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The precautionary principle at work: The case of neonicotinoids and the health of bees

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Abstract

In recent years, scientists have noted a decline in the health of bee populations. Whereas a whole host of possible causes have been identified, it is the use of pesticides in agriculture—specifically the use of neonicotinoids—that has warranted some investigation. The scientific evidence of their impact on the health of bees remains debated. This article examines how the UK Government has responded to the decline in bee populations and the apparent link to neonicotinoids. While notionally committed to deploying the Precautionary Principle in such instances, the government has tended to err more on 'sound science' as a policymaking tool. Early evidence indicates that the government used the latter initially but has become more amenable to utilising a precautionary approach recently. Whether this can be attributed to an embrace of the Precautionary Principle, or simply a change caused by the installation of a new Secretary of State for the Environment, is open to interpretation.

Key words: bee health, precautionary principle, government regulation

Introduction

Governments rely on scientific advisors in much of their policymaking and having the authority and status of scientists to approve policy decisions provides governments with an important kind of support. However, governments tend to expect scientists to always provide positive evidence on what are often difficult issues, and this is because there are often uncertainties in the evidence, as the examples from medical science discussed below will illustrate. In cases where there is uncertainty, there are two alternative ways of proceeding: either to wait until the evidence becomes conclusive that a problem does exist which requires governmental intervention (the sound science approach); or to take immediate action in advance of conclusive evidence that there is a problem which requires governmental intervention, because, if action is delayed until that evidence becomes available, it might be too late to prevent irreversible harm being done (that is, a precautionary approach, or one based on the precautionary principle). There are many examples, as we will see, that suggest 'that while nominally committed to the precautionary principle, the UK government tends to take a more "sound science" approach to regulating environmental risk' (Patterson and McLean 2017: 2). Somewhat unexpectedly, however, in the case of neonicotinoids and bee health the government's position has evolved into a more precautionary stance than might otherwise have been expected, based on previous action.

Although the issue of pesticides and bee health had been periodically debated for some time, the use of neonicotinoids and their potential impact on bee populations became news in March 2011. This was due to a report in the Beekeeper newssheet *BeeMail* on March 2011, noting that a former Home Office Minister, David Hanson, had put a parliamentary question to Spelman about the issue (BeeMail 2011). In addition, an *Ecologist* petition titled 'Save the Bees' that was handed to the then Secretary of State for the Environment, Caroline Spelman (Lee 2011). By December 2012, the Environmental Audit Committee held a session on 'Insects and Insecticides' (but not specifically on neonicotinoids). In this session, a group of scientists presented evidence about their paper on the issue, stating they had sent their paper to Spelman and the Chief Scientist who had confirmed they had read it, but who replied that the scientists 'did not have enough proof' of a link between insecticides/neonics and bee health (House of Commons 2012). By this time, a new Secretary of State for the Environment, Owen Paterson, had been appointed, and since that time the issue has not abated. A useful way of tracking the UK's stance on neonicotinoids is to follow the actions/speeches of the Secretaries of States for the Environment during the period 2010 to 2018, given that the issue of neonicotinoids and bee health fall under their remit (coincidentally, this particular issue became salient around the same time that the Labour Government lost its parliamentary majority in 2010; hence we have not sought to examine developments whilst Labour was in office). During the subsequent period, when the issue of pesticides in farming has been most salient, there have been five heads of that department, three of these, Caroline Spelman, Liz Truss and Andrea Leadsom have not made their thoughts on the issue very public except to be sceptical of any evidence of problems with neonicotinoids.

The other two incumbents, Owen Paterson and Michael Gove, however, have been very interventionist and vocal on public forums. It is the stances of these latter two, therefore, that forms the majority of our analysis of UK government stances.

Our methodology in carrying out this study is a qualitative one and chosen because of the highly complex relationships between government institutions, scientists, the political stances of some of the main actors in the decision-making on the issue, and the various institutions of the EU to which we have referred in some detail. Evidence to support the theoretical framework and the case study itself has been gathered in a number of ways. These include an analysis of published scientific papers, books and articles on the PP, relevant parliamentary select committee papers and speeches by politicians. The methods employed in this paper to retrieve information include an analysis of published scientific papers, speeches by politicians (specifically those of the two then Secretaries of State for the Environment—Owen Paterson and Michael Gove), news reports and the contribution of environmentalists to the debates on this issue. In these investigations, we sought out both evidence that supports the case for the banning of neonicotinoids and also dissenting opinions. We also looked at the political stances of the political actors involved in the controversy by analysing their speeches. As mentioned above, although there have been five Secretaries of State for the Environment, we were unable to uncover any statements made by Spelman, Truss, or Leadsom on the issue of bees and neonicotinoids, and hence we have not discussed these individuals in this article.

This article is organised in the following manner. It begins by unpacking the precautionary principle/approach dichotomy, before then outlining how the precautionary principle is used as a policy tool. The article then examines the issue of bee health and scientific research into the use of agricultural pesticides, before outlining how industry has reacted to these scientific findings. The paper then investigates policy options that were open to successive governments and how they implemented decisions. The analysis concludes by weighing whether the government took a sound science or precautionary approach to the issue of pesticides and bee health. On the issue outlined in this article, namely, the proposition that the bee population is declining because of the use of certain pesticides, we will see that the government actually adopted a precautionary approach, but only after a change of the Secretary of State. This confounds how the UK government has traditionally sought to make environmental policy, which more often than not has been based on the sound science approach.

The precautionary principle or a precautionary approach?

There is considerable debate as to whether the terminology 'precautionary principle' and 'precautionary approach' are equivalent or used differently depending on the context (Cooney and Dickson 2005: 5). The fact that much of the literature agonises over the significance, meaning and application of the precautionary principle, indicates that it has one central difficulty—lack of clarity of meaning. It is not surprising, therefore, that much of the literature on the precautionary principle is critically against the whole concept (for example, Bodansky 1991; Manson 2002 and Sunstein 2005).

One convenient way of coping with the problem of defining precaution is to categorize it into 'strong' and 'weak' versions (Morris 2000; McLean and Patterson 2006; Patterson and McLean 2008). In its strongest formulation, and preferred by 'green' NGOs, environmentalists, and interest groups, the precautionary principle can be said to insist upon absolute proof of safety before allowing new technologies to be adopted. This formulation can be seen clearly in the Wingspread declaration. A number of environmentalists from the USA, Canada, and Europe, undertook the task of attempting to outline ways in which the precautionary principle could be integrated into decision-making. This group convened a Conference at the Wingspread Conference Centre, Racine, in January 1998, which resulted in the issuing of a consensus statement defining the precautionary principle:

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof (Raffensperger and Tickner 1999: 8).

Here the onus is, for example, placed on the polluters to prove beyond doubt that his/her polluting activities will not damage the environment: that is, there has to be *certainty* that no harm will befall the environment if no intervention is made. In considering this strong formulation of the precautionary principle Sunstein argues it 'is incoherent, and for one reason: There are risks on all sides of social situations. It is therefore paralyzing; It forbids the very steps that it requires' (Sunstein 2005: 4).

In contrast, a weaker version of the precautionary principle was agreed in the Ministerial Declaration of the UN Conference on Environment and Development (the 'Earth Summit') in Rio de Janeiro—popularly known as the 'Rio Declaration'. Principle 15 states: 'Where there are threats of serious or irreversible damage, lack of scientific certainty shall not be used as a reason for postponing *cost-effective* measures to prevent environmental degradation' (United Nations 1992—emphasis added). This is a weaker version than the Wingspread formulation because it has added the caveat that any measures taken should be 'cost-effective' and is often seen as a management approach to dealing with risk and uncertainty. Here again, Sunstein is critical: 'The weak versions of the precautionary principle state a truism – uncontroversial in principle and necessary in practice only to combat public confusion . . .' (Sunstein 2005: 24).

A more recent analysis of the precautionary principle addresses this dilemma—that it is trivial or incoherent. Daniel Steel, a philosopher, in his book (2014) dismisses these objections. He develops a precautionary principle consisting of three components. First, is what he terms the Meta-Precautionary Principle (MPP) which states that in the face of serious environmental threats, uncertainty should not be a reason for inaction (Steel 2014: 21). Secondly, the 'Tripod', consisting of the knowledge condition, the harm condition and the recommended precaution (Steel 2014: 9). Finally, proportionality—tackles the criticism of the precautionary principle that it is incoherent and therefore irrational. It is the idea that precaution should correspond to how plausible and severe the threat. This works through two sub-components: consistency and efficiency (Steel 2014: 27).

Proportionality is an important feature of the precautionary principle and simply means that remedial measures should be tailored to a chosen level of protection. This places the focus on the *magnitude* of the effect. Rather than simply saying 'there is uncertainty therefore we should not proceed,' policymakers and regulators must weigh up the level of that uncertainty. In other words, the

application of precaution 'is context and case specific, that is it depends on the level of risk a society considers acceptable for a specific substance or activity at a given moment in time' (Christoforou 2003: 206). Similarly, the EU Commission has stated: 'Proportionality means tailoring measures to the chosen level of protection. Risk can rarely be reduced to zero, but incomplete risk assessments may greatly reduce the range of options open to risk managers. A total ban may not be a proportional response to a potential risk in all cases. However, in certain cases, it is the sole possible response to a given risk' (Commission of the EC 2000: 3).

In the EU there was much discussion in the 1990s on the precautionary principle and how it should be applied (Douma 2003: 230). In 2000, the EU Commission produced a Communication (Commission of the EC 2000) that established guidelines for applying the principle to enable a common understanding of how to appraise, manage, and communicate risk that science was unable to definitively conclude. This Communication states that in specific circumstances where scientific evidence is insufficient, inconclusive, or uncertain, and there are indications through preliminary objective scientific evaluation of reasonable grounds for concern, then the precautionary principle is the correct risk strategy to use (Commission of the EC 2000: 8–9). Its final purpose was to ensure that recourse to the principle was not used as a form of protectionism.

However, one professor of risk management believes there is too much focus on the precautionary principle. He notes that the EU has been concerned that in an increasingly globalised world there was a need to remain competitive to ensure sustained economic growth. The EU Commission was also concerned about how to regain public credibility after a number of regulatory scandals. In light of this, according to Lofstedt, the drivers of European regulation were to be competitiveness, sustainable development, and governance (Lofstedt 2004: 24). In his working paper for the AEI/Brookings Joint Centre for Regulatory Studies, he noted that the two regulatory philosophies the EU used are the precautionary principle and impact analysis, but that '...to date most of the academic attention has been focused on the precautionary principle, but I think greater attention needs now to be paid to impact analysis (Lofstedt 2004: 24).

In the USA, the George W. Bush Administration appeared to object to the principle on the grounds that it interferes with the ability of industry to make profits. The President's Office of Management and Budget argued that, 'precaution is sensible but susceptible to misuse'. If precaution is taken to an extreme, it can be very harmful to technological innovation. (Graham 2002). A year later Graham noted that the EU Communication was 'following views that are similar to the perspectives of the US government' (Graham 2003: 4).

Other American analysts have asked the question who is more precautionary: the USA or the EU? In their comprehensive book comparing risk regulation in both the USA and the EU (Wiener *et al.* 2011), their conclusions were that:

> ... the reality of precaution is particularity, not principle. The real pattern of precaution across the Atlantic since the 1970...has been general parity, punctuated by occasional differences over particular risks, some of which become high-visibility disputes (Wiener *et al* 2011: 555).

Two of the examples they mention are growth hormones in beef such as bovine somatotropin (BST) and bovine spongiform encephalopathy (BSE). These examples show that while the EU was more precautionary about beef hormones than the USA, the USA was more precautionary than the EU on BSE: the USA was much quicker than the EU in banning the export of British beef (Wiener *et al.* 2011: 65). Historically, this is what Wiener *et al.* call the 'flip-flop' hypothesis, with the USA more precautionary than Europe in the 1970s, while the EU became more precautionary in the 1990s (Wiener *et al.* 2011: 5). However, Vogel, in an article on European environmental regulation believes that EU regulatory policies since the 1990s resemble the policies of the USA in the 1970s. His conclusions were that:

> ... in many respects European and American regulatory politics have 'traded places'. Regulatory issues were formerly more politically salient and civic interests more influential in the United States than in most individual European countries or the EU. More recently, this pattern has been reversed (Vogel 2003: 558).

The precautionary principle as a policy tool

Using the precautionary principle in the presence of uncertainty can be explained by reference to public policy decisions. Policy fields may show characteristics that are either routine, complex, or technically difficult. In these categories, strategies for coping can be made as outcomes are certain. There are some fields, however, where there are scientific unknowns with no determined solutions, or indeed there are rival claims from experts. As a result, there is scientific uncertainty which goes beyond the range of known, observable uncertainties that are recognised within the parameters of the system being researched. As Wynne puts it: 'scientific knowledge gives prominence to a restricted agenda of defined uncertainties – ones that are tractable – leaving invisible a range of other uncertainties, especially about the boundary conditions of applicability of the existing framework of knowledge to new situations' (Wynne 1992: 115). In this seminal work, Wynne introduced a typology to identify four different kinds of uncertainty: risk, uncertainty, ignorance, and indeterminacy. *Risk* is considered to occur when we 'know the odds'—that is, when we know the boundaries of the system under investigation and are able to measure in some way the factors involved. *Uncertainty* represents knowledge of the parameters of a system—'limitations of observational and measurement techniques' (Salter 1988: 201). *Ignorance* is that which is not known: for ignorance to be identified, new knowledge must be discoverable. The last category, *indeterminacy*, is the 'recognition of the open-ended and conditional nature of knowledge and its embeddedness in social contexts' (Hunt 1994: 117). This fourth category recognizes that social behaviour has to be included into the policy process, and generally fits the categories of the precautionary principle and the precautionary approach outlined in our introduction. This typology highlights the point that the conventional debate on risk implies that risk is always quantifiable, but in doing so, it reduces scientific uncertainties to the notion that what is studied by experts is controlled and all ambiguities are solvable. It is also worth noting that in applying the precautionary approach to particular situations, there is an important distinction between prevention and precaution. The precautionary approach is applied when there is *uncertainty* as to the effects of a disease, substance, or industrial process. Where it is known that, for example, a substance resulting from industrial emissions will cause harm, the principle is one of prevention (Haigh 1994: 241).

In the European Environmental Agency study on the precautionary principle, the authors conducted 14 case studies of environmental disaster that had occurred around the world and found, among their other conclusions that 'If more account, scientifically, politically and economically, is taken of a richer body of information from

more diverse sources, then society may do substantially better in the future at achieving a better balance between innovations and their hazards' (Harremoes *et al.* 2002: 216).

Several decades ago, two analysts argued that an appeal to objective facts can increase, rather than close off, political debate. Science will always encounter either an 'under-critical' or an 'over-critical' environment when it is linked to policy. In the under-critical model, a policy consensus exists before new research is undertaken, and so ensures a too easy reception of scientific claims that appear to support the policy. In the over-critical model, political adversaries are sharply divided, and scientific claims are subjected to close scrutiny by experts from rival groups, 'technical debate therefore becomes endless... in either case the impact of science on policy is negligible' (Collingridge and Reeve 1986: 31).

Two recent medical science issues illustrate this point. First, the issue of sugar in diets. For at least three decades, fat was seen as the problem in most diets—the under-critical model. However, more recently, sugar has arisen to the fore with some medical researchers sounding the alarm that sugar, not fat, was the greatest danger to human health. This created a long debate amongst the nutritional scientists as to whether sugar or fat was the cause of obesity. One nutritionalist, Nina Teicholz, wrote an article in the BMJ criticising the established dietary guidelines which resulted in 173 scientists signing a letter to the BMJ demanding it retract the article (Leslie 2016). The second example of scientific disagreement is the issue of parents being convicted of shaking their baby, causing death. Many scientists believed in the hypothesis that shaking a baby was the only cause of bleeding in the brain and retina, combined with brain swelling, again, the under-critical model. Meanwhile, other scientists who had been expert witnesses in court cases did not believe this was necessarily the case. Some of these scientists were vilified by their colleagues, and one expert witness was struck off for her views (Storr 2017).

Therefore, these, and many other recent issues which have posed potential threats to the environment or human health have become the subject of controversy, not necessarily because of any novelty factor, but because of competing views over proposed solutions, or even as to whether a problem exists. Many of these issues reveal a split between those actors who take a sound science approach, relying on firm evidence of risk, and those who would take a precautionary approach when there appears to be significant risk. The former approach can be discerned in the UK policy style in the cases of BSE in cattle, in the development of genetically modified organisms (GMOs) and in the use of organophosphates (OPs) in sheep farming (Patterson 2008). The UK government's instinctive response at the time was to invoke the 'sound science' principle. In other words, action had to be based on concrete evidence that a causal relationship had been established between the alleged threat and human health before remedial measures were taken, and furthermore, in the above cases it was claimed that there was no evidence to support such remedial action' (Patterson and McLean 2017: 3). This demonstrates a culture of deference, where the public must rely on the 'expert' to decide, using risk assessment techniques; where events are manipulated; where demands are made for verifiable evidence of proof of damage; and where the government's own experts are chosen selectively, while at the same time efforts are made to discredit 'outside' expert opinion. It is also a culture of avoidance; evidence that is controversial is presented to the public in ways that play down its importance. Despite all of this, the UK government has committed itself to the precautionary principle: the government's inter-departmental Liaison Group on risk assessment paper (ILGRA) was first published in 2002 and is still extant (ILGRA 2002). This document clearly states: 'The government is committed to using the precautionary principle which is included in the 1992 Rio Declaration on Environment and Development' (ILGRA 2002: 2).

The issue of bee health

Pesticides are an important tool in intensive agriculture and food production. There has to be, however, a trade-off between the effects of these pesticides on nature and the protection of the environment, and therein lies the problem. Over the past several decades, for example, scientists have noted a global decline in bee populations. Climate change, viruses, fungi, the varroa mite and other parasites, and the destruction of habitats have all been put forward as explanations for this decline. More recently, the widespread use of neonicotinoid pesticide seed dressings has come under close scrutiny as the likely cause of this decline. Neonicotinoids, first used in the 1990s, are systematic neurotoxins that affect 'the central nervous system in insects, causing nervous stimulation at low concentrations, but receptor blockage, paralysis and death at higher concentrations', and they 'act systematically, travelling through plant tissue and protecting all parts of the crop, and are widely applied to seed dressings' (Goulson, 2013: 977). These pesticides find their way through the plant's system. Worryingly, according to the UK's Chief Scientific Advisor, neonicotinoids '...were being used widely throughout the arable cereal industry and in some specialised crops such as carrots, parsnips and sugar beet, not just on flowering crops' (Boyd 2018: 921).

The EU proposed to ban three of the most used neonicotinoids in 2013, but the then UK Secretary for the Environmental did not support the measures proposed because he wanted 'scientific proof based on "real world, not theoretical" studies that pesticide poisoning is to blame' (McCarthy 2013). Rather predictably, the pesticide industry was vigorous in its denial that there is a problem with its products. However, by November 2017, the present Secretary of State for the Environment, Michael Gove had become worried about the fall in the numbers of flying insect populations, 'because of the critical role played by bees and other pollinators. These particular flying insects are absolutely critical to the health of the natural world' (Gove 2017). He went on to observe that such deterioration in the environment is also bad economic news, as pollinators 'contribute somewhere between £400-600 m every year to agricultural productivity...' (Gove 2017). He proposed supporting restrictions on neonicotinoids.

The chief scientific advisor at the Department for Environment, Food and Rural Affairs Professor Ian Boyd, said at the time: 'The important question is whether neonicotinoids' use results in harmful effects on populations of bees and other pollinators as a whole. The available evidence [now] justifies taking further steps to restrict the use of neonicotinoids' (Carrington 2017).

Scientific research into the issue of agricultural pesticides

Behind the calls for more research and bans on the use of these pesticides are a number of scientific studies that show that when insects are fed on neonicotinoid insecticides some negative effects on their behaviour and life cycles will be found. A number of high profile scientific studies have shown neonicotinoids to increase mortality in

honeybees (Biesmeijer *et al.* 2006; van der Sluijs *et al.* 2013; Woodcock *et al.* 2017) and reduce the reproductive success of bumblebees (Whitehorn *et al.* 2012). A Royal Society paper summarised much of the research:

> Evidence continues to accumulate from semi-field experiments that sublethal exposure to neonicotinoid insecticides, chiefly but not exclusively at the high end of what is likely to be experienced in the environment can affect foraging and other behaviours in the field. Several true field studies have reported no effect of exposure to neonicotinoid-treated crops on honeybee colony performance, but the first large-scale study of the exposure of bumblebees found strong evidence of harmful effects' (Godfray *et al.* 2015: A27).

And so the debate on neonicotinoid insecticides has found that: '... major gaps in our understanding remain, and different policy conclusions can be drawn depending on the weight one accords to important (but not definitive) science findings and the weightings given to the economic and other interests of different stakeholders' (Godfray *et al.* 2015: para 4). In 2009, the EU issued a Guidance Document on the risk assessment of plant products and bees (Regulation (EC) 1107/2009). The EU had in the past approved five neonicotinoid insecticides for plant protection; clothianidin, imidacloprid, thiamethoxam acetamiprid, and thiacloprid. A new scientific review of these neonicotinoids was published in the European Food Safety Authority (EFSA) Journal in 2013 (EFSA 2013). This review studied 30 scientific papers submitted to the EU Commission by the agrochemical industry when seeking approval and registration of the three of these products. The conclusions of this review were that these three insecticides, clothianidin, imidacloprid, and thiamethoxam, were a: 'significant risk to honey bees when used on flowering crops. In addition, risks were identified through their use on winter cereals, and other crops that are not attractive to bees, especially through exposure to insecticide-laden dust dispersed into the atmosphere at sowing' (McGrath 2014: 3). In the light of these conclusions, in March 2013 the EU Commission banned the use of these three products for two years: (EU Commission 2013). Under this ban, farmers were not able to buy or sow seeds of crops treated with the three insecticides in question that were attracted for bees. This decision was due to be reviewed by November 2017.

An article co-authored by the UK's Chief Scientific Adviser noted the unsatisfactory way in which pesticides are regulated in the EU. The article, in *Science*, suggested that a new system:

> ... would place responsibility for monitoring the use and effects of these chemicals on manufacturers and growers by applying preregistered designs for how data should be collected. It would improve decisions concerning approved use and would avoid sole reliance on ad hoc studies and sparse data (Milner and Boyd 2017: 4).

They named their idea pesticidovigilance as an equivalent to pharmacovigilance, an existing system through which pharmaceuticals undergo data collection and monitoring. Moreover, a professor of law and risk regulation, Alberto Alemanno, in an article published in the *European Journal of Risk*, sees the decision of the EU to ban neonicotinoid pesticides, while not expressly relying on the precautionary principle, as clearly based on the principle but has problems with the legality of the decision. This, he notes is because of the different member state approaches and farming practices which have made the task of the EU difficult (Alemanno 2013: 202). He sees the neonicotinoid issue as a new test case for the precautionary principle.

In addition to the debates between scientists on neonicotinoids there was conflicting opinions in the news media, typified by the writings of George Monbiot, an environmental journalist and Matt Ridley who writes on many subjects. Monbiot, a supporter of the precautionary principle, writing in the *Guardian*, supports the EU's review of the impacts of neonicotinoids (Monbiot 2014). Ridley, not a supporter of the precautionary principle, and having a eurosceptic tendency, stated in a *Times* article that banning neonicotinoids would prove counter-productive for bees and the EU's addiction to the precautionary principle... has caused many perverse policy decisions' (Ridley 2014).

Industry response

The neonicotinoid pesticides that are widely used in Europe and the UK are manufactured by Bayer AG in Germany, and Syngenta, manufactured in the UK. Both companies, not surprisingly, denied that their products are the cause of problems with bees and both companies were present at the hearings in the European General Court where the Commission-proposed ban was debated. At the hearing, a lawyer representing Bayer, Kristina Nordlander, claimed that 'there is no evidence despite over 20 years of intense study that neonicotinoids have any link to colony honeybee losses' (Bodoni 2017).

There has been criticism from Bayer and Syngenta of many of the scientific studies because they were carried out in laboratory conditions where bees were fed on pesticide-treated food, whereas, in the wild bees are free to choose where they forage. But the agrochemical industry's own research appears to be also flawed, as will be shown below. Also, and damaging to the industry case, there has been some research that indicates that there are no yield benefits from insecticidal seed treatments (Seagraves and Lundgren 2011; Lechenet *et al.* 2017), which negates the industry and farmers' objections that the ban on the products will damage their industry.

There are several industry studies into the problem, but many of them remain unpublished, and it is said by some that this is because the results do not completely back up industry claims that their products are safe (Greenpeace 2016). For example, in 2014, Bayer and Syngenta asked the UK Centre for Ecology and Hydrology (CEH), a UK government funded research organisation to conduct an independent field trial of two neonicotinoids (clothianidin, manufactured by Bayer and thiamethoxam, manufactured by Syngenta), in three countries: Germany, Hungary, and the UK. This research was eventually published in the journal *Science* (Woodcock *et al.* 2017). The results were mixed. Exposure to treated crops reduced the overwintering success of honey bee colonies in two of the three countries. This meant that the neonicotinoids investigated caused a reduced capacity for all three bee species to establish new populations in the following year, at least in the UK and Hungary. The research conclusions were: 'Taken together, our results suggest that exposure to neonicotinoid seed treatments can have negative effects on the interannual reproductive potential of both wild and managed bees, but these effects are not consistent across countries' (Woodcock *et al.* 2017: 2)

One journalist quoted Dave Goulson, a professor at the University of Sussex, as saying: 'Given all the debate about this subject, it is hard to see why the companies don't make these kinds of studies available. It does seem a little shady to do this kind of field study – the very studies the companies say are the most important

ones – and then not tell people what they find' (Carrington 2016). Moreover, parliament's audit select committee recently reported that much of bee research is tainted by corporate funding. The chair of the committee has declared, 'When it comes to research on pesticides, the Department of Environment, Food and Rural Affairs (DEFRA) is content to let manufacturers fund the work', and further stated that, 'This testifies to a loss of environmental protection capacity in the department responsible for it. If the research is to command public confidence, independent controls need to be maintained at every step' (Carrington 2014).

A further stakeholder, the National Farmers Union (NFU), is firmly against the ban on neonicotinoids given the possible economic impact it might make. The NFU told the government that, for example, it was becoming impossible to grow oilseed rape without the use of these pesticides (AgroPages 2017). According to one environmental scientist, many of the reports about the effects of the ban on farming are exaggerated. She cites the report from the UK farming press that without the pesticides 'UK wheat yields could decline by up to 20%. This is a disingenuous interpretation of an industry-funded report, and the EU is not proposing to ban neonicotinoid use in wheat anyway, because wheat is not a crop attractive to bees' (Dicks 2013). These exaggerations were not restricted to industry interests according to Dicks: 'The Guardian, a pro-environment British newspaper, mangled my parliamentary evidence on moths and beetles to claim that three-quarters of all UK pollinator species, including bees, were in severe decline' (Dicks 2013).

Policy options and government decisions

When the EU first proposed a ban on neonicotinoids the UK government did not support the proposal. It claimed that it wished to see the results of its own trials of the effects of the pesticides before taking any decision. When DEFRA, received the results, it decided, based on three published studies (Gill *et al.* 2012; Henry *et al.* 2012; Whitehorn *et al.* 2012) that:

> While this assessment cannot exclude rare effects of neonicotinoids on bees in the field, it suggests that effects on bees do not occur under normal circumstances. This assessment also suggests that laboratory-based studies demonstrating sub-lethal effects on bees from neonicotinoids did not replicate realistic conditions, but extreme scenarios. Consequently, it supports the view that the risk to bee populations from neonicotinoids, as they are currently used, is low (Defra 2013).

Following this conclusion, the Secretary of State at DEFRA, Owen Paterson, one of the UK's most prominent Eurosceptic politicians campaigned against the EU ban. In a speech to the National Farmers Union he criticised the Commission: 'I have asked the Commission to consider all the evidence and to wait for the results of our field trials, rather than rushing to a decision based on lab tests alone' (Paterson 2013a). Yet, the process in Europe was one where the ban on the three neonicotinoids was imposed after a scientific review, and a series of two votes. The first vote, on 15 March 2013, followed a meeting of the Standing Committee on the Food Chain and Animal Health and resulted in a stalemate. The UK abstained. On 29 April 2013, the second vote was held, and 15 countries voted for the ban, eight against, including the UK and four countries abstained.

Furthermore, Paterson sent a letter to Sygenta supporting their objection to the EU ban. He wrote: 'There is good evidence that effects of concern can be triggered in bees by sub-lethal doses of neonicotinoids. However, the field evidence suggests that this will not be a normal occurrence' (Paterson 2013b). Paterson also claimed that: '...the honey bee population has not been in decline', '...honeybee numbers are higher than they were two decades ago when neonics were first introduced' (Andrews 2017). He did not offer any evidence to back up this statement. Yet, as we have seen above, all of the scientific papers we have cited believe that all pollinator populations have declined worldwide, while acknowledging there is no single cause. From the UK point of view, here we can see that DEFRA, or at least its then Secretary of State, were in a sound science frame of mind: waiting until the evidence becomes conclusive that a problem exists before undertaking governmental intervention.

Michael Gove is similarly Eurosceptic, and was a leading proponent of the Vote Leave campaign during the Brexit referendum. On becoming Secretary of State for the Environment, however, he was more guarded on scientific evidence regarding the issue of neonicotinoids, and on a number of other environmental issues. Specifically, on the question on the precautionary principle he appears to have an open mind. In answer to a question from Parliament's Environmental Audit Committee as to whether the government would drop the principle he said:

> No. The striking thing if one talks to environmental lawyers is they make the point that these are interpretive principles. They are there to govern how policy is designed and devised. I do not think the right answer, and I know lots of environmental lawyers take this view, is to place these principles on a statutory basis (Environmental Audit Committee 2017; Q15).

On neonicotinoids he announced on the UK government's own website that: 'I have set out our vision for a Green Brexit in which environmental standards are not only maintained but enhanced. I've always been clear I will be led by the science on this matter' (Gov.uk 2017). Gove made clear in an article in *The Guardian* that a deteriorating environment is bad for the economy while understanding the importance of neonicotinoids to farmers but that '...ultimately we must ensure that we think about the long-term health of our environment, because unless we take steps now to arrest environmental damage we will all be the losers' (Gove 2017).

Discussion

The concern amongst the scientific and environmental communities over a number of neonicotinoid insecticides inevitably found its way into the policy arena. Moreover, there have been over 30 separate scientific studies in the last 3 years that have shown adverse effects on bees and other insects resulting from neonicotinoids. The problem is that all pesticides are by their very nature toxic to insects and getting this balance between the different stakeholders is difficult for policymakers. In the case of neonicotinoid insecticides, there appears to be evidence to support both those who would ban these insecticides and the agrochemical and farming interests: some field studies have found no effects of exposure to neonicotinoid treated crops, while other high-grade studies have found evidence of harm to bees.

On the one hand, many EU member states appear to have supported the case put forward by the agrochemical industry rather than be persuaded by the scientific advice. On the other hand, environmental interests may have exaggerated the risks posed by neonicotinoids. And it is interesting the way that industry picked fault with some scientific papers and not others and generally tried to distort the evidence it did not like (and hid evidence not convenient to

its case) as noted by the parliamentary audit committee (House of Commons 2013). Also, over the course of these events there appears to have been much exaggeration and misinformation by the agrochemical industry and farming interests. And it seems, at one time, the UK government was very partial to the agrochemical interests to the extent that the UK Environment Secretary had sent a letter of support to Syngenta's case that neonicotinoids were not harmful to bees. Moreover, what did not seem to get much publicity was the admittedly limited evidence that shows using neonicotinoid insecticides does not greatly increase crop yields.

In the UK, there has clearly been a move from a position of the government waiting for absolute conclusive evidence that neonicotinoid insecticides were harming bees before taking any action at all, moving to a position of applying responsible management practices based on the best available scientific evidence—in other words being proactive rather than reactive. The government's position went from one secretary of state stubbornly refusing to do anything about the warnings (Owen Paterson), to a successor secretary of state accepting that a lack of full scientific certainty was not a justification for postponing action to prevent what may turn out to be serious harm to the environment (Michael Gove). The move from a sound science approach to a precautionary one seems to have been based more on the personalities of the Secretaries of State than a paradigm shift in government thinking, however, despite the government being notionally committed to deploying the Precautionary Principle as outlined in the ILGRA (2002) report. Owen Patterson is an MP whose policymaking seems to fit the sound science mindset. He has a record as a secretary of state of making decisions based on 'no scientific evidence' being found, as in the irrational policy shift on the case of the government's attempts to control bovine tuberculosis by culling badgers (Flynn 2017). Similarly, he promoted the extension of GM crops, claiming that 'greater regulatory scrutiny probably makes GMOs even safer than conventional plants and food' (UK Government 2015). He went on to state: 'We need evidence-based regulation and decision making in the EU' (UK Government 2015). This is remarkably complaisant attitude given the number of studies that show that insects could rapidly evolve resistance to genetically engineered crops, what one scientist described as 'the natural evolutionary "arms race" between insects and plants' (Nottingham 2003: 55). Moreover, a major concern remains that GM herbicide-tolerant crops may become invasive, and that genes may be transferred to wild relatives and the ensuing offspring will in some way be detrimental to existing flora and fauna (Patterson 2008: 141–2). The whole tone of his thinking is that, as noted in the introduction, we wait until the evidence becomes conclusive that a problem does exist before government intervenes.

Michael Gove, however, is perhaps is more circumspect towards relying on science alone to determine environmental policymaking. As one political commentator has noted, he has recently, 'chameleon-like… recycled himself as an eco-warrior', and 'convinced green campaigners that he is one of their own' (Grice 2018). Since becoming environmental secretary, he has banned the sale of ivory products, the manufacture of plastic microbeads and has planned to reintroduce beavers into the countryside. So, it is possible that while the decision on neonicotinoids appears to be consistent with a government's commitment to the precautionary principle, this adherence is more likely to be based on the particular world-view of a politician as opposed to a consistent government stance on the Precautionary Principle.

Conclusions

Our examination of this issue shows that the UK government's consideration of the EU proposed ban on neonicotinoid insecticides, probably swayed by the agrochemical industry's stance, had initially followed a sound science approach in that it preferred to wait until there was conclusive evidence that there was a problem. Furthermore, it is clear that the government supported the agrichemical industry in their denials that there may be a problem with neonicotinoid products. The government initially played down the potential risk until the sheer pressure of new scientific evidence made it difficult for the government to maintain its position. When this occurred, it became increasingly expedient to take action in advance of conclusive evidence that pesticides might be harming bee health, therefore warranting intervention. At that point, the secretary of state for the environment made a decision to support the restrictions.

In this case study, we can see the fourth factor in Wynne's risk typology: indeterminacy; that is the open-ended and conditional nature of knowledge—the very large number of scientific studies into neonicotinoid herbicides with no consensus on whether or not there is conclusive evidence of harm and also the opinions of the various stakeholders. This is an example of the selective use of the precautionary principle. Selective because of the part played by a particular decision-maker, Michael Gove. But it was clearly the use of the weaker version of the precautionary principle because, in the words of the Rio definition of the PP (UN 1992): 'lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'.

References

AgroPages. (2017) World Agrochemical Yellow Pages Online, 'NFU: 'Million hectares' at risk from neonicotinoid ban extension in Europe', available from <http://news.agropages.com/News/NewsDetail---21985.htm> accessed 11 December 2017.

Alemanno, A. (2013) 'The Science, Law and Policy of Neonicotinoids and Bees: A New Test Case for the Precautionary Principle', *European Journal of Risk Regulation*, 4/2: 191–207.

Andrews, M. (2017) 'Brexit can help Save the Environment, says Shropshire MP Owen Paterson' *Shropshire Star*, 9 October 2017, available from <https://www.shropshirestar.com/news/politics/2017/10/09/brexit-can-help-save-the-environment-says-shropshire-mp-owen-patterson/> accessed 9 September 2018.

BeeMail (2011) 'Pesticides: questions in parliament' <www.bee-craft.com/wp-content/uploads/BeeMail/28Mar2011.pdf/> accessed 27 September 2018.

Biesmeijer, J. C., Roberts, S. P., Reemer, M., Ohlemuller, R. et al. (2006) 'Parallel Declines in Pollinators and Insect-pollinated Plants in Britain and the Netherlands', *Science*, 313/5785: 351–4.

Bodansky, D. (1991) 'Scientific Uncertainty and the Precautionary Principle', *Environment*, 33/4: 43–4.

Bodoni, S. (2017) 'Bayer, Syngenta Clash with EU over Bees amid M&A Charm Offensive', *Bloomberg News*, available from <https://www.bloomberg.com/news/articles/2017-02-15/bayer-syngenta-clash-with-eu-over-bees-amid-m-a-charm-offensive> accessed 7 December 2017.

Boyd, I. L. (2018) 'An Inside View on Pesticide Policy', *Nature Ecology and Evolution*, 2: 920–1.

Carrington, D. (2014) 'Bee Research Tainted by Corporate Funding, MPs say', *The Guardian*, 28: July, available from <https://www.theguardian.com/environment/2014/jul/28/bee-research-funding-pesticides-mps> accessed 29 July 2014.

—— (2016) 'Pesticide Manufacturers' Own Tests Real Serious Harm to Honeybees', *The Guardian, 22 September*, available from <https://www.theguardian.com/environment/2016/sep/22/pesticide-manufacturers-own-tests-reveal-serious-harm-to-honeybees> accessed 7 December 2017.

—— (2017) 'UK will back Total Ban on Bee-Harming Pesticides, Michael Gove reveals', The Guardian, 9 *November* <https://www.theguardian.com/environment/2017/nov/09/Uk-will-back> accessed 25 June 2018.

Commission of the EC. (2000) 'Communication from the Commission on the Precautionary Principle' *COM (2000)*, Brussels: 1 Final.

Christoforou, T. (2003) 'The Precautionary Principle and Democratizing Expertise: A European Legal Perspective', *Science and Public Policy*, 30/3: 205–11.

Collingridge, D. and Reeve, C. (1986) *Science Speaks to Power: The Role of Experts in Policy-Making*, London: Pinter.

Cooney, R. and Dickson, B. (2005) *Biodiversity and the Precautionary Principle: Risk and Uncertainty in Conservation and Sustainability*, London: Earthscan.

Defra. (2013) "An assessment of key evidence about Neonicotinoids and bees", *Gov.uk*, available from <http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221052/pb13937-neonicotinoids-bees-20130326.pdf> accessed 12 December 2017.

Dicks, L. (2013) 'Bees, Lies and Evidence-Based Policy', *Nature*, 494: 283.

Douma, W. T. (2003) The Precautionary Principle: Its Application in International, European and Dutch Law, PhD Thesis, Rijksuniversiteit Groningen.

EFSA. (2013) 'EFSA Guidance Document on the Risk Assessment of Plant Protection Products on Bees (*Apis melliferea, Bombus* spp. and solitary bees)', *EFSA Journal 2013*, 11/7: 3295.

EU Commission (2013) 'Commission Implementing Regulation (EU) No 485/2013 of 24 May 2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing those active substances', *Official Journal of the European Union*, L139: 12–26.

Flynn, P. (2017) 'Extending the Expensive Badger Cull is a Mistake', *The Times, 27 March*, available from <https://www.thetimes.co.uk/article/extending-the-expensive-and-ineffective-badger-cull-is-a-mistake-z8m5pz359> accessed 13 January 2018.

Gill, R. J., Ramos-Rodriguez, O. and Raine, N. E. (2012) 'Combined Pesticide Exposure Severely Affects Individual and Colony-level Traits in Bees', *Nature*, 491: 105.

Godfray, H. C., Blacquiere, T., Field, L. M., Hails, R. S. et al. (2015) 'A Restatement of Recent Advances in the Natural Science Evidence Base Concerning Neonicotinoid Insecticides and Insect Pollinators', *Proceedings of the Royal Society B*, doi:10.1098/rspb.2015.1821.

Goulson, D. (2013) 'An Overview of the Environmental Risks Posed by Neonicotinoid Insecticides', *Journal of Applied Ecology*, 50: 977–87.

Gov.uk (2017) 'Environment Secretary Backs further Restrictions on Neonicotinoid Pesticides: Michael Gove says the UK Supports Further Restrictions on the Use of Neonicotinoids Due to their Effects on Bees and Other Pollinators', 9 November 2017, available from <https://www.gov.uk/government/news/environment-secretary-backs--further-restrictions-on-neonicotinoid-pesticides> accessed 13 September 2018.

Gove, M. (2017) 'The Evidence Points in One Direction – we must Ban Neonicotinoids', *The Guardian, 9 November*, available from <https://www.theguardian.com/environment/2017/nov/09/the-evidence-points-in-one-direction-we-must-ban-neonicotinoids> accessed 2 February 2018.

Graham, J. D. (2002) 'The Role of Precaution in Risk Management', US Office of Management and Budget, 20 June 2002. <http://www.whitehouse.gov/omb/inforeg/risk_mgmt_speech062002.aspx? print=1> accessed 26 February 2009.

——— (2003) *'The Perils of the Precautionary Principle: Lessons from the American and European Experience'*, Heritage Foundation: Heritage Lectures, No 818, 20 October 2003

Greenpeace Unearthed Website. (2016) 'Neonicotinoids: Landmark European Court Verdict could Change Bee Deaths Debate', available from <https://unearthed.greenpeace.org/2016/11/24/bayer-syngenta-bees-neonicotinoids-european-court> accessed 12 December 2017.

Grice, A. (2018) 'Michael Gove has Undergone a Serious Political Rehabilitation – he is Becoming Credible on the Environment', *The Independent*, 12 January, available from <http://www.independent.co.uk/voices/Michael-gove-environment-tory-education-brexit-leavesecretary-conservative-theresa-may-a8155776.html> accessed 13January 2018.

Haigh, N. (1994) 'The Introduction of the Precautionary Principle into the UK', in T., O'Riordan and J., Cameron (eds), *Interpreting the Precautionary Principle*, London: Earthscan.

Harremoes, P., Gee, D., MacGarvin, M., Stirling, A. et al. (eds) (2002) *The Precautionary Principle in the 20th Century: Late Lessons from Early Warnings*, London: Earthscan.

Henry, M., Beguin, M., Requier, F., Rollin, O. et al. (2012) 'A Common Pesticide Decreases Foraging Success and Survival in Honey Bees', *Science*, 336: 348–50.

House of Commons. (2012) Environmental Audit Committee, 'Insects and Insecticides, Written Evidence', 2 December, <https://publications.parliament.uk/pa/cm201213/cmselect/cmenvaud/writev/668/668.pdf/> accessed 29 September 2018.

——. (2013) Environmental Audit Committee, Seventh Report of Session 2012-13, *Pollinators and Pesticides*, Volume 2, London: The Stationary Office Limited.

Hunt, J. (1994) 'The Social Construction of Precaution', in T., O'Riordan and J., Cameron (eds), *Interpreting the Precautionary Principle*, London: Earthscan.

ILGRA. (2002) *'The Precautionary Principle: Policy and Application'*, London: Health and Safety Executive Inter-Departmental Liaison Group on Risk Assessment.

Lechenet, M., Dessaint, F., Py, G., Makowski, D. et al. (2017) 'Reducing Pesticide Use while Preserving Crop Productivity and Profitability on Arable Farms', *Nature Plants*, 17008, doi:10.1038/nplants.2017.8

Lee, M. (2011) 'Take Action to Protect Britain's Bees' Ecologist website: <https://theecologist.org/2011/jul/05/take-action-protect-britains-bees/> accessed 29 September 2018.

Leslie, I. (2016) 'The Sugar Conspiracy', *The Guardian*, 7 April, available from <https://www.theguardian.com/society/2016/apr/07/the-sugar-conspiracy-robert-lustig-john-yudkin> accessed 2 February 2018.

Lofstedt, R. (2004) *'The Swing of the Regulatory Pendulum'* in Europe: From Precautionary Principle to (Regulatory) Impact Analysis, Working Paper 04/07, March 2004, *AEI/Brookings Joint Centre for Regulatory Studies*.

Manson, N. A. (2002) 'Formulating the Precautionary Principle', *Environmental Ethics*, 24: 263–74.

McCarthy, M. (2013) 'Britain Opposes EU Pesticide Ban on Neonicotinoid Pesticides Blamed for Bee Deaths around the World', *The Independent, 19 March*, available from <http://www.independent.co.uk/environment/green-living/britain-opposes-eu-pesticide-ban-on-neonicotinoid-pesticides-blamed-for-bee-deaths-around-the-world-8539870.html> accessed 5 January 2018.

McGrath, P. (2014) 'Politics Meets Science: The Perspectives Integrating Environment and Society', *S.A.P.I.E.N.S*, 7/1: available from <http://journals.openedition.org/sapiens/1648> accessed 28 December 2017.

McLean, C. and Patterson, A. (2006) 'A Precautionary Approach to Foreign Policy? A Preliminary Analysis of Tony Blair's Speeches on Iraq', *British Journal of Politics and International Relations*, 8/3: 351–67.

Milner, A. M. and Boyd, I. L. (2017) 'Towards Pesticidovigilance: Can Lessons from Pharmaceutical Monitoring help Improve Pesticide Regulation?', *Science*, 357/6357: 1232–4.

Monbiot, G. (2014) 'Ban Neonicotinoids now – to Avert Another Silent Spring', *The Guardian, 15 July*, 2014 <http://www.theguardian.com/commentisfree/2014/jul/15/ba-neonicotinoids> accessed 24 June 2018.

Morris, J. (ed.) (2000) *Rethinking Risk and the Precautionary Principle*, Oxford: Butterworth/Heinemann.

Nottingham, S. (2003) *Eat Your Genes*, 2nd edn, London: Zed Books.

Paterson, O. (2013a) 'Owen Paterson speech at the National Farmers Union Annual Conference' 27 February 2013 available from <https://www.gov.uk/government/speeches/owen-patterson-speech-at-the-national-farmers-union-annual-conferene-2013> accessed 11 September 2018.

——— (2013b) 'Personal letter to Syngenta, Basel', *The Guardian*, 29 April 2013, available from <https://www.theguardian.com/environment/interactive/2013/apr/29/environment-secretary-letter-syngenta-insecticide-ban> accessed 7 December 2017.

Patterson, A. (2008) *Risk Regulations and Scientific Expertise in the United Kingdom: The Precautionary Principle in Public Policy*, New York: Edwin Mellen Press.

——— and McLean, C. (2008) 'The Management of Risk in Foreign and Defence Policy: the Precautionary Principle and Decisions on War', *Medicine, Conflict and Survival*, 24/1: 42–58.

——— and ——— (2017) 'The Regulation of Risk: the Case of Fracking in the UK and the Netherlands' *Science and Public Policy*, 45/1: 45–52.

Raffensperger, C. and Tickner, J. (1999) *Protecting Public Health and the Environment: Implementing the Precautionary Principle*, Washington DC: Island Press.

Ridley, M. (2014) 'Brussels and its Busy Bees are a Perfect Pest', *The Times*, 6 October <http://www.thetimes.co.uk/article/brussels-and-its.> accessed 24 June 2018.

Salter, L. (1988) *Mandated Science: Science and Scientists in the Making of Standards*, Dordrecht, Holland: Kluwer Academic Publications.

Seagraves, M. P. and Lundgren, J. G. (2011) 'Effects of Neonicotinoid Seed Treatments on Soybean Aphid and its Natural Enemies', *Journal of Pest Science*, 85: 125–32.

Steel, D. (2014) *Philosophy and the Precautionary Principle: Science, Evidence, and Environmental Policy*, Cambridge: Cambridge University Press.

Storr, W. (2017) '" We Believe you Harmed your Child": the War over Shaken Baby Convictions', *The Guardian*, 8 December, available from <https://www.theguardian.com/news/2017/dec/08/shaken-baby-syndrome-war-over-convictions> accessed 1 February 2018.

Sunstein, C. (2005) *Laws of Fear; Beyond the Precautionary Principle*, Cambridge: Cambridge University Press.

UK Government. (2015) 'Rt. Hon Owen Paterson MP speech to Rothamsted Research', available from <https://www.gov.uk/government/speeches/rt-hon-owen-paterson-mp-speech-to-rothamsted-research> accessed 13 January 2018.

United Nations. (UN) Report of the United Nations Conference on Environment and Development, A/CONF.151/26 (Vol. I), available from <http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm> accessed 2 February 2018.

Van der Sluijs, J. P., Simon-Delso, S., Goulson, D., Maxim, L. et al. (2013) 'Neonicotinoids, Bee Disorders and Sustainability of Pollinator Services', *Environmental Sustainability*, 5: 293–305.

Vogel, D. (2003) 'The Hare and the Tortoise Revisited: The New Politics of Consumer and Environmental Regulation in Europe', *British Journal of Political Science*, 33: 557–80.

Whitehorn, P. R., O'Connor, S., Wackers, F. L. and Goulson, D. (2012) 'Neonicotinoid Pesticide Reduces Bumble Bee Colony Growth and Queen Production', *Science*, 336: 351–2.

Wiener, J. B., Rogers, M. D., Hammitt, J. K. and Sand, P. H. (eds) (2011) *The Reality of Precaution: Comparing Risk Regulation in the United States and Europe*, Washington DC: RFF Press.

Woodcock, B. A., Bullock, J. M., Shore, R. F., Heard, M. S. et al. (2017) 'Country-specific Effects of Neonicotinoid Pesticides on Honey Bees and Wild Bees', *Science*, 356: 1393–5.

Wynne, B. (1992) 'Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm', *Global Environmental Change*, 2/2: 111–127.