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The Traditional Environmental Knowledge of Beekeepers:

A Charter for Sustainability?

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Summary

In recent years, dramatic levels of pollinator decline have captured the attention of scientists, policy-makers and wider publics. This precipitous drop in honey bees and other pollinators threatens food security and biodiversity. Recent policy initiatives call upon multiple, diverse stakeholders to work together for pollinator wellbeing, and wider ecosystem health. Many of these initiatives forefront beekeepers, whose role in both monitoring and ensuring bee health is recognised as paramount.

This thesis investigates beekeepers' knowledge of both honey bees, and the wider environment. Using archival analysis, interviews and participant observation, I demonstrate that long-term beekeepers generate and use Traditional Environmental Knowledge (TEK) through their beekeeping practice. Their knowledge incorporates wide understanding of both the environmental factors that have affected pollinator health since the mid-20th century, as well as the socioeconomic and political drivers behind the physical deterioration of much of the environment that we, and pollinators, rely upon.

This research project explores beekeepers' knowledge within the context of debates on TEK, and Citizen Science. I explore the relationship between formal scientific research and other methods of environmental inquiry and engagement. While there has been a dramatic increase in media, public and scientific attention to pollinator and bee decline, this thesis documents a worrying dissonance between the knowledge and recommendations of long-term beekeepers, and the wider public's understanding and actions, in response to this environmental challenge. Although beekeepers' tacit understanding is often deeply infused with wider scientific knowledge, resulting in a uniquely hybrid knowledge, this research finds a hegemonic prioritisation of objectivist epistemologies, which results in a failure for the scientific and policy communities to fully engage with the observations and concerns of beekeepers. While TEK is recognised as supporting environmentally sustainable practices, this epistemological tension limits the capacity for the knowledge of TEK holders, and beekeepers, to be fully utilised.

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Glossary and Abbreviations

AFB – American Foul Brood

Apiary – a collection of beehives

Apis Mellifera – European Honey Bee

BBKA – British Beekeepers Association

Bee Base – an online information portal for beekeepers, run by the National Bee Unit

BFA – Bee Farmers Assocation

BIBBA – Bee Improvement and Bee Breeders Association

COLOSS – international honey bee research association focussed on improving the well-being of bees at a global level

CS – Citizen Science

CSO – Civil Society Organisations

DEFRA – Department of Environment Food and Rural Affairs

EFB – European Foul Brood

EBPM – Evidence Based Policy Making

GEI – COLOSS Genotype-Environment Interactions Experiment – set up to understand the effects of environmental factors on the health and vitality of European honey bee genotypes.

Hive years – the number of years a person has kept bees, multiplied by the number of hives they have each year. Eg – keeping 10 colonies for 3 years results in 30 hive years' experience. Another measure of beekeepers' experience, within the beekeeping community.

IK – Indigenous Knowledge

Local bees – bees which have been bred from local queens, as compared to importing queens from other countries, and possibly other subspecies of Apis Mellifera. The term is hotly debated.

Melissopalynology – The study of pollen residues in honey.

MTH – More Than Human

NBU – National Bee Unit

Nosema – dysentery-like illness affecting bees that is a common cause of colony illness and death.

Phenology- relationships between seasonal patterns, and animals and plants life cycle events. Commonly known as 'nature's calendar'.

Queen failure – death of queen, which, if not replaced by a new queen, will inevitably lead to the death of the colony.

Queen rearing – Raising new queen bees to then be added to bee colonies.

Scale Hive - a hive which is permanently on a scale, and honey is not removed by the beekeeper. All additions and subtractions to the weight of the hive are solely a result of the nectar collection and honey consumption patterns of the bee colony.

SICAMM – *Societas Internationalis pro Conservatione Apis Melliferae Melliferae* - the International Association for the Protection of the European Dark Bee

Splitting colonies – dividing large colonies to create new colonies. Generally carried out in late spring / early summer, as a method to prevent swarming and increase colony numbers.

Ssp – sub species.

STEMM – Science, Technology, Engineering, Mathematics and Medicine

Swarming – natural method of colony reproduction. Queen and some of the colony leave to set up a new colony, and a new queen is reared.

WBKA – Welsh Beekeepers Association

Chapter 1: Introduction

In recent years, the global decline of the honey bee has captured the public imagination to a degree usually associated with charismatic megafauna, rather than comparatively humble invertebrates. The inexplicable demise of colonies throughout the US and Europe has generated both significant scientific research into its causes, as well as policy responses, in an attempt to arrest the loss of honey bees. There are many reasons for this broad range of cross-sectoral responses. Humans have engaged with honey bees, and honey, for millennia. The ancient Egyptians used honey for embalming deceased royalty, while the Bible's Song of Solomon is one of the earliest references linking honey, sweetness and romance, in a tradition that lives throughout art and literature today. As well as providing one of the main sources of dietary sweetness in the centuries before sugar was produced, we admire honey bees for their behaviour. Their industriousness and undying devotion to serving their queen is presented as a model of virtuous behaviour, to which we should aspire. On a more corporeal level, the decline of bees worries us. Einstein's apocryphal warning of mankind having only four years left if the bees die out has gained popular credence in recent years, regardless of its exaggerated warnings of mass starvation in a post-pollinator apocalypse.

While the decline in honey bees is the leader in headline inches, it is part of a wider loss of biodiversity, and a possible 'insectageddon'(Thomas et al., 2019). In a seemingly concerted effort to address this ecological crisis, there have been calls to enlist the efforts of all relevant stakeholders, with beekeepers being singled out for their experience and knowledge of bees, and their capacity to ensure bee health. This thesis set out to investigate the past, present, and potential role of beekeepers in monitoring, and ensuring, pollinator wellbeing. Analysing the diverse yet interconnected responses of beekeepers, scientific researchers, policy-makers and the wider public to the shared environmental challenge of pollinator decline presents an opportunity to interrogate efforts to bring together diverse epistemologies, and understand the wider social and structural barriers to environmental change, when confronted with a complex, wicked problem. This research project investigates the distinctive knowledge of beekeepers, how they use this knowledge in their practice, and how they understand the challenges faced by their bees, and other pollinators. It then investigates how they use and communicate this knowledge when working with other stakeholders in pollinator health as part of shared efforts to understand, and reverse, pollinator decline. To understand the role of beekeepers in pollinator protection, we must first understand the current status of pollinators.

1.1: Pollinator Decline: Reasons Not To Be Cheerful

The global decline in pollinators has attracted increasing media and scientific attention in recent years. (Aizen et al., 2009; Pettis and Delaplane, 2010; Potts et al., 2010). Within this broader invertebrate decline, the unexpected deaths of vast numbers of honey bee colonies in the early 2000s attracted a particularly high level of attention, with the inexplicable, multifactorial syndrome of Colony Collapse Disorder generating immense concern amongst scientists, policy-makers, and beekeepers (Suryanarayanan and Kleinman, 2013; Vanegas, 2017; Williams et al., 2010). As well as playing a central role in ensuring biodiversity, pollinators are key components of agricultural productivity (Allen-Wardell et al., 1998; vanEngelsdorp and Meixner, 2010). Although there are over 250 species of bees in the UK, as well as many other pollinators, honey bees are one of the major pollinators in the agricultural sector. Their decline has caused a great deal of anxiety in the sector, and in the media. The scale of the colony losses, coupled with the centrality of bees' role in our food systems, has triggered a high degree of public awareness and concern, as films such as *Vanishing of the Bees* (Henein, 2009) ominously warned of the apocalyptic effect of a global disappearance of honeybees. While it is doubtful that we would starve without bees, as most of the key global food crops such as rice, wheat and maize do not require insect pollination, our diet would surely be less varied, less nutritious, and less interesting. Within the UK, honey bees are the primary pollinators for approximately 34% of commercial crops (Breeze et al., 2011). Globally, bees pollinate between 15-90% of commercial crops, depending on the location and crops grown (Aizen et al., 2009; Gallai et al., 2009; Hanley et al., 2015). Increasingly, the decline in pollinators is seen as a threat to food security (Allen-Wardell et al., 1998; Gonzalez-Varo et al., 2013; Kevan, 1999). It is widely accepted that there is a range of causes impacting bees and other pollinators and leading to a decline, including, but not limited to: a decrease in quality and quantity of available food, or forage (Decourtye et al., 2010), diseases such as varroasis and nosema (Little et al., 2016; Seitz et al., 2016), and pesticide usage, with particular recent attention on the impact of neonicotinoids (Potts et al, 2010a; VanEngelsdorp and Meixner, 2010). It has been found that diseases which are traditionally associated with honey bees are now also spreading to other pollinator species, particularly bumble bees and other solitary bees (Goulson and Hughes, 2015; Graystock et al., 2015). Climate change is another key driver in pollinator decline (Brown et al., 2016; Vanbergen and Initiative, 2013). Changing weather patterns are creating stresses on bee health, due to their impact on forage availability, and disrupting specific climactic niches (Baude et al., 2016; Potts et al., 2015). Climate change is also resulting in a shift in phenological patterns, with flowers coming into bloom at different times; this can have a negative effect on many pollinator species, particularly in areas of low biodiversity and associated environmental resilience (Bartomeus et al., 2013). Some researchers have suggested that contemporary intensive beekeeping practices, which often decrease genetic diversity and include regular use of a wide variety of miticides and antibiotics, are contributing to honey bees lacking biological resilience to changing environmental circumstances (Le Conte, 2007; Locke and Fries, 2011). In 2013, the EU introduced a two year ban on neonicotinoids (aka neonics). Further research continues to find detrimental impacts of neonics on pollinators and the wider ecosystem (Gibbons et al., 2015; Gross, 2014; Henry et al., 2012; Sandrock et al., 2014).

Many argue that, ultimately, the decline in bees and other pollinators is due to negative synergies from the various factors listed above (Gonzalez-Varo et al., 2013; Goulson et al., 2015; Potts et al., 2010). The decline in pollinators is part of a wider decline in invertebrates, with recent estimates suggesting up to a 75% decline in insect biomass (Hallmann et al., 2017). Dramatic declines have recently been documented across a range of wild pollinator species throughout the UK, although with notable variation between species and habitats (Powney et al., 2019). While the drivers behind the decline are multiple and synergistic, many are seen as rooted in current industrial food production systems, and climate change (Sánchez-Bayo and Wyckhuys, 2019). Although the effect on bees is biological and physical, the challenges they face are, ultimately, anthropogenic. Thus, alleviating pollinator decline will require a multidisciplinary response which engages with both life sciences, and social sciences. Pollinator decline is an example of a wicked problem, characterised by complexity and multiple drivers, which will require 'clumsy solutions' that cannot be generated via traditional linear analyses (Ney and Verweij, 2015; Rayner, 2012). The multiple, interwoven drivers behind pollinator decline require a broad systemic approach to both understanding, and solving this critical environmental challenge. Within this highly complex framework, beekeepers are positioned as holding relevant expertise in both monitoring bee health, and acting as their custodians in a challenging environment. The decline of beekeepers is associated with a decline in bees (Potts et al., 2015), thus adding an impetus to ensure beekeepers continue their practice, and work with others to look after pollinators. Clearly, beekeepers have a central role in addressing the crisis of pollinator decline.

1.2: Understanding, and responding to the crisis

There is a range of current strategies for improving the environment for pollinators, most of which are the result of ecological and/or apicultural research on the impact of land use practices on pollinators (Hardman et al., 2016; Wood et al., 2015). Researchers note, however, that altering one or more variables may not lead to the proposed results, due to synergies of other interrelated factors (Gonzalez-Varo et al., 2013). A key challenge in understanding and improving the environment for pollinators, is the difficulty of controlling, and measuring, all relevant variables. The overwhelming majority of research on pollinator decline is carried out within the life sciences, which struggle to replicate the multifactorial environmental hazards seen as challenging pollinator wellbeing (Maxim and van der Sluijs, 2011; Suryanarayanan, 2013).

When considering government response to pollinator decline, there is a notable lack of impetus for decreasing pesticide usage in DEFRA's strategy (DEFRA, 2014). In contrast, there are calls for the agricultural sector to engage with a range of voluntary measures to decrease agrochemical use, amongst other suggestions. This is in stark contradiction to mounting evidence on the negative impact of pesticides on pollinator health (Potts et al., 2010). This is also a point of contention between beekeepers, researchers, farmers, and government policy (Pettis and Delaplane, 2010; Saunders et al., 2016; van der Sluijs et al., 2013). Conflicts have arisen in recent years between beekeepers, farming unions, and agrochemical firms, as many of the former campaign for moratoriums, if not outright bans, on the chemical products which are ubiquitous in contemporary agriculture (Maxim and van der Sluijs, 2007; Suryanarayanan, 2013). While beekeepers defend their analysis as a result of their direct experience in the field, critics are prone to dismiss their claims as lacking scientific rigour, and being biased (Maderson and Wynne-Jones, 2016; Maxim and van der Sluijs, 2007). This highlights a debate on the possible role, and capacity, of beekeepers' knowledge in monitoring, and reversing, pollinator decline. The potential for beekeepers' observational insights to complement scientific research and address knowledge gaps on local pollinator decline, and associated environmental and agricultural impact, has been noted in France (Lehébel-Péron et al., 2016) and India (Smith et al., 2017). Beekeepers' knowledge is often passed on through families, creating a localised, temporally rich understanding of factors relevant to the ecosystem services associated with bees (Uchiyama et al., 2017). Korean forest beekeepers have been found to exhibit traditional environmental knowledge that is also associated with sustainable forest management (Park and Youn, 2012). The tacit knowledge of beekeepers provides another perspective to environmental understanding which can complement, and elucidate, scientific study; this potential complementarity of knowledge forms has been observed amongst other land workers (Barbero-Sierra et al., 2017; Harvey and Riley, 2005).

1.3: Understanding Bees: From Aristotle to the Anthropocene

Honey bees have a long relationship with humans, dating back to the ancient Egyptians (Crane, 2004). A rich history of meticulous biological observation and manipulation by interested amateurs, early natural historians and more recently, by professional scientists, can be dated back to the earliest known observations about honey bees, by Aristotle in Ancient Greece (ibid). Such careful observation has continued for centuries, leading to the knowledge that colonies were led by queen bees, not kings, in the 17th century, and that honey and wax were produced in the colony, rather than emerging miraculously from the environment – a key point of bee biology that was finally clarified in the 1700s (ibid). Subsequently, much of the recent scientific research and media attention on pollinators tends to focus on *Apis mellifera,* or honey bees, even though they are but one of many species of pollinator (Ollerton et al., 2012; Potts et al., 2010). The 20th and early 21st century have seen a transformation in pollinator habitat, and, recently, an explosion in life science understanding of bees and their microbiology. Although there are a wide range of pollinators serving key functions in biodiversity and food security, honey bees are recognised as a key indicator species for wider ecosystem and pollinator health, with many of the threats to honey bees also affecting other pollinators (Dicks et al., 2013; Gross, 2014; Kevan, 1999). While there are sometimes conflicts between honey bees' needs and those of other pollinators (Goulson and Hughes, 2015; Graystock et al., 2015), it is frequently found that conditions which are deleterious to honey bee health, in particular loss of forage, and negative impacts from various agrochemicals, are also problematic for other pollinators (Potts et al., 2010). The prevailing industrial agricultural system focuses on large-scale monocrop production, which is reliant upon the usage of large quantities and varieties of agro-chemicals (Tscharntke et al., 2012). This has a negative impact on biodiversity, and is recognised as having a significant negative impact on pollinator numbers and well-being (Gonthier et al., 2014; Power, 2010). The impact of various agricultural approaches on pollinators is a key question for land managers, and for beekeepers (Phillips, 2014; Saunders et al., 2016). Pollinator decline is situated as a manifestation of the Anthropocene, with climate change and other anthropogenic challenges to pollinator wellbeing ultimately threatening food security (Marshman et al., 2019).

As environmental challenges grow, there are calls for new ways of understanding, and responding to them, in ways that can ensure environmental sustainability and resilience. Some argue for a deeper engagement with other forms of environmental knowledge, which are often associated with intergenerational knowledge transmission, situated knowledge, and cultural recognition of the interdependence of species (Berkes et al., 2000; Olsson et al., 2004). These forms of understanding are often referred to as Traditional Environmental Knowledge, or TEK, which is recognised in a diverse range of environments and communities (Burton and Riley, 2018; Hernández-Morcillo et al., 2014; Ianni et al., 2015). Other communities of tacit environmental knowledge holders, such as farmers and anglers, are also positioned as holding the potential to understand monitor and enhance the physical environment, as a result of their environmental practices (Bear, 2006; Šūmane et al., 2018). This experiential, localised knowledge is often seen as providing a necessary temporal, social and spatial context to scientific knowledge, which is posited as providing linear explanations of complex environmental realities, and thus overlooking important factors (Šūmane et al., 2018). While there are valid critiques of the limitations of scientific understandings as a sole explanation of the environment (Fairhead and Leach, 2000; Goldman et al., 2011), this can belie the diversity within science itself. Laboratory-based science has become more complex and exclusive since the 19th century (Secord, 1994). Even today, field studies often attract a different type of practitioner (Lorimer, 2008; Reiners et al., 2013) than those who are more comfortable working in the epistemological and physical confines of laboratories. Field realities are complex, fluid and unpredictable, with local and temporal variants – and it is within these complexities that beekeepers have worked, and observed their bees' responses to multifactorial conditions, for centuries.

There is a history of beekeepers observing the impacts of environmental trends and land use on bee health, often before these impacts are formally scientifically verified. Analysis of the Bee Farmers archives finds beekeepers recognising the impact of organochloride and pyrethroid pesticides many years before this link was scientifically verified (Maderson & Wynne Jones, 2016). While researchers do corroborate with beekeepers, and incorporate some of their data into research projects (Neumann and Carreck, 2015; Seitz et al., 2016), such research usually calls on beekeepers to submit basic quantitative data on colony losses and similar observations. Other authors note the multisensory engagement of beekeepers with their practice, and highlight the distinct tacit nature of beekeepers' knowledge, in contrast to research carried out within scientific studies (Moore and Kosut, 2013a; Phillips, 2014). Beekeepers are highly aware of the fluidity and breadth of multiple synergistic influences on bees (Suryanarayanan, 2013). Limited social science research on beekeepers and their knowledge notes a consistent trend for their management decision-making to be based on a constant iterative process of observing and analysing a broad, diverse range of factors, many of which are outside their control; these are ultimately assessed via strong intuitive, tacit approaches (Phillips, 2014; Suryanarayanan, 2013; Suryanarayanan and Kleinman, 2013). Bees are unusual in that they blur the boundaries between domestic and wild animals. They are managed by beekeepers and bee farmers, yet are reliant on free foraging from plant resources. Honey bees are affected directly and indirectly by many stakeholders such as farmers, land owners, policy makers, pesticide manufacturers and more (Phillips, 2014). The complexities of bees' lives and environments are dealt with daily by beekeepers, who are all too aware that life in the field is far more complicated and unpredictable than any scientific hypothesis.

Since the sudden decline in bees and other pollinators began over ten years ago, there has been a tremendous amount of research into the microbiology of bees (Hawthorne and Dively, 2011; Le Conte, 2007; Pettis and Delaplane, 2010). While this plethora of scientific attention has expanded our knowledge of bees and their response to diseases and exposure to various chemicals, we are still faced with declining pollinators, who continue to face a broad range of challenges in the physical environment (Sánchez-Bayo and Wyckhuys, 2019). Clearly, understanding and responding to the challenges facing honey bees today requires not just an inspection of their diseases and diets, but also an understanding of the individuals who influence and observe bees' lives.

While much of the research into pollinator decline tends to focus on biological factors impacting bees, there are some researchers engaging with the role of beekeepers in documenting, maintaining, and ensuring bee health (Lehébel-Péron et al., 2016; Potts et al., 2015). Beekeepers tend to assess their practices, and the wellbeing of their bees, according to a range of diverse, inter-related, systemic factors. Their decision-making is often guided by an intuitive analysis of a multiplicity of factors (Phillips, 2014). This often transcends the individual factors that may be the subject of scientific hypotheses. There are also significant structural limitations to beekeepers' capacity to act upon their knowledge, when they ascribe the cause of pollinator decline to the many agrochemicals that are a defining feature of industrial agribusiness (Maxim and van der Sluijs, 2007; van der Sluijs et al., 2013). While understanding beekeepers' knowledge can contribute to our understanding, and reversing pollinator decline, it is equally important to be aware of the obstacles they perceive as hindering efforts to improve the environment for pollinators.

When considering the potential role of beekeepers' knowledge in observing environmental factors impacting pollinator health, it is important to note that the beekeeping community is notably heterogenous (Moore and Kosut, 2013a). There are several distinct sub-categories which have developed in recent years. The majority of UK beekeepers would describe themselves as 'traditional beekeepers': in practice, this is associated with using movable frame hives, and a tendency to treat bees with miticides and other medications in order to cope with varroa mites and other afflictions. 'Natural' beekeeping, on the other hand, has recently gained prominence, as a new community of beekeepers has developed, who question many common beekeeping practices, and see them as deleterious to bee health (Green and Ginn, 2014). Their concerns are being recognised by some within the scientific community, who also acknowledge the role of orthodox contemporary beekeeping practices as being counter to the biological integrity and wellbeing of honey bees (Neumann and Blacquiere, 2017). Many of those who self-identity as 'natural' beekeepers have come to the activity inspired by a concern over pollinator decline, and often have a personal background in other ‘green’ activities and political movements (Maderson and Wynne-Jones, 2016). For the majority of beekeepers today, one of the main challenges to bee health is varroa, and the associated viruses of which this parasitic mite is the vector (Le Conte et al., 2010; Wilfert et al., 2016). Within a wider environmental context, ‘natural’ beekeepers primarily perceive bee health as far more dependent on the condition of the wider environment: they believe pollinator decline must be understood, and ultimately addressed, within the context of a flawed agro-environment complex, which has led to decreases in available forage, and an excess of agrochemicals that act in a way to produce negative synergies (Scott et al, 2013). While the terms traditional and natural are by no means fully representative of the broad spectrum of practices and approaches followed by beekeepers, they do begin to convey a sense of the diversity of perceptions, which do have an impact on beekeepers’ views of the environment, and its impact on pollinator health. The increase in ‘natural’ beekeeping has been quite recent, and is disproportionally reflected in people who have begun beekeeping in recent years, often as a response to bee declines. This influx has been greeted with scepticism by many more experienced beekeepers, who often ascribe the failure of new beekeepers’ colonies to ‘PPB’ – piss-poor beekeeping. This illustrates a serious flaw in relying on quantitative data from beekeepers of annual colony loss as a marker of bee health and wellbeing, as experienced beekeepers recognise a significant difference between the survival rates of colonies managed by novice, as compared to experienced, beekeepers. Similarly, the willingness of beekeepers to treat their bees for varroa, and/or give bees supplementary feeding in times of poor weather, will also influence colony survival. Clearly, the world of beekeeping has factions and disagreements, which must be acknowledged when carrying out any social science analysis. Regardless of the specific nuances of their practice, beekeepers are united by far more than separates them (Scott et al, 2013). They share concerns regarding the environment, and all acknowledge, to varying degrees, the impact of the current agro-food system on bees and other pollinators (Lehébel-Péron et al., 2016; Potts et al., 2015). Understanding and engaging with multiple, and at times contradictory perspectives is crucial to successfully engaging with beekeepers’ knowledge to enhance environmental sustainability. Of the limited social science research carried out to date on beekeepers’ knowledge, it has primarily focused on their actual practice (Moore and Kosut, 2013a; Phillips, 2014). However, there have been some references to wider environmental observations generated by this tacit practice (Lehébel-Péron et al., 2016; Maderson and Wynne-Jones, 2016; Park and Youn, 2012; Uchiyama et al., 2017). These have often been as an aside, rather than the central point of investigation. This thesis aims to focus on an issue which has been peripheral to earlier studies, and explore how beekeepers learn about the environmental factors affecting their bees, and act upon this knowledge within a complex wider environment.

As the practice of beekeeping is so intrinsically linked to wider environmental awareness and sensitivities, it is a reasonable hypothesis that qualitative exploration of beekeepers' knowledge is well placed to discover a wide range of relevant data on the environment. This includes the full range of environments where it is practiced, including cities. Recent years have seen a notable increase in urban beekeeping (Lorenz and Stark, 2015; Moore and Kosut, 2013a). At the same time, scholarly attention is exploring urban landscapes, and the impact of urban land use on biodiversity (Gaston et al., 2005; Lin et al., 2015; Speak et al., 2015). This issue raises new questions regarding the quality and quantity of forage available for pollinators in this environment (Clermont et al., 2015; Fukase and Simons, 2016; Garbuzov et al., 2015a; Hostetler and McIntyre, 2001; Potter and LeBuhn, 2015; Quistberg et al., 2016). Urban beekeepers are well-placed to play a key role in observing and ensuring the wellbeing of pollinators in this changing landscape (De Palma et al., 2015; Dixon and Richards, 2015; Lin et al., 2015; Opitz et al., 2015). As we live in an increasingly urbanised world, we face new challenges in food security, ecosystem stability, and socio-ecological resilience. The status of urban pollinators is central to all of these challenges (Chiesura, 2004; Langellotto et al., 2018; Potter and LeBuhn, 2015). Therefore, the observations and insights of urban beekeepers should be investigated alongside those who keep bees in rural and/or agricultural areas.

The increase in urban beekeeping also illustrates several wider points surrounding the public response to pollinator decline. As stated earlier, while honey bees are but one species of pollinator, their plight has captured the public imagination – and much of the media coverage of pollinator decline (Smith et al., 2016). For many years, beekeeping was an activity primarily associated with rural life, and learned via direct, personal mentoring relationships (Adams, 2016). A decline in trained, skilled beekeepers has been linked to a decline in honey bees throughout Europe (Potts et al., 2015). Although the revival in popularity of this interesting hobby may seem to alleviate this decline, there are areas for concern. While the public response to pollinator decline by increasing urban beekeeping may be highly visible, and generate media coverage, it is unclear as to whether it actually addresses the significant challenges to pollinator wellbeing. The rapidity of the rise in beekeeping, coupled with the tendency for diseases of honey bees to now spread to other pollinators (Goulson and Hughes, 2015), has led some ecologists to point out that keeping managed honey bees is not necessarily effective in addressing wider pollinator decline (Geldmann and González-Varo, 2018). Many of the most substantial challenges to pollinator wellbeing are associated with agricultural practices that have less of an impact on bees kept in urban areas (Lorenz, 2016). The 'feel-good factor' of urban beekeeping seems to outweigh its wider practical impact on pollinator wellbeing. There is also a growing concern that the rapid influx of newcomers to beekeeping associations has strained teaching and training capacity, with the number of inexperienced beekeepers having significantly higher rates of colony losses, and poorer husbandry skills (Seitz et al., 2016). Beekeeping is facing many challenges to successful communication within its community – and to the other stakeholders in pollinator health.

1.4: Pollinator Policy, and Beekeepers' Role

As public awareness of pollinator decline has grown, there have been a range of government responses in the UK and further afield (Vanegas, 2017). In 2013, the Welsh Government launched the Wales Pollinator Action Plan. In 2014, DEFRA launched the UK's National Pollinator Strategy. A key feature of these policy initiatives is their focus on engaging with beekeepers, who are positioned as both observers, and stewards, of bees and other pollinators (DEFRA, 2014; Welsh Government, 2013). The distinct knowledge of beekeepers is recognised as having the potential to make a unique and valuable contribution to the success of pollinator policies. Such an approach is indicative of a wider 'participatory turn' in governance, where diverse communities are encouraged to contribute to decision-making processes (Edelenbos et al., 2011; Maynard, 2015). If the decline in pollinators is to be successfully halted, it is imperative that the nature of beekeepers' environment knowledge, and their perspective on efforts to understand, and reverse pollinator decline, are accurately assessed. Often beekeepers' situated knowledge adds valuable environmental insights that can be overlooked by relying solely on scientific data analysis. In one study, attempts to limit the spread of transgenic plants were found to have been accidentally undermined by common beekeeping practices and hive siting, thus bringing beekeepers to the forefront of political attention (Lezaun, 2011). Beekeepers are centrally positioned within a wider growing cultural engagement with pollinators. The devastating effect of Colony Collapse Disorder illustrated the economic significance of honey bees to agriculture, and captured the public imagination; these factors led to campaigners calling for tighter regulation on pesticides (Vanegas, 2017). However, the regulatory response has failed to address many of the concerns of campaigners, or beekeepers (ibid). Creating effective pollinator protection policy that will garner public support is found to be more successful at local levels, with significant barriers to broader national and/or international success (Hall and Steiner, 2019). However, this is not without its own challenges, as policy makers often search for definitive evidence that may be missing, or contradictory, within issues of ecological complexity (Gustafsson, 2017; Gustafsson et al., 2017). The complexity of contemporary ecological challenges, of which pollinator decline is a classic example, has led some to suggest moving towards a Post-Normal Science approach, which acknowledges the need for a plurality of analyses, and would also create space for more inclusive subsequent governance (Guimaraes Pereira and Saltelli, 2017). Ecological problems are recognised as necessitating broad partnerships to understand, and resolve them, as part of efforts to utilise ecological knowledge to support sustainability (Palmer et al., 2005). Such partnerships are not always equal, however. Struggles for epistemological parity result in those whose knowledge has been generated through tacit activities often being unable to have their insights respected and recognised by other stakeholders, particularly the scientific, and policy-making communities (Nadasdy, 2005; Robbins, 2003, 2006). This threatens to undermine efforts to constructively engage with beekeepers' knowledge, as their activities rely on, and generate, knowledge that does not conform to models of scientific objectivity (Suryanarayanan, 2013; 2016; Suryanarayanan et al., 2018). As evidence-based policy making has become the preferred model for environmental governance, questions have arisen as to what counts as evidence (Cartwright and Hardie, 2012). The relationships between science and policy often limit the potential of other forms of knowledge, with some calling for the need to develop Multiple Evidence Bases (Tengo et al., 2014). Such a broadening of perspective acknowledges differing epistemologies, and a subsequent political space for alternative ways of knowing the environment.

If we are to ensure the wellbeing of pollinators, the quality and quantity of knowledge about their needs and challenges are not the only factors that must be addressed. As pollinators are both a part of, and affected by, the food system, their decline should be perceived and addressed within wider debates on food policy (Candel and Pereira, 2017). Enhancing land capacity for both food production and pollinator conservation is recommended (Burkle et al., 2017) which highlights the need for integrated policy responses to pollinator decline, situated firmly in the wider food system. This presents an added challenge to the epistemological struggles listed above, as it is clear that knowledge – on the part of beekeepers, or scientists - is not enough to improve the situation.

Equally challenging to contemporary environmental policy is the increasingly powerful role of media and public pressure, which is rooted in varied levels of accuracy and understanding. Honey bees have been found to generate a high level of public interest and concern, which is not correlated with accurate knowledge about pollinators or related ecological literacy (Wilson et al., 2017). Media coverage of pollinator decline is being linked to rapid policy responses and pubic actions, which have questionable levels of relevance or efficiency (Gustafsson et al., 2017; Smith et al., 2016). The impact of media and ideologically-influenced coverage of this key environmental challenges has been noted in discussions of climate change (Carvalho, 2007). It is important to explore the role of media and public understandings and responses to pollinator decline, as social and public understandings and concerns about environmental challenges play a role in motivating policy responses (Gustafsson, 2017; Gustafsson et al., 2015).

This chapter has set out the current status of pollinators, the causes of their decline, and the motivation behind policy responses to arrest this decline. It has introduced the tacit knowledge of beekeepers, and instances where their distinct understanding of pollinators and environmental factors affecting their wellbeing has contradicted, or enhanced scientific understanding and policy responses. It has noted the contemporary challenges to appropriate policy response, including political and structural preferences for decision-making based on knowledge generated through a particular method, which often precludes more subjective, tacit observations. It also notes the effect of recent developments in media and public (mis)understanding of pollinator wellbeing. Ultimately, developing effective methods of engagement with beekeepers' environmental knowledge will depend on a reappraisal of epistemological divergence. Operationalising this multiple evidence based understanding of bees and pollinators may then face structural supports, or challenges, within wider food systems and environmental governance.

These issues underpin the research objectives of this thesis. The aim is to investigate the distinct forms of knowledge generated and used by beekeepers, both in their practice and in their negotiations with other stakeholders in bee and pollinator health. The potential contribution of social sciences in understanding, and reversing pollinator decline, is also an objective of this research.

1.5: Structure of Thesis

I will now outline how this thesis will be structured. Chapter Two will discuss the contextual foundations of this research project. There is a range of significant, and inter-related theoretical debates which are relevant to the question of how beekeepers' knowledge is positioned in understanding and reversing pollinator decline. This chapter will explore pertinent writings on the broader subjects of what different types of knowledge exist, how they are created, how they complement, or contradict each other, and how they are validated and utilised by other epistemological communities.

Chapter Three will describe the rationale for the methods used in this thesis, and the subsequent methods used to carry out this research. A variety of methods and data were used, to generate a historical context to contemporary questions of beekeepers' environmental knowledge, as well as their engagement with policy, and science. The methods chosen facilitate a temporally rich analysis of the effect of long-term beekeeping on an individual's environmental knowledge, and their observations on how the physical, as well as the economic and political landscape, has changed over time, with subsequent effects on pollinators.

This thesis will then analyse the empirical findings of this research. Chapter Four will investigate the defining characteristics of beekeepers' knowledge, and their knowledge-making practices. It will discuss the relationships between their tacit practice, and formal scientific understanding of bees and the environment. As beekeeping is a practice carried out primarily on an individual basis, civil society organisations play a varied and important role, particularly for sharing knowledge. This chapter will illustrate the complementary, interdependent nature of beekeepers' individual, and civil society knowledge. Chapter Five will then explore how this distinctive knowledge is used by beekeepers in their practice. As honey bees and other pollinators are facing a range of environmental challenges, this chapter will discuss how beekeepers use their knowledge in their efforts to safely navigate what can be a difficult and challenging environment. It will also discuss when there are limits to the potential for beekeepers' knowledge to be acted upon in their efforts to ensure the health, wellbeing and productivity of their bees. Chapter Six will evidence how beekeepers have worked with other key stakeholders in pollinator wellbeing, namely, scientists, policy-makers, and, increasingly, the wider public. It will discuss differences in knowledge-making practices between different communities, and the impact this has on efforts to operationalise beekeepers' environmental knowledge in efforts to improve the environment on behalf of pollinators. It will also discuss systemic structural challenges to full engagement with the concerns of beekeepers and other stakeholders. Finally, Chapter Seven will be the conclusion to this thesis. The implications of epistemological differences, imbalances in the political status of different knowledge forms, and how this affect pollinators, and the wider environment, will be discussed.

1.6: Notes on terminology, style, and referencing archival sources

As this thesis concerns itself with different forms of knowledge and understanding of the environment, it must first address the fact that in wider discussions of bees, there are certain terms and phrases that are often used interchangeably, but mistakenly. In the UK alone, there are over 250 species of bees, including honey bees, bumble bees, and many more. The subject of discussion in most interviews, archives and secondary data sources was generally 'bees'. In actuality, these instances are usually referring to honey bees – which themselves are commonly referred to as honeybees. However, this conjunction belies a taxonomic truth. Entomological nomenclature uses two words for the common name of insects, when one of these refers to its order. As all true flies belong to the order Diptera, so entomologists use two words for common true fly names: horse fly, house fly, etc. Other insects which are not true flies have their names combined – dragonfly, butterfly, etc. All bees belong to the order of Hymenoptera, so entomologists spell out their name as two words, such as bumble bee, and honey bee. This thesis will follow the guidelines of the Entomological Society of America, and refer to honey bees. It will also, at times, discuss bumble bees, and other bees. When the word 'bee' is used on its own, it will almost certainly be referring to honey bees. If not, this will be stated.

This thesis also makes use of a hitherto unanalysed source of data; namely, the archives of the Bee Farmers Association (originally known as the Honey Producers Association). Since their inception in the 1950s, they distributed a bulletin to their members approximately six times per year. Throughout this thesis, when these bulletins are referred to, it is in the following format: (BFA Bulletin 48: 5/59). This refers to the BFA Bulletin number 48, which was written in May 1959. In 2015, this was renamed *Bee Farmer*, and now has Volume and Issue numbers. For the sake of continuity, the same referencing style has been adopted. So, Bee Farmer 3:4 (8/17) refers to Volume 3, Issue 4, published in August 2017.

Chapter 2: Contextual setting of this research

While the recognition of the significance of pollinator decline, and the stated policy intentions of actively engaging with beekeepers to reverse this decline, are to be lauded, there is a range of challenges to any efforts to connect diverse epistemological communities. The preceding chapter identified beekeeping as an ancient, global practice, where skills and knowledge are often passed down through generations. The practice requires a high level of environmental observation and assessment of multiple, dynamic, synergistic factors. The community of beekeepers is 'a broad church', with different approaches to management and a common tendency to experiment. While the disparate perspectives amidst the sub-communities of beekeepers presents challenges to scientists and policy-makers aiming to engage with their knowledge, these are not insurmountable. There are theoretical and methodological challenges, as well as templates for successfully engaging with multiple publics, which I will discuss in this contextual chapter.

Varied attempts have been made in recent years to deepen human understanding of other species' lives and realities, with some scholars applying a More Than Human (MTH) perspective to their analyses of other species, and *Homo sapiens* engagement with them (Bennett, 2009; Lorimer, 2008; 2015; Whatmore, 2016). As much of beekeepers' practice is based on tacit knowledge and multisensory engagement with bees and their environment, there are potential parallels with this perspective. Notably, Lorimer's work on corncrake surveyors bears some relevance to understanding beekeepers' practice, as both communities describe their multisensory engagement with another species in their efforts to understand it (Lorimer 2008). Lorimer draws important distinctions between the controlled objective research carried out in laboratory-based research conditions, and the messier, more sensual world of ecological field studies. However, I believe that the question of beekeepers' knowledge and its potential utilisation in promoting environmental sustainability is best addressed via other theoretical perspectives.

2.1: Beekeepers' Knowledge in Context

While the MTH approach has been partially utilised by some scholars exploring beekeepers' knowledge (Phillips 2014), in my research I will be primarily engaging with the analytical frameworks surrounding TEK, and Citizen Science (CS). Both these frameworks connect to debates on environmental publics, the role of the amateur enthusiast, and the increasingly hybrid nature of knowledge, where binaries of tacit and scientific understandings are seen as limited when investigating the knowledge, and subsequent decision-making processes, of farmers and other land-workers. Knowledge claims themselves are also examined, as epistemological conflicts and hierarchies manifest a political energy, with contrasting and complementary forms of understanding having disparate levels of power (Mahony and Hulme, 2016; Willems-Braun, 1997). There are also debates surrounding science, power and policy, with scientific environmental understandings recognised as having a stronger knowledge claim than those of other epistemic communities, and subsequently have greater power in environmental governance (Dunlop, 2014; Riesch and Potter, 2014; Robbins, 2006). Therefore, I will address a broad range of theoretical literature in this chapter, and in subsequent empirical chapters. This decision is a result of my research objectives, which aim to investigate the environmental observations and knowledge of beekeepers; their use of their knowledge when making management decisions, and the obstacles to operationalising their knowledge; and their efforts to communicate their unique experiential perspective to other stakeholders in pollinator wellbeing. There is a substantial body of work assessing Traditional / Local Environmental Knowledge, and how it is used within conservation (Bethel et al., 2014; Huntington et al., 2002; Nadasdy, 2014; Oteros-Rozas et al., 2013; Turner et al., 2000). There are also relevant explorations of these issues within Citizen Science studies, exploring different conceptualisations of knowledge, and the challenges of engaging with multiple communities (Evans and Plows, 2016; Irwin, 2001; McQuillan, 2014; Riesch and Potter, 2014). As environmental challenges become more public, and attract media and public attention, new audiences are brought into the realm of understanding and decision-making, and policy responses. Pollinator decline is a global challenge, which has generated a wide of media and public responses (Gustafsson et al., 2017; Smith et al., 2016). However, public interest does not guarantee public knowledge; research has shown that increasing public awareness of, and concern about, pollinator decline has not led to an increase in understanding about pollinators and their environmental needs (Wilson et al., 2017). As the environmental challenges of the anthropocene grow more complex, and more demanding of urgent, radical response, we see that increased media engagement with issues such as climate change often results in simply reinforcing ideological viewpoints, rather than increasing understanding of the challenges of the situations we face (Carvalho, 2007). Similarly, media coverage of pollinator decline is stimulating public actions of limited, or questionable, ecological significance (Gustafsson, 2017). This has been of questionable benefit in terms of significantly rectifying challenging environmental conditions (Hall and Steiner, 2019). Any investigation of the interface between science, policy, and diverse knowledges must also include the possibly superficial, or even inaccurate knowledge generated by media responses to scientific events of consequence. The changing role of media and the public in current environmental challenges is therefore also relevant to this thesis.

Historical and current tensions between beekeepers' knowledge and government policies that impact bee health clearly resonate with a broad range of debates: on citizen science as a way of collecting and monitoring diverse environmental data (Cooper, 2007); on reconciling food security and environmental stability (Ericksen, 2008; Hinrichs, 2014); and the relationships between knowledge and power (Nadasdy, 2003; Ogwuche, 2012, Turner, 2011). These are all significant issues both within academia, and in broader society, as we aim to tackle wicked problems such as climate change, food security and pollinator decline (Candel and Pereira, 2017; Sánchez-Bayo and Wyckhuys, 2019). There are thus both academic and wider motivations for understanding, and, ultimately resolving this tense relationship between beekeepers and policy-makers. The complex changing human relationship with the wider environment, and how best to guide this relationship are topics under investigation in many spheres, not least human geography. The interacting political, environmental, and socio-economic complexities that impact pollinator health make it imperative to bring diverse viewpoints together in a way that deepens understanding of the reality of animal lives in the anthropocene, if we are to improve the wellbeing of pollinators – and other species.

2.2: Environmental Publics

Relating to the topics of Citizen Science, and Traditional Environmental Knowledge, are discussions about Environmental Publics, and Amateurs, as all of these categories interrogate notions of inclusion in understanding, and governing, the environment. Efforts to expand inclusion in decision-making are often affected by the identity and political status of the groups involved, with the very nature of expertise being re-examined (Collins and Evans, 2016). The diverse nature of 'the public' is explored by Evans & Plow (2007). They argue that the distinction between ‘scientists’ and ‘publics’ common to discussions on public participation in science, is misleading. Science is too narrow a category, and public – even ‘publics’ – conflates distinct multiple groups. A simple dichotomy of science and public overlooks the diverse natures of both categories. The multifaceted identity of ‘environmental publics’ has been explored in relation to anglers (Eden and Bear, 2012), illustrating the depth of environmental knowledge generated by this group as they engage in this outdoor activity. The authors also note the movement of individuals between ‘amateur’ and ‘professional’ status, as hobbyists utilise their experience to gain, and inform, professional positions within environmental organisations (ibid).

Eden’s *Environmental Publics* (2016) explores the multifaceted environmental identities of individuals – including but not limited to their knowledge of, participation in, or working in, the environment. We see how any one individual can embody a range of environmental practices and identities, with varied levels of power associated with these positions, even though the knowledge held by an individual is the same, regardless of their personal or professional status. However, their knowledge will be granted different political power depending on the public position in which it is manifest. This relates to points made regarding the nature of ‘citizens’ and ‘publics’: they are diverse groups, often highly educated and already holding a significant degree of scientific knowledge (Ellis et al., 2010; Wynne, 2008). Some detailed ethnographic studies of citizen science projects note that, for many participants, the line between scientist and citizen is blurred, as retired academics, and other post-graduate-level educated persons, engage with gathering data for other projects (Ellis and Waterton, 2016; Jue and Daniels, 2015). This has ramifications for beekeepers, as the level of knowledge and expertise held by participants may be quite high, but not be fully utilised within a consultation, or a citizen science project. Or, they may not be asked questions that have sufficient capacity to engage with the experiential knowledge held by members of the group (Nadasdy, 2005; Nadasdy, 2014; Suryanarayanan and Kleinman, 2013). A similar dissonance has been found in other studies, where the tacit knowledge of communities of natural resource users is either underutilised in land management strategies (Nadasdy, 2014) or is not given the same weight in the decision-making process (Edelenbos et al., 2011).

Current changes in funding streams available to academic scientists have led to a financially pragmatic move towards greater utilisation of CS by research, with civil society organisations being called upon to participate in data collection and generation (Lave, 2012). In the US, recent developments in the shale gas industry have led to shifts in relations between interdependent fields of academic science, environmental regulation, and participatory water monitoring, as community activists forge working relationships with researchers and regulators in shared efforts to understand the effects of fracking, and monitor environmental pollution (Kinchy et al., 2014). Such interdependence creates opportunities, and challenges, for all parties involved. Discrepancies have been found between motives, experiences and understandings of various policy actors towards theory and practice of conservation (Goodwin, 1998). This has been linked to differing relationships with place, and local participation implying, to some degree at least, a shift in the balance of power between technical and political elites - hitherto responsible for directing policy and action - and 'ordinary' people within a locality (ibid). There is an assumption that local involvement will mobilise people to support laudable initiatives. Similarly, there are implicit assumptions – often inaccurate - that local people and conservation professionals have shared expectations regarding ideas, organizational forms, and subsequent outcomes of local participation (Edelenbos et al., 2011). There are significant differences between local initiatives: those that come from participants' production, and those that are seen as contributing to, but not conflicting with, centrally determined objectives. Such differences impact the ultimate success of initiatives (Hegger et al., 2012). These tensions are also an issue in research which relies upon participation from amateurs; this will now be explored.

2.3: Amateurs

As the traditional research agenda has shifted due to economic pressures and political efforts to broaden inclusion, the nature, and role of volunteers in environmental monitoring has also come under investigation. It is clear that these individuals often bring extensive biological and environmental knowledge to their work, coupled with a level of personal commitment and concern for the environment that often transcends the supposed objectivism that is considered key to scientific investigations (Ellis and Waterton, 2016; Ellis and Waterton, 2004). Related studies on the geographies of enthusiasm also note the centrality of emotional involvement amongst members of local historical groups, and in Citizen Science (CS) projects

(Craggs et al., 2016; Geoghegan, 2013). The capacity and commitment of amateurs in generating meteorological knowledge is of immense value in understanding microclimates and phenological changes (Endfield and Morris, 2012a). Multiple obstacles to wider recognition of amateurs' talents abound; not least being gendered perspectives of 'appropriate' interests (Endfield and Morris, 2012b). This manifests in current debates on beekeeping practices, where a new approach emphasises a more nurturing, ecological stewardship, and a move away from what some see as historically exploitative practices (Green and Ginn, 2014). This change in emphasis is seen by some as underlying an increase in the attraction of more women to a traditionally male activity (Lorenz and Stark, 2015; Moore and Kosut, 2013a). This shift in practitioners coincides with struggles within the admittedly heterogeneous beekeeping community to have their environmental concerns recognised by wider stakeholders in bee health: methods of knowing bees, and the environment, often face obstacles to being acknowledged in knowledge spheres which emphasise linear analyses (Suryanarayanan, 2016; Suryanarayanan et al., 2018)

Natural history is a field which attracts a tremendous range of individuals, united in their immense dedication and rich expertise, whether they utilise this in a formal academic and/or a personal, informal capacity (Ellis and Waterton, 2004; 2016; Ellis et al., 2010). Ironically, historians of science point out that the current divide between science and the wider public has only evolved since the 20th century (Secord, 1994). Scientific investigations in the 19th century engaged with an eclectic group of knowledge holders and creators (ibid). Although there has been a hardening of boundaries between science and amateurs, recent years have also seen a dramatic increase in the number of people accessing higher education, with a resultant significant impact on the nature of amateurs, and volunteers. Many countries in the global North present an increasingly educated populace at all points of the demographic spectrum, particularly amongst retirees. This groups' potential contribution to society and the economy is being recognised (Heley and Jones, 2013), with clear implications for environmental knowledge and assessment.

Although individuals who participate in many environmental monitoring and assessment activities are notably well informed, questions of legitimacy, professionalism, objectivity and quality of knowledge produced are recurrent themes in debates on CS and knowledge production (Ellis and Waterton, 2004; Jalbert and Kinchy, 2015; Lave, 2012). There are also questions as to the purposes of data collection, and ownership of data once generated (Riesch and Potter, 2014). When scientific questions are investigated as a response to social and environmental challenges, the future relevance and applicability of results is important to consider in the outset of research design. Pollinator decline presents the scientific community, and the wider public, with several distinct, and inter-related, challenges. Research projects which incorporate CS in their methodology are often aiming to achieve multiple, seemingly disparate goals; namely, to generate data on environmental challenges, and also to raise the consciousness of participants, and the general public who may encounter the projects and/or research participants (Bonney et al., 2009; Donnelly et al., 2014; Kinchy et al., 2014). In contrast, beekeepers are already highly engaged with the environment. If they are being encouraged to participate in projects which are presented as a way of encouraging people to become more engaged with the natural environment, this research goal is redundant at best, and potentially alienating due to a tone which is designed to appeal to a very different demographic than most experienced beekeepers.

As much of the predominant research on pollinator wellbeing is carried out via life science analyses of bee biology and ecology, the qualitative and quantitative data provided by beekeepers often sits uncomfortably within this formal network. Wider debates on CS note the diverse benefits of having individuals actively engaging with the environment they are seeking to monitor (Donnelly et al., 2014; Trumbull et al., 2000). With regard to water quality sampling, some authors note that, while computerised data loggers may generate a quality and quantity of data preferred by industry and policy-makers, there are advantages to having volunteers out collecting samples manually (Jalbert and Kinchy, 2015). The presence of people publicly carrying out monitoring activities can serve to generate conversation, debate, and exploration of key environmental issue. Similarly, the recent rise in beekeeping as an activity has led some to propose that one of the key benefits of pollinator policies that encourage beekeeping and landscape enhancement for pollinators is the potential for public education regarding the importance of forage for pollinators (Moore and Kosut, 2013a). It is also worth deeper investigation of beekeepers' observations of planting changes in the areas they manage apiaries, and whether they perceive this as having had any impact on bees.

There is also the wider question of visceral responses to landscape. Authors have found that volunteers who are engaged in environmental monitoring projects develop a stronger sense of ecosystems' functioning, and fragility (Goodwin, 1998; Lorimer, 2008). While automated data loggers and other remote monitoring devices can make significant contributions to environmental monitoring, there is strong evidence that they should complement, rather than replace, direct human observations (Jalbert and Kinchy, 2015). The multisensory nature of environmental engagement is also discussed by Lorimer, in his work on corncrake surveys (Lorimer, 2008). He examines the often awkward relationship between surveyors working in the field, utilising all their senses in their quest for corncrakes – and the scientists who require such data to be transformed into quantitative results that can be easily analysed (ibid). Similarly, the changing relationship between volunteers and formal researchers is also explored by Ellis & Waterton (2005). Here, again, we see a tension between volunteers, who bring a multisensory passion, as well as expertise to their observations of the natural world, and the scientists who make use of the data collected. Volunteers are often highly informed and skilled, and express concern that their broad, holistic environmental perspective is subsumed within the more formal analytical processes to which they are being asked to contribute.

While it may be tempting to dismiss such tensions as the personal and professional differences between differing communities – the professional, and the amateur – studies show how decision-making on resource management is altered according to the type of data utilised (Turner, 2003). Beekeepers are known to base their practice decisions on a broad range of inter-related factors, many of which are interpreted via tacit knowledge developed over years of engagement with bees (Phillips, 2014; Suryanarayanan & Kleinman, 2013a). Beekeepers are ideally placed to provide direct observational evidence on bee health, and the state of the wider environment. Over the past five years, local beekeeping organisations have witnessed unprecedented increases in people wanting to study beekeeping courses. This presents a tremendous social and scientific opportunity to increase the quantity, and quality, of observational data on bees and their environment. The potential for this within the context of Citizen Science will now be explored.

2.4: Citizen Science

Beekeepers exhibit many of the characteristics of informed amateurs, and complex environmental publics, who therefore hold a great potential to make a unique and invaluable contribution to Citizen Science (CS) projects focusing on pollinators. As well as honey bees, other pollinators are being monitored via CS projects (Birkin and Goulson, 2015). While this widening of analysis of pollinator well-being should be lauded and encouraged, it is important to consider the historical structural challenges, limitations and complexities associated with CS that may limit this potential. Underlying much of CS is a fairly rigid hierarchical structure, with scientists at the top, and citizens below (Geoghegan et al., 2016; McQuillan, 2014). The second group is in an inherently subsidiary position; often encouraged to carry out nominal tasks which generate straightforward quantitative data, which is then supplied to those with higher authority and training. This leads to questions about who owns, controls, holds and utilises the data once it is gathered (Ellis and Waterton, 2004; 2016). Research done on the outcomes of CS projects has noted that one of the central critiques, namely, that 'citizens' are incapable of providing quality data, is not borne out (Cohn, 2008; Follett and Strezov, 2015).

CS has been promoted as a method to increase public engagement with the natural environment (Aceves-Bueno et al., 2015; Levitt, 2002), an educational tool (Bonney et al., 2009) and a way to improve monitoring of biodiversity and climate change (Donnelly et al., 2014). It is also questioned by some who doubt the veracity and quality of data collected (McKelvey et al., 2008). Some see it as a means of outsourcing scientific research, and part of a broader neoliberal restructuring of academia (Lave, 2012; Riesch and Potter, 2014). Others are increasingly exploring the political potential of CS, as communities become involved in monitoring pollution, deforestation, and other environmental hazards impacting their lives, and use the data they collect to support campaigns for environmental justice (Jalbert and Kinchy, 2015; Kinchy et al., 2014). These differing conceptualisations of CS have an impact on research methodologies, type of data collected, generated, and utilised (Cohn, 2008; Jalbert and Kinchy, 2015; Riesch and Potter, 2014).

Much conservation work is rooted in the idea that humans are far more prone to engage with environmental protection once they have some degree of understanding of, and connection to, a particular landscape (Barthel et al., 2013; Ellis and Waterton, 2004). This serves as the guiding premise for many projects using CS, which aims to encourage people to interact with the natural environment. Encouraging and facilitating such engagement is seen as a cornerstone of many CS projects (Bonney et al., 2009; Donnelly et al., 2014; Jue and Daniels, 2015). Indeed, the assessment of a 'successful' CS project, and its impact, often entails measuring the improvement in public scientific literacy generated by a project (Bonney et al

2009). CS is also seen as a tool to help people to develop critical thinking skills (ibid). CS projects such as the US Christmas Bird Count, and the UK's RSPB Garden Bird Watch, are classic models based on this approach. The public is conceptualised as a 'blank slate', suitable for collecting fairly simple, straightforward data, which is then handed over to 'real' scientists, who can study it properly. This approach raises a variety of questions, particularly with regard to engaging with beekeepers in CS projects. First – this model implies a 'knowledge deficit' amongst participants. In contrast, research has found that many who take part in a broad range of CS projects are already scientists, science teachers, students or others with a relatively high level of education and knowledge (Bell et al., 2008; Cohn, 2008; Ellis and Waterton, 2016; Ellis and Waterton, 2004). As many CS projects are framed according to an assumption of a low level of scientific knowledge amongst participants (Irwin, 2001; Riesch and Potter, 2014; Trumbull et al., 2000) there is a serious risk of projects failing to maximise the potential benefits of participant engagement.

While beekeepers are a diverse group, many bring to their practice a high level of experience and education about the wider environmental conditions which affect their bees (Green and Ginn, 2014; Maderson and Wynne-Jones, 2016; Moore and Kosut, 2013a; Phillips, 2014). This leads to a high potential for a fundamental weakness when designing CS projects that are intended to engage beekeepers; namely, many of this group have a high level of experience and knowledge of the environment. Unlike the hypothetical participant of many CS projects, beekeepers do not need to be encouraged to engage with the environment – they are already highly engaged, and knowledgeable. If a project is developed and promoted in a way which emphasises the opportunity for participants to engage with, and learn about the environment, those who are already learned and engaged may well be disinclined to take part, thus reinforcing the image of CS participants as relatively uninformed novices. Similarly, CS project designers run the risk of under-utilising the breadth of knowledge held by beekeepers, if the project has not been co-designed, or offer the capacity for high level contributions. Similar failures to engage with local epistemologies have hindered the contributory potential of subsistence communities and resource users to policy (Robbins, 2006).

For diverse reasons, CS projects are increasingly being designed in ways that engage with participants on deeper, more significant levels. Bonney et al (2007) call for projects where people are fully engaged with the scientific process, from beginning to end. Interestingly, they do not suggest that the public should be setting the research agenda – rather, they should simply be part of the project throughout the full process. This is different from the growing attention to the 'countercultural' potential of CS (McQuillan 2014). As CS becomes an accepted part of the academic establishment and its data is acknowledged as valid, so there are others who question the fundamentally top-down design of most CS projects. For this latter group, the potential of the Internet to connect researchers, campaigners, crowd-sourcing funders, and more, ushers with it the potential for CS to connect with countercultural movements and motivations. UCL's Extreme Citizen Science (ExCiteS) group, and the US-based Public Laboratory for Open Technology and Science are both driven by an ethos of democratizing science, and collecting – and sharing – data, to help communities gain environmental justice. Rather than the traditional format of most conventional science, and CS projects, this approach is noted for research questions that are focused on addressing local issues, and driven by on-the-ground community work.

2.4a: Data: who collects what, how – and what do they do with it?

For many scientists and policy-makers, data collected via automate data loggers, or other technological means, is seen as less biased and of higher quality than observations by people in CS or other projects (Jalbert and Kinchy, 2015). Ironically, much of CS was developed to increase the amount of data available to scientists working on research projects. Now, as technology has become cheaper and more accessible, there is frequently more data generated than can be assessed (ibid). A growing number of scholars and activists see CS as a tool for challenging the hierarchies and entrenched power relations associated with much of contemporary science (Buckingham Shum et al., 2012; Stevens et al., 2014). In one example, community activists felt that the scientific averages of air pollutants ignored 'spikes' on pollution, which they felt were damaging their health (Jalbert, 2014). Groups such as the Community Science Institute run several projects which aim to enable people to 'collect scientifically credible data for use in protecting the environment and the sustainable management of natural resources' (Community Science 2016). This approach is indicative of a more politicised, activist approach to CS, where communities are encouraged to collect data that can be used within government and scientific spheres of decision-making on resource use. There is also a growing move towards participatory decision-making on governance

(Irwin, 2001; Maynard, 2015). Engaging with stakeholders, and utilising data produced and collected by multiple, diverse communities, is one method to ensure more representative decision-making. Here, we see a distinct shift in purpose of CS. The direction of the information flow is two-way, and for a purpose above and beyond academic research. While the Cornell Laboratory of Ornithology (CLO) and many of its CS projects are conceptualised in terms of engaging publics to learn about, engage with, and protect their environments and biodiversity, we are now seeing a growth in organisations, and researchers, who span the categories of scientist, academic, researcher, and campaigner. Current developments in pollinator policy all encourage the participation of beekeepers as well as many other recognised stakeholders, such as land managers, scientific researchers, and government representatives (DEFRA, 2014). Such policies may well benefit from engaging with all stakeholders from the outset in ways which aim for epistemological parity and the coproduction of knowledge (Aceves-Bueno et al., 2015; Edelenbos et al., 2011)

Within the rapidly expanding field of participants and technologies in CS projects, attention is moving to consideration of the types of data collected, and the technologies used to do so, as well as who is involved in collecting data (Aceves-Bueno et al., 2015; Cohn, 2008; Irwin, 2001; Jalbert and Kinchy, 2015). The methods of data collection are recognised as having a profound impact on how questions are posed, and answers. The advent of easily accessible, hand-held mobile technologies has revolutionised CS and other research. While this has helped support the development of many projects, and to increase the numbers of people participating, there are questions as to whether such monitoring devices can reduce perceptions of environmental complexity down to what can be represented in quantitative measurements (Buckingham Shum et al., 2012; Donnelly et al., 2014; Jue and Daniels, 2015). These methods can decontextualize, and depoliticise, issues. Other studies on the use of Geographic Information Systems and Remote Sensing (GIS and RS, respectively) raise similar questions. Turner (2003) writes that their usage reinforces earlier forms of scientific enquiry, which have been questioned since the mid-1980s by both social and physical scientists. In contrast, social scientists are more inclined to carry out field-orientated research, and engage with the multi-stranded complexities of human – environment relationships. He addresses the challenge of integrating views from 'above' and 'below', stating that overcoming this challenge is 'far from automatic, epistemologically hazardous, and time-consuming' (ibid). A key point of Turner's argument is that it is not enough to ignore social and ecological variables because we do not have the data: the choice of data will very much influence causal inference. Increased use of GIS and RS data has not revolutionised the ways we analyse people-environment relations in the Sahel, but actually further entrenched traditional modes of analysis. Turner argues that the widespread failure of the application of these technologies to elucidate and resolve human ecological issues rests largely with theories and methodologies within which these technologies have been integrated. This is a key issue in understanding the position of beekeepers' knowledge, as similar tensions have been found in efforts to understand bees, which exist in an inescapably, inherently complex world, which struggles to be reduced to singular factorial analysis (Suryanarayanan, 2016). In contrast to epidemiological methods of understanding health and generating reliable evidence, bee health is seen as exemplary of requiring a transdisciplinary analytical approach, which actively accepts the existence of diverse epistemological understandings of the situation (Suryanarayanan et al., 2018). The authors argue for the necessity of a pluralistic analysis that engages with both scientific and tacit forms of understanding this crisis (ibid).

It has been proposed that there is a false dichotomy between 'scientific' and 'local' knowledge (Robbins, 2003). He points out that there are aspects of culture impacting ALL knowledge forms. For both local knowledge producers and expert managers, the cultural meaning of landscapes is dependent on their roles in regional production and resource politics. An objective scientific analysis, of the kind preferred in evidence-based policy decisions, risks overlooking important cultural contexts and historical factors that impact physical resource use and condition. The spatial and ecological understanding expressed by those with long familiarity with local environments has been shown to be superior in quality and resolution to those gathered remotely and modelled digitally (Turner & Hiernaux, 2001). Similarly, when examining the potentially complementary analyses of GIS and ethnographic research, Robbins discusses variants of forest, vegetation and soil types, according to foresters, and herders. Political conditions encourage foresters to increase the acreage under forest cover. In reality, this might not actually be happening - it might be different types of ground cover. Such subtleties are more accurately assessed by on the ground analyses, which can enrich GIS analysis (Robbins 2003). Similar discrepancies, and potential complementarities, have been found in some of the limited current work on bees and beekeepers' practices (Lehébel-Péron et al., 2016; Lezaun, 2011). As pollinator decline is recognised as resulting from complex synergies, it is important to engage with all forms of data, particularly observational and historical records of beekeepers, many of whom have kept bees in one area for decades. Beekeepers' knowledge, and their decision-making process, is subtle, complex, and incorporates a range of information, including but not limited to local agricultural practices, weather patterns, and more tacit, experiential knowledge (Phillips, 2014; Suryanarayanan and Kleinman, 2013). If pollinator strategies focus on collecting basic quantitative observations from beekeepers and other members of the non-academic community, there is a risk that the full range of knowledge held by beekeepers cannot, and will not, be accessed via comparatively simplistic technological data capture. Thus, the importance of actively engaging with beekeepers and their direct experiential knowledge when both designing and analysing results of CS projects analysing bees and the environment, is paramount.

2.4b: Data quality and reliability

Although some CS projects may be emphasising the public education / consciousness raising aspect of a project, the importance of scientific rigour when collecting samples is always critical, to maximise political impact of data (Riesch and Potter, 2014). This emphasis on all participants 'speaking the same language' – eg, generating data that is presented in the same form - relate to discussions on the same terminology and frameworks being utilised by scientist and policy-makers, but which may differ from that of on-the-ground stakeholders (Edelenbos et al., 2011; Nadasdy, 2014). This is a recurrent challenge found within debates on CS, and also within discussions of TEK, and participatory governance (Hegger et al., 2012; Irwin, 2001; Nadasdy, 2005).

A constant refrain amidst discussions of CS is the issue of data quality. For many scientists, the data collected by volunteers is inherently suspect (Follett and Strezov, 2015; Riesch and Potter, 2014). However, analyses of CS projects do not bear out these concerns (ibid). Indeed, these authors found that research projects based on CS-generated data have high rates of publication in peer-reviewed journals, and have been successfully used to attain biodiversity conservation regulations. The high level of quality of data collected in CS projects could be linked to the demographics of participants. While the early CS model frames projects as a means to educate and engage the public in their local environment, studies of CS projects show that participants are usually highly educated and informed (Bell et al., 2008; Ellis and Waterton, 2004; Ellis et al., 2010; Evans and Plows, 2007). Interestingly, some involved with CS projects argue that there is currently a higher expectation on such projects than there is in conventional science, which, they argue, is equally prone to errors and oversights, particularly in the current 'publish or perish' academic landscape (McQuillan, 2014). It has also been found that CS projects which engage with stakeholders from the outset in program design and implementation are more effective in supporting adaptive management programmes (Aceves-Bueno et al., 2015). Although the authors admit the risk of projects being 'hijacked' by activist stakeholders, their findings reflect a growing trend towards going beyond the public education model of CS, to a more politically and environmentally engaged vision. This growing trend towards a CS model that goes beyond rudimentary public education holds potential for capturing far more of beekeepers' nuanced knowledge.

2.4c: Citizen Science and Beekeepers' Knowledge

A key reason for engaging with critical literature on CS for this project is the frequent use of beekeepers' quantitative data in CS studies on bee health. An example of this is the COLOSS project 'CSI Pollen', which ran from 2014 – 15, enlisting beekeepers to collect pollen for analysis. The project's aim was 'to make an international inventory of pollen diversity linked to land use and the honey bee season' (van der Steen and Brodschneider, 2015). This project clearly fits in with the early, classic CS model of large scale projects devised by professional research scientists, enlisting the support of volunteers in collecting data which is then passed 'up the ladder' to scientists. The data collection is relatively menial, the project did not enlist stakeholders in its design, and participants are not engaged in the data analysis. Other similar projects have also called on beekeepers to submit honey samples, which are then analysed to assess the pollen contents as a way of gauging what plants bees are feeding on (de Vere et al., 2017). Annual reports to Bee Base in the UK, and the Bee Informed Project in the US, ask beekeepers how many of their colonies survive the winter, possible causes of the colony's demise, and other aspects of bee husbandry (Seitz et al., 2016). While all the projects described here show that researchers on pollinator health do work directly with beekeepers, the extent of this working relationship is open to question. These projects suggest a preponderance of quantitative analyses which position beekeepers as raw data providers, distanced from the research design and subsequent analysis.

The current rise in CS projects which are designed to help communities monitor their environment, and lobby for environmental protection, is clearly relevant when considering how beekeepers' knowledge can be utilised to support environmental protection. As the current international drive to address pollinator decline explicitly promotes engaging with beekeepers as key stakeholders, the success of such strategies is bound to be impacted by the quality of communications, and the ability of strategies to fully engage with the observations and recommendations of beekeepers. Much of the potential for successful engagement requires a reappraisal of how we consider knowledge. I have discussed different categories of knowledge holders, and how different conceptualisations of amateurs, experts, and citizens affect the design and implementation of research projects and their participants. I will now discuss how the actual knowledge generated and held by individuals is being re-examined and repositioned in ways which increases their potential benefits to environmental understanding and monitoring.

2.5: Tacit & Hybrid Knowledge

As perceptions of the public and expertise have grown more nuanced, so have explorations into knowledge revealed a far more complex arena of different forms of knowledge. As there are multiple publics, and sub-categories of science, so there are also multiple forms of knowledge. Stehr, in his aptly entitled article '*A world made of knowledge*' states 'The power of science / technical knowledge in modern society is that this form of knowledge, more than any other, incessantly creates new opportunities for action' (Stehr, 2001, p 89-90). He goes on to state 'If knowledge is the main constitutive characteristic of modern society, then the production, reproduction, distribution and realization of knowledge cannot avoid becoming politicized. Thus one of the most important questions facing us in the next decade will be how to monitor and control knowledge.' (ibid, p 92) As policy-makers work to address environmental challenges, debates are increasingly about understanding, and integrating, different types of knowledge (Fazey et al., 2014; Jasanoff, 2004; Whatmore, 2009). The current preference for evidence-based policy assumes a higher level of veracity and reliability within scientific data, and prefers such evidence to support practical decision-making (Dicks et al., 2013). However, this model is based on a particular approach to testing hypotheses within Randomised Control Trials (RCT), and generating quantifiable data (Cartwright and Hardie, 2012; Cowen et al., 2017). While this is acceptable and appropriate for some decisions, it is not necessarily appropriate for understanding and acting on environmental complexities (Saltelli and Giampietro, 2017). This is a question that resonates powerfully with debates on CS, TEK, and with the question of beekeepers' views on, and engagement with, pollinator policy. Problems of legitimacy in knowledge production and decision making, and the associated problems of the different motivations and perspectives of different groups, have led to situations where expertise has shifted. No longer is knowledge seen as the sole domain of a limited elite; rather, it is public property, held by many, and in diverse forms. Some authors talk of 'coproduced knowledge' as meeting the full criteria of being scientifically valid, socially robust, and useful for policy-making (Edelenbos et al., 2011). The importance of understanding multiple knowledges and bringing together diverse perspectives is noted by many studying communities' approaches to land management (Bethel et al., 2014; Ingram, 2008; Tengo et al., 2014). This is particularly common when researching the environmental knowledge of farmers, hunters and other land workers, and its potential to support sustainable management practices. It has been said that 'conservation biology needs to be …eclectic and multidisciplinary' (Fazey et al., 2006, p4). This eclecticism is recognised by others working on combining scientific and lay knowledges, and has been found amongst organic farmers, who developed knowledge-sharing opportunities within their communities to supplement a lack of formal support (Ingram, 2008). It is recognised that farmers have significant pre-existing tacit knowledge of local environmental conditions, which must be understood and respected, with appropriate supplementation to address knowledge gaps relevant to conservation (ibid). Analysis of soil and related conditions central to successful farming frequently show individuals combining both tacit experience, and formal education and training (Barbero-Sierra et al., 2017; Šūmane et al., 2018). Similarly, gaps in scientific understanding of local agricultural conditions have been found to be successfully addressed through partnerships with local farmers, where epistemological parity of diverse knowledge systems is accepted (ibid). Experiential knowledge of wider environmental conditions is recognised as complementary to, yet distinctive from, scientific analysis (Mukherjee et al., 2018; Sutherland et al., 2013). Oral histories of farmers' knowledge have been found to offer a valuable perspective on land use practices, and the historical socioeconomic forces which have driven environmental changes (Riley and Harvey, 2007). Such experiential knowledge offer a rich counterbalance to scientific analyses of soil conditions and landscape development (Harvey and Riley, 2005). Efforts to develop sustainable agricultural systems are found to benefit from constructivist approaches to working with tacit knowledge (Curry and Kirwan, 2014). Given the centrality of industrial agriculture to pollinator decline, it is appropriate to consider tackling pollinator decline within the context of alternative agricultural systems, and the hybrid knowledge systems of farmers and other land users that can support such developments. Constructive scientific and policy engagement with hybrid knowledge systems relies on a reappraisal of experts, and expertise, and the relationship of such knowledge to scientific understandings.

Fazey et al (2006) define experiential and expert knowledge, then look at how these can complement scientific knowledge. The authors examine the interplay between experiential knowledge and conservation research. They address the lack of research and data in much conservation work. Since environmental systems are complex, and conservation often requires immediate action, experiential knowledge is often the best evidence that is available. There are further subdivisions of experiential knowledge – explicit, implicit and tacit. Recognised experts gain this status via extensive experience which often includes awareness of broader socioeconomic conditions and ecological systems. The benefits of combining different forms of environmental understanding have also been promoted by researchers investigating the decline of heather honey in France (Lehébel-Péron et al., 2016); marine mammals in China (Turvey et al., 2013); and the role of neonicotinoids in bee decline (Maxim and van der Sluijs, 2007; van der Sluijs et al., 2013). The challenge is to assess different forms of knowledge, and develop practical methodologies for integrating seemingly disparate perspectives into a successful blueprint for action. This is certainly the case when addressing pollinator decline. While the majority of research on this topic is within the life sciences, there is a wealth of observational data generated by beekeepers which can contribute to successfully guiding land use and natural resource management policy. While beekeepers develop a strong experiential understanding of the environmental conditions in the areas they keep their bees, this knowledge is often used in tandem with other information sources, as part of a diverse information framework that underlies their beekeeping practice (Maderson and Wynne-Jones, 2016; Phillips, 2014). It is also relevant to note that beekeeping practices are not uniform; there is a broad range of practices followed, with a recent rise in those who link their beekeeping to wider environmental and political perceptions (Green and Ginn, 2014).

This section has illustrated how diverse land users combine a range of information sources to guide their practice. These communities emphasise the importance of tacit knowledge, both in itself and in combination with scientific knowledge as a hybrid form of understanding. While their practices often require a high level of environmental knowledge, this often takes forms which are epistemologically different from that relied upon in scientific analysis and policy-making. The final section of this chapter will focus on how these issues manifest within the context of Traditional Environmental Knowledge, or TEK.

2.6: Traditional Environmental Knowledge (TEK)

Rooted in the work of anthropologists such as Levi-Strauss, Geertz and others, a growing number of authors in the 1990s began to promote the concept of TEK – or Traditional Environmental Knowledge (Agrawal, 1995; Berkes et al., 2000; Turner et al., 2000; Usher, 2000). Specific definitions vary, but the following is widely accepted and used within discussions of TEK:

> *TEK is the cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down in generations by cultural transmission, about relationships of living beings (including humans) with one another and their environment (Berkes et al., 2000, p 1252).*

Before TEK became a commonly used term, similar forms of knowledge were primarily referred to as Indigenous Knowledge (IK). The terms are often used interchangeably; however, IK is seen as uncomfortably linked to a post-colonial framework, with an inherent secondary status of 'indigenous'. Indigenous knowledge connotes a form of knowledge that is less impacted by modernity; in contrast, TEK systems are increasingly found to be open to external influences, and combine various technologies and forms of engaging with the environment (Inglis, 2004; Raymond et al., 2010). The use of the term 'traditional' has not transcended such debates on status and the pejorative connotations of terminology, as shall be discussed later.

For many authors, TEK is associated with the particular world views of its holders, and elements of spirituality (Berkes, 2004; Olsson et al., 2004). This has led some to argue that

TEK is not an appropriate component of formal contemporary environmental assessment, as its rationality is limited by wider spiritual components (Howard and Widdowson, 1996 – in Martin et al 2009). For others, the key defining feature of TEK is as a form of situated knowledge (Ianni et al., 2015; Ogwuche, 2012; Oteros-Rozas et al., 2013). Similarly, others emphasise TEK's defining feature as being linked to a long-term association with a specific physical area; often, this link is over several generations (Altieri, 2008; Ianni et al., 2015; Knudsen, 2008). Huntington et al (2002) write 'in a broad sense, TEK refers to knowledge gained by persons with a long history of living or working in a given area'. This knowledge is not static, but reflects changes in resource use patterns and other aspects of the relationship between people and their surroundings, including the influence of scientific and other forms of knowledge. This admission of the plasticity of TEK, and its capacity to become infused with other forms of knowledge, is important. Although this knowledge can be, and increasingly is, combined by practitioners with formal training, and/or modern technologies, the practical element of TEK, rooted in a particular location, is a paramount feature.

The geographically situated specificity of TEK and its individual holders is problematic for some authors. Raymond et al (2010) list different definitions of knowledge within the environmental management literature. TEK is noted for being passed down through generations, and rooted in place-based practices. In contrast, scientific knowledge is distinguishable via its methodological approach, based on universally agreed principles which are associated with creating knowledge which is reliable, applicable and valid, regardless of local factors. This universality of rules surrounding scientific knowledge is key. However, the authors note that such categorisation can be misleading, as they may not sufficiently address the complex realities of how individuals learn, and assess new information.

Methodological differences between TEK and scientific knowledge are a central concern for some authors. Don (2010) notes that the purported benefits of TEK in terms of its long-term analysis can be, and are, provided by other long-term studies which adhere to rules of scientific objectivity. It is suggested that a broader use of scientific method and research may generate sufficient, and more reliable environmental knowledge, which would subsequently make the inclusion of TEK redundant in environmental understanding and management. The risk of erroneous information being perpetuated via TEK has been noted by Moller (2009), and Bart (2010). Science is seen by some as an inherently more reliable method of generating knowledge, as not all ways of knowing are reliable and accurate (Dickison 2009). The confusion surrounding TEK's accuracy, validity and potential role in environmental understanding may be partially rooted in a tendency for a lack of methodological clarity when discussing the use of TEK (Breton-Honeyman et al 2015). Authors note a lack of explicit detail surrounding the collection, documentation and use of TEK in relevant literature. Given the potential for internal contradiction of TEK, Usher (2000) suggests TEK must be subject to the same critical analysis as any knowledge claim, and is best used in conjunction with other forms of knowledge.

While this thesis recognises debates concerning TEK's epistemological validity and limitations, it also notes historical developments surrounding the description and application of TEK, which have ultimately led to a more refined and nuanced engagement with this rich form of environmental understanding. As this thesis both uses, and aims to contribute to the theoretical developments of TEK as a method of environmental understanding and management, it is important to reflect on the historical understanding, and use, of the term. Amongst the literature on different forms of situated environmental knowledge, there is often reference to Local Environmental Knowledge, or Local Knowledge (LEK and LK, respectively). While the terms TEK, LEK, and LK are sometimes used interchangeably, some researchers find a subtle difference between them, particularly when utilised in conservation research. It has been proposed that LK may be more accurate in providing objective quantitative data of the type emphasised by conservationists and biologists working to monitor biodiversity (Turvey et al., 2013). The authors frame TEK as linked to long-term, multi-generational engagement with a particular region. In comparison, LK is portrayed as a type of environmental knowledge that can be 'learned' more quickly, and is more flexible and responsive to actual conditions (ibid). The authors describe TEK as being prone to influence from traditions and history which may not be fully accurate in the present situation. It is important to note that here, the authors are discussing the potential for LEK to provide *quantitative* data for use in scientific studies. In contrast, TEK is often qualitative as well as quantitative. Most social scientists investigating TEK use ethnographic, qualitative research methods to fully comprehend the depth and breadth of knowledge held in TEK systems (Cruikshank, 2012; Luo et al., 2009; Oteros-Rozas et al., 2013). Some would argue that merely extracting the quantitative elements alone is an inaccurate and incomplete engagement with TEK systems, and further evidence of a common misuse amongst attempts to incorporate TEK with other knowledge systems (Nadasdy, 2005).

Variability and distinctions within, and between, the terms TEK and LEK are important to understand, particularly with regards to how these terms can help understand beekeepers' knowledge. Ultimately, these terms are all rooted in the experiential understanding of individuals and communities in a particular location. The cultural significance of the elements of cultural values, spirituality, and technological usage are variable. Key features of both LEK and TEK are the practical, location-based understandings of a particular ecosystem's complexities. There are often strong intuitive elements. Decisions regarding natural resource use and management are taken based on a fundamentally instinctive analysis of a range of factors, including weather and animal behaviour (Luo et al., 2009; Nadasdy, 2007; Royer et al., 2013).

The reframing of TEK from knowledge intrinsically linked to a particular world view, or spiritual element, to a form of knowledge primarily characterised by its rootedness to a particular location, and transmitted from one generation to another, has led to its being recognised as an active guiding paradigm in a variety of communities. While early writers on TEK were primarily looking at remote, First Nation communities (Berkes et al., 2000; Davidson-Hunt, 2006; Nadasdy, 2007) TEK's relevance is now seen to be far wider. TEK has been found to be present and pertinent in Italian Alpine villages (Ianni et al., 2015); Spanish transhumanists (Oteros-Rozas et al., 2013); Turkish fishing communities (Knudsen, 2008), Norwegian farmers (Wehn et al., 2018) and Louisiana coastal communities (Bethel et al., 2014). It is also being examined in archival sources on the internet, and being seen as a potential approach to environmental restoration in agricultural regions (Burton and Riley, 2018). TEK's rootedness in particular environments is increasingly seen as a potential source of agricultural and environmental resilience, as these knowledge systems encourages flexible, sustainable, ecosystem management, and emphasise feedback learning, within the context of inherently fluid and unpredictable ecosystems (Berkes et al., 2000). The future survival of TEK is seen by some as dependent on its ability to evolve, and merge with western, scientific knowledge systems (Davidson-Hunt, 2006; Ogwuche, 2012). It is important to note that TEK is not solely limited to static practices passed down through generations, but is also used in combination with a broad range of contemporary equipment. While TEK holders may be working with 'modern' technologies, their assessment of environmental conditions, and the decision-making process, are still linked to users' experiential, historical local knowledge of their distinct physical setting. These elements of first-hand knowledge, linked to a particular locale, are key aspects of beekeepers' knowledge (Lehébel-Péron et al., 2016; Phillips, 2014).

Given that many beekeepers have worked in one region for several generations, while others have travelled and / or kept bees in a variety of locations, there are benefits and disadvantages associated with both TEK and LEK as conceptual frameworks for understanding beekeepers' knowledge. As much of the wider research on the political factors impacting TEK & LEK predominantly talks about TEK, for the purposes of consistency, I will use the term TEK, albeit with the caveat that there are times when LEK would be more appropriate.

While there are points of similarity and overlap, a key difference between TEK and classical 'scientific' knowledge, is TEK's situated nature, characterised by a view of ecosystems from within. It is important to note that TEK is not fixed, and is constantly evolving: new knowledge is created via a 'conversation' with the local ecosystem. So, while TEK is flexible, any new knowledge generated is specific to its locale. Research has been carried out bringing together Evolutionary Biology Knowledge (EBK) and TEK (Fraser et al., 2006). The authors concluded that the two forms of knowledge can be complementary, with TEK providing deep detail on geographically specific small areas.

There is increased awareness of the potential for traditional environmental knowledge, or TEK, to complement other forms of data when monitoring environmental conditions (Bethel et al., 2014; Fazey et al., 2006; Royer et al., 2013). Anthropological engagement with environmental conservation is often rooted in issues of local or indigenous knowledge (Nazarea 2006). The anthropological perspective, and methodology, focuses on the importance of space, and the specificity of local knowledge (ibid). This approach brings a practical, if challenging, element to conservation projects, in that it is specifically rooted to a locality. Such localism can be a boon and an obstacle to researchers and policy makers who may be aiming to develop strategies which can be presented as being widely applicable, and able to incorporate local adaptations (Barron et al., 2015; Bear, 2006; Edelenbos et al., 2011; Fraser et al., 2006; Harrison, 2006; Tengo et al., 2014)

2.6a: TEK's practical application in resource management

A growing body of research is exploring the success and failure of efforts to incorporate TEK into wider policy frameworks, and decision-making processes (Inglis, 2004; Davidson-Hunt, 2006; Luo et al., 2009; Barthel et al., 2010; Ogwuche, 2012). Most policy decisions utilise western scientific data to guide these processes (Agrawal, 1995; Berkes et al., 2000). A problem with many scientific studies is they are spatially and temporally limited, thus rendering any results inherently curtailed by these limits. In contrast, TEK is accumulated through long term experiential observations and incorporates a broad range of factors into its analysis (Toledo et al., 2002). By supplementing and / or cross-referencing results from scientific investigations with information produced by traditional environmental knowledge systems, it is possible to devise more accurate, relevant ecosystem management programmes. The importance of constant feedback learning in TEK, coupled with ecological theories focusing on nonlinear, multi-equilibrium factors, have led some to propose TEK as holding great potential for inspiring ecological engineering (Martin et al., 2010). Folke & Ollson (2004) describe how to bring together indigenous knowledge and scientific analysis for devising resource management systems. TEK is increasingly recognised as having the potential to help combat climate change and other contemporary environmental challenges (Inglis, 2004; Royer et al., 2013; Turner and Spalding, 2013). Currently, much of the research combining TEK with other forms of scientific knowledge is taking place amongst First Nation Arctic communities. First Nation knowledge of patterns and changes in ice behaviour is being combined with formal scientific observations on weather patterns, to help develop understanding of climatic changes, and devise sustainable strategies for life in areas affected by these changes (Royer et al., 2013; Turner and Spalding, 2013). TEK is widely recognised amongst many communities which use natural resources, such as fishing, hunting and herding communities, with their knowledge increasingly being used to develop, and measure the efficacy, of resource management policies (Barron et al., 2015; Robbins, 2006; Turvey et al., 2013). Barthel et al (2013) have written of the role of 'bio-cultural refugia' in protecting biodiversity and food security. They address the key role of land-based understanding and knowledge of practical management of biodiversity and ecosystem services. TEK has been used recently to contribute to coastal restoration projects in Louisiana (Bethel et al, 2013). Revitalising TEK has also been recognised as a key element of wider plans to support socio-ecological resilience in the Italian Alps (Ianni et al, 2015). It is worth noting that much of the current drive to incorporate TEK into wider conservation schemes relate to efforts to ensure biodiversity and food security. These are the key elements of concern regarding pollinator decline, and the motivation for policy responses. Therefore, the literature on TEK contributes to an appropriate contextual framework for this thesis.

2.6b: Knowledge politics and TEK

As TEK has grown as a conceptual framework, the political processes underlying the relationship between TEK and scientific knowledge has come under scrutiny, with rigid understandings of the nature of both forms of knowledge hindering efforts for greater synthesis (Barron et al., 2015; Forbes and Stammler, 2016; Smith and Sharp, 2012). A key element of TEK which is highly relevant for further exploration in relation to beekeepers is the political context of their knowledge. Preliminary interview and archival data paint a picture of beekeeping as an occupational subculture whose activity is strongly impacted by forces – both economic and environmental - beyond their control (Maderson and Wynne-Jones, 2016). Attempts to influence these forces are limited due to uneven power relationships between beekeepers, and wider society.

As TEK is recognised in wider contexts, so the debate has widened from the defining characteristic of TEK, and the communities who both create it, and rely on it, to the processes involved in recognising and utilising TEK within policy and environmental management. Although TEK is found to be a relevant form of environmental understanding in diverse communities, its acknowledgement by outside communities is still problematic. TEK is increasingly engaged with as part of conservation programmes: this has led to a growing focus on the complex politics of integrating multiple, diverse epistemologies (Goldman et al., 2011; Nadasdy, 2005; 2014). At the same time, scientific knowledge is being re-examined in the wider context of its social creation, understanding and practice (Turner, 2011). As the networks of knowledge utilisation become more complex and are recognised as often expressing vested interests (Forsythe, 2011; Zimmerer, 2011), knowledge production from informal networks is seen as a political counterpart to mainstream perspectives. (Vandergeest and Peluso, 2011). While the importance of knowledge from alternative sources is recognised, writers such as Agrawal and Nadasdy see strategies to integrate TEK and scientific models as often flawed. They argue that the latter are granted precedence and superiority in the 'integration' process, and only engage with the elements of TEK which are seen to fit easily into such models and paradigms (Agrawal, 1995; 2002; Agrawal et al., 2001; Nadasdy, 2005; 2014). This results in a superficial engagement with community's knowledge that fails to engage with all the environmental features and ecosystem mechanisms which are recognised by them as being highly significant. Notably, Nadasdy (1999) has written on the issue of TEK's status in wider debates. He argues that, far from TEK and scientific systems complementing each other, in practice, attempts to bring together multiple knowledge frames result in forcing TEK holders to present their knowledge in the bureaucratic and epistemological frameworks of dominant paradigms. Following on from Nadasdy, others note the growing movement towards integrating multiple knowledge systems, particularly within the field of resilience studies (Bohensky and Maru, 2011). They note the risk of such integration growing into a 'box-ticking exercise', rather than a sincere effort to blend multiple knowledges. In an attempt to address the potential, and challenges, of working with Multiple Evidence Bases, authors stress the importance of grounding collaborators on an equal starting point (Tengo et al., 2014). Interestingly, they emphasise the inherently political nature of evaluating biodiversity, ecosystem services, and environmental change. This is an important point: while it is widely accepted that actions taken regarding biodiversity and environmental issues are political, to step further back and engage with the political aspect of the very process of evaluation is at the heart of addressing the power imbalances between holders of different forms of knowledge. Addressing this at the outset, and confronting the need to speak of collaborators with 'multiple evidences' is part of the process of challenging power inequities involved with environmental perception and engagement.

A recurrent concern with efforts to integrate TEK with other systems of environmental knowledge is the commoditisation and generalisation of TEK that results from such efforts, and the challenge of attaining parity between disparate perspectives (Ogwuche, 2012; Ween and Riseth, 2011). While TEK is increasingly recognised as a potentially powerful tool for conservation, biodiversity protection and resource management, there is apprehension that what is seen as relevant by conservationists is only a partial element of what is considered significant to TEK holders. Similarly, some of the research projects which have aimed to engage with beekeepers tend to focus on limited, quantitative data, (Neumann and Carreck, 2015; Seitz et al., 2016) which may or may not reflect the complexities of beekeepers' observations, practices and decision-making processes.

It is frequently the case that communities which have and utilise TEK, exist at the margins of dominant, mainstream societies (Forbes and Stammler, 2016; Smith and Sharp, 2012; Wehn et al., 2018). These knowledge forms are often concentrated amongst older members of communities, and varied socio-economic changes are leading to a decrease in TEK amongst younger members of the community (Luo et al., 2009; Oteros-Rozas et al., 2013, Ianni et al 2015). As TEK is recognised as a potentially important component to enhancing socio-ecological resilience, there are efforts to both preserve it in communities where it is under threat (Oteros-Rozas et al., 2013), and rediscover TEK in new locations and sources, including the internet, and archives (Burton and Riley, 2018). The theoretical context described thus far illustrates the relevance of this framework for exploring TEK in a hitherto unrecognised source: beekeepers.

2.6c: Political Ecology, TEK, beekeepers, and civil society

The knowledge generated and held by beekeepers holds strong similarities to TEK, as discussed originally by anthropologists and development workers in the 1990s, and now considered more widely in fields such as resilience studies and environmental sciences (Agrawal, 1995; Berkes et al., 2000). As well as the knowledge itself being parallel to such environmental understandings, the political framing and utilisation of this knowledge in the wider decision-making arena holds relevant parallels when considering how this tacit understanding of pollinator well-being can be harnessed for sustainability. It is important to consider the nature of this knowledge, and the political issues associated with its use. The question of how TEK is used and treated in policy-making spheres also bears parallels with the debates on Citizen Science discussed in section 4 of this chapter, as well as wider debates in Political Ecology. Since the pioneering work of key writers in the late 20th century (Blaikie, 1987; Fairhead and Leach, 1995), growing scholarly attention has addressed the need to engage with wider political and economic factors, when investigating environmental transformations and challenges. Biophysical transformations are increasingly understood through a transdisciplinary lens, which is rooted in a firm grasp of relevant political and economic factors driving changes 'on the ground'. From the environmental effect of jatropha plantations in India (Ariza-Montobbio et al., 2010), to water scarcity in spain (Otero, 2011), and wetland management and restoration in the US (Robertson, 2002), we see that understanding and alleviating environmental challenges requires engaging with the biophysical, as well as the political and economic drivers behind such earthly manifestations. Pollinator decline, and beekeepers' knowledge, correlates to this shift in understanding of the environment, as most of the challenges to pollinators are firmly anthropogenic by-products of the anthropocene, including pesticides, climate change, and land use practices (Potts et al., 2010; Sánchez-Bayo and Wyckhuys, 2019). Both scientific and beekeepers' knowledge of pollinator decline must be addressed within a wider environment that is, by its very nature, political.

Certain elements of TEK make it a highly relevant framework for critically examining the environmental knowledge of beekeepers, both individual, and their civil society organisations. Within beekeeping communities, there is a distinct tendency for newer practitioners to look to older, more experienced beekeepers for advice and guidance. Conversely, beekeeping is undergoing profound changes in how the activity is practiced and transmitted, with radical environmental changes impacting pollinators (Brown et al., 2016; Vanbergen and Initiative, 2013), interruptions to multi-generational practices (Potts et al., 2015; Uchiyama et al., 2017), and new methods of training new practitioners (Adams, 2016; Lorenz and Stark, 2015). This is one of the key reasons why I am aiming to predominantly interview long-term beekeepers, as they best exemplify TEK holders. They have also observed significant changes in the physical, agricultural, and policy landscape during their beekeeping careers, and are best placed to reflect on recent, and historical, land use changes, within the context of how these changes impact pollinator wellbeing. Beekeepers stress the importance of learning by doing, and emphasise that it is a craft that is developed and refined through many years of practical engagement. Through this practice, beekeepers develop an intimate understanding of their local environment, which may well have subtle specificities that limit the transferable relevance of another practitioner's experience. Beekeepers place a high value on learning from others who have long (25 +) years of experience. Recent writings have emphasised that TEK is found amongst European smallholders (Ianni et al., 2015; Oteros-Rozas et al., 2013). I propose that the underlying fundamentals of TEK as a knowledge system, as well as the practical, political challenges associated with incorporating such knowledge into wider environmental management schemes, are of great relevance for this thesis on beekeepers' knowledge. There are some complications with using this framework, however. While some members of beekeeping communities would be recognised as being holders of

TEK, having lived in, and practiced beekeeping, in one specific locale for decades, this occupation has undergone a dramatic demographic shift in recent years. Previously, beekeeping was very much an activity learned through varied forms of apprenticeship, by individuals who had long-term relationships with one region (Adams, 2016; Maderson and Wynne-Jones, 2016). It was often part of the wider economic activity of agricultural smallholdings. In recent years, the activity has been taken up as a hobby by a much broader demographic range. Many of the 'new beekeepers' are individuals who have moved to an area recently. Similarly, there has also been an unprecedented rise in urban beekeeping, which raises further complications when considering beekeepers' levels of knowledge of the local environment. This thesis will focus on the knowledge of long-term beekeepers, who exemplify many defining characteristics of TEK. However, the wider environmental question of beekeepers' role in addressing pollinator decline does not necessarily delineate between differing levels of practice and experience of beekeepers. For this reason, it is also important for this thesis to engage with theoretical insights on citizen science, enthusiasm, amateurs and environmental publics.

2.7: Conclusion

As illustrated in this contextual chapter, pollinator decline is a serious environmental issue, with profound ramifications for biodiversity and food security. It is hoped that a deeper understanding of the nature of environmental publics and amateurs, as well as lessons from debates on TEK, CS, and political ecology, can contribute to a positive dialogue amongst the diverse stakeholders in these key environmental strategies. However, this dialogue takes place in an arena of epistemological imbalance, where not all knowledge claims are treated equally. By analysing both archival and contemporary experiences of beekeepers' views on, and engagement with policy, this thesis aims to demonstrate historical insights into the working relationships of diverse stakeholders in pollinator health and wellbeing. These can serve to inform current efforts at environmental governance, as well as contribute to debates on stakeholder engagement (Edelenbos et al., 2011), the status of TEK in political spheres (Nadasdy, 2005; Nadasdy, 2014), and the potential contribution of practitioners' knowledge to sustainable and resilient land management practices (Hernández-Morcillo et al., 2013; Oteros-Rozas et al., 2013; Riley, 2009). These theoretical insights will be used to address the following research questions, which form the central focus of this thesis:

- *How does the long-term practice of beekeeping generate distinctive knowledge of the environment, and other factors influencing bee health?*
- *How do beekeepers use their environmental knowledge in their beekeeping practice, and what other factors affect their capacity to act on this knowledge?*
- *How do long-term beekeepers see their knowledge as distinct from other stakeholders in pollinator health, and how do they communicate their knowledge to scientists, policy-makers, and the wider public?*

The next chapter will describe the methodological basis of this research, and the methods carried out to collect data to address these research questions.

Chapter 3: Methodology, Methods & Discussion of Respondents / Participants

3.1: Explanation of choices of method

This chapter will present the background and reasoning to my choice of research methods for this project. I will outline the relationship between the primary and secondary research questions, and the multiple methods chosen to address these questions. Following on from work by key writers in Political Ecology (Blaikie, 2012; Castree et al., 2014), I was driven to carry out research that would both contribute to the theoretical and evidence base surrounding TEK, as well as be of use and relevance to a wider audience. My multidisciplinary MSc in Food and Water Security had been funded via the European Social Research Fund / Access to Masters programme, which required working with a non-academic partner, in an effort to strengthen links between academia and the wider community. Throughout my PhD, I presented my research findings to non-academic groups. This background, coupled with reflection on methodologies and the potential benefits and shortcomings of various methods, shaped the research questions and the subsequent choices of data collection methods for this research project.

This thesis seeks to illuminate the environmental knowledge and understanding of long-term beekeepers, and how they perceive their knowledge to be used within a wider scientific and policy context. Therefore, my methods were chosen based on their capacity to identify the holders of such knowledge, and investigate their environmental knowledge. I collected and generated data from static materials such as archives, and direct engagement with interviewees, as per recognised qualitative research methods (Mills and Birks, 2014, p 37).

The epistemological tensions between multiple 'environmental publics' are recognised as having a detrimental impact on efforts to both understand, and protect, the wider physical environment (Eden and Bear, 2012; Ellis and Waterton, 2016). The construction and understanding of nature is recognised as inherently political (Otero, 2011; Willems-Braun, 1997). Questions of expertise, and the power associated with particular types of environmental assessment and knowledge, are central themes in political ecology, and some writers in STS (Nadasdy, 2014; Turner, 2003). Tensions between the lived environmental knowledge of communities, in contrast to the assessments made by scientists, led me to explore beekeepers' knowledge and experience within these wider contexts of debates in political ecology, citizen science and traditional environmental knowledge.

My previous research for my MSc had generated preliminary data regarding the environmental engagement of long-term beekeepers. I had also found that this group engage with, and assess environmental conditions differently from the linear, scientific analysis used by most quantitative researchers (Maderson and Wynne-Jones, 2016). For this research project, my aim was to develop a wider historical understanding of how long-term beekeepers construct their knowledge of the environment, how they use this knowledge in their practice, and their experience of how their knowledge is understood and engaged with by others outside of the beekeeping community. Most of the research done on bees and pollinator wellbeing is carried out in the life sciences. While recent policy initiatives argue for the importance of engaging with beekeepers' knowledge, to date, there has been limited progress in this arena (Scott et al, 2013). There is little qualitative, or mixed-method data on beekeepers' environmental knowledge. Therefore, my research aim was to begin countering this gap in current research and understanding, and begin in-depth qualitative research on this group.

My research questions seek to explore whether the practice of beekeeping has historically been associated with enhanced environmental observations. If the practice has traditionally generated a distinct, deeper environmental understanding, I was also aiming to discover if this is still the case in modern-day beekeepers, and how this knowledge is perceived and utilised by others, such as scientists and policy-makers. It was beyond the remit of this research project to deeply enquire about the views and practices of these latter groups. This current research focuses on how beekeepers generate and use their knowledge, and how they perceive it as being used and treated in wider arenas. However, data collection for this project has suggested potential future lines of inquiry into the environmental knowledge of other land users, both hobbyists and professionals.

Based on the above, I initially decided it was most appropriate to use two primary methods for data collection: Archival / Secondary Data Analysis; and Semi-structured interviews. However, as the project developed, I realised that several Participant Observation (PO) / Ethnographic experiences had generated significant developments in understanding and analysing data in the context of the initial research questions. Refinement of research questions is an iterative process (Agee, in Mills & Birk, 2014, p 11). In the case of this research, participation in various meetings and conferences raised questions and understandings that may not have arisen without these experiences. This subsequently affected some of the issues explored in the interview schedules. Therefore, I decided it would be appropriate to include these PO in the wider methods discussion, and empirical analysis.

My research explores the traditional environmental knowledge (TEK) of beekeepers. TEK's potential for supporting conservation measures leads to concerns about the endangered nature of this form of tacit knowledge (Hernández-Morcillo et al., 2014; Ianni et al., 2015; Oteros-Rozas et al., 2013). Recent projects to digitise historical documents on land management, and make them available via the Internet, suggest the benefits of engaging with such texts as a way of both documenting historical forms of TEK, and understanding them in relation to contemporary manifestations (Burton and Riley, 2018). These issues led me to explore archives and secondary data sources as relevant to my research questions.

3.2: Participant Observation

As a result of my personal and academic interests, I took a 10 week beekeeping course run by the Aberystwyth Beekeeping Association, from autumn 2015 – spring 2016. This was highly relevant to this PhD on many levels. On a personal level, my earlier MSc research had generated a strong interest in bees and beekeeping, and it was very satisfying to learn more about the bees, and begin to keep some hives myself. Experiencing the all-consuming sensory engagement of opening a hive, looking for the queen, hearing and feeling the bees, led to a deeper empathy with my interviewees, and a greater understanding of their descriptions of their experiences, and their environmental engagement. On a research level, I soon found that my keeping bees, albeit as an absolute beginner, generated a connection with many of my interviewees, which helped facilitate open, inclusive communication during interviews. This parallels observations by Valentine (2005), who notes that 'sharing a similar identity to your informant can have a positive effect… and (produce) a rich, detailed conversation based on empathy and mutual respect and understanding' (Valentine, in Flowerdew and Martin, 2005, p 113). My own beekeeping practice enhanced discussion of issues of shared interest and concern during interviews, which further opened channels of communication.

I attended several meetings of local beekeeping associations, as well as lectures and conferences. These are a common and popular fora for beekeepers to share and gain information relating to bees. Both scientific research, and practical experience of beekeeping, are commonly the subjects of such talks. Attending such meetings provided an opportunity to meet potential interviewees, as well as to hone my interview questions to best reflect and explore beekeepers' environmental knowledge, as well as their views on policy and research. Throughout my research, I was invited to present my work at several international conferences, including the CoLOSS B-RAP group, and the Hive of Science conference (details in Box 1, below). Both of these meetings were overwhelmingly dominated by life scientists. Participating in these offered an unparalleled opportunity to hear first-hand how the experience of practical beekeepers was seen by these groups, and how some leading scientists viewed communication between themselves and beekeepers. It also illustrated the movement between different 'environmental publics', such as described by Eden (2012). She notes how some Environment Agency (EA) professionals had been recreational anglers before they were employed by the EA, and continued to practice this hobby once they became professional monitors of water quality. In many cases, research, profession and hobby overlap, thus generating epistemological complexities and overlapping categories of identity (Eden, 2012; Ellis and Waterton, 2016). Meeting with some of the world's most eminent researchers on honey bee health, and discussing their personal journey into research, led me to realise that these individuals had begun as hobby beekeepers, whose enthusiasm led them towards deeper investigation via a particular avenue. Similarly, many of my interviewees had complex identities and relationships with bees and the environment. A full list of Participant Observation events follows:

Event	Dates
Aberystwyth Beekeeping Association (ABKA) beginners course	autumn 2015- spring 2016
Welsh Beekeeping Association (WBKA) spring conference	1st – 2nd April 2016
Prof. Francis Ratnieks Lectures to East Carmarthen Beekeeping Association	14th May 2016
Peter Guthrie Lecture to Lampeter Beekeeping Association	8th November 2016
Midlands and South Western Counties (MSWCC) Beekeepers Convention	14th – 16th November 2016
OPAL Wales Citizen Science Committee Meeting	2nd February 2017

Keeping Local Bees Workshop – Centre for Alternative Technology, Wales	23rd February 2017
CoLOSS Bridging Research and Practice (B-RAP) Conference, Bologna, Italy	21st-22nd March 2017
British Beekeeping Association (BBKA) Spring Conference, Harper Adams University, England	8th April 2017
Bee In Transition: Beekeeping and Social Anthropology Workshop, Zurich, Switzerland	11th – 13th May 2017
Hive of Science Workshop on Pollinator Decline, Axilan, France	9th-14th October 2017
National Honey Show, Surrey, England	27th-28th October 2017

Box 1: List of Participant Observation events, and dates

Attending these events enabled me to observe communication, including question and answer sessions, between beekeepers and presenters. Often, conferences feature guest speakers who are carrying out scientific research on bee and wider pollinator health. Question and Answer sessions often provided insights into several themes relevant to this PhD thesis. Attendees showed themselves to be highly informed and engaged. This may be a distinct feature of UK beekeepers. At one of the BBKA Spring Conference lectures, given by a highly respected US entomologist who has frequently travelled in the UK and lectured to beekeepers here, he commented during a Q & A about the highly scientifically informed nature of questions from UK beekeeping audiences. It was sometimes the case that what presenters held to be a fact about honeybee behaviour was contradicted by the experiential observations of attendees. By attending these conferences, and speaking with fellow participants afterwards, it provided an opportunity to gather feedback on the lecture, and the research on which it was based, and whether practicing beekeepers felt these were relevant to their beekeeping and personal observations and experience. Some of these events also provided an opportunity to make contact with potential interviewees; several were contacted this way. Although several of the PO activities took place after I had completed the majority of the interviews, the themes that arose influenced my analysis of interview data, as I explored new themes.

3.3: Archives and Secondary Data

In my earlier MSc research, I came across the archives of the Bee Farmers Association (BFA), and realised their potential to contribute to current challenges and significant questions regarding contemporary pollinator wellbeing. It was therefore decided that deeper engagement with this material would be a key aspect of this PhD research.

3.3a: Bee Farmers Association Archives

The BFA archives which I was able to investigate included copies of the organisation's bulletins, newsletters, and conference notes, dating back to 1953. Diverse data sources, such as naturalists' journals and club records, are recognised as an underutilised resource in developing an evidence base on the phenological impacts of a changing climate (Primack and Miller-Rushing, 2012). Due to the small, informal nature of the BFA, there is a strong possibility that there is further information which has been separated from the current collection, and has been misplaced over time, or is held separately, in the personal records of individual members. However, for the purposes of this research project, accessing the full catalogue of newsletters and bulletins for members provided sufficient data to develop an understanding of the environmental knowledge of this beekeepers' civil society organisation, and their relationships and communication with other relevant stakeholders in bee health.

Much of the content of the BFA archives was comparative ephemera that I did not consider relevant to my research, such as receipts for bulk orders of glass honey jars. I was interested in material which related to my research questions, and provided data about the environmental observations of these individuals, and their views and experience of the wider political, economic, scientific and agricultural landscape, and other factors affecting their bees.

Early editions contain pieces written by some of the 20th century's most prominent beekeepers and bee farmers, such as TJ Hillyard, and R.O.B Manley. When they were writing in the mid-20th century, they were aged in their 50s – 70s. These men had been born in the late 19th – early 20th century, and therefore had learned beekeeping in the pre-industrial agricultural landscape which has now disappeared. As well as the landscape having changed, they had also learned beekeeping in the way it had been learned for generations – as a practical skill, handed on via direct experiential learning. Bee farmers tend to have significant length and breadth of beekeeping experience. Therefore, they are key informants to provide data for this research project. Indeed, the archives of the BFA contain significant discussion about beekeepers' observations of agricultural changes throughout the 20th century, and the impact of these on bee and pollinator wellbeing. Using the BFA archives as a data source generated a historical perspective on beekeepers' engagement with, and knowledge of, the wider physical environment. It also documented bee farmers' relationships with the scientific and policy communities. This informed research questions, and provided a unique opportunity to how these relationships have changed over time, when compared to interview data and ethnographic experiences related to these questions.

3.3b: International Bee Research Association (IBRA)

Another rich source of information on beekeepers' environmental observations was the Eva Crane Library of the International Bee Research Association (IBRA) Collection. This is one of the world's most extensive and valuable collections of material related to bees, beekeeping and bee research. It is held at the National Library of Wales (NLW), Aberystwyth. In archival research, like so much of life, there can be too much of a good thing. In the case of the IBRA Collection, this first presented itself in the form of an Excel spreadsheet listing the 4,165 items held in the collection. As this is one of the world's greatest collections, items were in many languages; Arabic, Armenian, Croatian, French, German, Japanese, Uzbek, Vietnamese, and more. By concentrating only on the items in English, this brought the list down to a comparatively manageable 1,847. June - August 2016 were spent selecting and reviewing pertinent material from this collection. Many items within the Eva Crane Library were lengthy books, on a huge range of subjects related to bees and beekeeping. Unlike the BFA archives, which I could easily examine, the NLW requires users to submit a list of up to 10 items, which are then retrieved by library staff and given to the reader to peruse on site. The scale of the material, coupled with the system for accessing it, led me to start my research by reviewing the list of titles on the Excel spreadsheet to try and establish which would be relevant to my research. For the purposes of this thesis, of principal interest to me were a variety of memoirs, biographies, and autobiographies of long-term beekeepers, as well as historical records of local beekeeping associations throughout the UK. This secondary data enabled me to contextualise and triangulate data found in the Bee Farmers Association archives, and the primary data generated via interviews and participant observation. When reviewing the spreadsheet for potentially relevant data for this thesis, I concentrated on titles which reflected the length of time the author, or organisation, had practiced beekeeping. This selection process led to the study of several memoirs and autobiographies by individuals who had kept bees for over forty years. The authors' descriptions of the environmental changes they had witnessed, and their beekeeping knowledge, provided detailed examples of the type and depth of environmental knowledge resultant from extensive beekeeping practice. This preliminary analysis of secondary data influenced subsequent interview questions and thematic development for this thesis.

Another key data source held in the IBRA archives was the histories of various local beekeeping associations in the United Kingdom. Many of these local associations were founded in the late 19th – early 20th Century. A range of short histories of groups were published in the late 20th Century, in honour of the centenary, or other significant anniversary of the association. These titles often contained regionally specific data on environmental changes and patterns, changes in land use, and more. They also illustrate the role of these organisations in creating a social space for the construction and sharing of knowledge.

Most of the archival information I utilised for this research was written by beekeepers who had worked and practiced primarily in the UK and Ireland, as this is the main focus of my research project. However, there were a couple of notable exceptions, written by beekeepers based in the US, New Zealand and Canada. The similarities in environmental observations are close enough to UK experiences for these works to be relevant to this research project. The key defining feature that led me to use any secondary data source was its description of extended personal experience of beekeeping, and associated environmental observations and knowledge resultant from the practice. By utilising secondary data and archival analysis, along with interviews and participant observation, I was able to develop an enhanced historical understanding of the relationship between long-term beekeeping and its impact on environmental observations and understandings.

3.4: Interviews

The decision to use interviews as a data collection method was rooted in this project's aims to explore, in depth, the environmental observations and knowledge of long-term beekeepers, and their views of how this knowledge connects and contrasts to the knowledge of scientists, policy-makers and the wider public. Questionnaires and/or surveys were considered, as these methods have the comparative advantage of generating substantial quantities of data. However, this project seeks to investigate the rich detail found in beekeepers' TEK. The nature of my research questions meant that I would collect far more relevant information via interviews than through any survey.

It is worth noting that most research which engages with beekeepers, tends to use surveys and questionnaires, such as the annual Bee Informed Partnership survey mentioned in Chapter 2, and other surveys. This is typical of a model of scientific inquiry which often fails to engage with elements that participants may prioritise and see as highly relevant to the topic being discussed (Nadasdy, 2005). This thesis aims to explore the temporal richness and spatial specificity of beekeepers' environmental knowledge. Therefore, methods were chosen which allowed these qualities to be expressed, and subsequently investigated in depth.

It is relevant to this project's aims to note that researchers specialising in conservation also recognise the importance of engaging with interviews and other forms of qualitative data collection (Young et al., 2018). As the decline in pollinators is acknowledged to be a threat to biodiversity, which is a conservation issue, it is appropriate that interviews are one method of data collection to investigate this issue. While interviews are often used in conservation work, it is suggested that there is significant room for improvement in both *how*, and clarifying *why* they are used (ibid). Weaknesses included a failure to provide a rationale as to why interviews were used, and not critically reviewing their use (ibid). These critiques guided my choice of using interviews, and critically reviewing data generated via this method.

As noted by Valentine (p 112), researchers often use interviews as part of a mixed-methods approach to data collection. By triangulating multiple perspectives and/or data sources, one can potentially maximise understanding of research questions (Valentine, in Flowerdew and Martin, 2005). Semi-structured interviews are best seen as 'a conversation with a purpose'. (ibid) As noted earlier, these conversations were enhanced by my practical experience of beekeeping, and my work with the IBRA archives. The existence of the IBRA Collection at the NLW is known by many interviewees, but few had accessed them personally. Therefore, being able to discuss my engagement with them, and some of the material and themes I had found, created a shared point of interest which enriched the conversations with my interviewees. For my data collection, all interviews followed a guideline (included in appendix 2). It was apparent within each interview that most respondents had particular knowledge, experience, or perspective on particular aspects of the issues being discussed, which often dominated the resulting discussion. As well as having a high level of personal, practical experience, many of my interviewees are writers and lecturers. This exemplifies their position as holders of TEK, and also creates an opportunity for interviews with individuals to provide wider relevant information regarding knowledge and experience of the broader beekeeping community. One common critique of qualitative research methods is the question of small sample size (Mills and Birks, 2014, p 36). As I was frequently encountering life scientists who work with data sets of up to 40,000, I was constantly reflecting on my own methods and data, to ensure they were robust enough to support my research questions. The BBKA currently has approximately 25,000 members. There are also many beekeepers who are not registered members of associations. Compared to this, interviewing 39 individuals may seem too limited in scale. However, my research focuses on long-term beekeepers. There has been a recent dramatic increase in beekeepers throughout the UK. Also, as many of my interviewees were key informants, they were able to provide information that transcended their own individual experience.

The question of sampling and generalisation from interview data is a common concern in qualitative research (Arksey and Knight, 1999). The key criteria for potential interviewees was based on the number of years of their beekeeping experience. This was due to the central research questions being focused on the link between long-term practice, and environmental knowledge. As communication of this knowledge to other communities, including scientists, policy-makers and the wider public, was also a research avenue, efforts were also made to contact a broad range of long-term beekeepers, some of whom were known by the researcher to have a critical perspective on current environmental practices, scientific research on bees, and on many mainstream beekeeping practices. Beekeepers are a heterogeneous population, with often radically opposed views of challenges to bee health, environmental management for pollinator wellbeing, and the capacity of policy to respond appropriately to these challenges (Scott et al, 2013). As these were all topics related to the research questions of this thesis, efforts were made to reflect some of the diversity of perspectives found across the community within the interview sample. Ultimately, this was not a random sample, and therefore generalisations from the results should be made with caution.

Interviewees were contacted via a range of approaches, including an article published in key beekeeping magazines, approaching individuals at meetings and conferences, and snowballing. As many beekeepers do not belong to associations, or attend meetings, it is clear that there are many other potential interviewees and sources of information relevant to this research. Therefore, some interviewees were selected and recruited based on their prominent roles in calling for more radical approaches to bee and pollinator health. While there are clearly many voices and perspectives in the 'broad church' that is the beekeeping community, data collected and generated was deemed sufficient to address the research questions. The data also suggests a rich potential for future research building on this project. The generation, collection, sharing and use of beekeepers' traditional environmental knowledge; the effect of local and regional phenological changes and microclimates; synergistic effects of environmental and genetic factors on pollinator health; and beekeepers' capacity to affect and control factors affecting their bees are but some of the avenues of potential further investigation.

Most of the current research on pollinator decline is focused on life sciences. Limited work has been carried out on beekeepers, although this group are recognised as key stakeholders in bee and pollinator health (Scott et al, 2013). Several research projects, such as the Bee Informed Partnership, use an epidemiological approach to investigate beekeepers' management practices and annual colony losses (Seitz et al., 2016). They have developed large-scale surveys to investigate primarily quantitative data about beekeepers' annual hive losses and management practices. The BBKA, and Bee Base, also carry out winter losses surveys. These seek to collect quantitative data on colony losses and potential causes, such as queen failure, disease, starvation, etc. Such surveys aim to collect and analyse large quantities of primarily quantitative data. However, interviewing highly experienced individuals, who also have historical and practical relationships with other beekeepers, generated data that had a relevance beyond the individual respondent. The qualitative data gathered in these interviews also provides a unique picture of the relationship between practice, knowledge, values and more.

As noted by Valentine (2005, p 111), the aim of an interview is not to be representative, but to understand how individuals experience and make sense of their lives. However, there is also a critique of a possible over-reliance on interviews as a source of qualitative data, suggesting that there is too much attention to how people 'see things' over the importance of how people 'do things' (Silverman, 2016, p 105). With this in mind, coupled with my interdisciplinary approach and a desire to carry out research of relevance to both social and life scientists, my work brings together texts / archives, and interviews. In all the data I engaged with, I explored both how people see, and do, their beekeeping.

When attending the week-long Hive of Science meeting in France, October 2017, I found myself the sole social scientist in a group of 15 life scientists, including entomologists, virologists, and geneticists. This experience let me to critically reflect on the value of my work in a wider interdisciplinary context. One participant asked me 'how do you know your interviewees aren't lying to you?' This is an important question, and correlates with broader critiques of qualitative research, and the social sciences. It has been said that there is a tendency within social science to assume that interviews are the 'gold standard' of data collection (Mills & Birk 2014, p 40), and that it is therefore important for researchers to 'recognise what they are doing when they do it, and what it means to take data at face value.' (Sandelowski 2002, in Mills & Birk 2014). My project seeks to complement the plethora of life science research on bee and pollinator health and wellbeing with an investigation into the experiential knowledge and observations of long term beekeepers. It does not aim to verify or contradict their observations. Like similar work on the Arctic (Royer et al., 2013; Usher, 2000), Black Sea fisheries (Knudsen, 2008), Italian Alps (Ianni et al., 2015), Spanish pastoralists (Oteros-Rozas et al., 2013), and Cameroonian beekeepers, (Ingram and Njikeu, 2011), my aim is to explore the environmental knowledge generated from the practice of beekeeping in the United Kingdom, and how this knowledge is used and communicated. Therefore, semi-structured interviews were deemed an appropriate data collection method, particularly as this data was triangulated with archives, secondary data, and ethnographic data. I do not have reason to believe my interviewees would lie to me. I also note that there is a saying within the beekeeping community: 'ask 9 beekeepers a question, and get 10 different answers'. With this in mind, I was highly conscious of questions which generated high levels of agreement, and, particularly, those rare questions which generated near unanimous agreement. It would be disingenuous to present my respondents as universal in their outlook.

Beekeepers are a heterogeneous community; their points of divergence are as pertinent and revealing as their congruence.

The selection criteria for interviewees was their having personal practical experience of keeping bees for twenty years or more. The relationship of this experience to their subsequent knowledge of wider environmental conditions and trends was a key research question. Beekeeping in the UK has changed significantly in the past twenty years since varroa mites became endemic. This fact, and previous research on the bee farmers association, led me to decide that twenty years' experience would be a suitable minimum length of experience to generate notable environmental observations of relevance to this project. In actuality, respondents often had far greater experience, which led to an unexpected richness in the data. The average length of respondents' beekeeping practice was 40 years, with several individuals having 70 years' experience.

Within beekeeping, experience is often discussed in terms of 'hive years'. This is the number of years someone keeps bees, multiplied by the number of hives they keep. For my research purposes, I am interested primarily in chronological years of experience, as I am investigating observations of environmental patterns and changes long-term beekeeping puts people in a position to observe environmental patterns and changes.

They were contacted via a collection of personal contacts, requests in beekeeping magazines, and snowballing. Thirty-nine individuals were interviewed. Demographic characteristics such as gender, years' beekeeping, and roles in beekeeping CSOs are listed below in Table 1.

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

While some interviewees had never been involved with any senior roles in beekeeping CSO's, several interviewees had held various roles in these over the years, which is why the sum total listed above is more than the number of interviewees.

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, while over 20% of interviewees stated that they had come from a farming background. Throughout collection and analysis of data, it became apparent that the personal characteristics of interviewees were highly significant in terms of their environmental knowledge.

3.4a: Significant Personal Characteristics of Interviewees

Many interviewees described a lifelong interest in, and engagement with the natural world, which frequently manifested from a very young age. Some interviewees found it difficult to disentangle their beekeeping practices from their understanding of, and engagement with the natural environment. This was due to beekeeping having always been such a long-running, significant feature of their lives. The longevity of practice for many beekeepers is indicative of the distinctive form of environmental knowledge associated with TEK systems, as described in the previous chapters.

Seven interviewees had close family members, such as parents and/or grandparents, who had kept bees. For these interviewees, this family connection served several purposes which enhanced their knowledge of factors being investigated. Throughout most of history, beekeeping was a practice learned experientially, via personal mentoring / apprentice relationship (Adams, 2016; Crane, 1999). Interviewees who had learned beekeeping from a family member served multiple purposes for this research. As I am investigating beekeepers' environmental knowledge and views, particularly of how certain areas have changed in terms of their quality as habitat for bees and other pollinators, this multi-generational perspective accentuates the long-term climate and habitat patterns that are observed.

Eight interviewees came from a personal and / or professional farming background. The impact of farming on individuals' sense of identity, and wider environmental knowledge, was discussed by interviewees, and parallels wider research on this issue (Hinrichs, 1998; Wynne-Jones, 2013).

During data collection, it rapidly became clear during the interview process that a significant number of interviewees have a professional background in a STEMM subject (science, technology, engineering, mathematics or medicine). While I had not initially planned to investigate this link, it has a clear significance to this research. One of the key themes this thesis is investigating is the environmental knowledge and observations held by interviewees, and their view of how their knowledge is treated by the scientific and policy communities. Many interviewees come from a background where they are trained in a broad range of scientific practices and principles. As part of their professional responsibilities, and/or as a matter of interest, they read scientific papers in peer reviewed journals, and have the ability to understand and critique experiments on a diverse level of criteria. Their position as 'environmental publics' (Eden, 2016) is complex and multi-layered. This can sometimes create tensions when dealing with scientists and policy-makers, as the nature and basis of beekeepers' expertise is ascribed differing levels of validity and respect in different fora – an epistemological conflict that occurs throughout the world of environmental monitoring (Ellis and Waterton, 2004; 2005).

When originally conceptualising this research project, I was positioning beekeepers' knowledge as different from, and often in opposition to, scientific understandings of bee / pollinator / environmental health. However, as the research and interviews progressed, it became apparent that respondents traversed the categories of tacit vs scientific / amateur vs professional. This generated a far more nuanced analysis, which also expanded the original research questions to engage with wider issues of environmental understanding.

3.5: Description of different roles in beekeeping civil society organisations

Over their beekeeping lives, many interviewees have held multiple official and / or semi-official roles related to their practice. Some of these have been linked to the government outreach service, working as seasonal bee inspectors. Others have held teaching and / or management roles within their local and / or national beekeeping associations. The TEK of these key informants commands high status throughout the beekeeping community. As the experience and wider community relevance of these roles significantly contributes to the input of interviewees, for the sake of clarity, it is worth providing brief descriptions on some of these roles, and why it is relevant to this research project that interviewees have held these roles. Box 1, below, briefly describes key roles held at some point by many interviewees, and the impact of these roles on their environmental and beekeeping knowledge.

Bee Inspector	This is a highly significant professional role for experienced, knowledgeable beekeepers. Organised by the National Bee Unit (NBU), regional bee inspectors are responsible for inspecting colonies throughout the country and treating notifiable bee diseases such as European and American Foul Brood (EFB & AFB, respectively), on behalf of DEFRA and the Welsh Assembly Government. They also carry out training and education services for beekeepers throughout the UK. Regional bee inspectors also manage staff of seasonal bee inspectors (National Bee Unit, 2018). The job requires them to spend much of the main beekeeping season (April – October) inspecting bee colonies throughout the country. They are seen as a source of information by other beekeepers, and act as key liaisons between the government's National Bee Unit (which is part of FERA – Food and Environment Research Agency), and beekeepers. Several of my interviewees were, or had been, seasonal Bee Inspectors. All commented on the immense educational opportunities associated with this role, and how they had learned a tremendous amount about bees and beekeeping as a result of this professional activity.
Apiary Manager	Many local beekeeping associations have a 'teaching apiary', used both for teaching new beekeepers, and as a source of practical beekeeping experience for people who do not own their own bees. The Apiary Manager is responsible for managing the bees

	of the association's apiary. They hold a key role in the education of new association members, and are recognised as a source of information and guidance. It is usually a voluntary role, held by individuals who have extensive practical experience of beekeeping. Their work entails their working closely with other beekeepers.
Lecturer / Writer / Education	The beekeeping community has wide and diverse sources of information which have changed as the years have gone on, and technology has altered communication. Local and national beekeeping associations hold regular meetings; guest speakers are often invited. There are also larger, regional and national conferences, where scientists and experienced beekeepers are invited to speak. Other beekeepers run training courses and workshops throughout the country on general beekeeping, and more specialised aspects, such as queen rearing, bee breeding and microscopy (for identifying pollen, bee diseases and more). Over half of interviewees were actively involved in providing some sort of national training.
Bee Farmer	The Bee Farmers Association is a professional trade association established in the 1950s, to reflect the aims and concerns of members of its members. Bee farmers traditionally learned their trade via some sort of apprenticeship. It is often an inherited profession, with family businesses spanning several generations. For those who do not come from professional bee farmers' families, many initially begin as hobby beekeepers, who scale up their operation to a professional level, then may scale it down, but continue as hobbyists, as they get older or otherwise decide to end their professional practice.
Swarm Liaison Officer (SwLO)	Most local beekeeping associations have a Swarm Liaison Officer. This individual is the point of contact for members of the public who believe they have observed a swarm of bees, and require assistance in the safe removal of the possible swarm. Due to the wide range of places where swarms end up, such as chimneys, roof eaves, and old trees, one needs to be an experienced, confident beekeeper to perform this role. Being a Swarm Liaison Officer also requires beekeepers to engage with the wider public, and their understanding, knowledge and feelings about bees and other pollinators.
Spray Liaison	The role of Spray Liaison Officer acts as a bridge between the wider agricultural sector, and the beekeeping community. In this role, experienced beekeepers are the point of contact between farmers who are planning to use agricultural sprays on their

Officer (SpLO)	crops, and local beekeepers, who may want to protect their bees from exposure to these sprays. Theoretically, the SpLO's role offers the potential for bees to be protected from immediate acute exposure to such sprays.
Chair / Trustee / Senior post-holder (of BIBBA, BFA, BKA)	Beekeeping throughout the UK and Ireland has a range of civil society / membership organisations. These serve to represent members' interests, provide education for members, and act as a point of contact with other relevant bodies such as government and the agricultural sector, and more. They also run local and national events such as meetings, conventions, lectures, etc. As per the management structure of Voluntary / Civil Society organisations, these are run primarily by volunteers. Many interviewees hold, or have held, posts in these groups. This illustrates their respect from other members, and the wider beekeeping community. By holding such posts, they are often in strong positions of knowledge and communication with other members. As these post-holders are often in liaison positions with other professional and amateur bodies, they are in positions where they are highly informed of the knowledge and views of other organisation members.

Box 1: Description of various roles in beekeeping civil society organisations, and the impact of roles on individuals' beekeeping and environmental knowledge.

As seen above, interviewees were predominantly male, with 8 female, and 31 male respondents. While this may initially appear to be a gender imbalance in responses, beekeeping has traditionally been a highly male dominated activity. As my research is focusing on long-term beekeepers, who have practiced for a minimum of 20 years, the ratio of female to male respondents does not have a negative impact on the data. The increase in women taking up beekeeping may lead to significant developments and transitions in the future of this practice, and associated environmental knowledge and engagement. Gender distinctions in valuation of ecosystem services (Fortnam et al., 2019) may lead to changes in beekeeping practices in the future, as the rise in female beekeepers has been associated with a change in motivation, often moving away from an earlier focus on honey yields (Moore and Kosut, 2013a).

The number of current or past professional bee farmers is noted in the table above. The relationship between beekeepers and bee farmers is strong, fluid and complex, with movement between the categories. Individuals often move back and forth between these categories, increasing and decreasing the scale of their operations based on a range of circumstances. Bee farmers keep bees on a professional basis, for honey production and/or pollination services. Throughout this thesis, I will generally discuss data providers as beekeepers, unless a particular aspect of data was specifically generated by bee farmers, as a result of their professional beekeeping activities.

Respondents were located throughout England, Wales and Ireland. Several potential interviewees in Scotland were contacted, but failed to respond to multiple attempts to arrange interviews. Interviewees kept their bees in diverse habitats, including urban, peri-urban, woodland, and varied agricultural land, such as arable and top fruit. Many kept multiple colonies in differing habitats, and noted significant differences in colony health and performance that they associated with such disparities. This established that their responses engaged with the diverse environmental conditions and changes affecting pollinators.

An added benefit of interviewees' length of beekeeping experience was the associated wider community / civil society roles they had enacted as a result of their experience. Throughout the beekeeping community, on both a local and national level, practical experience is highly valued. As seen in the table above, many interviewees for this project often held significant positions in local, national and international beekeeping associations. Due to the length of their experience, several had held multiple roles over the years. This facilitated interviewees' capacity to knowledgeably report on the observations and experience of the wider beekeeping community, thus countering some of the disadvantages of a limited number of interviewees in data collection. While I had not planned on using a key informant approach to my data collection, after I had carried out my interviews, it was apparent that many fit this definition (Marshall, 1996). While my informants were not necessarily representative of the wider, and clearly more extensive beekeeping community, they were often well positioned in these communities, highly knowledgeable and able to provide data relevant to my research. The key informant is often seen as a proxy for their associates at the organization or group (Lavrakas, 2008, p 407).

Interestingly, for my research, there are parallels between TEK systems, and key informant approach. Within the former, there is often a community recognition that certain individuals are particularly knowledgeable, and hold a particular social position associated with this experiential knowledge (Berkes et al., 2000; Oteros-Rozas et al., 2013; Usher, 2000). My key criteria for suitability for interview was that individuals had to have been keeping bees for 20 years of more. This was due to several factors. First, the framework I am using to investigate and understand beekeepers' knowledge is that of Traditional Environmental Knowledge (TEK). As explored in the preceding contextual chapter, TEK is closely related to Local Environmental Knowledge and Indigenous Knowledge systems (LEK & IK, respectively) (Agrawal, 1995; Berkes et al., 2000; Bohensky and Maru, 2011; Turvey et al., 2010). Secondly, the devastating effects of varroa on beekeeping in the past 20 years have resulted in many beekeepers ceasing their activities (Potts et al., 2015); requiring those who have continued their practice to be highly skilled and knowledgeable.

Interviewees were recruited through a variety of channels. I wrote a short piece explaining my research project and requesting suitable persons who were willing and able to be interviewed, to contact me (See Appendix 1). I then contacted the publishers of the BBKA and WBKA magazines and asked them if they would be willing to publish my request. This generated 12 responses, including one from the publisher of An Beachaire, the journal of the Irish Beekeeping Association. She both volunteered to be interviewed, and offered to publish my request in their journal. While I had not initially planned on including Irish beekeepers in my research, it was logical to do so, due to historical links and similarities in both the environmental conditions, and beekeeping communities of Ireland, England and Wales. Pollinator decline is an international issue, with many governments drafting policy responses to this issue. Ireland's pollinator policy has many similarities to those of England and Wales. Carrying out interviews with Irish beekeepers provided an excellent opportunity to begin to explore the international aspects of my research questions. The subsequent article generated two more responses, both of whom fit the definition of key informants / TEK holders.

Some interviews were carried out in person, for several reasons. Two couples had agreed to be interviewed, and were located in North Wales. They had specifically said they preferred to speak in person, so I travelled to them for these interviews. Another pair were based in Reading, and had stated that their age (over 80) meant they had difficulties with hearing, and preferred to speak in person. Coupled with the fact that these interviews were with more than one person, it was preferable to speak with them face-to-face for the sake of ease and clarity. The majority of interviews were carried out via Skype video calls. Preliminary arrangements for the call were made via phone and / or email communication. Using Skype communication had several logistic, research and environmental advantages. My interviewees were widely distributed throughout the United Kingdom. Communicating via Skype gave greater flexibility in the timing of interviews, so that conversations could take place at a time of convenience for the subjects. As beekeeping is a seasonal activity, it is common for beekeepers to have free time only from late October– March, as during the rest of the year, they are very busy with their bees. One interviewee, who I spoke with in February, was emphatic that if I had tried to carry out the interview in the main beekeeping season, he would not have been able to participate. Therefore, using Skype allowed me to be far more efficient and carry out more interviews in a constrained time period. There is also growing concern about the environmental impact of scientists and academics who travel extensively for conferences, workshops and meetings (Langin, 2019). As the use of Skype would not restrict my research, and would benefit me in time saved, and the environment in less travel, I was comfortable with using Skype as a tool for communicating with interviewees. The majority of interviews were carried out from October 2016 – March 2017.

There are benefits and challenges associated with virtual, as compared to face to face interviews (Braun and Clarke, 2013, p 98-101). However, the nature of my research questions, and previous work in this field, led me to decide that my current research would not suffer any negative impact from utilising technology to communicate, and that there would even be possible benefits, as discussed above. Previous interviews carried out for my MSc showed that beekeepers are extremely open and happy to discuss their practice, and their wider views surrounding the topic. Plus, as the topics were clear, and non-confrontational, there was no need to be unduly concerned about issues such as putting interviewees at ease, etc. Similarly, potential cues from surroundings and related ephemera were not considered necessary to enhance understanding of responses. My research focused on articulated verbal responses to questions.

All interviewees were informed of the nature of the project, the purposes of the interview, how interview data would be used, and that they had the opportunity to withdraw their participation at any point. Most interviews were approximately one hour long. All conversations were recorded via Evaer software. This allowed me to transcribe them fully, and thus have both the original recording, and transcription, for analysis. By carrying out full transcription, I was able to ensure that all comments and responses would be available to be re-examined at later dates, if necessary.

3.6: Data Analysis

Transcripts were imported into, and then coded and analysed, via Nvivo 11 (this was updated to Nvivo 12 in March 2018, but did not affect the data analysis*)*. Nvivo is a computer assisted qualitative data analysis software (CAQDAS) programme, frequently used for analysing transcripts of interviews (Silver and Lewins, 2014).

Preliminary codes were outlined, which focused on the central objectives and questions of this research project. Background information on interviewees' beekeeping practice was noted in codes on Number of Colonies; Location of Colonies; Personal Beekeeping History; Beekeepers' Personal Background, and Reasons for Beekeeping. Environmental knowledge was investigated within the codes of Agricultural Change; Beekeepers' Experiential Knowledge and Observations; Observation of Other Species; Bee Health; Food System. Interviewees were asked about their engagement with research, and policy. These questions, generated a range of data which was classified primarily in nodes on Pollinator Policy, and Scientific Research on Pollinators.

As interviews and analysis progressed, unexpected themes evolved, which led to further codes and avenues of analysis. The non-linear nature of coding in Nvivo makes it an appropriate method for the iterative analytical process (Bringer et al., 2016), allowing for the node hierarchy to be developed further. Child nodes were created, as a result of noted themes which appeared within the parent nodes. For example, the Parent Node of Beekeepers' Experiential Knowledge contains a combined total of 561 references, distributed across 12 child nodes: agricultural changes, climate change, concerns about agricultural sprays, different hive types, different subspecies of bees, environmental observations, importance of wild areas for bees, loss of habitat for bees, questioning decline in bees, treatment by policy-makers, and treatment by scientific community. One of these child nodes – environmental observations – contains 11 second level, subsidiary child nodes, including changes in rainfall, flowering time changes, forage, general views on local environment for bees, improving the environment, plant changes, pollen, regional variations and impact on bees, seasonal changes, temperature changes, and views on farming. It became clear when analysing transcripts that considerable data had arisen on Public attitudes to nature; Public

Engagement with Science; Public Response to Pollinator Decline. A full list of Parent nodes, and an example of some Parent-Child nodes, is included in Appendix 5.

3.7: Conclusion

This chapter has discussed the range of methods used in this thesis to explore historical and current environmental knowledge of long-term beekeepers. It has explained the relationship between the archives and secondary data found in the IBRA and BFA archives, and the interviews and participant observation carried out to explore contemporary beekeepers' knowledge. It has defined the personal and professional characteristics of interviewees, and clarified the relationship of these qualities to the research questions. By working with a range of data sources, this thesis is able to develop a unique perspective on beekeeping at a time of environmental change, and transition of the practice. This chapter has shown the relationship between the conceptual framework, and the theoretical questions surrounding expertise, Citizen Science, Traditional Environmental Knowledge, and how these issues relate to current efforts to monitor and protect the environment. I will now proceed to the second section of this thesis, which will address my empirical findings.

Chapter 4: How do long-term beekeepers construct their environmental knowledge?

> *Part of the psyche of people who are willing to work with insects is that they are aware of the wider environment. They are very observant, and passionate about their environment. (CD)*

4.1: Introduction

In this first empirics chapter, I will discuss how beekeepers acquire and develop their environmental knowledge. If we are to consider this knowledge as distinct, and having the capacity to add a unique perspective to understanding and alleviating pollinator decline, it is necessary to first understand what are the defining features of their knowledge, and how it is generated.

A central feature of beekeepers' knowledge is its frequently hybrid quality, bringing together diverse methods of understanding the wider environment. For centuries, beekeepers have carefully observed their bees, and developed a wealth of knowledge about their life cycle, behaviour, and their relationship with the wider physical environment. This knowledge has often been passed down across the generations, through practical training with family members, and other members of the beekeeping community. This experiential learning and observation is increasingly infused with relevant scientific knowledge of bee biology, disease and more. As scientific knowledge has progressed, so has beekeepers' knowledge. Formal scientific study and understanding of biological processes is utilised alongside practical experience and personal observations. The current training offered for new beekeepers through beekeepers' civil society organisations, such as the BBKA and WBKA, emphasises key aspects of bee biology, as this underlies much of the behaviour of bees, and assists beekeepers in successfully managing their colonies. So, we see that a certain level of scientific knowledge is central to beekeepers. It synthesises experiential insights, formal study, and information shared through civil society organisations. Hybrid knowledge transcends outdated binaries between scientific analysis and local, tacit knowledge, as it combines elements of multiple forms of knowledge acquisition (Bear, 2006). It is recognised as highly significant to the sustainable land management practices of farmers (Barbero-Sierra et al., 2017; Šūmane et al., 2018). It is also being more widely encouraged as a way of strengthening environmental understanding and adaptation, through the synthesis of different observations of local land using communities and scientific researchers (Maynard, 2015; Raymond et al., 2010; Turvey et al., 2013). This chapter will illustrate how beekeepers generate their own distinct hybrid knowledge. I will show how their experiential knowledge of the specific environment where their bees are located is the basis for their beekeeping practices, as well as their assessment of the wider environment as a suitable location for bees and other species. I will illustrate how their observational knowledge bears the hallmark of TEK, which relies on practical experience of both the individual, and previous generations within a community (Berkes et al., 2000; Fazey et al., 2006; Hernández-Morcillo et al., 2013). Due to the combination of both scientific and tacit methods beekeepers use to construct environmental knowledge, I will begin with an introductory overview of the importance beekeepers ascribe to the knowledge they generate via their practical experience. I will then delve into the particular observations and engagement with weather, seasonal variation, and forage which lead to their practical understanding of environmental factors impacting their bees. While there is a consistent emphasis on the importance of observation and experience, the results of such practices are often collected and analysed in ways akin to the use of scientific data. This blending of scientific and experiential knowledge is found in other TEK systems, and influences how holders of this hybrid awareness perceive their environments (Knudsen, 2008). Similarly, many beekeepers have a professional background in STEMM subjects; this training influences their approach to observing bees, and the wider environment. While TEK is often associated with knowledge gained through practice, and transmitted across the generations, TEK systems are also recognised as adaptable, and able to incorporate information generated via seemingly disparate epistemologies to enhance environmental understanding and resilience (Ianni et al., 2015). I will therefore discuss the role of formal studies, and/or the influence of their professional training and background, to beekeepers' hybrid knowledge. Lastly, I will discuss how they share their knowledge via Civil Society Organisations (CSOs) such as beekeeping organisations, and the Bee Farmers Association.

4.2: Observational Learning: The Bedrock of Beekeeping

This section will investigate the importance beekeepers ascribe to observation and practical experience as a method of generating knowledge relevant to their beekeeping. The centrality of beekeepers' long-term environmental observations in constructing understanding of the complex interactions that affect their bees' health, productivity and foraging behaviour, is evidenced extensively in both archival and interview data. While beekeepers frequently hold disparate, contradictory views on many subjects, it is important to note that empirical results from interviews carried out for this research project noted some universal themes. One of the most important, in their view, is the significant impact of the practice of beekeeping on interviewees' environmental knowledge, understanding and awareness. All interviewees emphatically note the importance of their situated practice on enhancing their engagement with the natural world. The practice is carried out in particular locations, with specific climatic and environmental characteristics that demand multisensory engagement. Beekeeping is a lived experience, generating an embodied knowledge of the environment similar to that of farmers (Carolan, 2008a) and fishers (Eden and Bear, 2011b):

> *I mentioned people on the land-it doesn't really matter what stock you've got. Whether it's cattle or sheep or poultry or bees. They are all to a degree-the principles are the same-looking after them is the same.… Because these people were used to stock, they tended to understand. People who come into beekeeping now are very much-I think I mentioned it earlier-beekeeping by numbers. In the first week in March I do this. In the third week in May I do so and so. Because that's what the book says. But the books are written by somebody who is in one particular place-and I know from getting around the country quite a bit-Cornwall to Northumberland-you could be a month apart in spring. (RP)*

Here we see the value placed on the highly localised, and contextualised, aspect of beekeepers' experiential environmental observations. The affective, embodied quality of hybrid knowledge is also found in ecological surveyors (Lorimer, 2008), thus illustrating the complex blurring of scientific and tacit engagements with the environment. Many beekeepers discuss how their practice has generated within them a heightened sensitivity to wider environmental conditions. Beekeepers describe this in terms of its importance in understanding what is happening to their bees, and how they need to manage their bees in response to these environmental conditions. Almost all interviewees commented on how their beekeeping activities serve as a precursor to wider observations of the natural world:

> *I think (beekeepers) are more aware of things. And even more so now that we've had all of these problems over the years. It does make you wonder what we are*

building up for ourselves. Because bees are a fair indication of how…it's going to affect all pollinators isn't it? (BG)

For some, beekeeping built on childhood interests in natural history and the wider environment:

I've always been what you would call a naturalist – ever since I was a child. I've always been interested in birds, trees, anything that flies or crawls. Moving into beekeeping was natural for me – learning, understanding more about the environment, and its relationship to bees, was a natural move. It colours my life still – I am constantly aware of the weather, and what is in flower. (VF)

For others, beekeeping stimulated a wider interest in the physical environment, and the relationships between flora and fauna. This heightened awareness is described by one interviewee who had also worked as a Conservation Officer with beekeepers, farmers, and other land managers:

It's entirely fair to say that beekeepers have a different form and degree of botanical knowledge. They are interested in where their bees are going, and what they are feeding on, and the nectar they are bringing back. …I think once you have a certain knowledge and awareness of plants, and develop an appreciation of them, you are slightly more inclined to conserve them. (MS)

The relationship between environmental knowledge and appreciation in conservation efforts is noted as a benefit of integrating TEK into adaptive management (Berkes et al., 2000; Olsson et al., 2004; Oteros-Rozas et al., 2013). As a result of repeated observations of environmental systems, TEK users develop methods of recognising and responding to the inherently fluid, and often unpredictable shifts of resource availability in ecosystems. We also see how the process of environmental engagement leads to stimulation of questions about natural processes and relationships, as noted in discussions surrounding citizen science and natural history (Everett and Geoghegan, 2016). Consequently, this enquiring mind leads to a desire to understand ecological relationships, which subsequently leads to changes in behaviour, and a drive to conserve plants and the wider environment in which they live.

Even amongst those who have kept bees for years, there is a common admission that the activity requires constant learning and reappraisal of conditions. Such iterative engagement is valued throughout the community:

> *And I think that the beekeepers I respect the most are the ones that say "you know I've been keeping bees for 40 years and I now, I know less now than I did when I started". That's a very honest assessment. (JP)*

This illustrates beekeepers' consistent engagement with dynamic environmental conditions, and a recognition that an open, multisensory responsiveness to changing circumstances is at the heart of beekeeping. A fascinating recurring theme amongst all interviewees was the development of a consciousness which 'sees like a bee'. All discuss looking at nature, and assessing potential sites for their bees in terms of what plants, flowers and trees they see, and whether or not they are good for bees. They speak of how beekeeping has made them more aware of their surrounding environment, particularly in terms of a long-running, cumulative, growing awareness:

> *But over the years, I've learnt about things. I've learnt about the environment. Just keeping bees has led me that way. (DS)*

The significance of cumulative observations over years is recognised and seen as key:

> *I think it is something that you can only be conscious of when you have had quite a lot of experience. …you don't really put it together until you are quite old. I find it's like that with the weather. And how it affects the flowering. It tends to be the people who have been beekeeping for a very long time who are aware of these things. (DP)*

We see beekeepers' universal emphasis on the centrality of embodied knowledge to their practice. Knowing the environment as a lived experience is recognised as a factor in both amateur and scientific knowledge production (Lorimer, 2008; Whatmore, 2009). This is considerably different from the idea of beekeeping as a skill that can be learned as a course of study. Amongst the beekeepers whose memoirs and interviews served as data for this thesis, the centrality of long-term practice is always recognised and emphasised. The value ascribed to time and continuous practice is notable. It is common to hear beekeepers with decades of experience comment that they are 'still learning', and that 'the bees will always show you something new'. For many, the result of this constant iterative process of observation and engagement is a fundamentally altered perception of the wider environment, which is attuned with their bees:

> *When I drive around the countryside now, I find myself looking at it in terms of bee habitat…I just see the whole countryside now as bee forage. It's completely changed the way I think about the seasons, too. Now, summer ends at the end of July, when most of the honey flow is over. (LD)*

This fundamental sensory engagement with the physical environment creates a rich localised understanding of dynamic environmental factors (Brace and Geoghegan, 2010). Beekeepers' environmental knowledge combines aspects which are both broadly general, but also highly site specific, as they apply universal knowledge about bees to the specific micro-climates and environmental conditions where their hives are sited. Considering that beekeepers are positioned as key stakeholders in pollinator protection policies, it is significant that many of them discuss how their beekeeping practice has also generated increased knowledge of *other* pollinators, not just honey bees – and how this environmental knowledge is different from that of the general public:

> *I think being a beekeeper has made me much more aware of how many more bees there are - types of bees, I mean - I'm sure that to the general public, bees are bees. You know, there are big fat ones that are bumblebees, and other ones that aren't. But there are more bees. And I now know much more about all the different types. Not all, because obviously there are far too many. But um, you know, I know much more about the different types now. (PA)*

For others, their beekeeping practice stimulated other areas of related interest, particularly in botany. Some went on to study botany, with varying degrees of intensity. This included adult education courses in wildflower recognition, and/or the BBKA microscopy module, where students learn detailed pollen analysis, as well as how to identify bee anatomy, and common bee diseases via microscopic analysis. Others carried out MSc studies in melissopalynology – the identification of pollen in honey. For some, developing an increased awareness of the environment was fundamental to developing as a beekeeper:

(Beekeeping) automatically increases your awareness (of the environment). You have to be aware if you want to progress. Yes. It's a very good educator (CB)

While many had expanded their interest and knowledge with formal study, all emphasised the practical element of their understanding and learning:

People these days are so geared towards learning. They think that if you read this and do this - but it's hands-on practical learning that to me makes far better beekeepers. (BD)

In terms of how the two facets of their hybrid knowledge– formal and practical – related to each other, the formal was either a facet of their professional livelihood, and/or a drive towards further learning to complement interests generated through the practical activity of beekeeping. However, when making environmental assessments and management decisions, the knowledge generated through their practice is prioritised.

There is also an acknowledgement of the constant evolving knowledge generated by repeat exposure to different bees, colonies and environments. Engaging with other beekeepers, on a casual or a professional basis, is a central part of their practical education:

I learned a lot by meeting a lot of beekeepers. …Because they have all got a different story to tell. … And I think it was worth doing the bee inspection [job], not for the money, because it was rubbish…. But for the knowledge that you gained from doing it, it was worth it to me, it was worth its weight in gold. It was priceless. (PH)

This theme of learning by experience, whether from working with family members, or visiting other members of a local bee association, or traveling throughout an area as a bee inspector, is central to the development of beekeepers' knowledge.

Beekeepers' practical environmental engagement, often coupled with formal study, leads them to develop a rich awareness of local and wider conditions which are of importance to their bees, and often also of wider environmental significance. This deep, local knowledge is a common facet of TEK systems, increasingly recognised as having the potential to enhance biodiversity conservation schemes (Fraser et al., 2006). However, due to the experiential and situated element of beekeepers' knowledge, which often lies outside of standardised methods for scientific confirmation, it is frequently dismissed by both scientists and policy-makers (Kleinman and Suryanarayanan, 2012). The blending of seemingly contradictory epistemologies creates a dynamic space for hybrid knowledge, where generations of observations are consistently reviewed and supplemented with new information (Ianni et al., 2015).

This dynamic approach to their practice, and further learning, manifests in varying degrees of formality, with some beekeepers maintaining extensive records about factors relevant to their practice. These records are kept for their own individual practice, and are often shared and communicated throughout associations. In the next section, I will explore how recordkeeping and observation of environmental factors support their practice.

4.3: Record-Keeping and Construction of Knowledge

Throughout archival data for this thesis, there is constant referral to the importance of recordkeeping and analysis as part of beekeepers' environmental knowledge construction. One archival source describes the records he kept for over six decades of beekeeping, and their importance to his practice:

> *'I make a note about weather, times of flowering of important nectar sources, honey yield and more, on a page opening preceding the colony entries, and at the end of the year I record the yield of each colony and the average yield per colony (winter count) in the form shown below… For me, (records) are an essential management tool.' (Sims, 1997, p 94)*

Another writer clearly illustrates complex multifactorial data collection, and describes the resultant analysis from such recordkeeping:

> *"1942: up to June 25, owing to poor weather, it seemed as though there would not be a honey harvest. However, at this date the weather really set in fine and at the very same time the lime trees began to bloom. During the next 18 days the hive increased in weight to 49.5 lbs. For 5 of these days (marked 'K' on the chart), when the lime trees were giving off nectar at their best, the weight went up 32.5 lbs gross, but on each of the five nights there was a loss of 2 - 2.5 lbs, making the increase in 5 days 22 lbs net. After this, clover nectar began to come*

in and the loss at night stopped. By this it appears that the lime nectar is very thin and watery as compared to clover nectar." Spiller (1952, p 22-3)

This information was analysed by the beekeeper in terms of the potential honey productivity as a result of access to specific forage crops. Such data are collected and analysed in a manner that spans amateur and scientific observation.

All interviewees were asked about their record-keeping. This was to help understand the scale, breadth, formality, and analytic approach beekeepers bring to their practice, and their engagement with the environment. Almost all beekeepers interviewed tend to keep what can be considered standard records, such as the date of inspection, whether the Queen is seen, the presence of eggs, larvae and brood, and whether supers are added or taken off of hives:

So it's very important to keep records. And I would use those records. I have modified and changed and hopefully improved them over the years. But you can't take action unless you have a pretty good idea of what you are doing, or you shouldn't. (CB)

An example of the BBKA standard record-keeping form is provided in Appendix 4. Seen within the context of hybrid knowledge, the record keeping practices of beekeepers are significant. While they are carried out by both hobby beekeepers and professional bee farmers, their compilation and usage by both groups shares many of the characteristics of scientific data. It is collected in a methodical way, and often consists of a range of quantitative information. It is then analysed in an objective, singular way:

(I have recorded) the weather for many many years. But I've collated it more since about 1990. There's about 57,000 entries in my records. Date, maximum temperature, minimum temperature, the type of weather-rain, sunny, whether whatever. And the amount of rainfall. And the amount of sunshine as well. (RR)

Some beekeepers, such as this one, use this data for their own personal research purposes. A common focus of investigation is to analyse their bees' honey yields in relation to local weather patterns for that season. Others record the productivity of particular colonies and then use the more successful for raising more queens, which will, in turn, lead to further productivity. Queen breeding is popular amongst beekeepers who wish to develop or minimise particular traits in their colonies. This entails both keeping and using records over several seasons. While there has been a historic preference for behaviours such as productivity and/or calm behaviour, there is an increasing drive to breed for resistance to disease, particularly varroa:

> *We very seldom tolerate fussers and followers up there. They've got to be calm, because it is a teaching apiary. The farm apiary-we will tolerate a little bit more in terms of fussing about. Having said that, the farm is the breeding area, where we're trying to improve them. (KH)*

> *But I also try and maintain my own work in developing native bees, and varroa resistant bees. Because my bees are resistant to varroa, you see….I keep records of the Queen lines that I keep going. ..But I got rid of one of them because they were quite aggressive. …I keep records of what line I have got, and this is partly because I want to preserve those lines if I want to later go into DNA analysis, to sort out what I've got and what and how different they are. (DP)*

This level of detailed recordkeeping raises important questions about the nature of amateurs. Diverse epistemic communities utilise a range of assessment techniques in their practices, which, although carried out as hobbies, highlight the informed nature of their amateur status (Endfield and Morris, 2012a). The binary dichotomy between amateurs and experts, particularly in the context of environmental monitoring, is questioned, as we see communities of amateurs and volunteers manifesting a high level of expertise in their practice (Ellis and Waterton, 2016; Ellis and Waterton, 2004). Many of the long-term beekeepers interviewed for this thesis clearly demonstrate a level of engagement and expertise that is notable for its capacity and its depth. The second interviewee quoted above spans multiple categories of scientist and amateur, and holder of both TEK, and scientific knowledge. His experiential knowledge is deeply contextualised in his geographic area, and he has become a highly respected source of information amongst the local, national and international beekeeping community. While he is a scientist by background, he currently lacks access to equipment, and institutional support for his research. Thus, he exemplifies the epitome of the rich hybrid knowledge held by numerous long-term beekeepers.

It is important to note that data for this project found diverse levels of formality of recordkeeping and approaches to data collection and analysis. Some beekeepers admit to keeping their records and observations 'in their heads'. As one interviewee said 'country folk don't always write things down!' While some interviewees did not keep written records, they were still engaged in intense, regular observations and analysis of environmental conditions and bees' responses, which they relied upon for their hive management decisions. Awareness of seasonal trends is noted as a guideline for practice:

> *The springtime can be, like, I start my beekeeping - in Ireland traditionally, you start your beekeeping on the first fine day after Saint Patrick's Day. So, but, that can actually - I was actually writing an article recently. I looked it up, and in the last 10 years, it has varied from March 12 to April the 22nd. (EC)*

Here we see how a fixed date – St. Patrick's Day (March 17th) – is used as a marker in the beekeeping calendar; however, fluctuations and variations in practice in relation to this date, still exist. This approach is closely aligned with that recognised in holders of TEK across the globe (Ingram and Njikeu, 2011; Luo et al., 2009; Oteros-Rozas et al., 2013). The records are not always written down, but the powers of observation and analysis are still active. These seemingly idiosyncratic forms of traditional environmental understanding has been found to be complementary to other, more formal methods, in such diverse environments as the forests of Peru and Korea (Park and Youn, 2012; Thomas et al., 2017), as well as in France (Lehébel-Péron et al., 2016), and India (Robbins, 2003). Indeed, Robbins notes a growing acknowledgement that local knowledge *is* scientific, in that it originates from experimentation, trial and error. However, it is important to heed his call for a politically balanced engagement with knowledge derived from epistemologically diverse sources, if we are to gain an accurate, and democratic, understanding of environmental conditions, resources, and their users (ibid).

Several interviewees kept extensive written records relating to a range of factors influencing bees and other pollinators, including flowering times, rainfall and general weather conditions. They discuss the importance of this detailed awareness of, and engagement with, wider environmental patterns and available crops and forage, as this is "what their bees survive on". Others combine their detailed observations of phenological information, with notes on bees' behaviour. The noting of pollen going in, is frequently used by beekeepers to assess whether their colony is 'queen-right' – eg, that the queen is alive and laying eggs:

Going back a little more - 4th of March - rain all day. 11th March-cherry and plum out. The bees on hellebores. All flying well and pollen going in. Going back-February-turned very cold-hard frost all week. Snow quite heavy. Cold all week. 11°. -11 overnight. So it's quite interesting looking back at what's out. (PHu)

Another interviewee, who is a professional bee farmer, discusses her daily recording of rainfall levels:

I am the original anorak with a rain gauge…I have rain gauge records going back to 2000. I am an absolute nerd about weather records. I also have records from a scale hive in my garden (MC).

A scale hive is a hive permanently kept on a scale; no honey is ever removed by the beekeeper. Records of the changes in weight are used to assess the behaviour and productivity of the colony, and are often assessed in relation to weather records. This interviewee then discusses observing the patterns and relationships between the scale hive and the weather. The interviewee talks about 'developing a feel' for the patterns in the weight changes of the hive. They note how very dry, warm days are mistakenly assumed by many members of the general public to be good for bees, when actually, the lack of precipitation will result in a slower nectar flow, and poorer foraging conditions. Bees (and other pollinators) ideally need a delicate balance of precipitation and temperature, at very particular times of the year. This evidences the differing environmental perceptions and tacit knowledge generated by beekeepers' regular environmental practice, and how these differ from observations of members of the general public.

While there is a plethora of quantitative data on temperature and rainfall available from the UK Met Office and other sources, in terms of understanding local plant-pollinator relationships, the observations of beekeepers generate situated knowledge of these interactions (Lehébel-Péron et al., 2016). The next section of this thesis will explore how beekeepers use their observations to construct an understanding of the specific local areas in which they keep their bees.

4.4: Constructing Local Knowledge

While certain information relevant to beekeeping is broadly universal, such as the general lifecycle and biology of the colony, there are important regional variations and manifestations, eg, when particular events occur in relation to the local climate and conditions. For centuries, beekeepers have been attuned to specific local characteristics and microclimates, and how these are relevant to the health and productivity of their bees. *One Thousand Years of Devon Beekeeping* (Brown, 1975) provides some of the oldest, detailed discussion of UK beekeeping and associated environmental observations within the IBRA archives. Brown notes that beekeeping is mentioned in the Exon Domesday book, referring to the practice in Lustleigh, on the edge of Dartmoor. This area, on the chalk uplands, has long been considered a good habitat for bees, with a foraging season that included heather in autumn, as well as early spring flowers. This recognition of the benefits of certain soils and their associated flora as habitat for bees continues today. This regional information, and beekeepers' analysis, provides a strong, continuous temporal context to beekeepers' local environmental observations and resultant preferences for the siting of hives based on these observational assessments.

Calhoun's *A Lifetime with Bees* (1979) provides further historical examples of complex phenological information, which is both collected and contextualised by beekeepers:

> *"Here in this area, our principal honey comes relatively early in the spring. Usually, the flow from poplar, gum and other plants starts between the 15th and 21st of April. Records show that in some years it may start as early as the 1st of April. When the flow begins at the earlier date, the flow has been less and swarming worse than in normal years….Warm weather with lots of sunshine and dry weather - but not excessively dry - gives the best results. The weather will definitely influence swarming fever. This is a factor over which there is no control." (Calhoun, 1979, p 22)*

The author specifically notes that his observations of weather refer to *the area he is in*; this implies that conditions, dates and behaviours will be different in other areas. This author is writing from long-term practical experience, which he situates within his local area, and local conditions. Beekeepers have a common tendency to observe and record phenological data and patterns, regardless of their location. Calhoun's recordkeeping has generated knowledge and understanding of variables in nectar flows from year to year, and the relationship of this flow to wider weather conditions. He is constantly observing and analysing multiple components which are relevant to his bees. Calhoun goes on to further discuss his long-term, repeated observations of local weather trends and his theoretical interpretation of their relationship to bee behaviour and honey production:

> *The weather has a decided effect on the amount, flavour and colour of our honey. … During the honey flow, warm, sunny days with southerly breezes and light rain provide the conditions that allow the bees to produce a good quality, very light amber-coloured honey. The bees respond with bumper crops of high-quality honey under these ideal conditions. When the weather is cold or cool with lots of cloudy days and more rain than normal, the quality of honey produced during the flow is affected. … In our area, the direction of the wind effects the amount of honey produced in a given day.… My theory is that dry North and North-West winds evaporate the nectar from the blossoms before it can be gathered by the bees. On the other hand, South winds are more moist and reduce the rate of nectar evaporation, which gives the bees a longer time to secure the nectar. (P 52)*

The above passage illustrates a multifactorial awareness and analysis which is a distinct feature of long-term beekeepers' tacit knowledge. We see Calhoun's continuous environmental analysis over a lifetime of beekeeping mirrored by other writers of similar levels of experience. *World of a Bee Farmer* (Rawson, 2008) also emphasises the role of local knowledge in recognising the significant factors when choosing sites for apiary placement. This included the role of microclimates, which are affected by latitude, the acidity level of soil, and the lie of the land: 'Narrow, steep-sided valleys produce variable air currents which sometimes make chilly gusts of wind.' (ibid, p 17). Such continuous assessment over years of practice also generates heightened awareness of the relevant proxy behaviour of other species: 'A better guide is to notice where gnats congregate during warm summer afternoons and evenings'. (ibid, p 18) Rawson notes similarities between honey bees and ants, which he ascribes to their both being aculeates. Ultimately, his final advice to other beekeepers is 'It is not easy to find an apiary site that meets every sensible requirement. Many are good in some ways but not so good in others, and one needs to take an overall view.' (ibid, p 25). We see here the issue of overall assessment of conditions, rather than understanding them as singular features. This focus on a holistic understanding of the environment is a key distinguishing feature of beekeepers' knowledge, which was also evidenced in Calhoun's 1979 memoir.

As evidenced above, beekeepers have historically been highly attuned to their surroundings, observing and analysing their environs, and the behaviour of their bees. Throughout my interviews, I investigated beekeepers' views and knowledge about key features and qualities of the local environment where they kept their bees. I also questioned whether there were areas which beekeepers avoided, or refused to keep their bees, and the reasons for their rejection of particular sites. Several interviewees talked about the decline in quality of forage and wider habitat and conditions for bees in particular regions, within their lifetime and beekeeping experience. This observational knowledge of environmental change, continuity, and/or deterioration is of wider significance, as it provides us with the opportunity to further examine exactly how beekeepers assess an environment's quality for both their bees, and other pollinators.

It was common for a large majority of interviewees and writers in the archives to maintain multiple apiaries, in areas which, to the untrained eye, may seem interchangeable. However, beekeepers' deep engagement and consistent analysis of multiple components results in their noting important differences in sites, and responding to these differences with perpetually iterative management decisions. Local variations can include wind, frost pockets, forage differentials, altitude, exposure to incinerator waste, and more. As noted in a leading beekeeping guide, and in archival material (Bruyn, 1997; Cumming, 1945), it is clear throughout the interviews that regional variations are highly significant to beekeepers:

> *There's no point in comparing records with a village that's 200 feet higher in the Wiltshire hills. (RR)*

It is notable that the broad range of relevant variables noted in archival and historical sources such as memoirs (Calhoun, 1979; Miller, 1911) remain consistent points of importance to contemporary interviewees:

> *Some hives are (3) miles n of Haverford West. .. They are under a heather and bracken (hill). Others are at estuary level, at Little Haven. They get sea level and tree honey as they are in woodland area near National Trust land. They do better in a poor year, because it's warmer. The other hives do better in a sunny and hot*

year because they've got so much wild country in particularly blackberries around them. But of course they don't survive winter so well … (KR)

We see here how the beekeeper is assessing multiple synergistic factors which impact the bees' productivity, and health. Although these two sites are close to each other, they generate different honey, and are distinctly different in their capacity to support bees over the course of a year, depending on annual weather patterns. One interviewee had incorporated his locally specific environmental knowledge of what is best for their bees directly into his own choice of personal habitation:

We picked the spot particularly for bees. That's why we moved down here. We used to live higher up on the hills, and it was about 800 feet up there, and it wasn't as good. But we moved down into the valley - down the Severn Valley….it's much better forage down here, and they've got longer, warmer days so it's much better. We've got everything here. (BG)

Such a deep level of engagement with their environment impacts how some beekeepers approach formal research on bees and the environment. While there is extensive research and guidance published on bees and beekeeping, the majority of beekeepers interviewed for this project emphasised the importance of experiential local knowledge in addition to, and sometimes above, much of the research carried out by scientists, as the local conditions and microclimate have such a significant impact on their individual beekeeping. Beekeepers often prefer the guidance of people dealing with the same conditions as themselves. Hence, there is a long tradition of working with mentors, colleagues, and others keeping bees in their area (Adams, 2016). Amongst the community, there is enormous value placed on the knowledge of long-term beekeepers, and a tendency for knowledge to be transmitted through social practice (Phillips, 2014). This intergenerational system of knowledge acquisition and transmission is found amongst TEK holders living and working in a highly diverse range of environments, including China, Spain, and the North American Arctic (Cruikshank, 2012; Luo et al., 2009; Oteros-Rozas et al., 2013), thus illustrating an important parallel amongst the knowledge generated through beekeeping, and TEK.

Due to the importance of flowering time and plant-pollinator relationships, any notable changes in flowering time are particularly significant to beekeepers, and feature regularly in their formal and informal records of local conditions. This enables beekeepers to utilise the results of their long-term observations of these phenological patterns in constructing actionable knowledge of their local environment:

> *the gorse… is flowering the whole winter now. It comes into flower in October, and it will flower right through the winter. When initially, when I came down here at first, it was coming into flower in January or the end of January. (EC)*

Several interviewees are bee inspectors. The nature of this employment entails travelling, often over a wide region, inspecting bee colonies. Subsequently, they develop detailed insights about differences between localities, and the potential benefits or attractions of these sites for bees. Regional variations are particularly significant in terms of how beekeepers respond to, and evaluate instructions, advice, and scientific reports on beekeeping. There is a common remark amongst beekeepers that 'the bees don't read the books'. Therefore if beekeepers encounter advice as to when to carry out certain activities, which differs from what they experience in their locale, they approach such material with scepticism. The centrality of local observations to their practice and management decisions leads them to be highly attuned to changes in phenological and seasonal changes in their locale. This may also help us understand the regional variation and location of environmental benefits and challenges for other species, as it is recognised that conditions that are challenging, or supportive, for honey bees are frequently of similar quality for other pollinators (Gross, 2014; Kevan, 1999; Vanegas, 2017).

We have seen how beekeepers' constant iterative assessment of changing local conditions is central to their environmental knowledge, and their practice. This emphasis on the characteristics and changes in specific locations, which is observed, recorded and analysed over decades, creates a highly distinctive form of environmental knowledge that enhances other broader, and more general environmental surveys and analyses. I will now discuss what beekeepers are observing in the specific environments in which they practice their craft.

4.5: What are beekeepers observing in their environment?

Related to beekeepers' observational knowledge of changes in flowering time are their observations on wider seasonal changes. This knowledge is highly relevant to a wider audience. As noted in this chapter's first section, on recordkeeping, beekeepers frequently collect a range of observational data on interrelated environmental factors, including weather, land use, and bees' responses to these factors. Both bee decline, and wider invertebrate decline demand investigation into the nexus of conditions, and their impact on a range of species (Hallmann et al., 2017). Managing honey bees requires a constant engagement with the seasons, using the knowledge created through past experience as a guide, but simultaneously maintaining an open responsiveness to changing conditions. Throughout the beekeeping year, there are particular tasks a beekeeper is expected to carry out at key times in the colony's development, as part of ensuring bees' health and productivity. The biology of the superorganism that is a bee colony undergoes annual cyclical changes, as its population rises from winter levels of approximately 5-10,000, to a maximum of approximately 50,000 in the months of May – July. These numbers and months can change as a result of various influences, such as specific microclimates, swarming, and seasonal changes. Due to the immense impact of seasons, beekeepers are highly engaged with changes in seasons, including changes in the start of seasons, and their intensity.

A History of beekeeping in Ireland (Watson, 1981) depicts beekeepers' longstanding awareness of, and engagement with, the significance of seasons for bees, not just in and of themselves, but their sequence. The relationship of summer and spring to each other, and the weather in both, is interpreted in terms of how it affects bee's forage, and how bees can starve if there is too much swarming, or if there is a cold, wet spring and summer. These complex synergies are also explored in *1000 years of Devon Beekeeping* (Brown, 1975). Brown mentions a famous 18th Century beekeeper, John Wildman. Wildman was quite astute in his observations of bee behaviour and health: *'many hives of bees which are thought to die of cold in winter, in truth die of famine; as was the case in the winter of 1759: for the constant rains of the preceding summer hindered the bees from laying in a sufficient store of provisions.'* Wildman's quote provides temporal depth to this experiential knowledge regarding cumulative seasonal factors affecting bees.

This historical evidence is also reflected in interview data. As part of a series of questions about their environmental observations, all interviewees were asked about whether they had observed any changes in the seasons during their years of beekeeping. Most stated that they had. This included changes in the beginning, end, duration, and intensity of seasons. Several noted that recent winters were increasingly milder and warmer than those when they first began keeping bees:

I suppose the changing climate - we do notice new patterns, in that the winters tend to be warm, and the summers are often wet. (DP)

I think things are flowering at different times, because of the weather. We have had some rather warm winters, and things that used to flower in the spring are actually flowering now. The mahonia is out in flower. It's been a bit weird. My bees are still out working the ivy. Even now [late November), because it is 8 or 9°. (MC)

The weather has definitely got warmer. There's no doubt about that. And the winters have got much less severe. When we first came here in the 70s, the children were little, and they went tobogganing every winter. Now the children don't go tobogganing at all. (AS)

While there is the risk of nostalgia colouring people's memories of past winters (Hall and Endfield, 2016), the fact that the majority of beekeepers maintain some form of records regarding their practice, and some have even adapted their practice over the years in response to seasonal changes, gives their observations an added weight. The grounded local experiences of changing weather patterns and seasonal characteristics can enrich wider understandings of climate change and associated weather patterns (Marin, 2010; Primack and Miller-Rushing, 2012). We see beekeepers constantly constructing knowledge of the environment through immersive observational practice over the years. Long-term comparisons of changing climatic patterns are assessed in relation to how bees – as well as other flora and fauna – respond to these conditions. Problems are observed if and when winters are milder:

"We have milder winters, and you only have a small number of bees to over-winter. If they are out and about too much, they can, if you are not careful, eat all their stores." (VF)

As this interviewee notes, there are significant challenges to bees from seemingly good weather. As part of its seasonal lifecycle, the colony's numbers drop significantly in preparation for the winter. Unseasonably good weather can lead to bees beginning to forage, as the temperature triggers behaviours associated with spring. This can lead to the bees expending energy for little return, and eating through their winter supplies. Another risk is of the colony growing in numbers due to the queen continuing to lay through the winter months, which also puts extra pressures on the colony's limited winter resources. If a beekeeper is not careful, a colony can rapidly starve in the late winter or early spring, if it has consumed its winter stores (Bruyn, 1997). The serious impacts of weather changes and seasonal variability on colony wellbeing leads to long-term beekeepers paying close attention to weather patterns.

The cumulative phenological observations made, and consistently reviewed and analysed, generate knowledge about weather changes that impact bees and other species. As well as seasons altering, interviewees also specifically referred to changes in the intensity of seasonal weather events. For example, interviewees note the practical impact of heavy summer storms on bees' forage:

> *one of the things that the bees suffer from is the heavier - much heavier - summer and spring rainstorms, which wash the nectar out of flowers. (AS)*

It is unclear if what the beekeeper is observing has been verified by formal studies, so we do not know if their observations represent 'undone science' – eg, areas of research which are considered by social movements and/or civil society organisations to be worth investigation, yet for various reasons fail to attract significant research engagement from the scientific community (Frickel et al., 2009; Hess, 2009). We do not know if the observation is even verifiable under Randomised Controlled Trial (RCT) conditions. However, the link is observed and deemed relevant by the beekeeper, as a result of their continuous observations and practical experience. We see the interaction between beekeepers' practical understanding of foraging needs and behaviour, and their observation of climatic changes. It is not simply a matter of noting that there is increased rainfall, which is quantitative data that can be easily collected from publicly available local and national records, such as Met Office data and other sources. Rather, it is a situated, contextual understanding of *how* rainfall lands in a particular area, and the force of wind, on particular days, at a particular time of year – and how these combined weather variables impact their bees.

Beekeepers are highly engaged with the prospect and the reality of climate change. One attendee at a beekeeping conference noted 'Ask anyone who's been keeping bees for 40 years if climate change is real, and they'll say of course it is!!'. Most climate models forecast increased frequency and intensity of storms and winds as a result of climate change (Beniston et al., 2007; Meehl et al., 2000; Trenberth, 2011). Such changes in historical weather patterns are already noted by beekeepers as a challenge to their bees' wellbeing and productivity:

> *I think we've had a few exceptional years, really, even in this part of world. 2012 was wettest on record. 2013 was probably the coldest until June. And certainly last year (2015) was cold and then wet until early June. And the other thing that's happening – we're getting warmer autumns, so if you like, the bees are active over a longer period than when I first started keeping bees. (GO)*

While there are questions about the role of climate change on fluctuating weather patterns, the fact that beekeepers are noting distinct variations in local weather, and the impact of these changes on local conditions and their bees, is relevant and worthy of further investigation. Observations about wind and stormy conditions are interpreted with reference to the impact such conditions will have on bees' ability to collect both nectar and pollen. As pollen is the key material needed for bees to feed their growing larvae, negative weather conditions that limit bees' ability to collect pollen will result in decreased egg-laying by the queen. Such biological factors necessitate beekeepers' careful monitoring of weather and hive conditions over time, if they are to ensure the wellbeing and productivity of their colonies.

As several interviewees note, there are a broad range of variables that can affect how particular environmental and climatic conditions impact bees' health, behaviour, and foraging habits. Several interviewees carried out independent research projects on the links between temperature, rainfall, and honey yield:

> *My original effort to correlate was to determine how many fine days there were during the summer and that relationship to the yield of honey per hive. That's fine, but I regard summer as from May to September. And of course, the bees produce honey only between April and July. Well my bees do, anyway. So I might have had some fine days in August and September, which might make the*

number of fine days in the year higher, but of course that's of no interest to the bees that particular year …So, again, my definition of a fine day is where there is 70% or less cloud …there might be no cloud, or they might be just 30% sunshine. But that is still a fine day in my opinion. And bees can fly during a warm cloudy day, just as much during a cool sunny day. So there are so many variables. (RR)

This quote illustrates the complex nexus of variables that can impact the relationship between weather, honey yield and available forage. This interviewee keeps his bees in an area where honey production takes place between April and July, which is the main honey production season for most of the United Kingdom. However, some interviewees observe that this traditional pattern is changing, due to a significantly extended honey production season, resultant from the availability of Himalayan Balsam and ivy. The wider ecosystem effects of changing seasonal patterns are also noted by TEK holders in other regions (Hernández-Morcillo et al., 2013; Smith et al., 2017). This illustrates the significance beekeepers ascribe to both regional variations, and the importance of long term observations, in generating knowledge that is used to manage their bees for maximum health and honey production.

Also of interest in this quote is the interviewees' caveat that 'my bees do (produce honey at a certain time)'. This helps us understand how beekeepers generate localised, specific knowledge of what is available as forage in a particular area, at a given time. Traditionally, the spring and early summer were seen as the foraging period for bees, with late summer and autumn dismissed as providing any potential for forage, unless beekeepers took their bees to the heather, for what is traditionally a late summer honey crop. However, as noted above, the increased availability of Himalayan Balsam, ivy and gorse in autumn, offers the possibility for changes in honey production and subsequent wellbeing of bees.

Beekeepers are consistently emphasising the fluidity of conditions and variables. One of the most important, and changeable environmental conditions they observe, is forage. A key distinction between bees and other animals managed by humans, is that bees' forage cannot be controlled by humans. It has long been observed by beekeepers that bees have an average foraging range of approximately 2 miles radius from their hives (Robinson, 1889). Scientific studies have verified that bees have a foraging range of up to 10 miles, although, on average, they tend to forage within a 2 mile radius of their hives (Beekman and Ratnieks, 2000; Garbuzov et al., 2014; Greenleaf et al., 2007; Seeley, 2016; Seeley, 2010). Due to the breadth of their foraging habits, the quality, quantity and consistent availability of forage for bees is one of the key concerns of beekeepers, and a driving force in their construction of environmental knowledge. All beekeepers consider forage as a key factor when deciding where to site their hives. This was one of the main themes within both archives and interviews. It is interesting to note the detail and sophistication of some observation and analysis dating back centuries, and how it correlates to recent scientific discoveries, and beekeepers' practical observations.

A history of English Beekeeping (Walker and Crane, 2001) mentions writings dating back to the 16th Century and earlier, which denote an awareness of links between bees and forage, and how much forage they need. The authors include extensive data from 17th century writer Charles Butler, on what plants to grow for bees:

> *'in addition to flowers, the garden should be conveniently beset with trees & bushes fit to receive the swarmes, as plumtrees, cheritrees, apletrees, filberds, hazels, thornes, roses, &c.'. (Butler, 1623)*

Butler's advice of appropriate trees exemplifies the trend for beekeepers' observations to precede scientific verification, as his recommendations precede recent DNA analysis of pollen residues, which provide evidence of bees' preferred forage sources. (de Vere et al., 2017).

Observing bees' behaviour, wellbeing and productivity within the context of forage quality and quantity has remained a key theme of beekeepers' environmental knowledge over the centuries. In the late 19th and early 20th century, Dr C C Miller wrote a column in one of the leading magazines for beekeepers, *Bee Culture*. The magazine serves as a forum for communicating to beekeepers the latest research on honey bee health and biology, as well as publishing articles on practical beekeeping, and a broad range of articles related to bees. In Miller's memoirs, *Fifty Years Among the Bees (1911),* he historically situates beekeepers' observations of forage plants, and their phenological linkage:

> *There are certain things always noticed by a beekeeper, with much interest, as heralding the beginning of spring or of the honey harvest….You will be surprised to find how long it is from the time the first (white clover) blossom may be seen, till the clover opens out so bees will work upon it. (Miller, 1911, p 120)*

Miller evidences an awareness of a significant difference between the appearance of blossom, and it reaching a state where it is attractive and of benefit to bees. This gap in time is perceived by the beekeeper, but may be easily overlooked by those who are not so highly attuned to the behaviour of other species. His environmental understanding is generated through careful, long-term observation of the environment, and how his bees respond to it. Miller describes the important benefits of there being multiple forages available for the bees. Over the years of his practice, he has observed what plants are available, at what times, and in what weather conditions. Miller keeps extensive plant lists: his date back to 1882. Such plant lists were commonly kept, shared and communicated amongst beekeepers to aid in planning apiary settings and management, and were transmitted amongst beekeeping organisations and publications (ibid). The keeping of detailed lists of plants which appeal to honey bees has been a common practice for centuries (Walker and Crane, 2001). This practice is found throughout the Anglophonic world, including England (ibid), America (Pellett, 1923), Canada (Sauriol, 1984) and New Zealand (Hopkins, 1916). F.N. Howes' *Plants And Beekeeping* (1945) is still referred to as 'the Bible' by British beekeepers, and used extensively for planting guidance, due to its detailed description of various fodder for bees.

Miller (1911) also discusses the importance of ensuring that areas are not too densely filled with colonies, so that adequate capacity of forage is guaranteed for all the colonies in an apiary:

> *'I can easily imagine a place where five colonies might store continuously for five months, and where a hundred colonies on the same ground might not store three weeks. There might be flowers yielding continuously throughout the entire season, but so small in quantity that, although they might keep a very few colonies storing right along, they would not yield enough for the daily consumption of more than ten to fifty colonies. Remember that the surplus is the smaller part of the honey gathered by the bees. (p 41)*

The knowledge behind this assessment was developed over years of careful observation and analysis of his colonies' health and productivity in different locales. Miller also discussed lessons learned over his beekeeping career, and the key importance of ensuring access to a diverse range of forage available. The importance of diverse forage is still discussed by beekeepers today, and has also been acknowledged by scientific research on bee and pollinator well-being (Naug, 2009; Neumann and Carreck, 2015; Vandame and Palacio, 2010). Consistent scientific evidence documents the link between a nutritionally varied diet, and the ability of colonies to withstand challenges to their health (Decourtye et al., 2010; Potts et al., 2010). This linkage is well-known, and frequently discussed by beekeepers:

> *And I believe, as with humans, that the best way to avoid disease is… is to keep bees healthy. When you are very healthy, you resist illness. I think a mixed diet for them is important for them as it is for us. (CB)*

It is important to acknowledge that, for all of the concern about loss of key forage crops, some beekeepers also note the additional forage availability in recent years as a result of both changing weather patterns, and the promulgation of new crops such as Oil Seed Rape (OSR), which supports bees in early spring, and wild plants, such as *Impatiens glandulifera,* better known as Himalayan Balsam, which is common in late summer. The impact of this high quality, high-energy forage source late in the season is seen by some beekeepers as being a powerful benefit to colonies' health and well-being. Increased late season forage availability allows the colony to continue growing, as the Queen can continue laying, substantially increasing its size, viability and potential for late-season forage collection as it approaches the winter months, when forage is not normally available:

> *And we're seeing a lot more surviving colonies of wild bees since we have had Himalayan balsam. Well normally they would starve to death. If they swarmed in July, by August 10 the nectar flow would be finished, and there would be nothing else apart from a bit of knapweed…(that) and a bit of willowherb will keep colonies ticking over, but it wouldn't build colonies up for winter. All these wild colonies would die out (without Himalayan Balsam). (PH)*

This increased late season forage is seen as creating a greater opportunity for feral bees to survive the winter, thus serving to reverse the decline in feral colonies which has happened in recent years as a result of varroa. While Himalayan Balsam is seen as an invasive species by many ecologists (Gallardo et al., 2016; Seeney et al., 2019), this is one of many issues where there is a discrepancy between scientific understanding, and beekeepers' observations:

> *There is a false perception about Himalayan Balsam. Yes it is a problem on stream sides. But not anywhere else that I have seen. Inner city council workmen pull it*

up from roadsides where there is no chance of it causing erosion. … Stream sides where it is going to outcompete…people think it is going to erode and erode, so you will get a (widening stream) but it doesn't. … And what has actually happened is, naturally, it has settled. (KB)

Some ecologists have expressed concern that Himalayan Balsam can lead to wild pollinators failing to be attracted to other plants, as they ignore them for the sake of feeding on Himalayan Balsam (Lopezaraiza–Mikel et al., 2007). This, too, has been disputed by beekeepers: they counter this attack on what they value as a late season source of forage by noting that the majority of other plants that could be seen as competing for pollinators' attentions have already flowered by the time Himalayan Balsam flowers. This thesis does not set out to prove who is right or wrong; rather, it highlights differing environmental understandings between beekeepers and other epistemological communities.

All interviewees described intense engagement with observing and recording bees' forage. As the honey bee colony, which is commonly considered a 'super-organism' (Tautz, 2008) moves through annual biological developmental stages, the relationship of the colony to the surrounding seasonal patterns is of crucial importance to the wellbeing of the colony. If suitable quantities and quality of forage are not available at the correct stages of development for a colony, its health will suffer (Hooper, 1979; Winston, 1987). By this combination of observation of the external environmental conditions, and years' of engaging with their colonies in response to their observations, beekeepers construct knowledge of the environment, and the impact of forage changes, and factors such as weather patterns, which drive these changes:

But it's just - when bees have enough forage, they are much better able to manage their own health, you know? And they are less stressed. (EC)

The above quote correlates with multiple scientific studies into honey bee health (Brodschneider and Crailsheim, 2010; Di Pasquale et al., 2013). A recent major study on the impact of neonicotinoids on honey bees noted that, when bees had access to a diverse range of forage, and were in generally good health, they were better able to withstand the negative impacts of exposure to neonicotinoids such as clothianidin and thiamethoxam (Woodcock et al., 2017).

Given the sharp rise in the popularity of beekeeping in some areas, and scientific debates about carrying capacity, pressure on forage, and the impact of honey bees on other pollinators (Breeze et al., 2011; Brown et al., 2016; Goulson et al., 2015), the experiential insights of long term beekeepers provide a valuable form of evidence to enhance our understandings of environmental networks. With the quality and quantity of forage being so central to bees' wellbeing, the capacity of a local area to support pollinators has long been recognised as a constraining factor. Beekeepers in both the archives and in interviews engage with the perceived impact of large, sudden influxes of other colonies in an area, on their bees' health and productivity:

> *Thomas Seeley …is looking at forests, and finding that bee density there is much lower. I've found that when I run my small apiaries, which are jogging along happily with a couple of hives, and I then find that some commercial beekeeper has moved in 20 nationals, or commercial hives, with Italian bees that have been fed sugar syrup to get them going early in the season…those bees were rampant. And they rob – they literally just cleaned out my 3 hives. (JH)*

An awareness of shifting, complex ecological networks resulting from practical observations is a key feature of beekeepers' environmental knowledge (Lehébel-Péron et al., 2016). Similarly, warmer seasons and milder autumns and winters are associated with continual flowering of plants such as ivy and gorse, both of which are recognised as key forage sources. As we are currently experiencing changes in weather patterns and associated phenological responses, the long-term observations of beekeepers allow us to develop our understanding of species' responses to our changing environment.

The preceding section has evidenced centuries of beekeepers' experience and observation generating insights about the environment, and its effect on bee health and productivity. As stated at the outset of this chapter, beekeepers emphasise the importance of such experiential knowledge – but they also bring their professional and/or amateur study of science to their practice, thus creating hybrid knowledge. This will be the focus of the next section.

4.6: Formal Study and Hybrid Knowledge

While archives and interview data all stress the ultimate importance of developing practical knowledge in regards to one's bees, a distinguishing feature of many long-term beekeepers is their hybrid knowledge. Such hybrid knowledge is increasingly recognised amongst farmers and other landworkers (Curry and Kirwan, 2014; Girard and Claude Paraponaris, 2015; Šūmane et al., 2018), as well as fishers (Bear, 2006), and hunters (Royer et al., 2013). It is common for such communities to develop and utilise TEK. As these environments, and life within them is changing, communities are also engaging with different methods of understanding, and working in, their environment (Royer et al., 2013; Turner and Spalding, 2013; Turner et al., 2000). This illustrates the flexible and dynamic nature of such knowledge systems, as well as their contemporary relevance.

Interviewees frequently combined experiential knowledge about the synergistic complexities and temporal fluidity of multiple environmental factors, with varying methods of formal education and training, which they use alongside their practical experience to guide their beekeeping practice. The result is a highly distinctive form of knowledge that transcends the boundaries between amateurs and scientists, tacit and formal. It is not simply a matter of the actual data collected by beekeepers; rather, this approach is indicative of a particular mind-set and analytical approach to the natural environment in which they keep their bees. We also see that beekeepers often combine multiple forms of environmental understanding, bringing together their practical cumulative experience with relevant scientific research. Thus, they construct and utilise a distinctly hybrid knowledge, which underlies their practice and generates a powerful, situated environmental awareness.

As noted in the Methods section, interviewees frequently come from a STEMM background. They clearly stated that this professional and/or academic experience was relevant to their beekeeping practice, and the two forms of knowledge and understanding – the observational practice of beekeeping, coupled with the technical and / or scientific training – complemented each other to generate an enriched practice and understanding of bees and the environment:

> *Because my training as an engineer – one of the things is that if things break down, you need to find the reason why. You can't just keep buying spare parts. You need to find the cause of the problem, and adjust things to suit. (JH)*

Another interviewee describes detailed records kept regarding fruit tree flowering and honey bee productivity. As well as being an amateur beekeeper, this individual has a professional background in horticulture, farm management, and beekeeping, and also gained a MSc in melissopalynology. This one individual combines amateur, academic, and professional knowledge into one distinct perspective that underpins his practice, and his engagement with the environment. When describing his observations, he blends observational and seemingly anecdotal references, with an underlying quantitative perspective:

> *I think spring is very much changing. When I started in horticulture, I trained in East Malling research station here in Kent. And the blossom of the fruit trees was Chelsea flower show week. Now (that date) does not move around. It is the last full week in May. But the flowering of the fruit trees does. And it is now earlier. (KH)*

The usage of particular notable events is a long-established technique, known as benchmarking, where demographers and other researchers supplement and contextualise qualitative records with fixed temporal data (Axinn et al., 1999; Glasner and van der Vaart, 2009; Nelson, 2010). Many beekeepers use such dates and associated environmental occurrences as guidelines for their practice. As well as collecting quantitative records on honey yield and weather, beekeepers use flexible occurrences to time their practice, such as recommending the first hive inspection to be carried out after the currant has come into flower. These knowledges are comfortably used alongside other, more specific and formal sources of information.

As several interviewees come from professional scientific backgrounds, they engage with research on bees and the environment in a critical way. One amateur beekeeper, who was a doctor by profession, stated:

> *Yes, the thing is I'm able to read a paper and tear it apart. One of the things I did as a GP was taught other GPs. One of the things I taught them was how to look at and read a paper. To criticise – never just accept it. (KR)*

Interestingly, while most beekeepers prioritise the practicality of beekeeping experience over the seemingly rigid and narrow analysis of scientific research, for one interviewee, even the scientific research on bees was too variable, given his background in chemistry:

I have found that the natural sciences are quite fascinating, coming from a pure science background. It has been an eye-opener really. I'm used to precision in science, and it doesn't quite work that way when you come onto the natural sciences! (BS)

The intensity of beekeepers' engagement with forage, on both an observation level, and a more scientific analytical level, was an issue that was clear in both archives and interviews. An example of this is beekeepers' awareness of, and study of, pollen. Bee nutrition is based on collecting both pollen and nectar from flowers, with the pollen being the protein source used to nourish developing brood. Beekeepers will often make a visual analysis of pollen their bees have collected, based on combining a knowledge of what is flowering at that time, within their bees' foraging range, with colour charts and pollen identification charts readily available (Kirk, 1994; Sawyer and Pickard, 1981). Such books and charts on identifying pollen are extremely popular amongst beekeepers, who often discuss collecting and analysing pollen to varying degrees of scientific specificity. A combination of analysing the colour of pollen grains, and a knowledge of what is flowering at different times of the year, allows most beekeepers to make an educated casual, visual analysis of pollen collected by their bees. However, some take this interest further. Several interviewees have carried out higher academic studies in melissopalynology, whether at an MSc level, or via one of the study modules offered by the BBKA:

I don't do anywhere near as much as I used to, but I went to college about 20 years ago. I went up to a guy at Stafford who was a microscopy lecturer. And he ran courses. And we got him to do courses for the whole of the winter, into beekeeping. So I was able to learn a lot about how to do it. Whereas now of course you have got the microscopy exam through the BBKA. … I used to enjoy that. And then the photography through the microscope. I enjoy that as well. (BD)

While most interviewees are not noticing significant, unexpected changes in the availability of pollen for their bees, it is the depth of their engagement with, and knowledge about pollen, and the capacity of so many of them to make detailed scientific analysis of pollen, that is noteworthy. Many beekeepers interviewed displayed characteristics associated with those of professional ecologists, such as valuing nature, and having broad training in various ecological disciplines (Reiners et al., 2013). This perspective underlies their practice, and their lifelong learning throughout their practice. The analysis of pollen conforms to common understandings and methodical procedures associated with laboratory-based scientific enquiry, and subsequently generated knowledge. The pollen structures of different plants are universal facts, which can be discovered through microscopic investigation and identification. Unlike other aspects of beekeepers' knowledge, a detailed study of pollen results in the acquisition of information which is transferable, non-context specific, and outside the influence of other factors. Methods for sampling, viewing and identifying pollen can be taught and used in any location. Pollen analysis requires a high level of training and access to equipment such as slides and microscope. The practice of pollen analysis often generates scientific understanding which is valued for its own sake, rather than having a direct use in practice. With regard to the blurring of boundaries between scientific and 'amateur' understandings (Ellis and Waterton, 2016; Endfield and Morris, 2012a), these interviewees engaged in pollen analysis illustrate a high level of scientific understanding, and training.

With this in mind, it is helpful to explore the pollen studies carried out by one interviewee. He keeps his bees in an area of Kent which is surrounded by prime agricultural and forage plants: apple and pear orchards, field beans, and market gardens. However, pollen analysis suggests that the bees tend to ignore the majority of what is easily available for them, and travel further so they can access the comparatively limited amounts of saltmarsh plants, which are wild, and quite unique. This interviewee presents an interesting example of a complex, multiple, 'environmental public' (Eden and Bear, 2012). While his beekeeping status would be seen as 'amateur', as compared to a professional scientific researcher studying bees, this individual is a chemist by profession, who has kept bees as a hobby for 40 years. He has kept abreast of scientific research on bees and forage, has studied and analysed the pollen his bees collect, and carried out individual research projects based on his own interests and observations, as well as participating in Citizen Science projects, such as CSI Pollen (Van Der Steen & Brodschneider 2015). His microscopic analysis of pollen samples is further analysed within the context of his local knowledge of plants available to his bees, within their foraging radius.

This interviewee, and others, bring their professional expertise in microbiology, medicine, chemistry and engineering to their beekeeping practice. The two approaches to knowledge construction – namely, the scientifically analytical, and the tacit experiential - complement each other in the real and complex world of beekeeping. However, interviewees often expressed unease with what they perceive as a shift in emphasis to prioritising academic study above practical experience. There is a concern that experiential knowledge of bees, where influencing factors are rarely singular, and understanding can often be difficult to quantify, is being superseded by a formal scientific knowledge of bees, which is rooted in an entomological framing of bee health (Kleinman and Suryanarayanan, 2012; Suryanarayanan, 2013; Suryanarayanan and Kleinman, 2013). This approach emphasises linear, singular analytical understandings, which leave little room for active engagement with complexity. Beekeepers' knowledge is traditionally extensive and situated within the context of a broader environmental understanding and engagement (Lehébel-Péron et al., 2016; Maderson and Wynne-Jones, 2016; Park and Youn, 2012; Uchiyama et al., 2017). While beekeepers are aware of the benefits of both methods of understanding bees and the environment, they often express frustration with a shift in emphasis which prioritises a more formal, objectivist approach to environmental understanding. This tension is exemplified by the rising status of exams and official qualifications, which is hotly debated within the beekeeping community. While some see the increased emphasis on formal education for new beekeepers as an opportunity to improve knowledge and standards of practice, others are more sceptical:

> *'I've done a course-I've done the basic BBKA course. Actually, to be honest with you, I think qualifications in beekeeping have sort of bumped themselves up, really. I don't really understand why you need qualifications, to be qualified, if you are just keeping the animals, or the insects that you love. (DC)*

Interviewees spoke of this move towards professionalisation of beekeeping in recent decades, and how it has changed the way practical experience is perceived, and valued:

> *It's something that crept into beekeeping in the last 20 years perhaps... if you haven't got qualifications, you don't know anything (about bees). Nobody takes any notice of you. (RP)*

This change in emphasis is also found in the bee inspection service:

> *When I first started in the bee inspection service they were looking for beekeepers. Now they are looking for graduates. And they may not be particularly anything more than, you know, just beginners…(PHa)*

Such tensions are commonly found in situations where TEK is struggling to be granted parallel, or equal status, to formal knowledge (Nadasdy, 2005; 2014). This is unfortunate, given the value of TEK to conservation strategies and environmental research (Barthel et al., 2013; Berkes et al., 2000; Ianni et al., 2015; Ingram, 2008). The fact that experienced beekeepers often combine tacit experiential knowledge with professional STEMM backgrounds, as well as embarking on part time courses related to beekeeping and the environment, illustrates the breadth of knowledge found in the beekeeping community, and its heightened capacity for constructing, and acting upon, complex ecological realities impacting pollinators. By developing frameworks which have the capacity to engage with these diverse epistemologies, we are better able to understand and benefit from beekeepers' environmental knowledge.

The unique quality of their knowledge is recognised, and lauded, within the beekeeping community. I will now explore how this individually constructed, hybrid knowledge is communicated and shared amongst the wider beekeeping community.

4.7: Creating and Disseminating Knowledge: Beekeepers' Civil Society Organisations

I have illustrated how beekeepers' detailed observations, often coupled with varied levels of formal study and / or professional experience, leads to the construction of complex environmental understanding. Much of this discussion has focused on the knowledge of individuals. Interviews, memoirs and other archival material all make abundantly clear that beekeeping is primarily a solitary activity. Occasionally, people may work with family members, mentors, or apprentices, but this leads to working in pairs at most – rarely in groups larger than two. Due to the solo nature of the practice, civil society organisations (CSO) such as beekeeping associations (BKA), or the Bee Farmers Association (BFA), served many vital roles for members, particularly in the time before the Internet. As many individuals and sources for this thesis began their beekeeping in this time, and these CSO are still active, relevant communities of practice, it is appropriate to investigate their role as avenues for constructing knowledge.

The sharing of experiential knowledge through the hobby organisations of local and national BKA, and the professional guild of the BFA is a common practice amongst beekeepers, in both the archives and interviews. Such civil society organisations are recognised as serving multiple roles, allowing members a space for meeting like-minded individuals who shared a common interest (Everett and Geoghegan, 2016; Geoghegan, 2013), and a venue through which to share information and education on their practice (Endfield and Morris, 2012a). Beekeepers' civil society organisations continue to be a central point for training today (Adams, 2016). Local branches of beekeeping associations hold regular meetings, where members meet and discuss matters relating to their shared interest of beekeeping. The health, wellbeing and productivity of colonies is discussed, within the context of local conditions that members recognise as influencing the colonies. Local association meetings provide an opportunity to compare notes and experiences with those who are working in the same microclimates. Updates on particular challenges, such as varroa or Asian Hornets, are shared, as are discussions of equipment and tools which can support oneself and one's colleagues. Since the mid-19th Century, there has been an active market in developing new types and designs of beekeeping equipment, all of which is energetically discussed amongst beekeeping associations, and much of which has distinctly varied local relevance or benefits. New polystyrene hives are greeted with scepticism by many in the southeast of the UK, due to their insulation potential risking colonies overheating; however, members of beekeeping associations in west Wales are enthusiastically sharing positive results of these new hives, which serve to protect their bees from the comparatively harsh western climatic conditions. There is also a strong social element to these associations, where friendships are developed and continue outside of the association. The all-consuming nature of beekeeping as an interest can create family tensions:

> *I'm involved with so many other aspects of beekeeping, that I try and limit myself, to not to go to much further, because I've got a home life as well…she tells me she's a bee widow (BD)*

The long summer hours which can be spent with bees, often at a time when friends and family might prefer to be on holiday, can make it all the more important for individuals to have the opportunity to be able to spend time with like-minded colleagues, who understand, and share their passion.

Material held in the IBRA archives includes a broad selection of books, journals, memoirs, and documents from individuals, as well as local beekeeping associations throughout the United Kingdom. Due to the historical development of beekeeping in the UK, and the establishment of numerous local beekeeping associations in the late 19th century – mid 20th century, many celebrated their semi centennial, or full centenary anniversary in the mid to late 20th century.

This inspired many to publish short histories of their group (An Beachaire, 1997; Charles, 2005; Essex Beekeepers Association, 1980). These documents evidence the role of these civil society organisations in generating and sharing information by and for their members. Such data also illustrates the role of local associations as centres of communication and information exchange for beekeepers, about relevant local conditions. Some of these association histories provide an astonishing level of local detail of microclimates and variance in conditions, which is a characteristic of TEK systems (Barthel et al., 2013; Berkes et al., 2000; Ianni et al., 2015). The history of the Cumberland BKA (CBKA), published in 1974, provides an excellent example of how locally specific information considered important by beekeepers was shared, compared and disseminated within the association. Originating in 1901, the CBKA was comprised of a compilation of local branches. Although individual branches were geographically close as the crow flies, the varied terrain of this wider region includes coastal areas, mountainous regions, diverse agriculture and heather. The association provided a forum for discussing how its members were affected by weather, land use, as well as socio-economic conditions, such as the post-war decline in beekeepers noted in 1951. The impact of war and major socio-economic disruption often created severe challenges for land management traditions such as beekeeping and gardening, which tended to be skills learned by practical experience and oral traditions (Burton and Riley, 2018; Williams and Riley, 2019). As most beekeepers were working alone, at a time when travel throughout the region was comparatively time-consuming and arduous, the association served a key role in informing and educating its members. The local association created a space for sharing knowledge of locally specific forage and weather variations, and for members to construct an understanding of the effect of local conditions on their bees, and those of others in similar or differing microclimates. A consistent interplay between individual and group observations of the wider environment led to particular management decisions, which resulted in variations in the honey yield, and bee health and colony viability. Beekeepers are invested in developing an astute understanding of the conditions that affect their bees, and constantly analysing microclimates of different scales: their own apiary; nearby apiaries affected by similar weather patterns, and possibly with similar forage available, and the conditions in differing microclimates.

Association histories provide us with a broad temporal overview of the changeable nature of particular forage and nectar sources, including a central recognition of the importance of weather. Amateur weather and phenological observations are an important example of the potential for the informed amateur to construct significant information, which is of wider social and scientific significance (Endfield and Morris, 2012a). Associations served as an avenue for collating and communications observational knowledge of the role, and availability of forage sources.

This sharing of knowledge through associations was, and continues to be, important for the practical training of new beekeepers. This is also addressed in archival material, particularly in terms of the effect of a breakdown in training and education. Isle of Wight Disease was a devastating infection of colonies in the early 20th century. At the time, its exact pathology was not fully understood, although it is now believed to have been caused by acarine mites (Bailey, 1999). Several early writers ascribe part of the cause of IOW's spread and extreme mortality to a breakdown in traditional training and education of beekeepers, as a result of many beekeepers being lost in WW1 (Charles, 2005). This resulted in an interruption to traditional channels of learning beekeeping, and is considered to have therefore resulted in an increase in bee disease due to general bad management (ibid). Associations play an important role in teaching and learning beekeeping, as they offer a structured avenue for gaining practical experience with others (Adams, 2016). The continued significance of this method of directly passing on information has been noted by interviewees:

> *When we moved to the New Forest, and partly due to the publicity about the plight of bees, we were asked by the local beekeeping association to mentor new beekeepers, and I became the education officer. (I was) teaching basic beekeeping courses. (TS)*

It is also addressed in archives, with Dr. Eva Crane, one of the world's leading experts on beekeeping, advising new beekeepers to 'work with, and listen to, good beekeepers in your locality'. (BfD Newsletter 22). The emphasis is on the importance of learning from direct personal contact about local conditions, and how they affect bees. This is a hallmark of knowledge exchange in TEK systems (Berkes et al., 2000; Turner and Spalding, 2013; Usher, 2000).

While beekeeping has traditionally been a skill passed on via practical training, often through a form of apprenticeship, and/or with a family member (Adams, 2016; Phillips, 2014) some beekeepers have expressed concern that the recent spike in media attention to pollinator decline has stimulated a huge, rapid increase in beekeeping. This has subsequently triggered an increase in local and regional hive density, which can be associated with several challenges, including increased pressure on forage sources, as well as disease risk – including varroa – from colonies which may not be particularly well-managed, due to a fundamental change in how people now learn beekeeping. Local associations, and key individuals within them, would traditionally have provided access to first-hand experiential training, and mentoring. A sudden tripling of new beekeepers has strained the capacity of local associations to provide the practical support that is traditionally considered necessary for beekeepers to develop their skills. This serves to emphasise the impact of the lack of this arena for knowledge generation and sharing.

Like other forms of TEK, beekeeping was, for generations, learned very much by practical involvement, oral knowledge transfer, and experience. It often attracted participants who already had a working knowledge of the wider environment:

> *One thing that's happened is that the type of beekeepers has changed. When I first started, I reckon 50% of our members worked on the land in some way. They were foresters, or they were cowmen, or, you know, chicken or pig farmers or something like that. And, um, they, a lot of them had anything between 15-50 colonies of bees. (RP)*

The number of hives kept by these individuals is notable. Today, to qualify for membership in the Bee Farmers Association (BFA), which is for professional beekeepers, one needs to maintain a minimum of 40 colonies. Meanwhile, the average number of hives kept by hobby beekeepers, who manage most of the colonies in the UK, is 3-5. Nowadays, a different demographic group are often entering beekeeping. They may lack experiential knowledge, and the structure of the BKA may not be able to provide the level of mentoring / training / practical support that people would traditionally have had when they learned beekeeping. This is seen as a challenge to modern beekeeping by many interviewees, as local associations do not have the capacity to provide the mentoring that is seen as key to developing successful beekeeping:

> *The idea of people having a hive, which came out of the Colony Collapse Disorder-people wanted a box in the garden-it's a waste of time. They were just condemning a colony-even if they bought one, because they didn't have the management skills. (KB)*

There is an awareness that extensive advice is available on the Internet and in books; however, such information may lack the locally contextualised knowledge that is a key element of beekeepers' environmental knowledge, or be relied upon uncritically, by new beekeepers who do not realise the importance of contextualisation of management techniques. Archival material and interviews consistently address the localised quality of knowledge. While some material is universal, such as recognising the pathology of diseases such as EFB and DWV, other knowledge is highly localised, and perceived by beekeepers as intrinsically relevant to their practice.

In other archival material from beekeeping CSOs, we find discussions about observed, experienced changes in agricultural and land-use patterns, and how these changes are interpreted and experienced by beekeepers. Due to the continued, repeated locating of hives in particular regions, beekeepers generate a long-running understanding of the environmental qualities of particular places. This is done on both a highly local, and a wider level. The UK's Bee Farmers Association (BFA) archives include detailed discussions about the quality and quantity of local forage for bees (BFA Bulletins 15: 8/55; 185: 2/79; 300: 5/96). While there is, and always has been, a difference between hobby beekeepers, small-scale bee farmers, and the handful of highly successful bee farmers, there has also always been communication and movement between these categories. Therefore, the BFA's role within wider construction of knowledge relevant to beekeepers is key. Due to the distinct character of the BFA as a forum for creating and disseminating knowledge, and its importance amongst its members, the next section of this chapter will discuss this organisation in more detail.

4.8: The Bee Farmers Assocation

In the pre-internet days of the Honey Producer's Association (HPA), which subsequently became the Bee Farmers Association (BFA), it was a real challenge for beekeepers to stay abreast of issues relating to bee health, and learn about practices that could improve their business. Bee farming is an inherently solitary profession, often carried out by individuals who run 'one-man operations'. This made it all the more necessary for there to be some sort of professional forum for members to share information and knowledge. Bee farming has always been a small sub-sector of the agricultural community. Membership has fluctuated over the years, but maintained an average of approximately 300 members throughout the UK. Amongst its various roles and functions, the BFA traditionally provided a magazine subscription service to all members. The organisation subscribed to a wide range of magazines, including, but not limited to, *Bee Culture; American Bee Journal; British Bee Journal; Bee Craft,* and the *Journal of Apicultural Research*. These magazines were the key source of information and distillation of current research on bee health, and provided an invaluable source of information to members. By keeping abreast of current research, and staying informed on scientific discoveries on bees and pollinators, bee farmers generate a distinct form of hybrid knowledge, where their tacit experience is compared with and influenced by their wider scientific knowledge of relevant factors.

The BFA has always generated, and disseminated, information of specific relevance to its members. Although this information was collated and utilised to support the professional practices of its members, it also provides historical insights into both the knowledge-making practices of this distinctive community, as well as information which can be used for wider environmental insights. Some of this is linked to its role in managing contract pollination throughout the UK. Many members of the BFA relied on pollination contracts for much of their annual income. The vital question of when to move the hives to the orchards to coincide with flowering of apple, plum and pear trees, coupled with intense debates as to the appropriate fee to charge for this key ecosystem service, given the number of farmers needing contracts and the number of available bee farmers, generated complex information on a range of factors relevant to beekeepers. Dates of the flowering of fruit trees were discussed and used to attempt to plan when each years' blossom would take place. This was estimated based on recent years, and the preceding winter's weather. While this information was collated for the professional guidance of its members, it can also illustrate phenological patterns and changes. Such sources are highly valued, and often difficult to find – yet are an underutilised resource in assisting our understanding of how climate change is manifesting (Primack and Miller-Rushing, 2012). Changing patterns in agriculture, and their impact on bees, was discussed and debated in terms of its impact on bees in different parts of the country. (BFA Bulletin 101: 10/66; minutes 1981 Spring Meeting). The pollination service also noted changes to fruit cultivation, and the factors driving these changes. As noted throughout this chapter, beekeepers' observational knowledge of relevant factors to bees entails not just the physical environmental conditions, but also a wider socio-economic component. The importance of addressing such factors when analysing the environment, and the significant risks of failing to address them, is noted in varied contexts, from natural resource management in British Columbia (Willems-Braun, 1997), to water usage in Spain (Otero et al., 2011), to jatropha plantations in India (Ariza-Montobbio et al., 2010). The BFA bulletins illustrate that constructing knowledge about pollinator welfare requires understanding wider political and economic forces, which underlie, and co-exist, with physical conditions. While such factors are outside the epidemiological framework of bee health which is prioritised by most researchers, a broader perspective on pollinator decline, which directly engages with anthropogenic challenges to pollinator wellbeing, is increasingly supported (Marshman, 2019).

A key topic observed and discussed within the BFA over the years was the impact of agricultural chemicals. The bulletin served to educate its members about their colleagues' observations of sprays, and the suspected results of sprays. This was particularly important, as the BFA came into existence in the post-war period, where large-scale farming, facilitated by nitrogen-based fertilisers and chemical pesticides, was taking off. Some writers pointed out that there was no use berating farmers for using sprays, as they, too, had begun their professional pre-bee farming lives in the wider agricultural sector, and would have welcomed the chance to use pesticides and weed killers, to make their lives easier and more profitable. R.O.B. Manley, one of the leading beekeepers of his generation, urged bee farmers to work for improved communication and understanding between themselves and other farmers (HPA Bulletin 53: 2/60).

Interestingly, the very first edition of the HPA bulletin contained an editorial which stated that 'the greatest danger to our profession is with the ever-increasing toxicity of insecticidal sprays' (HPA Bulletin 1: 4/ 53). While much of the concern was linked to the belief that these sprays could result in poisoning honey, it soon became clear that the bees themselves were at grave danger from these sprays. A symposium on organo-phosphates in autumn of that year led the author to write 'it seems…scientists showed a most reckless attitude to the effect of these dangerous substances to man and animal'. (HPA Bulletin 4: 10/53). These editions document the beginning of the growing division between the precautionary approach of beekeepers, in contrast to scientists' and policy-makers' reliance on definitive evidence.

The BFA, and its bulletin, served to educate its members of the factors affecting their practice; the effects of systemic agricultural change on beekeeping was a central issue. In BFA Bulletin 101 (10/66), Manley was emphatic that bee farming's main challenge was due to changes in agriculture, and the destruction of 'former best areas', which he put down to the advent of selective weed destroyers. Early editions also noted the inherent link between bee farmers and the wider agricultural world, and how the fortunes of both were intertwined (BFA Bulletins 52: 1/60; 165:2/76). Similarly, documentation of perceived historical deterioration of the environment, often as a result of agricultural change, was discussed. BFA Bulletin 300 (5/96), illustrates how bee farmers constructed their environmental understanding through the bulletin. Comparisons of regions both within England, and between England, Scotland, Wales and Ireland, present us with bee farmers' views of Ireland in the 1950s – 90s as a preferred location for beekeeping, in terms of available forage, and agricultural and land-use. This was due to BFA members seeing Ireland as being comparatively unaffected by the industrialisation of agriculture that was recognised as leading to a deterioration in the quality of much of England as a place for beekeeping: '*there is enormous flora (in Ireland) for the bees if they get the weather. All the little wayside and hedge flowers which have long disappeared in England and Scotland are still here in profusion, and the gorse…is spectacular*.' (BFA Bulletin 99: 6/66) By comparing the health and productivity of bees in different areas, bee farmers constructed knowledge about wider conditions – both physical, and economic - that supported, or challenged their bees and other fauna. The BFA provides documentary, historical evidence of a key facet of beekeepers' knowledge creation and transmission. Like individual beekeepers and other local amateur beekeeping associations, BFA members discussed aspects of the physical environment which affected their bees. Changing weather patterns and unusually challenging or prolific seasons were key topics. Forage diversity and changes were also important. However, the BFA archives illustrate a growing point of tension between beekeepers and the wider agricultural community, and the increasing awareness that there are factors outside of beekeepers' control, which have a political and economic context that is all too easily overlooked if we concentrate exclusively on the raw quantitative data that beekeepers can supply.

4.9: Conclusion

As we have seen, beekeepers are highly informed, active generators of formal and informal data on the environment in which their bees live. Beekeepers generate knowledge through a variety of practices and channels. Their knowledge is frequently highly specific, and responsive to local conditions, as we see in other communities where TEK is found (Burton and Riley, 2018; Fazey et al., 2006; Hernández-Morcillo et al., 2013; Ianni et al., 2015; Lehébel-Péron et al., 2016; Oteros-Rozas et al., 2013). While many keep bees as a hobby, we should not underestimate the commitment and level of study associated with their practice. The role of amateurs in studying environmental change is often underestimated, with these communities frequently displaying a high level of knowledge (Ellis and Waterton, 2016; Endfield and Morris, 2012a; Everett and Geoghegan, 2016). Experiential knowledge of wider environmental conditions is complementary to, yet distinctive from, scientific analysis (Mukherjee et al., 2018; Sutherland et al., 2013). Such types of experiential knowledge often engages with wider relevant factors, such as economics, local land use patterns, and historical relationships between people and the wider environment. While there are clear patterns of repeated practices generating actionable knowledge about the environment in which they keep their bees, beekeeping leads to wider changes in individuals' environmental perspective:

> *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. (EC)*

Interviewees mentioned 'there are so many variables' that affect their bees. This is a key issue which complicates research on bees, and is often a point mentioned by beekeepers when they query the wider relevance of scientific research on bees. There is growing recognition that anthropogenic actions which are deleterious to environmental well-being are not simply rooted in "information deficit". It is not simply a matter of people *not knowing* scientific facts about environmental conditions. This debate has been particularly pronounced in issues such as climate change and waste reduction (Quested et al., 2013; Whitmarsh and O'Neill, 2010). Human interactions with the environment are complex, engaging with economic, social, political, and emotional motivations. Beekeepers' practice exemplifies this consistent entanglement with fluid networks of information, and a wider moral and emotional context. The next chapter will explore how they use the knowledge they have constructed as the basis for their decisions on how to manage their bees.

Chapter 5: How do beekeepers use their hybrid knowledge when negotiating challenges that affect their bees?

5.1: Introduction

The preceding chapter evidenced how highly experienced beekeepers generate their distinctive hybrid knowledge as a result of long-term, locally situated observation of their bees. This tacit knowledge, generated through years of practice, is often combined with wider formal and informal study. This information is also shared amongst communities of other beekeepers, whether they are hobbyists or professionals, thus offering another avenue to generate collective knowledge throughout the community. This chapter will explore how they use this knowledge when assessing the environment's quality and suitability for their bees, and subsequently make management decisions based on their assessment. The modern environment presents multiple challenges for bees and other pollinators, which beekeepers must negotiate carefully. There is an inescapable paradox, in that bees are constantly affected by multiple synchronous, synergistic factors; as a result, beekeepers can never fully control what their bees experience. Nevertheless, there are varying degrees of control which a beekeeper can exert over their bees, which are affected by bees' foraging habits and the distances they can travel (Beekman and Ratnieks, 2000; Hooper, 1979). This struggle to manage a complex, fluid situation leads to beekeepers' continuous, iterative engagement with numerous factors. All of these fora of engagement call upon diverse, yet complementary aspects of beekeepers' fundamentally hybrid knowledge. This chapter will primarily focus on three challenges bees face, namely, forage, agrochemicals, and varroa. It will also briefly discuss bee genetics and breeding, as this is also a key issue for both beekeepers and researchers (Büchler et al., 2015) when considering how bees respond to the myriad challenges they face. Lastly, it will discuss how beekeepers attempt to operationalise their knowledge of the weather's direct and indirect effect on their bees. All of these factors are noted by beekeepers as central to their practice, and are also recognised as key drivers in pollinator decline (Potts et al., 2010; Sánchez-Bayo and Wyckhuys, 2019). These will all be explored in relation to how beekeepers use their hybrid knowledge when making management decisions. These aim to maximise the health and productivity of their bees, in wider complex environments which are only partially controlled by beekeepers.

The unpredictable, and localised nature of environmental challenges means that this is a highly complex issue to explore, which generates both certain commonalities amongst respondents, as well as issues of uncertainty, and divergent viewpoints. It is precisely such variation in perceptions and experiences that leads to beekeepers' views often being dismissed by quantitative researchers as 'anecdotal', as I was frequently told by scientific researchers I met at conferences. However, by taking a qualitative research approach to beekeepers' knowledge and experience, there is the potential to engage more deeply, and more constructively, with their wealth of experience. TEK is noted to have a positive impact on socio-ecological resilience (Ruiz-Mallen and Corbera, 2013; Šūmane et al., 2018) and land management practices which encourage biodiversity (Riley, 2009; Wehn et al., 2018). Understanding how beekeepers use their environmental knowledge when attempting to manage the multiple and entangled challenges to their bees can provide actionable insights towards developing more environmentally sustainable methods of land management.

Beekeeping is, above all, a practical skill carried out *in situ* (Adams, 2016). As evidenced in chapter four, this careful attention and intense concentration associated with the practice often leads to heightened observations of environmental changes such as notable differences in weather patterns, forage quantity and quality, and the effect of the use of varied agrichemicals:

> *You do see things when you are beekeeping, because you are quiet, and that is the joy of it. (MC)*

Beekeepers rely on the knowledge they generate via practice and study to guide their environmental assessments, and make management decisions:

> *Because as you've noticed, I have always believed that you must, you know, you should base any changes on what you actually observe (CB)*

The question of environmental suitability – and safety – for pollinators is of increasing importance (Goulson et al., 2015; Potts et al., 2010; Vanbergen and Initiative, 2013). Interviewees for this project keep their bees in a highly varied cross-section of environments, including agricultural areas, woodland, conservation areas, village cemeteries, and urban gardens. While most of the concern regarding bee health and wellbeing is due to their role in, and the impact of, the agricultural environment (Breeze et al., 2014; Brown et al., 2016), bees are also kept in urban and peri-urban environments. The status of urban and peri-urban environments as habitat for pollinators is attracting increased scientific and public attention (Garbuzov et al., 2015a; Gaston et al., 2005; Sivakoff et al., 2018). Wild spaces are also the preferred habitat for some beekeepers to site their colonies. How beekeepers utilise their hybrid knowledge to make practical assessments of these different environs can provide us with insights regarding conditions for both wild and managed pollinators, as well as other species dwelling in these disparate spaces. There are marked similarities between diverse pollinators and potentially detrimental conditions that affect them all (Brown et al., 2016). However, much of the discussion surrounding pollinator wellbeing is skewed by a disproportionate emphasis on honey bee colony numbers (Geldmann and González-Varo, 2018). Similarly, the impact of the environment on wild bees is inherently difficult to assess, due to the challenges in monitoring wild bees (Dicks et al., 2015). While there are differences between honey bees and other pollinators that should not be ignored (Ollerton, 2017), honey bees can often serve as an indicator species, whose numbers and well-being can help to illuminate wider environmental conditions (Crane, 1984; Kevan, 1999). By going beyond a solely quantitative assessment of colony numbers, and investigating beekeepers' systemic understanding of conditions affecting bees, we are better placed to utilise and incorporate their knowledge into wider environmental understanding and management.

Although this chapter will be organised into discussing varied challenges independently, it is important to remember that, for beekeepers, the complex, entangled nature of these factors is always at the forefront of their understanding, and their attempts at managing their bees. The complexity is illustrated in the following passage from *Advantages of a House Apiary* (Spiller, 1952):

> *"During the last war after 1940 many people in my district took up beekeeping, hoping to get some honey to compensate the shortage of sugar. The result of this was that my bees only gave about 35 lbs of surplus honey per hive instead of 80 lbs, and many of the beginners did not get any. I must say in fairness that part of my loss was caused by the poor quality of queen bees available in this country during the war and several clover grass fields ploughed up for growing corn."*

This passage illustrates beekeepers' understanding of the complex relationship between socio-economic drivers, increased pollinator competition, genetic qualities of the queen, and changes in local agriculture and land use. This observational account parallels other studies on the complex synergies which affect bees in ways that are distinct from standard agricultural stock, who can be more fully controlled (Alaus and al, 2010; Clermont et al., 2015). Spiller also notes a significant difference in honey yield between beginners, and experienced beekeepers, thus obliquely addressing the importance of experience in successful beekeeping. Finally, the passage also exemplifies beekeepers' engagement with agricultural change, and genetic characteristics of his bees. Such complex, multifactorial approaches illustrate a common distinction between beekeepers' knowledge, and that generated through scientific research; namely, bees, like other invertebrates who are experiencing recent catastrophic decline (Hallmann et al., 2017), live in a profoundly complex, locally specific environment, which cannot be easily replicated in lab or field studies.

The interwoven nature of these factors is always underlying beekeepers' knowledge, and this thesis. For the purpose of discussion, I will aim to explore key factors independently, although there will, at times, be points of overlap with other themes. The majority of this chapter will explore three key challenges which rely on beekeepers' hybrid knowledge to drive their management decisions, namely, forage, agrochemicals, and varroa.

5.1: Managing Challenges of forage

Beekeepers and scientists both recognise the importance of consistent, reliable access to quality forage in the maintenance of health and wellbeing. This observation has been known for centuries, as illustrated in Butler's *The Feminine Monarchie (1623)*

> *'While the stalls [hives] are few, your Garden of Hearbs and Flowers will serve....*
> *But when they are growne to a sufficient number, they require a square greene plot fitted for the purpose. (Butler, 1623)*

Note the author's management advice, four hundred years ago, of the need for growing extra plants to ensure suitable quantities of forage if one is keeping a large number of hives. More recently, the globally renowned authority on bees and beekeeping, Dr Eva Crane, also encouraged beekeepers to develop and utilise their knowledge of local forage availability, in both individual and community beekeeping: if it is too limited, there should not be any encouragement for expansion of beekeeping in an area (BfD Newsletter 22). Throughout these texts, we see the emphasis on beekeepers' observational knowledge over the centuries, and how this understanding was used for management purposes.

Developing knowledge about the quality, and quantity, of different types of forage available for their bees, and working to ensure their access to high quality forage, is therefore a central element of beekeepers' management. Successful beekeeping is reliant on a locally specific knowledge of when the majority of flowers produce nectar (the 'honey flow') will begin, and being prepared to take full advantage of this. Rev. Digges' *Practical Bee Guide: Manual of Modern Beekeeping* (1921) is one of the oldest key texts for beekeepers, and is still used today. The author describes a form of complex, iterative environmental understanding that is common amongst beekeepers (Lehébel-Péron et al., 2016; Phillips, 2014) as well as other land workers, such as farmers (Riley and Harvey, 2007; Šūmane et al., 2018). Beekeepers are exhorted to 'read the signs' – eg, develop and apply observational knowledge:

> *'Dr Miller …supered his hives ten days after the first white clover flowers were seen, and every beekeeper may soon discover some similar sign, that will tell him when to place supers on his hives, according to his district. When a drinking place is provided in the apiary, the onset of the flow is soon made apparent by the fact that the bees forsake the water. Whatever the signs may be, the beekeeper should endeavour always to have at least one super in position and occupied by the bees before the honey flow begins. (Digges, 1921, p 147)*

'Reading the signs', and managing one's bees in response to natural abundance, has become far more challenging in recent years. Loss of forage is widely accepted by beekeepers and scientists as a problem for all pollinators (Decourtye et al., 2010). Traditionally, the complex biological relationship between bees and forage is carefully monitored by beekeepers and can, to a certain extent, be manipulated and controlled by feeding syrup and/or fondant at certain times of the year. This is done by beekeepers to try and ensure the colony are of a size and strength to maximise foraging opportunities, particularly in spring and early summer (Hooper, 1979). However, their capacity to efficiently act upon this knowledge in a wider environmental context is often curtailed, due to the ultimately wild nature of bees, and the extent of their foraging range. Beekeepers regularly recount a changed perspective when traveling around the countryside. They are always on the lookout for 'a good site' for their bees, which meets a broad range of criteria. This results in a changed and critical perspective of all possible sites for their bees.

> *When I drive around the countryside now, I find myself looking at it in terms of bee habitat... I've become literally obsessed in forage plants and hedgerows. Particularly in spring. I think 'oh, the willow's come out, or the hawthorne'. I just see the whole countryside now as bee forage. It's quite bizarre. (LD)*

> *I'm always very conscious - there is never a journey that I go on that I don't take a look and think oh that's good. That's good. And if I have not got the bees to cover it all I will still be thinking oh the bees could be do well down there. (KB)*

While their experiential knowledge creates an awareness of potentially good sites for their bees, there is also an acknowledgement that such sites are increasingly difficult to find. For many, their decades of observational practice led to a recurrent expression of an overall decline in environmental habitat quality, which is clearly a concern:

> *You've got to work really hard to find spaces now. In England. I know when I talk to English beekeepers… You've got to look for natural places. (PH, Wales)*

It is noteworthy that this interviewee makes a distinction between conditions in different parts of the country, which he goes on to ascribe to different agricultural and land management practices in England and Wales. Industrial farming has led to a marked narrowing of crop diversity and variety. Over the past 150 years, many crops have seen an 80% reduction in cultivars (Pimentel and Pimentel, 1986; Tilman, 1999). Although there is a growing recognition of the importance of reversing this trend and supporting enhanced crop and wider biodiversity (Barthel et al., 2013; Heywood et al., 2007), data for this thesis suggests that lack of biodiversity in the agricultural sector is still a significant problem for bees. Similarly, and related to changes in land use and the rise of monocrops, the decrease in forage available for bees is also seen by many interviewees – and scientists - as a direct by-product of our current industrialised food system (Breeze et al., 2014; Vandame and Palacio, 2010). Several interviewees noted the decline in forage resulting from increased industrialisation of the food system, and the subsequent challenges this has created in finding suitable sites for their bees. The overall perspective on the current forage situation is that industrial food production has generally led to significant losses in forage quantity, quality and variety:

> *These areas were once good bee areas - and especially, our big problem is hedgerows. (In Ireland) we used to have one of the best hedgerow networks in Europe. Up to very recently. A lot of them have been absolutely butchered. Just in the last 10 years. (EMGC)*

The interviewee has now changed where he keeps his bees, in an effort to secure access to good quality forage. The above response is also notable for the timing of the changes observed. Awareness of the importance of hedgerows as habitat and forage has been known for many years; their loss throughout England since 1945 is widely accepted as a significant problem with the modern agri-environment (Decourtye et al., 2010; Ponisio et al., 2016). The significant impact of the loss of hedgerows is observed by other interviewees, who question how this can be rectified to improve the environment for pollinators, given the role of wider economic factors:

> *They need something big and significant that's got to be done to put hedgerows back, and have proper large areas (of forage). But I can't see that happening. Here or anywhere else. As we said earlier, other countries have much bigger areas. They are all planted with single crops. These don't do the bees any good. But that's how the economy goes. (BD)*

Others have noted the effect of a loss of orchards and small woods:

> *As a boy back in the 50s and 60s-we used to be able to go around Kent on a blossoming tour…you could drive for half a day, a day, and seen nothing but apples, pears, cherries-beautiful big orchards of flowers.… And the amount of orchards … those are gone as well… We haven't benefited the bees by everything moving on. It's been to the detriment of the bees. (KH)*

The loss of forage resulting from the grubbing out of orchards was recognised as problematic by bee farmers in the 1980s and 90s. This was outside of their control, as farmers chose to grub out orchards for financial reasons, including EC grants (BFA Bulletin 291; 11/94). Thus, the knowledge of beekeepers comes into conflict with wider circumstances. While beekeepers are constantly analysing the surrounding countryside in terms of its potential as a good site for their bees, they are ultimately limited by the agricultural and land use practices of other agents.

The increase in commoditisation of food since the mid-20th century and associated potential profits, has led to significant shifts in production and land use, and subsequent environmental impact (McMichael, 2009; Pretty, 2008). The dramatic shifts in 20th century farming and food production, with a rapid growth in farming as commodity production for the global market, is seen by interviewees and archival sources as one of the roots of the current tension between agriculture and pollinator well-being – and, ultimately, between beekeepers and the farming and land-managing community. One bee farmer's memoirs note:

> *"By the late 1960s these flower-filled slopes had been put to the plough and had become a vista of nitrogen-fed cereals, an example of the countryside vandalism being perpetrated by many farmers during that time. The idea that land owned by individual farmers was also OUR countryside was regarded with contempt by many of them. " (Rawson, 2008, p2-3).*

Such changes in land use, and the subsequent decline in quantity and quality of bee forage led to a notable recurring theme in interviews that "you can't keep bees in the country". As one of the primary motivations for national pollinator protection strategies is their role within the food system and ensuring food security (Allen-Wardell et al., 1998; Gallai et al., 2009), this disconnect is surely a cause for concern. Researchers note a growing gap between crop production which relies on managed pollinators, and the numbers of hives available (Breeze et al., 2011). There is frequent reference in both archival and interview data to a deterioration in the wider rural environment as pollinator habitat:

> *the big problem is that a lot of the agricultural land has become a desert for bees. There's nothing there. … But, I mean, these areas were once good bee areas. There is no doubt about it. (EC)*

Beekeepers and the wider agricultural community are inherently intertwined, with hives frequently situated on agricultural land. While many respondents and archival sources noted farmers' enthusiasm for having bee colonies situated on their farms, this desire is not always accompanied by a significant understanding of the symbiotic relationship between pollinators and crops. Interviewees reported having to reject requests for their colonies' presence, due to the poor conditions on offered sites. Instances were recounted which displayed a surprising lack of knowledge by farmers of the actual environmental requirements of bees and other pollinators. Frequently, farmers were described as receiving substantial grants for pollinator-friendly planting schemes which resulted in little or no forage growing for bees:

> *I've got one farmer near me who (got a grant for a nectar bank), and I said this is just grass. It's just ryegrass. But he's getting paid for this...there's no flowers in it at all. He was keen to have my bees in there, because if you have pollinators, you might get some nice honey. But I said there are no flowers there. (TA)*

Beekeepers' responses to changing environmental conditions contribute a temporal and spatial element to our understanding of changes and resilience within the agri-environment. While there is often a focus on the loss of certain types of forage, the advantage of engaging with long-term beekeepers is they observe, and work with, the transitions of different forages, which are associated with different agricultural and land use practices, and weather variations. Interviewees report a highly localised aspect of forage loss and associated pollinator decline that is often overlooked within wider national or regional analyses. The following interviewee lives in an area with almost no industrial farming, but has worked extensively in various land-based occupations, thus generating a strong understanding of environmental characteristics that support or challenge bees and other pollinators:

> *Interviewer: so you are reckoning that there is not much of a decline (of bees)?*
>
> *PH: not around here. There are declines where there is a lot of industrial farming. There's going to be a decline because there is not the forage there. But then there are other places where there are plenty of bees.*

The potential quantity and quality of local forage is subsequently linked to dominant crops, and land use patterns and potential. As discussed in Chapter 1, Section 3 the importance of microclimates and locally specific conditions is central to beekeepers' analytical processes and decision-making as to where they site their colonies. Their understanding of environmental impacts on pollinators is enriched via long-term engagement with particular locales, and methods of land management and farming.

While there is often discussion of loss of forage, both amongst beekeepers and within scientific research on challenges to pollinators (Brown et al., 2016; Potts et al., 2010), beekeepers also observe and amend their management in response to what can be seen as positive additions to the available forage at different seasons. These can be both beneficial, and problematic, depending on the scale and variety of new forage sources. Many beekeepers experience benefits to their honey bees from the increase in Oil Seed Rape (OSR) cultivation in the UK:

> *Oil Seed Rape has had a significant impact on beekeeping. It gets colonies ready for spring. (TS)*

This early flowering crop offers many colonies the opportunities to rapidly build in strength and size in the early spring. While it can therefore prepare them for significant honey production in the late spring and early summer, it is also seen as problematic by some beekeepers. OSR tends to be grown on a large-scale, monocrop level, which is often treated with significant inputs of agrochemicals (David et al., 2016). Due to OSR's prevalence as a crop in certain parts of the country, many beekeepers must engage with it and adapt their management one way or another - whether they choose to avail themselves of OSR's benefits, or actively avoid it as a forage crop, due to its cultivation relying heavily on agrochemicals. While OSR is sometimes seen as a beneficial crop for bees, it is also a crop that ends dramatically, leading to a wide-scale dearth of available forage. This dramatic transition can lead to problems for bees and other pollinators when it finishes flowering:

> *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. (TA)*

The challenge this creates for bees can be easily overlooked by those who are not highly observant and attuned to bees' behaviour. The intense peak in a highly attractive forage source, followed by a collapse in its availability, has also been recognised as problematic for other pollinator species (Holzschuh et al., 2011). Beekeepers are all too aware of the impact of this sudden forage loss:

> *If you go to a hive and the oilseed rape flow has stopped, for a few days afterwards they are not in good humour! (CB)*

There is also constant reference to the divergence between managed and wild pollinators:

> *How do you change the environment? How do you make all season forage available. Yeah oilseed rape is great…but what's going to follow it? And then if you go to East Anglia, that's all they've got. And that's great for honey bees. What about all the wild pollinators? What's the follow-on through the rest of the season? Bees don't just feed for three weeks and then shut down (KB)*

This distinction between managed and wild pollinators is highly important when considering how beekeepers' knowledge can be used to support pollinator wellbeing. Oilseed rape is a mixed blessing for honey bees and beekeepers, with its early high energy flow offering the potential to be carefully managed for their overall benefit. However, the rapid collapse of all available forage, coupled with intense usage of agrochemicals, creates a very different environment for other species. By engaging with beekeepers' wider knowledge of the environment and other pollinators, we are able to develop a far broader, and more accurate understanding, of the state of the environment for pollinators.

Most interviewees note with concern that it is getting increasingly difficult to find sites which they assess as 'good' – eg, being healthy, safe and providing both quality and quantity forage. This decline is associated with a rise in monocrops, and a loss of habitat. This illustrates the paradox of their environmental knowledge, in that much of their capacity to act upon what they know through experience and scientific understanding is ultimately limited by factors beyond their control. The industrial agricultural environment continues to be a place where beekeepers' knowledge is used to assess and respond to relevant factors – which are controlled by others. Such tensions are mirrored in wider efforts to enhance the sustainability, and minimise the risk of hazards, in the agri-environment (Harrison, 2008a; Marsden, 2012).

Much of the official advice for supporting pollinators focuses on planting for them. In 2014, DEFRA published 'Bees Needs' – a series of recommended actions to support bees and other pollinators. These include leaving some areas wild, and planting pollinator-friendly plants. Beekeepers emphasise the significance of wild forage sources, such as brambles and ivy, and other wild plants, which are sometimes found in small quantities. Interviewees note an active preference on behalf of their bees to seek out wild plants as a source of forage:

> *I'm in no doubt that the bees have evolved to work wild plants, and that seems to be the preference. (BS)*

Beekeepers actively search out sites where such plants flourish, as preferred locations and forage sources for their bees. They note the increasing difficulty of finding such sites, and the increase of what they refer to as 'green concrete', or 'green desert' – the huge fields of monocrops such as rye grass and maize, with few hedgerows breaking up the expanse:

> *I am looking for .. Heather and brambles, Himalayan balsam-you know, fairly wild landscape. (I am also) looking for the little fields. … Stone walls covered in ivy. Trees and hedges and bits of wild in between sort of thing. What I'm not looking for is huge great fields full of Italian ryegrass and hedges all grubbed out, because that's just green concrete you see. Green desert… We're seeing more and more of that, unfortunately. Plus fields of maize, which I give a wide berth. (PH)*

Another interviewee, who is a 4th generation professional beekeeper, mentions both the benefit of wild spaces, and the increasing difficulty in finding such sites:

> *I am looking for wild places, or as wild as possible. It seems that in recent years, it's harder. I'm trying to avoid tillage spots. (EC)*

This preference for, and increasing difficulty in finding, such wild sites was a common refrain amongst several interviewees, including long term professional bee farmers. These interviewees' responses highlight the tension between pollinators' significant role in the agri-environment, which has driven much of the recent concern about their decline, juxtaposed with a concern by many that the best places for bees forage are away from areas of food production.

The industrial agricultural environment is clearly a place of constant challenges for bees, which requires more than astute management by beekeepers; instead, changes to the wider landscape are necessary if beekeepers are to be able to fully apply their knowledge of what bees need for health and productivity. Growing awareness of the detrimental effect of modern agricultural practices has led to a proliferation of agri-environment schemes (AES) designed to enhance this space (Batary et al., 2015; Hardman et al., 2016). While AES would appear to be designed to ease tensions between beekeepers and the wider agricultural community, data from this project suggests that beekeepers' experience and perception of many of the AES that are supposed to improve biodiversity and habitat is that these schemes are often significantly flawed. Ironically, sometimes efforts to improve the environment for pollinators actually result in the opposite. As discussed earlier, most interviewees emphasise the importance of wild sources of forage. This observation is parallel to the results of scientific research (de Vere et al., 2017; Wood et al., 2015). However, due to many stewardship schemes focusing on planting for pollinators, interviewees note cases where land managers have actually destroyed what was already high quality pollinator habitat, in their funded efforts to create and improve pollinator habitat:

> *I've been to projects which have won biodiversity awards, handed out by the National Park, for people who have ripped up blackthorn scrub festooned with lichens in order to plant some ornamental shrubs. And that, somehow, is classified as biodiversity....People are very good at spinning concept of biodiversity for what they want to do, which is often gardening, which is not necessarily the most biodiverse thing they could do. Pollinators are often far more reliant on some willow scrub, or something that produces tree pollen early in the season, than a small patch of some flowers in the summer. (MS)*

Beekeepers now find themselves working to position their hives in a landscape that has been compartmentalised and commoditised. Respondents often noted beekeeping and honey production once being a common part of mixed farming, and this generating an awareness in farmers and land managers of pollinators' needs. Throughout the 20th century, honey production was often a part of mixed farming. One interviewee reports that, throughout many parts of Wales in the mid 20th century, it was not unusual for small, mixed, family farms to produce and sell a tonne of honey, along with other crops such as beef and lamb. Now, efforts to restore the landscape on behalf of pollinators are often mired in a highly bureaucratic framework of targets, in schemes which often achieve only modest aims (Hardman et al., 2016):

When considering how beekeepers use their knowledge of forage quality and quantity when managing their bees, it is important to consider that, while beekeeping is an activity often associated with rurality, many interviewees and archival writers maintain their colonies in a diverse and often urban, or peri-urban environment. Due to the challenges of the agricultural areas discussed earlier, these types of environment are often preferred sites:

> *I've got hives which are further into Birmingham city centre, and I know people in the city centre who keep bees - and you get a far better variety and quality of honey then you get out in the country. (BD)*

The often overlooked biodiversity within urban spaces is recognised by beekeepers as offering a potential wealth of forage for bees:

> *It's not just an urban sprawl of houses. There are gardens, there are parks. So they do all right. (DS)*

We see that their consistent observation and assessment of the environment has led beekeepers to often choose to site their bees in urban or peri-urban areas, in an effort to ensure diverse forage which is comparatively unaffected by the agrochemicals of industrial agriculture. However, increasing rates of urban beekeeping are leading some observers to question whether there is sufficient forage available to support rapidly increasing colony densities. Since 2008, the rate of urban beekeeping has dramatically increased. From 2008 – 2013, the number of hives in greater London doubled, from 1700 to 3500. London has a hive density of 10 hives per km^2, as compared to a UK national average of 1 hive per km^2. (Alton and Ratnieks, 2013). Recent research into the hive density of wild honey bee colonies suggests that natural behaviour of this species results in colony densities of approximately 1 per km^2 (Seeley et al., 2015). The unnaturally high densities of managed colonies are frequently noted by interviewees as problematic for honey bee health and productivity. This recent dramatic increase in urban beekeeping has led to some areas deteriorating, and now being seen as a challenging habitat. Some experienced beekeepers have stated that they now believe there are too many colonies being kept in cities, for the forage that is available: This interviewee observes that urban areas are at risk of excess pressures on forage:

> *But if you've got too many,… obviously it's going to have some sort of impact on the bees. On their honey anyway. (DS)*

Simultaneous with the rise in popularity of urban beekeeping is the loss of land to development, which urban beekeepers note as a factor which affects their placement of colonies. Several interviewees expressed concern about plans for extensive development in peri-urban areas which had historically been excellent habitat for pollinators:

> *What I see in suburban life is that reasonably large gardens where you would have had a chance of compost heaps and that sort of thing, on the whole are now being sold off for infill building, right, and in London, where I still have a cousin, I see that there are almost no front gardens left. (MM)*

We see that in the urban and peri-urban environment, as well as the rural and agricultural environment, beekeepers are constantly having to enact their environmental knowledge within contexts that are ultimately beyond their control. There is a consistent challenge, and a paradox, of beekeepers building up observational and formal knowledge of the benefits and limitations of an area, and then experiencing its changes, due to factors outside of their direct influence. The challenges to beekeepers' use of TEK in their practices parallels similar communities' experiences, who strive to continue traditional methods of environmental and land use practices within a rapidly changing socio-economic context, and a physical environment undergoing notable changes; this has been found amongst Italian alpine farming communities, French heather honey producers, and Spanish pastoralists (Ianni et al., 2015; Lehébel-Péron et al., 2016; Oteros-Rozas et al., 2013).

The importance, and challenges, of maintaining spaces for nature and biodiversity in an increasingly urbanised world was a recurrent theme in interviews. When considering how beekeepers' knowledge can support our understanding of the state of the environment for pollinators and other species, their perception of current development is relevant. While there is a policy drive towards enhancing the built environment for biodiversity (Fukase and Simons, 2016; Garbuzov et al., 2015a), according to interviewees, there is significant room for improvement. Interviewees note developers relying on 'easy to maintain shrubs', which provide little to no forage for pollinators. Their observational insights suggest we are often failing to successfully integrate the natural world and ecosystem services into planning and development. While there is also an effort to plant wildflowers on road verges and roundabouts, this, too raises some questions from interviewees:

> *Tarting up a few roundabouts with some Californian poppies isn't really going to get to grips with the issues. (MS)*

Both the location, alongside a busy, polluted road, and the risk to pollinators from flying in or across traffic, are seen as deeply problematic.

This section has shown how beekeepers use their hybrid knowledge to assess the quality and quantity of forage available for their bees. While this knowledge is highly informed by both their practice, and wider study, there are often limits to their capacity to act upon it, which are outside of their influence. Such knowledge also comes into play, and experiences similar challenges, when assessing the effect of agrochemicals. The complex management practices, involving the application of experiential and formal knowledge, as well as working relationships with other stakeholders in pollinators' lives, will be the subject of this next section.

5.3: Managing Challenges of Agrochemicals

Beekeepers have been at the forefront of observing and documenting the effects of agrochemicals for decades, with their knowledge often preceding formal scientific confirmation of their effect. Their knowledge of the impact of agrochemicals on honey bees, and other species, epitomises the qualities which distinguishes their environmental knowledge overall. For many, it is based on a combination of years of careful observation of bees' behaviour within a wider environment, coupled with educating themselves about the effects of agrochemicals via beekeeping magazines, scientific journals, and sharing information and experiences with colleagues in beekeeping CSOs. As a result of beekeepers' historical working relationship with scientists, the decades of communication between them and the UK's Rothamsted Institute (one of the world's leading agricultural research institutes), and their being at the forefront of experiencing and documenting the effects of agrochemicals, they are both highly aware of, and engaged with, science surrounding agrochemicals. However – they are also using this information within their management of their bees within a complex and at times paradoxical nexus of synchronous factors. These include a pragmatic understanding of the diverse pressures on farmers, historical observations of contradicted and/or revised advice on the safety of various chemicals, and the complex realities of life experienced by bees in nature as compared to lab data. Such decision-making in a context of hybrid environmental understanding is also found amongst farmers (Barbero-Sierra et al., 2017; Girard and Claude Paraponaris, 2015; Šūmane et al., 2018), as these land users work to amalgamate a diverse range of understandings of their physical environment.

As this project focused on the observations of long-term beekeepers, data generated on beekeepers' knowledge of agrochemicals often reflected 20th century patterns of agricultural transitions and developments. While attention often focuses on bees suffering the ill effects of the agricultural system, it is easy to overlook that, in many ways, honey bees are often a part of the agricultural system. This is most apparent in terms of contract pollination, where hives are brought to particular crops to provide and/or enhance pollination rates. Recent years have seen a growing reliance on honey bees as pollinators in the agricultural environment (Breeze et al., 2014; vanEngelsdorp and Meixner, 2010). Managed pollinators frequently serve to *replace* natural / wild pollinators, which have been destroyed via the wider food system. Archival data reflects this transition, and the resultant unease of some beekeepers when asked to put their bees into the same environment that has led to the demise of other pollinators:

> *65 years ago when we started with bees, no farmers ever dreamed that one day the many wild bees and insects would be gone. … Today so many different, very deadly and powerful insecticides are used that few native pollinating insects remain. …Before the intensive use of insecticides was started, we rented many of our hives of bees for pollination. … During the recent years, the wide use of insecticides, germicides and other poisons have caused such great losses that we can no longer afford to rent bees for pollination even to our customers of many years. (Calhoun, 1979, p 77)*

Wild pollinators still play a significant role in pollinating many crops (Park et al., 2015; Vanbergen and Initiative, 2013). However, the rise of industrial agriculture and resultant environmental pressures have led to many species dying out, due to loss of habitat and forage, and exposure to agrichemicals (Brown and Paxton, 2009). As a result of the loss of many wild pollinators, honey bees are now often relied upon as the dominant pollinator. We are now in a position where many areas and crops depend on the movement and supply of hives of honey bees to ensure pollination, because of this lack of other pollinators (Breeze et al., 2014):

> *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! They paid them $40-50 per hive per week. And that's one of the problems we might face if we go down the same route here. (RB)*

While the above quote refers to a specific situation in the US, comparable agricultural practices are observed by UK beekeepers as having similar results. The Essex Beekeepers' Association's history (1980) includes a discussion of how a county-wide Official Pollination Scheme was established in 1956. The authors specifically note that this was due to "farmers having destroyed their natural pollinators by intensive spraying of insecticides for most of the year". Farmers were then able to rent hives of managed honey bees to provide pollination at the specific time for fruit trees (and, eventually, beans and other crops). This soon provided a clear commercial advantage to local beekeepers, who promoted the scheme widely. Beekeepers' practice generates specialised knowledge of the number of hives required to ensure successful pollination of an orchard during its brief period of flowering, as well as any extenuating factors that may influence pollination, and the subsequent success of the farmer's crop. This knowledge is as valuable a commodity as the actual pollination carried out by the bees, and is brought in to the food system.

Today, beekeepers still need to carefully negotiate the same challenges and possible profits. Intensive agriculture continues to pose a threat to wild pollinators (Kremen et al., 2002), leading to a growing reliance on managed honey bees, which are not kept in sufficient numbers to meet the ever-growing demand for insect pollination in the current agri-environment (Breeze et al., 2014). There are also growing concerns that such a reliance on a limited number of species of insect pollinators poses the same types of challenges and threats to the agricultural system as a reliance on other monocrops (Marshman et al., 2019). This leads to beekeepers having to negotiate a potentially hazardous physical environment in which to site their bees, and assess risk within a potentially profitable wider agricultural system. Risk and uncertainty must be balanced and managed, with different criteria for different actors (Maxim and van der Sluijs, 2011). The need to balance out the seemingly contradictory needs of farmers and beekeepers requires communication and mutual understanding:

I've got one site – a big farmer, and his reputation as a chemical farmer is quite severe. But when I call him up, he's happy for me to put hives there. But he understands. He says he will call me when they are about to spray. He's obviously thinking – he's aware. He's enthusiastic. But he's a commercial farmer, so he farms the way he knows best, and he's a pretty good commercial farmer. (CD)

The reliance on often hazardous chemical inputs is central to a particular approach to farming and land management that is increasingly found throughout the world, and requiring beekeepers to work at ensuring the health and wellbeing of their bees, in a challenging environment. This creates a tension for beekeepers, and influences their management and decision-making, as they assess the risk of exposure to agrochemicals their bees may face in particular environments.

As discussed in chapter 4, section 8, throughout the BFA Bulletins and Association meeting notes, the issue of agricultural sprays and agrochemicals was a consistent concern for members. It should be stated at the outset that almost all interviewees note the decline in the type of extreme, fatal spray events which were commonly referred to throughout the BFA Bulletins, and in interviews:

Certainly in the past I have found colonies dramatically affected, and I have been able to identify it as a result of spray damage…. Because you can always tell from a colony if that is how they're suffering. Because the proboscis is always projected in mass numbers outside a hive. And I have had that experience and realised it was chemicals. I have not seen it in recent times so much. (BD)

However, although the scale and intensity of death from agrochemicals is usually not as dramatic and immediate now, there are still questions and concerns amongst many beekeepers about new chemicals. These concerns necessitate a constant iterative analysis of the risk of spray exposure, and where to site one's bees to minimise risk whilst taking advantage of environmental benefits. The subtle, indirect quality of modern agrochemicals – either on their own, or in complex synergistic relationships with other factors – is notoriously difficult to assess, and measure (Gonzalez-Varo et al., 2013; Goulson et al., 2015). Interviewees note the distinct change in impact on bees now:

> *In the 80s and 90s, the bees were being killed off by pesticides. You would see them just lying on the floor. That was straight outright kill. We recognised (it) as pesticide kill. But now I think we have what I would call…clean toxins (JP).*

While they accept that many chemicals may be safe – or at least manageable - on their own, the cumulative effect is of great concern:

> *(there is) a book that's called Bee Safe, Bee Careful, when using insecticides. Well it tells you how to spray insecticides and fungicides. Also did you know, they mix together, and it increases the properties. (BG)*

Clearly, modern agrochemicals present a range of challenges to bees, which requires careful management. However, this is complicated by economic relationships which often run counter to scientific and environmental awareness. Bees and beekeepers have become entangled in financial relationships with landowners and farmers which often result in their carrying out management practices on their bees that are increasingly recognised as counter to bees' welfare (Neumann and Blacquiere, 2017; Vandame and Palacio, 2010). This trend is also noted by beekeepers in the US, UK, and Australia (Phillips, 2014; Seitz et al., 2016; Suryanarayanan and Kleinman, 2013). This complex relationship is notable throughout the early years of the BFA archives, and was also a recurrent theme throughout interviews. In one of the earliest BFA bulletins, an editorial discussed the challenges to bee farming in the UK. 'The whole pattern of British agriculture is changing, and tied as we are to the crops that the general farmer grows, so it must follow that our conditions will change with them' (BFA Bulletin 11: 2/55). These tensions manifest in the BFA archives, which document bee farmers' efforts to become formally affiliated with the NFU, and subsequent frustration with the affiliation failing to deliver the understanding and benefits they had hoped (BFA Bulletins 54: 3/60; 80: 10/63; 181: 8/78). While many types of farming are reliant on bees and other pollinators, and fruit farmers would hire contract pollinators, tensions still existed. Beekeepers and bee farmers have consistently had to carefully enact their environmental knowledge within a challenging landscape. The BFA records illustrate the changing and complex interdependent relationships between bee farmers and the wider agricultural community. BFA Bulletin 68 (1/62) notes its members aiming to get the NFU to educate its members on 'intelligent use of pesticides', with earlier editions (BFA Bulletin 61, 1/61) noting tensions surrounding the timing of farmers' spray application and the effect on bees. BFA

Bulletins 80 (10/63) and 214 (5/83) show that tensions surrounding spray remained unresolved for many years.

As noted in the preceding section discussing beekeepers' engagement with forage, there is a constant challenge for them when acting upon their knowledge, due to factors outside their control. Beekeepers recognise the challenge to farmers in controlling crop-damaging pests, and many accept that agrochemicals are a part of modern life and agriculture. However, they note that agrochemicals must be used appropriately if pollinators are to be safe, and this is not always the case:

> *In a way I feel sorry for the farmers because they feel they have to use something. But I think the problem is when they have to use things in combination – like pesticides and fungicides, and I think that's when things can go wrong for the bees. And when they sprayed fields when the flowers are completely out-if they did it at night, or before the flowers come out, then that's all right. When the flowers finish, and the bees aren't on them anymore, then that's all right. But some farmers don't even think about the bees and pollinators. Maybe that's where pollinators have gotten lost over the past few years. (DS)*

To ensure their bees are safe from dangerous exposure to agrochemicals, beekeepers often emphasise the importance of personal communication that transcend prescriptive policy guidance. Beekeepers aim to develop personal working relationships with farmers, ensuring that they are notified of plans to spray. However, there are clearly variations in the timing and reliability of communication between beekeepers and farmers:

> *He phones me up and says oh I'm spraying in two days. So he lets me know. Whereas farmers don't do that anymore. … They are supposed to give you 48 hours' notice when they are going to spray. But they don't, you see. (RH)*

Communications can be further compromised by farmers using subcontractors for spray applications, thus interrupting the working bonds of mutual understanding between farmers and beekeepers that are already difficult to build, and maintain.

As beekeepers struggle to balance complex and contrasting knowledge of the effect of agrochemicals, they frequently opt to try and avoid them altogether by siting their bees in areas where chemicals will not be used. Interviewees reported increased difficulty in getting 'good' farm sites for bees. Many beekeepers prefer to site their hives on organically farmed land, so as to avoid the risk of exposure to agrochemicals. These limited sites are in high demand:

> *A lot of farmers where I keep hives are organic. In a good season, these produce really well... Those sites are difficult to get. (CD)*

There is a tendency for beekeepers to observe complex synergies which cannot be replicated in laboratory studies. While there is a growing move towards more experiments which aim to generate data closer to real world field exposures, to understand threats to pollinator well-being (David et al., 2016; Woodcock et al., 2017) it is difficult to accurately replicate the lived experience of pollinators in a complex environment. Uncertainty is a key facet of environmental risk and impact (Maxim and van der Sluijs, 2007; 2011; Udovyk, 2014), with beekeepers constantly being forced to make practical management decisions in ambiguous situations. Crops may be sprayed many times throughout a growing season; the timing, and effect, of applications may be unpredictable; and the cost and effort of going to the hives to close in the bees to prevent spray exposure can be difficult or impossible. These factors combine to make actual management in response to agrochemicals highly challenging, and often impossible. Beekeepers are often forced to simply hope for the best, albeit wondering about the direct or indirect effect of exposures.

Coupled with concerns about synergies, the length of practice of most interviewees often led to their perspective on agrochemicals being nuanced and historically situated, and frequently counter-intuitive to some important current debates. This was rooted in their hybrid knowledge: while they were often highly engaged with scientific developments and changes in agrochemicals, ultimately, their practical assessments, and subsequent decisions, were driven by personal and community experience, which generate a broad comparative temporal overview that is often left out of environmental assessments. For example, beekeepers' experiential knowledge of agrochemicals' impact on pollinators often resulted in data for this project revealing quite an unexpected, idiosyncratic, perspective on neonicotinoids, (aka neonics), the most common type of insecticide seed dressing. These systemic insecticides have been the subject of widespread debate and criticism, and subsequent legislation, due to their devastating impact on many invertebrates (Gross, 2014; Lu et al., 2014; van der Sluijs et al., 2013). There is a growing scientific evidence base that neonicotiniods are harmful to bees and other pollinators, as well as the wider environment (Gross, 2014; Sanchez-Bayo et al., 2016; Woodcock et al., 2017). Perhaps surprisingly, several respondents seemed relatively unconcerned about their bees' exposure to these ubiquitous chemicals. This may seem paradoxical and counter to beekeepers' frequently expressed sense of care for their bees (Thoms et al., 2018). However, land use and the decision-making process when assessing environmental risks and challenges is notoriously complex (Carolan, 2008b; Eloy and Coudel, 2013). For many beekeepers, particularly those in areas with high levels of arable agriculture, it would be extremely difficult to attempt to keep their bees from encountering crops grown with neonics. A consistent theme throughout all data is the near-impossibility of ensuring one's bees are not exposed to agrochemicals outside of one's control:

> *To me, the problem is that the bees will fly 3-5 miles for nectar. If they find something they like, they will stay closer. You have no control. You can't be in contact with every farmer within a 2 mile radius of your apiary. …The biggest problem is that you don't know what people are doing beyond the farmers that you know. (CD)*

Neonics are also commonly applied to some of the key forage crops for bees, including OSR (Schürch et al., 2016; Sterk et al., 2016). However, interviewees' willingness to tolerate neonics was primarily due to a fear of farmers resuming the use of sprays which are applied to crops and the surrounding ecosystem more broadly. All those who expressed a relative degree of acceptance of neonics also added that they believed that farmers would resume using other sprays if they could not use neonics:

> *I mean, I get criticised for saying this, but I believe that neonicotinoids are probably a better option than the former going out during the day and spraying the fields. (DC)*

It is important to note that all interviewees are aware of the risks associated with agrochemicals, including neonics. However, since many had had previous experiences of entire colonies dying out immediately as a result of chemical exposure, this led to their perception that the more subtle effects of neonics seem comparatively manageable. Neonics do not kill bees directly; instead, exposure leads their navigational capacity being damaged, so they either lose their way, and die out in the field, and/or have their foraging capacity damaged, which *indirectly* leads to their death (Henry et al., 2012; van der Sluijs et al., 2013). This is therefore experienced, and interpreted differently than chemicals which lead to piles of dead bees near the hives:

> *I think data from bee poisoning suggests that the use of neonics - it's difficult to see a correlation between the use of neonics, and bee deaths. And during the last couple of years, being fewer neonics round, they have been several cases where- in fact I have seen one-there have been several cases where bees have suffered very badly from spray. So I don't know. (BS)*

This is also an example of how long term beekeepers' environmental perspective is resultant from their assessing risks and hazards to bees from a personal practice perspective, where many had experiences of major losses as a result of chemical exposure. Perhaps most importantly, beekeepers can, and do, manage their colonies in ways that can make them more resilient to the impact of neonics, unlike other invertebrates, which suffer more acutely. The natural life cycle of a honey bee colony is managed by the beekeeper. It is fed in spring to try and ensure it increases in size to maximise the honey flow in May – July. At the end of the summer, weaker colonies are often combined into larger colonies in an attempt to ensure they are of sufficient size to survive the winter. These, and other techniques, can help to minimise the negative impact of neonic exposure, in ways that are not available to the myriad other species which are affected by these systemic insecticides.

This seeming contradiction between beekeepers' views on neonics, and the growing body of scientific evidence on the ecological hazard posed by these chemicals, illustrates some of the tensions between TEK and scientific knowledge. As noted in Chapter 2, TEK is sometimes critiqued as lacking the objectivity that is the basis of scientific knowledge (Don, 2010). When understood through a solely scientific perspective, the evidence is clear that neonics are highly damaging to bees and other invertebrates (Gross, 2014; Woodcock et al., 2017). However, beekeepers' analysis, and subsequent management and decision-making is carried out in the context of their experiential knowledge of the immediately lethal effects of agrochemicals that neonicotinoids have replaced.

As well as beekeepers sometimes seeing neonics as 'the lesser of two evils', it should also be noted that their relativistic framework also includes a broader cost-benefit analysis. Beekeepers often prioritise the benefits to their bees of early season high energy crops such as OSR, and deem the potential risks as being manageable. This, combined with their memories of the historical precedents to neonics, leads to their making a pragmatic, utilitarian assessment of the comparative risks associated with different agrochemicals. While TEK is often lauded as being holistic, and providing space for an ethical framework of environmental engagement, some beekeepers' perspective in this instance can be seen as pragmatic at best, and short-sighted at worst. This exemplifies some of the critiques of TEK, which insist that TEK must be compiled and analysed in the same way as scientific information, and subject to the same scrutiny (Usher, 2000).

The beekeeping community is notably heterogeneous: some are emphatic that neonics are an unacceptable risk to bees, and should be avoided on an individual level, and banned on a wider level. This variability of perspectives amongst the beekeeping community, coupled with an occasionally uncritical acceptance of scientifically proven hazards, illustrates the potential challenges to collating, and engaging with TEK in environmental management. Moller et al (2004) note areas of complementarity between science and TEK. Diachronic and synchronic complementarity are paramount, with the long-term knowledge of TEK often providing knowledge and a perspective that is frequently absent from scientific studies. Although Don (2010) notes that long-term knowledge can be, and is, generated through scientifically objective, robust, universal methods, the fact remains that most scientific studies are temporally limited (Moller et al 2004). In such situations, TEK can be effectively used to provide knowledge that lies outside the temporal boundaries of a research study. And, as in the case of some beekeepers' paradoxical equanimity towards neonics, the historically situated and reflective nature of TEK can illuminate what may appear to be a seemingly misguided or irrational assessment of factors, when situations are assessed solely within the context of objective scientific knowledge.

As the effect of many agrochemicals has changed, from those which resulted in immediate mass mortality, to those which contribute to sub-lethal negative effects, this has also led to a change in beekeepers' engagement with scientific knowledge. Rather than conforming to an earlier model of citizen science, where citizens gather data which will then be elucidated by experts, (Bonney et al., 2009), beekeepers are co-creators of knowledge, carrying out their own research, generating hypotheses, and, ultimately, thinking scientifically (Trumbull et al., 2000). Due to the complex environments in which they keep their bees, their analyses of situations frequently digress from those posited by scientific research, thus exemplifying a tension between differing analyses of the environment (Eden and Bear, 2012; Ellis and Waterton, 2004) which has direct bearings on their decision-making and actions taken in their beekeeping. The tensions resultant from differing engagements with science are exemplified here:

> *And nobody understands that they will kill bees by spraying during the day, and if the bee's visiting a flower, the bee will be picking up the chemicals that are on that flower, and taking it back to the hive. And it is, well, it doesn't seem to me, that the agronomists pass on the correct information about spray times, or the damage that they can cause-and I don't know if it is that, or if the farmers don't really care anyway. (DC)*

The interviewee notes the multiple ways that bees can be damaged by spray applications, as well as questioning whether it is the agronomists, or the farmers, who are to blame. The above quote illustrates the clear challenge to beekeepers' use of their environmental knowledge, in the many contexts which are outside their control. While interviewees often accepted the role of spray within the wider environment, it is the scale, degree and purpose of their use that they often question. One interviewee noted that apple crops can be treated with up to 20 different sprays per season. This is seen as a shift beyond what is fundamentally necessary to assure crop survival, and is, instead, relied upon by farmers to produce a crop which meets a certain level of consumer expectation, in terms of aesthetics.

Clearly, the contemporary agricultural landscape, redolent with chemical pesticides and fungicides, is a place of many potential hazards for bees. This presents consistent managerial challenges for beekeepers, who are dependent on the understanding and concern of farmers and land managers. Interviewees acknowledge that there are extensive guidelines for farmers regarding best practices of land management, and safe use of agrochemicals to support pollinators. While most interviewees note that, in theory, these guidelines are generally agreed to be excellent, they express concern about what they see as a disturbing disconnect between the advice for farmers and other landowners, and what is actually done:

> *We hold our local beekeeping meetings at this local farm advice centre. And they have these leaflets about hedgerow maintenance. And they're absolutely excellent! But, you know, no one-no one sticks to these guidelines. I have never seen any farmer, or any hedge cutter using these guidelines. Well what's the point in having guidelines when there's nobody enforcing (them)? (EC)*

Such voluntary measures and communication are at the heart of efforts to manage agrochemical exposure, yet they are, and always have been, fraught with weaknesses and potential failures. The BFA bulletins note consistent frustration on behalf of their members. One of the driving forces behind the BFA's efforts to become affiliated with the NFU was to promote better understanding of the needs of bee farmers – and, by extension, bees and other pollinators – throughout the farming community, particularly in regards to agrochemical spray risks. While bee farmers empathised and understood farmers' desire to use sprays on an economic and practical level, the issue has always been complex, and often strained. Even when beekeepers were advised about farmers' plans to use spray, this was not always of practical benefit. One bee farmer noted that '*spray warnings are not very useful to larger operations – who has time to dash off and go 20-30 miles to shut in their bees*?'. This was a major concern in the bulletins of this era. BFA Bulletin 156 (9/74) documents an increasingly terse relationship between farmers, bee farmers and government. It was clear by this point that bee farmers were very aware of the damage caused by sprays. They were frustrated with an inability to get farmers to agree and / or abide by voluntary agreements to restrict spray use, and government's unwillingness to pay any compensation in situations of colony loss resulting from spray exposure. Such challenge and conflict between farmers, beekeepers and government were a hallmark of discussions in the BFA bulletins, particularly from the 1950s – 1980s. While Bulletin 68 (1/62) notes that the HPA are 'firmly in partnership' with the NFU, this partnership appears to have been a rather fraught, unequal relationship. This same edition notes the HPA's efforts to encourage the NFU to educate its members on careful use of pesticides. The fact that this issue was a recurrent point of contention for decades, and continues today, evidences the structural challenges to fully engaging with beekeepers' knowledge and concerns.

As these bulletins record decades of frustration between farmers and beekeepers, it is worth addressing why there is still a continued reliance on voluntary measures to limit bees' exposure to spray. The same concerns of HPA / BFA writers in the 1960s and 70s were consistent refrains in interviews for this project. While in theory it is helpful for farmers to advise beekeepers of plans to apply spray to crops, in practice, this can require beekeepers to travel many miles to close up hives, often at very short notice. Many factors can make this impossible or impractical. Similarly, wasted journeys due to last minute changes of spray plans are common:

> *Farmers were very good. They 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. (CD)*

For many years, local beekeeping associations has Spray Liaison Officers (SpLO). Farmers were encouraged to advise them of their plans to spray, and they were then tasked with contacting their members, who could then ensure their bees were closed in their hives before spraying was due to take place. This was clearly a cumbersome process, rife with potential for important information to not reach all stakeholders in sufficient time to take action. Recognising the challenges to the Spray Liaison Scheme, and keen to make best use of technological advances, a recent scheme has been developed by the Voluntary Initiative, called Bee Connected. This web-based scheme aims to simplify communications between farmers and beekeepers, with farmers registering on the system, then identifying which field they are planning to spray, and which insecticide they will use. Beekeepers are also encouraged to register. Then they will be sent an email with details of any spray events which are scheduled to take place near their hives, up to a maximum of 5 km. "*It is then up to the beekeeper to decide what action to take, if any.*" (Italics mine) (Voluntary Initiative, 2019). Beekeepers are being encouraged via local and national beekeeping organisations to sign up to this scheme. Such an approach raises important questions. As has been the way for decades, the responsibility for action to avoid damaging chemical exposure is upon the beekeeper, rather than for the applicant to limit, or cease, their use of substances which cause harm to bees, which theoretically can be protected from exposure, and other species, which are outside of the realm of human protection and will thus bear the full brunt of any risk.

Another curious facet of the Bee Connected scheme is that it only addresses insecticides. Research has found that fungicides also present a significant threat to pollinator health, both individually and synergistically with insecticides and diseases (Bernauer et al., 2015; David et al., 2016; Tosi et al., 2018). These studies address the impact of fungicides on honey bees and other pollinators. During the course of this project, I asked several beekeepers about their views on the potential benefits of the Bee Connected scheme, and whether they would be signing up to it. Several specifically noted the scheme's lack of including fungicides as a reason they would not be supporting it:

> *At the moment, I'm concerned – they discovered in USA that the sprays they use - the fungicides are causing problems in America. They shorten the length the queen lives. That's the main problem in beekeeping in recent years. Queens aren't living long enough. (BH)*

While challenges and tension were constant themes, it is important to be aware that some beekeepers noted very positive working relationships with farmers, saying that they are always notified about spray, and their bees have never suffered any damage from spray. These positive relationships have a great deal to offer our understanding of the ways in which the agri-environment can best be managed to support pollinators and other species. Much of the potential for pollinator-friendly farming is often seen as resultant on personal relationships between beekeepers and farmers, which must be carefully cultivated, and maintained:

> *It's the individual. It's how you work with them. Making them understand your problems, and you understanding theirs. (KB)*

For beekeepers, the personal relationship with farmers is often central to ensuring the safety and wellbeing of their bees; ultimately, many beekeepers have more faith in these personal working relationships than in the actual training held by the individual. We see that beekeepers are constantly enacting a complex, multifaceted combination of their environmental knowledge and understanding, within what is often both a personal and professional environment, where official policies are ultimately enacted by individuals:

> *And he's spraying more. All these damn farmers are spraying more. I mean he's very good. If he sprays he rings me up the day before and says 'A, I'm going to*

> *spray tomorrow' so I can get up early in the morning and shut my bees away and then he rings me when he's finished so I can let them out again. So to that extent, he was very good. But they are spraying much more. (AS)*

While data often referred to empathetic views regarding farmers' reliance on some sprays to control pests and associated crop damage and loss, the role of agronomists was questioned by some respondents. Farmers rely on agronomists for information about what is safe to use, and how to use it. In contrast, beekeepers often expressed a lack of confidence in both the quality, and the objectivity, of the information being given to farmers:

> *A lot of education needs to be done to farmers. And the agronomists. They are the ones that are visiting the farmers, and giving the advice. The agronomists should have it hammered into them, about the damage of the chemicals that they are recommending, that are being used at the wrong time of day. I have actually known an incident, where I know that the agronomist was on site when I was looking at a swarm, and yet the guy that was talking to me was just about to go out and spray his fields with chemicals, that would kill bees. (DC)*

While the discussion has emphasised beekeepers' efforts to manage the challenge of agrochemicals in the rural environment, it is important to remember that pollinators also encounter hazardous chemicals in the urban and peri-urban environments. As we are seeing an increase in global urbanisation, and the percentage of people who live in cities, the importance of ensuring biodiversity within urban areas is of increasing importance (Fukase and Simons, 2016). Similarly, urban areas are also increasingly seen as places of food production, in which pollinators play a key role (Lin et al., 2015; Speak et al., 2015). Therefore, beekeepers' environmental knowledge of urban and peri-urban spaces is highly valuable. Perhaps unexpectedly, given the association of agrochemicals with industrial food production in rural areas, we see that cities and suburbs can also present such challenges for bees and beekeepers. Beekeepers therefore use their knowledge of agrochemicals' impacts on bees to assess urban, as well as rural environments. Several interviewees preferred siting their colonies in urban areas, believing that such regions were comparatively free of the agrochemicals often associated with large-scale food production:

I'm not keeping bees near agricultural land and the, um, my general feeling is that on the whole suburban beekeeping is actually much less likely to be affected by chemicals than agricultural land. (MM)

However, some respondents note an opposing view – namely, that farmers and agricultural workers usually need to undergo more training, and have more restrictions, on agro-chemical use, while the sale of common garden insecticides is unregulated, and allows anyone to use them without any training or restrictions. This included individual householders -

I think the general public needs to be educated a bit more about how to do better gardening…. I think they use chemicals more than the farmers do. (BH)

- and local authority employees who were responsible for maintaining public parks and gardens:

I suspect it was something the Council used to suppress weeds. I've lost bees, had lots of dead bees by entrance to hives. A couple of hives in an apiary were badly affected last year, and another previously. But it's mostly urban sites that are the problems. (CD)

It is beyond the scope of this thesis to assess who is 'right' or 'wrong' regarding the level of risk of chemical exposure in urban and peri-urban environments. Indeed, it would be impossible to make such blanket assessments of differing types of areas, due to the importance of individual factors – eg, particular farmers, or Council employees, in both understanding issues of pollinator wellbeing, and acting on this knowledge. However, the awareness of the issues, and the differing assessments of beekeepers working in these environments does address questions which are receiving legislative attention in other countries. When considering how beekeepers can personally manage the risk of agrochemical exposure in the urban / peri-urban environment, the importance of personal communication and working relationships, coupled with the distances flown by bees, suggests that this is an issue beyond the control of the individual, which requires a broader governance response. France has recently banned the domestic and local council use of various pesticides (Prevencia, 2019).

This section has shown beekeepers' historical and current efforts to manage the deleterious effects of agrochemicals. They rely on their personal and collective beekeeping experience, coupled with their formal and informal eduction, as they constantly appraise the omnipresent challenge of agrochemicals, in diverse landscapes. They recognise the central importance of personal communication as a way of knowing what chemicals are being used in areas their bees may be foraging, and therefore aim to develop working relationships with farmers and land managers, although these are unpredictable and unreliable as a method to ensure their bees are protected from spray exposure.

A similar blending of experiential and scientific knowledge, and diverse challenges to the application of this knowledge, is evidenced in regards to beekeepers' attempts to manage varroa; this will be the subject of the next section of this chapter.

5.4: Managing Challenges of Varroa

Varroa is considered one of the greatest challenges to contemporary beekeeping (Le Conte et al., 2010; Wilfert et al., 2016). Due to varroa's ubiquitous, devastating impact since the late 20th century, most interviewees had personal experience of its impact on their bees. This mite has long been endemic to Southeast Asia, where the indigenous ssp of honey bees, *Apis cerana*, have evolved a biologically balanced host-parasite relationship with varroa; the parasite does not destroy the host, due to its ultimate reliance on the host for its own survival. However, *Apis mellifera* - European honey bees - have not yet evolved such a capacity. Since the arrival of varroa mites in Europe in the 1970s, their effect on bees, and what beekeepers should do to protect them from varroa, has been the subject of enormous debate amongst the professional and amateur beekeeping community. Many interviewees and archival sources were highly engaged with the wealth of scientific research on the issue, but often come to different interpretations as to what is best practice. While public awareness of varroa has grown in recent years as media coverage of pollinator decline has increased (Smith et al., 2016), beekeepers' knowledge and response to varroa has been evolving dramatically over the past three decades. The temporally rich TEK analysed for this thesis illustrates the capacity, barriers and limits to beekeepers using their knowledge to manage this complex challenge to honey bees, and, increasingly, to other bee species as varroa-linked diseases such as Deformed Wing Virus spread to other pollinator species (Goulson and Hughes, 2015; Graystock et al., 2014)

The professional and economic challenge varroa presents to commercial beekeepers is enormous, and has caused tremendous problems since varroa first became well established in the UK in the early 1990s. After years of often tense relationships between beekeepers, scientists and government over the perceived and eventually scientifically acknowledged threat of agrochemicals, varroa presented an arguably greater challenge to bees, as it became endemic throughout the UK. Interviews and BFA bulletins note consistent frustration with government bodies such as Ministry for Agriculture, Fisheries and Foods (MAFF), who were tasked with responding to what was without a doubt a crisis for many commercial beekeepers:

> *Then in '94, I got varroa, and I treated for varroa. MAFF at the time said this is how you do this, this is how you do that, and I duly followed it and the treatments didn't work. And in 1994 I went from 500 hives down to 19. (AH)*

This interviewee also noted that this occurred at the time of BSE, when farmers were being financially compensated for their loss of cattle. Bee farmers were experiencing similar levels of 'livestock' loss and subsequent financial impact, yet did not receive financial compensation from the government. For many, this exemplified a sense of beekeepers and the pollination service they managed being somehow secondary within the official understanding, and valuation, of agricultural services. The BFA Bulletins devoted many pages to discussion of the inexorable spread of the parasite throughout the UK, as members struggled to protect their colonies from the effects of varroa. It was first mentioned in the BFA Bulletin 185 (2/79), where it was noted that varroa was not yet a serious issue in the UK, but beekeepers were advised to be aware of its potential impact. At this time, varroa was becoming an increasingly widespread problem throughout Europe, but had yet to become established in the UK. Bee farmers used their personal and professional networks to observe and share information about varroa. Soon, most countries in Europe were affected by varroa (BFA Bulletin 215: 6/83). From that point on, the development, trials, and access to evolving new treatments for varroa was a consistent point of discussion for bee farmers, whose livelihoods were threatened by this parasite, and the diseases of which it is a vector. (BFA Bulletins: 215: 6/83; 227: 5/85; 241: 2/87). Discussions were often heated, as bee farmers experienced the frustration of awaiting legislative responses to what they were experiencing as an existential threat. Bee farmers were also highly informed of the international aspect of the issue, both in terms of the effect of importing bees from areas where varroa was endemic (BFA Bulletin 186: 5/79), and the delays in the UK authorising varroa treatments which had been proved effective, and were readily available, in other countries (BFA Bulletin 298: 3/96). The tension between the bee farmers' knowledge of risks to their bees and possibilities to protect them, and their often limited capacity to act on this knowledge, was a source of immense frustration to bee farmers (BFA Bulletin 293: 2/95). Varroa is a biological risk, which is affected by international and domestic trade policies, veterinary drug licensing regulations (BFA Bulletin 314: 9/98), and, like so many other factors affecting bees, their innately wild nature, and ability to fly for miles. As found in research on bTB, there is often a sense that ultimately, government responses are far more important and effective in protection against potentially devastating diseases (Enticott et al., 2015), with beekeepers, like farmers, often recognising a low locus of control in the face of certain challenges to biosecurity.

Although much of the environmental knowledge held, and resultant decisions taken, is very similar between hobbyists and professionals, varroa is an issue where there is often a sharp divergence between these categories, with amateur beekeepers being better positioned to take a more experimental approach to alternative treatments, or not treating at all. Part of the divergence of perspectives is rooted in the reason for people's beekeeping. For some, this was based on whether they were hobbyists, or professional:

> *If you're a hobbyist, and you lose bees, it's a problem. But if you have 120 hives, and you lose 60, it's your business!! It's difficult. Some of these guys, with 1000+ hives – they can't possibly entertain going treatment-free (CD).*

Ever since varroa became established in the UK, beekeepers have been at the forefront of experimenting with new veterinary treatments, assessing their success rate in controlling mites, and any potential side effects on colony well-being. They have also recognised the broader complexities in observing and managing varroa. While the official guidance from the NBU, and many beekeeping associations, is to regularly treat bees with chemical miticides to manage varroa (National Bee Unit, 2018), an increasing number of beekeepers are deciding not to. There is a broad range of reasons behind people's decision to treat or not (Scott et al, 2013; Thoms et al., 2018). The management approach recommended by the NBU and others is seen by some beekeepers and, increasingly, researchers (Loftus et al., 2016; Neumann and Blacquiere, 2017), as contrary to natural evolutionary processes:

This adaptation – natural selection – should have been allowed to happen years ago. But it didn't. We can only hope that tolerant strains begin to appear. This is starting to happen. (CD)

A growing body of scientific research is now confirming damaging side effects from many of the standard varroa treatments. These include a reduction in bees' natural grooming behaviour, which is a behavioural characteristic which helps them defend the colony from varroa and other infestations (de Mattos et al., 2017), and, perhaps most importantly, miticides undermine the ability of bees and mites to evolve a normal, functional, host-parasite relationship (Locke and Fries, 2011). Miticides have also been linked to other challenges to bee health. Beekeepers are aware of this research, and note it as driving their management decisions:

'Research is being done on impact of miticides on drone sperm viability. This is why the Queens are not lasting. And in America (a noted bee researcher) reckons that some beekeepers are having to requeen as many as four times a year'. (EE)

This knowledge has been the result of a typically hybrid combination of reading current research, and observing the effect of various miticides which have been developed, and recommended by scientists and government bodies over the years. As a result of their concerns, beekeepers often use a range of alternative, non-chemical treatments, ranging from sprinkling icing sugar on their bees, to culling drone cells, to spending decades methodically breeding bees which appear to be resistant to varroa. They frequently experiment with potential new treatments, and share their findings with friends and civil society colleagues. Their experience has led them to be highly informed on the scientific debates surrounding assorted varroa treatments. Beekeepers are highly aware that scientific knowledge is not fixed; it is in flux, and often contradictory, as discoveries are tested, and new theories are developed. Over the past twenty years, some bee researchers have been moving away from efforts to develop new chemical miticides to kill varroa, and focusing efforts on understanding more about bees which are resistant to varroa, and/or have developed appropriately functioning host-parasite relationships (Le Conte, 2007; Rinderer and al, 2010). This can create challenges to decision-making, as new research can supercede previous discoveries and subsequent recommendations, and strengthen their reliance on their hybrid knowledge, where scientific recommendations are constantly tested and measured against observations from practice. As a result, their scientific understanding is one of several aspects of this decision-making process. The relationship of other factors, such as financial reasons for beekeeping, and other aspects of identity, combine with their scientific knowledge to create complex environmental identities and behaviours, as has been found in other land use communities (Hinrichs, 1998; Wynne-Jones, 2017). Even within the 'non-treaters' group, there are diverse reasons behind their management style, where scientific knowledge is but one of many motivating factors:

> *And there are loads of people around here (not treating), and everyone for their own reasons, from laziness to reading the scientific papers, people are thinking in a completely different way. Some are into a natural beekeeping way. (CH)*

The question of how beekeepers perceive and respond to varroa is a highly controversial issue throughout the beekeeping community. Part of the tension lies within some of the language used, with non-treaters sometimes using the term 'natural beekeeping' to describe their practice. However, as one highly knowledgeable, well-respected beekeeper pointed out:

> *The bit I dislike is the term 'natural beekeeping' – with the connotation that, if you are at another end, then it's unnatural. (JS)*

Within the varroa debate, we see contrasting views and experiences. For an increasing number of beekeepers, the importance of breeding for resistance and moving away from a reliance on chemical treatments is central to their management strategy:

> *If we can breed bees better, either tolerant of or resistant to varroa, that would make a huge difference. (CB)*

Several have run detailed independent research projects for years, working to breed bees which are resistant to varroa. This exemplifies the distinct knowledge of many beekeepers, blending observational knowledge over the years, with a scientific analytical approach often rooted in formal study. This knowledge is not merely a passive consuming of information; rather, it is an active, creative generation of information, rooted in hypotheses, testing and analyses. Scientific thinking and action plays a part, at diverse levels of expertise. The depth of knowledge utilised, and created, by beekeepers in their response to varroa parallels the increasing recognition of diverse levels and types of expertise, beyond outdated binaries of amateur and expert. From farmers (Barbero-Sierra et al., 2017; Riley, 2009) to weather recorders (Endfield and Morris, 2012a), to amateur naturalists (Ellis and Waterton, 2016), various epistemic communities are acknowledged for their capacity to generate knowledge of a type and level previously associated only with trained scientists. Like many who no longer use chemical miticides for varroa, the following interviewee had treated his bees for years. His decision to stop was based on what he saw as a decline in both the number of mites, and the associated degree of threat that these mites present:

> *I haven't treated them this autumn or winter because I believe that many bees are now resilient to varroa. Through my observations, it's that bees are either getting rid of the mites, or they are not coming in – the bees are not a good host for the mites now. It doesn't seem as if they are developing a different host-parasite relationship. I checked them in the autumn, and a couple of weeks ago (early Dec '16). Very low levels. So it's not that the bees are living alongside the mites. The bees are finding a way to get rid of them. (TS)*

This beekeeper is engaging with science, within his beekeeping practice. He is monitoring mite levels, and exploring different hypothetical possibilities, in that it could be a case of a different host-parasite relationship developing, which he discounts, due to the low number of mites present. Instead, he has deduced that bees are now capable of removing the mites, and therefore he chooses not to treat his colonies. Such practice exemplifies the interwoven, mutually interdependent perspectives of amateurs and professionals (Ellis and Waterton, 2016), and the scientific thinking exhibited by those outside formal research organisations (Trumbull et al., 2000). And, perhaps most significantly, this knowledge and analysis is being generated, and used, as the basis of management decisions.

Others bring their STEMM background to their beekeeping, and their response to varroa. The following beekeeper is a geneticist by training and profession, although he has been retired for many years. He had noted regarding varroa as 'a worthy challenge':

> *I also try and maintain my own work in developing native bees, and varroa resistant bees. Because my bees are resistant to varroa, you see. (DP)*

Varroa epitomizes the complex decision-making framework that beekeepers face, as well as illustrating the epistemological diversity, and heterogeneous nature of the beekeeping community. Often informed by science as well as practice, beekeepers express diverse views on varroa management. It is a highly emotive issue, with a growing body of scientific data, and experiential practice that can be presented to support contradictory courses of action. On the one hand, mite infestation is recognised as leading to a range of deadly viruses, most notably Deformed Wing Virus (DWV), which almost always lead to the collapse of a colony (Wilfert et al., 2016). For many years, most beekeepers believed the control and eradication of varroa was the primary goal of successful beekeeping. Manging mites was inextricably seen as part and parcel of responsible, appropriate management of one's colonies:

> *I've had to treat for varroa. I use Apiguard, which is based on thymol. I use that once a year, and I don't count the mites or anything like that. I just treat each hive once a year, after the honey's been taken off. Because anybody who's tried to do it without treating them during the last 20 years has generally lost them. (BH)*

In recent years, new problems have begun to present themselves to beekeepers. Over the years, varroa have developed resistance to many of the standard recommended treatments (Le Conte et al., 2010). This is one reason why some beekeepers prefer non-chemical treatments, such as sprinkling bees with icing sugar, which is said to both encourage grooming behaviour, and is also said to lead to mites losing the ability to stay on the bees (Oliver, 2017):

> *I've got a whole treatment program, which starts with icing sugar in spring, then it goes – well I try to requeen each year with my own queen cells... (RB)*

For some, the idea of exposing bees to the recommended chemical miticides is utterly unacceptable:

> *Well you will be told by your beekeeping fraternity to put chemicals in. Well we haven't put chemicals – R. hasn't put chemicals in for 25 years. And I have never put chemicals on mine. (EE)*

Varroa is a classic example of how beekeepers use their environmental knowledge in making decisions regarding their bees in an extremely complex, and often emotive arena. The tension is exacerbated due to issues of biosecurity and pathogen transfer. A 'non-treater' is often seen by other beekeepers as potentially posing a health risk to their bees, as varroa levels can become very high before a colony collapses, then leading to a 'varroa bomb': as the dying colony succumbs to the many viruses associated with varroa, the remaining bees can go out and spread varroa to other colonies in the area, via robbing other colonies of honey (Owen, 2017). However, other beekeepers believe that refusing to use chemical miticides, coupled with carefully monitoring which colonies appear resistant to varroa and breeding from them, supports an increase in drones who are resistant to varroa, and will therefore spread their genetic capacity throughout the wider honey bee community:

> *What we want is our drones to mate with their queens. We've created Swindon as a base for this. Lots of beekeepers in this area do not treat. (EE)*

Tensions also relate to beekeepers' wider perceptions of the food system, and relationships with and to the natural world. Some see beekeepers' emphasis on honey production as leading to an engagement with bees which has ultimately led to their becoming less able to withstand infections, due to both importation, and breeding for high productivity, rather than traits which can help bees withstand varroa, such as hygienic behaviour.

These conflicting views, which engage with genetics, biosecurity, pathogens, sub-lethal effects of miticides, and more, illustrate how beekeepers' knowledge regarding varroa is highly informed by science, but is not merely a collection of seemingly neutral scientific facts. Rather, it is based in a knowledge system that is inextricably rooted in each individuals' personal values and motivation for beekeeping. What becomes clear when analysing beekeepers' response to varroa is that their decision making and assessment is continuous, fluid, and connected to personal experience and observation, as well as wider ethical concerns. Beekeepers' responses to varroa are evidently complex. Their decision-making engages with scientific knowledge, as well as a sense of stewardship, which manifests in various, and often contradictory ways (Thoms et al., 2018):

> *I'm a bee friendly beekeeper. That's why I don't keep bees – I keep hives, and make them as attractive as possible to the bees, so if they are comfortable, they will stay. If they aren't constantly disturbed, and having nasty things put in their hives, then they tend to stay. (JH)*

The physical challenges presented by varroa are not solely material; rather, they exist within intricate epistemological and moral contexts (Carolan, 2008b). As noted throughout this thesis, beekeepers are highly engaged with their bees, and the wider environment, in ways which go beyond their factual, intellectual knowledge of their bees. Interviewees talk of their emotional distress and turmoil when confronted by colonies which are failing as a result of varroa infestation, and the challenge of acting in the way they believe is most appropriate in the situation:

> *We've taken out a lot of drones, and they've had little varroa mites on them – but even that feels bad. It just feels terrible to do that. It made me feel ill and sick to do it. Same as the times I've had to destroy a queen – I hate doing it. I think quite a lot of beekeepers are quite close to their bees and really don't like to do these sorts of things. You feel very conflicted about it. (KS)*

This interviewee, and others, discussed common varroa management techniques which are associated with wider issues of bee breeding. While varroa is a recent factor affecting beekeepers' attempts to choose, and improve, the genetic characteristics of one's bees, breeding has long been a central facet of attempts to manage bees, albeit a particularly challenging point. Breeding practices calls on beekeepers' experience, scientific knowledge, and wider values. This issue will be discussed in the next section of this chapter.

5.5: Bee Breeding and Genetics

One of the central concerns of beekeepers' efforts to manage their bees is around queens, breeding and genetics. This combines all the elements of beekeepers' knowledge: scientific understanding of bee biology, observation of colony behaviour, productivity, and health throughout the beekeeping season, as well as their personal reasons and motivations for beekeeping. A brief explanation of colony biology is necessary before discussing beekeepers' efforts to manage the challenges to bee breeding. It is also worth noting the advice of Brother Adam, one of the world's most respected practitioners and authors on bee breeding:

> *A word of warning about mere theory: The literature on breeding is from the scientific point of view quite bewildering in its quantity, but from the practical side it contains little of real value (Adam, 1987, p 49).*

Each colony has one queen. She goes on a mating flight, very early in her life. If successful, she will mate with approximately 10-15 male bees, or drones. She will then return to the colony, where she will stay until her death, or departure via swarming. Subsequently, all the bees in the colony are born from this one queen, and will carry the genetic characteristics of that queen, as well as the drones. Many factors influence the potential success of her mating flight. These include the weather, the availability of healthy, suitable drones in the area, and her safely returning to the hive. Due to the many risks associated with natural breeding, some beekeepers choose to buy queens which have already been mated. This can be done naturally, with queen breeders raising queens in fairly isolated areas, where they can be reasonably sure of the genetic characteristics of any drones a queen may encounter. Or, like other agricultural stock rearing, it can be done via artificial insemination, with queens being fertilised with a mixture of sperm from various drones, and the fertilised queen then being sold.

As recent years have seen dramatic shifts in the many challenges affecting bees, there has been a concurrent rise in the scientific and observational knowledge of beekeepers about bee breeding, and the role of genetics on bees' capacity to cope with varied environmental threats. As noted in earlier sections, all knowledge is enacted within wider contexts of an individual's ethical values and personal priorities, as well as wider political and economic forces. These issues, and conflicts, can be seen within the debate on keeping 'local bees'. The United Kingdom climate is a notably challenging environment for keeping bees. Therefore, UK beekeepers – particularly those in the cooler, wetter parts of the country - are strongly advised to keep and breed bees which have genetically adapted to thrive in this distinct Northern European environment. This is in contrast to much of the international trade in bees throughout Europe, including the UK, which trades in queens primarily from subspecies *Apis mellifera ligustica,* and *Apis mellifera carnica.* These strains are associated with Italy and southeastern Europe, respectively. While long popular amongst some UK beekeepers for their potential to produce high honey yields, critics argue that these subspecies have a tendency to fare badly in typical British climatic conditions:

> *So we have bees being imported who are not adapted to our climate, so you have failure. Particularly Italians, who fail in our winter, as theirs is warmer, with flowers. Whereas our problem is cold. Their issue is they need to survive a searing hot summer, so they are totally unprepared for our climate. (JH)*

This has long been a concern of beekeepers, with the issue discussed in *The Northern Beekeeper:* the Handbook of the Invernessshire Beekeeping Association. Published in 1945, it warned readers that

> *'to import a package of bees from abroad is to run the risk of importing disease or a type of bee unsuited by temper and constitution to the locality.'*

UK beekeepers are increasingly encouraged by their associations to keep 'local bees'. This is due to the varied perceived risks associated with importing bees. While earlier discussions focused on questions of climatic suitability, there are also increasing concerns about disease risk. The ubiquitous *varroa destructor* mite spread throughout Europe as a result of importing *Apis Cerana*, which is endemic to many parts of South and Southeast Asia (Rosenkranz et al., 2010). Similarly, an inability for non-native bees to cope with local environmental conditions is seen by many beekeepers and scientists as a key problem associated with importing bees from other parts of Europe. There has been extensive scientific research on the GEI – genotype-environment interaction (Büchler et al., 2015; Uzunov et al., 2015), which supports the long-held belief of many beekeepers that it is best to keep locally adapted bees. As noted in the Methods chapter, and glossary, there are several organisations which promote local bees, on national and international levels. Several interviewees are founding and/or committee members of these organisations. Advice on keeping, and breeding local bees is also promoted by many beekeeping associations. The Welsh Beekeeping Association (WBKA) is very active in providing information to its members about the benefits of locally adapted bees, and advice as to how beekeepers can rely on their own bee breeding activities to increase the number of colonies they manage, rather than importing bees from outside the area (Shaw, 2014). While it is recognised that queen rearing and breeding is often beyond the capacity of many beekeepers, the author emphasises that it is a comparatively straightforward management technique to actively engage with the natural reproductive cycle of a colony: the beekeeper recognises and decides which traits s/he wishes to encourage, and divides those colonies when they are raising their own new queen cells (ibid). If all goes well, the new queen will then emerge, carrying with it the traits the beekeeper is aiming to encourage.

Careful observation of a colony's health and vitality is key, with beekeepers advised to alter the genetic makeup of a colony that is unable to withstand the range of bee diseases which can afflict a colony: '*Susceptibility of bees to virus diseases appears to be determined by genetic factors and the best remedy to date is to requeen affected colonies*.' (BFA Bulletin 166: 4/76). This shift in emphasis from bee breeding for maximum honey yields and associated husbandry, to breeding for bee health and vitality, is increasingly supported by bee scientists, who are carrying out research on those bees which are seemingly immune to the ill effects of varroa (Le Conte, 2007; Seeley et al., 2015). While many beekeepers are now attempting to breed bees which are resistant to varroa and other diseases, for many years, breeding focused on enhancing characteristics such as productivity and behaviours which make bees easier to handle:

> *'it is believed, however, that disposition is inherited from the male parent, and much may be done by trying to have plenty of drones of some pure and gentle race in the apiary and by eliminating as far as possible all queens whose bees are vicious, whether such queens be old or young, or whether their bees are good in other respects or not. (Digges, 1921, p 41)*

Such beekeeping practices have subsequently affected bees at a genetic level (Neumann and Blacquiere, 2017). Decades of importing bees from other countries has led to a fundamental shift in the genetic diversity of honey bees in the UK and Ireland, which manifests in both their phenotype and genotype, with *Apis mellifera mellifera* often referred to as the 'British black bee' or the 'native black bee'. Efforts are growing to support a resurgence of this local strain:

> *I actually bred them back something very much like a native bee from the local hybrid around here. I was breeding for native characteristics. I was trying to re-impose natural selection, so I try to not cross them, or look after them in too close a fashion, so I was allowing nature, or the natural environment to select and guide the phenotype and genotype of bees that came out of my hives. (DP)*

The above quote illustrates an approach to management that is almost a form of benign neglect, as the respondent notes a belief that 'native characteristics' would best flourish with minimal human intervention in natural selection, which he believes had been subsumed through decades of selection for anthropocentrically chosen traits.

Interviewees expressed concerns about importing different strains of bees into areas where there is currently a concerted effort throughout the local beekeeping community to breed for varroa resistance. Such efforts can be easily undermined by importing bees with different genetic characteristics, and levels of varroa resistance:

> *We're worried because a commercial bee supplier on the other side of the town - she's discovered we have these bees, and they are probably varroa-tolerant, but she imports a lot of bees from Greece. She wants to move in our territory, because she's heard we have bees that are varroa-resistant. What happens when she moves all these Italian things in, and they start to cross? See what I mean? (JH)*

The interviewee and his colleagues have been carrying out a breeding programme for years, which is now under threat from personal decisions of others, and economic factors, beyond their control:

> *But it's very difficult when someone says look, I can buy in queens from Greece at £3-4 each, and sell them on at £40. …With your natural way of doing it, with swarming, you're only going to produce a few dozen a year. (JH)*

The above passage addresses debates about how to breed bees that can cope with varroa. The commercial breeder is keen to allow her imported queens to breed with drones which local beekeepers believe to be able to cope with both varroa, and wider environmental conditions. However, there is concern that importing queens from Greece will affect the wider characteristics of bees in the area.

While there is a strong coalition of voices promoting local bees, we see that there are also diverse viewpoints, as individuals strive to enact their environmental knowledge in a changing, unpredictable environment. What becomes clear when investigating these differing perspectives is that the uncertainty of future weather patterns creates confusion and stimulates debates within the beekeeping community as to how best to prepare for, and work within the context of, changing conditions. Some interviewees – particularly some professional bee farmers working in Ireland and West Wales - insist that it would be impossible for them to run their business with bees that couldn't cope with this notably cool, wet climate:

> *As a commercial beekeeper, it's the only bee that makes economic sense. If you want to make a living in the conditions of Ireland and Wales, Scotland, North of*

England, you are only going to get surpluses-reasonable, commercially viable surpluses, consistently, if you use native bees. (EC)

However, other beekeepers / farmers working in different parts of the country come up with different analyses, based on their observational knowledge and study of the behaviour of different subspecies:

I'm not particularly interested in issues of breeding pure, or black bees. The climate is changing. Flora and fauna is changing. To be honest – some of my best bees are lighter. I have no idea where they came from. (CD)

When deciding which strain of bees to keep, and breed from, beekeepers find themselves negotiating a complex and often contradictory epistemological terrain, where their hybrid knowledge may or may not lead them to pursue courses of action which align with scientific advice. While the scientific research suggests that locally bred and evolved bees show many characteristics associated with health and vitality, and ultimately productivity, which are adapted to local conditions (Uzunov et al., 2015), as noted in the preceding quote, the experience of some beekeepers notes rapidly changing environmental conditions, which might favour bees traditionally associated with other regions. It is noteworthy that the opposing views regarding the most suitable subspecies of bee for local conditions come from beekeepers working in very different parts of the country. Modelled predictions of climate change denote varied manifestations in different areas, with some areas experiencing increased rain and wind storms, and others hotter, drier temperatures (Beniston et al., 2007). This variance will affect species differently, resulting in particular microclimates being more or less suitable for different species, and subspecies. Changes in flowering times can potentially complicate the benefits of keeping locally adapted bees. This situation exemplifies a powerful tension between beekeepers' complex, situated local knowledge, and formal scientific understandings of a situation, when they are enacting their hybrid environmental knowledge within a managerial context.

Clearly, controlling the genetic nature of bees is an immense practical challenge, made even more complex as the decision-making surrounding preferred traits is affected by wider conditions, particularly weather and related phenological patterns. The final section of this chapter will briefly discuss the challenges associated with managing bees in response to the weather.

5.6: Managing challenges of weather

This chapter has been focusing on beekeepers' use of their hybrid knowledge when managing their bees, and the role and impact of factors outside of their control. Therefore, it is logical to conclude this chapter with a brief discussion of the crucial factor on bee health and behaviour which is furthest from their control; namely, the weather. As mentioned in discussions of forage and breeding, the fate of bees is powerfully affected by weather. One of the key insights arising from both archival and interview data is the richness of beekeepers' observation and understanding of environmental changes, which often includes strong temporal and spatial specificity. This manifests in relation to weather patterns:

> *I think we are in a situation now where (changing weather patterns) are having an effect (on beekeeping). (BG)*

As the manifestations of climate change become increasingly apparent, it is important to understand how varied species are affected by changing conditions. Climate change is increasingly recognised as a key threat to pollinators (Brown et al., 2016; Gonzalez-Varo et al., 2013; Marshman et al., 2019; Sánchez-Bayo and Wyckhuys, 2019). The practice of beekeeping has always involved a reflective engagement with seasonal variations, resulting in management decisions based on observational knowledge. Increasingly, this requires attempting to manage bees in response to stronger, less predictable fluctuations in weather patterns. As noted in Chapter 4, Section 3, beekeepers are highly aware of weather changes, and how this impacts their bees' forage sources, as well as colony wellbeing and productivity. They are being confronted with significant fluctuations in the landscape in which they practice:

> *Things are getting a lot earlier. Substantially earlier. Crops are coming in much earlier. And invariably, a lot of the crops, especially things like oilseed rape, are flowering much earlier. (BD)*

Due to the significant change in flowering times observed by this long-term beekeeper, he has now drastically changed his practice, in response to these new conditions. After 70 years of personal beekeeping experience, he now carries out certain management practices and activities up to one month earlier than he did in the past. Another interviewee notes a modification in her annual inspections schedule as a result of an increased tendency towards delayed and / or mild autumns:

> *And as far as the business of sort of trends-weather and stuff-well, you can see by looking back at the records, you can see things like the first time you did an inspection, and the last time you did an inspection - you can't say that (the timing of the first inspection) has changed very much. But the last inspection has definitely changed.' (PA)*

Amongst the challenges of a changing climate is bees having a shorter, or no winter broodless periods. This interviewee also noted that, due to weather changes:

> *We are now seeing brood right through into sort of September, October, whereas it used to be the end of August and that was it, really. (PA)*

In the very early days of European exposure to this varroa, the BFA observed that 'Varroa is a big problem in Mediterranean countries, due to continuing brood rearing in winter' (BFA Bulletin 249, 5/88). Colder northern European winters were seen by beekeepers as having a positive role in limiting varroa, as there would be brood-free periods, allowing colonies to be successfully treated for varroa. However, in recent years, such winters are experienced by beekeepers as having become less common, and less reliable. This weather change affects other managerial challenges and subsequent decisions, thus illustrating the complex field realities of applying hybrid knowledge.

A common concern shared by beekeepers and scientists is the challenge of new pests and diseases thriving (or not) as a result of changing climate (Gonzalez-Varo et al., 2013; Keeling et al., 2017). Beekeepers are increasingly concerned about Asian hornets, whose potential to spread throughout the UK may be limited by the comparatively cool climate (Keeling et al., 2017). However, a changing climate may result in an environment in which Asian Hornets can thrive, thus creating an immense challenge to the UK pollinator population (ibid):

> *Global warming is important…global warming is responsible for the Asian hornet (RB)*

Clearly, environmental changes necessitate different management and responses, but there are ultimately challenges beyond their control.

Interviewees note the challenges to bee health from changes in the dates, and severity, of winters:

> *'I think that down in this part of the world at this time, I suggest (problems for bees) are more to do with the weather, rather than scare stories. My bees and honey yields since varroa, shall we say, I think they compare quite favourably. The last few years have changed, but I think that's because of the weather.' (GO)*

Here, the interviewee is noting that he has been able to successfully manage his bees since the arrival of varroa, widely considered the dominant challenge to beekeeping. However, weather changes are creating challenges that he is unable to successfully manage.

Beekeepers are consistently assessing and reflecting on environmental conditions, as part of their decision-making process as to where to site their bees. One of the projected impacts of climate change is an increase in strong winds and storms (Beniston et al., 2007):

> *'Oh yes I would say the climate has a bigger effect than anything. Particularly the winds. We had very strong winds.' (BG)*

Combining this beekeepers' observational knowledge, with scientific assessments of climate models, allows us to generate an enhanced understanding that is akin to other work on incorporating TEK into environmental assessment and subsequent policy (Fazey et al., 2006; Hernández-Morcillo et al., 2013). We see that the weather is clearly a factor which the respondent has no control over, and it is seen as having the primary deleterious effect on his bees. Another interviewee notes that he does not see a lack of forage as being a problem; rather, it is the weather that challenges his bees:

> *'There should never be a problem with access to nectar, if the weather allows it, really.' (GO)*

This raises challenging questions about current efforts to improve the environment for pollinators. At the moment, much of the emphasis is on planting and ensuring a range of forage, as well as disease and pest management (DEFRA, 2014; Scott et al, 2013; Welsh Government, 2013). However, a growing number of beekeepers are noting the effect of changing weather, which is a powerful factor on their practice, and generally outside of their control:

(Weather changes) are definitely affecting the pollen and nectar that those pollinators need to live. There is no doubt about that. (AS)

There is often little that beekeepers can actually do to manage their bees in response to changes in weather patterns. Some have adjusted their annual beekeeping management strategy to try and ensure their colonies are larger and ready to maximise the earlier honey flow. Others are being forced to incorporate the increasingly common lack of a winter brood-free period into their decisions about varroa management. However, changing weather is bringing many challenges which are, at times, overwhelming, for even the most skilled and committed of beekeepers:

– because we have milder winters, you only have a small number of bees to over-winter. If they are out and about too much, they can, if you are not careful, eat all their stores. Also – nosema impacts in winter. Spring can see bees have bad nosema. Also – we get very changeable weather in winter. (VF)

The respondent is being confronted with a range of wider related managerial challenges, which are ultimately resulting from weather changes. Understanding both individual and community responses to weather patterns, and significant events, can elucidate conceptualisations of weather, and inform efforts to communicate the potential effects of climate change (Hulme et al., 2009; Jones et al., 2012). The benefits of engaging with a broad range of data, such as personal weather records, is noted as having potential to enhance our understanding of phenological patterns and the possible impact of climate change (Primack and Miller-Rushing, 2012). And, in the context of understanding how beekeepers use their environmental knowledge when managing their bees, we see how the weather acts as a challenge in and of itself, and also as a threat multiplier, increasing the negative effects of other environmental challenges.

5.7: Conclusion

This chapter has illustrated a range of challenges that beekeepers face:

Now, with varroa, loss of forage, agrochemicals – and new threats – Asian hornet, (beekeepers) are not an optimistic bunch. (MS)

Many talked about the increasing difficulties of the practice:

Because we have got more problems now than when we started. I think beekeeping is more difficult now, than it used to be. (PA)

As we have seen in this chapter, beekeepers' capacity to enact their environmental knowledge within their practice is constantly being challenged. The physical environment is in a state of perpetual flux: weather patterns are changing, forage sources are limited or experiencing phenological shifts, agrochemicals are difficult to avoid, and new pests and pathogens are emerging. The landscape and land use patterns in which they must site their bees are often problematic, or islands of safety in unpredictable wider food systems. Attempts to 'breed a better bee' that can cope with these multiple factors is hindered by the synergistic nature of multiple challenges, and the inherently wild nature, and breeding habits, of the bee. Thus, they are constantly having to negotiate multiple elements, many of which are outside of their control. This chapter has shown how beekeepers are constantly using and reflecting on their environmental knowledge to make management decisions about their bees. Their knowledge incorporates observations of environmental and land management factors which are relevant to other species. If we are to consider how beekeepers' knowledge can be utilised to support environmental sustainability, and, in particular, redress pollinator decline, it is important to investigate tensions between what beekeepers observe as supportive or detrimental to bees and the wider environment, and their capacity to act, due to both the environmental factors, and wider socio-economic and/or political factors. Tensions, as well as disparate perspectives and values also exist within the beekeeping community, which can present further challenges to communicating their experiential knowledge.

These tensions can be interpreted within the wider challenges to acknowledgement, and effective use of TEK as a management system. TEK systems are noted for their capacity to monitor and manage ecological resilience; this is often done through a range of social mechanisms, including social regulation, and appropriate world views and cultural values (Berkes et al., 2000). Contemporary TEK systems are commonly challenged by wider economic systems, which emphasise a market economy above a systemic engagement with the environment (Hernández-Morcillo et al., 2013). Such pressures are threatening the existence of TEK, and its capacity as a form of adaptive management.

The next, and final empirical chapter will investigate current efforts to reverse pollinator decline. It will explore beekeepers' capacity to communicate their environmental knowledge to other stakeholders in a way that brings about positive environmental changes. In particular, it will explore how they believe their knowledge has been used and understood by scientists, policy-makers and the general public, as well as barriers to constructive engagement with their knowledge.

Chapter 6: How do beekeepers view, and engage with, wider efforts to improve the environment for pollinators?

> *We know enough of our own history by now to be aware that people exploit what they have merely concluded to be of value, but they defend what they love. To defend what we love we need a particularizing language, for we love what we particularly know. (Berry, 2001, p 42)*

6.1: Introduction

The previous chapter focused on how long-term beekeepers use their observational and experiential knowledge in their practice. In particular, it explored their attempts to manage the challenges faced by their bees, in the context of their personal beekeeping practice. The challenges experienced when aiming to manage risk in a fluid and unpredictable physical environment often led to a recognition that there are many relevant factors which are outside their locus of individual, immediate control. This chapter will now focus on how beekeepers work to use and share their unique environmental knowledge in their efforts to improve the wider environment in which their bees live. This often entails communicating their knowledge and concerns to other key stakeholders in pollinator wellbeing: scientists, policy-makers, and the wider public. While the previous chapter discussed the personal and civil society management responses of beekeepers, this chapter will focus on both individual and civil society organisations' pro-active role in both communicating their knowledge and concerns, and working to bring about changes on behalf of bees and other pollinators. I will also be examining the challenges they perceive in their efforts to have their observations and concerns vindicated and utilised in these communications. However, due to the rapidly changing fora of communication and presentation of information – of all levels of accuracy – I will also explore beekeepers' views on the changing nature of public and media understandings of bees and pollinators.

Like many other contemporary environmental challenges, pollinator decline is a by-product of anthropogenic factors (Kevan, 1999; Marshman et al., 2019; Naug, 2009). As such, any attempt to reverse this decline requires investigating the role of human actions and decisions, as their central role in shaping the natural environment is noted in studies of the Anthropocene (Folke, 2006), Political Ecology (Robbins, 2012), and Conservation Biology (Mathevet et al., 2018) – all of which are relevant to the issue of contemporary pollinator decline. Economic and political decisions impact the physical environment (Forsyth, 2002; Robbins, 2012; Rocheleau, 2008). As well as humans being - to varying degrees - the cause of some, if not all, of the challenges bees and other pollinators now face (Neumann and Blacquiere, 2017), the policy response to their decline explicitly ascribes responsibility to diverse actors to monitor and improve the situation (All-Ireland Pollinator Plan, 2015; DEFRA, 2014; Scott et al, 2013; Welsh Government, 2013). Scientists are tasked with researching the role of diseases, environmental nutrition, and synergistic impacts of multifarious factors. Policymakers are responsible for drafting appropriate governance responses. The general public, on an individual personal and wider social media and/or a campaigning level, react in differing ways to the crisis we face; these disparate responses also take on a wider relevance at a cumulative level. These groups are not mutually exclusive, and members of each may have different impacts according to the particular roles associated with each group (Eden and Bear, 2012; Eden and Bear, 2011a). While individuals may move between different categories of 'environmental publics' (Eden, 2016), there are relevant common themes that beekeepers express when discussing these groups; these will be the subject of this chapter. As much of the policy response, and attempts to engage the public, are driven by scientific data – albeit with a disturbing tendency to misinterpret this data (Dicks, 2013; Gustafsson, 2017; Likens, 2010) – it is appropriate to begin this chapter with a discussion of beekeepers' working relationships with scientists. Data for this thesis reveals a long and changing pattern of communication, which will be explored chronologically.

6.2: Beekeepers and Scientists

6.2a: Historical Communication, Co-operation and Conflict

Both archival and interview data illustrate a history of diverse communications between beekeepers and professional scientists. As discussed in Chapter 5, Section 3, the impact of pesticides, insecticides, and fungicides has long been a subject of shared concern for beekeepers and scientists. Early editions of the BFA bulletin document the historical working relationship between professional bee farmers and the scientific community, as beekeepers witnessed first-hand the devastating impact of the early agrochemicals, and dutifully collected samples of dead and injured bees, which were then sent to government laboratories for scientific analysis.

From the very outset of the Honey Producers Association (HPA) (which subsequently became the Bee Farmers Association), prominent voices in the bee farming community, such as Hillyard and Manley, expressed profound concern over the impact of agrochemicals. It is important to note that these men understood the appeal of these modern developments in agricultural management. Many came from farming backgrounds themselves, and understood the financial and professional pressures generated by struggling to cope with weeds and pests. As a result of their intimate engagement with managed insects and the wider environment, bee farmers were uniquely placed to monitor and report the wider negative effects of such chemicals. The HPA /BFA Bulletin provided an excellent avenue for encouraging bee farmers to report any concerns to scientific researchers, and appropriate government bodies. Readers were regularly reminded of correct sampling procedures, as recommended by researchers at the UK's Rothamsted Institute. Dr Colin Butler, head of Rothamsted's entomology department and one of the world's most noted researchers on bees, was in regular contact with the HPA (BFA Bulletin 41, 8/58). Bee farmers who suspected that their bees had been harmed by chemical exposure were encouraged to collect 200 bees - approximately a cigarette box worth and send it in for analysis (BFA Bulletin 150, 9/73). During this time, bee farmers were regularly providing data and evidence to scientists, along with their wider knowledge and observations of what chemicals they believed their bees had been exposed to. Dr. Butler also kept beekeepers informed of scientific developments and discoveries regarding toxicity of agrochemicals, and legislative developments resultant from new scientific understandings of the impact of agrochemicals.

The BFA Bulletins of this period document clear and regular communications between bee farmers and scientists, as they worked together to address environmental threats to bees. It is important to note that this dialogue was occurring within a wider international, intellectual context of debate and concern about agrochemicals. Rachel Carson's *Silent Spring* was published in 1962. This seminal text was associated with growing concerns about chemicals impacting the environment, as well as humans. It was reviewed in BFA Bulletin 109 (11/67), reflecting the relevance of the book's topic to HPA / BFA members. Beekeepers' concerns, and their communication with the scientific community, were recurrent themes throughout the archives. In BFA Bulletin 4, (10 / 1953), a writer commented on attending a symposium on organophosphates (OPs – a common type of early pesticides), and expressed concern that 'scientists showed a most reckless attitude to the effect of these dangerous substances to man and animal'. Beekeepers then and now supported following the precautionary principle towards chemicals in the environment, rather than an approach which encourages and allows their use, unless and until they are scientifically proven to be hazardous (Sponsler et al., 2019; Suryanarayanan, 2016). In the early post-war period, when the transition to chemically assisted agriculture was first beginning, beekeepers were deeply concerned, and urging restraint and investigation of the effects of these various pesticides and herbicides. This illustrates an early manifestation of a tension that exists to this day (Suryanarayanan, 2013), with beekeepers often expressing a cautious scepticism about the safety of agrochemicals, while perceiving policy-makers', and regulatory bodies' insistence on definitive scientific evidence of environmental harm as an inappropriate method of managing and responding to the potential risks of chemicals to bees. Successful beekeepers have always needed a high level of scientific knowledge about a broad range of factors, including the many agrochemicals their bees may encounter. In BFA Bulletin 40 (6/58), members were encouraged to educate themselves about the use and impact of various sprays, so they can have an 'informed discussion with farmers when placing hives on their land'. This evidences beekeepers' role in communicating scientific knowledge to relevant stakeholders in bee and pollinator health. Beekeepers often served an intermediary communication role, between scientists and farmers. This position offered a potential opportunity to bring about positive changes in the environment.

Aside from providing data and samples, there were other avenues for scientists to constructively engage with the observational insights of beekeepers in the earlier days of the HPA / BFA. BFA Bulletin 57 (9/60), documents a Research Study group on toxic agrochemicals contacting the HPA, to enquire if they would like to suggest any particular research topic. Suggestions from two of the UK's largest honey producers included the potential to develop repellants which would stop bees from foraging on plants which had been treated with toxic agrochemicals. BFA Bulletin 68 (1/62) informs readers of the government's publication of *A Report of the Research Study Group on Toxic Chemicals in Agriculture*. The HPA were one of 28 organisations that contributed to the report. A 60 page booklet on the topic was published, and made available to HPA members. Although this report on agricultural chemicals seemed a positive step in raising awareness of these issues in the wider farming community, poisoning of bees continued, with bulletins in the coming years still exhorting bee farmers to send suspected victims of poisoning to Rothamsted for investigation.

The HPA/BFA bulletins provide historical documentation of the transitions in licensing and usage of various agrochemicals, as scientific confirmation of hazards caught up with the observational concerns of bee farmers. A process of testing dead bee samples for chemical residues, and then testing the suspected agent for toxicity, would be followed. If samples contained a scientifically determined toxic level of a particular substance, that data would then be used as a basis for controls on the particular substance. BFA Bulletin 54 (3/60) notes the Ministry for Agriculture, Fisheries and Foods (MAFF) taking a series of steps to deal with 'poison spray': these include a range of research projects at Rothamsted to investigate both the impact of closing hives to prevent bees' exposure, and a study group of scientists set up to look at the long term impact of sprays on wildlife, including bees. Appendix II lists and categorises sprays according to their recognised toxicity at the time, and their impacts on bees, with Group 1 including those considered most toxic to bees. Chemicals in this category included many which have subsequently been fully banned due to the subsequent discovery of their carcinogenic properties. Fungicides were listed as non-toxic to bees, with possible exceptions of mercury compounds. Recent research notes sub-lethal and synergistic risks from fungicides which belie their classification as non-toxic, or benign. (Manning et al., 2018; Simon-Delso et al., 2018). It is interesting to note the gradual shifts in understanding, and attitudes, regarding these chemicals, several of which are now being phased out globally. The historical perspective gained by engaging with the qualitative and quantitative date of beekeepers shows a common trend for their observations and concerns to precede formal confirmation by scientists, which is generally required as the basis for any governance response. BFA bulletins (108: 10/67; 144: 12/72) consistently denote bee farmers' frustration at the inherent procedural delays in getting their observations confirmed, and acted upon.

Research on pollinators has changed since the mid-late 20th century, and this has altered the working relationship between beekeepers and scientists. Due to the length of practice of some interviewees, this thesis is able to present a deep historical perspective on communication, and working relationships between beekeepers and scientists. One interviewee started working as an apiary assistant at Rothamsted in the 1940s, when he was 14 years old. He describes one of the strengths of the institutes' research as being the longevity of working relationships between the scientists and the apiary assistants, whose observational, practical knowledge directly fed into the formal research. This is also suggested by the BFA bulletins advising members to send in observations, samples, and concerns to Rothamsted. The interviewee described the mid-20th century as the 'golden age of bee research', with staff and funding at Rothamsted Research Institute comparatively higher than today. Adding to the current pressures of limited research funding, the contemporary challenges to pollinator health are more complex, with less clear-cut singular causes of the success or failure of a colony, and, instead, the interactions of a range of drivers for pollinator decline. This has affected the communication and relationships between the two groups, as the data beekeepers provide, and their concerns about the environmental challenges bees and other pollinators encounter, do not necessarily fit the dominant research model based in objectivist epistemologies (Curry and Kirwan, 2014; Hegger et al., 2012). As beekeepers are driven by immediate concerns about improving the environment on behalf of pollinators, they are often frustrated with the requirements for proof to be generated according to standardised entomological methods. This will be discussed in the next section, which will explore how beekeepers interviewed for this project view contemporary research, and their potential for involvement and communication with scientists.

6.2b: Contemporary Pollinator Decline, Beekeepers and Scientists: Current Complexities

A key focus of interviews was beekeepers' perspectives on current scientific research into bees and pollinators, and how their hybrid environmental knowledge is utilised by those investigating pollinator decline. Interviewees were asked about their views on, and involvement with, scientific research on bees and pollinators. Frequently, respondents had a high level of engagement with research projects. At the regional and national beekeeping conferences held throughout the UK each year, scientific researchers are often key speakers. In one of his talks at the National Honey Show 2017, noted U.S. entomologist Dr Jamie Ellis commented on the high level of scientific literacy and engagement amongst UK beekeepers, and the distinctly cognisant quality of UK beekeepers' questions at such events.

The highly informed nature of beekeepers has made them acutely aware of new threats to bees and pollinators, coupled with increasing challenges to epistemological parity in their communication with researchers. As time has passed and agrochemicals have changed, it is widely accepted that the extreme toxicity and resultant high mortality of earlier chemicals is a thing of the past; however, as noted in preceding chapters, the challenge today is to address the sub-lethal and/or synergistic effects of modern agro-chemicals (Gibbons et al., 2015; van der Sluijs et al., 2013). Numerous interviewees expressed concern about 'cocktail effects' – both between multiple agrochemicals, and between chemicals and other factors, such as weather and general nutrition:

> *Everyone is concerned. Not only chemicals interacting amongst themselves, but interacting with other stressors. Putting another stress on the bees, whether it's disease or... And then you might have a relatively poor summer, weather-wise. And you might have other problems. And, you know, you just wonder about the impact. (EC)*

This experiential concern is mirrored by researchers on pollinator health (Goulson et al., 2015). However, for both the scientists and beekeepers who are concerned about these complex synergistic interactions, the challenge today lies at the heart of the scientific and regulatory frameworks which includes all these stakeholders. The historical working relationships between beekeepers and scientists were based on comparatively straightforward research into singular effects. Modern environmental challenges to pollinators are deeply intertwined, and difficult to assess according to standard epidemiological procedures. The evolving complexity in assessing agrochemical impacts is exemplified by the current neonicotinoids debate. Beekeepers' observations on the situation were described in Chapter 5, Section 3. The lack of definitive results regarding toxicity and honey bees has been widely discussed in both the media and in scientific literature (Blacquière and van der Steen, 2017; Gross, 2014; Woodcock et al 2017.) While there has been extensive investigation to deduce the effect of neonics on bees, there is still a great deal of confusion, with contradictory perspectives on their impact on honey bees, bumblebees, and the wider environment (Gibbons et al., 2015; Suryanarayanan, 2013; van der Sluijs et al., 2013). While many beekeepers, particularly in America, have expressed a suspicion that neonics are associated with the dramatic declines of colonies in recent years, their concerns preceded scientific confirmation - although formal evidence of the negative effect of neonics on bees is accumulating (Sanchez-Bayo et al., 2016; Vanegas, 2017) This epistemological tension has been addressed by Suryanarayanan & Kleinman (2013 a, b) who see the fundamental difference in assessment methods used by beekeepers, scientists and policy-makers as central to the difficulties in ascribing causality to neonicotinoids for recent bee deaths, due to the multifactorial impacts on the physical realm of pollinators' lives. While beekeepers assess bee health using comparatively holistic and informal measures, which are difficult to quantify, scientists have formal monitoring criteria and systems, which can be statistically analysed (ibid). The authors note that current research models ascribe epistemic dominance to the results and analysis generated by scientific researchers. If a knowledge claim is not generated through this process, and does not meet these guidelines, it is not considered as knowledge, and therefore does not carry the same social, and ultimately political, significance (ibid). 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, particularly the lethal levels of exposure for most species. This model of knowledge generation has been prioritised above that of others, whose expertise is not validated or recognised within this model. And, this model does not currently have the capacity to accurately reflect synchronous challenges to pollinator health. It is worth noting that the change in challenges to pollinator wellbeing is generating an increased scientific research interest in 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). However, 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. They are living organisms. 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. (PA)*

There is also a concern amongst some of the more experienced beekeepers (for example, those who have kept bees over 30 years) that the emphasis on formal scientific understanding can be utilised to support a particular interpretation of causality, which closes down inquiry into other possible explanations of a situation. Singular assessments of toxicity and causality can lead to pronunciations on bees' health and welfare which limit alternative explanations that are considered by beekeepers to be as relevant, if not more:

Because all they need to do is find a couple of varroa, and the National Bee Unit (NBU) say that (death was) because of varroa. Now lots of people have a little bit of varroa, and it's not that much of a problem. And when the bees die from pesticides, it's totally different. (The NBU) say it's too expensive to do an examination… But all of a sudden to find 2 or 3 inches of dead bees outside your hives… (If it's pesticides) you've got bees being defensive on the landing board, they are pushing bees away, saying don't come in here, you are infected, or you are poisoned. And you see the bees crawling on the ground, with their tongues out - unlike the symptoms of varroa. But these people in York (NBU) just don't listen. (DC)

Here we see the beekeeper carrying out observational analyses of the behaviour of the colony which imply that pesticide exposure are the cause of death. However, due to the NBU's finding varroa, the possibility that there was another reason for the colony's decline – eg, agrochemical poisoning – is not considered.

Historical communications between beekeepers and scientists present a paradox which still effects contemporary efforts to understand, and reverse, pollinator decline. We have seen how beekeepers' observations and concerns often preceded validation from the scientific community. Beekeepers may observe what they recognise as definite signs of chemical poisoning in their bees. This observation is based on both their personal experience, as well as information shared via beekeeping networks. At times, it may also be a result of training and education they have undertaken. However, their observations are ultimately seen as subservient to scientific confirmation. Proving causality is challenging in any chemical analysis for toxicity (Maxim and van der Sluijs, 2007; Suryanarayanan and Kleinman, 2013); it has become significantly more challenging in recent years, as a wider range of substances are found in the environment. Tests can be prohibitively expensive, and they are usually unable to detect complex synergistic effects.

The structure of scientific research and validation grants epistemological superiority to particular forms of expertise (Suryanarayanan and Kleinman, 2013). Beekeepers' observations suffer a similar fate to that of many TEK holders, whose environmental knowledge struggles to gain a parallel status in contemporary scientific investigations, and subsequent policy decisions (Nadasdy, 1999; 2005):

Normally the scientists don't take any notice of what they call anecdotal evidence at all. (RP)

There are wider factors influencing bees, above and beyond standard epidemiological issues (BFA Bulletin 293: 2/95). Bee farmers discussed management factors that might promote disease, including rough handling, persistent interference (ie, intensive swarm control); unnatural methods of rearing queens, such as dividing colonies that aren't ready to be divided, and more. They observed that many diseases (except perhaps American Foul Brood) are present in every colony all the time, yet bees did not necessarily succumb to them. This documents a debate which continues today; namely, what is the relationship between disease, and other cumulative factors, on bee health? Understanding the multifactorial influences on bees is a challenge for beekeepers, and perhaps even more of a challenge for scientists studying bees, as the scientific model is based on investigating singular, or limited, numbers of factors (Kleinman and Suryanarayanan, 2012; Suryanarayanan, 2013). It is important to note that there are developments in the bee research agenda which are working to promote an understanding, and a management approach which more accurately models the natural life cycle of bees, rather than imposing a particular series of actions which benefit the beekeeper, or researcher (Blacquière and Panziera, 2018; Neumann and Blacquiere, 2017; Seeley, 2017). This shift in epidemiological perspective correlates with beekeepers' holistic understanding of bee health and the synergistic challenges faced outside of the controlled environment of the laboratory.

The complex relationship between 'professional' scientists, and amateurs, is found in other disciplines, including biodiversity monitoring (Ellis and Waterton, 2016), and meteorology, where weather and climate data are collected by amateur meteorologists (Endfield and Morris, 2012a; Morris and Endfield, 2012). There is growing awareness of the existence, and research potential, of highly informed, capable 'amateurs' in collecting important environmental information, both as a methods of data collection, and of both stimulating and sustaining wider environmental awareness (Eden and Bear, 2012; Kinchy et al., 2014). Conversely, the experiential, embodied component of environmental surveys is recognised as playing an important role in scientific research (Lorimer, 2008). The discrepancy between field studies and lab experiments is noted as a key factor challenging modern conservation studies, as the methods to understand multiple, interdependent factors require an analytical fluidity, and often a multisensory, emotional engagement which is generally absent from controlled experiments (ibid). Lorimer explores the multi-sensory, indefinite nature of field science – in this instance, corncrake surveys - which is complex and indeterminate in a way that is fundamentally different from lab science. Although census methods are developed which aim to be 'practical, rigorous and standardised', the reality of actually carrying out the census requires a heightened sensory engagement with the surrounding landscape, and embodied skill (ibid). Such an approach is closer to the practice of beekeeping, than the laboratory analysis of possible effects of agrochemicals or parasites. We see here an underlying tension in the efforts to practice, and use, science in a way to reverse threats to pollinators. Current models emphasise rigour, precision, standardisation and objectivity. In contrast, pollinator decline is taking place in a countryside that must be understood with embodied knowledge (Carolan, 2008a), where 'mind is body, consciousness is corporeal, and thinking is sensuous'. The embodied nature of knowledge is recognised as a potentially valuable component of understanding environmental challenges and complexities (Brace and Geoghegan, 2010), but current scientific studies on challenges to bees and other pollinators prioritise knowledge generated through other means (Suryanarayanan, 2013). This creates a fundamental challenge for their knowledge to be recognised and fully utilised in efforts to reverse pollinator decline.

As described in Chapter 1, beekeepers generate, and use, a distinctly hybrid environmental knowledge in their practice, and often engage with science, and scientists. In the current context of pollinator decline, there would seem to be an urgent need to share knowledge to reverse this situation. While most interviewees were intellectually interested in much of the pollinator research carried out, they expressed diverse perspectives on the wider relevance in terms of practical beekeeping, and the key issue of reversing pollinator decline. Some were very positive:

> *Some of it I would take on board straight away. Some I would think about a bit more. But yes all of it I think is directly relevant in different ways, and I follow as much as I possibly can get hold of. It's all out there, and it all moves us one little small step forward in understanding the little devils! (KH)*

However, when considering the current challenges to bees and pollinators, and the question of beekeepers working with scientists to overcome these challenges, others were more sceptical of the immediate, practical relevance of scientific research to beekeepers:

> *To be quite honest, I don't think that many beekeepers are (impressed by the scientific research) nowadays. No help seems to be forthcoming at all. (DC)*

Within the context of their recognition of multiple factors affecting bees, interviewees questioned the methods used for many research projects, and suggested that some beekeepers' style of beekeeping may influence their results, in ways which could not be registered within the controlled framework of the experiment:

> *D wonders whether the reason that C's honey hit the jackpot was slightly different than just saying he's got a different pollen in it. Because they are Warre hives. So he would take off the honey at a different time. So it would have a higher proportion of pollen and propolis. (CSH)*

This illustrates beekeepers' belief in the potential for differences in beekeeping practice to have influenced the result of a scientific investigation into pollen content in honey. However, the structure of the research project did not provide any opportunity for participants to communicate their perspectives on factors they deemed relevant to the results. This correlates with research into coproduction of knowledge, where the engagement of participants from the very beginning of research project design is deemed as crucial to the success, relevance, and acceptance of results by a wider audience (Edelenbos et al., 2011; Hegger et al., 2012).

For the purposes of this research, it can be beneficial to investigate what relationships between beekeepers and the scientific community have been viewed as mutually beneficial, and which exhibit traits which could be improved. There are also differences in views between those engaged in beekeeping on a professional level, often providing pollination services in the agri-environment, who may have a different perspective than those who carry out beekeeping as a hobby, driven primarily by personal interest in bees. As the criteria for interviewees being included in this project was their having been practicing for a minimum of 20 years, with an average of 40, and a maximum of over 70, they were able to provide a temporally rich perspective on what changes they had seen in the research agenda and practice. Several interviewees based their reservations concerning research results on the temporal element of experiments. They commented on the time pressures and limitations of research, and any field studies carried out:

> *A research project and research funds are time limited. The job has to be done, so there's less opportunity. We used to have Rothamsted and the National bee unit, there was research done in those days, but now there is no continuity to it. (KB)*

This theme was also elucidated at various events which were part of the participant observation data collection for this project. One presentation was given by a researcher who led a project on neonicotinoid impacts on field-level trials. This project received a high level of public and media attention upon publication of its results, as it was presented as being one of the first major studies to investigate field-level, 'real-world' levels of exposure to neonicotinoids and other environmental factors. Several experienced beekeepers in the audience noted what they perceived to be serious weaknesses in the design and implementation of the project, as they did not reflect many key aspects of actual beekeeping practice. This led to a scepticism to accept the broader implications of the research. There was also frustration that their observations on research design shortcomings appeared to be disregarded, leaving them with a sense that communication between scientists and practical beekeepers did not provide an opportunity for mutual epistemological respect.

A key critique of scientific research voiced by interviewees was the scale of experiments. As much of the current concern about bees is driven by their role as pollinators in the food system, the applicability of research to real world pollination was a key issue for some interviewees. The level of commercial pollination in the UK is comparatively small when compared to the US and other countries. However, it is still a key part of the UK agro-economy. Some bee farmers carry out contract pollination, mostly in the southern counties of Kent and Sussex, and the western counties of Hereford and Somerset. The individual bee farmers who carry out commercial pollination have hundreds, and sometimes thousands of 'hive years' of experience. Due to their professional experience, these individuals are highly knowledgeable about the hive density required for successful pollination of a wide variety of crops, as well as the potential impact of other factors such as weather variations. They discuss field studies on pollination rates which are carried out with numbers of hives per acre which are far lower than would be used in a practical pollination context.

But I'm certainly frustrated with what trials they were doing on bees. You know, they had some honey bees in a cage. And the trees they were using were in pots. You know, it's just - they were never even getting a proper flowering tree. I know you can't net off an acre of orchard. The cost would be phenomenal. But the tests they were doing were just so ridiculous, if you know what I mean. And they were trying to analyse this and analyse that. And it's just ridiculous, what they were trying to do so I think an awful lot of research money is being wasted in that respect. (AH)

This disconnect in the very basic level of project design leads to a fundamental wider scepticism about any results from an experiment which these key stakeholders see as inherently flawed. Interviewees report having frequently volunteered to participate in trials at both a design and/or data collection level, and often failing to be included, or even informed, of relevant experiments which they could have potentially supported:

Um, again, I've come away a bit disappointed really on those sort of things. They are aware of us, because we have spoken to them. We have been invited to various things. But I have since learned that there have been trials going on, doing various things, but we have not been asked to be involved in that at all. And I don't know why. (AH)

This disconnect between much current research, and the experience of beekeepers, is addressed and acknowledged by some scientists working on bees. The University of Sussex Laboratory of Apiculture and Social Insects carries out a wide range of research, clearly delineating different categories: "The applied research is aimed at helping the honey bee and beekeepers, whilst the basic research studies how insect societies function" (University of Sussex, 2019). Similarly, a key member of the WBKA tasks himself with reading current research on honey bees, and synthesising updates of that which is of practical benefit to local beekeepers; he estimates that this is, at most, 15% of the research which is carried out (personal communication). Considering how much funding has been directed to honey bee research in recent years, driven by a research agenda apparently responding to pollinator decline, this disconnect between scientific research concerns, and the experiential observations of beekeepers, raises important questions. Within the research agenda's current drive for impact, if the existing experimental model of information generation is failing to significantly contribute to a reversal of pollinator decline, there is a strong case to be made for a fundamental reappraisal of research design, and priorities.

As the decline in pollinators and other species shows no signs of abating (Ceballos et al., 2017; Hallmann et al., 2017; Marshman et al., 2019; Sánchez-Bayo and Wyckhuys, 2019), beekeepers and scientists continue to search for solutions, both within and across their communities. Several interviewees described constructive experiences of working with scientists. The defining characteristics of such positive examples are worth exploring in depth, and contrasting to other experiences which may be less beneficial.

6.2c: Beekeepers as Citizen Scientists

Earlier working relationships between beekeepers and scientists conformed to a model which is now common and standardised in many CS research projects, with relatively straightforward raw data being collated by volunteers, who then submit it to formal scientists for analysis (Bonney et al., 2009). CS has been championed as a way of widening participation, increasing data collection and evidence gathering on a larger scale than may otherwise be available, and, perhaps most significantly when analysing the constructive use of beekeepers' knowledge in pollinator conservation, as a way of educating the public and increasing scientific literacy (Aceves-Bueno et al., 2015; Birkin and Goulson, 2015; Cohn, 2008). There are several weaknesses of such a model, not least of which is an assumption that participants have a low level of scientific literacy from the outset (Shirk et al., 2012; Thomas et al., 2017). A continued utilisation of beekeepers' knowledge in such a way risks repeating this structurally limited approach to CS and participants' potential contribution, thus failing to maximise the potential benefits of engaging deeply with the knowledge of long-term beekeepers. As described in Chapter 3, Section 7, many interviewees evidenced a high level of scientific knowledge and analytical abilities. They often ran their own research projects, studying distances travelled by drones, the relative efficacy of varroa treatments, and the impacts of weather on honey production. One had done this as part of an academic research project, investigating links between weather patterns and honey yields. Another had earned an MSc in melissopalynology, and now teaches this to other interested beekeepers. Beekeepers also collect a broad range of phenological data which relates directly or indirectly to their bees' health and productivity. If we are to consider how beekeepers' environmental knowledge can play a more significant role in EBPM, as a valid form of evidence, their academic training, and STEMM knowledge is significant.

Beekeepers interviewed for this project describe an often complex relationship with formal scientific investigation. While most respondents expressed, as a minimum, an interest in scientific studies, and often also had varied levels of engagement with them, there was a recurrent theme of frustration and measured enthusiasm. This was exemplified in discussions regarding participation in research projects. Many interviewees had taken part in scientific research. These included various Citizen Science projects where beekeepers' participation primarily consisted of their supplying samples of bees and / or honey for analysis. Examples include CSI pollen, which was discussed in the investigation of Citizen Science in Chapter 2, and projects coordinated by the National Gardens of Wales, where honey was surveyed for pollen contents (de Vere et al, 2017). While interviewees were initially happy to participate, several commented on a lack of follow-up, which they found frustrating. They described sending in samples of pollen or honey and receiving limited responses from project investigators. Some stated that they were disinclined to participate in further Citizen Science projects on bees, due to this lack of feedback and response. This, coupled with a sense of disconnect from beekeepers' practice, combined to create a sense of tension and disconnect between beekeepers and current research:

> *There was very little feedback, which is probably why I lost interest. …I mean, it was sort of web reported. Every time you put in a set of data there was a thank you that came back but that was it. There was no such report on what was going on, or conclusions on the overall data. I think they recognised that they were having difficulty in that area. It wasn't helpful for people on the ground, I think. (BS)*

The relationship between amateurs and professional scientists is a growing field of inquiry, as Citizen Science is increasingly seen as both an inexpensive data source, and a way of engaging wider publics (Bonney et al., 2009; Donnelly et al., 2014). As CS projects have grown in frequency and scale, further questions have arisen regarding the roles played by academic project designers, and the 'amateurs' who provide much of the grounded data for analysis (Ellis and Waterton, 2004; 2016;). In a similar vein, beekeepers interviewed for this research project describe diverse and occasionally problematic relationships with scientific researchers. The question of 'ownership' of data is particularly problematic for those interviewees who have been carrying out independent research projects and then seek to communicate their findings to professional scientists:

> *Now when the paper was first published, we took exception to it, because it did not include us. And when I asked to be included in it, I was told that I couldn't be included in it because I wasn't a scientist. (EE)*

Such experiences are exemplary of the power relations between practitioners / citizens, and scientists, which are critiqued by those who propose a more cooperative style of research model (Edelenbos et al., 2011; McQuillan, 2014). This is indicative of wider challenges to coproduction of knowledge, and suggests that much of the research work with beekeepers adheres to the dynamics found in early models of CS, where the divide between academic researchers and others is maintained with rigid boundaries between the groups, thus limiting the potential for projects to be enhanced with diverse forms of knowledge (Aceves-Bueno et al., 2015; Edelenbos et al., 2011).

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. It also illustrates important steps towards coproduction of environmental knowledge, and the processes involved in developing Multiple Evidence Bases (Tengo et al., 2014).

One of the critiques and concerns regarding using CS for environmental management is the potential for errors (Riesch and Potter, 2014). However, wider assessments of the rich potential of CS (Jue and Daniels, 2015; van der Wal et al., 2015), coupled with the distinct richness of beekeepers' scientific and environmental capacity, support a stronger engagement with their observational knowledge. Similarly, CS projects based on systems of rudimentary data gathering fundamentally impact the way research questions are framed, and understood. Turner (2003) notes the role of choices of data collection methods in structuring research questions, and subsequent resultant data. If we rely on beekeepers primarily to supply singular quantitative data, such as bee samples, pollen and honey, this reinforces a particular model of understanding bee health and the environment, within a distinct scientific paradigm. This model, by its very design, leaves out locally specific experiential knowledge, and beekeepers' critical appraisal of social, economic and political factors that beekeepers may note as relevant (Lehébel-Péron et al., 2016), as has also been found in analyses of the TEK of hunters (Nadasdy, 1999) and fishers (de Magalhães et al., 2012). The entomological model is often at odds with the environment as understood and experienced by beekeepers, and leaves little room for engaging with the synergistic factors they often describe as central to bee health. The very methods used for generating environmental knowledge are in themselves political; this has been noted in discussions of RS and GIS, which can reinforce early forms of scientific enquiry and causal reasoning that have been critiqued by both physical and social scientists (Turner, 2003). While views of 'above' and 'below' can be successfully integrated, this is far from assured, and can be epistemologically problematic (ibid). Efforts to incorporate TEK into wider environmental understanding, and subsequent environmental governance, are frequently challenged due to epistemological inequalities, and a technocratic preference for scientific data as the basis for decision-making (Cruikshank, 2012; Nadasdy, 1999; 2005). Several of the Participant Observation experiences of this thesis included attending lectures on cutting edge developments on genetically analysing pollen. While this highly scientific method was lauded by the researchers as superior to beekeepers' observations, due to its scientific accuracy and specificity, the researchers went on to note that results of preferred forage were remarkably similar to that listed in 'the Bible' of British beekeepers, *Plants For Beekeeping* (Howes, 1945). Similarly, interviewees noted occasions where honey samples analysed with such technology confirmed what they knew:

> *But mainly it bore out what I already knew – blackberry blossom and clover were the main contributors to the honey around here. (BH)*
>
> *someone …asked for samples for analysis. And we got the results on a graph, with all of our pollens. The big hits were heather, brambles, holly. (CSH)*

Research projects which aim from the initial planning stage to transcend common limits and boundaries between researchers and CS data providers hold many potential benefits, and have the capacity to maximise the practical, and political potential of CS (McQuillan, 2014; Stevens et al., 2014). Several recent initiatives for collaborative research frameworks create an opportunity for effective, dynamic communication between beekeepers and scientists. In both these cases, the research is very much problem-orientated, with the challenges to bee health recognised, and prioritised, by the beekeepers and scientists. The research is focused on addressing threats to bees, as observed and expressed by beekeepers. It is important to note the central involvement of key stakeholders from the very origins of these research project. This is a key recommendation for developing successful co-production research projects (Ingram, 2008).

Recent years have seen many bee farmers in the UK experience a dramatic increase in their colonies suffering from Chronic Bee Paralysis Virus (CBPV), which can lead to high colony losses. This was having a severe impact on the economic viability of many BFA members, and impacting the success of contract pollination which these colonies were to carry out. The disease had been relatively uncommon for many years, but has become more common since 2016 (Bee Farmer 3:4 (8/17). Members of the BFA asked a representative of the NBU to give a presentation to their members on the disease. This resulted in the development of a research project which is currently underway at the time of writing, with BFA members having played a key role in both developing the research question and problems to be investigated, and also devising appropriate methods of data collection throughout the project, based on their field experiences, and practical knowledge of associated variables such as weather, local land use, and other health indicators of colonies affected by CBPV. This project emphasises the central roles of BFA stakeholders at all stages of the project's design and implementation. (ibid).

Similarly, research for the Black Bee Project in Ireland was described by Irish respondents as highly responsive to, and engaged with, the practical concerns, awareness and experience of beekeepers. This project is investigating the prevalence of *Apis Mellifera mellifera (Amm)* in Ireland. It is also indicative of scientific inquiry strengthening and confirming the observational perspective of many long-term beekeepers; namely, that 'black bees', or local bees, are more able to cope with the vagaries of the climate in the Ireland and the UK. Various subspecies of *Apis Mellifera* have long been imported into the UK. However, many beekeepers have noted over the years that other genotypes, such as *Am Carnica* and *Am Ligustica*, struggle to thrive in the UK climate. One interviewee who has been engaged with the Irish Black Bee Project argues that, for him, using local *Amm* is central to the success of his bee farming / honey production business, which has been going on for four generations, as only *Amm* are able to cope in local conditions. Such a sentiment is also expressed by beekeepers in other comparatively challenging climates, such as Wales and Scotland, where bees which are genetically closer to Southern European varieties are unable to cope with the climate. The Native Irish Black Bee Project (NIBBS) unites scientists researching the characteristics and distinguishing features of *Amm*, with local beekeepers. They have successfully started local conservation areas, where all beekeepers agree to use only locally adapted bees. Interviewees expressed a sense that researchers had become personally invested in the mission to promote the keeping and use of Black Bees, and it was this sense of personal involvement that was critical to the development and success of the project:

> *I think basically - there is an alliance with the native Irish honey beekeepers. And (the researchers) have become kind of invested themselves in that. And this is the only research on bees that they do-in collaboration with that. So they have come, you know, they have become part of the whole movement actually. (EMGC)*

This challenges the objectivist epistemological model, and engages with the multiple identities, and multiple ways of knowing, that blur the boundaries between the rational scientific, and the sensorially engaged (Lorimer, 2008). Here, the researchers are described as having stepped outside of an objective, distanced role, and invested themselves in a particular goal, which their research aims to achieve. This directly contradicts the perspective of other researchers who spoke at one of the Participant Observation events. They expressed concern that, if they were to voice an ideological perspective on threats to bee health, their research may be discredited in the policy sphere, as they would not be seen as neutral researchers. And yet, science exists in society, and benefits from social movements. Another researcher noted, albeit in jest, that bee researchers should be grateful for varroa and CCD, as these have generated a tremendous amount of funding opportunities for a wide range of bee-related research.

Apart from working relationships between beekeepers and scientists, there are also examples of beekeepers' websites documenting the evolution of research projects, and calling upon the international beekeeping community for data and perspectives on the appropriateness of research questions. Although he is based in the USA, Randy Oliver's 'Scientific Beekeeping' website is a popular source of information for beekeepers throughout the world. An entomologist by training and a beekeeper by profession, Oliver works with all stakeholders in bee health: scientific researchers, beekeepers, and farmers. He carries out experiments himself and also co-designs and runs Citizen Science projects where website visitors are invited to participate and submit data, as well as discuss the relevance of the research to them and their practice. While the impact of social media and online discussions presents challenges to designing and implementing conservation policy (Gustafsson, 2017; Smith et al., 2016), there is also a potential positive role for the internet as a method for disseminating TEK (Burton and Riley, 2018). Beekeepers' knowledge spans multiple categories which can initially appear diverse, and even contradictory. However, researchers on TEK note that holders of such knowledge are often very adept at amalgamating disparate sources of information. (Bethel et al., 2014; Royer et al., 2013)

Within the context of Evidence Based Policy Making (EBPM), scientific data is relied upon for the formation of policy, often at the expense of other forms of environmental knowledge (Castree et al., 2014; Maxim and van der Sluijs, 2011). The difficulties of contrasting epistemologies within different communities, and how these meet (or fail to) in scientific assessment, is a central challenge to subsequent policy decisions in regards to pollinators (Kleinman and Suryanarayanan, 2012; Maxim and van der Sluijs, 2007; 2011; Suryanarayanan, 2013; van der Sluijs et al., 2013). The standard process for policy development has traditionally been a reliance on scientific data to support EBPM (Edelenbos et al., 2011; Nadasdy, 1999). However, this relationship is based on an assured, positivist model of science which is not always possible in issues of uncertainty and risk assessment (Udovyk, 2014). A recurrent theme amongst interviewees was an interest in, and support of scientific research, with the caveat that 'they think they're experts, but actually, they're only expert in one very small part'. Frustration regarding the challenges to being heard in the current research structure was common. Similarly, there are significant barriers to attracting the necessary attention, and funding, to investigate certain issues which are seen as important by Civil Society organisations (Frickel et al., 2009). Recent moves towards Post Normal Science can create spaces for a broader acceptance of multiple forms of evidence (Rauschmayer et al., 2009). This creates opportunities, but there are also risks. How far should we – indeed, can we - go in broadening out the debate? There are challenges to finding the balance between robust data, and socially and economically acceptable courses of action, as well as engaging with the messy realm of emotional responses, which are all determinants in these issues. Such a muddled fora is increasingly the backdrop for many environmental risks, which society struggles to comprehend, and subsequently manage (Maye et al., 2017; Urquhart et al., 2017). 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). Environmental governance is linked to scientific evidence and data, which forms the basis for subsequent policy decisions (Edelenbos et al., 2011; Juntti et al., 2009). 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.

Some interviewees – particularly those who are critical of the wider industrial agricultural paradigm – voice scepticism as to whether current research priorities into pollinator wellbeing can significantly improving the situation for pollinators, as long as the current wider approach to agriculture and the environment stays as it is:

> *It's no good having a margin round a rape field and spraying bloody middle with insecticide and fungicide, is it? It's just a joke!! (BG)*

This raises the central question of how our understanding of pollinator wellbeing – whether it is generated by scientists, beekeepers, or working coalitions of these groups – is operationalised to reverse pollinator decline, within a wider economic and political context. The next section of this thesis will investigate beekeepers' perspective on policy efforts to improve the environment for pollinators. It will also explore their involvement with the world of policy, and how their knowledge has been perceived, and used, in the policy sphere.

6.3: Beekeepers in the world of policy-making, and monitoring

One of the challenges facing beekeepers, and other policy stakeholders, is the question of what is accepted by policy-makers as legitimate, robust evidence (Ekroos et al., 2017; Fazey et al., 2006; Tengo et al., 2014). As pollinator decline is addressed primarily as a biological, ecological phenomena – although admittedly driven by anthropogenic factors – policy responses have been rooted in evidence supplied by biologists, entomologists, and ecologists (Allen-Wardell et al., 1998; Pettis and Delaplane, 2010; Potts et al., 2010). This is in keeping with general trends in environmental management, where the relationship between governance and science is well-established, with both communities 'speaking the same language' (Edelenbos et al., 2011). The participatory turn is challenged by these communication dynamics, with other stakeholders often struggling to be acknowledged, as their assessment criteria, values, and priorities may lie outside the communication networks and shared backgrounds of the primary actors (ibid). Interviewees often expressed a sense that their experiential knowledge was not fully appreciated, or engaged with, by government officials tasked with drafting, and implementing policy:

> *The Welsh Government says the right things, but I don't really see anything at the end of the day. Politicians, and the people who advise them, are not knowledgeable enough. Then they go out and get advice from people who think they know, rather than people who do know. (VF)*

Repeated examples of frustration and socially unacceptable outcomes from such attempts at environmental governance are leading to new models, which explore the potential of widening the boundaries of what is accepted as evidence (Juntti et al., 2009; Tengo et al., 2014). This is in response to the still dominant model which assumes that 'gold standard' evidence will be quantifiable, objective and universally relevant (Udovyk, 2014). The initial model for EBPM was medical trials, which served a purpose in measuring the impact of various pharmaceutical products, to ensure efficacy and keep patients safe from harm (Saltelli and Giampietro, 2017). This model extended to other walks of life, including the wider academic community, and is accepted as the most appropriate form of data for decision-making and policy. However, a growing crisis in science is concurrently leading to a crisis in policy and governance (Hess, 2014; Likens, 2010). As society is faced with complex challenges, such as climate change and pollinator decline, definitive scientific understandings of causes and results may be difficult, if not impossible, to guarantee (Carvalho, 2007; Maxim and van der Sluijs, 2011). Tensions are inevitable, as policymakers attempt to govern based on parameters which may or may not correlate with individuals' values, circumstance or experience. Pollinator decline exemplifies this crisis in science as real world situations fail to provide definitive causal evidence (Suryanarayanan, 2013). Respondents 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. (JP)*

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 (Hall and Steiner, 2019; Juntti et al., 2009). Ultimately, beekeepers' environmental knowledge situates any appropriate 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):

> *But (the pollinator policies) don't challenge the farming practices enough! (RB)*
>
> *This belief that you can plant a border of wildflowers around a field which is laced with neonicotinoids, and think that that is actually helpful for the bees. When all the studies have shown that the verges … the concentration of neonicotinoids is greater than 10 ppb, which is shown to be lethal to the bees. Until we stop pumping these things in by the ton, we're going to have problems. And this is too radical for a lot of people. (JH)*

We have seen that issues of balance, access, democracy and validity are highly complex. As the relationship between science, the public and politicians has shifted in recent years, there has been a re-examination of experts and expertise, and subsequent issues of access to, and impact upon, decision-making (Collins and Evans, 2016). While this initially suggests a widening of access and the democratic process, and engaging with wider forms of expertise, such engagement is fraught with challenges, and often seen as ineffective (Edelenbos et al., 2011; Kleinman and Suryanarayanan, 2012). The difficulties of making policy, and taking action, based on incomplete and/or inconclusive data, coupled with a need to develop socially acceptable decisions which incorporate the engagement of diverse stakeholders, yet still consist of scientifically valid information, is a challenge throughout conservation, and is particularly notable in pollinator policy (Dicks et al., 2013; Dicks et al., 2015). Global conservation challenges are leading many scientists to engage more deeply with TEK and other forms of environmental monitoring (Lehébel-Péron et al., 2016; Raymond et al., 2010; Smith and Sharp, 2012). This would seem to be a golden opportunity for beekeepers' environmental knowledge to be recognised and acted upon. However, epistemological and structural challenges continue:

The whole of the community needs to understand some of the problems. A greenfield with hedges flailed down every year is a desert. For all of the pollinators. (KB)

It is worth reiterating that the inspiration for this thesis was the dramatic media and political response to pollinator decline in the early 21st century. Beekeepers were positioned as playing a key role in monitoring, and ensuring, pollinator well-being (DEFRA, 2014; Potts et al., 2015; Scott et al, 2013). The initial scope of this project was focused primarily on the relationships between scientists and beekeepers, and how the knowledge of these two communities was utilised within the policy sphere. However, it soon became apparent through preliminary investigation that interviewees' experience of, and perspective on, the policy process itself needed to be addressed in the analysis. As beekeepers are informed witnesses of the physical environment, and its impact on bees, many are also keen observers of the development, and impact, of policies which impact bees. This is documented throughout the BFA archives, and was a theme of inquiry throughout interviews. In particular, beekeepers' first-hand involvement with the drafting of policy, and their observations of subsequent actions taken as a result of policy development, is central to understanding both the epistemological conflicts within pollinator policy, which are reflective of wider conservation and environmental debates (Bell et al., 2008; Fazey et al., 2006; Silvertown et al., 2013), and the wider political and economic barriers to implementing necessary improvements for pollinator wellbeing. This will now be discussed within the context of the BFA's historical relationship with policy-makers, and contemporary beekeepers' reflections on their engagement with policy-making.

6.3a: Bee Farmers in the policy sphere

While all beekeepers have certain shared concerns, which give them a common perspective on environmental policy, bee farmers have specific needs and concerns. This is due to the nature of their professional beekeeping, and how it is impacted by a wide range of factors which are ultimately beyond bee farmers' individual practice and management. Reviewing the BFA Archives within this research context offers a historical lens to understanding how beekeepers' knowledge has been operationalised in the policy sphere – and when it has encountered wider structural obstacles which have limited its capacity to be utilised on behalf of pollinator wellbeing.

For many years, the BFA struggled to promote the importance of bees and pollination to the wider agricultural policy arena. As well as their role in documenting the impact of agrochemicals, bee farmers have also historically engaged with policy-makers on an organisational level. As the first editor, T. Hillyard said, in the HPA Bulletin 4 (10/53): '*the main benefit of the HPA to its members is its mere existence as a body of commercial beekeepers organised and watchful, ready to protect their interests against attacks from any quarter. This aspect is too often overlooked or taken for granted.*' Their efforts to represent their corporate interests used to be via MAFF and EC communication, and now occurs via DEFRA and EU communication. As the BFA originated as a professional guild, tasked with presenting and protecting its members' professional interests, the archives frequently discuss BFA representatives attending meetings in London and Brussels with UK and European government representatives, explaining the unique challenges and importance of this sub-sector of mainstream standard agriculture. As noted earlier in this chapter (Section 2a), and in Chapter 4, Section 8, the expertise and professionalism of the BFA was acknowledged and respected by many the scientific and political communities; however, this did not always ensure that their professional and environmental concerns were acted upon. As agriculture and land use changed, there was concern that bee farmers were 'falling through the cracks' between the Agriculture Act, Horticulture Bill, and Small Farmers Scheme (BFA Bulletin 52: 1/60). Constant effort was necessary to ensure the unique concerns of bee farmers were considered in wider policy discussions. In a 1970 meeting with representatives from the Ministry of Agriculture, the BFA representative was assured that organophosphate pesticides would be 'kept under review and replaced whenever possible by less persistent chemicals' (BFA Bulletin 125: 2/70). While this suggests constructive working relationships between bee farmers and policy makers, these were not secure. BFA Bulletin 156 (9/74), describes an increasingly strained relationship between farmers, bee farmers and the government. After years of following government guidance and submitting samples of bees for analysis, bee farmers were both aware of the damage caused by a broad range of agrochemicals, and what they considered a failure of appropriate government response to these hazards. The government generally promoted voluntary agreements that farmers were requested to comply with. (As discussed in the preceding chapter, voluntary agreements are still the preferred governance response to managing the risk of spray damage to bees.) 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). Their communication with policy-makers often failed to result in any significant improvement in conditions for them, and their bees. The government response to concerns over spray impact was to suggest better labelling, and education of farmers in best practice, and safe handling. Actual restrictions, and/or penalties for improper usage, were rare. Bee farmers were not entitled to any compensation for losses due to spray. BFA Bulletin 255 (5/89) continued to provide 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 Spray meetings need their complaints to be backed up*.' Clearly, communications between the BFA and the wider policy community were continuing, with a consistent need for scientific data, which conformed to the model of EBPM.

This struggle to link individual incidents into a call for wider systemic change is a common challenge in agrochemical regulation. Harrison (Harrison, 2006; 2008a;b) has investigated issues of scale, which have been used by California's powerful agricultural sector to detract from the inadequacies of neoliberalised pesticide control regimes. Rather than acknowledging cumulative illnesses from agrochemical exposure being inherent evidence of a failure to adequately regulate the sector, incidents are decontextualised and individualised. As the global agrifood system has developed economically and politically, individual actors have been forced to rely on personal efforts to protect themselves from the negative side effects of chemical exposure.

As their initial engagement with policy was rooted in the threats and challenges of agricultural sprays, the BFA's later engagement with policy-makers focused on efforts to control varroa infestation. As discussed in the preceding chapter, varroa was a challenge requiring a governance response, as bee farmers recognised that their individual management responses were insufficient to address the threat. The 1984 BFA Spring Conference minutes note MAFF being unwilling to impose restrictions on bee imports, although the bee farmers saw this as the only way to stop varroa entering the UK. (*It is worth noting that Australia has always been free of varroa, due to its rigidly enforced ban on the import of bees*.) Over the next decade, varroa slowly but inexorably spread throughout the UK. Within ten years, the confirmation of varroa outside the Statutory Infected Area (SIA) led to MAFF imposing domestic restrictions on bee movement (BFA Bulletin 292: 1/95). By this point, most bee farmers saw it as too late to control the mite. The varroa discussions illustrate frustration with official government responses, which seemed focused on looking for varroa and mapping it. Bee farmers were now far more concerned with actually developing methods and treatments to deal with it. (BFA Bulletin 296: 11/95). Within a few years, bee farmers throughout the UK were experiencing heavy losses.

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, efforts to control varroa were less about an epistemological difference, and more to do with the questions of wider economic and political priorities. 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).

Like many other TEK communities, beekeepers struggle on both an epistemological, and a wider political level, to have their environmental understandings validated and incorporated into wider environmental governance (Hernández-Morcillo et al., 2013; Nadasdy, 2005; Oteros-Rozas et al., 2013). Frequently, TEK communities today are politically disenfranchised, and experiencing challenges to their livelihoods from wider socio-economic systems, which are politically dominant (Ianni et al., 2015; Oteros-Rozas et al., 2013). Conflicting perceptions of what is reliable evidence, coupled with wider structural systems, affect the potential of diverse knowledge claims to be fully operationalised. This has been noted in efforts to contribute to recent pollinator policy initiatives, as I shall now discuss.

6.3b: Contributing to policy

After an initial promising period resulting from beekeepers' capacity to provide singular quantitative data for scientific investigations, which then served as the basis for regulatory policy on early agrochemicals, we have seen how an increasingly complex physical and political environment has led to challenges in beekeepers' concerns resulting in appropriate, timely responses from the policy arena. All interviewees were asked if they had been involved with any of the recent pollinator policy consultations – as individuals, and/or as representatives of any beekeeping civil society organisations. As a result of their professional beekeeping experience, and the communication networks they had subsequently fostered, several had been invited to take part in various meetings with DEFRA and/or the Welsh Government during the consultations which then informed the drafting of recent policy:

> *I remember the background to that - at one stage the 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 an ex-bee inspector known to some of the people in the table, I was a representative for amateur beekeepers. Professional bee farmers were still at the table, so I went along. (BS)*

While this individual felt it was important to ensure that amateur beekeepers were 'at the table', the professional bee farmers were also in attendance, with some scepticism over the direction of the proceedings. A recurrent theme was that beekeepers saw the policy discussions as abstract, and divorced from the realities with which they were concerned:

> *I went to the original (DEFRA) pollination strategy in London, what was that, in 2013 I think it was. 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 et cetera. I don't think it's their fault. It's a bit of ignorance if anything. (TA)*

The interviewee notes that there were already tensions emerging, with the BBKA, the main body representing amateur beekeepers in this country, having reservations about participating. Others at the early pollinator strategy meetings also expressed similar views:

> *Well I was (involved in the policy meetings) to start with, because I used to be the chairman of the WBKA... I was on some of the committees with DEFRA and their pollinator policies so I could see what was going on in England as well and, ah, I think the Welsh one came in first-not that I had anything to do with it- but it's only really, I don't know, just a lot of people speaking and not doing. (DS)*

The Welsh Government task force also elicited a mixed reaction from early contributors:

> *I had some links with Bee Scheme, etc…I declined to be an active person on 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. (MS)*

The particular characteristics of the individuals who participated, often at the behest of invitation from government representatives, coupled with their eventual reflection on a sense of disenfranchisement, and their knowledge being incompletely and/or ineffectually engaged with, is consistent with experiences of TEK holders in other similar negotiated situations (Barron et al., 2015; Huntington et al., 2002; Nadasdy, 2005). Such divisions between experiential knowledge and scientific training and policy makers have been regularly apparent in writings on TEK, and the challenges associated with broadening participation (Nadasdy, 2005; Raymond et al., 2010; Ween and Riseth, 2011). Those interviewees who had been invited to take part in consultations on policy development were highly experienced beekeepers, and nationally recognised for their many years of professional and personal involvement with bees and the beekeeping community. The diversity of perspectives amongst beekeepers also challenges efforts to incorporating their views into policy. As mentioned repeatedly throughout interviews, beekeepers are notoriously heterogeneous, with distinct sub-groups who tend to hold disparate views. Participants described a plethora of individuals and organisations being involved in policy consultations, often with their own particular views on what, if anything, should be done to address bee and pollinator decline. This breadth of stakeholders' perspectives can be a challenge to inclusive policy-making and conservation strategy (Robbins, 2006), and beekeepers' diverse practices can underlie seemingly contrary viewpoints (Lehébel-Péron et al., 2016). Following that caveat, it can be argued that it is therefore all the more important to take note when universal themes recur in their views and responses. 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). Within current policy initiatives, significant disagreements arose amongst those involved. Some reported that certain key individuals, representing various beekeeping civil society organisations, were only supporting honey bees, and resented any funding going into wider initiatives:

> *And T was angry when they, when DEFRA did actually give a very hefty grant of a few million to research, and they called it pollinators. And T was furious! Absolutely furious! Because he has maintained that we did all the work, we did all the publicity, for honey bees. I thought that's really shortsighted. I really did. And he said oh we've got them all jumping on the bandwagon, and there are*

people working on butterflies, and people working on hoverflies. Well I think that's a good thing. (PH)

As well as the creation of pollinator policy being subject to varied influences, interviewees also noted variation in the manifestation and impact of policies. While many pollinator strategies are national, data from this project suggests that implementation is highly variable and dependent on local factors. Interviewees describe both funding constraints, and the sheer level of (dis)interest of Council employees responsible for implementation and monitoring of 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. (DS)

Some questioned whether local authorities are actively engaging with the recommendations of national pollinator policies, or if some of the small, positive changes are fortuitous by-products of council spending cuts:

What I have noticed is that a number of things that would have been kept tidy cleaner-the hedges forced back, verges cut more often-they are not being treated so frequently. Now that may be part of one of these various initiatives, but it may also be economic pressures that are slowing people down. (KH)

As austerity measures have led to local councils cutting back on a variety of services, this has at times meant that they can no longer afford to cut roadside verges as often as they had done in the past. While this may accidentally lead to improved forage habitat for wildlife, including bees and other pollinators, it is not a reliable basis for policy enactment and environmental management.

There is a sense amongst many beekeepers that various schemes to enhance the environment for pollinators are taken up for financial reasons, and lack any wider 'emotional buy-in':

I have to be honest - most of the incentivisation is because of money, not because they want to improve pollinator levels. (LD)

However, there is also a recognition of the financial pressures on farmers and other land-owners, and the need to ensure that implementing any policies on behalf of pollinators is affordable:

> *I think (policies) have got to be maintained. And maintaining them means you've got to give the farmers money. … I would like to think that farmers are unselfish enough to want to do it out of the, sort of pay back to nature, but, like everyone else, they have businesses to run. The bottom line is (the) important thing, very often. (RR)*

While optimism prevails in some respondents, the overwhelming theme throughout interview responses was of policy bearing limited benefits. What actions were being done on behalf of bees and other pollinators was generally seen as limited, inappropriate, or misguided:

> *'they're a little bit suburban, a little bit gardeny' – MS*

Most reported a sense that policy responses were too limited in both scale and impact, and were disjointed. Interviewees consistently noted that measures were enacted which were very photogenic, but which had little ecological significance. Policy measures are frequently seen as too small in scale, and remit. Overall, respondents noted policies lacking wider government backing:

> *And I think they are great ideas. But it needs more support from big government agencies... Like county councils and corporations. All the government bodies, which always seem to be, you know, they are all doing different things in all the different agencies, and contradicting each other and, you know, more involvement from, say, farming organisations. It's such a low priority. …The big problem with these schemes is that they need to be beefed up. The scale is so small. It's the scale more than anything you know? (EC)*

Although beekeepers' knowledge contains a high degree of local specificity, their knowledge affects their environmental perspective when traveling in other areas. This enables them to recognise varied local manifestations of wider policy initiatives. Their observations illustrate complexities of environmental governance. While there is a high level of scientific influence on the creation of policy (Ekroos et al., 2017), operationalising data to support conservation is complex: the realities of governance present us with multiple actors, and contrasting local priorities (Juntti et al., 2009). Data for this thesis suggests a significant policy challenge, namely, how to ensure that people really do carry out recommended steps in land management, which will actually enhance the environment for pollinators? This is a significant issue at the time of writing, as we are looking towards the post-Brexit agricultural landscape being one where farmers will receive support for environmentally friendly land management and farming. Appropriate policy, and ensuring compliance, are recurrent themes in environmental management (Gunningham et al., 2004; Kagan et al., 2003). These include the values and behaviours of both policy-makers, and the wider electorate to whom politicians are ultimately responsible. The electorate's understandings and concern regarding environmental challenges is a central component in driving political response (Willis, 2018). Therefore, understanding how long-term beekeepers consider the wider public's knowledge of pollinator-related issues is a critical element of beekeepers' knowledge and capacity to improve the environment for pollinators.

A recent increase in public awareness and concern about bees has led to greater opportunities for 'policy entrepreneurs' to promote awareness of, and action on behalf, of bees and other pollinators (Gustafsson, 2013). Given that the BFA archives and other sources in the IBRA archives illustrate that significant environmental challenges to pollinator wellbeing have long been recognised by beekeepers, this shift in public awareness, and subsequent policy response, suggests that there are wider dynamics functioning within the policy process, above and beyond the established channels of communication between beekeepers, scientists and policy makers. Interrogating the changing manifestation of 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. The role of these wider publics and the media, and beekeepers' perspective on, and relationships with, these powerful actors will be explored in the final section of this chapter.

6.4: Beekeepers, Wider Publics, and the Role of Media

The preceding section has illustrated how relationships between the scientific community, bureaucrats and holders of TEK can reflect both ontological and epistemological divides, which can undermine efforts to understand, and address, environmental challenges (Agrawal, 2002; Barbero-Sierra et al., 2017; Bear, 2006; Cruikshank, 2012; Nadasdy, 2007). In addition to this already challenging arena, growing attention is addressing the role of the public, and the media, in contemporary environmental challenges (Eden, 2016; Evans and Plows, 2016; Smith et al., 2016; Wynne-Jones, 2016). A significant contribution of much of this current research is to highlight the complexities of multiple publics, and the risks of generalisation by referring to 'the public'. The term 'public' is rightly interrogated, with the existence of diverse, multiple environmental publics being noted as a more accurate description (Eden, 2016; Evans and Plows, 2016; Irwin, 2001). However, for the purposes of this thesis, I am using the term 'public' to refer to those who are not beekeepers, researchers on bees or pollinators, or policy-makers. This thesis is reflecting on and analysing the data of what beekeepers themselves have expressed, which is often expressed in comparatively binary terms. With this limitation in mind, the term 'the public' will be used, although analysis will address the complex and problematic elements of this term.

Data on this sub-theme came almost exclusively from interviews, and was an unexpected line of inquiry in this research project. Due to significant changes in media and information sharing over the years, coupled with the growth of pollinator decline as an issue in the media and public consciousness, it is unsurprising that this theme was not substantially addressed in the archives or other sources. The recent development of media as a significant influence on pollinator wellbeing correlates with findings on other contemporary environmental and conservation debates, including climate change, and monarch butterfly conservation programmes (Carvalho, 2007; Gustafsson, 2013). While questions within the semi-structured interview format were primarily investigating beekeepers' views on policy, the environment, and scientific research, the question format allowed interviewees to develop and pursue topics to which they ascribed importance. It was through this flexible data collection method that this significant avenue arose, and generated significant data on beekeepers' views on the general public's understanding of, and response to, pollinator decline.

All parties agree that monitoring and ultimately reversing pollinator decline relies very much on public knowledge and understanding of different pollinators, and the varied conditions they require for health. While intentions and concern about pollinator decline may be positive and increasing, a lack in environmental understanding can lead to misplaced efforts on the part of the public, and government bodies. Several of the interviewees who had grown up with beekeeping as a family practice, and subsequently kept bees throughout their entire life, felt that the practice had utterly suffused their identity, and their way of understanding and relating to the natural world. In contrast, when considering how beekeepers perceive the wider public's sense of the natural world, their own deep experiential connection and understanding often stands in opposition to the public's relationship to nature. It was widely noted throughout interviews that there is a pressing need for more understanding of the many different species of pollinators:

> *You know, there is this stock phrase that 'the bees are dying'. But there is no understanding of what a bee is, and what the different type of bees are, and even, you know - most people's understandings of nature is minuscule you know. And I think this is a great pity. (EC)*

One of the many public responses encouraged by policy has been to encourage gardeners to enhance their planting to support pollinators (Garbuzov et al., 2014; Gaston et al., 2005; Shackleton and Ratnieks, 2015). The link between beekeepers and gardeners has led to a significant increase in garden plants being marketed as 'pollinator friendly' (Fukase and Simons, 2016; Hicks et al., 2016). However, there is a notable discrepancy between plants commonly available in garden centres, and their actual attractiveness to pollinators (Garbuzov et al., 2015b; Shackleton and Ratnieks, 2015). This was echoed by many respondents, who stressed the importance of increased public knowledge about what plants actually work for pollinators, and other species:

> *I think more should be done to educate people to grow the right things for pollinators. I know they do a token bit on garden programs, about planting wild things, but I think that if they had more you know, plants advertised that were suitable, that would give people more chance. If you go through a seed catalogue and try and find things that are more suitable, they show something they say is*

good for butterflies, and I mean, you've got to get plants for the caterpillars as well, not just the flowers. (BH)

The unity of beekeepers' and scientists' awareness of public misunderstanding of plants for pollinators, and the failure of many plants marketed as pollinator friendly to actually attract pollinators, exemplifies a significant 'third force' in responses to pollinator decline – namely, that beekeepers and scientists are often closer in understanding of issues, while public, media, and commercial forces are either misinformed, or actively benefiting from the confusion about what is really best for pollinators. While issues of scientific literacy and education might sound comparatively trivial, they have a profound material impact on the environment in which pollinators and other species live (Juntti et al., 2009). As several interviewees mentioned, often policy responses are resultant upon the expressed concern of members of the public. And, similarly, there is a sense amongst interviewees that government follows public opinion, rather than leads it:

I think it comes back to persuading the people in a democracy-that's what you must do-I think the legislation only worked because people supported it. (CB)

As a result of their awareness of the need to increase public understanding of bees, pollinators and the wider environment, several interviewees are engaged in education outreach programmes at all age levels, from primary schools through to guest lectures at universities and U3A; they emphatically state that increasing understanding and appreciation of the natural world is a vital part of efforts to support pollinators. There was a recurring theme of the importance of increasing the public's understanding and appreciation of the natural world. For many, this took precedence over direct policy interventions:

So what we need is more public awareness about these being not these evil weeds, but we need to think about nature, and what purpose these things serve in nature. (KB)

This wider public awareness is crucial, as much of beekeepers' management is rooted in carefully cultivated personal relationships with members of the agricultural and land owning community. It was noted that there are significant practical differences between farmers, and contractors. Several interviewees make a distinction between different methods of farming, and land ownership and management. Several note that developing and maintaining communication is more difficult in situations where land is owned and farmed as a financial investment for 'city bankers':

> *…because I'm 40-50 miles south of London, you tend to get people come and buy a farm, and they are only interested in the house. They DO NOT understand what is involved in making the land productive. So either they just let it go, or they seem to let contractors work it, or perhaps 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. (RP)*

These tensions do not just occur with 'new farmers', who may be owning and managing the farm as part of a wider investment portfolio. Changing demographics, and sometimes even changes in family members managing a farm, result in new tensions and new relationships to be negotiated by beekeepers:

> *One of his sons is now doing it, and he knows absolutely nothing about farming. God knows why he doesn't send him to agricultural college, if he is going to do it. But no, they don't have a clue. This older chap, who does know the land and farming, but he's a bit despairing of them. And they've got very upmarket beef, which they charge a lot for, but it's not organic. And so frankly, no, they just dabble at it, they really do. (PHF)*

Interviewees described members of the public – in particular, farmers – carrying out policy initiatives for pollinators based on limited understanding, solely for the funding associated with these schemes. Sometimes, the problem with pro-pollinator schemes was seen as due to a lack of follow-up. Farmers received grants to plant something for pollinators, and were described as feeling they have 'done their part'. Whether or not what they had planted actually flowered seemed to not be a concern. In other cases, it was seen as due to a lack of knowledge about bees' needs:

> *And every farmer on this scheme has put in … about 2 tonnes of sand in a corner in the field! And it's obviously for mining bees and all that… They do it without*

any understanding of what bees they're helping. They think they're helping honey bees. A couple of farmers have brought me to the pile of sand and said 'we put these here for the bees'. And I say well they're not for my bees! (EC)

Such a failure to understand the forage and habitat needs of diverse pollinators is often interpreted by beekeepers as related to a shift in the demographics the farming communities. As noted by respondents in this project, farming has changed radically in the past 100 years, with many farmers having moved away from mixed farms to larger operations specialising in one or two crops, or animals. In contrast, a mixed farming approach was seen as supporting a wider understanding of the environment for all the different species on the farm. It is suggested by some interviewees that changes in farming practices and amongst the farming community is associated with a decrease in wider environmental knowledge and engagement:

I don't think the farmers even recognise bees, to be honest… I just don't understand it. They are educated in farming, and they don't understand what they are looking at. I would say that the farmers that I used to deal with years ago … they were all the old type farmers, you know-the farmers that had a pipe in their mouth and the dog by the side, and they were very knowledgeable about everything they dealt with. (DC)

While it is clear that public awareness and education is central to improving pollinator habitat and wellbeing, it was also evident from interviews that this is often challenged or hampered by the media response to pollinator decline, which has not always served to illuminate a complex situation. We are seeing a growing complexity in public and media response to political and environmental issues. It is increasingly recognised that policy development, particularly in regards to environmental management and response to contemporary challenges such as acid rain, is powerfully driven by media, even more than by science (Likens, 2010).

Due to their respected positions in national beekeeping organisations, it was not uncommon for interviewees to report having been contacted by media representatives over the years, to comment on pollinator decline and the status of bees. Several now refuse to engage with the media, as they believe the situation is being so inaccurately portrayed in the media. One prefaces all conversations with journalists with the warning that 'you don't want to talk to me – I don't think they are declining!!' This exemplifies several themes, and the tensions between them. First, we have the public's lack of distinguishing between honey bees and other pollinators. It is now widely accepted within the scientific and the beekeeping communities that there is currently not a serious decline of honey bees; wild pollinators, however, are still at great risk (Geldmann and González-Varo, 2018). Media failure to accurately report complexities of science and pollinators are common (Dicks, 2013; Smith et al., 2016). Interviewees and researchers have found that public awareness about pollinator decline is notable for a distinct gap between concern about bee health, and actual knowledge about various species of bees (Wilson et al., 2017). A historical cultural engagement with honey bees has been an active force in attracting media coverage of their decline, and driving international policy responses (Vanegas, 2017). This broader cultural empathy can be beneficial to efforts to support pollinators, but it can also lead to confused and ecologically inappropriate responses. This lack of understanding is not necessarily being alleviated by media coverage of pollinator decline. Research on pollinators highlights a massive imbalance in media reporting and depiction of pollinators, with honey bees being granted a highly disproportionate amount of media coverage compared to other pollinators (Ollerton et al., 2012; Smith et al., 2016). These authors' findings resonate with the observations of interviewees, who frequently report exchanges with land owners and / or members of the public which denote a worrying gap between concern about pollinator decline, and knowledge about how best to enhance and/or preserve the environment for them:

> *I think you could do a lot to educate people on what was really useful for bees… There's an awful lot from the horticulture industry about planting this and that - lavender and stuff… Planting all sorts of flowers in your garden, and shrubs in your garden, for the bees… But what we really need people to educate them about, and the things that are really important, is things like the ling heather, the bell heather, and how to manage them. (PH)*

Some respondents appreciated the general media efforts to raise public awareness:

> *And the decline in bees has absolutely caught people's attention. Every show you go to, people come up to you and say what's the trouble with the bees? It is very*

important it should be in the media- very important that it should be on the television and so on. I think it's very very useful. (MM)

Others were far more critical of the failure of media to accurately depict an often complex situation. The media response to Colony Collapse Disorder (CCD) was questioned. While CCD is now considered by bee researchers to be a specific condition that affected colonies in the US, during the period 2006-2008 (Seitz et al., 2016), CCD has become associated with any unexplained honey bee colony mortality, and assumed to be global. The role of the media in perpetuating misunderstanding was firmly criticised by some interviewees, who felt that 'the press like a bad news story':

There is so much media hype these days. Listening to the media and the television and all the people saying, everybody's saying have we still got the problem with bees. And frankly the answer is yes we have got problems. But if you do the right thing at the right time, which we know about, we've got no problem. (BD)

With the initial appearance of CCD in America in 2006, and subsequently in global headlines and cinemas, the urge for policy-makers and politicians to take action – or at least to be seen to take action - became a potent driver for meetings with a broad range of stakeholders seen as relevant to pollinator health. One interviewee reported his local MP noting that, during the height of media coverage of CCD, the overwhelming majority of constituents' written correspondence to his office concerned the plight of the bees. The MP was surprised by this, given wider local, domestic and international current affairs, including global economic crisis, war, and terrorism. Media attention was also seen as having driven policy response:

I wish DEFRA was managed more by the central government, they still respond too much to the media. It benefited (the BBKA) in getting money towards some sort of activities-£10 million over 10 years, from which we are still benefiting. And we benefit in terms of £40,000 a year to do training. So we feel that is worthwhile. But that was really money given on a false premise -that we had a big problem that was colony collapse disorder. They never recognised-well I think within DEFRA they do-they never recognised that we had other problems-serious problems. (KB)

As noted throughout this thesis, beekeepers bring a long-term temporal understanding to their practice, and the environmental conditions which enhance, and challenge, their bees. In contrast, they felt that media coverage of the issues tended to be overly simplistic, short-term, and inaccurate. General media coverage, and films such as *Vanishing of the Bees* (2009), and *More Than Honey* (2012) fed into public concerns, and stimulated an unprecedented rise in beekeeping. Interestingly, one of the primary threats to bees which has received extensive media coverage in recent years is *Varroa Destructor*. While it is still problematic for many beekeepers, it is generally considered by many to now be a manageable challenge; indeed, as discussed in Chapter 5, Section 4, many beekeepers are no longer using miticides, as they have either bred bees which appear to manifest varroa sensitive hygiene (VSH), or, for other reasons, do not appear to suffer from the mites.

The role of media coverage on public understanding, and resultant policy, with regard to scientific issues, has come under investigation particularly in relation to climate change (Carvalho, 2007). As scientific issues such as climate change and pollinator decline have global implications, the relationships between scientific research, media coverage, and public understanding of the issues are important. Carvalho's analysis depicts ideological factors impacting media coverage of climate change, particularly when discussing what socio-economic, and political response is appropriate (ibid). Ultimately, the fundamental shifts in the economy which may be necessary to mitigate climate change are highly unlikely unless the public can be made to understand both the severity of the situation, and the deep changes necessary throughout modern society. The same can be said in the case of pollinator decline.

From the initial launch of DEFRA's Pollinator Strategy, a sense was cultivated that bees could, and would, be supported by actions taken throughout the public arena:

> *'…we are doing everything we can to help (bees) thrive. Not everyone can become a beekeeper, but everyone from major landowners to window-box gardeners can play their part in boosting pollinators.' (Elizabeth Truss, Environment Secretary, 2014)*

While this sentiment may be accurate, there is a risk of the scale of responsibility for pollinator decline being distorted through such comments. Given that the industrialisation of agriculture in the 20th century has led to massive habitat loss and usage of agrochemicals which threaten pollinators (Baude et al., 2016; Brown et al., 2016), it is appropriate to ascribe responsibility to major landowners. However, much of the media response as perceived by interviewees seems to place the onus of responsibility onto individual beekeepers, and landowners following voluntary measures, as discussed in Chapter 5, Section 3.

Interviewees' frustrations were exacerbated by a sense that the media coverage of bee and pollinator wellbeing, and subsequent public response, was often being manipulated by individuals and organisations with particular agendas. When discussing the range of stakeholders and the process of policy construction, many interviewees referred to the role and impact of campaigning groups. Several interviewees expressed a sense that the policy-making process had been 'hijacked' by a variety of individuals and / or representatives of organisations with particular agendas to promote:

> *… (I am very sceptical of the government policies), because it was media driven. Friends of the Earth managed to raise awareness. They do this very effectively. And the government responds, because there is a public perception that there is a problem. But the government doesn't get involved in the problem. And they need policy changes, not just encouraging press releases. (KB)*

There was a concern that campaigning groups used bees as a way of getting people to donate money to them:

> *if I were perfectly honest, I think a lot of them jump on hobby horses, to do with things that are not as important. …their only aim, really, it to get money to use in whatever way they want to use it. (VF)*

The complexities of public (mis)understanding of scientific actualities are heightened by the increasingly powerful role of social media, and / or campaigning groups (Gustafsson, 2017). The challenges to making scientifically appropriate decisions are exacerbated when the debate becomes centred on emblematic species. Historical public relationships with charismatic minifauna can lead to courses of action that might not be the most ecologically appropriate (Gustafsson, 2013). Although this thesis focused on the environmental observations of beekeepers, who work with honey bees, many of them were also highly informed and concerned about other pollinators. It was also clear that interviewees were very aware of the general public's lack of ability to distinguish between the many different species of pollinators:

> *I think there's a limited understanding of what pollinators actually require – it's often very primitive. … and, 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. (MS)*

Those working in the field of conservation are also recognising the significance of perceptions to the success or failure of strategies (Bennett, 2016). This expansion of possible forms of evidence can provide opportunities, as well as challenges, to efforts to develop effective conservation policy, such as those which respond to pollinator decline. Like many other contemporary environmental challenges, pollinator decline is an excellent example of a 'wicked problem' (Ney and Verweij, 2015). Within that framework, solutions will not be simple, or one-dimensional. It will be necessary to engage with complex networks of scientific analysis, policy procedures and responses, as well as the general public's understanding and appreciation of the natural world. During one of the Participatory Observation elements of this research, an entomologist who has been investigating bee health and pollinator decline for over 25 years commented 'we have been looking at [this issue] for years, and nothing has changed - the situation has not improved'. This exemplifies the shortcomings of the positivist scientific approach when attempting to solve environmental challenges (Maxim and van der Sluijs, 2011). While recent years have seen a tremendous increase in entomological understanding, these will not be sufficient to reverse pollinator decline (Potts et al., 2010). The need to address contemporary scientific challenges within their social / economic / political contexts is well-established (Castree et al., 2014).

The decline in pollinators, and subsequent media furore, has generated multiple results, including a massive influx of new beekeepers, with the BBKA's membership rising from approximately 8,000 to 22,000 in the past 10 years. This has strained traditional training and support systems. Local beekeeping associations have often lacked the capacity to provide new beekeepers with the practical guidance and support which members believe is necessary to become a good beekeeper. This has resulted in a range of challenges, and leads some experienced beekeepers to suspect that much of the bee decline which has generated so much public concern is actually a result of a huge increase in novice beekeepers, who do not have the skills to appropriately care for their bees:

> *Because ever since this attitude of 'buy a hive save the world', you know, and people like the Co-op have not helped very much either-what with encouraging some beekeepers. I think they just do it when it's fashionable? …. And that goes away again. There is nothing consistent. (DC)*

This surge in new beekeepers is now recognised by researchers as one of the components in high winter losses, which are significantly higher amongst novice beekeepers (Seitz et al., 2016). Interviewees also express concern that this has generated, or will lead to, unsustainable pressure on available forage:

> *I mean, more people are keeping bees, and they probably have not taken into account whether there is enough forage in the area for them. The bees have obviously got to go further, haven't they? In an area like this, it could easily get swamped with pollinators. (BG)*

Interviewees note a dramatic shift in the demographics of beekeeping in recent years, much of it as a result of media coverage of pollinator declines. As the public has been inspired to 'save the bee', many people have taken up beekeeping as an activity. This has been associated with a recent move towards 'natural' beekeeping – avoiding the use of miticides, and limiting human intervention on bees' natural behaviours. This has generated a lot of conflict and tension – one highly experienced beekeeper pointed out that, 'as soon as you start calling yourself a natural beekeeper, this immediately suggests that doing it any other way is unnatural'. This has led to a great deal of conflicts and misunderstandings within the wider beekeeping community (Scott et al, 2013). While the emotion on this issue is settling down, there has developed a broader debate about beekeeping, both scientifically and individually. The approach to beekeeping which has developed over the past 100 – 150 years is now associated with conditions which are counter to the natural behaviour of bees, and seen as exacerbating disease and pathogen transfer (Neumann and Blacquiere, 2017).

Ultimately, these debates are about the fundamental question of how various publics understand nature, and pollinator wellbeing. One interviewee who is very involved in advanced training for beekeepers, states:

There might be a bit more public awareness, but, again, being involved in in the natural history society, there's lots of 'oh did you see that article about something'. I generally say something like oh no what was it about?', and they say oh I can't remember what it was about, but I remember reading it. There's lots of that sort of thing. Somehow, the general public don't seem to be able to take things in. (RP)

Within public understanding and popular media, there is often a tendency to express high levels of immediate concern over environmental changes and forage variations (Likens, 2010; Smith et al., 2016). This is being linked to driving policy responses, which may not be fully informed or scientifically appropriate (Gustafsson, 2013; 2017). However, beekeepers' long-term practice and associated environmental observations generates knowledge of environmental fluidity over time. While there is a great deal of public concern about bees' decline, appropriate action is often blurred by a broad polarity of human perceptions, ranging from economic and environmental needs for bees' ecosystem services, to the iconic positioning of honey bees in western thought and imagery, and ignorance of ecological principles and taxonomy (Breeze et al., 2015; Crane, 2004; Wilson et al., 2017). This has been explored in detail with regard to the monarch butterfly, where we see a complex blurring, and ultimate restructuring of traditional lines of communication and analysis (Gustafsson, 2017). Interviewees note the challenge of conveying the environmental damage they observe, and its effects on bee health, to a wider public who are often less aware of the comparatively subtle / discrete challenges:

We had the industrial revolution, what was so obvious to people-they could see the smokestacks, they could see the smoke, they could see the damage. It was very very obviously damaged. What happens now is you see a green field with rape, and you see no problems. (JP)

As mentioned earlier, much of the drive towards pollinator protection is framed within discussions of the economic value of pollination as an ecosystem service. Public concern about bee wellbeing, and pollinator decline, is encouraged within the context of the potentially profound subsequent negative impact on our food supplies. The apocryphal Einstein comment about humanity having only four years left if the bees were to die out has entered public consciousness; indeed, while carrying out this research project, many people told me of their concern at having recently heard this comment in media coverage about pollinator decline. There is growing scientific awareness, and media coverage, of the catastrophic challenges to insect life, and the potential wider impact of this decline (Hallmann et al., 2017; Sánchez-Bayo and Wyckhuys, 2019). However, the appropriate response to this systemic threat is still misunderstood. Many interviewees commented on the recent surge in grants and projects to support landscape enhancement for pollinators. Such projects should exemplify a healthy fusion of scientific and practical beekeepers' knowledge into constructive policy responses. It is broadly established that lack of forage creates serious challenges to honey bees and other pollinators (Naug, 2009; Wood et al., 2015). This has resulted in many attempts to increase forage availability, whether through agri-environment schemes, distributing packets of wildflower seeds to schoolchildren and the general public, or encouraging gardeners to grow pollinator-friendly plants (Shackleton and Ratnieks, 2015). However, interviewees note with concern and frustration that these are often enacted in ways that are at best benign, and at worst can actually lead to the destruction of excellent pollinator, and wider wildlife habitat. Similarly, the scale of such efforts is questioned, with many interviewees seeing them as far too small and disconnected to make a significant impact:

> *… the little measures they are doing-they think they might have a little corner, just a tiny little corner of, you know, 5' x 10', and they think by putting in loads of particular bee friendly plants they - that they have done their job. In the whole scheme of things, that is negligible, you know? (EC)*

It was observed that the environment could be improved by a shift in emphasis and values in consumer expectations:

> *All sorts of things follow from having a policy that puts the environment first. One of my sayings was 'bring back maggots in our mangoes'! Because when we buy mangoes, and we all do, they're all maggot free. Now when we lived in India and Nepal, every mango had a maggot in it. But Tesco's demands no maggots. So we export our pollution to all the countries that grow our mangoes. (RB)*

There are contrasting perspectives that emanate from different values, and manifest in the food system and the agri-environment. Beekeepers' views on sprays and the food system can be considered in the wider context of their self-professed shift in environmental perception. All interviewees emphatically self-identified as environmentally concerned and aware, and ascribed this awareness as inherently linked to their beekeeping practice. Many articulated a pragmatic concern about bees and other pollinators within the wider anthropogenic 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. (PA)*

It was not just a matter of specific facts which beekeepers held that they wished to pass on to others, but a wider sense of environmental sensitivity and engagement, from which pro-environmental behaviours could then arise. We see beekeepers enacting their hybrid knowledge, which combines experience of high bee mortality as a result of chemical spray exposure, with a set of wider environmental values that goes beyond simply observing facts and incidents. TEK systems are often associated with shared environmental values, as well as an openness to incorporating scientific and technological developments (Berkes et al., 2000; Inglis, 2004; Royer et al., 2013). Similarly, beekeepers' TEK engages with, and uses scientific knowledge when appropriate, yet situates this information into a cultural and ethical framework where assessments and decisions are made based on both scientific understandings, and underlying values.

6.5: Conclusion

This chapter has investigated both the communications between beekeepers and the traditional pollinator health stakeholders of scientists and policy-makers, as well as beekeepers' perspective on recent shifts in the public and media awareness of, and response to, pollinator decline. Archival records depict early communication networks between scientists and beekeepers as quite constructive, albeit framed within a singular quantitative approach which is now recognised as potentially limiting the capacity of Citizen Science projects to maximise participants' contributions. In contrast, beekeepers interviewed for this thesis present themselves as holding high levels of scientific literacy and engagement, which is severely underutilised within much of the current research on bee health. Similarly, information, observations and concerns of beekeepers often struggle to be investigated, and legitimised, within the dominant paradigm which prioritises investigating singular causality, and struggles to address multifactorial environmental complexities. We also see that policy-makers' willingness and capacity to act upon beekeepers' contributions and concerns has a long history of limitations, which have intensified as the challenges to pollinator health have grown increasingly complex, and embedded in wider political and economic systems. Beekeepers hold detailed hybrid knowledge, which, like many TEK holders, is processed, enacted and communicated through a network of values and perceptions. These values are not always shared by other publics, which creates further challenges to the capacity to communicate and share their knowledge:

> *If you could just persuade people that it doesn't actually matter if the roses have aphids! (PHF)*

A preference for relying on particular forms of evidence on which to develop environmental governance results in difficulties incorporating the knowledge and concerns of beekeepers. The potential for beekeepers, and other informed stakeholders, to improve the environment on behalf of pollinators is complicated due to the wide range of social, economic and political pressures affecting land use. Adding to these pressures on successful environmental management is the challenge of public misunderstanding of ecological principles, and a tendency for significant scientific issues to be presented in diverse media forms in ways which generate limited, or inappropriate wider responses from the wider public. While recent years have seen a dramatic increase in broad public awareness of problems with pollinator numbers and wellbeing, this is often not associated with a parallel increase in ecological understanding, or a willingness to engage with the wider systemic factors exacerbating pollinator decline, and other manifestations of current environmental crises.

This has been the final empirical chapter. The next chapter will conclude this thesis.

Chapter 7: Conclusion

This research project was inspired by wider scientific, policy and public concerns about pollinator decline. This is an issue of great significance, and one manifestation of what is recognised as the Sixth Great Extinction. We are living in an era of species loss not seen since the end of the Late Cretaceous Period, 66 million years ago. It is right that this concerns a wide range of audiences. It is equally important that the responses to pollinator decline are examined, to understand their historical and current context, their efficacy, and the barriers to successful implementation of necessary remedies to this, and possibly other, contemporary environmental crises.

To conclude this thesis, I will briefly reiterate the key points surrounding pollinator decline, and the official valorisation of beekeepers in responding to this situation. I will note the contextual relevance of certain theoretical writings in human geography, before reflecting on the appropriateness of the methods chosen for this project in addressing the research questions. I will summarise the empirical findings within the relevant conceptual frameworks, before then discussing the wider overall implications of this work to pollinator decline, and other complex current environmental challenges.

Recent years have seen a dramatic global decline in both managed and wild pollinators. Due to concerns about the effect of this on food security and biodiversity, there has been a range of local and national policy responses to this decline, many of which specifically forefront the role of beekeepers. Our understanding of bee health is predominantly based in the life sciences, which have experienced a dramatic increase in research in recent years. Comparatively little is known about beekeepers' knowledge, and their potential contribution to understanding and reversing pollinator decline. The limited research which has been carried out on this community has generally focused specifically on their beekeeping practice. There has been a significant lack of research about their knowledge-making practices, their wider environmental observations, and their historical perspective and experience on engaging with other key stakeholders in pollinator health, such as scientists and policy-makers. This thesis set out to address these knowledge gaps, and investigate the potential for beekeepers' knowledge to contribute to efforts to reverse pollinator decline. The research aimed to answer the key questions of:

1. How long-term beekeeping practice generates distinctive knowledge of the environment, and other factors influencing bee health.
2. How beekeepers use their environmental knowledge in their beekeeping practice, and what other factors affect their capacity to act on this knowledge.
3. How long-term beekeepers see their knowledge as distinct from other stakeholders in pollinator health, and how they communicate their knowledge to scientists, policy-makers, and the wider public.

These research questions correlate to wider theoretical investigations of the knowledge of other communities, such as farmers, land-workers, and others regularly engaging with natural resources in their work or daily life. These practices often generate a wide range of tacit, experiential knowledge, which is used in resource management and responding to environmental change. The intuitive, iterative elements of this knowledge are frequently passed on through inter-generational transmission. This TEK – Traditional Environmental Knowledge - may or may not be used in conjunction with other forms of knowledge. The potential role of TEK in devising socio-ecologically resilient approaches to land and resource management has been noted, as has the existence of TEK in a diverse range of communities, and sources (Hernández-Morcillo et al., 2014; Olsson et al., 2004). Similarly, the broad capacity of diverse environmental publics, including amateurs and enthusiasts, in both monitoring and alleviating environmental challenges, has been found to have a high potential capacity, which is currently underutilised (Ellis and Waterton, 2016; Everett and Geoghegan, 2016). In contrast to the plethora of tacit and hybrid environmental knowledge held by a diverse range of communities, much of environmental monitoring, and subsequent policy responses to management and resolution of challenges, is based on evidence which is generated through scientific analyses. While such an approach aspires to rationality, neutrality and efficacy, this perspective may struggle to incorporate the knowledge and perspectives held by individuals and communities who are outside this formal realm of knowledge construction. Epistemological discrepancies prioritise the use of information generated according to methods which may be appropriate for assessing the safety of medications, but are not necessarily the most suitable for understanding complex environments, which are themselves the result of complex interactions between biophysical, social, political and economic factors (Suryanarayanan, 2013).

This thesis explored historical and contemporary knowledge-making practices of beekeepers, and how their resultant knowledge underpins their practice, as well as generating environmental understandings which are temporally rich, and spatially specific. Such qualities are analogous to TEK. This thesis made use of a range of under-utilised sources of empirical data, including previously unanalysed material from the Bee Farmers Association. These bulletins date back to the early post-war period of the 1950s, and include material written by practitioners who had kept bees for decades. As beekeeping has traditionally been taught via direct practical training with an experienced mentor, these writers had learned beekeeping in a pre-war landscape, before the radical changes in land management resultant from the rise of industrial agriculture. As current agricultural practices are noted as a threat to pollinators and other species, engaging with the knowledge and practices of these long-term beekeepers illustrates how communities respond to environmental change; this is a key aspect of understanding and cultivating resilience (Barthel et al., 2010; Folke, 2006). Other data sources included personal memoirs of people who had kept bees for decades, and histories of local beekeeping associations. These were accessed from the International Bee Research Association collection at the National Library of Wales, another hitherto underutilised source of data. Such material is recognised as having a rare capacity to provide insights into the local manifestation of climate change, which can then be communicated more effectively to the wider public (Primack and Miller-Rushing, 2012). This historical data was then analysed in conjunction with interviews of long-term beekeepers (over 20 years' experience) and participant observation at lectures, conferences and workshops. This resulted in a research project that explores beekeepers' knowledge of environmental patterns and changes, as well as their struggles and capacity to ensure the wellbeing of their bees in a changing landscape. These data sources also document a history of communications and relationships between beekeepers, scientists, policy-makers and land managers. These can inform current plans to incorporate the insights of beekeepers into contemporary efforts to reverse pollinator decline. These data sources were used to create a clear picture on how beekeepers create knowledge of the environment, and subsequently use this knowledge in their practice. They also illustrate historical successes, and barriers, to effective engagement with beekeepers' knowledge.

7.1: Empirical Reflections

The empirical data of this thesis served to address the three research questions listed above. Chapter Four investigated how long-term beekeepers learn their beekeeping practice, and about the environment. Data for this project shows beekeepers as highly inquisitive, and observant of the natural world. This is often a driving force behind them initially taking up beekeeping as a practice, which is subsequently enhanced through their beekeeping. The central role of personal experience is a key defining feature of their learning. This is emphasised as the basis of one's own practice, and important in deciding which sources one should engage with for advice and guidance. Data sources for this thesis had usually learned their practice from working with other experienced beekeepers. They emphasised the importance of this method of practical education as compared to seeing beekeeping as a skill that could be learned solely by academic study. These elements of learning through grounded practice, and passing on knowledge via intergenerational transmission, are characteristics which beekeeping shares with TEK systems. As data sources were all long-term beekeepers, this practical, tacit knowledge reflected temporally rich, spatially specific data on a range of physical factors. These observations are often recorded, and contain a high degree of relevant phenological information, on rainfall, temperature, and when various plants come in to bloom. Many respondents keep multiple apiaries, and are highly attuned to their difference qualities as bee habitat, although they are often only a short distance away from each other. This locally specific information is seen as highly important to successful beekeeping, with new practitioners encouraged to work with an experienced beekeeper in their area (Crane, 1999), who had developed their situated knowledge in parallel conditions. Although not all informants kept detailed written records, they were all highly sensitive to patterns and changes in the environment. Respondents noted the differences between areas which may appear to others as interchangeable, but to the experienced beekeeping eye, had significant differences which affected the wellbeing and productivity of their bees. This perspective on the environment led to many reporting seeing the environment in a completely different way from non-beekeepers, as they are continually assessing the environment in terms of its potential for bees. This changed perspective is highly significant. It is experiential, intuitive, and embedded in the landscape, resulting in a unique knowledge of local environments' potential, and challenges, for pollinators. While interviewees all emphasised the fundamental importance of learning through practice, their beekeepers was often underpinned by further training, and/or professional backgrounds in STEMM subjects. This leads to a distinctive perspective, and knowledge of the environment, which transcends any possible boundaries associated with its tacit nature. As well as heightening their own knowledge, it also resulted in a sceptical approach to research on bees and the environment which contradicted their own experience, which, on a practical level, is prioritised.

While there are clear patterns of repeated practices generating actionable knowledge about the environment in which they keep their bees, it was also clear that beekeeping leads to wider changes in an individuals' environmental perspective:

> *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. (EC)*

This change in outlook is highly significant, and variations on this theme were universal throughout interviewees. Beekeeping is consistently described as a skill that is learned through practice and observation, which results in a changed engagement with the environment. An embodied knowledge is generated which transcends binaries: 'mind is body, consciousness is corporeal, and thinking is sensuous' (Carolan, 2008a). This multisensory environmental knowledge is utilised in environmental field studies, yet is structurally devalued in the majority of research on bee health, which conforms to an epistemological framework that emphasises neutrality and repeatability (Suryanarayanan, 2013; 2016). In contrast, TEK systems frequently blend ways of knowing, and responding, to the wider environment, accepting that our engagement with the natural world is fluid and responsive, and requires a capacity to adapt to changing complex situations. This fundamental difference in environmental knowledge can lead to challenges for other epistemological forms to be fully recognised in regulatory systems based on objective evidence.

As beekeepers are quick to point out that theirs is 'a broad church', their universal admission of beekeeping impacting their awareness of the environment generates a distinctive collective identity that is manifest in beekeeping organisations. While beekeeping is a highly personal, individual practice, civil society organisations (CSO) play multiple roles. They are a shared social space for individuals with shared interests, distinct from the wider populace and therefore reinforcing a sense of shared identity in an occupational sub-culture. This sense of identity is noted as a key feature influencing how individuals engage with the environment (Hinrichs, 1998; Wynne-Jones, 2013). CSO are also central for disseminating information, and were an important source of data for this project. These often note an awareness of challenges to bees' health and productivity before their formal recognition by other key stakeholders, such as scientists or policy-makers. Beekeepers' CSO serve multiple roles, as both a space for sharing relevant information, and serving as a collective voice in efforts to protect their interests in a wider physical and political environment that has grown increasingly problematic for bees and other pollinators. This historical record of beekeepers' engagements with other stakeholders should serve as guidance for current efforts to incorporate beekeepers' knowledge into current policy; it is hoped that this thesis has made a contribution to facilitating a more effective engagement with beekeepers' environmental knowledge.

Chapter Five investigated how beekeepers utilise both their practical experiential knowledge, as well as their understanding of scientific issues relevant to their bees, when making management decisions. There are key challenges to bees that are recognised by beekeepers, and scientists; namely, forage quality and quantity; agrochemical exposure, climate change, pests and introduced species (Potts et al., 2010; Sánchez-Bayo and Wyckhuys, 2019). Data for this project suggests varying levels of success at managing these challenges, albeit with a near-universal refrain that beekeeping is fundamentally more difficult than it was in the past. Interviewees often reported it being possible to successfully practice 'let-alone beekeeping' in the past, which was hands-off, and allowed a beekeeper to simply harvest honey at the end of the season. The current synergistic negative impacts of diseases, forage loss, agrochemical risks and changing weather patterns means that beekeeping today requires a far higher level of monitoring and intervention on the part of the beekeeper. Respondents also note that conditions are notably different in various parts of the country, due to different agricultural practices. The popular refrain of 'the bees are dying' is questioned by some, who note that bees are comparatively successful in areas where there is limited industrial agriculture. This is in flux in urban areas, where a rapid rise in beekeeping, often by untrained individuals who lack a reliable source of mentoring in local management, is leading to both pressure on limited forage sources, and a rise in disease and pests, due to increased pollinator densities.

The current emphasis on training beekeepers is understandable in the context of the sudden influx of newcomers to this hobby, and the oft-repeated emphasis on the importance of understanding what one is observing, in order to respond to challenges, and plan one's practice. However, the results of Chapter Five make clear that a lack of knowledge is not always the sole impediment to successful beekeeping. Interviews, memoirs and archives illustrate that long-term beekeepers are highly knowledgeable, and often managed to negotiate serious challenges, such as varroa, with high levels of personal success. What is clear throughout all the data is that knowledge is not always enough. Improving training for beekeepers is certainly important, as it equips individuals to recognise disease in their colonies. However, there are other, broader situated challenges to bees, which require responses above and beyond that of the individual beekeeper. There are inherent difficulties of maintaining working relationships with all land managers whose plants or crops may be possible forage for one's bees, due to the foraging range of bees. This makes the current policy emphasis on developing beekeepers' management skills unusual at least, and symptomatic of an individualised, deregulated approach to risk management that is a characteristic of neoliberalised food systems, yet challenges successful environmental governance (Harrison, 2008a). This thesis has found that beekeepers' knowledge is actionable, and successful, only insofar as it does not encounter serious structural, or climatic obstacles which are beyond the individual beekeepers' control. While many factors can be managed by the beekeeper, several significant factors cannot. These rely on the response and engagement of other stakeholders.

The final empirical chapter built on the preceding investigation of how beekeepers use their hybrid environmental knowledge. While chapter five focused on the individual manifestations of this enactment, this chapter focused on beekeepers' wider communication with other stakeholders, and contextual enactment, of their knowledge. Archival material shows several important points in beekeepers' communication with both the scientific, and the policy communities. The current drive to engage with beekeepers to understand pollinator decline has clear historical precedent, as beekeepers have been working with scientists, and policy makers, for decades. However, these historical links have often been limited, and/or challenged by wider systemic factors that failed to be resolved by dialogue with beekeepers. While beekeepers were often the first to know the effect of varied agrochemicals, and provided key evidence of these effects, this information did not always lead to a timely, or complete, regulatory response. Such challenges to incorporating the knowledge and concerns of TEK holders are common in the relationship of TEK to policy reaction and implementation, as TEK holders and communities are often peripheral to dominant hegemonies (Nadasdy, 2005). Beekeepers are but one of many stakeholders in pollinator decline. Data for this thesis illustrates decades of tension between beekeepers and land managers. While this is often successfully managed on an ad-hoc, individual basis, this illustrates one of many contradictions between the fate of managed, and wild pollinators. By a deep, qualitative engagement with the experiences of beekeepers, we can make better use of their knowledge on behalf of other pollinators.

There is also clearly a new and dynamic force in pollinator wellbeing, and that is the wider public. Pollinator decline, and, in particular, Colony Collapse Disorder, has generated an enormous amount of public concern and media coverage, which has stimulated a dramatic increase in new beekeepers. This has stretched the traditional teaching structure of beekeepers' organisations. For centuries, beekeeping has been taught via personal relationships, where new beekeepers work with an experienced mentor, as they learn this tacit, intuitive craft. The disproportionate influx of new practitioners, coupled with a rise in published literature and online forums, is changing how people learn about bees, and the wider environment. Data for this thesis noted the centrality of local, situated, iterative analysis underpinning beekeepers' practice, and their environmental knowledge. This multisensory engagement is associated with a broader environmental knowledge, which can support measures to understand, and enhance the environment. It is unclear what effect, if any, will result from a new approach to learning beekeeping which emphasises a generic, formal approach to knowledge acquisition. As this thesis specifically focused on individuals with decades of experience, it did not explore the knowledge of those who had learned via a relatively new approach to learning beekeeping. This is a question for a follow-up study.

This thesis has made significant preliminary findings on beekeepers' TEK, and its potential contributions to environmental understanding and improved management on behalf of bees and other species. It has also noted some of the potential challenges of excessive reliance on beekeepers' perceptions of the environment, as there can be an element of unenlightened self-interest underpinning beekeepers' views. The potential for bees to be managed in a way that transcends challenges to other pollinators and invertebrate species denotes a need to critically engage with beekeepers' knowledge. The heterogeneity of beekeepers' knowledge, and practice, also warrant further investigation in future study. This could possibly generate further insights into discrepancies within beekeepers' environmental knowledge, and how to address such internal contradictions when using beekeepers' knowledge in wider environmental management.

Beekeepers interviewed for this thesis note a lack of wider environmental understanding amongst the general public that hinders efforts to alleviate pollinator decline. While the surge in efforts to 'save the bee' may appear to demonstrate a concerted public desire to act constructively on behalf of pollinators, data from this thesis suggests that current knowledge, and efforts, are often superficial and tokenistic. It can be argued that such gestures are actually worse than doing nothing at all, as they can lead people to believe that action has been taken to rectify a problem, when, in actuality, nothing of significance has taken place. Beekeepers consistently expressed frustration with highly visible, yet ultimately inconsequential, efforts to 'do something' for bees. There is also the question of scale, and location, of such efforts. The main drivers of pollinator decline include loss of forage and habitat; agrochemical usage in industrial agriculture, diseases, and climate change. The recent surge in urban beekeeping may have some direct and indirect benefits: as humans are increasingly living in urban areas, their role as places of both biodiversity, and food production, should not be underestimated. However, the feel-good factor of a hive in an urban allotment will do little to arrest pollinator decline in our primary food producing areas. It will also fail to address the challenge climate change presents to all pollinator species.

Like any thesis, the empirical results summarised above must be interpreted with some caution. Every research project has limitations, and this one is no exception. Data for this project consisted of archival and secondary data, participant observation, and semi-structured interviews. A representative selection of material from the extensive collection at the National Library of Wales was analysed to create a historical picture of beekeepers' environmental knowledge. Analysing more material may have added further elements to this project. Participant observation was useful in and of itself, and as a way of making contact with potential interviewees. Articles in national beekeeping magazines requested individuals to volunteer to be interviewed for this project. Both these methods run a risk of self-selection, as not all beekeepers attend conferences, or read magazines, or will be driven to respond to a request for research participation that is printed in a magazine. However, as many of the respondents held notable positions in wider beekeepers' civil society organisations, their individual responses took on an added weight in terms of generating an understanding of beekeepers' knowledge and experiences.

As several participant observation experiences involved attending meetings with entomological researchers whose data sets numbered in the tens of thousands, there were times when this thesis seemed an insignificant contribution to understanding pollinator decline, as it worked with the type, and quantity of data normally associated with a thesis in human geography. However, it was important to focus on the fact that this research project offers a new perspective on pollinator wellbeing and decline. It has engaged with an unusual community of environmental practitioners, which is currently undergoing significant demographic change, and challenges to its practice. This thesis provides a detailed snapshot in time, creating a benchmark of human geography's contribution to understanding and addressing pollinator decline. This chapter will conclude with a discussion of the wider significance of these empirical findings.

7.2: Wider Significance of Results

Current policy responses position beekeepers as key stakeholders in what should be a concerted effort to redress the challenges to pollinator wellbeing. The common surveys of annual colony productivity and losses provide some important information, which should not be discounted. However, this fairly standard quantitative data belies the wealth of environmental information they can provide, which can support the drafting and implementation of pollinator policies, as well as inform wider environmental governance.

When beekeepers' contribution to pollinator protection is limited to their supplying rudimentary quantitative data, this precludes the benefits of their wider environmental observations. While skilled, successful long-term beekeepers may be able to practice successfully in a hostile environment, their refrain of beekeeping being harder now that it has been in the past bears important potential relevance to the plight of other pollinators. If beekeepers are to be positioned as primary stakeholders in policy efforts which aim to address all pollinators, it is important to interrogate beekeepers' knowledge to see what elements are of wider relevance to other pollinator species. Successful beekeeping often requires overcoming physical conditions which can be overwhelming for other species. Beekeepers may be successful as a result of their careful management of their bees. Empirical data for this project has shown that managerial practices have often changed significantly in response to environmental changes. These changes, noted by beekeepers, can enhance our understanding of the challenges facing other, non-managed pollinators. Honeybees can serve as an indicator species for understanding and monitoring the status of other pollinators (Kevan, 1999). The very fact that such alterations in practice are necessary has the potential to shed light on the changing conditions impacting other wild, non-managed pollinators. It is worth noting that beekeepers are aware that the potential success of their bee colonies may not reflect the ecosystem's viability for other pollinators. This is an issue where the difference between the ecological fate of managed colonies, versus that of wild pollinators, comes into question. Changing seasons create clear challenges for all pollinators (Brown et al., 2016; Brown and Paxton, 2009). Beekeepers' observations of these climatic variations, and subsequently changing the timing of management practices to ensure their bees' wellbeing, can serve as proxy information for the effects of climate change on other species.

While bees and other pollinators share many of the same needs, and face similar risks, there are important distinctions. These do not preclude the potential benefit of beekeepers' knowledge to supporting other pollinators; rather, it strengthens the argument for a deeper exploration of their environmental insights. This is currently not the case in most physical science research that generally positions beekeepers as basic data providers in the form of honey samples, and/or information on the status of their colonies, and the perceived reasons for colony losses.

While there are some possibilities for beekeepers to protect their bees from agricultural sprays, they are also well positioned to note the breadth of usage, and subsequent impact of such chemicals on other species who are outside of human management. Data from this project reflected a wealth of broad environmental awareness and knowledge in beekeepers, often with a temporal richness that is non-existent in other environmental analyses.

The dissonance between species is a key concern as scientific debates continue regarding the wellbeing of managed and wild pollinators, and the implications for ecosystem services and biodiversity (Senapathi et al., 2015). Monitoring wild pollinators creates significant ecological challenges as they are, by their nature, solitary. The ability to manage honey bees makes them ideally suited for scientific research. Beekeepers' observations and experience can often provide knowledge than can illuminate important aspects of ecosystem viability for other species that can all too easily be left out of scientific analysis, and public debate. There are many different species of pollinators, and it is widely acknowledged that managed honeybees can have environmental risks and challenges mitigated through anthropogenic management and attention. In contrast, other pollinators are at far greater risk due to challenges with monitoring their status, and the transferability of diseases between managed and wild pollinators (Dicks et al., 2013; Goulson and Hughes, 2015; Graystock et al., 2014). However, we must carefully reflect on how honey bees' status can, or cannot, serve as a proxy indicator for other species. This thesis has discussed how beekeepers often compare the contemporary risks of neonicotinoids as being more manageable than the more common sprays which neonics are designed to replace; thus, beekeepers often tolerate neonics, seeing them as a 'least worst' option. In contrast, there is a growing body of evidence surrounding the hazard neonics pose to other species and the wider environment. A deeper engagement with beekeepers' knowledge can illuminate points of enlightened self-interest, which may or may not benefit other species.

Research is increasingly addressing factors which have long been a concern for beekeepers; namely, synergistic relationships between common colony diseases and agrochemicals, and significant factors impeding bee health which are sub-lethal (Gibbons et al., 2015; Little et al., 2016; Sanchez-Bayo et al., 2016). While this increased scientific attention towards engaging with the complexity experienced by beekeepers is to be welcomed, this should be done with caution. Ultimately, there will still be limits to the range of synergistic factors that can be tested; this limit will be far below the number of factors experienced in the field. And, such an approach is still prioritising the epistemic framework based on controlled, repeatable, experiments. This limits the potential for engaging with the insights, and concerns, of beekeepers and other land users. By framing beekeepers as providers of comparatively simplistic data, their capacity is limited from the outset. While beekeepers can contribute an increase in data quantity that can enhance our environmental understanding, we will benefit more from also addressing the different quality of much of beekeepers' knowledge.

Beekeepers' phenological observations are an underutilised form of contextual knowledge of how climate change manifests on a local scale. Communicating the current and future hazards of climate change is problematic, as humans relate to their local experience, and struggle to engage with broad, global events (Hulme, 2010). By providing locally situated information that people can relate to, beekeepers' knowledge can contribute to successfully communicating the reality of climate change. The temporal richness of beekeepers' knowledge also enables us to investigate issues of shifting baselines, and questions of what is 'normal' in weather patterns, and phenological responses. As new beekeepers are often learning through books and online fora, locally specific patterns can be overlooked, or forgotten.

There is a risk of assuming that more and/or better beekeepers can arrest the crisis of pollinator decline. This will not necessarily address wider challenges to biodiversity, which is the environmental context of pollinator decline. These issues are also highly relevant to understanding our current and future food system. New challenges to bees will result in new challenges to our food system. Similarly, if a changing climate impacts food production and changes in crops that are grown, this can have an impact on both the forage that is available for bees, and possible agrochemical use by farmers to manage pests that may arise in a new climate.

Aside from discrepancies in the potential for risk management, current methods of engagement with beekeepers tend to overlook the wider contextual information they hold, as well as their experience and understanding of structural challenges to biodiversity. Like other TEK communities, beekeepers' knowledge has political implications that cannot be assessed via the methodologies of evidence-based policy making (Nadasdy, 2005). This thesis has found a history of beekeepers lobbying politicians in an effort to bring about structural regulatory responses to a range of threats to honey bees, and other species. Such responses have often been slow, or inadequate.

Both empirical data for this thesis, and wider theoretical discussions of TEK, and Citizen Science, highlight key challenges to successfully utilising beekeepers' knowledge in efforts to halt pollinator decline. Although beekeepers often took part in CS projects, they reported that those which they felt were most successful were those which incorporated an element of co-design from the outset, thus facilitating a deeper engagement with beekeepers' knowledge throughout all stages of research. However, their knowledge faces many of the epistemological challenges faced by others whose knowledge is not always generated via politically sanctioned methodologies. This can sometimes lead to challenges and frustration, as scientific information, and advice based on scientific research, may be contradictory to beekeepers' experiential knowledge and observations (Suryanarayanan, 2013; Suryanarayanan and Kleinman, 2013). Beekeepers engage with scientific research, and may bring a highly scientific, analytical approach to their own practice, but ultimately rely on an intuitive interpretation of environmental factors which may affect their bees (Maderson and Wynne-Jones, 2016). Scientific research is often seen as interesting, but of comparatively nominal relevance to the actual situated practice of beekeeping, which requires, and emphasises, experiential knowledge (ibid). Such tensions have resulted in questions on the legitimacy of expertise (Whatmore, 2009). The very nature of evidence-based policy, and its reliance on scientific data, is being re-examined as a result of a disconnect between experienced complexities, and a current positioning of science as removed from wider factors that influence practical decision-making (Saltelli and Giampietro, 2017).

One of the entomological researchers mentioned earlier expressed deep scepticism on the potential for him and his colleagues to contribute to a reversal of pollinator decline. 'We've been working on this for 25 years, and nothing has changed'. This thesis suggests that this is possibly due to the decontextualised, limited focus of their analyses. While recent years have seen a massive increase in knowledge about the microbiology of bees, and their biochemical response to a range of environmental hazards, research carried out for this thesis has found a radically different form of knowing bees and other pollinators, where environmental observations are embedded in a duty of care, and a profound empathy with bees, which affects one's whole outlook. Much of the emphasis on beekeepers in pollinator policies notes their role as custodians of honey bees, which is seen as important for food security, and biodiversity. However, this thesis argues that their contribution can be far greater, if we move beyond reliance on their providing quantitive data, and create an epistemological space for their wider concerns and observations.

Currently, evidence based policy prioritises knowledge that has been generated via reductive analysis, which is decontextualised, neutral and relevant to all situations. In contrast, beekeepers' knowledge is highly specific, rooted in specific locality, and is often imbued with a wider empathetic engagement with bees and the environment. Such knowledge does more than address a lack of facts that can be transferred to other stakeholders to address their relative information deficit. Rather, it valorises the emotional stewardship that is associated with their knowledge. Knowing is not a compilation of isolated actualities for beekeepers; the facts manifest in a highly complex wider environment. Debates surrounding conservation efforts recognise that to support and enhance pro-environmental behaviour, it is necessary to both understand, and engage with, individual and community values and behaviours. Such a perspective challenges our current systems of environmental governance. Are we to simply teach people facts, or aim to cultivate a more visceral connection between people and their wider environment? A tendency to rely on a materialistic understanding has been shown to overlook the complex, multidimensional nature of contemporary environmental problems, as well as the ethical and political challenges of representative decision-making (Carolan, 2008b). The shortcoming of a solely academic, unemotional analysis of environmental degradation is discussed in McCarthy's *Moth Snowstorm:*

> *…" Far-reaching images, such as the Anthropocene and the Sixth Great Extinction are, help us register the true degree of the planet's predicament and the real magnitude of the processes we have set in train which may bring about our ruin. They are of enormous value. They are talked about daily. Indeed, they are generating an academic industry on their own. But they do not necessarily convey the immediacy and astringent character of environmental loss, which in every case, somewhere along the line, involves hurt. If loss of nature becomes a sort of essay subject, we miss its immediacy; we may lose sight of its sadness and its nastiness, its sharp and bitter taste, the great wounding it really is." (McCarthy, 2015, p 65)*

Accurately understanding the environment, and responding to current crises, requires a transdisciplinary perspective. Pollinator decline has multiple drivers, many of which are anthropogenic. If our resultant analysis of rates of decline overlooks a full engagement with those stakeholders best placed to assess the situation, we will find ourselves collecting an ever-increasing mass of quantitative data recording the demise of species, but doing little to counteract the extinction. Beekeepers' sensitivity towards other species, and the resultant change in their behaviours, echoes debates on how best to alleviate environmental harm. Research on climate change has noted that cultivating pro- environmental behaviours cannot be achieved by assuming that there is an information deficit which must be overcome. Rather, people's environmental values are central to this (Corner et al., 2014). Beekeepers show themselves to hold an immense amount of factual environmental knowledge – but this is inextricably linked with a sensitivity to their wider environment, which results in them 'seeing like a bee'. They have moved beyond stewardship, and embody the complex sensitivity of their bees.

This thesis expands our knowledge of possible methods to counteract damaging Global Environmental Change, by a rich description of a hitherto overlooked community. The use of both historical and contemporary data evidences the structural barriers faced by beekeepers as they work to keep their bees safe from harm. If we attempt to use their knowledge in current efforts to arrest pollinator decline, without acknowledging previous historical shortcomings, we are doomed to repeat a failed approach. Most respondents had critical observations on the industrial food system, and saw it as inherently challenging to pollinators. Historical and current data highlights a failure for beekeepers' critical observations of wider food systems, and economic systems, to be fully engaged with by policy-makers. Using oral histories to understand changes in land use and farming practices provides an opportunity for researchers to maximise the potential of the contextualised knowledge of land users. Changes in land management practices, and the driving economic and political forces behind such changes, are difficult to extrapolate from quantitative data collection, but can be investigated in interviews, and archival analysis.

Concluding a research project is always challenging, as the research is reviewed through the clear lens and illumination of hindsight. Unasked questions and unexplored avenues appear paramount – but must be left for future studies. The abundance of previously underutilised data sources holds a potentially fertile avenues of exploration. As has been noted in discussions of combining TEK and scientific knowledge, TEK can be seen as a rich source of hypotheses for investigation (Moller et al 2004). This has been noted in Chapter 6 as already happening, with bee farmers collaborating with researchers to investigate CBPV. This thesis notes many other possible future studies which could be carried out using beekeepers' TEK, with or without additional scientific knowledge contributing to the analysis. This thesis noted a common trend for beekeepers to collect phenological data, particularly in its relation to bee health and productivity. Given the increasing global concern surrounding species loss and climate change, such information could be highly relevant to future studies of the impact of climate change. The high level of scientific knowledge amongst many interviewees suggests a strong potential for future co-produced citizen science projects, investigating a range of factors relating to bee and pollinator health, land use, weather patterns and more.

This thesis has shown the potential benefits of engaging with the quantity of data held by beekeepers, which has previously been unexplored in the life sciences, and the limited social science research on beekeepers. There is also a distinct quality to beekeepers' knowledge, which emphasises the importance of experiential, situated, and temporally rich awareness. An intuitive, embodied knowledge of the environment underlies successful beekeeping, and generates a wealth of wider observations. As well as the quantity and quality of data being potentially rich for environmental understanding, this thesis introduces long-term beekeepers as a distinct knowledge community. Data for this thesis evidences the manifestation of TEK amongst older beekeepers, where long-term locally specific environmental trends and changes are observed and discussed, and knowledge is transmitted across generations (Agrawal, 1996; Berkes, 2004; Berkes et al., 2000; Inglis, 2004). There is often a link between the practice of beekeeping, and wider environmental values. These are characteristics shared with other TEK communities. TEK has been linked to socio-ecological resilient practices; it has also been found to face structural challenges in political spheres. The creation of knowledge in TEK communities follows methods which are not seen as valid within wider political spheres. Similarly, TEK communities are at the peripheries of dominant economic and political structures. This thesis has evidenced beekeepers' knowledge-making practices, shared values, and political challenges. Beekeepers' TEK has not previously been explored, in terms of its potential role in wider pollinator protection, or its historical, and contemporary, political barriers. It is hoped that this thesis has contributed to a greater appreciation of both the unique qualities of beekeepers' knowledge, and the allure of charismatic minifauna.

Appendices

Appendix 1: Article published in BBKA, WBKA and An Beachaire journals, inviting interviewees

Calling all long-term beekeepers!!

Researcher needs to hear from YOU!

By Siobhan Maderson, MSc

- *Have you kept bees for 20 years or more?*
- *Have you noticed changes in the environment, or weather, where you keep your bees?*
- *Do you feel government policies to support pollinators are having an effect?*

I am currently undertaking an Economic and Social Research Council (ESRC)-funded PhD to explore the environmental knowledge of beekeepers. This project builds on my MSc research on Food and Water Security, which showed that beekeepers generate unique knowledgeable about the environment, and hold important insights into the multiple factors interacting with, and impacting upon bees' wellbeing. My earlier research was based on interviews, and analysis of the Bee Farmers Association archives. This indicated that beekeepers often hold particular knowledge of late 20th/early 21st century agricultural, land-use and environmental changes, which often precedes formal recognition by scientific and policy-making communities. Recent years have seen a sharp increase in media coverage, public awareness and concern regarding pollinator decline. While much of the research into this decline has been centred on the life sciences, there is a growing recognition of the importance of tapping into specialist knowledge of groups such as the WBKA. During my PhD research I will be interviewing long-term beekeepers, and exploring the records they keep which relate to beekeeping and the environment.

I am, therefore, calling on readers who are interested in participating to contact me. I am particularly keen to speak with people who have kept bees for several decades, and with second or third generation beekeepers. Have you noticed changes in the environment or weather where you keep your bees? Do you feel Government policies to support pollinators are having an effect? There are many recommendations for individuals, local councils, farmers, and other land managers to improve the environment for pollinators. Do you see these recommendations having any impact on the area where you keep your bees? Do you feel the environment could be further improved for pollinators?

Your environmental observations, and views on pollinator policy, are central to my research.

I am very interested to examine the records kept and used by beekeepers; particularly records of weather, honey production and local agricultural and land-use changes. Since the mid-20th century, land-use, agriculture and weather have all undergone dramatic changes, which have had a powerful impact on bees. Your records are important to help understand local and wider trends in bee health and stability, and how beekeepers cope with environmental changes and challenges. Beekeepers' observations, and experiential knowledge of bees and the environment in which your bees forage can help assess the success and shortcomings of efforts to make the environment better for bees. I am interested to hear what long-term beekeepers believe is working for and against their bees' best interests, so I hope readers will contact me and participate in this research. All interviews will be confidential.

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Appendix 2: Original Interview Schedule

Personal and beekeeping background:

(Basic demographics: gender, age, apiary location)

How long have you been keeping bees? (*Who taught you? Did you have a family member who kept bees? Did you inherit hives / business from family member? How would you describe your bk – hobby? Sideline? Business?*

How many hives do you keep? Where do you keep them? How do you choose hive location?

Aim 1: To explore views, knowledge and records about bees

What records do you keep about your bees? *(Including diaries, photos, filmed recordings)* (*weather, Hive numbers, Honey production, Land use in the area, etc).*

If you have a question about your bees, and the environment they forage in, where would you go to get information? (*books, websites, friends, mentors)* Are there any sources of information that you choose to avoid?

Aim 2: To explore knowledge, and perceptions, of environment

How do you feel about the environment where you keep your bees? Has it changed during your time as a bk? (*land use change, planting*) If so, how? Could it be better for them? *(Better forage, weather, more sheltered, less competition from other beehives, etc) If so, how? Are changes likely, or not? Why or why not? (Environmental / political / economic / social)*

Does keeping bees influence your views of the environment? *Have you noticed any environmental issues (problems, improvements, or trends) where you keep your bees? Discuss*

Do you notice other animals / birds / insects when you are beekeeping? *Which ones? Have you noticed any changes in these other animals during the time you have kept bees?*

Are you a member of any environmental groups *(RSPB, Buglife, etc)*

Aim 3: To explore views on how to improve the environment for bees / pollinators

Could more be done to improve the environment for pollinators? If so, what? Do you think these changes will happen? *What is the best way to bring about an improved environment for pollinators? (Improved training? Raised awareness? Changes in legislation? Public pressure? Media pressure? Public interest groups?)*

In recent years, there have been several initiatives (*DEFRA healthy bee plan, WPAP)* developed to improve the environment for pollinators. :

- Do you see evidence of these efforts where you keep your bees? Anywhere else?
- What do you think of these initiatives?

(2014: DEFRA - *beesneeds 5 simple actions: Grow more flowers, shrubs and trees that provide pollen and nectar; leave patches of land to grow wild; cut grass less often; avoid disturbing or destroying nests; think carefully about whether to use pesticides.): Have you been involved with any policy initiatives relating to bees & pollinators..*

Aim 4: To explore views of, and engagement with, research projects and policies on bee health

As you are probably aware, there is a great deal of scientific research on bee and pollinator well-being, and the environment.

How much of this research is relevant to your beekeeping? To beekeeping in general? *Do you think they ask the right questions? Address the important issues? Do you feel they are in a position to make significant impact? If not, why not?*

Have you been involved with any research projects focused on pollinators? *(Citizen Science project? If so – which one? What information did they provide? Do they know what happened to that data? If so, did they feel it was well used?*)

Appendix 3: BBKA Hive Recording System

BBKA
Hive Recording System

Name

Aplary No:
Colony No:

Queen Breeding

Date of Visit	Q	QC	Brood	Stores	Room	Health	Varroa	Temper	Feed	Supers	Weather	Notes

BBKA Hive Recording System - Notes

- **Date** Date of the inspection
- **Q** Presence of the Queen
[✔ Queen seen, **X** Queen not found, **C** Queen clipped, **W,Y,R,G,B** Queen marked with appropriate colour code]
- **QC** Presence of Queen cells
[**x** = none seen, **10x** = 10 seen but all removed, **2L** = 2 seen and left alone]
- **Brood** State of the brood
[**e** = eggs seen, ✔ = brood pattern ok, **3** = brood covering 3 frames, **X** = no brood]
- **Stores** The quantity of stores available
[**10** = equivalent of 10 super frames available]
- **Room** The available space for the queen to lay eggs
[**5** = equivalent of 5 brood frames available]
- **Health** The state of the brood and adult bees
[✔ = all ok, CB? = Possible chalk brood, EFB? = Possible EFB, etc.]

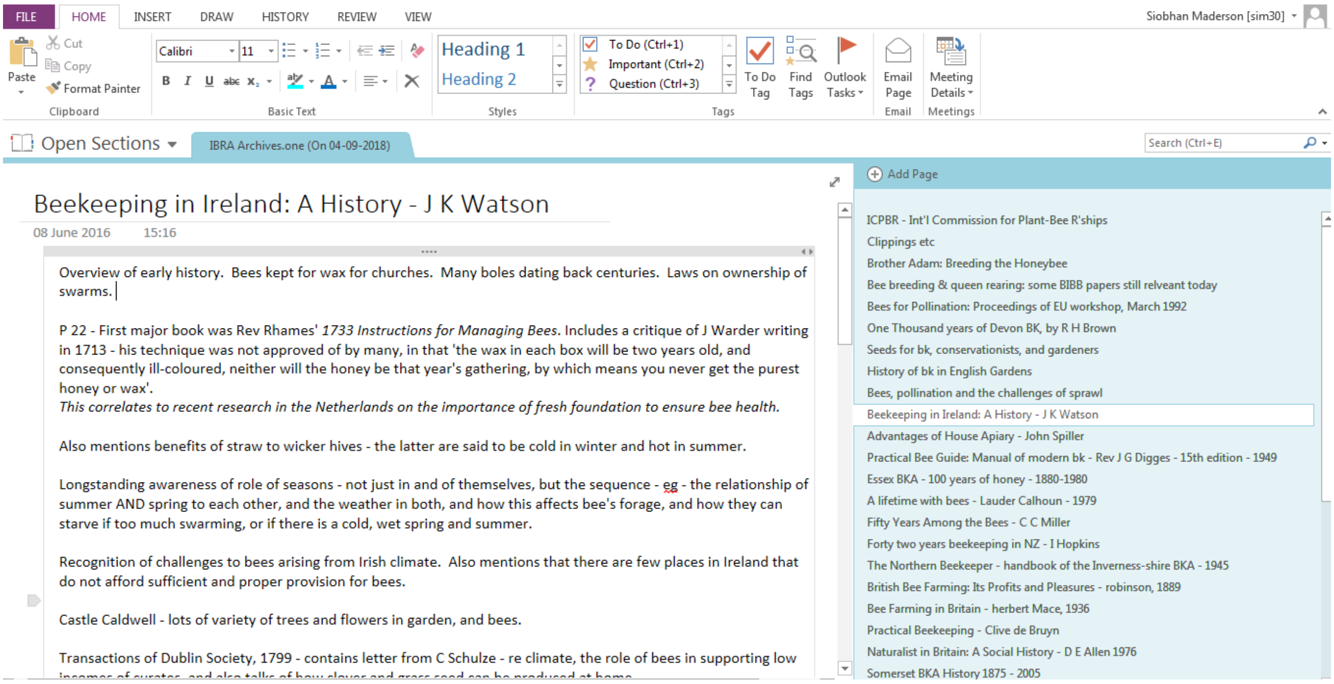
If you are not sure whether a disease is present, it is advised that you consult a more experienced beekeeper. If you think EFB or AFB may be present it is mandatory that you call the Appointed Bee Inspector.

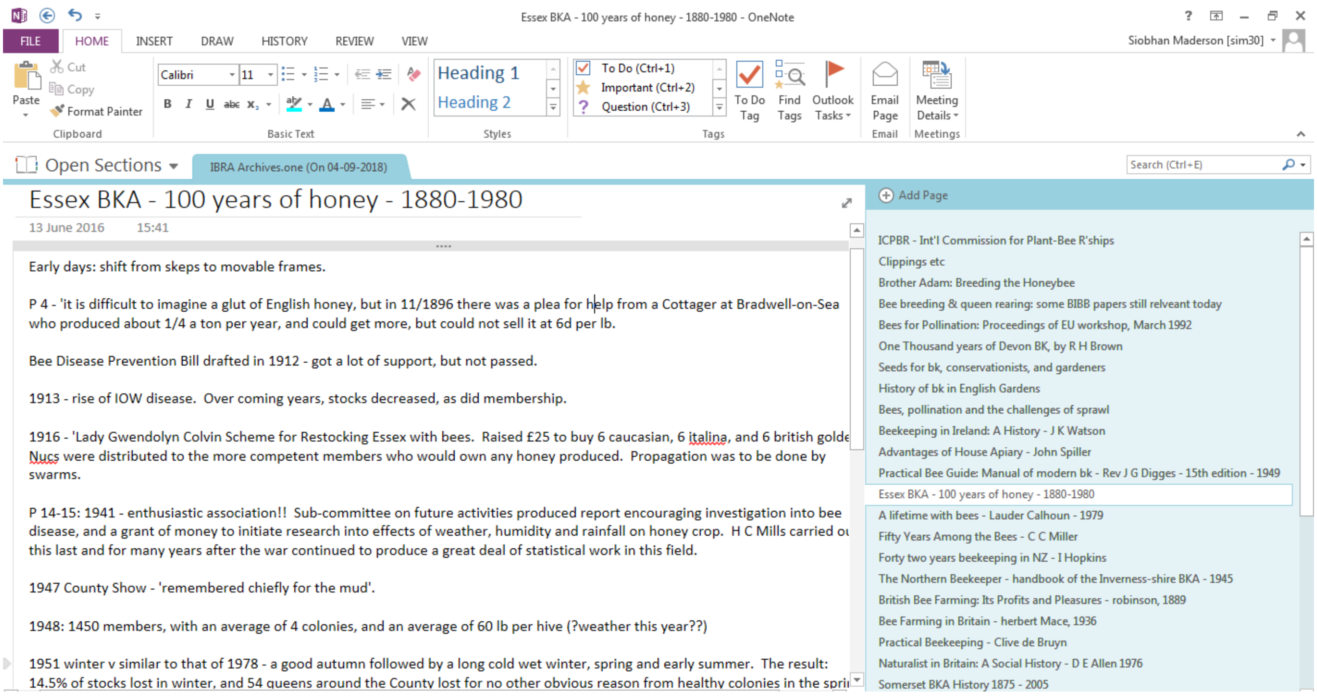
- **Varroa** The number of Varroa mites in colony
[**l,m,h** = low, medium or high, (say) 1000 = the estimated Varroa population in the hive calculated from natural drop, or other estimation methods].
It is recommended that the mite drop is checked regularly and a numerical value of the Varroa population estimated.
- **Temper** The docility of the colony
[**10** = nice calm bees, **8** = bees agitated, **6** = bees sting, **4** = bees that follow too much, etc]
- Feed How much feed given
[**2 LS** = 2 litres of light syrup, **1 HS** = 1 litre of heavy syrup, etc.]
- Supers How many supers removed or added
[**+1** = one super added, **-0.5** = 5 frames removed, etc]
- Weather The temperature and cloud cover
[**c** = cloudy, **s** = sunny, **r** = rainy, **f** = fair]
- Notes Anything of interest to add
[lot of propolis, brood box needs repair, etc.]

The examples given in brackets illustrate how a numerical scoring system can be derived. If the records are to be used for the Certificate in Beekeeping Husbandry the scoring system should be explained to the assessor.
Either metric or imperial units may be used.

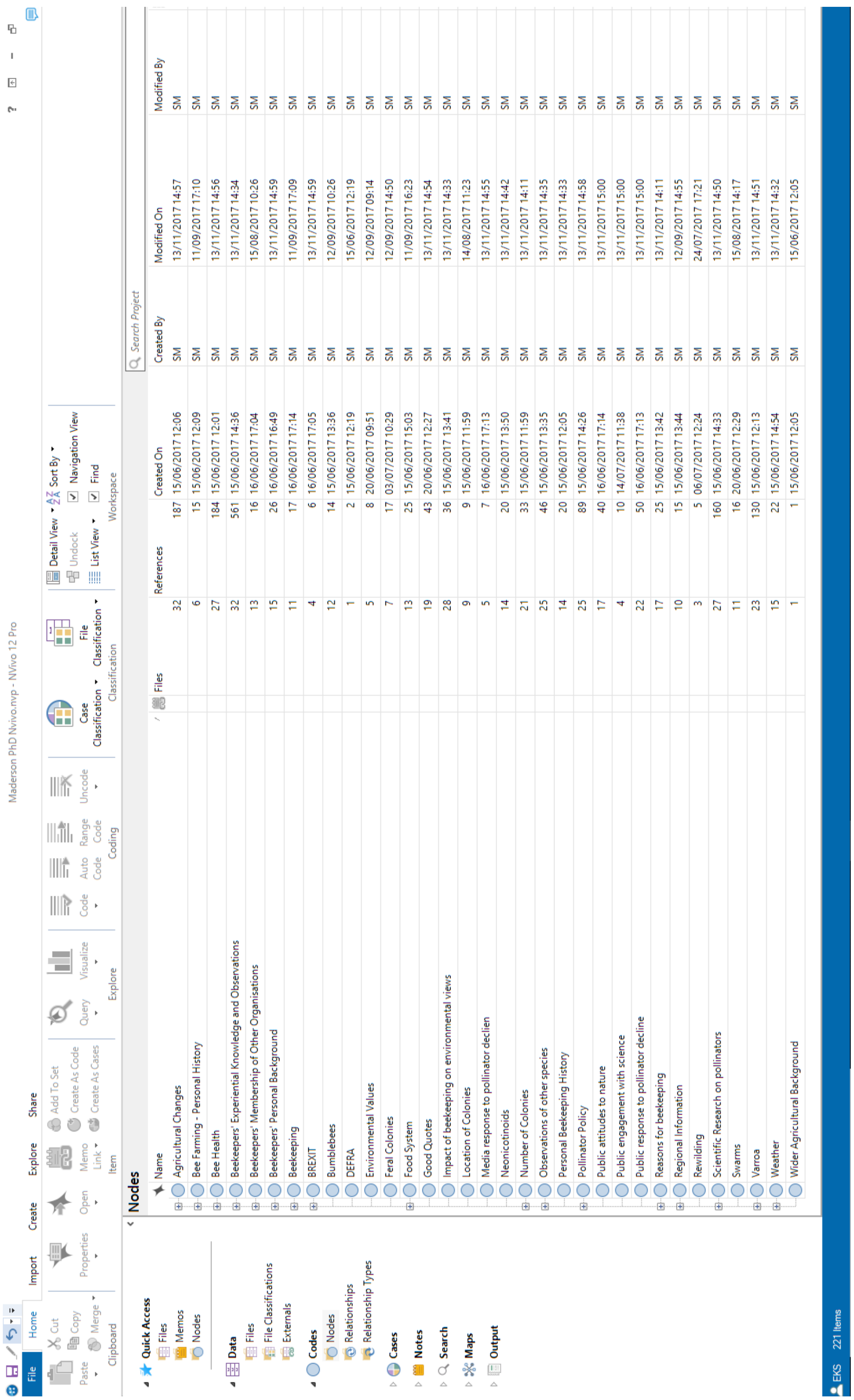
The headings marked in bold are important and must be maintained for the Certificate in Beekeeping Husbandry.

Appendix 4: Example Notes on the IBRA Archives

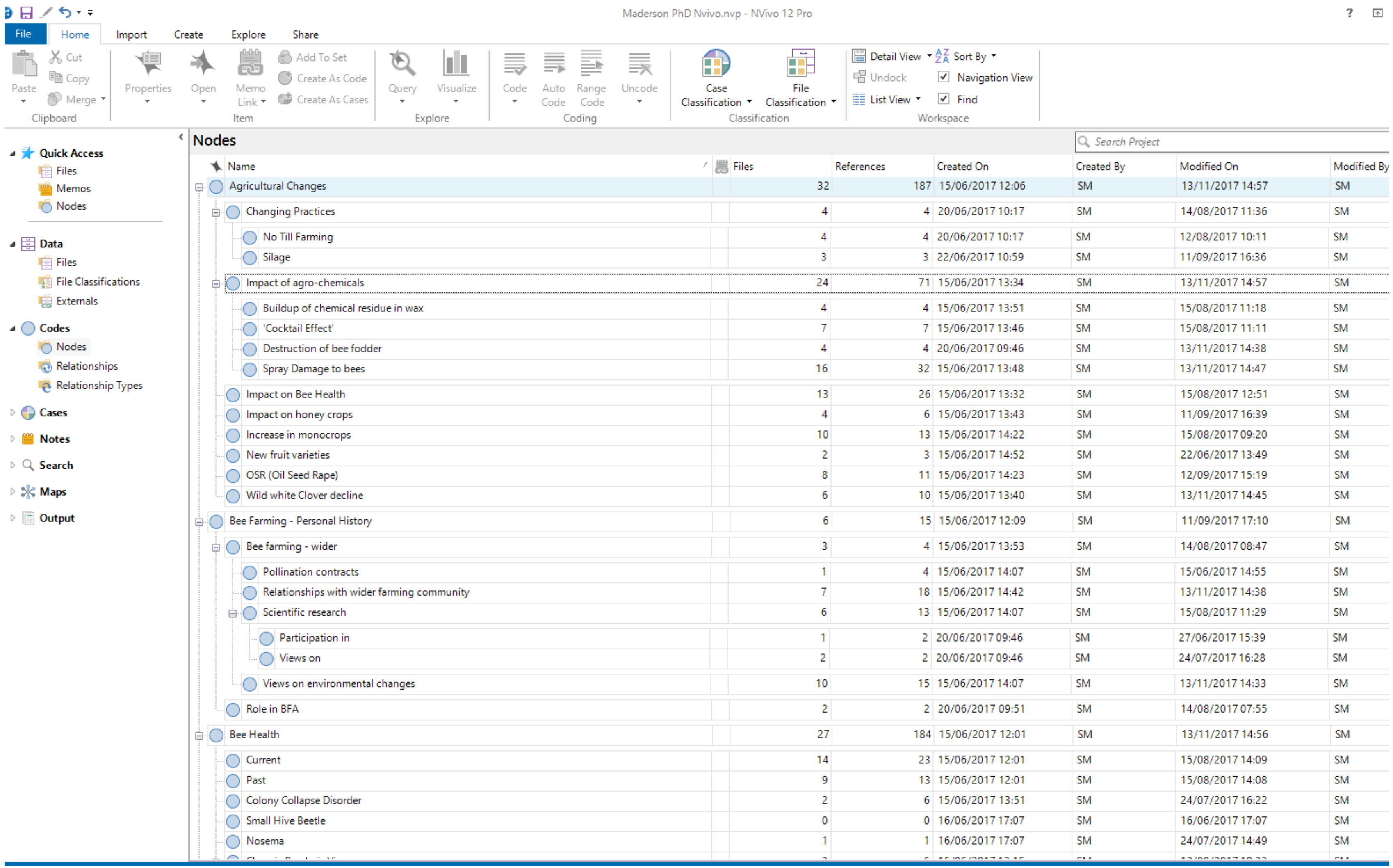




Appendix 5: Nvivo Nodes: All Parent, and examples of Child Nodes



Name	Files	References	Created On	Created By	Modified On	Modified By
Agricultural Changes	32	187	15/06/2017 12:06	SM	13/11/2017 14:57	SM
Bee Farming - Personal History	6	15	15/06/2017 12:09	SM	11/09/2017 17:10	SM
Bee Health	27	184	15/06/2017 12:01	SM	13/11/2017 14:56	SM
Beekeepers' Experiential Knowledge and Observations	32	561	15/06/2017 14:36	SM	13/11/2017 14:34	SM
Beekeepers' Membership of Other Organisations	13	16	16/06/2017 17:04	SM	15/08/2017 10:26	SM
Beekeepers' Personal Background	15	26	16/06/2017 16:49	SM	13/11/2017 14:59	SM
Beekeeping	11	17	16/06/2017 17:14	SM	11/09/2017 17:09	SM
BREXIT	4	6	16/06/2017 17:05	SM	13/11/2017 14:59	SM
Bumblebees	12	14	15/06/2017 13:36	SM	12/09/2017 10:26	SM
DEFRA	1	2	15/06/2017 12:19	SM	15/06/2017 12:19	SM
Environmental Values	5	8	20/06/2017 09:51	SM	12/09/2017 09:14	SM
Feral Colonies	7	17	03/07/2017 10:29	SM	12/09/2017 14:50	SM
Food System	13	25	15/06/2017 15:03	SM	11/09/2017 16:23	SM
Good Quotes	19	43	20/06/2017 12:27	SM	13/11/2017 14:54	SM
Impact of beekeeping on environmental views	28	36	15/06/2017 13:41	SM	13/11/2017 14:33	SM
Location of Colonies	9	9	15/06/2017 11:59	SM	14/08/2017 11:23	SM
Media response to pollinator declien	5	7	16/06/2017 17:13	SM	13/11/2017 14:55	SM
Neonicotinoids	14	20	15/06/2017 13:50	SM	13/11/2017 14:42	SM
Number of Colonies	21	33	15/06/2017 11:59	SM	13/11/2017 14:11	SM
Observations of other species	25	46	15/06/2017 13:35	SM	13/11/2017 14:35	SM
Personal Beekeeping History	14	20	15/06/2017 12:05	SM	13/11/2017 14:33	SM
Pollinator Policy	25	89	15/06/2017 14:26	SM	13/11/2017 14:58	SM
Public attitudes to nature	17	40	16/06/2017 17:14	SM	13/11/2017 15:00	SM
Public engagement with science	4	10	14/07/2017 11:38	SM	13/11/2017 15:00	SM
Public response to pollinator decline	22	50	16/06/2017 17:13	SM	13/11/2017 15:00	SM
Reasons for beekeeping	17	25	15/06/2017 13:42	SM	13/11/2017 14:11	SM
Regional Information	10	15	15/06/2017 13:44	SM	12/09/2017 14:55	SM
Rewilding	3	5	06/07/2017 12:24	SM	24/07/2017 17:21	SM
Scientific Research on pollinators	27	160	15/06/2017 14:33	SM	13/11/2017 14:50	SM
Swarms	11	16	20/06/2017 12:29	SM	15/08/2017 14:17	SM
Varroa	23	130	15/06/2017 12:13	SM	13/11/2017 14:51	SM
Weather	15	22	15/06/2017 14:54	SM	13/11/2017 14:32	SM
Wider Agricultural Background	1	1	15/06/2017 12:05	SM	15/06/2017 12:05	SM



Name	Files	References	Created On	Created By	Modified On	Modified By
Agricultural Changes	32	187	15/06/2017 12:06	SM	13/11/2017 14:57	SM
Changing Practices	4	4	20/06/2017 10:17	SM	14/08/2017 11:36	SM
No Till Farming	4	4	20/06/2017 10:17	SM	12/08/2017 10:11	SM
Silage	3	3	22/06/2017 10:59	SM	11/09/2017 16:36	SM
Impact of agro-chemicals	24	71	15/06/2017 13:34	SM	13/11/2017 14:57	SM
Buildup of chemical residue in wax	4	4	15/06/2017 13:51	SM	15/08/2017 11:18	SM
'Cocktail Effect'	7	7	15/06/2017 13:46	SM	15/08/2017 11:11	SM
Destruction of bee fodder	4	4	20/06/2017 09:46	SM	13/11/2017 14:38	SM
Spray Damage to bees	16	32	15/06/2017 13:48	SM	13/11/2017 14:47	SM
Impact on Bee Health	13	26	15/06/2017 13:32	SM	15/08/2017 12:51	SM
Impact on honey crops	4	6	15/06/2017 13:43	SM	11/09/2017 16:39	SM
Increase in monocrops	10	13	15/06/2017 14:22	SM	15/08/2017 09:20	SM
New fruit varieties	2	3	15/06/2017 14:52	SM	22/06/2017 13:49	SM
OSR (Oil Seed Rape)	8	11	15/06/2017 14:23	SM	12/09/2017 15:19	SM
Wild white Clover decline	6	10	15/06/2017 13:40	SM	13/11/2017 14:45	SM
Bee Farming - Personal History	6	15	15/06/2017 12:09	SM	11/09/2017 17:10	SM
Bee farming - wider	3	4	15/06/2017 13:53	SM	14/08/2017 08:47	SM
Pollination contracts	1	4	15/06/2017 14:07	SM	15/06/2017 14:55	SM
Relationships with wider farming community	7	18	15/06/2017 14:42	SM	13/11/2017 14:38	SM
Scientific research	6	13	15/06/2017 14:07	SM	15/08/2017 11:29	SM
Participation in	1	2	20/06/2017 09:46	SM	27/06/2017 15:39	SM
Views on	2	2	20/06/2017 09:46	SM	24/07/2017 16:28	SM
Views on environmental changes	10	15	15/06/2017 14:07	SM	13/11/2017 14:33	SM
Role in BFA	2	2	20/06/2017 09:51	SM	14/08/2017 07:55	SM
Bee Health	27	184	15/06/2017 12:01	SM	13/11/2017 14:56	SM
Current	14	23	15/06/2017 12:01	SM	15/08/2017 14:09	SM
Past	9	13	15/06/2017 12:01	SM	15/08/2017 14:08	SM
Colony Collapse Disorder	2	6	15/06/2017 13:51	SM	24/07/2017 16:22	SM
Small Hive Beetle	0	0	16/06/2017 17:07	SM	16/06/2017 17:07	SM
Nosema	1	1	16/06/2017 17:07	SM	24/07/2017 14:49	SM

Nodes

Name	Files	References	Created On	Created By	Modified On	Modifiec
Antibiotics and other drug treatments	2	3	24/07/2017 14:54	SM	15/08/2017 13:27	SM
Beekeepers' Experiential Knowledge and Observations	32	561	15/06/2017 14:36	SM	13/11/2017 14:34	SM
Treatment by scientific community	8	25	15/06/2017 14:36	SM	13/11/2017 14:31	SM
Treatment by policy-makers	5	6	15/06/2017 14:36	SM	15/08/2017 13:27	SM
Concerns about agricultural sprays	18	41	16/06/2017 11:26	SM	13/11/2017 14:57	SM
Land Use Changes	12	20	16/06/2017 17:02	SM	15/08/2017 14:18	SM
Councils cutting down trees	1	2	20/06/2017 15:09	SM	20/06/2017 15:49	SM
Decline in hedgerows	7	16	15/06/2017 13:37	SM	12/09/2017 10:02	SM
Decrease in gardens	3	4	20/06/2017 09:48	SM	15/08/2017 14:18	SM
Loss of Elm Trees	1	2	22/06/2017 13:54	SM	22/06/2017 13:55	SM
More houses and buildings	6	11	20/06/2017 09:48	SM	15/08/2017 14:18	SM
Municipal plantings	2	3	20/06/2017 15:48	SM	29/06/2017 15:16	SM
Agricultural Changes	13	24	16/06/2017 17:02	SM	13/11/2017 14:57	SM
grubbing out of fruit orchards	2	3	20/06/2017 09:47	SM	18/07/2017 13:47	SM
impact of heavy agricultural machinery	7	9	20/06/2017 09:47	SM	15/08/2017 12:51	SM
Increase in monocrops	6	11	20/06/2017 09:46	SM	12/09/2017 10:02	SM
Loss of Forage	13	32	20/06/2017 12:24	SM	13/11/2017 14:45	SM
OSR	9	11	20/06/2017 09:47	SM	12/09/2017 15:19	SM
Environmental Observations	32	362	15/06/2017 13:30	SM	13/11/2017 14:37	SM
Importance of wild areas for bees	8	15	20/06/2017 15:35	SM	12/09/2017 10:02	SM
Climate Change	2	2	22/06/2017 11:21	SM	03/07/2017 10:33	SM
Different ssp of bees	9	20	22/06/2017 13:57	SM	14/08/2017 09:42	SM
Different hive types	2	2	22/06/2017 13:59	SM	24/07/2017 14:02	SM
Questioning decline in bees and pollinators	1	4	14/08/2017 08:32	SM	14/08/2017 08:49	SM
Loss of habitat for bees	4	5	14/08/2017 08:56	SM	12/09/2017 10:02	SM
Beekeepers' Membership of Other Organisations	13	16	16/06/2017 17:04	SM	15/08/2017 10:26	SM
Beekeepers' Personal Background	15	26	16/06/2017 16:49	SM	13/11/2017 14:59	SM
Beekeeping	11	17	16/06/2017 17:14	SM	11/09/2017 17:09	SM
BREXIT	4	6	16/06/2017 17:05	SM	13/11/2017 14:59	SM
Bumblebees	12	14	15/06/2017 13:36	SM	12/09/2017 10:26	SM
DEFRA	1	2	15/06/2017 12:19	SM	15/06/2017 12:19	SM
Environmental Values	5	8	20/06/2017 09:51	SM	12/09/2017 09:14	SM

Bibliography

ACEVES-BUENO, E., ADELEYE, A. S., BRADLEY, D., TYLER BRANDT, W., CALLERY, P., FERAUD, M., GARNER, K. L., GENTRY, R., HUANG, Y., MCCULLOUGH, I., PEARLMAN, I., SUTHERLAND, S. A., WILKINSON, W., YANG, Y., ZINK, T., ANDERSON, S. E. & TAGUE, C. 2015. Citizen Science as an Approach for Overcoming Insufficient Monitoring and Inadequate Stakeholder Buy-in in Adaptive Management: Criteria and Evidence. *Ecosystems,* 18**,** 493-506.

ADAM, B. 1987. *Breeding the honeybee : a contribution to the science of bee-breeding,* Hebden Bridge, Hebden Bridge: Northern Bee.

ADAMS, E. C. 2016. How to become a beekeeper: learning and skill in managing honeybees. *cultural geographies,* 25**,** 31-47.

AGRAWAL, A. 1995. Dismantling the Divide Between Indigenous and Scientific Knowledge. *Development and Change,* 26**,** 413-439.

AGRAWAL, A. 1996. The cultural dimension of development: Indigenous knowledge systems - Warren,DM, Slikkerveer,LJ, Brokensha,D. *Development and Change,* 27**,** 582-583.

AGRAWAL, A. 2002. Indigenous knowledge and the politics of classification. *International Social Science Journal,* 54**,** 287-297.

AGRAWAL, A., ELLEN, R., PARKES, P. & BICKER, A. 2001. Indigenous Environmental Knowledge and Its Transformations: Critical Anthropological Perspectives. *The Journal of Asian Studies,* 60**,** 1123.

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**,** 1579-88.

ALAUS, C. & AL, E. 2010. Interactions between nosema microspores and a neonicotinoid weaken honeybees (apis mellifera). *Environmental Microbiology,* 12**,** 774-782.

ALTON, K. and RATNIEKS, F.L., 2013. To bee or not to bee. *Biologist*, *60*(4), pp.12-15.

ALL-IRELAND POLLINATOR PLAN 2015. All-Ireland Pollinator Plan 2015-2020. *In:* NATIONAL BIODIVERSITY DATA CENTRE (ed.). Waterford.

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. *Conservation Biology,* 12**,** 8-17.

ALLEN, D. 1976. The naturalist in Britain: a social history Allen Lane. London.

ALTIERI, M. & KOOHAFKAN, P. 2008. Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities. *In:* THIRD WORLD NETWORK (ed.). FAO.

AN BEACHAIRE 1997. *An Beachaire: The Irish Beekeeper: Golden Jubilee Edition, 1947-1997,* Ireland, An Beachaire.

ARIZA-MONTOBBIO, P., LELE, S., KALLIS, G. & MARTINEZ-ALIER, J. 2010. The political ecology of Jatropha plantations for biodiesel in Tamil Nadu, India. *The Journal of Peasant Studies,* 37**,** 875-897.

AXINN, W. G., PEARCE, L. D. & GHIMIRE, D. 1999. Innovations in Life History Calendar Applications. *Social Science Research,* 28**,** 243-264.

BAILEY, L. 1999. The century of Acarapis woodi. *American Bee Journal,* 139**,** 541-542.

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 Research and Management,* 32**,** 111-129.

BARRON, E. S., STHULTZ, C., HURLEY, D. & PRINGLE, A. 2015. Names matter. *Progress in Physical Geography: Earth and Environment,* 39**,** 640-660.

BART, D. 2010. 'Using Weed Control Knowledge from Declining Agricultural Communities in Invasive-Species Management', *Human Ecology*, 38: 77-85.

BARTHEL, S., CRUMLEY, C. & SVEDIN, U. 2013. Bio-cultural refugia—Safeguarding diversity of practices for food security and biodiversity. *Global Environmental Change,* 23**,** 1142–1152.

BARTHEL, S., FOLKE, C. & COLDING, J. 2010. Social–ecological memory in urban gardens—Retaining the capacity for management of ecosystem services. *Global Environmental Change,* 20**,** 255–265.

BARTOMEUS, I., PARK, M. G., GIBBS, J., DANFORTH, B. N., LAKSO, A. N. & WINFREE, R. 2013. Biodiversity ensures plant-pollinator phenological synchrony against climate change. *Ecol Lett,* 16**,** 1331-8.

BATARY, P., DICKS, L. V., KLEIJN, D. & SUTHERLAND, W. J. 2015. The role of agri-environment schemes in conservation and environmental management. *Conserv Biol,* 29**,** 1006-16.

BAUDE, M., KUNIN, W. E., BOATMAN, N. D., CONYERS, S., DAVIES, N., GILLESPIE, M. A., MORTON, R. D., SMART, S. M. & MEMMOTT, J. 2016. Historical nectar assessment reveals the fall and rise of floral resources in Britain. *Nature,* 530**,** 85-8.

BEAR, C. 2006. Salmon by numbers: quantification and understandings of nature. *Scottish Geographical Journal,* 122**,** 185-203.

BEEKMAN, M. & RATNIEKS, F. L. W. 2000. Long-range foraging by the honey-bee, Apis mellifera L. *Functional Ecology,* 14**,** 490-496.

BELL, S., MARZANO, M., CENT, J., KOBIERSKA, H., PODJED, D., VANDZINSKAITE, D., REINERT, H., ARMAITIENE, A., GRODZIŃSKA-JURCZAK, M. & MURŠIČ, R. 2008. What counts? Volunteers and their organisations in the recording and monitoring of biodiversity. *Biodiversity and Conservation,* 17**,** 3443-3454.

BENISTON, M., STEPHENSON, D. B., CHRISTENSEN, O. B., FERRO, C. A. T., FREI, C., GOYETTE, S., HALSNAES, K., HOLT, T., JYLHÄ, K., KOFFI, B., PALUTIKOF, J., SCHÖLL, R., SEMMLER, T. & WOTH, K. 2007. Future extreme events in European climate: an exploration of regional climate model projections. *Climatic Change,* 81**,** 71-95.

BENNETT, J. 2009. *Vibrant matter: A political ecology of things*, Duke University Press.

BENNETT, N. J. 2016. Using perceptions as evidence to improve conservation and environmental management. *Conserv Biol,* 30**,** 582-92.

BERKES, F. 2004. Rethinking community-based conservation. *Conservation biology,* 18**,** 621-630.

BERKES, F., COLDING, J. & FOLKE, C. 2000. Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications,* 10**,** 1251-1262.

BERNAUER, O. M., GAINES-DAY, H. R. & STEFFAN, S. A. 2015. Colonies of Bumble Bees (Bombus impatiens) Produce Fewer Workers, Less Bee Biomass, and Have Smaller Mother Queens Following Fungicide Exposure. *Insects,* 6**,** 478-88.

BERRY, W., 2000. *Life is a miracle: An essay against modern superstition*. Catapult, Washington D.C.

BETHEL, M. B., BRIEN, L. F., ESPOSITO, M. M., MILLER, C. T., BURAS, H. S., LASKA, S. B., PHILIPPE, R., PETERSON, K. J. & PARSONS RICHARDS, C. 2014. Sci-TEK: A GIS-Based Multidisciplinary Method for Incorporating Traditional Ecological Knowledge into Louisiana's Coastal Restoration Decision-Making Processes. *Journal of Coastal Research,* 297**,** 1081-1099.

BIRKIN, L. & GOULSON, D. 2015. Using citizen science to monitor pollination services. *Ecological Entomology,* 40**,** 3-11.

BLACQUIÈRE, T. & PANZIERA, D. 2018. A Plea for Use of Honey Bees’ Natural Resilience in Beekeeping. *Bee World,* 95**,** 34-38.

BLACQUIÈRE, T. & VAN DER STEEN, J. J. 2017. Three years of banning neonicotinoid insecticides based on sub-lethal effects: can we expect to see effects on bees? *Pest Management Science,* 73*:* 1299-1304

BLAIKIE, P. 2012. Should some political ecology be useful? The Inaugural Lecture for the Cultural and Political Ecology Specialty Group, Annual Meeting of the Association of American Geographers, April 2010. *Geoforum,* 43**,** 231-239.

BLAIKIE, P. M. 1987. *Land degradation and society,* London, London: Methuen.

BOHENSKY, E. L. & MARU, Y. 2011. Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on “integration”. *Ecology and Society,* 16**,** 6.

BONNEY, R., COOPER, C. B., DICKINSON, J., KELLING, S., PHILLIPS, T., ROSENBERG, K. V. & SHIRK, J. 2009. Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience,* 59**,** 977-984.

BRACE, C. & GEOGHEGAN, H. 2010. Human geographies of climate change: Landscape, temporality, and lay knowledges. *Progress in Human Geography,* 35**,** 284-302.

BRAUN, V. & CLARKE, V. 2013. *Successful qualitative research: A practical guide for beginners*, London: Sage

BREEZE, T. D., BAILEY, A. P., BALCOMBE, K. G. & POTTS, S. G. 2011. Pollination services in the UK: How important are honeybees? *Agriculture, Ecosystems & Environment,* 142**,** 137-143.

BREEZE, T. D., BAILEY, A. P., POTTS, S. G. & BALCOMBE, K. G. 2015. A stated preference valuation of the non-market benefits of pollination services in the UK. *Ecological Economics,* 111**,** 76-85.

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.

BRETON-HONEYMAN, K., C. M. FURGAL, AND M. O. HAMMILL. 2016. 'Systematic Review and Critique of the Contributions of Traditional Ecological Knowledge of Beluga Whales in the Marine Mammal Literature', *Arctic*, 69: 37-46.

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.

BRITISH ISLES BEE BREEDERS ASSOCIATION 1993. *Seeds for beekeepers, conservationists and gardeners,* Ripley: British Isles Bee Breeders' Association.

BRITISH ISLES BEE BREEDERS ASSOCIATION 1994. *Bee breeding & queen rearing : some BIBBA papers still relevant today,* Condor: British Isles Bee Breeders Association

BRODSCHNEIDER, R. & CRAILSHEIM, K. 2010. Nutrition and health in honey bees. *Apidologie,* 41**,** 278-294.

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.

BROWN, M. J. F. & PAXTON, R. J. 2009. The conservation of bees: a global perspective. *Apidologie,* 40**,** 410-416.

BROWN, R. 1975. *One thousand years of Devon beekeeping,* Devon, UK, Devon Beekeepers Association.

BRUYN, C. D. 1997. *Practical beekeeping,* Marlborough, Crowood Press.

BÜCHLER, R., COSTA, C., HATJINA, F., ANDONOV, S., MEIXNER, M. D., CONTE, Y. L., UZUNOV, A., BERG, S., BIENKOWSKA, M., BOUGA, M., DRAZIC, M., DYRBA, W., KRYGER, P., PANASIUK, B., PECHHACKER, H., PETROV, P., KEZIĆ, N., KORPELA, S. & WILDE, J. 2015. The influence of genetic origin and its interaction with environmental effects on the survival of Apis mellifera L. colonies in Europe. *Journal of Apicultural Research,* 53**,** 205-214.

BUCKINGHAM SHUM, S., ABERER, K., SCHMIDT, A., BISHOP, S., LUKOWICZ, P., ANDERSON, S., CHARALABIDIS, Y., DOMINGUE, J., DE FREITAS, S., DUNWELL, I., EDMONDS, B., GREY, F., HAKLAY, M., JELASITY, M., KARPIŠTŠENKO, A., KOHLHAMMER, J., LEWIS, J., PITT, J., SUMNER, R. & HELBING, D. 2012. Towards a global participatory platform. *The European Physical Journal Special Topics,* 214**,** 109-152.

BURKLE, L. A., DELPHIA, C. M., O'NEILL, K. M. & GIBSON, D. 2017. A dual role for farmlands: food security and pollinator conservation. *Journal of Ecology,* 105**,** 890-899.

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.

BUTLER, C. 1623. *The Feminine Monarchie,* (facsimile published) Hebden Bridge 1985, Northern Bee Books.

CALHOUN, L. 1979. *A Life With Bees,* Laurinburg, Lauder E Calhoun.

CANDEL, J. J. L. & PEREIRA, L. 2017. Towards integrated food policy: Main challenges and steps ahead. *Environmental Science & Policy,* 73**,** 89-92.

CAROLAN, M. S. 2008a. More-than-Representational Knowledge/s of the Countryside: How We Think as Bodies. *Sociologia Ruralis,* 48**,** 408-422.

CAROLAN, M. S. 2008b. The Multidimensionality of Environmental Problems: The GMO Controversy and the Limits of Scientific Materialism. *Environmental Values,* 17**,** 67-82.

CARTWRIGHT, N. & HARDIE, J. 2012. *Evidence-based policy: A practical guide to doing it better*, Oxford University Press.

CARVALHO, A. 2007. Ideological cultures and media discourses on scientific knowledge: re-reading news on climate change. *Public Understanding of Science,* 16**,** 223-243.

CASTREE, N., ADAMS, W. M., BARRY, J., BROCKINGTON, D., BÜSCHER, B., CORBERA, E., DEMERITT, D., DUFFY, R., FELT, U., NEVES, K., NEWELL, P., PELLIZZONI, L., RIGBY, K., ROBBINS, P., ROBIN, L., ROSE, D. B., ROSS, A., SCHLOSBERG, D., SÖRLIN, S., WEST, P., WHITEHEAD, M. & WYNNE, B. 2014. Changing the intellectual climate. *Nature Climate Change,* 4**,** 763-768.

CEBALLOS, G., EHRLICH, P. R. & DIRZO, R. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc Natl Acad Sci U S A,* 114**,** E6089-E6096.

CHARLES, D. 2005. *Somerset beekeepers and beekeeping associations: a history 1875 - 2005,* Great Britain, Somerset Beekeepers' Association.

CHIESURA, A. 2004. The role of urban parks for the sustainable city. *Landscape and Urban Planning,* 68**,** 129-138.

CILIA, L. 2019. The Plight of the Honey Bee: A Socioecological Analysis of Large-scale Beekeeping in the United States. *Sociologia Ruralis*

CLERMONT, A., EICKERMANN, M., KRAUS, F., HOFFMANN, L. & BEYER, M. 2015. Correlations between land covers and honey bee colony losses in a country with industrialized and rural regions. *Sci Total Environ,* 532**,** 1-13.

COHN, J. P. 2008. Citizen Science: Can Volunteers Do Real Research? *BioScience,* 58**,** 192.

COLLINS, H. M. & EVANS, R. 2016. The Third Wave of Science Studies. *Social Studies of Science,* 32**,** 235-296.

COMMUNITY SCIENCE INSTITUTE 2016 *What is Community-Based Science?* Available at <http://www.communityscience.org/2016/02/12/what-is-community-based-science/> Accessed 5 July 2019

CORNER, A., MARKOWITZ, E. & PIDGEON, N. 2014. Public engagement with climate change: the role of human values. *Wiley Interdisciplinary Reviews: Climate Change,* 5**,** 411-422.

COWEN, N., VIRK, B., MASCARENHAS-KEYES, S. & CARTWRIGHT, N. 2017. Randomized Controlled Trials: How Can We Know "What Works"? *Critical Review,* 29**,** 265-292.

CRAGGS, R., GEOGHEGAN, H. & NEATE, H. 2016. Managing enthusiasm: Between 'extremist' volunteers and 'rational' professional practices in architectural conservation. *Geoforum,* 74**,** 1-8.

CRANE, E. 1984. BEES, HONEY AND POLLEN AS INDICATORS OF METALS IN THE ENVIRONMENT. *Bee World,* 65**,** 47-49.

CRANE, E. 1999. Recent research on the world history of beekeeping. *Bee World,* 80**,** 174-186.

CRANE, E. 2004. A short history of knowledge about honey bees (Apis) up to 1800. *Bee World,* 85**,** 6-11.

CRUIKSHANK, J. 2012. Are Glaciers 'Good to Think With'? Recognising Indigenous Environmental Knowledge. *Anthropological Forum,* 22**,** 239-250.

CUMMING, A. R. 1945. *The northern beekeeper: handbook of the Inverness-shire Beekeepers' Association,* Inverness: Inverness Beekeepers Association.

CURRY, N. & KIRWAN, J. 2014. The Role of Tacit Knowledge in Developing Networks for Sustainable Agriculture. *Sociologia Ruralis,* 54**,** 341-361.

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.

DAVIDSON-HUNT, I. J. 2006. Adaptive Learning Networks: Developing Resource Management Knowledge through Social Learning Forums. *Human Ecology,* 34**,** 593-614.

DE MAGALHÃES, H. F., NETO, E. M. C. & SCHIAVETTI, A. 2012. Local knowledge of traditional fishermen on economically important crabs (Decapoda: Brachyura) in the city of Conde, Bahia State, Northeastern Brazil. *Journal of ethnobiology and ethnomedicine,* 8**,** 13.

DE MATTOS, I. M., SOARES, A. E. E. & TARPY, D. R. 2017. Effects of synthetic acaricides on honey bee grooming behavior against the parasitic Varroa destructor mite. *Apidologie,* 48**,** 483-494.

DE PALMA, A., KUHLMANN, M., ROBERTS, S. P., POTTS, S. G., BORGER, L., HUDSON, L. N., LYSENKO, I., NEWBOLD, T. & PURVIS, A. 2015. Ecological traits affect the sensitivity of bees to land-use pressures in European agricultural landscapes. *J Appl Ecol,* 52**,** 1567-1577.

DE VERE, N., JONES, L. E., GILMORE, T., MOSCROP, J., LOWE, A., SMITH, D., HEGARTY, M. J., CREER, S. & FORD, C. R. 2017. Using DNA metabarcoding to investigate honey bee foraging reveals limited flower use despite high floral availability. *Sci Rep,* 7**,** 42838.

DECOURTYE, A., MADER, E. & DESNEUX, N. 2010. Landscape enhancement of floral resources for honey bees in agro-ecosystems. *Apidologie,* 41**,** 264-277.

DEFRA 2014. The National Pollinator Strategy: for bees and other pollinators in England. Department for Environment, Food and Rural Affairs London, UK.

DI PASQUALE, G., SALIGNON, M., LE CONTE, Y., BELZUNCES, L. P., DECOURTYE, A., KRETZSCHMAR, A., SUCHAIL, S., BRUNET, J. L. & ALAUX, C. 2013. Influence of pollen nutrition on honey bee health: do pollen quality and diversity matter? *PLoS One,* 8**,** e72016.

DICKISON, M. 2009. The asymmetry between science and traditional knowledge, *Journal of the Royal Society of New Zealand*, 39: 171-72.

DICKS, L. 2013. Bees, lies and evidence-based policy. *Nature,* 494**,** 283.

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. & LEATHER, S. R. 2013. Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6**,** 435-446.

DICKS, L. V., BAUDE, M., ROBERTS, S. P., PHILLIPS, J., GREEN, M. & CARVELL, C. 2015. How much flower-rich habitat is enough for wild pollinators? Answering a key policy question with incomplete knowledge. *Ecol Entomol,* 40**,** 22-35.

DIGGES, J. R. G. 1921. *The practical bee guide: a manual of modern beekeeping*, Simpkin, Marshall, Hamilton, Kent & Company.

DIXON, J. & RICHARDS, C. 2015. On food security and alternative food networks: understanding and performing food security in the context of urban bias. *Agriculture and Human Values,* 33**,** 191-202.

DODD, V. 1983. *Beemasters of the past,* Hebden Bridge, U.K. : Northern Bee Books.

DODD, W. 1970. *Cumberland Beekeepers' Association: a history compiled from official records,* S.l., S.l. : s.n.

DON, W. 2010. The titi project, traditional ecological knowledge and science: a critique, *Journal of the Royal Society of New Zealand*, 40: 39-43.

DONNELLY, A., CROWE, O., REGAN, E., BEGLEY, S. & CAFFARRA, A. 2014. The role of citizen science in monitoring biodiversity in Ireland. *International Journal of Biometeorology,* 58**,** 1237-1249.

DUNLOP, C. A. 2014. The Possible Experts: How Epistemic Communities Negotiate Barriers to Knowledge Use in Ecosystems Services Policy. *Environment and Planning C: Government and Policy,* 32**,** 208-228.

EDELENBOS, J., VAN BUUREN, A. & VAN SCHIE, N. 2011. Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science & Policy,* 14**,** 675-684.

EDEN, S. 2012. Counting fish: Performative data, anglers' knowledge-practices and environmental measurement. *Geoforum,* 43**,** 1014-1023.

EDEN, S. 2016. *Environmental publics*, Abingdon: Routledge.

EDEN, S. & BEAR, C. 2011a. Models of equilibrium, natural agency and environmental change: lay ecologies in UK recreational angling. *Transactions of the Institute of British Geographers,* 36**,** 393-407.

EDEN, S. & BEAR, C. 2011b. Reading the river through 'watercraft': environmental engagement through knowledge and practice in freshwater angling. *cultural geographies,* 18**,** 297-314.

EDEN, S. & BEAR, C. 2012. The Good, the Bad, and the Hands-on: Constructs of Public Participation, Anglers, and Lay Management of Water Environments. *Environment and Planning A: Economy and Space,* 44**,** 1200-1218.

EKROOS, J., LEVENTON, J., FISCHER, J., NEWIG, J. & SMITH, H. G. 2017. Embedding Evidence on Conservation Interventions Within a Context of Multilevel Governance. *Conservation Letters,* 10**,** 139-145.

ELLIS, R. & WATERTON, C. 2004. Environmental citizenship in the making: the participation of volunteer naturalists in UK biological recording and biodiversity policy. *Science and public policy,* 31**,** 95-105.

ELLIS, R. & WATERTON, C. 2016. Caught between the Cartographic and the Ethnographic Imagination: The Whereabouts of Amateurs, Professionals, and Nature in Knowing Biodiversity. *Environment and Planning D: Society and Space,* 23**,** 673-693.

ELLIS, R., WATERTON, C. & WYNNE, B. 2010. Taxonomy, biodiversity and their publics in twenty-first-century DNA barcoding. *Public Underst Sci,* 19**,** 497-512.

ELOY, L. & COUDEL, E. 2013. Roldan Muradian and Esteve Corbera: "The Simplicity of PES is Very Alluring, but We Cannot Use Simple Solutions to Solve Complex Problems". *Sustainability in Debate,* 4.

ENDFIELD, G. H. & MORRIS, C. 2012a. Exploring the role of the amateur in the production and circulation of meteorological knowledge. *Climatic Change,* 113**,** 69-89.

ENDFIELD, G. H. & MORRIS, C. 2012b. 'Well weather is not a girl thing is it?' Contemporary amateur meteorology, gender relations and the shaping of domestic masculinity. *Social & Cultural Geography,* 13**,** 233-253.

ENTICOTT, G., MAYE, D., CARMODY, P., NAYLOR, R., WARD, K., HINCHLIFFE, S., WINT, W., ALEXANDER, N., ELGIN, R., ASHTON, A., UPTON, P., NICHOLSON, R., GOODCHILD, T., BRUNTON, L. & BROUGHAN, J. 2015. Farming on the edge: farmer attitudes to bovine tuberculosis in newly endemic areas. *Vet Rec,* 177 (17)**,** 439.

ESSEX BEEKEEPERS ASSOCIATION 1980. *One hundred years of honey: Essex Beekeepers Association, 1880-1980: recording the centenary of the Essex Beekeepers Association*, S.l. : s.n. .

EVANS, R. & PLOWS, A. 2007. Listening without prejudice? Re-discovering the value of the disinterested citizen. *Social Studies of Science,* 37**,** 827-853.

EVANS, R. & PLOWS, A. 2016. Listening Without Prejudice? *Social Studies of Science,* 37**,** 827-853.

EVERETT, G. & GEOGHEGAN, H. 2016. Initiating and continuing participation in citizen science for natural history. *BMC Ecol,* 16 Suppl 1**,** 13.

FAIRHEAD, J. & LEACH, M. 1995. False Forest History, Complicit Social Analysis - Rethinking Some West-African Environmental Narratives. *World Development,* 23**,** 1023-1035.

FAIRHEAD, J. & LEACH, M. 2000. Desiccation and domination: Science and struggles over environment and development in colonial Guinea. *Journal of African History,* 41**,** 35-54.

FAZEY, I., BUNSE, L., MSIKA, J., PINKE, M., PREEDY, K., EVELY, A. C., LAMBERT, E., HASTINGS, E., MORRIS, S. & REED, M. S. 2014. Evaluating knowledge exchange in interdisciplinary and multi-stakeholder research. *Global Environmental Change,* 25**,** 204-220.

FAZEY, I., FAZEY, J. A., SALISBURY, J. G., LINDENMAYER, D. B. & DOVERS, S. 2006. The nature and role of experiential knowledge for environmental conservation. *Environmental Conservation,* 33**,** 1.

FLOWERDEW, R. & MARTIN, D. 2005. *Methods in human geography: a guide for students doing a research project*, Abingdon, Routledge.

FOLKE, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change,* 16**,** 253-267.

FOLLETT, R. & STREZOV, V. 2015. An Analysis of Citizen Science Based Research: Usage and Publication Patterns. *PLoS One,* 10**,** e0143687.

FORBES, B. C. & STAMMLER, F. 2016. Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. *Polar Research,* 28**,** 28-42.

FORSYTH, T. 2002. *Critical political ecology : the politics of environmental science,* London: Routledge.

FORTNAM, M., BROWN, K., CHAIGNEAU, T., CRONA, B., DAW, T., GONÇALVES, D., HICKS, C., REVMATAS, M., SANDBROOK, C. & SCHULTE-HERBRUGGEN, B. 2019. The gendered nature of ecosystem services. *Ecological Economics,* 159**,** 312-325.

FOSTER, C. 2016. *Being a beast: An intimate and radical look at nature*. London: Profile Books.

FRASER, D. J., COON, T., PRINCE, M. R., DION, R. & BERNATCHEZ, L. 2006. Integrating traditional and evolutionary knowledge in biodiversity conservation: a population level case study. *Ecology and Society,* 11**,** 4.

FRICKEL, S., GIBBON, S., HOWARD, J., KEMPNER, J., OTTINGER, G. & HESS, D. J. 2009. Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting. *Science, Technology, & Human Values,* 35**,** 444-473.

FUKASE, J. & SIMONS, A. M. 2016. Increased Pollinator Activity in Urban Gardens with More Native Flora. *Applied Ecology and Environmental Research,* 14**,** 297-310.

GALLAI, N., SALLES, J.-M. & SETTELE, J. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics,* 68**,** 810–821.

GALLARDO, B., ZIERITZ, A., ADRIAENS, T., BELLARD, C., BOETS, P., BRITTON, J. R., NEWMAN, J. R., VAN VALKENBURG, J. & ALDRIDGE, D. C. 2016. Trans-national horizon scanning for invasive non-native species: a case study in western Europe. *Biological Invasions,* 18**,** 17-30.

GARBUZOV, M., FENSOME, K. A., RATNIEKS, F. L. W., LEATHER, S. R. & DENNIS, P. 2015a. Public approval plus more wildlife: twin benefits of reduced mowing of amenity grass in a suburban public park in Saltdean, UK. *Insect Conservation and Diversity,* 8**,** 107-119.

GARBUZOV, M., SAMUELSON, E. E. & RATNIEKS, F. L. 2015b. Survey of insect visitation of ornamental flowers in Southover Grange garden, Lewes, UK. *Insect Sci,* 22**,** 700-5.

GARBUZOV, M., SCHÜRCH, R. & RATNIEKS, F. L. W. 2014. Eating locally: dance decoding demonstrates that urban honey bees in Brighton, UK, forage mainly in the surrounding urban area. *Urban Ecosystems,* 18**,** 411-418.

GASTON, K. J., SMITH, R. M., THOMPSON, K. & WARREN, P. H. 2005. Urban domestic gardens (II): experimental tests of methods for increasing biodiversity. *Biodiversity and Conservation,* 14**,** 395-413.

GELDMANN, J. & GONZÁLEZ-VARO, J. P. 2018. Conserving honey bees does not help wildlife. *Science,* 359**,** 392-393.

GEMMILL-HERREN, B. 2016. *Pollination services to agriculture: sustaining and enhancing a key ecosystem service*, Abingdon: Routledge.

GEOGHEGAN, H. 2013. Emotional geographies of enthusiasm: belonging to the Telecommunications Heritage Group. *Area,* 45**,** 40-46.

GEOGHEGAN, H., DYKE, A., PATEMAN, R., WEST, S. & EVERETT, G. 2016. Understanding motivations for citizen science. *Final report on behalf of UKEOF, University of Reading, Stockholm Environment Institute (University of York) and University of the West of England*.

GIBBONS, D., MORRISSEY, C. & MINEAU, P. 2015. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. *Environ Sci Pollut Res Int,* 22**,** 103-18.

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. *Journal of Knowledge Management,* 19**,** 949-967.

GLASNER, T. & VAN DER VAART, W. 2009. Applications of calendar instruments in social surveys: a review. *Qual Quant,* 43**,** 333-349.

GOLDMAN, M., NADASDY, P. & TURNER, M. 2011. *Knowing Nature : conversations at the Intersection of political ecology and science studies,* Chicago ; London, University of Chicago Press.

GONTHIER, D. J., ENNIS, K. K., FARINAS, S., HSIEH, H. Y., IVERSON, A. L., BATARY, P., RUDOLPHI, J., TSCHARNTKE, T., CARDINALE, B. J. & PERFECTO, I. 2014. Biodiversity conservation in agriculture requires a multi-scale approach. *Proc Biol Sci,* 281**,** 20141358.

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**,** 524-30.

GOODWIN, P. 1998. 'Hired Hands' or 'Local Voice': Understandings and Experience of Local Participation in Conservation. *Transactions of the Institute of British Geographers,* 23**,** 481-499.

GOULSON, D. 2015. *A Buzz in the Meadow: The Natural History of a French Farm*, Macmillan.

GOULSON, D. 2016. *A Sting in the Tale*, Random House.

GOULSON, D. & HUGHES, W. O. H. 2015. Mitigating the anthropogenic spread of bee parasites to protect wild pollinators. *Biological Conservation,* 191**,** 10-19.

GOULSON, D., NICHOLLS, E., BOTIAS, C. & ROTHERAY, E. L. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science,* 347**,** 1255957.

GRAYSTOCK, P., GOULSON, D. & HUGHES, W. O. 2014. The relationship between managed bees and the prevalence of parasites in bumblebees. *PeerJ,* 2**,** e522.

GRAYSTOCK, P., GOULSON, D. & HUGHES, W. O. 2015. Parasites in bloom: flowers aid dispersal and transmission of pollinator parasites within and between bee species. *Proc Biol Sci,* 282**,** 20151371.

GREEN, K. & GINN, F. 2014. The Smell of Selfless Love: Sharing Vulnerability with Bees in Alternative Apiculture. *Environmental Humanities,* 4**,** 149-170.

GREENLEAF, S. S., WILLIAMS, N. M., WINFREE, R. & KREMEN, C. 2007. Bee foraging ranges and their relationship to body size. *Oecologia,* 153**,** 589-96.

GROSS, M. 2014. Systemic pesticide concerns extend beyond the bees. *Curr Biol,* 24**,** R717-20.

GUIMARAES PEREIRA, A. & SALTELLI, A. 2017. Post-normal institutional identities: Quality assurance, reflexivity and ethos of care. *Futures,* 91**,** 53-61.

GUNNINGHAM, N., KAGAN, R. A. & THORNTON, D. 2004. Social License and Environmental Protection: Why Businesses Go Beyond Compliance. *Law & Social Inquiry,* 29**,** 307-341.

GUSTAFSSON, K. M. 2013. Environmental discourses and biodiversity: the construction of a storyline in understanding and managing an environmental issue. *Journal of Integrative Environmental Sciences,* 10**,** 39-54.

GUSTAFSSON, K. M. 2017. Narrating the Monarch Butterfly: Managing Knowledge Complexity and Uncertainty in Coproduction of a Collective Narrative and Public Discourse. *Science Communication,* 39**,** 492-519.

GUSTAFSSON, K. M., AGRAWAL, A. A., LEWENSTEIN, B. V. & WOLF, S. A. 2015. The Monarch Butterfly through Time and Space: The Social Construction of an Icon. *BioScience,* 65**,** 612-622.

GUSTAFSSON, K. M., WOLF, S. A. & AGRAWAL, A. A. 2017. Science-Policy-Practice Interfaces: Emergent knowledge and monarch butterfly conservation. *Environmental Policy and Governance,* 27**,** 521-533.

HALL, A. & ENDFIELD, G. 2016. “Snow Scenes”: Exploring the Role of Memory and Place in Commemorating Extreme Winters. *Weather, Climate, and Society,* 8**,** 5-19.

HALL, D. M. & STEINER, R. 2019. Insect pollinator conservation policy innovations at subnational levels: Lessons for lawmakers. *Environmental Science & Policy,* 93**,** 118-128.

HALLMANN, C. A., SORG, M., JONGEJANS, E., SIEPEL, H., HOFLAND, N., SCHWAN, H., STENMANS, W., MULLER, A., SUMSER, H., HORREN, T., GOULSON, D. & DE KROON, H. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One,* 12**,** e0185809.

HANLEY, N., BREEZE, T. D., ELLIS, C. & GOULSON, D. 2015. Measuring the economic value of pollination services: Principles, evidence and knowledge gaps. *Ecosystem Services,* 14**,** 124-132.

HARDMAN, C. J., HARRISON, D. P., SHAW, P. J., NEVARD, T. D., HUGHES, B., POTTS, S. G. & NORRIS, K. 2016. Supporting local diversity of habitats and species on farmland: a comparison of three wildlife-friendly schemes. *J Appl Ecol,* 53**,** 171-180.

HARRISON, J. 2008a. Abandoned bodies and spaces of sacrifice: Pesticide drift activism and the contestation of neoliberal environmental politics in California. *Geoforum,* 39**,** 1197-1214.

HARRISON, J. 2008b. Lessons learned from pesticide drift: a call to bring production agriculture, farm labor, and social justice back into agrifood research and activism. *Agriculture and Human Values,* 25**,** 163-167.

HARRISON, J. L. 2006. ‘Accidents’ and invisibilities: Scaled discourse and the naturalization of regulatory neglect in California's pesticide drift conflict. *Political Geography,* 25**,** 506-529.

HARVEY, D. & RILEY, M. 2005. Country stories: the use of oral histories of the countryside to challenge the sciences of the past and future. *Interdisciplinary Science Reviews,* 30**,** 19-32.

HAWTHORNE, D. J. & DIVELY, G. P. 2011. Killing them with kindness? In-hive medications may inhibit xenobiotic efflux transporters and endanger honey bees. *PLoS One,* 6**,** e26796.

HEGGER, D., LAMERS, M., VAN ZEIJL-ROZEMA, A. & DIEPERINK, C. 2012. Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. *Environmental Science & Policy,* 18**,** 52-65.

HELEY, J. & JONES, L. 2013. Growing older and social sustainability: considering the 'serious leisure' practices of the over 60s in rural communities. *Social & Cultural Geography,* 14**,** 276-299.

Vanishing of the Bees, 2009. Directed by HENEIN, G. L. A. M. United Kingdom: Hive Mentality Films and Hipfuel Films.

HENRY, M., BEGUIN, M., REQUIER, F., ROLLIN, O., ODOUX, J. F., AUPINEL, P., APTEL, J., TCHAMITCHIAN, S. & DECOURTYE, A. 2012. A common pesticide decreases foraging success and survival in honey bees. *Science,* 336**,** 348-50.

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. *Environment: Science and Policy for Sustainable Development,* 56**,** 3-17.

HERNÁNDEZ-MORCILLO, M., HOBERG, J., OTEROS-ROZAS, E., PLIENINGER, T., GÓMEZ-BAGGETHUN, E. & REYES-GARCÍA, V. 2014. Traditional ecological knowledge in Europe: status quo and insights for the environmental policy agenda. *Environment: Science and Policy for Sustainable Development,* 56**,** 3-17.

HESS, D. J. 2009. The Potentials and Limitations of Civil Society Research: Getting Undone Science Done. *Sociological Inquiry,* 79**,** 306-327.

HESS, D. J. 2014. Publics as Threats? Integrating Science and Technology Studies and Social Movement Studies. *Science as Culture,* 24**,** 69-82.

HEYWOOD, V., CASAS, A., FORD-LLOYD, B., KELL, S. & MAXTED, N. 2007. Conservation and sustainable use of crop wild relatives. *Agriculture, Ecosystems & Environment,* 121**,** 245-255.

HICKS, D. M., OUVRARD, P., BALDOCK, K. C., BAUDE, M., GODDARD, M. A., KUNIN, W. E., MITSCHUNAS, N., MEMMOTT, J., MORSE, H., NIKOLITSI, M., OSGATHORPE, L. M., POTTS, S. G., ROBERTSON, K. M., SCOTT, A. V., SINCLAIR, F., WESTBURY, D. B. & STONE, G. N. 2016. Food for Pollinators: Quantifying the Nectar and Pollen Resources of Urban Flower Meadows. *PLoS One,* 11**,** e0158117.

HINRICHS, C. 1998. Sideline and Lifeline: The Cultural Economy of Maple Syrup Production. *Rural Sociology,* 63**,** 507-532.

HOLZSCHUH, A., DORMANN, C. F., TSCHARNTKE, T. & STEFFAN-DEWENTER, I. 2011. Expansion of mass-flowering crops leads to transient pollinator dilution and reduced wild plant pollination. *Proc Biol Sci,* 278**,** 3444-51.

HOOPER, T. 1979. *Guide to bees and honey,* Poole, Dorset, Blandford Press.

HOPKINS, I. 1916. *Forty-Two Years of Bee-Keeping in New Zealand 1874-1916-Some Reminiscences,* Auckland, N.Z.

HOSTETLER, H. & MCINTYRE, M. 2001. Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis. *Basic and Applied Ecology,* 2**,** 209–218.

HOWES, F. N. 1945. *Plants and Beekeeping,* London, Faber and Faber.

HULME, M. 2010. Problems with making and governing global kinds of knowledge. *Global Environmental Change-Human and Policy Dimensions,* 20**,** 558-564.

HULME, M., DESSAI, S., LORENZONI, I. & NELSON, D. R. 2009. Unstable climates: Exploring the statistical and social constructions of 'normal' climate. *Geoforum,* 40**,** 197-206.

HUNTINGTON, H. P., BROWN-SCHWALENBERG, P. K., FROST, K. J., FERNANDEZ-GIMENEZ, M. E., NORTON, D. W. & ROSENBERG, D. H. 2002. Observations on the workshop as a means of improving communication between holders of traditional and scientific knowledge. *Environmental Management,* 30**,** 0778-0792.

IANNI, E., GENELETTI, D. & CIOLLI, M. 2015. Revitalizing traditional ecological knowledge: a study in an Alpine rural community. *Environ Manage,* 56**,** 144-56.

INGLIS, J. (ed.) 2004. *Traditional Ecological Knowledge: Concepts and Cases,* Ottawa, Canada: Internatiopnal Program on Traditional Ecological Knowledge.

INGRAM, J. 2008. Combining Scientific and Lay Knowledges: Participatory Approaches to Research in Organic Farming. *In:* SEYMOUR, S., WATKINS, C., STEVEN, M. D., C.A.B. INTERNATIONAL, I. B., FISH, R. & EBRARY, I. (eds.) *Sustainable farmland management transdisciplinary approaches.* Wallingford, Oxfordshire, UK: CABI.

INGRAM, V. & NJIKEU, J. 2011. Sweet, sticky, and sustainable social business. *Ecology and Society,* 16**,** 18.

IRWIN, A. 2001. Constructing the scientific citizen: science and democracy in the biosciences. *Public Understanding of Science,* 10**,** 1-18.

JACOBSEN, R. 2010. *Fruitless fall: The collapse of the honey bee and the coming agricultural crisis*, New York: Bloomsbury Publishing USA.

JALBERT, K. & KINCHY, A. J. 2015. Sense and influence: environmental monitoring tools and the power of citizen science. *Journal of Environmental Policy & Planning***,** 1-19.

JASANOFF, S. 2004. *Earthly politics: local and global in environmental governance*, Mit Press.

JOHNSON, E. A. & KLEMENS, M. W. 2005. *Nature in fragments : the legacy of sprawl,* New York, New York : Columbia University Press

JONES, C. A., DAVIES, S. J. & MACDONALD, N. 2012. Examining the social consequences of extreme weather: the outcomes of the 1946/1947 winter in upland Wales, UK. *Climatic Change,* 113**,** 35-53.

JUE, D. K. & DANIELS, J. C. 2015. A successful model for citizen scientist involvement in building a statewide at-risk butterfly database. *Journal of Insect Conservation,* 19**,** 421-431.

JUNTTI, M., RUSSEL, D. & TURNPENNY, J. 2009. Evidence, politics and power in public policy for the environment. *Environmental Science & Policy,* 12**,** 207-215.

KAGAN, R. A., GUNNINGHAM, N. & THORNTON, D. 2003. Explaining Corporate Environmental Performance: How Does Regulation Matter? *Law & Society Review,* 37**,** 51-90.

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.

KEELING, M. J., FRANKLIN, D. N., DATTA, S., BROWN, M. A. & BUDGE, G. E. 2017. Predicting the spread of the Asian hornet (Vespa velutina) following its incursion into Great Britain. *Sci Rep,* 7**,** 6240.

KEVAN, P. 1999. Pollinators as bioindicators of the state of the environment: species, activity and diversity. *Agriculture, Ecosystems & Environment,* 74**,** 373–393.

KINCHY, A., JALBERT, K. & LYONS, J. 2014. What is volunteer water monitoring good for? Fracking and the plural logics of participatory science. *Political Power and Social Theory,* 27**,** 259-289.

KINGSOLVER, B., 2012. *Flight Behaviour*. Faber & Faber.

KIRK, W. 1994. *A colour guide to pollen loads of the honey bee*, International Bee Research Association.

KLEINMAN, D. L. & SURYANARAYANAN, S. 2012. Dying Bees and the Social Production of Ignorance. *Science, Technology, & Human Values,* 38**,** 492-517.

KNUDSEN, S. 2008. Ethical know-how and traditional ecological knowledge in small scale fisheries on the eastern Black Sea coast of Turkey. *Human Ecology,* 36**,** 29-41.

KREMEN, C., WILLIAMS, N. M. & THORP, R. W. 2002. Crop pollination from native bees at risk from agricultural intensification. *Proc Natl Acad Sci U S A,* 99**,** 16812-6.

LANGELLOTTO, G., MELATHOPOULOS, A., MESSER, I., ANDERSON, A., MCCLINTOCK, N. & COSTNER, L. 2018. Garden Pollinators and the Potential for Ecosystem Service Flow to Urban and Peri-Urban Agriculture. *Sustainability,* 10**,** 2047.

LANGIN, K., 2019. Climate scientists say no to flying. *Science*, 364, 6441

LAVE, R. 2012a. Bridging Political Ecology and STS: A Field Analysis of the Rosgen Wars. *Annals of the Association of American Geographers,* 102**,** 366-382.

LAVE, R. 2012b. Neoliberalism and the production of environmental knowledge. *Environment and Society: Advances in Research,* 3**,** 19-38.

LAVE, R. 2014. Engaging within the Academy: A Call for Critical Physical Geography. *ACME: An International E-Journal for Critical Geographies,* 13**,** 508-515.

LAVE, R. 2015. The Future of Environmental Expertise. *Annals of the Association of American Geographers,* 105**,** 244-252.

LAVE, R., MIROWSKI, P. & RANDALLS, S. 2010. Introduction: STS and Neoliberal Science. *Social Studies of Science,* 40**,** 659-675.

LAVRAKAS, P. J. 2008. *Encyclopedia of survey research methods*, Sage Publications.

LE CONTE, Y., ELLIS, M. & RITTER, W. 2010. Varroa mites and honey bee health: can Varroa explain part of the colony losses? *Apidologie,* 41**,** 353-363.

LE CONTE, Y. E. A. 2007. Honey bee colonies that have survived varroa destructor. *Apidologie,* 38**,** 566-572.

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. *Journal of Rural Studies,* 44**,** 132-142.

LEVITT, J. N. 2002. *Conservation in the internet age: threats and opportunities*, Island Press.

LEZAUN, J. 2011. Bees, Beekeepers, and Bureaucrats: Parasitism and the Politics of Transgenic Life. *Environment and Planning D: Society and Space,* 29**,** 738-756.

LIKENS, G. E. 2010. The role of science in decision making: does evidence-based science drive environmental policy? *Frontiers in Ecology and the Environment,* 8**,** e1-e9.

LIN, B. B., PHILPOTT, S. M. & JHA, S. 2015. The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. *Basic and Applied Ecology,* 16**,** 189-201.

LITTLE, C. M., SHUTLER, D. & WILLIAMS, G. R. 2016. Associations among Nosema spp. fungi, Varroa destructor mites, and chemical treatments in honey bees, Apis mellifera. *Journal of Apicultural Research,* 54**,** 378-385.

LOCKE, B. & FRIES, I. 2011. Characteristics of honey bee colonies (Apis mellifera) in Sweden surviving Varroa destructor infestation. *Apidologie,* 42**,** 533-542.

LOFTUS, J. C., SMITH, M. L. & SEELEY, T. D. 2016. How Honey Bee Colonies Survive in the Wild: Testing the Importance of Small Nests and Frequent Swarming. *PLoS One,* 11**,** e0150362.

LOPEZARAIZA–MIKEL, M. E., HAYES, R. B., WHALLEY, M. R. & MEMMOTT, J. 2007. The impact of an alien plant on a native plant–pollinator network: an experimental approach. *Ecology letters,* 10**,** 539-550.

LORENZ, S. 2016. The endangerment of bees and new developments in beekeeping: a social science perspective using the example of Germany. *International Journal of Environmental Studies,* 73**,** 988-1005.

LORENZ, S. & STARK, K. 2015. Saving the honeybees in Berlin? A case study of the urban beekeeping boom. *Environmental Sociology,* 1**,** 116-126.

LORIMER, J. 2008. Counting Corncrakes. *Social Studies of Science,* 38**,** 377-405.

LORIMER, J. 2015. *Wildlife in the Anthropocene: Conservation after Nature,* Minneapolis, University of Minnesota Press.

LU, C., WARCHOL, K. & CALLAHAN, R. 2014. Sub-lethal exposure to neonicotinoids impaired honey bees winterization before proceeding to colony collapse disorder. *Bulletin of Insectology,* 67**,** 125-130.

LUO, Y., LIU, J. & ZHANG, D. 2009. Role of traditional beliefs of Baima Tibetans in biodiversity conservation in China. *Forest Ecology and Management,* 257**,** 1995–2001.

MACE, H. 1936. *Bee farming in Britain,* Harlow, Essex, Harlow, Essex : The Beekeeping Annual Office

MADERSON, S. & WYNNE-JONES, S. 2016. Beekeepers' knowledges and participation in pollinator conservation policy. *Journal of Rural Studies,* 45**,** 88-98.

MAHONY, M. & HULME, M. 2016. Epistemic geographies of climate change. *Progress in Human Geography,* 42**,** 395-424.

MANNING, P., RAMANAIDU, K. & CUTLER, G. C. 2018. Correction: Honey bee survival is affected by interactions between field-relevant rates of fungicides and insecticides used in apple and blueberry production. *Facets,* 3**,** 530-530.

MARIN, A. 2010. Riders under storms: Contributions of nomadic herders' observations to analysing climate change in Mongolia. *Global Environmental Change,* 20**,** 162-176.

MARRIS, E. 2013. *Rambunctious garden: saving nature in a post-wild world*, New York: Bloomsbury Publishing USA.

MARSDEN, T. 2012. Sustainable place-making for sustainability science: the contested case of agri-food and urban–rural relations. *Sustainability Science,* 8**,** 213-226.

MARSHALL, M. N. 1996. The key informant technique. *Fam Pract,* 13**,** 92-7.

MARSHMAN, J. 2019. Communing with bees: A whole-of-community approach to address crisis in the Anthropocene. *Journal of Agriculture, Food Systems, and Community Development,* 9**,** 1-24.

MARSHMAN, J., BLAY-PALMER, A. & LANDMAN, K. 2019. Anthropocene Crisis: Climate Change, Pollinators, and Food Security. *Environments,* 6**,** 22.

MARTIN, J. F., ROY, E. D., DIEMONT, S. A. & FERGUSON, B. G. 2010. Traditional ecological knowledge (TEK): ideas, inspiration, and designs for ecological engineering. *Ecological Engineering,* 36**,** 839-849.

MATHESON, A., LINNEAN SOCIETY OF, L. & INTERNATIONAL BEE RESEARCH, A. 1996. *The conservation of bees,* London, London : Academic Press

MATHEVET, R., BOUSQUET, F. & RAYMOND, C. M. 2018. The concept of stewardship in sustainability science and conservation biology. *Biological Conservation,* 217**,** 363-370.

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.

MAXIM, L. & VAN DER SLUIJS, J. P. 2011. Quality in environmental science for policy: Assessing uncertainty as a component of policy analysis. *Environmental Science & Policy,* 14**,** 482-492.

MAYE, D., ENTICOTT, G. & NAYLOR, R. 2017. Using scenario-based influence mapping to examine farmers' biosecurity behaviour. *Land Use Policy,* 66**,** 265-277.

MAYNARD, C. M. 2015. Accessing the environment: Delivering ecological and societal benefits through knowledge integration - The case of water management. *Applied Geography,* 58**,** 94-104.

MCCARTHY, M. 2015. *Moth Snowstorm: Nature and Joy,* London, John Murray.

MCKELVEY, K. S., AUBRY, K. B. & SCHWARTZ, M. K. 2008. Using Anecdotal Occurrence Data for Rare or Elusive Species: The Illusion of Reality and a Call for Evidentiary Standards. *BioScience,* 58**,** 549-555.

MCMICHAEL, P. 2009. A food regime analysis of the 'world food crisis'. *Agriculture and Human Values,* 26**,** 281-295.

MCMULLAN, J. 2012. *Having healthy honeybees : an integrated approach,* Enfield, Enfield : Federation of Irish Beekeepers' Associations

MCQUILLAN, D. 2014. The countercultural potential of citizen science. *M/C Journal,* 17.

MEEHL, G. A., ZWIERS, F., EVANS, J., KNUTSON, T., MEARNS, L. & WHETTON, P. 2000. Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change. *Bulletin of the American Meteorological Society,* 81**,** 427-436.

MILLER, C. C. 1911. *Fifty years among the bees,* Medina, Ohio, A. I. Root Co. .

MILLS, J. & BIRKS, M. 2014. *Qualitative methodology: A practical guide*, Sage.

MOLLER, H. 2009. 'Matauranga Maori, science and seabirds in New Zealand Foreword', *New Zealand Journal of Zoology*, 36: 203-10.

MOORE, L. J. & KOSUT, M. 2013a. Among the colony: Ethnographic fieldwork, urban bees and intra-species mindfulness. *Ethnography,* 15**,** 516-539.

MOORE, L. J. & KOSUT, M. 2013b. *Buzz: Urban beekeeping and the power of the bee*, NYU Press.

MORRIS, C. & ENDFIELD, G. 2012. Exploring contemporary amateur meteorology through an historical lens. *Weather,* 67**,** 4-8.

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 in Ecology and Evolution,* 9**,** 54-63.

NADASDY, P. 1999. The politics of TEK: Power and the "integration" of knowledge. *Arctic Anthropology,* 36**,** 1-18.

NADASDY, P. 2003. *Hunters and bureaucrats: power, knowledge, and aboriginal-state relations in the southwest Yukon*, UBC Press.

NADASDY, P. 2005. The Anti-Politics of TEK: The Institutionalization of Co-Management Discourse and Practice. *Anthropologica,* 47**,** 215-232.

NADASDY, P. 2007. The gift in the animal: The ontology of hunting and human-animal sociality. *American Ethnologist,* 34**,** 25-43.

NADASDY, P. 2014. The Politics of Tek: Power and the 'Integration' of Knowledge. *Arctic Anthropology,* 36**,** 1-18.

NATIONAL BEE UNIT, 2018. *Protecting the Honey Bee*, available from <http://www.nationalbeeunit.com/index.cfm?sectionid=43>, (Accessed 12/1/2018).

NAUG, D. 2009. Nutritional stress due to habitat loss may explain recent honeybee colony collapses. *Biological Conservation,* 142**,** 2369–2372.

NELSON, I. A. 2010. From Quantitative to Qualitative: Adapting the Life History Calendar Method. *Field Methods,* 22**,** 413-428.

NEUMANN, P. & BLACQUIERE, T. 2017. The Darwin cure for apiculture? Natural selection and managed honeybee health. *Evol Appl,* 10**,** 226-230.

NEUMANN, P. & CARRECK, N. L. 2015. Honey bee colony losses. *Journal of Apicultural Research,* 49**,** 1-6.

NEY, S. & VERWEIJ, M. 2015. Messy institutions for wicked problems: How to generate clumsy solutions? *Environment and Planning C: Government and Policy,* 33**,** 1679-1696.

OGWUCHE, J. 2012. Integrating indigenous environmental knowledge into the environmental impact assessment process. *Global Advanced Research Journal of Social Science,* 1**,** 22-27.

OLIVER, R. 2017. *Powdered sugar dusting – sweet and safe, but does it really work? Part 1.* (Online) Available at <http://scientificbeekeeping.com/powdered-sugar-dusting-sweet-and-safe-but-does-it-really-work-part-1/> [Accessed 10 July 2019]

OLLERTON, J. 2017. Pollinator Diversity: Distribution, Ecological Function, and Conservation. *In:* FUTUYMA, D. J. (ed.) *Annual Review of Ecology, Evolution, and Systematics, Vol 48.*

OLLERTON, J., PRICE, V., ARMBRUSTER, W. S., MEMMOTT, J., WATTS, S., WASER, N. M., TOTLAND, O., GOULSON, D., ALARCON, R., STOUT, J. C. & TARRANT, S. 2012. Overplaying the role of honey bees as pollinators: a comment on Aebi and Neumann (2011). *Trends Ecol Evol,* 27**,** 141-2; author reply 142-3.

OLSSON, P., FOLKE, C. & BERKES, F. 2004. Adaptive comanagement for building resilience in social-ecological systems. *Environmental Management,* 34**,** 75-90.

OPITZ, I., BERGES, R., PIORR, A. & KRIKSER, T. 2015. Contributing to food security in urban areas: differences between urban agriculture and peri-urban agriculture in the Global North. *Agriculture and Human Values,* 33**,** 341-358.

OTERO, A. 2011. Water scarcity, social power and the production of an elite suburb : the political ecology of water in Matadepera, Catalonia. *Ecological Economics,* 70**,** 1297-1308.

OTERO, I., KALLIS, G., AGUILAR, R. & RUIZ, V. 2011. Water scarcity, social power and the production of an elite suburb. *Ecological Economics,* 70**,** 1297-1308.

OTEROS-ROZAS, E., ONTILLERA-SANCHEZ, R. & AL, E. 2013. Traditional ecological knowledge among transhumant pastoralists in Mediterranean Spain. *Ecology and Society,* 18.

OWEN, R. 2017. Role of Human Action in the Spread of Honey Bee (Hymenoptera: Apidae) Pathogens. *J Econ Entomol,* 110**,** 797-801.

PALMER, M. A., BERNHARDT, E. S., CHORNESKY, E. A., COLLINS, S. L., DOBSON, A. P., DUKE, C. S., GOLD, B. D., JACOBSON, R. B., KINGSLAND, S. E., KRANZ, R. H., MAPPIN, M. J., MARTINEZ, M. L., MICHELI, F., MORSE, J. L., PACE, M. L., PASCUAL, M., PALUMBI, S. S., REICHMAN, O. J., TOWNSEND, A. R. & TURNER, M. G. 2005. Ecological science and sustainability for the 21st century. *Frontiers in Ecology and the Environment,* 3**,** 4-11.

PARK, M. G., BLITZER, E. J., GIBBS, J., LOSEY, J. E. & DANFORTH, B. N. 2015. Negative effects of pesticides on wild bee communities can be buffered by landscape context. *Proc Biol Sci,* 282**,** 20150299.

PARK, M. S. & YOUN, Y.-C. 2012. Traditional knowledge of Korean native beekeeping and sustainable forest management. *Forest Policy and Economics,* 15**,** 37-45.

PELLETT, F. C. 1923. *American honey plants: together with those which are of special value to the beekeeper as sources of pollen*, American bee journal.

PETTIS, J. S. & DELAPLANE, K. S. 2010. Coordinated responses to honey bee decline in the USA. *Apidologie,* 41**,** 256-263.

PHILLIPS, C. 2014. Following beekeeping: More-than-human practice in agrifood. *Journal of Rural Studies,* 36**,** 149-159.

PIMENTEL, D. & PIMENTEL, M. 1986. The Future of U.S. Agriculture. *Science***,** 1491-1492.

PONISIO, L. C., M'GONIGLE, L. K. & KREMEN, C. 2016. On-farm habitat restoration counters biotic homogenization in intensively managed agriculture. *Glob Chang Biol,* 22**,** 704-15.

POTTER, A. & LEBUHN, G. 2015. Pollination service to urban agriculture in San Francisco, CA. *Urban Ecosystems,* 18**,** 885-893.

POTTS, S. G., BIESMEIJER, J. C., KREMEN, C., NEUMANN, P., SCHWEIGER, O. & KUNIN, W. E. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution,* 25**,** 345-53.

POTTS, S. G., ROBERTS, S. P. M., DEAN, R., MARRIS, G., BROWN, M. A., JONES, R., NEUMANN, P. & SETTELE, J. 2015. Declines of managed honey bees and beekeepers in Europe. *Journal of Apicultural Research,* 49**,** 15-22.

POWER, A. G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. *Philos Trans R Soc Lond B Biol Sci,* 365**,** 2959-71.

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.

PRETTY, J. 2008. Agricultural sustainability: concepts, principles and evidence. *Philos Trans R Soc Lond B Biol Sci,* 363**,** 447-65.

PREVENCIA, 2019. *Prepare to say goodbye to chemical pesticides and herbicides in your garden* (online). Available at <https://www.insurance.fr/blog/prepare-say-goodbye-chemical-pesticides-and-herbicides-your-garden> [Accessed 5 July 2019].

PRIMACK, R. B. & MILLER-RUSHING, A. J. 2012. Uncovering, Collecting, and Analyzing Records to Investigate the Ecological Impacts of Climate Change: A Template from Thoreau's Concord. *BioScience,* 62**,** 170-181.

QUESTED, T. E., MARSH, E., STUNELL, D. & PARRY, A. D. 2013. Spaghetti soup: The complex world of food waste behaviours. *Resources, Conservation and Recycling,* 79**,** 43-51.

QUISTBERG, R. D., BICHIER, P. & PHILPOTT, S. M. 2016. Landscape and Local Correlates of Bee Abundance and Species Richness in Urban Gardens. *Environ Entomol,* 45**,** 592-601.

RAUSCHMAYER, F., VAN DEN HOVE, S. & KOETZ, T. 2009. Participation in EU Biodiversity Governance: How Far beyond Rhetoric? *Environment and Planning C: Government and Policy,* 27**,** 42-58.

RAWSON, J. 2008. *The World of a Bee Farmer,* Hebden Bridge, UK, Northern Bee Books.

RAYMOND, C. M., FAZEY, I., REED, M. S., STRINGER, L. C., ROBINSON, G. M. & EVELY, A. C. 2010. Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management,* 91**,** 1766-77.

RAYNER, S. 2012. Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses. *Economy and Society,* 41**,** 107-125.

REINERS, W. A., REINERS, D. S. & LOCKWOOD, J. A. 2013. Traits of a good ecologist: What do ecologists think? *Ecosphere,* 4.

RIESCH, H. & POTTER, C. 2014. Citizen science as seen by scientists: Methodological, epistemological and ethical dimensions. *Public Understanding of Science,* 23**,** 107-120.

RILEY, M. 2009. Experts in Their Fields: Farmer — Expert Knowledges and Environmentally Friendly Farming Practices. *Environment and Planning A: Economy and Space,* 40**,** 1277-1293.

RILEY, M. & HARVEY, D. 2007. Oral histories, farm practice and uncovering meaning in the countryside. *Social & Cultural Geography,* 8**,** 391-415.

RINDERER, T. & AL, E. 2010. Breeding for resistance to varroa destroctur in North America. *Apidologie,* 41**,** 409-424.

ROBBINS, P. 2003. Beyond ground truth: GIS and the environmental knowledge of herders, professional foresters, and other traditional communities. *Human Ecology,* 31**,** 233-253.

ROBBINS, P. 2006. The politics of barstool biology: Environmental knowledge and power in greater Northern Yellowstone. *Geoforum,* 37**,** 185-199.

ROBBINS, P. 2012. *Political ecology: a critical introduction,* Chichester, U.K.: J. Wiley & Sons.

ROBERTSON, M. M. 2002. No Net Loss: Wetland Restoration and the Incomplete Capitalization of Nature. *Antipode,* 32**,** 463-493.

ROBINSON, J. F. 1889. *British Bee-Farming: its profits and pleasures,* S.l., S.l. : Chapman and Hall Ltd

ROCHELEAU, D. E. 2008. Political ecology in the key of policy: From chains of explanation to webs of relation. *Geoforum,* 39**,** 716-727.

ROOT, A. I. 1910. *The ABC and XYZ of bee culture*, AI Root Company.

ROSENKRANZ, P., AUMEIER, P. & ZIEGELMANN, B. 2010. Biology and control of Varroa destructor. *J Invertebr Pathol,* 103 Suppl 1**,** S96-119.

ROYER, M.-J. S., HERRMANN, T. M., SONNENTAG, O., FORTIER, D., DELUSCA, K. & CUCIUREAN, R. 2013. Linking Cree hunters' and scientific observations of changing inland ice and meteorological conditions in the subarctic eastern James Bay region, Canada. *Climatic Change,* 119**,** 719-732.

RUIZ-MALLEN, I. & CORBERA, E. 2013. Community-Based Conservation and Traditional Ecological Knowledge: Implications for Social-Ecological Resilience. *Ecology and Society,* 18.

SALTELLI, A. & GIAMPIETRO, M. 2017. What is wrong with evidence based policy, and how can it be improved? *Futures,* 91**,** 62-71.

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.

SÁNCHEZ-BAYO, F. & WYCKHUYS, K. A. G. 2019. Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation,* 232**,** 8-27.

SANDROCK, C., TANADINI, M., TANADINI, L. G., FAUSER-MISSLIN, A., POTTS, S. G. & NEUMANN, P. 2014. Impact of chronic neonicotinoid exposure on honeybee colony performance and queen supersedure. *PLoS One,* 9**,** e103592.

SAUNDERS, M. E., PEISLEY, R. K., RADER, R. & LUCK, G. W. 2016. Pollinators, pests, and predators: Recognizing ecological trade-offs in agroecosystems. *Ambio,* 45**,** 4-14.

SAURIOL, C. 1984. *A beeman's journey,* Toronto, Natural Heritage/Natural History Inc.

SAWYER, R. & PICKARD, R. S. 1981. *Pollen identification for beekeepers*, University College Cardiff Press.

SCHÜRCH, R., COUVILLON, M. J. & RATNIEKS, F. L. W. 2016. Determining the foraging potential of oilseed rape to honey bees using aerial surveys and simulations. *Journal of Apicultural Research,* 54**,** 238-245.

SCOTT, R. M., BRADLEY S, BRYCE R AND CURZON R. 2013. Honey Bee Health: Mapping, analysis and improved understanding of stakeholder groups to help sustain honey bee health. London: DEFRA.

SECORD, A. 1994. Science in the Pub - Artisan Botanists in Early-19th-Century Lancashire. *History of Science,* 32**,** 269-315.

SEELEY, T. D. 2009. *The wisdom of the hive: the social physiology of honey bee colonies*, Harvard University Press.

SEELEY, T. D. 2010. *Honeybee democracy*, Princeton University Press.

SEELEY, T. D. 2016. *Following the wild bees: the craft and science of bee hunting*, Princeton University Press.

SEELEY, T. D. 2017. Life-history traits of wild honey bee colonies living in forests around Ithaca, NY, USA. *Apidologie,* 48**,** 743-754.

SEELEY, T. D. 2019. *Following the wild bees: the craft and science of bee hunting*, Princeton University Press.

SEELEY, T. D., TARPY, D. R., GRIFFIN, S. R., CARCIONE, A. & DELANEY, D. A. 2015. A survivor population of wild colonies of European honeybees in the northeastern United States: investigating its genetic structure. *Apidologie,* 46**,** 654-666.

SEENEY, A., EASTWOOD, S., PATTISON, Z., WILLBY, N. J. & BULL, C. D. 2019. All change at the water's edge: invasion by non-native riparian plants negatively impacts terrestrial invertebrates. *Biological Invasions,* 21**,** 1933-1946.

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. *Journal of Apicultural Research,* 54**,** 292-304.

SENAPATHI, D., BIESMEIJER, J. C., BREEZE, T. D., KLEIJN, D., POTTS, S. G. & CARVALHEIRO, L. G. 2015. Pollinator conservation—the difference between managing for pollination services and preserving pollinator diversity. *Current Opinion in Insect Science,* 12**,** 93-101.

SHACKLETON, K. & RATNIEKS, F. L. W. 2015. Garden varieties: How attractive are recommended garden plants to butterflies? *Journal of Insect Conservation,* 20**,** 141-148.

SHAW, W. 2014. *Simple Methods of Making Increase*, Welsh Beekeeping Association.

SHIRK, J. L., BALLARD, H. L., WILDERMAN, C. C., PHILLIPS, T., WIGGINS, A., JORDAN, R., MCCALLIE, E., MINARCHEK, M., LEWENSTEIN, B. V., KRASNY, M. E. & BONNEY, R. 2012. Public Participation in Scientific Research: a Framework for Deliberate Design. *Ecology and Society,* 17**,** 20.

SILVER, C. & LEWINS, A. 2014. *Using software in qualitative research: A step-by-step guide*, Sage.

SILVERMAN, D. 2016. *Qualitative research*, Sage.

SILVERTOWN, J., BUESCHING, C. D., JACOBSON, S. K. & REBELO, T. 2013. Citizen science and nature conservation. *Key topics in conservation biology,* 2**,** 127-142.

SIMON-DELSO, N., SAN MARTIN, G., BRUNEAU, E. & HAUTIER, L. 2018. Time-to-death approach to reveal chronic and cumulative toxicity of a fungicide for honeybees not revealed with the standard ten-day test. *Sci Rep,* 8**,** 7241.

SIMS, D. 1997. *Sixty years with bees*, Hebden Bridge: Northern Bee Books.

SIVAKOFF, F., PRAJZNER, S. & GARDINER, M. 2018. Unique Bee Communities within Vacant Lots and Urban Farms Result from Variation in Surrounding Urbanization Intensity. *Sustainability,* 10**,** 1926.

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. *Biological conservation,* 211**,** 20-28.

SMITH, H. A. & SHARP, K. 2012. Indigenous climate knowledges. *Wiley Interdisciplinary Reviews: Climate Change,* 3**,** 467-476.

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 Conservation and Diversity,* 9**,** 384-390.

SOUTH TIPPERARY BEEKEEPERS'S ASSOCIATION 1995. *South Tipperary Beekeepers' Association golden jubilee, 1945 - 1995,* Belfast : BeeLines

SPEAK, A. F., MIZGAJSKI, A. & BORYSIAK, J. 2015. Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity. *Urban Forestry & Urban Greening,* 14**,** 772-781.

SPILLER, J. 1952. *The Advantages of the House Apiary,* Taunton, W J Cornwell & Company.

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.

STEHR, N. 2001. A world made of knowledge. *Society,* 39**,** 89-92.

STERK, G., PETERS, B., GAO, Z. & ZUMKIER, U. 2016. Large-scale monitoring of effects of clothianidin-dressed OSR seeds on pollinating insects in Northern Germany: effects on large earth bumble bees (Bombus terrestris). *Ecotoxicology,* 25**,** 1666-1678.

STEVENS, M., VITOS, M., ALTENBUCHNER, J., CONQUEST, G., LEWIS, J. & HAKLAY, M. 2014. Taking Participatory Citizen Science to Extremes. *Ieee Pervasive Computing,* 13**,** 20-29.

ŠŪMANE, S., KUNDA, I., KNICKEL, K., STRAUSS, A., TISENKOPFS, T., RIOS, I. D. I., RIVERA, M., CHEBACH, T. & ASHKENAZY, A. 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies,* 59**,** 232-241.

SURYANARAYANAN, S. 2013. Balancing Control and Complexity in Field Studies of Neonicotinoids and Honey Bee Health. *Insects,* 4**,** 153-67.

SURYANARAYANAN, S. 2016. Intractosoma: Toward an Epistemology of Complexity Based on Intra-acting Bodies. *Engaging Science Technology and Society,* 2**,** 322-330.

SURYANARAYANAN, S. & KLEINMAN, D. L. 2013. Be(e)coming experts: The controversy over insecticides in the honey bee colony collapse disorder. *Social Studies of Science,* 43**,** 215-240.

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.

SUTHERLAND, W. J., GARDNER, T. A., HAIDER, L. J. & DICKS, L. V. 2013. How can local and traditional knowledge be effectively incorporated into international assessments? *Oryx,* 48**,** 1-2.

TENGO, M., BRONDIZIO, E. S., ELMQVIST, T., MALMER, P. & SPIERENBURG, M. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. *Ambio,* 43**,** 579-91.

THOMAS, C. D., JONES, T. H. & HARTLEY, S. E. 2019. "Insectageddon": A call for more robust data and rigorous analyses. *Glob Chang Biol,* 25**,** 1891-1892.

THOMAS, E., VALDIVIA, J., ALCAZAR CAICEDO, C., QUAEDVLIEG, J., WADT, L. H. O. & CORVERA, R. 2017. NTFP harvesters as citizen scientists: Validating traditional and crowdsourced knowledge on seed production of Brazil nut trees in the Peruvian Amazon. *PLoS One,* 12**,** e0183743.

THOMS, C. A., NELSON, K. C., KUBAS, A., STEINHAUER, N., WILSON, M. E. & VANENGELSDORP, D. 2018. Beekeeper stewardship, colony loss, and Varroa destructor management. *Ambio***,** 1-10.

TILMAN, D. 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. *Proc Natl Acad Sci U S A,* 96**,** 5995-6000.

TOLEDO, V. M., STEPP, J. R., WYNDHAM, F. S. & ZARGER, R. K. 2002. Ethnoecology: a conceptual framework for the study of indigenous knowledge of nature. Athens, Ga: The International Society of Ethnobiology

TOSI, S., COSTA, C., VESCO, U., QUAGLIA, G. & GUIDO, G. 2018. A 3-year survey of Italian honey bee-collected pollen reveals widespread contamination by agricultural pesticides. *Sci Total Environ,* 615**,** 208-218.

TRENBERTH, K. E. 2011. Changes in precipitation with climate change. *Climate Research,* 47**,** 123-138.

TRUMBULL, D., BONNEY, R., BASCOM, D. & CABRAL, A. 2000. Thinking scientifically during participation in a citizen-science project. *Science Education,* 84**,** 265-275.

TSCHARNTKE, T., CLOUGH, Y., WANGER, T., JACKSON, L., MOTZKE, I., PERFECTO, I., VANDERMEER, J. & WHITBREAD, A. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. 151**,** 53–59.

TURNBULL, W. H. 1958. *One hundred years of beekeeping in British Columbia, 1858-1958,* S.l., S.l. : B.C. Honey Producers' Association

TURNER, M. D. 2003. Methodological reflections on the use of remote sensing and geographic information science in human ecological research. *Human Ecology,* 31**,** 255-279.

TURNER, N. & SPALDING, P. 2013. “We Might Go Back to This”; Drawing on the Past to Meet the Future in Northwestern North American Indigenous Communities. *Ecology and Society:,* 18.

TURNER, N. J., IGNACE, M. B. & IGNACE, R. 2000. Traditional Ecological Knowledge and Wisdom of Aboriginal Peoples in British Columbia. *Ecological Applications,* 10**,** 1275-1287.

TURVEY, S. 2008. *Witness To Extinction: How We Failed to Save the Yangtze River Dolphin,* Oxford, Oxford University Press.

TURVEY, S. T., BARRETT, L. A., YUJIANG, H., LEI, Z., XINQIAO, Z., XIANYAN, W., YADONG, H., KAIYA, Z., HART, T. & DING, W. 2010. Rapidly shifting baselines in Yangtze fishing communities and local memory of extinct species. *Conserv Biol,* 24**,** 778-87.

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? *Biological Conservation,* 157**,** 352-360.

UCHIYAMA, Y., MATSUOKA, H. & KOHSAKA, R. 2017. Apiculture knowledge transmission in a changing world: Can family-owned knowledge be opened? *Journal of Ethnic Foods,* 4**,** 262-267.

UNIVERSITY OF SUSSEX, 2019. *The Laboratory of Apiculture and Social Insects* (Online) Available at <(http://www.sussex.ac.uk/lasi/> Accessed 10 July 2019

UDOVYK, O. 2014. Models of science-policy interaction: exploring approaches to Bisphenol A management in the EU. *Sci Total Environ,* 485-486**,** 23-30.

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.

USHER, P. J. 2000. Traditional ecological knowledge in environmental assessment and management. *Arctic***,** 183-193.

UZUNOV, A., COSTA, C., PANASIUK, B., MEIXNER, M., KRYGER, P., HATJINA, F., BOUGA, M., ANDONOV, S., BIENKOWSKA, M., CONTE, Y. L., WILDE, J., GERULA, D., KIPRIJANOVSKA, H., FILIPI, J., PETROV, P., RUOTTINEN, L., PECHHACKER, H., BERG, S., DYRBA, W., IVANOVA, E. & BÜCHLER, R. 2015. Swarming, defensive and hygienic behaviour in honey bee colonies of different genetic origin in a pan-European experiment. *Journal of Apicultural Research,* 53**,** 248-260.

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. *Current Opinion in Environmental Sustainability,* 5**,** 293-305.

VAN DER STEEN, J. S. & BRODSCHNEIDER, R. 2015. Public Participation In Bee Science: C.S.I. Pollen. *Bee World,* 91**,** 25-27.

VAN DER WAL, R., ANDERSON, H., ROBINSON, A., SHARMA, N., MELLISH, C., ROBERTS, S., DARVILL, B. & SIDDHARTHAN, A. 2015. Mapping species distributions: a comparison of skilled naturalist and lay citizen science recording. *Ambio,* 44 Suppl 4**,** 584-600.

VANBERGEN, A. J. & INITIATIVE, T. I. P. 2013. Threats to an ecosystem service: pressures on pollinators. *Frontiers in Ecology and the Environment,* 11**,** 251-259.

VANDAME, R. & PALACIO, M. A. 2010. Preserved honey bee health in Latin America: a fragile equilibrium due to low-intensity agriculture and beekeeping? *Apidologie,* 41**,** 243-255.

VANEGAS, M. 2017. The Silent Beehive: How the Decline of Honey Bee Populations Shifted the Environmental Protection Agency's Pesticide Policy towards Pollinators. *Ecology Law Quarterly,* 44**,** 311-341.

VOLUNTARY INITIATIVE, 2019. *Bee Connected: How It Works* (online) Available at: <https://beeconnected.org.uk/how-it-works/> [Accessed 10 July 2019]

VANENGELSDORP, D. & MEIXNER, M. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. *Journal of Invertebrate Pathology,* 103**,** S80–S95.

WALKER, P. & CRANE, E. 2001. English beekeeping from c. 1200 to 1850: evidence from local records. *Local Hist,* 31**,** 3-30.

WARING, S. 2015. *Farming for the Landless: new perspectives on the cultivation of our honeybee,* Great Britain, Platin Press.

WATSON, J. K. 1981. *Bee-keeping in Ireland, a history,* Dun Laoghaire, Glendale Press.

WEEN, G. B. & RISETH, J. Å. 2011. Doing is Learning: Analysis of an Unsuccessful Attempt to Adapt TEK/IK Methodology to Norwegian Sámi Circumstances. *Acta Borealia,* 28**,** 228-242.

WEHN, S., BURTON, R., RILEY, M., JOHANSEN, L., HOVSTAD, K. A. & RØNNINGEN, K. 2018. Adaptive biodiversity management of semi-natural hay meadows: The case of West-Norway. *Land Use Policy,* 72**,** 259-269.

WELSH GOVERNMENT 2013. Action Plan For Pollinators in Wales *In:* TEAM, B. (ed.).

WHATMORE, S. 2016. Materialist returns: practising cultural geography in and for a more-than-human world. *cultural geographies,* 13**,** 600-609.

WHATMORE, S. J. 2009. Mapping knowledge controversies: science, democracy and the redistribution of expertise. *Progress in Human Geography,* 33**,** 587-598.

WHITMARSH, L. & O'NEILL, S. 2010. Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *Journal of Environmental Psychology,* 30**,** 305-314.

WILFERT, L., LONG, G., LEGGETT, H. C., SCHMID-HEMPEL, P., BUTLIN, R., MARTIN, S. J. & BOOTS, M. 2016. Deformed wing virus is a recent global epidemic in honeybees driven by Varroa mites. *Science,* 351**,** 594-7.

WILLEMS-BRAUN, B. 1997. Buried epistemologies: the politics of nature in (Post)colonial British Columbia. *The Annals of the Association of American Geographers,* 87**,** 3.

WILLIAMS, B. & RILEY, M. 2019. The challenge of oral history to environmental history. *Environment and History*.

WILLIAMS, G. R., TARPY, D. R., VANENGELSDORP, D., CHAUZAT, M. P., COX-FOSTER, D. L., DELAPLANE, K. S., NEUMANN, P., PETTIS, J. S., ROGERS, R. E. & SHUTLER, D. 2010. Colony Collapse Disorder in context. *Bioessays,* 32**,** 845-6.

WILLIS, R. 2018. Constructing a 'Representative Claim' for Action on Climate Change: Evidence from Interviews with Politicians. *Political Studies,* 66**,** 940-958.

WILSON, J. S., FORISTER, M. L. & CARRIL, O. M. 2017. Interest exceeds understanding in public support of bee conservation. *Frontiers in Ecology and the Environment,* 15**,** 460-466.

WINSTON, M. L. 1987. *The biology of the honey bee,* Cambridge, Mass. , Harvard University Press.

WINSTON, M. L. 2014. *Bee time: Lessons from the hive*, Harvard University Press.

WINSTON, M. L. 2018. *From where I sit: essays on bees, beekeeping, and science*, Cornell University Press.

WOOD, T. J., HOLLAND, J. M. & GOULSON, D. 2015. Pollinator-friendly management does not increase the diversity of farmland bees and wasps. *Biological Conservation,* 187**,** 120-126.

WOODCOCK, B. A., BULLOCK, J. M., SHORE, R. F., HEARD, M. S., PEREIRA, M. G., REDHEAD, J., RIDDING, L., DEAN, H., SLEEP, D., HENRYS, P., PEYTON, J., HULMES, S., HULMES, L., SAROSPATAKI, M., SAURE, C., EDWARDS, M., GENERSCH, E., KNABE, S. & PYWELL, R. F. 2017. Country-specific effects of neonicotinoid pesticides on honey bees and wild bees. *Science,* 356**,** 1393-1395.

WULF, A. 2015. *The Invention of Nature: The Adventures of Alexander von Humboldt, the Lost Hero of Science,* London, John Murray

WYNNE-JONES, S. 2013. Ecosystem Service Delivery in Wales: Evaluating Farmers' Engagement and Willingness to Participate. *Journal of Environmental Policy & Planning,* 15**,** 493-511.

WYNNE-JONES, S. 2016. Flooding and media storms – controversies over farming and upland land-use in the UK. *Land Use Policy,* 58**,** 533-536.

WYNNE-JONES, S. 2017. Understanding farmer co-operation: Exploring practices of social relatedness and emergent affects. *Journal of Rural Studies,* 53**,** 259-268.

WYNNE, B. 2008. Elephants in the rooms where publics encounter "science"?: A response to Darrin Durant, "Accounting for expertise: Wynne and the autonomy of the lay public". *Public Understanding of Science,* 17**,** 21-33.

YOUNG, J. C., ROSE, D. C., MUMBY, H. S., BENITEZ-CAPISTROS, F., DERRICK, C. J., FINCH, T., GARCIA, C., HOME, C., MARWAHA, E., MORGANS, C., PARKINSON, S., SHAH, J., WILSON, K. A. & MUKHERJEE, N. 2018. A methodological guide to using and reporting on interviews in conservation science research. *Methods in Ecology and Evolution,* 9**,** 10-19.