich in information on pollinator species, habitats, types of agricultural lands, etc, based on the model of the UN Biodiversity Lab.[51] The

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50 https://map.unbiodiversitylab.org/

resource can also allow businesses to showcase their best practices and community projects, inspiring other organisations to implement similar initiatives and enabling collaborations. This tool can be combined with the map of high-quality pollinator habitats suggested in paragraph G.18.

4. Whether the threat to UK food security from insect decline receives sufficient cross-government priority

5. Additional policy initiatives and solutions needed in the UK and internationally to reduce and reverse the trends in insect decline

G.1. Historically, the most important driver of insect declines is thought to have been habitat loss and fragmentation, as the UK's countryside has been progressively converted into agricultural and urban areas. However, looking to the future, **climate change is set to become the leading cause of biodiversity loss worldwide**. Lots of work has been done on improving habitat suitability for insects and linking up fragmented landscapes. This will continue to be important, especially as species try to move north through the country to track warming climates, as they will require suitable habitat to do so. Research should focus on both of these negative drivers, to better understand their causes and investigate ways to reduce or reverse associated population declines.

G.2. New interventions can help protect insect species from the negative impacts of climate change: Matthew Hayes (Wolfson College PhD student in Zoology) is working with the Wildlife Trust (Bedfordshire, Cambridgeshire & Northamptonshire) to trial new ways to provide shade and shelter for butterflies by converting flat areas into more complex landscapes. Habitat loss and fragmentation has left many species restricted to small, isolated reserves and unable to respond to temperature change by moving across the landscape. These new management options will help species heat up and cool down during projected global warming and extreme weather events.[52]

G.3. Opportunities but also barriers exist for testing interventions in urban areas. For institutions with grounds like Wolfson College to test out new pollinator management techniques, money for their initial set up would be required. This would cover costs for equipment such as diggers as well as staff time. The continued monitoring of the intervention would also require funding for staff time. Access to researchers and individuals with expertise in recording insects would also be needed. While the College and its Hub have research expertise and community energy, start-up costs and dedicated project funding are often too difficult to source.

G.4. Recommendation: Support research into ways to help insects adapt to climate change. Funding is needed for the initial establishment of management interventions, as well as the continued monitoring of their impact. Access to researchers with expertise in insect recording will also be needed.

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[51] https://map.unbiodiversitylab.org/
[52] https://www.wildlifebcn.org/banking-butterflies-project

G.5. Recommendation: Set aside land to test new protective interventions. These areas do not have to be big: for example, it is possible to set up artificial banks of earth within urban areas and gardens.

G.6. Recommendation: Encourage local institutions including educational sites to offer their grounds as sites for testing, particularly via funding to offset initial costs of equipment and implementation.

G.7. Fostering a balanced ecosystem in gardens can reduce and eliminate use of insecticides, this requires a shift in gardening attitudes towards 'pests'. The gardening staff at Wolfson College have stopped the use of insecticides in outdoor settings since Autumn 2020, in favour of supporting a natural ecosystem with a pest/prey cycle keeping everything in check on the nine-acre site. For example, we allow ants to farm aphids and wait for our ladybird populations to eat aphids. This approach requires a mindset change towards 'pests': some insects will cause minor damage to plants, but living with some damage and working with insects is a far better approach than a neat and clean environment with insect decline. Some insect control measures are still used for other ornamental garden pests, and these controls are chosen specially for their very selective nature and low impact on non-targeted organisms, including biological control of the box moth caterpillar using a Bacillus bacteria, and slug control pellets with ferric phosphate. Box plant topiaries have historically played an important role in our gardens' designs, but we are now aiming to change our planting to one the caterpillar is unsuited to, so we can stop spraying insecticides where possible. This natural approach towards insect control is shared with visitors to the College site on our regular garden tours.

G.8. Recommendation: Create education material to encourage gardeners to decrease their use of pesticides in favour of natural prey alternatives.

G.9. Recommendation: Create education material to encourage gardeners to value insects over aesthetics of their gardens.

G.10. Recommendation: Keep neonicotinoids banned.

G.11. Successful centres of biodiversity researchers and advocates can catalyse important interventions in neighbouring spaces and wider communities. Wolfson's Hub serves as a source of expertise and assistance for nearby residents and their rewilding community group, Action for Barton Close. Hub members and the local community have worked together since 2019 to improve a large road island site on Barton Close, turning it into a wildlife corridor for insects and other organisms between the surrounding gardens. Wolfson researchers, including PhD candidate Matthew Hayes, lent their expertise in analysing the ideal configuration and choices for plants and structures that would cater for local butterflies and other insects.[53] The running of a College Hub that convenes researchers and practitioners has led to increased knowledge share between the academic institution and local communities, the nurturing of biodiversity hotspots in the local area and the incubation of inter-community partnerships that bring biodiversity dividends. The Hub also

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[53] https://www.wolfson.cam.ac.uk/about/news/wolfson-staff-and-students-promote-biodiversity-community

runs a 'Living Lab' that uses the College grounds to test new research ideas in sustainability and biodiversity.[54] However, the Hub is unable to support longer-term and larger projects because it depends heavily on volunteer time and time-limited financial support. Students on one- to three-year courses drive many of the Hub's initiatives, including the Student Garden and the College's Insect Hotel for solitary bees and other pollinators. The Hub's ability to generate more impact and to sustain projects would be strengthened if it was able to hire more permanent staff, who would help prolong institutional memory and sustain ties within the College community and its neighbours. Targeted funding for scholarships and visiting fellows would multiply the number of ideas and initiatives the Hub could put into action, with potentially generative links to local industry and business owners.

G.12. Recommendation: Encourage the creation of centres of biodiversity innovation and knowledge via community funding, tax incentives, and research council funding that is specifically for sustaining such centres (potentially on the model of Leverhulme Centres)

G.13. Investing in new biodiversity initiatives will start a positive cycle of action. Our first initiatives at Wolfson College have increased biodiversity on-site, leading to increased interest from various monitoring groups. We have now hosted four teams with another three visits planned soon. Investments in time in social media, awareness weeks, and garden tours have paid off - the Wolfson community (alumni, students, affiliates) have responded with monetary contributions to support further biodiversity projects. Our Student Garden, which produces herbs and a small amount of food, has been an important conversation starter and a way for students to try organic farming. From our experience, most people understand the need to change but don't know how to go about making positive change. Our solution has been to provide a baseline understanding of issues like insect decline, followed by giving examples of simple improvements they can make. Online workshops are effective to an extent, but we have found that participants are encouraged more when working hands-on in an in-person workshop. Finding the finances to pay for materials within our organisation's budget can be challenging.

G.14. Recommendation: Leverage the existing expertise of local experts and groups, by providing targeted funding to help them conduct workshops for the community.

G.15. Organisational changes are crucial to effective interventions for biodiversity. At Wolfson College, the combined interest and efforts of researchers and students led to the creation of a sustainability committee. This committee has since pushed for important measures, including the commissioning of an ongoing biodiversity survey and the approval to replace some traditional college grass lawns with a wildflower meadow. Other significant interventions include the replacement of our fishpond to a wildlife pond, the student-led institution of insect hotels, and a push to move away from insecticides towards more organic plant management methods. The committee makes recommendations on the College's climate and biodiversity goals, and holds the College to account in fulfilling its sustainability objectives. Visually, there has been greater amounts of variance in the insect life here, a result of having more log piles and the wildflower meadow. This also has had a beneficial effect on bird life onsite too.

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[54] https://www.wolfson.cam.ac.uk/sustainability-hub/living-lab

G.16. Recommendation: Create sustainability committees in educational institutions with either over 200 members, or with grounds larger than a particular size.

G.17. A collection of educational sites with biodiversity actions plans in place can substantially defragment the natural habitat. In the recent Colleges Biodiversity Baseline Summary Report (2022), it is noted that across the Colleges there are 75 areas of grasslands that are flower-rich or not intensely-managed (left to grow and only cut once or twice a year). Gaps between these high-quality grasslands, barring two exceptions, are about 300 metres. Including University and Cambridge City Council grasslands, no matter its management regime, 'there are virtually no gaps of greater than 100m across the west and centre of the city'.[55] A key suggestion of a 2021 study of college biodiversity initiatives was to create a city-wide map of wildflower areas, which would help gardeners identify gaps in wildlife and pollinator connectivity across sites.[56] Buglife's 'B-Lines' project has some existing county-level information that should be augmented further via more targeted local data collection and reviews of recent local biodiversity reports.

G.18. Recommendation: Create a national map of high-quality grasslands to identify gaps in pollinator connectivity, using data and potentially infrastructure from 'B-Lines' project combined with a deeper engagement with local biodiversity reports.

G.19. Advanced advice for gardeners on supporting pollinators is not easily available. Wolfson College gardeners have spearheaded well-known types of initiatives, including planting wildflower meadows, setting up insect hotels and providing log piles to increase habitability for insects on-site. However, more advanced information is difficult to come by, including what the most optimal trees to plant are, what types of foods insects prefer, which types of wood and materials are best for insect habitation, and what modified man-made habitats for insects are best to make. A good model to follow would be the RSPB's website, which provides succinct and targeted information for supporting bird populations.[57]

G.20. Recommendation: Create an online resource for gardeners with information about the optimal ways to support different types of insects, with specific practical information about materials and designs for habitats, and recommended plants suitable for their diets and behaviours. This resource can be developed based on outreach and guidance for growers and land managers (under the National Pollinator Strategy), and based on the existing Bug Directory resource created by Buglife.[58]

Appendix: The Archaeology and History of Honey-hunting and Beekeeping in Britain

H.1. Whereas various non-human animal species are known to explore wild honey and even have developed target specific toolkits to access different types of hives,[59, 60, 61, 62, 63, 64] only

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55 https://www.environment.admin.cam.ac.uk/sites/www.environment.admin.cam.ac.uk/files/copy_of_college_biodiversity_baseline_summary_report_-_october_2022-compressed.pdf

56 https://drive.google.com/file/d/17x7qZ3jpELguKaGihWKroIl7hX9qQ-LF/view

57 https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/

58 https://www.buglife.org.uk/bugs/bug-directory/

59 S.M. Brewer and W.C. McGrew (1990) Chimpanzee use of tool set to get honey. Folia

humans have managed to form reciprocal relationships with honeybees (genus *Apis*). Early *Homo* and the expanding hominin brains were suggested to have benefited from the energy-dense honey that allowed them to nutritionally out-compete other species.[65, 66, 67] There is no reason to doubt that the early human population on the British Isles started extracting wild honey resources as soon as the honeybees (*Apis* mellifera) recolonized the region from their Pleistocene glacial refugia in the Mediterranean following the accelerating post-Glacial warming around 13,000 BP.[68, 69]

H.2. The earliest definitive evidence of human use of bee-product to date has come from beeswax lipid remains on pot sherds from Eton Rowing Lake, Buckinghamshire and Runnymede Bridge, Berkshire dated to the 5th millennium BC.[70, 71, 72] Whilst it is hard to hypothesise whether the neolithic farmers had started artificial beekeeping, honey-hunting or the exploration of wild honey does not require less knowledge about bees' ecology and behaviour but in contrast good understanding of the bees' habitats and seasonality. Honey-hunting therefore operates in a managed landscape which was evident from codes of law from much later periods regarding the ownership and compensation over trees nested by wild honeybees in such as the ancient Welsh laws codified in the 10th century and the famous *Charter of the Forests* of King Henry III from 1225.[73, 74, 75, 76]

Primatologica 54, pp. 100–104.

[60] M. Bermejo and G. Illera (1999) Tool-set for termite-fishing and honey extraction by wild chimpanzees in the Lossi Forest, Congo. Primates 40 (4), pp. 619–627. https://doi.org/10.1007/BF02574837

[61] T.C. Hicks *et al.* (2005) Chimpanzee (Pan troglodytes troglodytes) tool use in the Ngotto Forest, Central African Republic. American Journal of Primatology 65, pp. 221–237. https://doi.org/10.1002/ajp.20111

[62] C.M. Sanz and DB Morgan (2009) Flexible and persistent tool-using strategies in honey-gathering by wild chimpanzees. International Journal of Primatology 30, pp. 411–427. https://doi.org/10.1007/s10764-009-9350-5

[63] C. Boesch *et al.* (2009) Complex tool sets for honey extraction among chimpanzees in Loango National Park, Gabon. Journal of Human Evolution 56 (6), pp. 560–569. https://doi.org/10.1016/j.jhevol.2009.04.001

[64] J. Bessa *et al.* (2021) First Evidence of Chimpanzee Extractive Tool Use in Cantanhez, Guinea-Bissau: Cross-Community Variation in Honey Dipping. Front. Ecol. Evol. Sec. Behavioral and Evolutionary Ecology 9. https://doi.org/10.3389/fevo.2021.625303

[65] M. Skinner (1991) Bee brood consumption: An alternative explanation for hypervitaminosis A in KNM-ER 1808 (Homo erectus) from Koobi Fora, Kenya. Journal of Human Evolution 20, pp. 493–503. https://doi.org/10.1016/0047-2484(91)90022-N

[66] A.N. Crittenden (2011) The Importance of Honey Consumption in Human Evolution, Food and Foodways 19 (4), pp. 257-273. https://doi.org/10.1080/07409710.2011.630618

[67] W. Frank *et al.* (2014) Honey, Hadza, hunter-gatherers, and human evolution. Journal of Human Evolution 71, pp. 119-128. https://doi.org/10.1016/j.jhevol.2014.03.006

[68] G.W. Hewitt (1999) Post-glacial re-colonization of European biota. Biological Journal of the Linnean Society 68 (1-2), pp. 87-112. https://doi.org/10.1006/bijl.1999.0332

[69] F. Han *et al.* (2012), From where did the Western honeybee (*Apis mellifera*) originate?. Ecol Evol 2, pp. 1949-1957. https://doi.org/10.1002/ece3.312

[70] S. Needham and J. Evans (1987), Honey And Dripping: Neolithic Food Residues From Runnymede Bridge. Oxford Journal of Archaeology 6, pp. 21-28. https://doi.org/10.1111/j.1468-0092.1987.tb00138.x

[71] M.S. Copley *et al.* (2005) Dairying in antiquity. III. Evidence from absorbed lipid residues dating to the British Neolithic. Journal of Archaeological Science 32 (4), pp. 523-46. https://doi.org/10.1016/j.jas.2004.08.006

[72] M. Roffet-Salque *et al.* (2015) Widespread exploitation of the honeybee by early Neolithic farmers. Nature 527, pp. 226–230. https://doi.org/10.1038/nature15757

H.3. The beginning of traditional beekeeping using wicker or straw skep hives was argued to predate the Roman period[77]. However, such beekeeping methods involving mostly organic material are unlikely to survive in archaeological deposits in normal conditions. Remains of honeybee body parts and traces of bee products detected through lipid or palynological analysis are known throughout the archaeology of Iron Age Britain,[78, 79, 80, 81, 82, 83] suggesting an increased importance of honey products but offering no conclusive evidence to the practice of artificial beekeeping. Records of hive beekeeping became abundant after the 5th century AD with clear mentions of skep hives, swarming, and beekeepers in the ancient laws of Ireland said to have been codified by St. Patrick in 438-441 AD, the ancient Welsh laws, various Anglo-Saxon treatises, and most importantly the Domesday Book which documented a total of 2,738 hives from 292 places in Essex, Norfolk and Suffolk and an additional 88 entries of tax payments with honey from the rest of the country.[84, 85] It can therefore be safely argued that hive beekeeping had become a common feature of the English socio-agricultural landscape from the Norman period onwards. It is also a common landscape feature in a more realistic sense that 1,608 bee boles (wall recesses to shelter beehives) and other beekeeping structures were registered[86] across the British Isles with a chronological span from the 12th to the 19th century when skep hives were largely replaced by the modern box hives.[87, 88]

H.4. In summary, the history of human-bee entanglement on the British Isles stretches as far back as 13,000 BP whereas managed hive beekeeping started no later than the early Iron Age. Both honey-hunting and beekeeping should be considered as stakes of landscape and forestry management. Woodland density, population, hydrology, and its shifting relationship with other competing forms of land use patterns would all have been mutually affected by the bees and beekeepers over the last few millennia. It is inconceivable that the contemporary

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[73] H.M. Ransome (1937) The Sacred Bee in Ancient Times and Folklore. George Allen & Unwin, London.
[74] H.M. Fraser (1958). History of Beekeeping in Britain. Bee Research Association, London.
[75] E. Crane and P. Walker (1984) Evidence on Welsh Beekeeping in the Past. Folk Life 23 (1), pp. 21-48. https://doi.org/10.1179/flk.1984.23.1.21
[76] E. Crane (1999) The World History of Beekeeping and Honey Hunting. Duckworth, London.
[77] *ibid.*
[78] J.H. Dickson (1978) Bronze age mead. Antiquity 52 (205), pp. 108–13. https://doi.org/10.1017/S0003598X00071921
[79] F. Ruttner *et al.* (1990) The Dark European Honey Bee, Apis mellifera mellifera Linnaeus 1758. British Isles Bee Breeders Association, Derby, UK.
[80] R. Brown (1994) Great masters of beekeeping. Bee Books New and Old. Charleston,UK
[81] H.K. Kenward and AR Hall (1995) Biological evidence from Anglo-Scandinavian deposits at 16–22 Coppergate. The Archaeology of York 14 (7), pp. 435–797.
[82] C. Dickson and J.H. Dickson (2000) Plants and people in ancient Scotland.Tempus Publishing.
[83] M.A. Robinson (2007) Analysis of insects from middle Bronze Age to Roman deposits from Perry Oaks. http://www.scribd.com/doc/388452/Analysis-of-insects-from-Middle-Bronze-Age-to-Roman-deposits-from-Perry-Oaks
[84] H.M. Fraser (1958). History of Beekeeping in Britain. Bee Research Association, London.
[85] E. Crane and P. Walker (1999) Early English beekeeping: the evidence from local records up to the end of the Norman period. Local Historian 28 (3), pp. 130-51.
[86] https://www.beeboles.org.uk/en/page/about-us#text-block-1
[87] E. Crane and P, Walker (2000) Wall Recesses for Bee Hives. Antiquity 74, pp. 805-11. https://doi.org/10.1017/S0003598X00060452
[88] R.B. Ogden (2001) In pursuit of liquid gold. Bee Books New and Old, Charlestown, United Kingdom.

agricultural landscape and evolution of major ecosystems of Britain was not shaped partly through past human-bee entanglements. Carreck[89] therefore called for an urgent study into the pollinator community and the role honeybees played in major 'wild' ecosystems such as nature reserves that represent rarely wilderness but artificially managed traditional farmland be it hay meadows, coppiced woodland, or heathland. Furthermore, future research may also focus on the complex dynamism of the shifting honeybee-landscape entanglement in history during periods of declining bee population such as the reformation, the outbreaks of the so-called 'Isle of Wight disease' in early 20th century and the second World War. Such historical insights may offer a long-term view to address future impact of pollinator deficiency on our multispecies ecosystems.

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[89] N. L. Carreck (2008) Are honey bees (*Apis mellifera* L.) native to the British Isles? Journal of Apicultural Research and Bee World 47 (4), pp. 318–322. https://doi.org/10.1080/00218839.2008.11101482