Land Use Policy 128 (2023) 106603

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

# Co-producing agricultural policy with beekeepers: Obstacles and opportunities

Siobhan Maderson

*School of Geography and Planning, Cardiff University, Glamorgan Building, King Edward VII Avenue, Cardiff CF10 3WA, Wales, United Kingdom*

ARTICLE INFO

*Keywords:*
Beekeepers
Pollinators
Knowledge politics
Agricultural policy
Food systems
Environmental values

ABSTRACT

Dominant agricultural practices are widely recognised as one of many factors leading to severe declines in honey bees and other pollinators. Improving the agri-environment for pollinators and other species is an urgent ecological priority. Beekeepers have long been at the forefront of recognising agricultural and environmental challenges to their bees; many of these also impact other pollinators. As the UK moves towards a post-Brexit agricultural policy, this should be an excellent time for beekeepers' observations and concerns to be recognised, and contribute to a system where farmers and land managers ensure the delivery of 'public goods'. However, evidence suggests significant obstacles to effectively co-producing agricultural policy that ensures pollinator wellbeing. This paper is based on archival and interview data on long-term beekeepers throughout the UK. Beekeepers' past experience of engaging with agricultural, and pollinator health policy stakeholders highlights significant obstacles to effective co-production of policy. Beekeepers' experiential observations are commonly dismissed as anecdotal, and subsequently irrelevant knowledge, according to scientifically and politically acknowledged epistemological categories. Multiple stakeholders in agriculture and land management have opposing priorities, and unequal access to power. This presents significant challenges to government efforts to overcome boundaries and co-produce actionable policy. Internationally, significant steps have been made to incorporate hybrid knowledge, and its associated value systems into environmental governance. Developing agricultural policy which acknowledges and incorporates multiple forms of evidence and pro-environmental values is necessary for a successful post-Brexit agricultural system focused on Environmental Land Management, public goods, and multiple values of nature.

## 1. Introduction

Dramatic declines of honey bees in the early 2000s prompted intense scientific investigation, and subsequent policy responses, due to their central role in the agricultural landscape (Hall and Steiner, 2019; Pettis and Delaplane, 2010). While some factors linked to their decline are particularly problematic for honey bees (Neumann and Blacquiere 2017), they and other pollinators experience many common challenges to health and wellbeing. Honey bee decline is concurrent with a wider decline in pollinators, which is a matter of serious concern due to its implications for biodiversity (Brown and Paxton, 2009) and food security (Aizen et al., 2009). This decline is driven by a series of factors, including land use and agricultural practices (Potts et al., 2010). The contemporary agricultural landscape is seen as highly challenging for pollinators, due to the widespread use of agrochemicals and the loss of pollinator habitat and forage associated with large-scale monocrop cultivation (Sánchez-Bayo and Wyckhuys, 2019). Improving floral resources and diversity within the agricultural landscape is recognised as important for pollinator wellbeing (Durant and Otto, 2019). For years, the UK agricultural policy was that of Europe's Common Agricultural Policy (CAP). The challenge of balancing food production with biodiversity and environmental sustainability has driven the development of agri-environment schemes (AES) central to CAP reforms (Tylianakis and Martin-Ortega, 2021), although some analysts note shortcomings of many AES in resolving these tensions (Batáry et al., 2015). Since leaving the EU, the UK has been developing its post-Brexit agricultural policy, with some observers questioning how the UK will manage tensions between food production and environmental aims that, previously, were supposed to be addressed through CAP (Arnott et al., 2021). In the new UK system, farmers will receive 'public money for public goods'; this approach aims to prioritise environmentally beneficial land management within the agricultural sector (Bateman and Balmford, 2018). Pollinator well-being is one of many such 'public goods' that could be supported by these new Environmental Land

*E-mail address:* madersons@cardiff.ac.uk.

https://doi.org/10.1016/j.landusepol.2023.106603
Received 18 October 2021; Received in revised form 8 December 2022; Accepted 20 February 2023
Available online 2 March 2023

Management Schemes (ELMS) (Burkle et al., 2017). To deliver the environmentally transformative ambitions of ELMS, there is a stated recognition of the importance of co-production of agricultural policy, with farmers and land managers being actively encouraged to participate in designing new policies and planning their implementation (Defra, 2018, 2020).

This shift in agricultural policy priorities, coupled with already extant pollinator protection policies which position beekeepers as both monitors and stewards of pollinator wellbeing (Maderson and Wynne-Jones, 2016), suggests a potentially effective avenue for incorporating beekeepers' environmental observations into agricultural policy. Integrating beekeepers' insights and perspectives would resonate with wider calls for the co-production of policy, particularly in the context of efforts to develop sustainable socio-ecological transitions (Hill et al., 2020). Co-production and co-design are well-established in academic literature and research and generally suggest stakeholder engagement at all stages of a research project (Norstrom et al., 2020), or policy formation (Edelenbos et al., 2011). While the current emphasis on greater inclusivity in agricultural policy is promising, understanding past and present obstacles which limit effective engagement with different communities' knowledge, environmental insights and concerns will be necessary to ensure that future policy initiatives are not limited by previous failings. Designing and implementing environmental policy requires actively engaging with different communities' sense of risk and threat, which is interpreted differently by scientists, policy-makers and other stakeholders (Urquhart et al., 2017). At times, evidence-based policy making has been criticised on the grounds of its prioritising scientific understandings, and assuming decisions are being made in a realm of certainty and clarity that is not representative of the contexts where policies are applied (Ansell and Geyer, 2016). The methods underpinning this approach to policy-making often prioritise experimental findings from randomised controlled trials, which are recognised by many stakeholders as insufficient in reflecting real-world complexity (Cowen et al., 2017). This is particularly relevant to bee and pollinator health, where laboratory studies often fail to represent field realities as experienced by bees, and managed by beekeepers (Suryanarayanan et al., 2018). Agri-environmental policy must respond to a complex physical and political context, marked by knowledge gaps (Dicks et al., 2013; Durant, 2020), uncertainty (Maxim and van der Sluijs, 2007), and conflicting priorities (Dicks et al., 2013). Notable obstacles to successful coproduction of environmental policy include a tendency to ignore unequal power dynamics in the process (Turnhout et al., 2020), prioritising the perspective of those who 'speak the same language' as those in power (Edelenbos et al., 2011), and a common failure to engage with those individuals or groups who may be harder to reach (Hurley et al., 2022). Communities' land management practices and understandings may also be motivated by relational and/or cultural values, which may not be addressed within environmental policies (Chapman et al., 2019; Raatikainen and Barron, 2017). Local communities and traditional land users often have environmental values which are fundamental to their natural resource use and understanding; these values are overlooked when their knowledge is decontextualised and quantified by policy-makers (Nadasdy, 1999; Joa et al., 2018; Mathevet et al., 2018).

This paper uses archival and interview data to explore historic and systemic barriers to effectively co-producing policy with beekeepers. This paper will discuss the role of beekeepers in monitoring and influencing historical and current agricultural and pollinator policy, as well as their observations on policy successes and shortcomings. The past ten years have seen a significant range of policy responses to bee and other pollinator decline (Vanegas, 2017; Maderson and Wynne-Jones, 2016; Hall and Steiner, 2019); many highlight the role of beekeepers in monitoring and protecting pollinators. Beekeepers' perspectives on the policy-making process, and the impact and potential of these policies, is relevant when devising future agricultural and land management policies (Galbraith et al., 2017). Beekeepers' environmental knowledge, their embeddedness within the agricultural landscape, and the current emphasis on co-producing agricultural policy, suggests an opportunity for successful engagement with a distinctive environmental public, whose knowledge and values emanating from their tacit practice have much to contribute to reformed agri-environmental policy. Successfully incorporating diverse knowledge forms into policies designed to counter biodiversity loss, such as pollinator decline, will require participatory mechanisms that support shared governance, and acknowledge the multiple relationships between people and nature (Hill et al., 2020). This paper finds that the situated, multi-factorial knowledge of the beekeeping community often supports calls for a broader systemic transition of both the agricultural, and wider food systems. While the current move towards ELMS may create opportunities in the policy realm for beekeepers' knowledge to be used more effectively in agri-environmental policy, previous obstacles limiting successful co-production should be considered, to ensure that they are learned from and overcome in future.

## 2. Background

### 2.1. Pollinators, beekeepers and agriculture

The decline of bees and other pollinators has sparked significant concerns due to the implications for agricultural productivity (Gallai et al., 2009), and biodiversity (Allen-Wardell et al., 1998; Powney et al., 2019). As well as the financial significance of pollinators to agricultural yield (Gallai et al., 2009), many insect-pollinated crops are nutritionally important, providing a wide range of vitamins and minerals (Eilers et al., 2011). There are insufficient honeybees across Europe to ensure maximum crop yields of pollinator-dependent crops; wild pollinator populations are not seen as adequate in number to ensure pollination levels (Breeze et al., 2014). While much of agriculture is dependent on pollinators, the contemporary industrial agricultural landscape is highly problematic for many of them, due to the ubiquitous use of agrochemicals, and the loss of forage quantity and diversity (Potts et al., 2010; Sánchez-Bayo and Wyckhuys, 2019). The past 30 years have been notably challenging for beekeepers and bees,[1] with the challenges of Varroa mites, associated viruses, and Colony Collapse Disorder all contributing to increases in public awareness of bees and their environmental significance (Althaus et al., 2021).

As the industrial food system is seen as a challenge to global environmental thresholds (Pretty, 2008; Kennedy et al., 2021), so is pollinator decline increasingly situated as a manifestation of the Anthropocene (Marshman, 2019). Pollination is seen as having transitioned from unmanaged ecological processes which frequently benefit humans and agriculture as a 'free gift of nature', to a managed commodity, which emphasises the economic value of species to the wider industrial agricultural system (Ellis et al., 2020). Bees, and wider pollinator wellbeing, face significant threats from the contemporary agricultural system, with tensions growing between beekeepers, and contemporary agriculture (Cilia, 2019; Durant and Otto, 2019). As the need for transformation of the agricultural system grows more apparent, the question of epistemological bases for decision-making, and how to develop more sustainable agricultural policies, raises important questions as to how to utilise beekeepers' hybrid environmental knowledge. Such knowledge combines tacit, locally specific experiential knowledge with scientific information, and is increasingly valued within agricultural assessments and those working with farmers (Girard and Claude Paraponaris, 2015; Barbero-Sierra et al., 2017). Tacit environmental knowledge is often embedded in value systems that are inextricably linked to such practices (Nadasdy, 1999; Joa et al., 2018). A sustainable

[1] There are thousands of species of bees. When the term 'bee' is used in this paper, unless otherwise stated, it is referring to *Apis mellifera*, commonly known as the honey bee. The factors contributing to pollinator decline affect many other bees and pollinators, as well as honey bees.

transformation of the agri-environment will require engagement with values and motivations, which are often complex, relational and rooted in personal concepts of stewardship and responsibility (Chapman et al., 2019; Hinrichs, 2014). Actively supporting pollinator conservation is often motivated by, and grounded in an individual's values, which can be targeted to encourage people to take actions on behalf of pollinators (Knapp et al., 2021). Beekeepers work at the interface between bees, agriculture, and scientific understanding of pollinator health (Andrews, 2019; Donkersley et al., 2020). Through their practice, beekeepers engage with multiple categories of stakeholders in the changing agri-environment (Phillips, 2014). Their positioning, coupled with their environmental knowledge and values, generates a unique perspective which, if engaged with successfully, holds the potential to inform and enrich current and future land use policy.

### *2.2. Beekeepers, scientists and policy-makers: epistemological tensions*

In an effort to understand the scale, and the causes of honeybee decline, as well as other factors associated with bee health and behaviour, there has been a dramatic increase of research on honeybee health in the past 30 years. Elements of beekeepers' knowledge have been utilised in some of this research, in the form of various citizen science surveys, which have collected extensive data from beekeepers on colony numbers, foraging patterns, and, increasingly, beekeepers' practices and motivations (Van der Steen and Brodschneider, 2015, Thoms et al., 2019). While this data has supported increased knowledge of some aspects of bee health and behaviour (Seitz et al., 2016; Jones et al., 2021), there are concerns about the limited capacity of such research to fully engage with the multiplicity of factors and complex causality driving challenges to bee health; in contrast, fluid, situated multifactorial understandings are the practical hallmark of beekeepers' experiential knowledge (Sponsler et al., 2019).

Recent debates on the role of systemic insecticides known as neonicotinoids, or neonics, on honeybee (and other invertebrate) health exemplify the challenges in scientifically identifying, and subsequently developing policy responses to complex, ambiguous, and sub-lethal impacts on bee health (Maxim and Van der Sluijs, 2007, Van der Sluijs et al., 2013, David et al., 2016). For years, many beekeepers have argued for restrictions on neonics, but other stakeholders have countered their concerns with the argument that there was a lack of proof of neonics harming bees (Suryanarayanan and Kleinman, 2013). The neonic debate is indicative of a wider recurrent tension between communities which recommend following the Precautionary Principle, and a policy environment which relies upon definitive evidence (Harrison, 2006; Udovyk, 2014) which is not always appropriate to the challenges facing pollinator wellbeing. Contemporary challenges to pollinator health are complex, with a network of causes interacting and driving the success or failure of a colony (Potts et al., 2010; Phillips, 2014;). Bee health is primarily investigated within the context of a scientific model of environmental health and ecotoxicology, where individual compounds are tested for specific impacts, and questions of pesticide load and impact require complex assessments (Kudsk et al., 2018). Beekeepers' systemic observations on bee health have long been seen as subservient to scientific confirmation of causality, which is challenging in any chemical analysis for toxicity (Maxim and Van der Sluijs, 2007; Suryanarayanan, 2013). Scientifcally proving toxicity has grown increasingly challenging given the sub-lethal but still problematic effects of contemporary agrochemicals such as neonicotinoids (Lu et al., 2014), which do not cause the immediate lethal effects associated with earlier common agrochemicals, such as many organophosphates (Pimentel et al., 1992).

More recent efforts to develop experiments which reflect real-world challenges to bee health note the importance of collaborations which incorporate beekeepers' knowledge, and unite different stakeholder communities to co-produce environmental understandings (Suryanarayanan et al., 2018; Kleinman and Suryanarayanan, 2019). While this can result in improved experimental design and more nuanced research, it still prioritises an epidemiological understanding of bee health. Those beekeepers who identify large-scale land use and food system change as the key drivers necessary to improve bee health may struggle to have these wider concerns addressed by scientists and policy-makers (Andrews, 2019; Cilia, 2019).

There is a consistent underlying tension in efforts to engage science and policy with diverse forms of knowledge, and situated values, in a way to reverse threats to pollinators. Epidemiological models emphasise rigour, precision, standardisation and objectivity (Suryanarayanan, 2013). Such data is prioritised within evidence-based policy making, which emphasises a positivist interpretation of a world that is far more complex than the evidence suggests (Parsons, 2002). In contrast, pollinator decline is taking place in a countryside that must be understood with embodied knowledge (Carolan, 2008), where 'mind is body, consciousness is corporeal, and thinking is sensuous'. Scott (2008), notes the recurrent inability for modern agronomic science to incorporate knowledge created outside its paradigm; an emphasis on controlling all variables except the one or two under investigation result in research that is often seen as being of limited relevance to those land workers whose practice necessitates a constant iterative engagement with complex interactions and unexpected events (Scott, 2008).

The embodied nature of knowledge is recognised as a potentially valuable component of understanding environmental challenges and complexities (Brace and Geoghegan, 2010). Beekeepers generate and apply locally situated knowledge of bee health throughout their practice; this experiential, observational knowledge often combines both formal scientific knowledge as well as a practical element (Lehébel-Péron et al., 2016; Donkersley et al., 2020). Highly informed, capable 'amateurs' can provide important environmental data for research purposes, as well as stimulate and sustain wider environmental awareness (Eden and Bear, 2012; Kinchy et al., 2014). The complex relationship between 'professional' scientists and amateurs has been noted in some biodiversity monitoring projects, where highly knowledgeable amateurs are tasked with translating what they perceive as complex, situated, multifactorial understandings of species and wider ecosystem functioning, into simplified data points lacking nuance, yet fit within the scientific models to which they are asked to contribute their knowledge (Ellis and Waterton, 2004).

### *2.3. Beekeepers, Knowledge and Power*

The locally situated, experiential nature of beekeepers' tacit practice results in a distinctive form of hybrid environmental knowledge that incorporates a range of factors, including socio-economic driving forces resulting in particular environmental manifestations (Burton and Riley, 2018). Beekeepers' local environmental knowledge (LEK) can be a valuable component of ecological surveys and efforts to monitor biodiversity and environmental challenges, including their historical roots and socio-economic factors driving change (Galbraith et al., 2017). Incorporating local communities' knowledge into land management policies is a key recommendation by the International Panel on Biodiversity and Ecosystem Services (IPBES), as part of an effort to deliver an inclusive and sustainable future (Hill et al., 2020). However, hegemonic barriers to incorporating these locally distinctive forms of environmental knowledge are commonly noted (Lofmarck and Lidskog, 2017; Turnhout et al., 2020), highlighting the situated nature of knowledge, and subsequent systemic barriers to co-production. LEK is often found amongst communities who are on the perimeters, or outside of mainstream dominant societies, and/or lack economic and political power (Reyes-Garcia et al., 2019; Lam et al., 2020; Mckemey et al., 2020,). This can hinder efforts to successfully engage with the knowledge of these communities, and incorporate it into scientific research, and environmental management. Some scientists working on global pollinator decline have acknowledged their non-academic partners as co-authors (Smith et al., 2017). While such a move may seem trivial, it signifies a wider acknowledgement of the importance and validity of knowledge and observations generated outside of formal scientific research projects. If beekeepers are to successfully co-produce land use policy, it is necessary to recognise the range of barriers that have previously hindered full scientific and political engagement with such local and/or hybrid knowledge.

## 3. Methods

This paper brings together a range of hitherto unexamined data resources, including material held in the International Bee Research Association (IBRA) archives, held at the National Library of Wales, as well as historical archives and records from the Bee Farmers Association (BFA). These were analysed in conjunction with interviews with 39 long-term beekeepers (20 years or more of experience). Although wider data collection involving scientists and policy-makers was originally planned, this project ultimately prioritised focusing on a deep exploration of historical and contemporary beekeepers' experience and knowledge.

### 3.1. Data collection

An MS Excel spreadsheet of items held in the IBRA collection was examined to identify potential sources of information relevant to this project. As the emphasis was on the observations, experiences and environmental knowledge of long-term beekeepers, memoirs and diaries of individual beekeepers, and historical records of local beekeeping associations, were selected for detailed study. Titles which conveyed reference to substantial lengths of time of beekeeping experience were chosen for detailed research. This material covered many of the agricultural changes that had affected beekeepers throughout the 20th century. The author also had access to the BFA archives, including newsletters and bulletins dating back to the organisation's inception in the 1950s. As the longest-running organisational body for professional beekeepers in the UK, these archives provided a rare source of information of the history of beekeepers' contributions to agricultural policy formation, as well as this professional community's wider environmental observations and concerns. Key themes of interest and relevance to beekeepers were developed through archival research. These included agricultural practices, the role of tacit learning, their sense of perceived threats to bees and the environment, and their relationships with other stakeholders in pollinator health, including scientists, policy-makers, and the agricultural community. The archives clearly illustrated that many contemporary concerns about pollinator health have a long-standing history. The themes discovered through archival analysis underpinned the interview schedule. As well as archival analysis, 39 interviews were carried out with long-term beekeepers. They were reached via a collection of personal contacts, requests in beekeeping magazines, and snowballing. The selection criteria for interviewees was participants having personal practical experience of keeping bees for a minimum of 20 years. Earlier research by the author on beekeepers, coupled with the impact of Varroa on beekeeping over the past 20 years, led to the decision that 20 years experience would be an appropriate minimum length of experience to generate notable environmental observations relevant to this project. In actuality, interviewees' personal beekeeping experiences were often significantly longer, with an average of 40 years, and some interviewees having over 70 years of experience.

Interviewees' demographic characteristics such as gender, years beekeeping, and roles in beekeeping Civil Society Organisations (CSOs) are listed below in Table 1. Interviewees frequently had multiple and/or changing roles within the beekeeping community throughout their years of practice. The UK beekeeping community sees some fluidity between hobbyists and bee farmers; this latter category includes all those who kept over 40 colonies and self-identified as bee farmers when interviewed. The scale of their operation was highly variable, and tends to be significantly smaller than the larger operations commonly found in the US and Australia (Phillips, 2014; Cilia, 2019).

The two final categories, regarding professional backgrounds in farming or STEMM careers, were not specifically investigated in the original interview schedule. However, during interviews, many interviewees referred to either their professional and/or personal background. Nearly half of interviewees commented that they came from a STEMM background,[2] and over 20% of interviewees stated that they had come from a farming background. Throughout collection and analysis of data, it became apparent that such personal characteristics of interviewees were highly significant in terms of their environmental knowledge.

**Table 1**
Interviewees' demographic characteristics.

| Gender | |
|---|---|
| Male | 31 |
| Female | 8 |
| **Years Beekeeping Experience** | |
| 20–29 | 11 |
| 30–39 | 10 |
| 40–49 | 11 |
| 50 – 59 | 3 |
| 60 + | 4 |
| **Bee Farmer (Past or Present)** | 11 |
| **Role in Beekeeping CSO (past or present)** | |
| Bee Inspector | 3 |
| Apiary Manager | 3 |
| Education / Lecturer / Writer | 20 |
| Chair / Trustee / Senior Post in National BK CSO | 13 |
| Swarm Liaison Officer (SwLO) | 3 |
| Spray Liaison Officer (SpLO) | 1 |
| **Multigenerational Experience** | 7 |
| **Farming Background** | 8 |
| **Background in STEMM professions** | 18 |

The majority of interviews were carried out via Skype, with a minority carried out in person. Interviews ranged from one to two hours. Interviewees were advised of the purpose of the research, and gave their consent to be interviewed and recorded, with the option to withdraw at any time. All interviews were recorded, transcribed into MS Word, and coded in NVivo 11 (subsequently upgraded to NVivo 12) by the author. As interviews and analysis progressed, unexpected themes evolved, which led to further codes and avenues of analysis (Bringer et al., 2016). The non-linear nature of coding in NVivo was an appropriate method for this iterative analytical process (Bringer et al., 2016), allowing for the node hierarchy to be developed further.

Although many interviewees were happy to be quoted, to ensure anonymity throughout this paper, interviewees' quotes are referred to via a system that notes: gender (M/F), location of practice (E,W or I – for England, Wales or Ireland), a personal referencing letter, and a number indicating years of practice.

## 4. Results and discussion

### 4.1. Obstacles

Obstacles to successfully co-producing policy were found to be rooted in three primary causes: epistemological differences, policy structure and process, and wider systemic barriers.

A distinguishing characteristic of beekeepers' knowledge is its emphasis on the central role of experiential learning. This creates potential obstacles for policy-makers and other advisory bodies, which

[2] The author gave several presentations to beekeeping associations during and after this research was carried out, and noted a frequently high percentage of STEMM professionals in the audience. This correlation between beekeeping and a background in the STEMM professions would be an interesting avenue for further research, as many interviewees noted the significance of their STEMM training in their beekeeping practice, and their assessment of formal advice given to beekeepers.

prioritise scientific environmental knowledge above other forms of assessment. Policy processes also struggle to incorporate heterogeneous communities' views, particularly when these views challenge hegemonic structures.

#### 4.1.1. Epistemological differences

The epistemological differences and hierarchies between beekeepers, scientists and other stakeholders have significant implications for the potential success of coproducing agricultural policy. The licensing of agrochemicals, decisions about land use and planting, and developments of agri-environment strategies and payment systems – all these, and more, rely on scientific data as evidence upon which to base policy. In contrast, beekeepers assess bee health, and the conditions they recognise as supporting such health, using comparatively holistic and informal measures. While there are many instances of scientific evidence being overridden in the policy-making arena due to misunderstanding of scientific uncertainty and complexities (Dicks et al., 2013) as well as wider social, economic and political pressures (Colla and Macivor, 2017; Stout and Dicks, 2022), it is still the preferred basis of many policy decisions. Beekeepers' observations and concerns have been most effective in influencing policy when they are scientifically confirmed; this creates challenges when their concerns are difficult to validate within the epidemiological model.

A recurrent theme amongst interviewees was an interest in, and support of scientific research on bees and pollinators, with the caveat that '*they think they're experts, but actually, they're only expert in one very small part*' (FWF40). Beekeepers consistently apply a hybrid assessment to the environment in which they keep their bees. This combines ecological and scientific knowledge with a more intuitive 'feel' for the landscape, as well as engagement with the political and economic drivers behind the landscape and its management. All interviewees emphasised the importance of learning beekeeping, and the relationship of bees to their wider environment, through practice: *'…It's hands-on practical learning that to me makes far better beekeepers'* (MEP55). Beekeeping is seen as an activity of life-long learning, which generates significant cumulative observations; the complex and fluid relationships between weather, flowering times, and its impact on bees are seen as something that '*tends to be the people who have been beekeeping for a very long time are aware of' (MEP45)*. As well as their observational knowledge, interviewees frequently expressed a fascination with more formal knowledge surrounding bees, with many pursuing related studies and hobbies such as botany, microscopy, and detailed studies of bee biology. However, within their own practices, when confronted with information or guidance that contradicted their own experience and/or observations, beekeepers tended to prioritise their own experiential knowledge as the basis for understanding and any subsequent action.

Different communities' contrasting epistemologies, and how these meet (or fail to) in scientific assessment, is a recurrent obstacle when attempting to incorporate diverse knowledge systems into pollinator policy (Maxim and Van der Sluijs, 2007, Van der Sluijs et al., 2013). Data for this project offers a historical perspective on the relationship between beekeepers' knowledge and its eventual contribution to agricultural policy, in the shape of scientific research on, and resultant legislation of many early agrochemicals. Since the mid-20th century, different categories of agrochemicals have been developed and popularised, including organochlorines, organophosphates, carbamates, synthetic pyrethroids, and neonicotinoids (David et al 2016). Earlier popular agrochemicals such as DDT, triazophos, aldrin and others were eventually proven to have dramatic lethal effects on bees: beekeepers contributed to providing key evidence that led to the extensive banning of some of these chemicals, such as DDT and aldrin, and restrictions on the agricultural use of others, requiring them to only be applied by trained operators.

BFA archives document a persistent trend for beekeepers' observations and concerns to precede formal confirmation by scientists, which is generally required as the basis for any governance response. BFA bulletins provided advice on correct procedures if spray damage was suspected. Readers were reminded that '*it's no use complaining about Triazophos or whatever and pressing for its approval to be withdrawn if the statistics of damage are incomplete. Your representatives at the MAFF*[3] *Spray meetings need their complaints to be backed up*.' (BFA Bulletin 255 (5/89)). Beekeepers would note piles of dead bees outside hives, and send these off for investigation. Samples would be subjected to standard entomological assessment of toxicity. When beekeepers' samples of dead bees met these standards, their observations were in a stronger position to support policy restrictions. Bee farmers have a long history of frustration at the inherent procedural delays in getting their practical observations confirmed by scientists and leading to appropriate changes in policy. BFA bulletins (108: 10/67; 144: 12/72)[4] denote bee farmers' frustration at the inherent procedural delay in getting their observations formally confirmed and acted upon. This delay in formal scientific confirmation of beekeepers' concerns, coupled with a reluctance for policy-makers to support the Precautionary Principle, continues in the present day, as can be seen in the debate on the effects of neonicotinoids (Drivdal and Van der Sluijs, 2021).

As scientific expertise becomes increasingly narrow and specialised, and the physical and scientific environment grows more complex, so does the decision-making process (Whatmore 2009). While there has been an increase in scientific research into sub-lethal effects of various agrochemicals (Lu et al., 2014), as well as the effects of combined stressors (Gonzalez-Varo et al., 2013; Kairo et al., 2017), beekeepers express an element of scepticism as to whether research projects can ever truly depict the reality of bees' lives: '*There are just so many variables. There are all sorts of things that can affect them. I think it's tremendously difficult for the scientists who actually even design these experiments*' (FEA40). Beekeepers – and some scientists – are also concerned about the 'cocktail effect' – the impact of exposure to multiple agrochemicals throughout the season (Goulson et al., 2015). While beekeepers' observations of earlier, clearly defined landscape risks conformed to scientific models of understanding, their interpretations and concerns regarding complex contemporary challenges are difficult to confirm or deny within epidemiological models (Suryanarayanan, 2013). Conversely, interviewees note a recurrent tension between their experiential insights, and the expectations of scientists for a particular form of knowledge claim: *'normally the scientists don't take any notice of what they call anecdotal evidence'* (MEP55). This is problematic, as the dominant model for understanding environmental health and ecotoxicology is the scientific model, where individual compounds are tested for specific impacts. While this model of knowledge generation has been prioritised above that of other forms of expertise, it does not currently have the capacity to accurately reflect field conditions, and/or synchronous challenges to pollinator health (Kleinman and Suryanarayanan, 2020).

Interviewees also expressed concern that the epidemiological model of pollinator health prioritises singular interpretations of causality which, if found, close down any further inquiry into other possible explanations of colony demise. Varroa infestation is recognised as a key cause of colony collapse, due to the viruses for which varroa is a vector, as well as the parasite weakening the bee host (Thoms et al., 2019). As varroa has become near-ubiquitous, the mite's presence is seen by some beekeepers as precluding formal investigation into other possible causes of bee death, such as pesticide poisoning. One interviewee noted that

[3] MAFF was the Ministry of Agriculture, Fisheries and Food, and was the precursor to DEFRA – the Department of Environment Food and Rural Affairs

[4] The BFA produced bulletins for its members on an approximately bimonthly schedule from the 1950 s to the early 2000s. Each bulletin was numbered, with its publication date listed. Editions of the BFA bulletin are referred to in this paper by their number and publication date – eg, 108: 10/67 was edition 108, published in October 1967. A new journal title and numbering system was developed in 2015, with annual volumes and issue numbers, eg: Bee Farmer 3:4 (8/17) would refer to Volume 3, Issue 4, published in August 2017

when bees have been poisoned, '*you see the bees crawling on the ground, with their tongues out – unlike the symptoms of Varroa. But (the National Bee Unit) just doesn't listen*' (MEC20). In this example, the interviewee saw the focus on Varroa as being a less confrontational explanation of bees' ill health, which avoided any challenge to the powerful agricultural industry in the area. Varroa can be seen as a less politically charged challenge to bee health, as the onus is on beekeepers to monitor their hives for infestation, and treat accordingly (Thoms et al., 2019; Phillips, 2020), in contrast to wider agri-environmental issues which may require a policy response to ensure pollinator wellbeing.

Like many other communities of tacit and/or hybrid knowledge-holders, beekeepers struggle on both an epistemological, and a wider political level, to have their environmental understandings validated and incorporated into wider environmental governance (Nadasdy, 2005; Hernández-Morcillo et al., 2013; Oteros-Rozas et al., 2013). The political obstacles resultant from epistemological differences must be acknowledged and understood if they are to be overcome in future successful coproduction. Conflicting perceptions of what is reliable evidence, coupled with wider structural systems, combine to affect the potential of diverse knowledge claims to be fully operationalised.

#### 4.1.2. Policy processes: the challenge of co-production with diverse stakeholders

As well as differing perceptions and priorities between beekeepers and other agri-environmental policy stakeholders, the community's heterogeneity (Andrews, 2019; Thoms et al., 2019) also creates challenges to coproduction. One interviewee noted varying opinions and resultant tensions amongst disparate amateur and professional beekeeping representatives at pollinator policy consultations: '…*at one stage the British beekeepers association (BBKA) backed out of it, saying they didn't want to sit at the table, and it left a bit of a gap, so me (being known to some of the people at the table) I was a representative for amateur beekeepers. Professional bee farmers were still at the table, so I went along*' (MES45). Another interviewee also noted tensions emerging throughout those invited to contribute to policy development; some were sceptical about the benefits of engaging with scientists or policy-makers at all, due to a belief the process was unable to address systemic agri-environmental challenges to bees and other pollinators: '*the BBKA do NOTHING for British beekeepers… when it comes to banning neonicotinoids, (they) voted not to ban it, and so did the government*' (MEG50); '*there are too many people who can be bought*' (MEH40). Others at the early pollinator strategy meetings expressed a sense that there was '*just a lot of people speaking and not doing*' (FWS45). The Welsh Government Pollinators Task Force also elicited a mixed reaction from early contributors. The bureaucratic processes left some interviewees sceptical and unwilling to engage: '*I declined to be an active person on the Task Force. By the third meeting, they were still discussing what to call themselves, and the possible logo…I figured they could contact me if needs be. I'm not really engaged with it*'' (MWS20).

Incorporating beekeepers' diverse perspectives into policy can be challenging (Scott et al., 2013). As mentioned repeatedly throughout interviews, beekeepers are notoriously heterogeneous; distinct sub-groups often hold disparate views. Participants described a plethora of individuals and organisations being involved in policy consultations, often with their own particular views on what should be done to address bee and wider pollinator decline. Some reported that certain individuals representing beekeeping civil society organisations were only interested in supporting honey bees, and resented any funding going into wider initiatives to protect other pollinators. '*And he was furious [when … DEFRA.gave a grant of a few million to research, and they called it pollinators]!. Because he maintained that [beekeeping associations] did all the work, we did all the publicity, for honey bees. I thought that's really short-sighted. And he said oh we've got them all jumping on the bandwagon, and there are people working on butterflies, and … hoverflies. Well I think that's a good thing' (FEH35).*

As well as the beekeeping community's heterogeneity being a challenge, the differing epistemologies and practices of beekeepers as compared to other stakeholders were also problematic within the policy negotiations. Those interviewees who had been involved with policy consultations were asked their views on how their knowledge, concerns and recommendations had been utilised in the policy sphere. Interviewees often expressed a perception that their experiential knowledge was not fully appreciated, or engaged with, by government officials tasked with drafting, and implementing policy. A recurrent theme was that beekeepers saw the policy discussions as abstract and divorced from the immediate pollinator and environmental realities with which they were immersed: '*I went to the original (DEFRA) pollination strategy in London…. And I sort of came away from there thinking that I had landed on a different planet…. Just totally wrong ideas about how things work, with bees et cetera. I don't think it's their fault. It's a bit of ignorance if anything*' (MEH40). This ignorance was described as being based in a detached, bureaucratic perspective on the practical environmental challenges beekeepers observed and worked with on a daily basis. In contrast, the interviewee felt that policy development would be enhanced and more effective if grounded in the practical knowledge of those who were directly working on these issues. Scientists researching pollinators, and their resultant data which beekeepers noted as relied upon by policy-makers, were described as being 'out of touch', with their findings not indicative of the real world experiential knowledge of beekeepers. Interestingly, interviewees stressed the importance of the views and knowledge of farmers being more actively engaged with in the policy process, thus illustrating the potential coalitions and opportunities for policy enhancement throughout the wider tacit knowledge community.

Respondents also felt recent policy initiatives left little opportunity for them to actually contribute their insights: '*Unless you are familiar with the tools of government and effective lobbying, it's really hard' (MEP20).* The failure of governance to be truly inclusive, particularly for those outside the scientific and/or political arena, is a consistent refrain within discussions on environmental governance (Juntti et al., 2009; Hall and Steiner, 2019). This interviewee spoke of the policy system being dominated by those who had experience in dealing with government bodies, leaving little room for the input of those outside this system: *'I have contacted my MP, and I have just been dismayed. Every time I get mixed up in that I just think it's not making a difference. You are trying to play on their wicket, and you don't stand a chance'* (MEP20).

Challenges to successful, inclusive engagement with 'hard to reach' stakeholders, and a tendency to rely on communicating with 'the usual suspects' have been noted in preliminary efforts to co-design ELMS (Hurley et al., 2022). It can be difficult to maintain a balance between transparency and engagement, and efficiency and engaging with informed, constructive, robust knowledge (Dicks et al., 2017; Mukherjee et al., 2018). However, these challenges can be surmounted, and embrace diverse perspectives and knowledge. While beekeepers hold a range of contrary viewpoints about the environment and bee health and productivity (Lehébel-Péron et al., 2016), recent research on developing successful collaborations within and beyond the heterogeneous beekeeping community notes enthusiasm and willingness amongst all participants to work together to address issues of shared concern (Kahane et al., 2022). Participatory models that bring together a wide range of diverse stakeholders can transform agri-environmental systems (Kanter et al., 2016; Gullino et al., 2018), in contrast to attempts to drive socio-ecological transformations which exclude people from decision-making processes (Bennett et al., 2019). While such efforts will contribute to more effective co-production, there are also structural challenges that must be addressed.

#### 4.1.3. Systemic challenges to bee and pollinator health

Archives and interviews all show beekeepers emphasising the importance of systemic, fundamental challenges to bee and pollinator health that are rooted in 'wicked problems', such as food systems, climate change, and associated challenges: '*(People) want to keep food prices low. That's at conflict with having a good environment*' (FWS45);

*'Global warming is important…'* (MWB30)*; 'I think we are in a situation now where (changing weather patterns) are having an effect on beekeeping'* (MEST40). Such broad-reaching systemic concerns are difficult to incorporate into co-produced policy, if there is no acknowledgement of, and subsequent confrontation of, embedded power relations (Turnhout et al., 2020) thus leaving a potentially significant contribution from beekeepers out of any enhanced land use policy.

Ultimately, many beekeepers situate any truly effective policy response to pollinator decline within an integrated reappraisal of food systems, with all the challenges and opportunities this may entail (Candel and Pereira, 2017; Sánchez-Bayo and Wyckhuys, 2019). The negative impact of the dominant industrial agricultural system on pollinators is widely recognised by scientists (Brown et al., 2016; Sanchez-Bayo et al., 2016; Sánchez-Bayo and Wyckhuys, 2019) and was a consistent theme throughout both archives and interviews. Archival data concerning agricultural sprays clearly illustrates the tensions and challenges associated with co-producing policy with stakeholders who represent contradictory interests. Early BFA Bulletins from the 1960s note members encouraging the NFU to educate its members on 'intelligent use of pesticides' (BFA Bulletin 68: 1/62), with earlier editions (BFA Bulletin 61, 1/61) noting tensions surrounding the timing of farmers' spray application and the effect on bees. Tensions surrounding spray remained unresolved for many years (BFA Bulletins 80 (10/63); 214 (5/83)). While some agrochemicals, such as DDT, were eventually banned, voluntary agreements, rather than prescriptive agricultural policies, are still the preferred governance response to managing the risk of spray damage (Hillocks, 2012) and pesticide exposure (Harrison, 2006). The BFA had regular meetings with MAFF but were often disappointed and frustrated by these exchanges (BFA Bulletins 52: 1/60; 156: 9/74; 229: 8/85). As noted in Section 4.1.a, the onus of responsibility was placed upon beekeepers, to supply evidence of spray damage. The government response to concerns over spray impact was to suggest better labelling, and education of farmers in best practice and safe handling. Interviewees note the same concerns that consistently show throughout the archives; that agricultural policies meant to protect pollinators are seen as consistently failing to challenge farming practices: '*Until we stop pumping (agrochemicals) in by the ton, we're going to have problems. And this is too radical for a lot of people*' (MEH20).

While much of the earlier tension between beekeepers and policy officials surrounded proving the damage of agricultural sprays as a precursor to introducing legislating controlling their use, subsequent efforts of beekeepers to influence policy and protect bee health directly challenged wider economic and political priorities. From the late 1970s bee farmers were aware of the devastating impact of Varroa on bees in mainland Europe. In an attempt to prevent the introduction of the parasite to the UK, an early ban on importation of bees from other countries was promoted by bee farmers, yet this clashed with wider international free trade policies (BFA Bulletin 186: 5/79). Several years later, the 1984 BFA Spring Conference minutes note MAFF was still unwilling to impose restrictions on bee imports, which bee farmers saw as the only way to stop Varroa entering the UK.

The commoditisation of the industrial food system is seen by many as inherently problematic: '*…contract farmers and, ah, it's those that seem to be causing a bit of a problem, because they really are pushing absolutely everything to the limits to get maximum return, so they are the ones who tend to plough up the footpaths, and go right out to the hedges, they spray absolutely everything with anything that's going. There's no flowers, they cut down the trees, and all sorts of daft things are done. But it's a business*' (MEP55). Challenges to pollinator health are increasingly contextualised in a food production system that prioritises economic profit over environmental wellbeing (Nimmo, 2014; Ellis et al., 2020). Efforts to co-produce effective agricultural policy with beekeepers would benefit from this systemic perspective. As one interviewee summarised '*All sorts of things follow from having a policy that puts the environment first*' (MWB30).

The overwhelming theme throughout interview responses was of current pollinator policy being too limited in both scale and impact, with disjointed efforts bearing limited benefits. Actions purportedly done on behalf of bees and other pollinators were generally seen as limited, inappropriate, or misguided; as one interviewee noted '*they're a little bit suburban, a little bit gardeny…tarting up a few roundabouts with some Californian poppies isn't really going to get to grips with the issues (*MWS20). The interviewee noted that enacted measures were often very photogenic, but had little ecological significance if not connected to other wider habitat transformation. While there are efforts to coordinate networks of small, ecologically informed local initiatives (Vasiliev and Greenwood, 2020) if these local efforts are not embedded in a wider context and planning initiatives, there is a serious risk that they will not yield significant benefit. (Senapathi et al., 2017; Kremen et al., 2007) As embedded observers of the local landscape, beekeepers can play a valuable role in informing and monitoring local landscape enhancement, as well as educating and advising on how best to implement policies.

### *4.2. Opportunities*

While there have been historical obstacles to beekeepers' knowledge being utilised in the policy sphere, there are also opportunities to amplify their knowledge and associated environmental values. Beekeepers are often discussed in wider literature in terms of being in specific camps ie 'traditional' versus 'natural' – with those in the former category more willing to use in-hive interventions as part of their practice (Scott et al., 2013; Andrews, 2019; Thoms et al., 2019). While many beekeepers have different priorities and approaches to their practises, data for this research project finds that most beekeepers are united by a willingness to work with other stakeholders in agri-environmental and pollinator policy, although current structural and procedural elements are often challenging and frustrating.

#### *4.2.1. Building on extant relationships with farmers and land managers*

Archives and interviews all highlight the embeddedness of beekeepers within the agri-environment, with many interviewees self-identifying as food producers and/or coming from an agricultural background. Beekeepers often have long-standing relationships with farmers and land managers, based on mutual understanding: *'It's the individual. It's how you work with them. Making them understand your problems, and you understanding theirs' (MEB60)*. For those farmers whose crops benefit from pollination, the synergies are clearly recognised and appreciated, and underpin positive working relationships between beekeepers and land managers: *'… they benefit from the pollinating. So they are very accommodating. They really want to promote (bees). And it's not just for the green badge to say we have bees on our land. It is an integrated part of their land management. they are so careful. And they are so considerate*' (MEB60). Most interviewees noted how these working relationships resulted in farmers and landowners notifying them if and when agrochemicals would be applied, thus offering the opportunity for bees to be moved or hives closed to avoid exposure. While this is useful, there can be logistical challenges to putting this advice into practice. *'Farmers … would tell me of plans to spray. I would go up there, and shut the bees in. I'd phone the next day, and find that spraying had been postponed till the next day!!…I made so many trips, closing up and re-opening hives'* (MED20). Interviewees prioritised placing their hives on sites where agrochemicals are not used, although they note increasingly strong competition for such sites, and limited availability. The positive working relationships between land owners and beekeepers could be operationalised to promote the synergistic benefits, and encourage other land managers, to develop and maintain their sites in ways that are recognised as appealing to beekeepers and pollinators.

As we look towards a future where agricultural policy is co-produced with stakeholders, beekeepers have expressed concern over how policy is actually enacted in practice. Respondents observed that much of the advice available for farmers on hedgerow maintenance was excellent, but that the guidelines were not correctly followed by farmers, or contractors responsible for hedge maintenance. The importance of integrating beekeepers' knowledge into the co-production, and subsequent monitoring of agricultural policy is highlighted by respondents' observations on how some agri-environmental schemes are carried out. *'I've got one farmer near me who got a grant for a nectar bank,*[5] *and I said this is just ryegrass. But he's getting paid for this…there's no flowers at all. He was keen to have my bees in there, but I said there are no flowers there'* (MEH40). Interviewees note the frequent gap between policy advice, and what is practiced: '*What's the point in having guidelines when there's nobody reinforcing those guidelines?'* (MIM50). As much of agri-environmental policy is based on advisory recommendations rather than regulations (Hillocks, 2012), this will need to be considered in any attempts to coproduce policy.

One interviewee, who is a fourth-generation beekeeper who also self-identifies as a food producer, also emphasised the importance of ensuring that policy recommendations are enforced and incentivised: '*Rather than make it voluntary, make it incentivised more. Where farmers get rewarded for becoming involved in environmental projects. And even, you know, even enforce what's there already'* (MIM50). Interviewees note potential improvements in the agri-environment as being rooted in a combination of information and financial incentivisation of the farming community, with policies on behalf of pollinators being affordable: '*policies have got to be maintained…and that means you've got to give the farmers money…like everyone else, they have businesses to run'* (MER25). Interviewees highlighted the importance of farming organisations being involved in, and scaling up, pollinator habitat improvement schemes. They recognise that this will require significant central and local government support, as well as support from businesses.

There is a potential role for beekeepers' environmental observations, and their working relationships with land managers, to support the development of locally appropriate, relevant actions to enhance the landscape for pollinator wellbeing. Public and media interest in bees and pollinators (Smith et al., 2016), coupled with agri-environmental expectations for landowners to manage sites on behalf of the wider environment, should be operationalised to strengthen and expand working synergies between farmers and landowners. Interviewees noted that most farmers are very keen and enthusiastic to have beekeepers on their land. As agricultural policies are transformed to emphasise environmentally beneficial practices, confirmation from beekeepers that one's farm benefits pollinators, could enhance one's status as a 'good farmer' (Riley, 2016). It is important to note that beekeepers are often aware of how land management practices can benefit honeybees, but may not benefit, and indeed, may challenge or harm, other pollinators: '*If you are growing oilseed rape, if you are growing 150 acres in one big blob, once that's finished flowering, there is nothing else*' (MEH60). '*My son worked for a while in Minnesota, where they drop off beehives on edges of fields. And he was amazed that there were no other pollinators! There's just nothing else! In the Great Plains, they've killed everything! And that's one of the problems we might face if we go down the same route here'* (MWB30). '*How do you change the environment?. Yeah oilseed rape is great… for honey bees. What about all the wild pollinators? What's the follow-on through the rest of the season?'* (MEB60). Recognising and pursuing a broader and more nuanced engagement with beekeepers' expertise, which encompasses knowledge of the wider environment and its impact on other species aside from honey bees, can enhance its capacity within agri-environmental policy.

#### *4.2.2. Highly localised, situated knowledge*

Beekeepers' practical knowledge is highly localised and site-specific, with respondents noting significant differences in colony behaviour and success resulting from what might appear to a non-beekeeper as subtle, insignificant differences and distances between sites: *'there's no point in comparing records with a village that's 200 feet higher in the Wiltshire hills'* (MER25). This hyper-localisation can create barriers to incorporating beekeepers' insights into broad agricultural policy. However, much of policy interpretation and enactment ultimately takes place at a local level, with fundamental tensions existing between local assessments, and formal standardised understandings developed and applied by state representatives. (Scott, 2008, p 25) The political challenges to developing effective broad policies which succesfully address local conditions, coupled with the gap in local relevance of state assessments, has led to a recent proliferation of comparatively small-scale initiatives to protect pollinators. (Hall and Steiner, 2019) There is an increasing move towards strengthening the role of local environmental knowledge in environmental monitoring and management (Turvey et al., 2013). Place-based environmental knowledge, which is interwoven with knowledge of locally specific socio-economic factors affecting the physical environment, can play a transformational role in environmental governance (Hakkarainen et al., 2022) ensuring that agri-environmental policies are appropriate to local conditions, and reflect local variances (Austin et al., 2015).

Interviewees describe experiencing a dramatic decline in the quality of the surrounding environment for bees during their, and their families', beekeeping history. 20% of interviewees came from families who had kept bees in the same area for four generations or more. This generated deep knowledge of local environmental conditions, and common declines in recent years; as one interviewee noted '*and these used to be good areas for bees, no doubt about it'* (MIM50). Oral histories of land-workers have been noted as holding significant understandings of underlying processes driving land management (Riley and Harvey, 2007); stronger engagement with this local knowledge can support improved future policy and management.

While many pollinator strategies are national, data from this project notes that implementation is highly variable and dependent on local factors. Interviewees describe both funding constraints, and the sheer level of (dis)interest of local Council employees responsible for local authority implementation and monitoring of national guidelines. One interviewee, who worked as a bee inspector in multiple councils, noted a broad range of implementations of policies designed to support pollinators: *'I think that's just because different councils have different ideas, and maybe they don't want to spend the money on certain things, and maybe they do, because they want to promote their eco-credentials'* (FWS45). Some questioned whether local authorities are actively engaging with the recommendations of national pollinator policies, or if some of the small, positive changes, such as decreased frequency of mowing and hedge trimming, are fortuitous by-products of council spending cuts. '*What I have noticed is …(hedges and verges are not being cut so frequently). Now that may be part of one of these various (bee-friendly) initiatives, but it may also be economic pressures that are slowing people down'* (MEH45). While these changes in land management may inadvertently lead to improved forage habitat for wildlife, including bees and other pollinators, they are not a reliable basis for policy enactment and environmental management.

As noted in the preceding section, respondents note the importance of financially supporting environmentally sustainable transitions. However, there was a sense amongst many interviewees that various schemes to enhance the environment for pollinators are taken up solely for financial reasons and lack any wider commitment. '*I have to be honest - most of the incentivisation is because of money, not because they want to improve pollinator levels*' (FWD20). Like other hybrid knowledge communities, beekeepers' environmental knowledge is informed by both practical experience and scientific understandings, yet is also embedded in a wider value system that must be considered by policy-makers if its capacity in coproducing policy is to be maximised (Riley, 2016; Chan et al., 2020).

[5] Nectar banks are areas of diverse floral planting near other crops, and are meant to provide a wider range of forage for pollinators.

#### 4.2.3. Operationalising values in policy

Data for this project notes beekeepers frequently providing quantitative and/or material data which led to policy actions, most notably in the restriction or banning of some agrochemicals throughout the mid-late 20th century. However, the capacity of policy to be affected by beekeepers' knowledge tends to depend on it being in the form of data which fits the constraints of the epidemiological model of pollinator health; in contrast, the systemic engagement which underpins their practice generates environmental understandings and values that are central to their potential contribution to coproduced policy.

Beekeepers are enthusiastically engaged with the wider environment in which they keep their bees – and this transforms their environmental understanding. '*There is never a journey that I go on that I don't take a look and think oh that's good. …I will still be thinking oh the bees could be doing well down there*' (MEB60). All interviewees emphatically agreed that their practice had influenced their views of the total environment, and associated values. *'My whole outlook, philosophy, is bee oriented. It affects my view. I am very much into nature, environment, the green movement, all this, you know food, you know, kind of the slow food movement, and good quality food, and all that kind of thing'* (MIM50). Given the highly heterogeneous nature of the beekeeping community, any universal consensus is highly significant and must not be ignored. As a result of their wider appreciation of the physical environment, rooted in their beekeeping practice, many had changed how they managed their immediate environment. *'We consider our garden to be a wildlife garden. We are on about half an acre. So it's run for insects, if you like. Insects and creatures. You know, the birds and whatever, pollinators - that's exactly the way we keep them'* (FEA40). Interviewees often noted an interest in other pollinators aside from honey bees, which often grew, or intensified, as a result of their beekeeping practice*: 'I also do - what we have here is bumblebee walks. I would be very interested to understand about hoverflies as well'* (FIM20)[6] ….

Interviewees noted the challenges of ensuring that pollinator policy also benefited less well-known species:.*' … sadly, in today's climate, it's hard to sell the value of a hoverfly, because it's not making honey! Unfortunately, the kind of wild pollinators have to ride on coat-tails of honey bee conservation'* (MWS20). This exemplifies a tension noted in devising both rationales and methods for protecting wild pollinators, who may not be seen as having the same economic value as honey bees or other managed pollinators (Kleijn et al., 2015). In contrast to prioritising the financial value of pollination services, which have often been used to assess the value of bees and pollinators and the importance of conserving them (Gallai et al., 2009), interviewees discussed relational values and care, which are central to stewardship (West et al., 2018). The recent IPBES Values Assessment notes the potential for working with multiple values of other species and the wider environment to support transformational policies; this is in contrast to earlier models which emphasisie economic values (IPBES, 2022). Relational values emphasise people feeling connected to, and taking responsibility for the natural environment; incorporating diverse values of nature can broaden and strengthen governance for conservation (Buijs et al., 2022). This approach can support more sustainable land management policies, which can benefit pollinators and the environment. When asked about what they felt would improve the environment for pollinators, interviewees extolled the importance of a transformational engagement with bees and the physical environment: *'People don't realise the importance of pollinators, and I think that if they did they would be not so bad about spraying them and … killing them off'* (FWS45); '*Most other countries that I have been to, whether it is in the built-up areas, or whether it is in the country, they have a much … better understanding of what beekeeping is'* (MED70) '*People are terrified of stinging insects! I would like people to understand the bees [bumblebees as well] are not aggressive creatures and they can happily be very close to you without doing any harm to you'* (FIM20). '*I'm very sympathetic to this idea of rewilding, and reintroducing lots of these old animals. It's partly an emotional thing. It could all be a good thing in the long run if we try these things'* (MEP45). The practice of beekeeping generates a sense of stewardship and connection to the natural world; this can motivate pro-environmental behaviours that have implications for policy (Richardson et al., 2020).

As efforts to improve coproduction grapple with the challenges of incorporating diverse perspectives, experiences and forms of knowledge, there are also moves to incorporate concepts of stewardship (Mathevet et al., 2018), values (Chapman et al., 2019) and biocultural approaches to the environment and conservation (Hill et al., 2019) into environmental assessment and management. If beekeepers are to be active, effective co-producers of agricultural policy, the breadth of their hybrid knowledge, and its associated insights and values, presents rare opportunities for a potentially radical reappraisal of both the process, and the content, of policy-making. Rather than policy-makers dismissing the abstract, qualitative, relational values beekeepers develop through their practice, these can play a transformative role in leveraging sustainable agricultural policy, and coproducing policy with stakeholders.

## 5. Conclusion

Stated government efforts to forefront environmental benefits, and to co-produce agricultural policy with diverse stakeholders, are a potentially positive step towards addressing the myriad environmental challenges currently affecting the agri-environment. Significant environmental challenges to pollinator wellbeing have long been recognised by beekeepers, who have historically engaged with scientists and with policy-makers in an attempt to contribute to improving agricultural and land use policy. While some of their observational knowledge was successfully engaged with, and resulted in the ban or restrictions on use of many early agrochemicals, growing environmental complexity, including the development of agrochemicals with sub-lethal negative impacts on bees and other pollinators, coupled with the rise of an economically and politically powerful industrial food system, has created epistemological and political challenges to engaging fully with beekeepers' observational knowledge and their suggestions as to how to improve the environment. A policy arena which prioritises positivist understandings of environmental complexities struggles to incorporate the experiential and observational hybrid knowledge of beekeepers, and address their concerns, which may lack formal scientific confirmation. Political and economic dynamics within the policy process can be alien and/or frustrating to beekeepers, who may otherwise be willing and able to contribute to the drafting, implementation and monitoring of policy. Understanding the historically mixed policy responses to beekeepers' contributions not only informs understanding of pollinator policy, but also wider conservation and environmental management debates. These debates are taking place in a dynamic arena, open to a shifting range of influences, and a broad spectrum of understanding and expertise. Historical and contemporary scientific and policy engagements with beekeepers' knowledge have prioritised their quantitative and/or scientific knowledge, which conforms to positivist, depoliticised expectations of public contributions to evidence-based policy-making. However, beekeepers have a much broader range of knowledge, as well as wider perceptions of the environment, and of the actions of other stakeholders in the contemporary food system. They also possess an appreciation of the natural world which underlies many other pro-environmental behaviours. Such behaviours are often driven by values and identity more than factual knowledge or material concerns. The transformational capacity of forms of local communities' knowledge has a clear role to play in developing transformational land management policies that are necessary in the current era of environmental challenges. Actively engaging with the full range of beekeepers' knowledge and environmental values, including their critiques of pollinator and agricultural policy, and contemporary food systems, can support the transformations necessary to ensure a sustainable food system that provides food while

[6] A citizen science project monitoring bumblebees.

supporting wider environmental benefits.

## Funding

Research for this article was funded by ESRC Studentship 1645591. Writing was supported by ESRC Post Doctoral Fellowship ES/V011723/1.

## Declaration of interests

None

## Data Availability

The data that has been used is confidential.

## Acknowledgements

I would like to thank the interviewees who generously gave their time for this research. I also thank Mike Woods, Sarah Davies and Sophie Wynne-Jones, who supported this research, Mark Whitehead, who read earlier drafts of this article, and two anonymous reviewers whose suggestions improved the quality of this article.

## References

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A., Klein, A.M., 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. Ann. Bot. 103, 1579–1588. https://doi.org/10.1093/aob/mcp076.

Allen-Wardell, G., Bernhardt, P., Bitner, R., Burquez, A., Buchmann, S., Cane, J., Cox, P. A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C.E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G.P., Pavlik, B., Tepedino, V., Torchio, P., Walker, S., 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conserv. Biol. 12, 8–17.

Althaus, S.L., Berenbaum, M.R., Jordan, J., Shalmon, D.A., 2021. No buzz for bees: media coverage of pollinator decline. Proc. Natl. Acad. Sci. USA 118 https://doi.org/ARTN e2002552117.

Andrews, E., 2019. To save the bees or not to save the bees: honey bee health in the Anthropocene. Agric. Hum. Values 36, 891–902. https://doi.org/10.1007/s10460-019-09946-x.

Ansell, C., Geyer, R., 2016. 'Pragmatic complexity' a new foundation for moving beyond 'evidence-based policy making'? Policy Stud. 38, 1–19. https://doi.org/10.1080/01442872.2016.1219033.

Arnott, D., Chadwick, D.R., Wynne-Jones, S., Dandy, N., Jones, D.L., 2021. Importance of building bridging and linking social capital in adapting to changes in UK agricultural policy. J. Rural Stud. 83, 1–10. https://doi.org/10.1016/j.jrurstud.2021.02.001.

Austin, Z., Penic, M., Raffaelli, D.G., White, P.C.L., 2015. Stakeholder perceptions of the effectiveness and efficiency of agri-environment schemes in enhancing pollinators on farmland. Land Use Policy 47, 156–162. https://doi.org/10.1016/j.landusepol.2015.04.003.

Barbero-Sierra, C., Ruíz Pérez, M., Marqués Pérez, M.J., Álvarez González, A.M., Cruz Maceín, J.L., 2017. Local and scientific knowledge to assess plot quality in Central Spain. Arid Land Res. Manag. 32, 111–129. https://doi.org/10.1080/15324982.2017.1377781.

Batáry, P., Dicks, L.V., Kleijn, D., Sutherland, W.J., 2015. The role of agri-environment schemes in conservation and environmental management. Conserv. Biol. 29 (4), 1006–1016.

Bateman, I.J., Balmford, B., 2018. Public funding for public goods: a post-Brexit perspective on principles for agricultural policy. Land Use Policy 79, 293–300. https://doi.org/10.1016/j.landusepol.2018.08.022.

Bennett, N.J., Blythe, J., Cisneros-Montemayor, A.M., Singh, G.G., Sumaila, U.R., 2019. Just Transformations to Sustainability. Sustainability 11. https://doi.org/10.3390/su11143881.

Brace, C., Geoghegan, H., 2010. Human geographies of climate change: landscape, temporality, and lay knowledges. Prog. Hum. Geogr. 35, 284–302. https://doi.org/10.1177/0309132510376259.

Breeze, T.D., Vaissiere, B.E., Bommarco, R., Petanidou, T., Seraphides, N., Kozak, L., Scheper, J., Biesmeijer, J.C., Kleijn, D., Gyldenkaerne, S., Moretti, M., Holzschuh, A., Steffan-Dewenter, I., Stout, J.C., Partel, M., Zobel, M., Potts, S.G., 2014. Agricultural policies exacerbate honeybee pollination service supply-demand mismatches across Europe. PLoS One 9, e82996. https://doi.org/10.1371/journal.pone.0082996.

Bringer, J.D., Johnston, L.H., Brackenridge, C.H., 2016. Using computer-assisted qualitative data analysis software to develop a grounded theory project. Field Methods 18, 245–266. https://doi.org/10.1177/1525822x06287602.

Brown, M.J., Dicks, L.V., Paxton, R.J., Baldock, K.C., Barron, A.B., Chauzat, M.P., Freitas, B.M., Goulson, D., Jepsen, S., Kremen, C., Li, J., Neumann, P., Pattemore, D. E., Potts, S.G., Schweiger, O., Seymour, C.L., Stout, J.C., 2016. A horizon scan of future threats and opportunities for pollinators and pollination. PeerJ 4, e2249. https://doi.org/10.7717/peerj.2249.

Brown, M.J.F., Paxton, R.J., 2009. The conservation of bees: a global perspective. Apidologie 40, 410–416. https://doi.org/10.1051/apido/2009019.

Buijs, A., Kamphorst, D., Mattijssen, T., Dam, V.A.N., Kuindersma, R., Bouwma, I, W., 2022. Policy discourses for reconnecting nature with society: the search for societal engagement in Dutch nature conservation policies. Land Use Policy 114, 105965. https://doi.org/10.1016/j.landusepol.2021.105965.

Burkle, L.A., Delphia, C.M., O'neill, K.M., 2017. A dual role for farmlands: food security and pollinator conservation. J. Ecol. 105, 890–899. https://doi.org/10.1111/1365-2745.12784.

Burton, R.J.F., Riley, M., 2018. Traditional Ecological Knowledge from the internet? The case of hay meadows in Europe. Land Use Policy 70, 334–346. https://doi.org/10.1016/j.landusepol.2017.10.014.

Candel, J.J.L., Pereira, L., 2017. Towards integrated food policy: main challenges and steps ahead. Environ. Sci. Policy 73, 89–92. https://doi.org/10.1016/j.envsci.2017.04.010.

Carolan, M.S., 2008. More-than-representational knowledge/s of the countryside: how we think as bodies. Sociol. Rural. 48, 408–422. https://doi.org/10.1111/j.1467-9523.2008.00458.x.

Chan, K.M.A., Boyd, D.R., Gould, R.K., Jetzkowitz, J., Liu, J., Muraca, B., Naidoo, R., Olmsted, P., Satterfield, T., Selomane, O., Singh, G.G., Sumaila, R., Ngo, H.T., Boedhihartono, A.K., Agard, J., DE Aguiar, A.P.D., Armenteras, D., Balint, L., Barrington-Leigh, C., Cheung, W.W.L., Díaz, S., Driscoll, J., Esler, K., Eyster, H., Gregr, E.J., Hashimoto, S., Hernández Pedraza, G.C., Hickler, T., Kok, M., Lazarova, T., Mohamed, A.A.A., Murray-Hudson, M., O'farrell, P., Palomo, I., Saysel, A.K., Seppelt, R., Settele, J., Strassburg, B., Xue, D., Brondízio, E.S., 2020. Levers and leverage points for pathways to sustainability. People Nat. 2, 693–717. https://doi.org/10.1002/pan3.10124.

Chapman, M., Satterfield, T., Chan, K.M.A., 2019. When value conflicts are barriers: can relational values help explain farmer participation in conservation incentive programs. Land Use Policy 82, 464–475. https://doi.org/10.1016/j.landusepol.2018.11.017.

Cilia, L., 2019. The plight of the honeybee: a socioecological analysis of large-scale beekeeping in the United States. Sociol. Rural. 59, 831–849. https://doi.org/10.1111/soru.12253.

Colla, S.R., Macivor, J.S., 2017. Questioning public perception, conservation policy, and recovery actions for honeybees in North America. Conserv Biol. 31, 1202–1204. https://doi.org/10.1111/cobi.12839.

David, A., Botias, C., Abdul-Sada, A., Nicholls, E., Rotheray, E.L., Hill, E.M., Goulson, D., 2016. Widespread contamination of wildflower and bee-collected pollen with complex mixtures of neonicotinoids and fungicides commonly applied to crops. Environ. Int 88, 169–178. https://doi.org/10.1016/j.envint.2015.12.011.

Defra, 2018. Health And Harmony: The Future For Food, Farming And The Environment In A Green Brexit. [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/fi le/684003/future-farming-environment-consult-document.pdf (Accessed 25 July 2021).

Defra, 2020. Environmental Land Management. Policy discussion document. [online] Available at: https://consult.defra.gov.uk/elm/elmpolicyconsultation/supporting_documents/elmdiscussiondo cument20200225a%20002.pdf (Accessed 25 July 2021).

Dicks, L., Haddaway, N., Hernández-Morcillo, M., Mattsson, B., Randall, N., Failler, P., Ferretti, J., Livoreil, B., Saarikoski, H. & Santamaria, L. 2017. Knowledge synthesis for environmental decisions: an evaluation of existing methods, and guidance for their selection, use and development: a report from the EKLIPSE project.

Dicks, L.V., Abrahams, A., Atkinson, J., Biesmeijer, J., Bourn, N., Brown, C., Brown, M.J. F., Carvell, C., Connolly, C., Cresswell, J.E., Croft, P., Darvill, B., DE Zylva, P., Effingham, P., Fountain, M., Goggin, A., Harding, D., Harding, T., Hartfield, C., Heard, M.S., Heathcote, R., Heaver, D., Holland, J., Howe, M., Hughes, B., Huxley, T., Kunin, W.E., Little, J., Mason, C., Memmott, J., Osborne, J., Pankhurst, T., Paxton, R.J., Pocock, M.J.O., Potts, S.G., Power, E.F., Raine, N.E., Ranelagh, E., Roberts, S., Saunders, R., Smith, K., Smith, R.M., Sutton, P., Tilley, L.A. N., Tinsley, A., Tonhasca, A., Vanbergen, A.J., Webster, S., Wilson, A., Sutherland, W.J., 2013. Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. Insect Conserv. Divers. 6, 435–446. https://doi.org/10.1111/j.1752-4598.2012.00221.x.

Donkersley, P., Elsner-Adams, E., Maderson, S., 2020. A one-health model for reversing honeybee (Apis mellifera L.) decline. Vet. Sci. 7. https://doi.org/10.3390/vetsci7030119.

Drivdal, L., Van der Sluijs, J. P, 2021. Pollinator conservation requires a stronger and broader application of the precautionary principle. Curr. Opin. Insect Sci. 46, 95–105. https://doi.org/10.1016/j.cois.2021.04.005.

Durant, J.L., 2020. Ignorance loops: how non-knowledge about bee-toxic agrochemicals is iteratively produced. Soc. Stud. Sci. 50, 751–777. https://doi.org/10.1177/0306312720923390.

Durant, J.L., Otto, C.R.V., 2019. Feeling the sting? Addressing land-use changes can mitigate bee declines. Land Use Policy 87, 8. https://doi.org/10.1016/j.landusepol.2019.05.024.

Edelenbos, J., Van Buuren, A., Schie, N, V.A.N., 2011. Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. Environ. Sci. Policy 14, 675–684. https://doi.org/10.1016/j.envsci.2011.04.004.

Eden, S., Bear, C., 2012. The good, the bad, and the hands-on: constructs of public participation, anglers, and lay management of water environments. Environ. Plan. A: Econ. Space 44, 1200–1218. https://doi.org/10.1068/a4495.

Eilers, E.J., Kremen, C., Smith Greenleaf, S., Garber, A.K., Klein, A.M., 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS One 6, e21363. https://doi.org/10.1371/journal.pone.0021363.

Ellis, R., Waterton, C., 2004. Environmental citizenship in the making: the participation of volunteer naturalists in UK biological recording and biodiversity policy. Sci. Public Policy 31, 95–105.

Ellis, R.A., Weis, T., Suryanarayanan, S., Beilin, K., 2020. From a free gift of nature to a precarious commodity: bees, pollination services, and industrial agriculture. J. Agrar. Change 20, 437–459. https://doi.org/10.1111/joac.12360.

Galbraith, S.M., Hall, T.E., Tavarez, H.S., Kooistra, C.M., Ordonez, J.C., Bosque-Perez, N. A., 2017. Local ecological knowledge reveals effects of policy-driven land use and cover change on beekeepers in Costa Rica. Land Use Policy 69, 112–122. https://doi.org/10.1016/j.landusepol.2017.08.032.

Gallai, N., Salles, J.M., Settele, J., Vaissiere, B.E., 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ. 68, 810–821. https://doi.org/10.1016/j.ecolecon.2008.06.014.

Girard, N., Claude Paraponaris, D.M.S.P., 2015. Knowledge at the boundary between science and society: a review of the use of farmers' knowledge in agricultural development. J. Knowl. Manag. 19, 949–967. https://doi.org/10.1108/jkm-02-2015-0049.

Gonzalez-Varo, J.P., Biesmeijer, J.C., Bommarco, R., Potts, S.G., Schweiger, O., Smith, H. G., Steffan-Dewenter, I., Szentgyorgyi, H., Woyciechowski, M., Vila, M., 2013. Combined effects of global change pressures on animal-mediated pollination. Trends Ecol. Evol. 28, 524–530. https://doi.org/10.1016/j.tree.2013.05.008.

Goulson, D., Nicholls, E., Botías, C., Rotheray, E.L., 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 347 (6229), 1255957. https://doi.org/10.1126/science.1255957.

Gullino, P., Battisti, L., Larcher, F., 2018. Linking multifunctionality and sustainability for valuing peri-urban farming: a case study in the turin metropolitan area (Italy). Sustainability 10, 1625.

Hakkarainen, V., Soini, K., Dessein, J., Raymond, C.M., 2022. Place-embedded agency: Exploring knowledge–place connections for enabling plurality in governance of social–ecological systems. People and Nature, 4(5), pp 1141-1158. https://doi.org/10.1002/pan3.10365.

Hall, D.M., Steiner, R., 2019. Insect pollinator conservation policy innovations at subnational levels: lessons for lawmakers. Environ. Sci. Policy 93, 118–128. https://doi.org/10.1016/j.envsci.2018.12.026.

Harrison, J.L., 2006. 'Accidents' and invisibilities: Scaled discourse and the naturalization of regulatory neglect in California's pesticide drift conflict. Political Geogr. 25, 506–529. https://doi.org/10.1016/j.polgeo.2006.02.003.

Hernández-Morcillo, M., Hoberg, J., Oteros-Rozas, E., Plieninger, T., Gómez-Baggethun, E., Reyes-García, V., 2013. Traditional ecological knowledge in Europe: status quo and insights for the environmental policy agenda. Environ.: Sci. Policy Sustain. Dev. 56, 3–17. https://doi.org/10.1080/00139157.2014.861673.

Hill, R., Nates-Parra, G., Quezada-Euan, J.J.G., Buchori, D., Lebuhn, G., Maues, M.M., Pert, P.L., Kwapong, P.K., Saeed, S., Breslow, S.J., DA Cunha, M.C., Dicks, L.V., Galetto, L., Gikungu, M., Howlett, B.G., Imperatriz-Fonseca, V.L., Lyver, P.O., Martin-Lopez, B., Oteros-Rozas, E., Potts, S.G., Roue, M., 2019. Biocultural approaches to pollinator conservation. Nat. Sustain. 2, 214–222. https://doi.org/10.1038/s41893-019-0244-z.

Hill, R., Adem, C., Alangui, W.V., Molnar, Z., Aumeeruddy-Thomas, Y., Bridgewater, P., Tengo, M., Thaman, R., Yao, C.Y.A., Berkes, F., Carino, J., DA Cunha, M.C., Diaw, M. C., Diaz, S., Figueroa, V.E., Fisher, J., Hardison, P., Ichikawa, K., Kariuki, P., Karki, M., Lyver, P.O.B., Malmer, P., Masardule, O., Yeboah, A.A.O., Pacheco, D., Pataridze, T., Perez, E., Roue, M.M., Roba, H., Rubis, J., Saito, O., Xue, D.Y., 2020. Working with Indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. Curr. Opin. Environ. Sustain. 43, 8–20. https://doi.org/10.1016/j.cosust.2019.12.006.

Hillocks, R.J., 2012. Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. Crop Prot. 31, 85–93. https://doi.org/10.1016/j.cropro.2011.08.008.

Hinrichs, C.C., 2014. Transitions to sustainability: a change in thinking about food systems change. Agric. Hum. Values 31, 143–155. https://doi.org/10.1007/s10460-014-9479-5.

Hurley, P., Lyon, J., Hall, J., Little, R., Tsouvalis, J., White, V., Rose, D.C., 2022. Co-designing the environmental land management scheme in England: The why, who and how of engaging 'harder to reach' stakeholders. People Nat. https://doi.org/10.1002/pan3.10313.

IPBES Summary for Policymakers of the Methodological Assessment Report on the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services 2022 IPBES secretariat Bonn, Germany.https://doi.org/10.5281/zenodo.6522392.

Joa, B., Winkel, G., Primmer, E., 2018. The unknown known - a review of local ecological knowledge in relation to forest biodiversity conservation. Land Use Policy 79, 520–530. https://doi.org/10.1016/j.landusepol.2018.09.001.

Jones, L., Brennan, G.L., Lowe, A., Creer, S., Ford, C.R., Vere, N, D.E., 2021. Shifts in honeybee foraging reveal historical changes in floral resources. Commun. Biol. 4, 37. https://doi.org/10.1038/s42003-020-01562-4.

Juntti, M., Russel, D., Turnpenny, J., 2009. Evidence, politics and power in public policy for the environment. Environ. Sci. Policy 12, 207–215. https://doi.org/10.1016/j.envsci.2008.12.007.

Kahane, F., Osborne, J., Crowley, S., Shaw, R., 2022. Motivations underpinning honeybee management practices: a Q methodology study with UK beekeepers. Ambio. https://doi.org/10.1007/s13280-022-01736-w.

Kairo, G., Biron, D.G., BEN Abdelkader, F., Bonnet, M., Tchamitchian, S., Cousin, M., Dussaubat, C., Benoit, B., Kretzschmar, A., Belzunces, L.P., Brunet, J.L., 2017. Nosema ceranae, Fipronil and their combination compromise honey bee reproduction via changes in male physiology. Sci. Rep. 7, 8556. https://doi.org/10.1038/s41598-017-08380-5.

Kanter, D.R., Schwoob, M.H., Baethgen, W.E., Bervejillo, J.E., Carriquiry, M., Dobermann, A., Ferraro, B., Lanfranco, B., Mondelli, M., Penengo, C., Saldias, R., Silva, M.E., Lima, J. M. S, D.E., 2016. Translating the Sustainable Development Goals into action: a participatory backcasting approach for developing national agricultural transformation pathways. Glob. Food Secur. -Agric. Policy Econ. Environ. 10, 71–79. https://doi.org/10.1016/j.gfs.2016.08.002.

Kennedy, E., Webb, P., Block, S., Griffin, T., Mozaffarian, D., Kyte, R., 2021. Transforming food systems: the missing pieces needed to make them work. Curr. Dev. Nutr. 5, nzaa177. https://doi.org/10.1093/cdn/nzaa177.

Kinchy, A., Jalbert, K., Lyons, J., 2014. What is volunteer water monitoring good for? Fracking and the plural logics of participatory science. Political Power Soc. Theory 27, 259–289.

Kleijn, D., Winfree, R., Bartomeus, I., Carvalheiro, L.G., Henry, M., Isaacs, R., Klein, A.M., Kremen, C., M'gonigle, L.K., Rader, R., Ricketts, T.H., 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nat. Commun. 6 (1), 1–9. https://doi.org/10.1038/ncomms8414.

Kleinman, D.L., Suryanarayanan, S., 2019. Pollinating collaboration: diverse stakeholders' efforts to build experiments in the wake of the honey bee crisis. Sci., Technol., Hum. Values 45, 686–711. https://doi.org/10.1177/0162243919865962.

Kleinman, D.L., Suryanarayanan, S., 2020. Pollinating collaboration: diverse stakeholders' efforts to build experiments in the wake of the honey bee crisis. Sci. Technol. Hum. Values 45, 686–711. https://doi.org/10.1177/0162243919865962.

Knapp, J.L., Phillips, B.B., Clements, J., Shaw, R.F., Osborne, J.L., 2021. Socio-psychological factors, beyond knowledge, predict people's engagement in pollinator conservation. People Nat. 3, 204–220. https://doi.org/10.1002/pan3.10168.

Kremen, C., Williams, N.M., Aizen, M.A., Gemmill-Herren, B., Lebuhn, G., Minckley, R., Packer, L., Potts, S.G., Roulston, T., Steffan-Dewenter, I., Vazquez, D.P., Winfree, R., Adams, L., Crone, E.E., Greenleaf, S.S., Keitt, T.H., Klein, A.M., Regetz, J., Ricketts, T.H., 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecol. Lett. 10, 299–314. https://doi.org/10.1111/j.1461-0248.2007.01018.x.

Kudsk, P., Jorgensen, L.N., Orum, J.E., 2018. Pesticide Load-a new Danish pesticide risk indicator with multiple applications. Land Use Policy 70, 384–393. https://doi.org/10.1016/j.landusepol.2017.11.010.

Lam, D.P.M., Hinz, E., Lang, D.J., Tengo, M., Von Wehrden, H., Martin-Lopez, B., 2020. Indigenous and local knowledge in sustainability transformations research: a literature review. Ecol. Soc. 25 https://doi.org/Artn 310.5751/Es-11305-250103.

Lehébel-Péron, A., Sidawy, P., Dounias, E., Schatz, B., 2016. Attuning local and scientific knowledge in the context of global change: The case of heather honey production in southern France. J. Rural Stud. 44, 132–142. https://doi.org/10.1016/j.jrurstud.2016.01.005.

Lofmarck, E., Lidskog, R., 2017. Bumping against the boundary: IPBES and the knowledge divide. Environ. Sci. Policy 69, 22–28. https://doi.org/10.1016/j.envsci.2016.12.008.

Lu, C., Warchol, K., Callahan, R., 2014. Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder. Bull. Insect 67, 125–130.

Maderson, S., Wynne-Jones, S., 2016. Beekeepers' knowledges and participation in pollinator conservation policy. J. Rural Stud. 45, 88–98. https://doi.org/10.1016/j.jrurstud.2016.02.015.

Marshman, J., 2019. Communing with bees: a whole-of-community approach to address crisis in the Anthropocene. J. Agric. Food Syst. Community Dev. 9, 87–110. https://doi.org/10.5304/jafscd.2019.091.029.

Mathevet, R., Bousquet, F., Raymond, C.M., 2018. The concept of stewardship in sustainability science and conservation biology. Biol. Conserv. 217, 363–370. https://doi.org/10.1016/j.biocon.2017.10.015.

Maxim, L., Van der Sluijs, J. P, 2007. Uncertainty: cause or effect of stakeholders' debates? Analysis of a case study: the risk for honeybees of the insecticide Gaucho. Sci. Total Environ. 376, 1–17. https://doi.org/10.1016/j.scitotenv.2006.12.052.

Mckemey, M., Ens, E., Rangers, Y.M., Costello, O., Reid, N., 2020. Indigenous knowledge and seasonal calendar inform adaptive savanna burning in Northern Australia. Sustainability 12 https://doi.org/ARTN 99510.3390/su12030995.

Mukherjee, N., Zabala, A., Huge, J., Nyumba, T.O., Adem Esmail, B., Sutherland, W.J., Everard, M., 2018. Comparison of techniques for eliciting views and judgements in decision-making. Methods Ecol. Evol. 9, 54–63. https://doi.org/10.1111/2041-210x.12940.

Nadasdy, P., 1999. The politics of TEK: power and the "integration" of knowledge. Arct. Anthropol. 36, 1–18.

Nadasdy, P., 2005. Transcending the debate over the ecologically noble Indian: indigenous peoples and environmentalism. Ethnohistory 52, 291–331. https://doi.org/10.1215/00141801-52-2-291.

Nimmo, R., 2014. The bio-politics of bees: industrial farming and colony collapse disorder. Hum.: J. Hum. /Anim. Interface Stud. 6, 1–20.

Norstrom, A.V., Cvitanovic, C., Lof, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., De Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J.B., Leach, M., Le Tissier, M., Martin-Lopez, B., Louder, E., Loutre, M.F., Meadow, A.M., Nagendra, H., Payne, D., Peterson, G.D., Reyers, B., Scholes, R., Speranza, C.I., Spierenburg, M., Stafford-Smith, M., Tengo, M., Van Der Hel, S., Van Putten, I., Osterblom, H., 2020. Principles for knowledge co-production in sustainability research. Nature Sustainability 182–190. https://doi.org/10.1038/s41893-019-0448-2.

Oteros-Rozas, E., Ontillera-Sanchez, R., Al, E., 2013. Traditional ecological knowledge among transhumant pastoralists in Mediterranean Spain. Ecol. Soc. 18.

Parsons, W., 2002. From muddling through to muddling up-evidence based policy making and the modernisation of British Government. Public Policy Adm. 17, 43–60.

Pettis, J.S., Delaplane, K.S., 2010. Coordinated responses to honey bee decline in the USA. Apidologie 41, 256–263. https://doi.org/10.1051/apido/2010013.

Phillips, C., 2014. Following beekeeping: more-than-human practice in agrifood. J. Rural Stud. 36, 149–159. https://doi.org/10.1016/j.jrurstud.2014.06.013.

Phillips, C., 2020. The force of Varroa: anticipatory experiences in beekeeping biosecurity. J. Rural Stud. 76, 58–66. https://doi.org/10.1016/j.jrurstud.2020.04.002.

Pimentel, D., ACQUAY, H., BILTONEN, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A., D'amore, M., 1992. Environmental and economic costs of pesticide use. BioScience 42 (10), 750–760. 〈https://www.jstor.org/stable/1311994〉.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., Kunin, W.E., 2010. Global pollinator declines: trends, impacts and drivers. Trends Ecol. Evol. 25, 345–353. https://doi.org/10.1016/j.tree.2010.01.007.

Powney, G.D., Carvell, C., Edwards, M., Morris, R.K.A., Roy, H.E., Woodcock, B.A., Isaac, N.J.B., 2019. Widespread losses of pollinating insects in Britain. Nat. Commun. 10, 1018. https://doi.org/10.1038/s41467-019-08974-9.

Pretty, J., 2008. Agricultural sustainability: concepts, principles and evidence. Philos. Trans. R. Soc. Lond. B Biol. Sci. 363, 447–465. https://doi.org/10.1098/rstb.2007.2163.

Raatikainen, K.J., Barron, E.S., 2017. Current agri-environmental policies dismiss varied perceptions and discourses on management of traditional rural biotopes. Land Use Policy 69, 564–576. https://doi.org/10.1016/j.landusepol.2017.10.004.

Reyes-Garcia, V., Fernandez-Llamazares, A., Mcelwee, P., Molnar, Z., Ollerer, K., Wilson, S.J., Brondizio, E.S., 2019. The contributions of Indigenous Peoples and local communities to ecological restoration. Restor. Ecol. 27, 3–8. https://doi.org/10.1111/rec.12894.

Richardson, M., Passmore, H.-A., Barbett, L., Lumber, R., Thomas, R., Hunt, A., 2020. The green care code: How nature connectedness and simple activities help explain pro-nature conservation behaviours. People Nat. 2, 821–839. https://doi.org/10.1002/pan3.10117.

Riley, M., 2016. How does longer term participation in agri-environment schemes [re] shape farmers' environmental dispositions and identities? Land Use Policy 52, 62–75. https://doi.org/10.1016/j.landusepol.2015.12.010.

Riley, M., Harvey, D., 2007. Oral histories, farm practice and uncovering meaning in the countryside. Soc. Cult. Geogr. 8, 391–415. https://doi.org/10.1080/14649360701488823.

Sanchez-Bayo, F., Goulson, D., Pennacchio, F., Nazzi, F., Goka, K., Desneux, N., 2016. Are bee diseases linked to pesticides? A brief review. Environ. Int. 89–90, 7–11. https://doi.org/10.1016/j.envint.2016.01.009.

Sánchez-Bayo, F., Wyckhuys, K.A.G., 2019. Worldwide decline of the entomofauna: a review of its drivers. Biol. Conserv. 232, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020.

Scott, J.C., 2008. Seeing Like a State. Yale University Press, Binghamton, New York.

Scott, R.M., Bradley, S., Bryce, R., Curzon, R., 2013. Honey Bee Health: mapping, analysis and improved understanding of stakeholder groups to help sustain honey bee health. DEFRA,, London.

Seitz, N., Traynor, K.S., Steinhauer, N., Rennich, K., Wilson, M.E., Ellis, J.D., Rose, R., Tarpy, D.R., Sagili, R.R., Caron, D.M., Delaplane, K.S., Rangel, J., Lee, K., Baylis, K., Wilkes, J.T., Skinner, J.A., Pettis, J.S., Vanengelsdorp, D., 2016. A national survey of managed honey bee 2014-2015 annual colony losses in the USA. J. Apic. Res. 54, 292–304. https://doi.org/10.1080/00218839.2016.1153294.

Senapathi, D., Goddard, M.A., Kunin, W.E., Baldock, K.C.R., 2017. Landscape impacts on pollinator communities in temperate systems: evidence and knowledge gaps. Funct. Ecol. 31, 26–37. https://doi.org/10.1111/1365-2435.12809.

Smith, B.M., Chakrabarti, P., Chatterjee, A., Chatterjee, S., Dey, U.K., Dicks, L.V., Giri, B., Laha, S., Majhi, R.K., Basu, P., 2017. Collating and validating indigenous and local knowledge to apply multiple knowledge systems to an environmental challenge: a case-study of pollinators in India. Biol. Conserv. 211, 20–28.

Smith, T.J., Saunders, M.E., Leather, S.R., Packer, L., 2016. Honey bees: the queens of mass media, despite minority rule among insect pollinators. Insect Conserv. Divers. 9, 384–390. https://doi.org/10.1111/icad.12178.

Sponsler, D.B., Grozinger, C.M., Hitaj, C., Rundlof, M., Botias, C., Code, A., Lonsdorf, E. V., Melathopoulos, A.P., Smith, D.J., Suryanarayanan, S., Thogmartin, W.E., Williams, N.M., Zhang, M., Douglas, M.R., 2019. Pesticides and pollinators: a socioecological synthesis. Sci. Total Environ. 662, 1012–1027. https://doi.org/10.1016/j.scitotenv.2019.01.016.

Stout, J.C., Dicks, L.V., 2022. From science to society: implementing effective strategies to improve wild pollinator health. Philos. Trans. R. Soc. B-Biol. Sci. 377. https://doi.org/10.1098/rstb.2021.0165.

Suryanarayanan, S., 2013. Balancing control and complexity in field studies of neonicotinoids and honey bee health. Insects 4, 153–167. https://doi.org/10.3390/insects4010153.

Suryanarayanan, S., Kleinman, D.L., 2013. Be(e) coming experts: the controversy over insecticides in the honey bee colony collapse disorder. Soc. Stud. Sci. 43, 215–240. https://doi.org/10.1177/0306312712466186.

Suryanarayanan, S., Kleinman, D.L., Gratton, C., Toth, A., Guedot, C., Groves, R., Piechowski, J., Moore, B., Hagedorn, D., Kauth, D., Swan, H., Celley, M., 2018. Collaboration matters: honey bee health as a transdisciplinary model for understanding real-world complexity. Bioscience 68, 990–995. https://doi.org/10.1093/biosci/biy118.

Thoms, C.A., Nelson, K.C., Kubas, A., Steinhauer, N., Wilson, M.E., Vanengelsdorp, D., 2019. Beekeeper stewardship, colony loss, and Varroa destructor management. Ambio 48, 1209–1218. https://doi.org/10.1007/s13280-018-1130-z.

Turnhout, E., Metze, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. Curr. Opin. Environ. Sustain. 42, 15–21. https://doi.org/10.1016/j.cosust.2019.11.009.

Turvey, S.T., Risley, C.L., Moore, J.E., Barrett, L.A., Yujiang, H., Xiujiang, Z., Kaiya, Z., Ding, W., 2013. Can local ecological knowledge be used to assess status and extinction drivers in a threatened freshwater cetacean. Biol. Conserv. 157, 352–360. https://doi.org/10.1016/j.biocon.2012.07.016.

Tyllianakis, E., Martin-Ortega, J., 2021. Agri-environmental schemes for biodiversity and environmental protection: How we are not yet "hitting the right keys". Land Use Policy 109. https://doi.org/10.1016/j.landusepol.2021.105620.

Udovyk, O., 2014. Models of science-policy interaction: exploring approaches to Bisphenol A management in the EU. Sci. Total Environ. 485–486, 23–30. https://doi.org/10.1016/j.scitotenv.2014.03.046.

Urquhart, J., Potter, C., Barnett, J., Fellenor, J., Mumford, J., Quine, C.P., 2017. Expert risk perceptions and the social amplification of risk: a case study in invasive tree pests and diseases. Environ. Sci. Policy 77, 172–178. https://doi.org/10.1016/j.envsci.2017.08.020.

Van der Sluijs, J.P., Simon-Delso, N., Goulson, D., Maxim, L., Bonmatin, J.-M., Belzunces, L.P., 2013. Neonicotinoids, bee disorders and the sustainability of pollinator services. Curr. Opin. Environ. Sustain. 5, 293–305. https://doi.org/10.1016/j.cosust.2013.05.007.

Van Der Steen, J.S., Brodschneider, R., 2015. Public participation in bee science: C.S.I. pollen. Bee World 91, 25–27. https://doi.org/10.1080/0005772x.2014.11417585.

Vanegas, M., 2017. The silent beehive: how the decline of honey bee populations shifted the environmental protection Agency's pesticide policy towards Pollinators. Ecol. Law Q. 44, 311–341. https://doi.org/10.15779/Z38gq6r199.

Vasiliev, D., Greenwood, S., 2020. Pollinator biodiversity and crop pollination in temperate ecosystems, implications for national pollinator conservation strategies: mini review. Sci. Total Environ. 744. https://doi.org/10.1016/j.scitotenv.2020.140880.