Wilder FUTURE

THE wildlife TRUSTS SOMERSET

Insect declines and why they matter

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Commissioned by the South West Wildlife Trusts

Protecting Wildlife for the Future

Contents

Executive summary

In the last fifty years, we have reduced the abundance of wildlife on Earth dramatically. Many species that were once common are now scarce. Much attention focusses on declines of large, charismatic animals, but recent evidence suggests that abundance of insects may have fallen by 50% or more since 1970. This is troubling, because insects are vitally important, as food, pollinators and recyclers amongst other things. Perhaps more frightening, most of us have not noticed that anything has changed. Even those of us who can remember the 1970s, and who are interested in nature, can't accurately remember how many butterflies or bumblebees there were when we were children.

The bulk of all animal life, whether measured by biomass, numerical abundance or numbers of species, is comprised of invertebrates such as insects, spiders, worms and so on. These innumerable little creatures are far more important for the functioning of ecosystems than the large animals that tend to attract most of our attention. Insects are food for numerous larger animals including birds, bats, reptiles, amphibians and fish, and they perform vital roles such as pollination of crops and wildflowers, pest control and nutrient recycling.

There have been several recent scientific reports describing the rapid decline of insects at a global scale, and these should be a cause of the gravest concern (summarised in Sanchez-Bayo & Wyckhuys 2019). These studies suggest that, in some places, insects may be in a state of catastrophic population collapse. We do not know for sure whether similar reductions in overall insect abundance have happened in the UK. The best UK data are for butterflies and moths which are broadly in decline, particularly in farmland and in the south. UK bees and hoverflies have also shown marked range contractions. The causes of insect declines are much debated, but almost certainly include habitat loss, chronic exposure to mixtures of pesticides, and climate change. The consequences are clear; if insect declines are not halted, terrestrial and freshwater ecosystems will collapse, with profound consequences for human wellbeing.

The good news is that it is not too late; few insects have gone extinct so far, and populations can rapidly recover.

We urgently need to stop all routine and unnecessary use of pesticides and start to build a nature recovery network by creating more and better connected, insect friendly habitat in our gardens, towns, cities and countryside.

Only by working together can we address the causes of insect decline, halt and reverse them, and secure a sustainable future for insect life and for ourselves.

This report summarises some of the best available evidence of insect declines and proposes a comprehensive series of actions that can be taken at all levels of society to recover their diversity and abundance.

> *“Every space in Britain must be used to help wildlife”*
>
> Sir David Attenborough

Insect declines: the evidence

Public perception of biodiversity loss is particularly focussed on extinction events, especially those of large mammals such as the northern white rhino or birds such as the dodo. Nonetheless the actual proportion of species that are known to have gone extinct is relatively small. Just 80 species of mammal and 182 species of bird have been lost since 1500, representing 1.5% and 1.8%, respectively, of known species [McPhee et al. 1999; Butchart et al. 2006]. On the face of it, these figures would seem to be at odds with the notions that we are in the midst of the 'sixth mass extinction event' or that biodiversity is in crisis. However, evidence has recently begun to emerge suggesting that global wildlife is being affected far more profoundly than these relatively modest figures for actual extinctions might suggest.

The loss of bio-abundance

While most species may not yet have gone extinct, they are, on average, far less abundant than they once were. In 2018 the World Wildlife Fund and Zoological Society of London's *Living Planet Report* [WWF 2018] estimated that the total population of the world's wild vertebrates (fish, amphibians, reptiles, mammals and birds) fell by 60% between 1970 and 2014. Within living memory, more than half of our vertebrate wildlife has been lost.

Another demonstration of the scale of human impacts on wildlife abundance was provided by a recent landmark paper by scientists in Israel which estimated that 83% of wild mammal biomass has been lost since the rise of human civilization [Bar-On et al. 2018]. To put it another way, roughly five out of every six wild mammals have gone. The scale of human impact is also revealed by their estimate that wild mammals now comprise a meagre 4% of mammalian biomass, with our livestock comprising 60% and we humans the remaining 36%. It is hard to grasp, but if they are correct then all the world's 5,000 wild mammal species – the rats, elephants, rabbits, bears, lemmings, caribou, wildebeest, whales and many more – when combined, tot up to just one-fifteenth of the weight of our cattle and pigs. The same scientists also calculate that 70% of global avian biomass is now comprised of domestic poultry.

Whilst declines of wild vertebrates are well documented and significant, it seems that another even more dramatic change may have been quietly taking place, one that may have more profound implications for human wellbeing. The large majority of known species are invertebrates, dominated on land by the insects. Insects are far less well studied than vertebrates, and for the majority of the one million species that have so far been named we know essentially nothing about their biology, distribution or abundance. Often all we have is a "type specimen" on a pin in a museum, with a date and place of capture. In addition to the one million named types of insect, there are estimated to be at least another four million species that we have yet to discover [Stork et al. 2015]. Although we are decades away from cataloguing the staggering insect diversity on our planet, evidence has emerged that these creatures are fast disappearing, and it is likely that many will be lost before we have recognized they ever existed.

41% OF INSECT SPECIES THREATENED WITH EXTINCTION

The unnoticed apocalypse

23 BEE AND FLOWER-VISITING WASP SPECIES HAVE GONE EXTINCT IN THE UK SINCE 1850

APPROXIMATELY 3/4 OF THE CROP TYPES GROWN BY HUMANS REQUIRE POLLINATION BY INSECTS

UK "WIDER COUNTRYSIDE" BUTTERFLIES DECLINED 46% AND HABITAT SPECIALISTS BY 77% between 1976 and 2017

NUMBER OF PESTICIDE APPLICATIONS HAS APPROXIMATELY DOUBLED OVER THE LAST 25 YEARS

A SURVEY OF HONEY SAMPLES FROM AROUND THE WORLD REVEALS THAT 75% CONTAIN NEONICOTINOID INSECTICIDES

UK POPULATIONS OF THE SPOTTED FLYCATCHER FELL BY 93% BETWEEN 1967 AND 2016

Other once-common insectivorous birds have suffered similarly, including

THE GREY PARTRIDGE –92%
NIGHTINGALE –93%
AND CUCKOO –77%

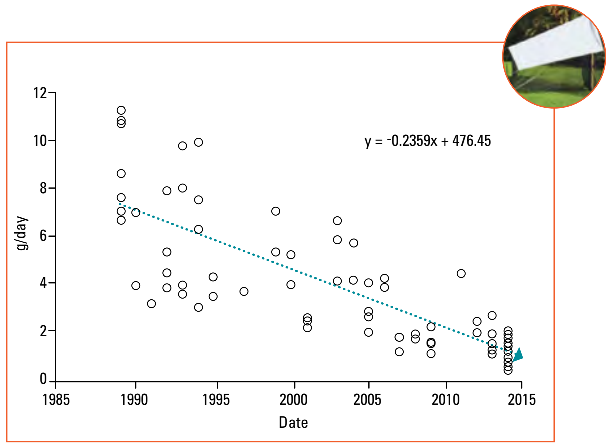
THE RED-BACKED SHRIKE, A SPECIALIST PREDATOR OF LARGE INSECTS, WENT EXTINCT IN THE UK IN THE 1990S

In early 2019, Australian entomologist Francisco Sanchez-Bayo published a scientific review of all existing evidence for insect declines Sanchez-Bayo & Wyckhuys 2019. He located 73 studies, mainly from Europe and North America, which collectively suggest that the rate of local extinction of insect species is eight times faster than that of vertebrates. He also estimated that, on average, insects are declining by 2.5% each year, with 41% of insect species threatened with extinction. The paper concludes: "we are witnessing the largest extinction event on Earth since the late Permian" (a geological epoch 250 million years ago).

Krefeld Society report

The most talked-about study of insect declines was published in 2017 by the Krefeld Society, a group of entomologists who had been trapping flying insects in malaise traps on 63 nature reserves scattered across Germany since the late 1980s [Hallmann et al. 2017]. Malaise traps are tent-like structures that passively trap any flying insects unlucky enough to bump into them. The German entomologists amassed insects from nearly 17,000 days of trapping, a total of 53 kg of insects. **Their paper describes the only long-term, large-scale data set in existence that encompasses a broad suite of insect species. They found that the overall biomass of insects caught in their traps fell by 75% in the 26-year period from 1989 to 2014.** In midsummer, the peak of insect activity, the decline was even more marked, at 82%. That these sites could have lost such a large proportion of insect biomass in such a short period of time was shocking.

The study was reported around the world and has been much discussed. Some argue that the data set is not robust as some of the 63 sites were sampled only in one year. Nonetheless the pattern is very strong see figure, and it is hard to avoid the conclusion that there has been a major decline in insect biomass. We should also bear in mind that the impacts of mankind on the planet were at play long before 1989, which was 27 years after the publication of Rachel Carson's *Silent Spring*. It seems probable that this 75% drop, if it is real, is just the tail end of a much larger fall. We will never know how many insects there were, say, 100 years ago, before the advent of pesticides and industrial farming.



The weight of insects caught per trap per day declined by 76% between 1989 and 2014, a decline which is, statistically speaking, highly unlikely to be due to chance (p<0.001) [Hallmann et al. 2017].

There has been much debate as to whether similar declines in insect abundance are occurring elsewhere, or whether something peculiar is going on in German nature reserves, but hard data are largely lacking. Only butterflies and moths have been monitored extensively and continuously elsewhere, in various localities from California to Europe from 1970 onwards, and they show pervasive patterns of decline, though rarely as dramatic in magnitude as that found in Germany [Fox et al. 2014; Forister et al. 2011, 2016]. The most high-profile example is the eastern North American population of the monarch butterfly (*Danaus plexippus*), famed for its long migration to and from overwintering sites in Mexico, populations of which fell by 80% in the ten years to 2016 [Semmens et al. 2016].

> *We are witnessing the largest extinction event on Earth since the late Permian (a geological epoch 250 million years ago).*

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Marsh fritillary

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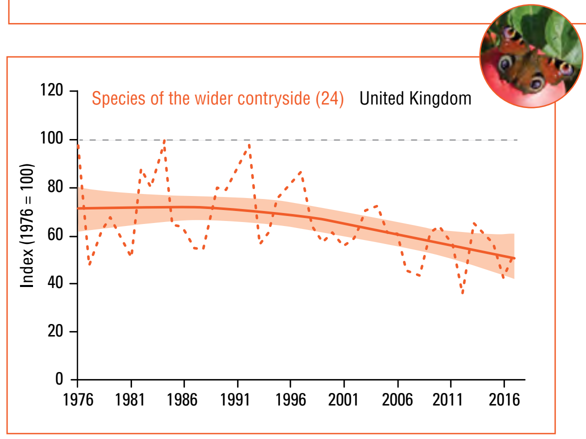
Bordered beauty

Overall abundance of larger moths in Britain fell by 28% in the period from 1968 to 2007, with the decline more marked in southern Britain where the overall count fell by 40% [Fox et al. 2013]. More than one-third of species (37%) declined by more than 50% during the period. An analysis of trends in Europe-wide populations of 17 widespread grassland butterflies found a drop of 30% between 1990 and 2011 [Van Swaay et al. 2015].

Perhaps the best-studied insect populations in the world are the UK's butterflies, which are counted along more than 2,500 transect walks each year as part of the Butterfly Monitoring Scheme. These data have been analysed in detail, and **the Joint Nature Conservation Committee concluded that, overall, numbers of butterflies of the "wider countryside" fell in abundance by an estimated 46% between 1976 and 2017**, despite marked increases in a small number of species such as the speckled wood and comma. They estimate that habitat specialists fell more markedly, by 77% over the same period, despite concerted conservation efforts directed at many of them [JNCC 2018].



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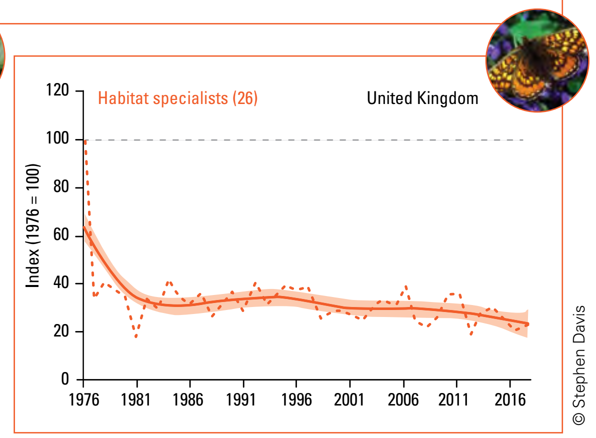

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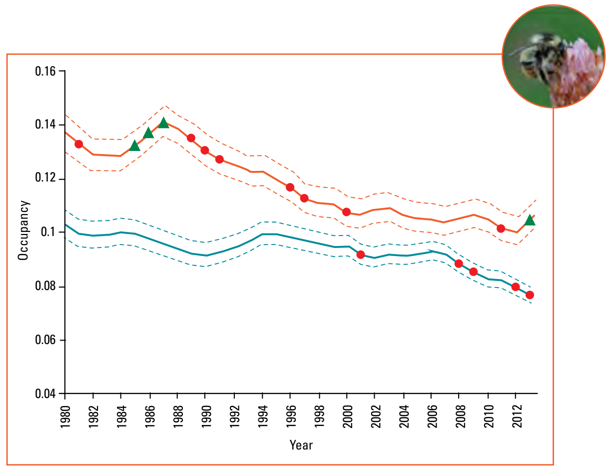
Trends in butterfly populations in the UK, 1976 to 2017: top, species of the wider countryside; bottom, habitat specialists [JNCC 2018]. The dashed lines show the unsmoothed trends, and the solid line shows the smoothed trend and 95% confidence intervals.

Bee declines

Declines of bees have received much media attention due to their importance as pollinators, but unfortunately there are no long-term data sets on the abundance of wild bee species comparable to those available for butterflies. However, we do have accurate distribution maps for some of the better-studied wild bees, particularly bumblebees, which enable us to see how the size of their range is changing over time. These maps reveal severe geographic range contractions of many species. One of the first signs that a species is declining is that it tends to disappear from the periphery of its range. In the UK, geographic ranges of 13 out of 23 bumblebee species more than halved between pre-1960 and 2012, with two species (the short-haired bumblebee and Cullum's bumblebee) going extinct [Casey et al. 2015]. The great yellow bumblebee, once found across the UK, can now only be found in the far north and west of Scotland, while the shrill carder bumblebee, formerly abundant across the south of the UK, now clings on at just five sites.

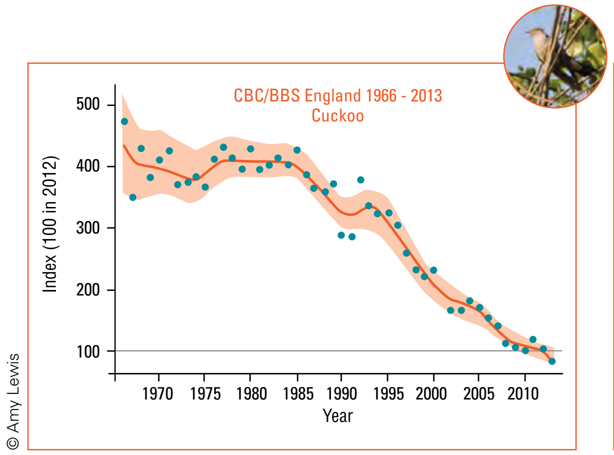
Very recently, detailed analyses of patterns of range change of all Britain's wild bees (not just bumblebees), and also hoverflies, was completed, and found similar patterns [Powney et al. 2019]. Both insect groups declined between 1980 and 2013, with an average of 11 species lost from each 1 km² of Britain.

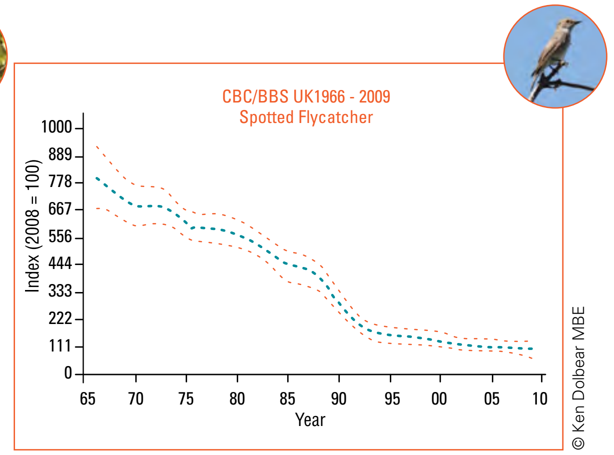


Patterns of change in the ranges of wild bees (blue) and hoverflies (orange). Trend lines show average occupancy of 1 km grid cells in Britain across all modelled bee (n = 139) and hoverfly (n = 214) species. Red circles and green triangles highlight years with notable decreases or increases, respectively [Powney et al. 2019].

Nationally, 23 bee and flower-visiting wasp species have gone extinct in the UK since 1850 [Ollerton et al. 2014]. In North America, five bumblebee species have undergone massive declines in range and abundance in the last 25 years, with one, Franklin's bumblebee, going globally extinct [Cameron et al. 2011].

> *Nationally, 23 bee and flower-visiting wasp species have gone extinct in the UK since 1850*





Data on population change of cuckoo (top) and spotted flycatcher (bottom), two specialist insectivores that have undergone dramatic declines over the last 50 years. Figures are from the British Trust for Ornithology.

Impacts on other animals

Although the bulk of insect species – the flies, beetles, grasshoppers, wasps, caddis flies, froghoppers and so on – are not systematically monitored at all, we often have good data on population trends for birds that depend on insects for food, and these are mostly in decline. **Populations of aerial insectivorous birds have fallen by more than any other bird group in North America, by about 40% between 1966 and 2013 [Michel et al. 2015; Stanton et al. 2018]. In the UK, populations of the spotted flycatcher fell by 93% between 1967 and 2016 [Woodward et al. 2018]. Other once-common insectivores have suffered similarly, including the grey partridge (– 92%), nightingale, (– 93%) and cuckoo (– 77%) [Woodward et al. 2018]. The red-backed shrike, a specialist predator of large insects, went extinct in the UK in the 1990s.**

All of the evidence above relates to populations of insects and their predators in highly industrialized, developed countries. Information about insect populations in the tropics, where most insects live, is sparse. We can only guess what impacts deforestation of the Amazon, the Congo or South East Asian rainforests has had on insect life in those regions. We will never know how many species went extinct before we could discover them (most of those approximately four million species that we haven't named live in these forests). However, one long-term tropical study was recently published, and it provides perhaps the most concerning evidence of insect declines so far. In 1976 and 1977 US entomologist Bradford C. Lister sampled arthropod abundance in a Puerto Rican rainforest using sweep nets and sticky traps. Returning to the same sites 35 years later, he repeated the sampling between 2011 and 2013 [Lister and Garcia 2018]. He found that the biomass of insects and spiders in sweep net samples had fallen between 75% and 88%, depending on the time of year. Sticky trap sample catches had fallen by 97% to 98%. The most extreme comparison was between identical sticky traps placed out in January 1977 and in January 2013, with the catch declining from 470 mg of arthropods per day to just 8 mg.

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Causes of declines

What might be driving the landscape-scale disappearance of insects? Causes of the decline of wild bees have been discussed more than those of other insects, and although there is still debate, most scientists believe that it is the result of a combination of man-made stresses, including habitat loss, chronic exposure to complex mixtures of pesticides, the spread of non-native insect diseases within commercial bee nests, and the beginnings of the impacts of climate change [Goulson et al. 2015]. The disease issue primarily affects only bees, but the others are problems that all insects face.

Habitat loss

Over the last century or more, natural and semi-natural habitats have been cleared at an accelerating rate to make way for farming, roads, housing estates, factories, lorry parks, golf courses, out-of-town shopping centres and a multitude of other human endeavours. Insect populations persisting on small, highly fragmented and isolated islands of habitat (such as the nature reserves sampled in Germany) are liable to go extinct over time. The local population becomes ever more inbred, or may just have a bad year due to vagaries of the weather. One way or another, populations fizzle out, and if the sites they are on are isolated from one another then there is little chance of them being recolonized. This may happen decades after the islands were first created, so we see the gradual, inexorable payback of an extinction debt. The process will be accelerated if islands become polluted with agrochemicals or other pollutants from the surrounding land uses, or are in other ways degraded.

Farming itself has radically changed in the last 80 years. Historically, less intensive farming practices resulted in a patchwork of habitats that were favourable to bees and other insects, including our beautiful flower-rich hay meadows and chalk downlands, fallow fields rich in flowering weeds, and flowering hedgerows separating the small fields.

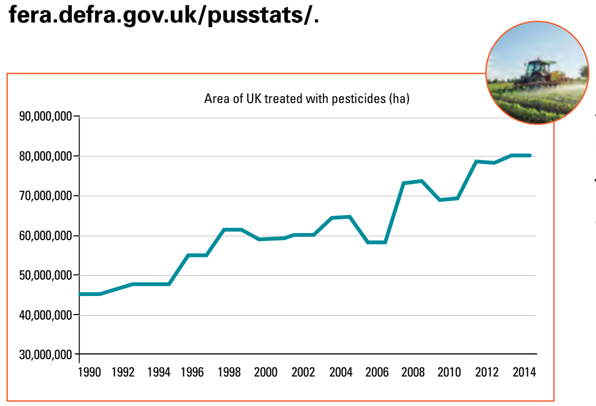
Since 1950 it is estimated that in the UK we have lost 150,000 miles of hedgerow, 50% of downland, 98% of wildflower meadows and 50% of ancient woodlands

In many parts of Britain, traditional family farms have given way to large agribusinesses, typified by large fields, often managed by external contractors, maintained as near-perfect monocultures by high inputs of pesticides and fertilizers [Goulson et al. 2018]. The result is a landscape that produces more food, more cheaply, than it used to, but is largely inhospitable to wildlife and provides employment for very few people. The low price of food that we have become used to on the supermarket shelves does not reflect the true environmental costs of its production. It is also important to note that farmers only receive a fraction of the retail sale price of food, so the cost of improved on-farm practice would have a relatively small impact on shoppers.

Pesticides

Numerous pesticides (insecticides, fungicides and herbicides) are freely available from garden centres, DIY stores and even supermarkets. They are bought and used by untrained members of the public who may not bother to read the instructions before using them, may apply a little extra for good measure, or may fail to wear protective clothing such as rubber gloves.

The pesticides associated with intensive farming are implicated in driving declines of bees and other insects – after all, these are chemicals intended to kill. Pesticide use is better documented in the UK than anywhere else in the world. Whilst the tonnage of pesticides used has gone down over the last 25 years, the more worrying trends are that the number of applications, the area of land treated and the toxicity of many of the products have increased. According to Department for Environment, Food and Rural Affairs (Defra) statistics, there were, on average, 17.4 applications of pesticide to each hectare of arable land in 2015, using a total of 16.9 thousand tons of active ingredients (i.e. toxins) [Goulson et al. 2018]. These figures are available for anyone to see at **https://secure.fera.defra.gov.uk/pusstats/**.



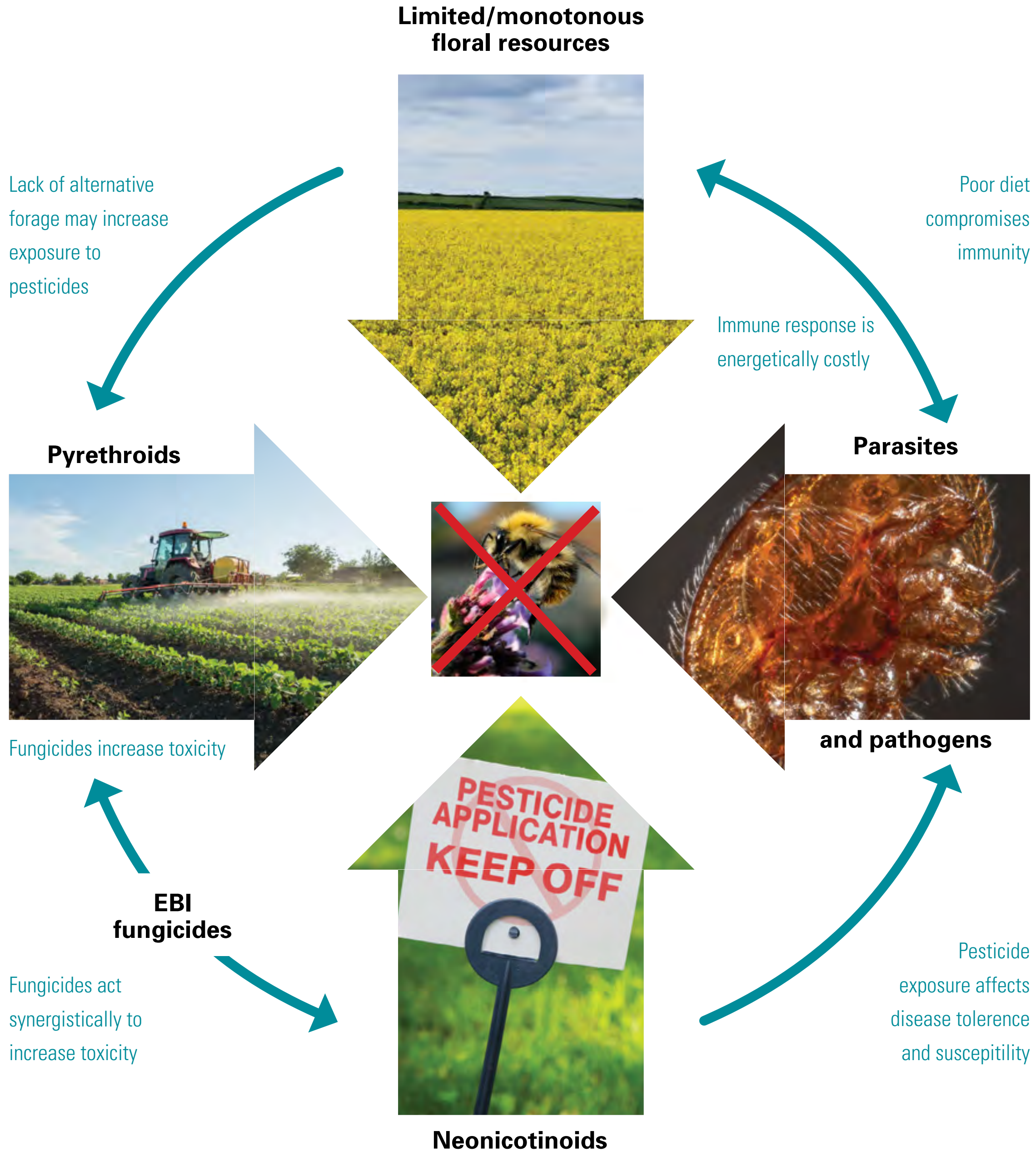
Every year, farmers make more pesticide applications to their crops. Official Defra figures [PUSSTATS website] show that the total area of crops treated in the UK has approximately doubled between 1990 and 2015.

These figures do not include amenity use of pesticides in parks, streets and along road verges, or domestic use. With nearly 17,000 tons of poison broadcast across the landscape every year, it is little wonder that our wildlife is in trouble. Pesticides accumulate in the soils, seep into watercourses and may drift into hedges.

It has recently become apparent that exposure to even tiny doses of pesticides can have complex and unpredictable sublethal impacts on insect behaviour. Most insecticides are neurotoxins, and they can leave the bees they don't kill dazed and confused, unable to find their way back to the hive. On top of this there can be unexpected synergistic interactions between different pesticides and between pesticides and other stressors such as disease, so that the combined effects of two or more stressors can be much worse than one might expect from just adding the effects together [Wood and Goulson 2017]. As an example, truly miniscule amounts of neonicotinoids (1 part per billion in food) impairs the immune systems of bees, leaving them susceptible to diseases such as deformed wing virus. None of this is adequately captured by the regulatory process for pesticides, which focusses on short-term exposure of otherwise healthy organisms to single chemicals.

As a result, even Defra's chief scientist, Ian Boyd, recently admitted that it is not currently possible to predict the environmental repercussions of landscape-scale use of large quantities of multiple pesticides [Millner and Boyd 2017].

Wild pollinators such as bumblebees struggle to cope with the many stressors they face in the modern world: much of their flower-rich habitats have been lost so there is little food; they are infected with foreign diseases; they are exposed to complicated cocktails of insecticides and other pesticides which can be more toxic in combination than separately.



The green desert

It might not be intuitively obvious why, but fertilizer use is also likely to be impacting on insects. Farmland soils have high fertility due to regular applications of nitrogen-rich pig or poultry manure, slurry and synthetic fertilizers, and in meadows this leads to the rapid growth of grasses that outcompete flowers. A single application of artificial fertilizer can destroy an ancient flower-rich meadow.

Much of South West England is bright green when seen from a passing train or from the air, and commuters might assume this "green and pleasant land" is teeming with wildlife, but they would be wrong. Much of it is a green desert, a flowerless monoculture of fast-growing rye grass.

In arable areas of Britain, the leaching of fertilizer into the field margins and hedge bottoms leads to the dominance of the vegetation by a small number of nutrient-loving plants such as hogweed, nettles, cock's foot grass and docks. These tall, fast-growing plants squeeze out hedgerow flowers, reducing botanical diversity, with inevitable knock-on effects for insects that eat plants and for pollinators [Kleijn and Snoeijing 1997].

The roadside hedge-banks of South West England are famed for their wildflowers, which might create the impression that the hedge-filled landscape is full of flowers. Yet scientists from the University of Plymouth recently discovered that the sides of the hedges that face farmed fields (which is most of them) have many fewer flowers, and attract far fewer bees than the sides that face the roads [Hanley and Wilkins 2015].

Mass hatchings of aquatic insects used to be the norm.

Freshwater habitats

Over 3,800 invertebrate species in the UK spend at least part of their life cycle in freshwater Davies & Edwards, 2011. These include well-known freshwater invertebrates from dragonflies, mayflies, pond skaters and crayfish to lesser-known worms and mites. They play a vital role in maintaining clean water; they help to break down and filter organic matter and provide a food source for fish, birds and mammals. Their presence is the standard indicator of the health of the habitat they live in. However, many of our freshwater invertebrates are declining in the face of pollution, invasive species, abstraction and development

Freshwater habitats draining from agricultural land are often polluted with fertilizers (and/or insecticides and metaldehyde from slug pellets), and this eutrophication can be highly detrimental to aquatic life. Indeed, the relationship between insect diversity and eutrophication in streams is so tight that insects are often used as bioindicators of aquatic pollution.

Other pollutants

Aside from pesticides and fertilizers, human activities produce numerous other pollutants, from heavy metals such as mercury released by mining and industrial processes to the approximately 30 million tons of 144,000 different man-made chemicals which are deliberately manufactured for a diversity of purposes – many of which have pervaded the global environment [UNEP 2013]. High levels of polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) (along with plastic bags) were recently found in crustaceans (crabs, shrimps and so on) living at the bottom of the Marianas Trench (the deepest place in the world's oceans) [Jamieson et al. 2017].

For the vast majority of pollutants there have been no studies of their impacts on invertebrates, other wildlife, or for that matter on humans.

Other stressors

There are other likely contributors to insect declines that have received less attention to date. Invasive species have profoundly reduced biodiversity in some ecosystems; think for example of the spread across Australia of South American cane toads, voracious predators of insects. Light pollution has been found to have significant impacts on nocturnal insects such as moths [Fox 2012]. The cognitive abilities of honeybees has been found to be impaired by low electromagnetic fields such as those created around high-voltage cables, and it has been suggested that this might have contributed to bee colony losses and more broadly could impact on insect navigation and dispersal [Shepherd et al. 2018]. It seems likely that there are other human activities which impinge upon insect health in ways that we have yet to recognize, for the pace of development and deployment of new technologies far outstrips that of scientists to assess their impacts on the environment, and also far outstrips the ability of nature to adapt.

Climate change

Of course the most pervasive man-made pollutants are greenhouse gas emissions leading to climate change at a global scale. Until recently, direct evidence that climate change has already had major impacts on insect populations was not strong. The analysis of the German insect data specifically investigated whether changing climate could be the cause of the decline. Although day-to-day weather patterns had big impacts on the numbers of insects caught, the overall climate in Germany did not change much over this relatively short period (26 years) and so could not explain the decline.

There is evidence that the ranges of some insects have begun to shift in response to climate, with European and North American bumblebees tending to disappear from the southern edges of their range [Kerr et al. 2015] and occupy higher elevations in mountainous regions [Pyke et al. 2016]. There is also evidence that the timing of emergence of some herbivorous and pollinating insects is becoming decoupled from that of their host plants; for example, some mountain plants in Colorado are now coming into flower before bumblebees have emerged from hibernation, when previously they did not [Pyke et al. 2016]. Similarly, many leaf-feeding moths time the emergence of their caterpillars to match the bud burst of their host plants, a time when the leaves are most palatable. If the host plant and moth are using different cues to time their emergence – for example one using temperature and the other day length – then their timing may become unsynchronized, with potentially severe consequences for the insects and any animals that might feed on them. There is evidence that this may have begun to impact on populations of the oak leafroller moth and winter moth [Cornelissen 2011]. So far the effects observed have all been fairly subtle, but they are likely to become much stronger as climate change accelerates through the 21st century.

Until very recently, it seemed unlikely that climate change could account for much of the insect loss to date. Then, in 2018, evidence emerged for declines in insect biomass of between 80% and 98% (for sweep-net and sticky trap samples, respectively) in the rainforests of Puerto Rico since the 1970s [Lister and Garcia 2018]. These forests have not been logged or otherwise directly altered by humans in the last 30 years, and no pesticides have been used on or near them, so far as anyone knows. Unlike in Germany, however, the climate of these forests has changed since the late 1970s, with an increase of 2ºC in the mean maximum daily temperature and the scientists who conducted the Puerto Rican study tentatively concluded that this was the most likely cause of the declines, though it is possible that other, as yet unidentified, factors may be at play.

Why should we care about disappearing insects?

Opinions are divided about insects. For some of us, insects are beautiful, fascinating, joyful creatures, the sight and sound of which are a vital part of spring and summer. Ecologists, farmers or knowledgeable gardeners might value for them for the good they do, pollinating flowers, recycling nutrients, controlling pests, providing food for pretty birds and so on. On the other hand, sadly, there are many people for whom the idea of fewer insects seems attractive, for insects are often associated with annoyance, bites, stings and the spread of disease. When recently asked about the seriousness of global wildlife declines on national UK radio, medical doctor, professor and well-known TV presenter Lord Robert Winston replied: *"There are quite a lot of insects we don't really need on the planet"*. This response likely typifies the attitude of many.

Ecologists and entomologists should be deeply concerned that they have done such a poor job of explaining the vital importance of insects to the general public. Insects make up the bulk of known species, and are intimately involved in all terrestrial and freshwater food webs. Without insects, a multitude of birds, bats, reptiles, amphibians, small mammals and fish would disappear, for they would have nothing to eat. Eighty-seven percent of all plant species require animal pollination, most of it delivered by insects [Ollerton et al. 2011]. That is pretty much all of them aside from the grasses and conifers. **Approximately three-quarters of all crop types grown by humans require pollination by insects, a service estimated to be worth between $235 billion and $577 billion per year worldwide [Lautenbach et al. 2012].** Financial aspects aside, we could not feed the global human population without pollinators.

The importance of insects is often justified in terms of the ecosystem services they provide, which can be ascribed a monetary value. In addition to pollination, insects such as ladybirds, hoverflies, ground beetles and lacewings are important biocontrol agents (often controlling other insect pests). Wood-boring beetles and wasps help to recycle the nutrients in decaying timber, while an army of tiny invertebrates including springtails, silverfish, worms and woodlice help to break down the leaves that fall every autumn. Animal dung would build up in our pastures were it not for the prompt arrival of dung beetles and flies, which swiftly recycle it, providing nutrients for the grass to grow. Animal corpses, which otherwise might take months to rot, are rapidly consumed by maggots and carrion beetles. Ants and other burrowing insects help to aerate the soil and disperse seeds. Silk moths give us silk and honeybees provide us with honey [reviewed in Noriega et al. 2018]. **These ecosystem services are estimated to be worth at least $57 billion per year in the United States alone [Losey and Vaughan 2006].**

For many insects, we simply do not know what they do. We have not even given a name to perhaps four-fifths of the perhaps five million insect species that are thought to exist, let alone studied what ecological roles they might perform. As Aldo Leopold said: *"The first rule of intelligent tinkering is to keep all the parts"*. We are nowhere near understanding the multitude of interactions that occur between the thousands of organisms that comprise most ecological communities, and so we cannot say which insects we 'need' and which ones we do not. Studies of crop pollination have found that most pollination tends to be done by a small number of species, but that pollination is more reliable and resilient when more species are present.

Ecosystem services provided by insects and other invertebrates


Food for other species


Nutrient cycling


Pollination

© Vaughn Matthews


Decomposition


Pest control

APPROXIMATELY 3/4 OF THE CROP TYPES GROWN BY HUMANS REQUIRE POLLINATION BY INSECTS

a service estimated to be worth between **$235** and **$577 billion** per year worldwide

Relying on only one pollinator, such as the honeybee, is a risky strategy because if anything happens to it there is no backup. As the climate changes so pollinator communities will change, and species that seem unimportant today could be the dominant pollinators of tomorrow.

American biologist Paul Ehrlich famously likened loss of species from an ecological community to randomly popping out rivets from the wing of an aeroplane [Ehrlich and Ehrlich 1981]. The plane might continue to fly for a while, but if enough rivets are removed then at some point there will be a catastrophic failure.

As we have seen, there are strong practical, economic arguments for conserving insect species that either are, or might one day prove to be, valuable to humans. However, perhaps this anthropocentric approach to conservation is missing the most compelling arguments to conserve biodiversity. Despite what Aldo Leopold said, there are insects which could go extinct without us feeling any economic impact. The St Helen's giant earwig has already done so, and none of us noticed. New Zealand's giant wetas could follow it to oblivion and it is highly unlikely that there would be adverse repercussions, save for the heartbreak of a few New Zealand entomologists. Wart biter crickets could disappear from their last few haunts in the South Downs, and black bog ants from wet heaths in Dorset and Hampshire, without any ecological catastrophe unfolding.

Perhaps we humans could survive in a world with minimal biodiversity; parts of Kansas or Cambridgeshire are pretty close to that already. Soon we may well have the power to eradicate entire species at will; for example, gene drive technology can exterminate lab populations of the mosquito *Anopheles gambiae*, offering the possibility that one day we might be able to use it to wipe them out in the wild [Kyrou et al. 2018]. If we gain that power, should we use it, and where will we stop? Robotics engineers in several labs around the world are developing robotic bees to pollinate crops, the premise being that real bees are in decline and that therefore we may soon need a replacement. Is this the future we would wish for our children, one in which they will never see a butterfly flying overhead, where there are no wildflowers, and where the sound of birdsong and the buzz of insects is replaced by the monotonous drone of robot pollinators?

These arguments value nature for what it does for us humans, either practically or for the joy and inspiration it can provide. There is a final argument that is not focussed on human wellbeing: one can argue that the rest of the organisms on our planet have as much right to be here as we do. Do we not have a moral duty to look after our fellow travellers on planet Earth, be they penguins, pandas or silverfish?

Farmers have to pollinate pears by hand in Sichuan province because all the insects are gone

Shifting baselines

The evidence suggests that insects, and also mammals, birds, fish, reptiles and amphibians, are all now much less abundant than they were a few decades ago, but because the change is slow it is difficult to perceive. Amongst scientists it is now recognised that we all suffer from shifting-baseline syndrome, whereby we accept the world we grow up in as normal, although it might be quite different from the world our parents grew up in. We humans are also poor at detecting gradual change that takes place within our lifetime. The only aspect of insect declines that has impinged on the consciousness of significant numbers of people has become known as the "windshield phenomenon". Anecdotally, almost everybody over the age of about 50 years old can remember a time when any long-distance drive in summer resulted in a windscreen so splattered with dead insects that it was necessary to stop occasionally to scrub them off. Driving country lanes at night in high summer would reveal a blizzard of moths in the headlights. Today, drivers in Western Europe and North America are freed from the chore of washing their windscreen. It seems unlikely that this can be entirely explained by the improved aerodynamics of modern vehicles.

It seems probable that our children's children will grow up in a world with even fewer insects, and birds and flowers, than we have today, and they will think that normal. They may read in books, or more likely online, that hedgehogs were once common, everyday creatures, but they will never experience the joy of hearing one snuffling about for slugs in a hedge bottom. They won't miss the flash of a peacock butterfly's wing any more than the present-day citizens of the USA miss the passing of flocks of passenger pigeons, which once darkened the sky. They may be taught at school that the world once had great tropical coral reefs, teeming with fantastic and beautiful life, but these reefs will be long gone, no more real to them than mammoths or dinosaurs.

In the last 50 years, we have reduced the abundance of wildlife on Earth dramatically. Many species that were once common are now scarce. We can't be sure, but in terms of numbers, we may have lost 50% or more of our insects since 1970. It could be much more. We just don't know, which is scary, because insects are vitally important, as food, pollinators and recyclers amongst other things. Perhaps more frightening, most of us have not noticed that anything has changed. Even those of us who can remember the 1970s, and who are interested in nature, can't really remember how many butterflies or bumblebees there were when we were children. Human memory is imprecise, biased and fickle. You may have a vague nagging feeling that there used to be more than just one or two butterflies on your buddleia bush, but you can't be sure.

Does it matter, if we forget what once was, and future generations do not know what they have missed? Perhaps it is good that our baseline shifts, that we become accustomed to the new norm, as otherwise perhaps our hearts might break from missing what we have lost. A fascinating study of photographs of trophy fisherman returning to Key West, Florida with their catches estimated that the average size of the fish fell from 19.9 to 2.3 kg, but the smiles on the fisherman's faces are not any smaller. The fishermen of today would presumably be sad if they knew what they were missing.

On the other hand, one could argue that we should fight to remember, and hold on to that sense of loss as best we can. Wildlife monitoring schemes can help us, by measuring the change. If we allow ourselves to forget, we will doom future generations to living in a world of concrete and wheat, not knowing the joy and wonder that birdsong, butterflies and buzzing bees can bring to our lives.

Together we can reverse insect declines

Ecosystem crashes due to a critical loss of insect abundance and diversity are a real and present threat to society but they are not inevitable. Insect declines in the UK are mainly caused by a loss of habitat in which to thrive, and the use of pesticides[1] on farmland, urban green spaces (such as parks etc.) and gardens. These can be addressed without major economic or cultural cost, and we believe that there is a critical mass of concerned people in all walks of life who support changes in policy and practice.

We need to:

STOP all routine and unnecessary use of pesticides.

The Government must set a compulsory pesticide reduction target for the UK and we should all stop using insecticides and weed killers wherever possible in our homes, parks, gardens and places of work.

START to build a nature recovery network.

Create more and better connected, insect friendly habitat in our gardens, towns, cities and countryside.

© Nick Tomlinson

1 Insecticides, herbicides (weedkillers), and fungicides

By greening our cities and towns...

We can turn our cities, towns, villages and gardens into a buzzing network of insect friendly habitats. We have about half a million hectares of gardens in the UK, plus city parks and green spaces, school playing fields, railway embankments and cuttings, road verges and roundabouts; they are managed favourably, and if we avoid pesticide use, these areas could go a long way towards creating a national 'Nature Recovery Network'.

What is the potential?


© Nick Turner

250,000 miles of road verges. More should be managed for wildlife by sowing insect friendly seed mixes, mowing later in the year and removing the cuttings. Green bridges should be a part of transport infrastructure projects.


© Cat Bolado

430,000 hectares of gardens. Wildflowers in gardens have huge potential to help pollinators such as bees. A network of small patches will help bees thrive in urban areas.


© Hugh Barton

80% of the UK's population live in urban areas. New parks, street trees, green roofs and walls are an important way to help everyone experience nature in daily life.


© Devon Wildlife Trust

Our public spaces. Two-thirds of amenity land is shortmown grass, but meadow habitats support eight times more wildlife. Greener and more biodiverse neighbourhoods provide health and wellbeing benefits for people.

...and helping farms to be more wildlife friendly and sustainable

Some 70% of UK land is farmland, so making our farms more wildlife friendly and sustainable is vital. Whilst there is a wide spectrum of farming practice in the UK, the overuse of pesticides and fertilizers is a major driver of wildlife declines and other environmental problems such as climate change, pollution and soil degradation.

Farming is vital to feeding the nation and is at the heart of rural culture, enterprise and employment. Our challenge is to design and implement policies to encourage productive and ecologically sustainable farming,[2] which supports livelihoods, biodiversity and healthy soils and has much reduced greenhouse gas emissions.

The current food and farming system is hugely inefficient, with about one-third of all the food that is grown going to waste and too large a proportion of land devoted to growing crops to feed to livestock. We don't need to destroy our precious natural capital to feed this country or for export purposes. Numerous and extensive United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) studies have concluded that agroecological methods are the best way to feed the world, curb greenhouse gas emissions and address food poverty.

Globally and in the UK there is an unnecessary reliance on routine prophylactic use of pesticides which are a key driver of insect declines and a cause for concern over impacts on human health. Policies to significantly reduce use of toxic agrochemicals should include free advice plus financial incentives for farmers to apply agroecological, integrated pest management (IPM) and other practices. This could be funded by a "pesticide tax" and contributions by water companies, for whom drinking water treatment costs would be significantly reduced.[3]

We are a prosperous nation with fantastic natural capital, great farmers and world-leading researchers. If we put our minds to it and create the right policy and economic conditions for our farmers, we can massively reduce the use of harmful and polluting agrochemicals and rebuild biodiversity in the farmed environment.

2. www.wildlifetrusts.org/news/new-agriculture-bill-vital-recover-nature
3. www.pan-europe.info/issues/pesticide-taxation.

French study shows that pesticide use can be significantly reduced with little impact on yield or profit

France is one of Europe's biggest consumers of pesticides (per unit of agricultural area). In 2013, after controversy over levels of pesticide concentration in drinking water, the French government set a target of a 50% decrease in pesticide use, promoting the principles of agroecology and advocating integrated pest management for a reduction of pesticide reliance.

Food security and economic impacts were a major consideration for policy advisors and researchers:

"We demonstrated that low pesticide use rarely decreases productivity and profitability in arable farms. We analysed the potential conflicts between pesticide use and productivity or profitability with data from 946 non-organic arable commercial farms showing contrasting levels of pesticide use and covering a wide range of production situations in France.

We failed to detect any conflict between low pesticide use and both high productivity and high profitability in 77% of the farms." (*Lechenet et al. 2017)*

Tackling insect declines requires action at many levels, and we all have a role to play

Green our cities so they become part of nature's recovery network

Gardens, villages, towns and cities have the potential to become vast nature reserves, and people can get directly involved in conservation where they live. Growing vegetables; creating wildlife friendly gardens with ponds and nectar-rich flowers; ensuring there are substantial wild zones in urban parks; turning road verges into wildflower habitats; ensuring that built development contributes towards nature's recovery – these are achievable solutions to help our cities to buzz with insect life and to ensure that all urban areas are part of a robust nature recovery network.

Stop the routine use of pesticides in public green spaces and private gardens

There are always more benign alternatives, though they may take a little more effort: we can encourage natural predators for pest control; hand pull or strim weeds, enjoy the presence of more hedgehogs and insectivorous birds; and take pride in not exposing children and pets to toxins.

Protect, enhance and link existing wildlife hotspots and nature-rich protected areas

These core places are vital 'nodes' in a Nature Recovery Network, acting as sources from which insect populations can recover in the wider rural and urban landscape. Currently designated Sites of Special Scientific Interest (SSSIs) are inadequate as many endangered invertebrate species do not occur on them. We need to support UK conservation organisations' and societies' efforts to identify and protect Local Wildlife Sites, to ensure that more and bigger areas of semi-natural habitat are given protected status and that protections are robustly enforced. We need to identify a new series of Important Invertebrate Areas, and work in partnership to deliver initiatives such as 'B-lines', which links flower-rich habitats throughout the UK.

Make our food and farming system more wildlife friendly and sustainable

Getting agriculture policy right is key to nature's recovery. Whilst there is a wide spectrum of farming practice in the UK covering approximately 70% of the land, the overuse of pesticides and fertilizers is a major driver of wildlife declines and other environmental problems such as climate change, pollution and soil degradation. We need a new agriculture policy and support regime, as the current system serves agribusiness rather than farmers, consumers or wildlife.

As well as introducing and enforcing a UK Pesticide Reduction Target, the Government should provide free technical advice and financial incentives for farmers to apply integrated pest management (IPM) and other agroecological practices. In other European countries this has been funded via a "pesticide tax" and contributions by water companies, for whom drinking water treatment costs would be significantly reduced.

Strong legal protection for insects and the rest of the natural world

We need an Environment Act to protect our natural world by establishing legally binding targets to improve the environment and biodiversity; an independent environmental watchdog that can take action against councils and the Government if they break the law; and a duty on Government to establish nature recovery networks across our towns, cities and the countryside to provide enough space for wildlife to recover and for everyone to be able to enjoy wildlife and wild places.

Wildlife Trusts and supporters taking action

Wildlife Trusts are campaigning, creating habitats, inspiring kids and helping others to take action for insects and other invertebrates all over the country. Here are a few examples:

ACTION
Green infrastructure (building with nature)

We're working with Somerset County Council on its county-wide pollinator strategy to help deliver, optimise and connect habitats and environments where pollinator populations can grow and thrive.

ACTION
Habitat restoration

We're working in partnership with Aggregate Industries to restore and enhance habitats on sites that they own and, with support from local volunteers, we are undertaking woodland enhancement works at Cheddar Wood Nature Reserve, as well as grassland and hedgerow restoration works on sites in East Mendip.

ACTION
Wildlife friendly farming

We've brought together a group of farmers and other land managers to work collaboratively to enhance the landscape for wildlife, helping to connect fragmented habitats and provide the variety of habitats needed for pollinator species to thrive and move through the landscape.

ACTION
Pesticide free allotments and gardens

Gardening is a great way to get outside, boost your health and wellbeing, meet new people and provide homes for wildlife, including invertebrates. We run a wonderful community garden project just off Lisieux Way where we hold regular volunteer sessions. We also run courses at the garden on skills such as hedgelaying and provide advice on ensuring that gardens provide spaces for our unsung invertebrate heroes.

ACTION
Habitat restoration

On our Westhay Moor Nature reserves we manage our scrub in areas of peat mire to ensure floral diversity to attract pollinators and, by cutting channels and open areas in our reedbed areas we increase the muddy edge areas where a variety and abundance of insects can thrive and act as food sources for breeding waders, wildfowl and winter visitors.

© Nick Turner

We need everyone to understand the scale of the problem to feel empowered to take individual action to protect insects where they live and work, and to share their concerns with politicians and policymakers.

A key challenge is to embed the growing evidence that, whether we live in an urban or rural environment, invertebrate life is a cornerstone of human wellbeing and prosperity. We need it to be easy for people to contribute towards the recovery of our insects and to feel inspired to act.

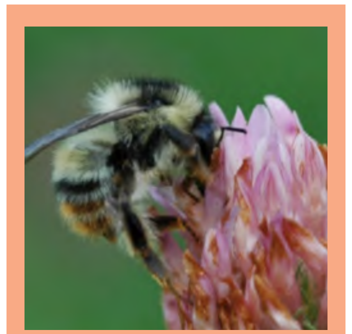
The Wildlife Trusts, Greener UK partners, and specialist invertebrate organisations are working to halt insect declines through political pressure and influence; practical action on the ground; and by engaging as many people as possible to support nature's recovery.

But we need more people to take action – and now – if we are to halt these alarming insect declines.

Appendix 2 of this document outlines a range of actions that can achieve this: helping people to understand why they need a healthy environment; encouraging policymakers both locally and nationally to put nature and people's wellbeing at the heart of decision-making; and incentivising sustainable business and land management practices.

If we work together and act now, we can reverse the catastrophic decline in abundance and diversity of insects.

Appendix 1 - Featured species

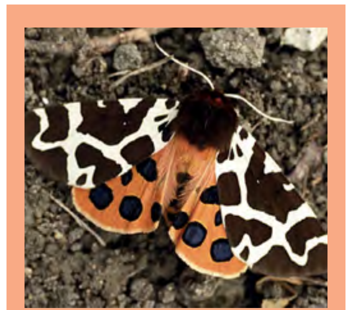


© Dave Goulson

This once-common wild bee depends on flower-rich grasslands and is now on the brink of extinction

Shrill carder bumblebee, *Bombus sylvarum*

A century ago, shrill carders were a familiar sight and sound in the south of Britain. The species gains its name from its unusually high-pitched buzz, which is often the best giveaway that there is one foraging nearby. The shrill carder is a species fond of flower-rich meadows, where it loves to feed on flowers such as red clover, red bartsia, kidney vetch, knapweed and viper's bugloss. The loss of 98% of such meadows during the 20th century nearly drove this handsome bee extinct, and now it clings on in a handful of sites, including Pembrokeshire, the Somerset Levels and the Thames Estuary. Some of the best populations in the Thames Estuary are brownfield sites, abandoned industrial areas that have become rich in flowers.

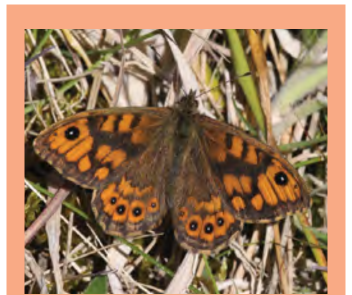


© Ken Dolbear MBE

The decline of the garden tiger is likely to be one of the drivers behind the rapid disappearance of the cuckoo

Garden tiger moth, *Arctia caja*

The garden tiger is one of our most spectacular moths, being large and furry, with chocolate and cream forewings hiding scarlet and blue-dotted hindwings. The orange and black caterpillars are ridiculously hairy, and as a result are often known as 'woolly bears'. Both caterpillars and adult moths were a common sight 30 years ago, the caterpillars crawling speedily about on the ground in search of dandelions and other favoured leaves to eat, with the adults commonly seen sitting about near outside lights. Sadly, this species declined by 89% between 1968 and 2002, thought to be a combination of the effects of climate change and increased tidiness of the countryside, with many fewer weeds. The decline of the garden tiger is likely to be one of the drivers behind the rapid disappearance of the cuckoo (down 77%), a bird species that specialized in eating large hairy caterpillars.



© Ken Dolbear MBE

The wall butterfly's decline is an indicator of high fertilizer use and habitat degradation

Wall butterfly, *Lasiommata megera*

Forty years ago the wall butterfly was considered an everyday, slightly drab butterfly, that turned up in almost any sunny habitat including gardens. It has declined by 85% in the UK, and by nearly 99% in the Netherlands. A huge hole has opened up in the distribution of this species in the UK, so that it is now absent from much of the midlands, eastern and south eastern counties. The decline is not fully understood, but seems to correlate with geographic patterns of high fertilizer use, and there is some evidence that the lush vegetation resulting from high soil fertility shades and cools the sunny, warm microhabitats that the caterpillars prefer.

The collapse of grey partridge populations illustrates how herbicides can indirectly impact on birds

Grey partridge, *Perdix perdix*

The grey partridge was a common farmland bird but it has declined by 92% since 1967. Peter Melchett, formerly of Greenpeace and the Soil Association, was inspired to convert to organic farming by the collapse of grey partridge numbers on his farm, from 150 pairs to just 12 following the introduction of pesticides and herbicides in the 1960s [Melchett 2017]. Long-term scientific studies performed in Sussex showed that, perhaps surprisingly, herbicides were one of the biggest drivers of the decline, more so than insecticides. It was not that the herbicides were poisoning the birds, but that they were greatly reducing the number of weeds in crops and field edges, and in turn was greatly reducing the abundance of caterpillars and other herbivorous insects which are the main diet of partridge chicks.

Unloved and under-appreciated, this fascinating creature performs a crucial role controlling crop pests

Common earwig, *Forficula auricularia*

Earwigs are misunderstood creatures. Most people think they look a little creepy, and think that they can give a nasty nip with their pincers. Some are afraid that they might creep into their ear and lay eggs. Until recently fruit farmers regarded them as a pest, and sprayed insecticides to kill them. In fact, earwigs are loving parents, never enter our ears voluntarily, and do a wonderful job of eating aphid pests in apple orchards and elsewhere. Studies have shown that a healthy earwig population in an orchard can consume as many aphids each year as can be killed by three rounds of insecticide spray.

A humble and benign recycling hero

Woodlouse, *Oniscus asellus*

Pesticides designed to kill woodlice are widely available from garden centres and via the internet. The gardening section of a national newspaper recently promoted "controlling" them in compost heaps by applying insecticides. In reality, woodlice are benign creatures, doing a fantastic job in the compost heap of chewing up woody material and helping it become dark, rich compost. They particularly thrive in damp wood piles, quietly recycling the nutrients from the wood and eventually making them available to your garden plants. They are food for birds and small mammals. These are beneficial creatures, and should be celebrated.

Healthy worm populations are critical for healthy soil and healthy crops

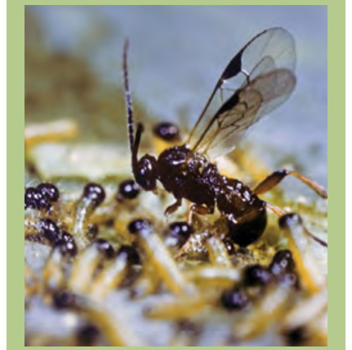
Earthworm, *lumbricus terrestris* and relatives

These most humble of creatures are ignored by most of us, but are enormously beneficial to soil health. Worms drag into their tunnels and consume dead leaves, fungi and all manner of other organic matter, and defecate a beautiful, nutrient-rich soil (or cast). Aristotle described earthworms as "the intestines of the Earth", but they could also be considered the lungs of the Earth, for as they move through their tunnels they act like slimy pistons, pumping oxygen down to the roots of plants. Their tunnelling greatly improves drainage, reducing flooding. Worms are food for a great range of garden wildlife, from thrushes to hedgehogs to badgers. Darwin wrote a whole book about worms, in which he opines: "It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures." As usual, Darwin was spot on. Worms can reach very high densities in healthy soils rich in organic matter, but are scarce in intensively farmed arable fields, probably a consequence of injury from tillage and the low organic matter content [Blakemore 2018]. Healthy soils can have more than 450 worms per square meter, while intensively managed fields often have fewer than 30.

These tiny creatures perform a vitally important job in the soil food web

Springtail, *Collembola*

Springtails are minute, primitive relatives of insects, often under 1mm long. Most people will never know they exist, but there are millions of them in most (healthy) gardens, living in the soil and in vast numbers in the compost heap. They are named from their ability to escape predators by firing themselves high into the air, using a spring-loaded 'furcula' which sits under their body. We may never notice them, but this army of miniscule beasts does an important job, nibbling on tiny fragments of organic matter and helping to break them up into smaller pieces which are then further decomposed by bacteria, releasing the nutrients for plants to use. Springtails are a vital and neglected component of healthy soils. Some of them are surprisingly cute too, resembling tiny, chubby sheep (with a bit of imagination).



The original 'Alien'

Parasitoid wasp, *Cotesia glomerata*

The word 'wasp' conjures up images of the yellow-and-black striped social wasps, but most wasps are much smaller, and they include the world's smallest insect, a species of fairy wasp which is just 0.14mm long. Most of these small wasps are parasitoids, laying their eggs on or in other unfortunate insects, which are then consumed alive by the developing wasp grub. *Cotesia glomerata* is one such creature, and a great friend of the vegetable gardener because it chooses to lay its eggs only in the caterpillars of the large and small white butterflies, both rather annoying pests of cabbages. The wasp lays dozens of eggs in a single host, and when her offspring have finished growing they burst out of the caterpillar, killing it in the process, and then spin their bright yellow cocoons on its fresh cadaver.

Midges are generally loathed, but unexpectedly important!

Midge, *nematoceran*

Visit the Highlands of Scotland in late summer and you will soon learn to loathe the swarms of blood-sucking midges that can make life very uncomfortable. In the tropics, sandflies and black flies (which are also types of midge) spread unpleasant diseases. But even midges have their important roles: they are food for many birds such as swallows and for our smaller bat species, and some types of midge are the sole pollinator of the cacao tree, meaning that without midges we would have no chocolate.

Consuming corpses is a macabre but important job

Burying beetle, Sylphidae

Also known as sexton beetles, these are specialists in consuming corpses of dead animals such as mice or birds. Some species of burying beetle excavate under their corpse so that it falls into the hole, and then cover it with soil to avoid the attentions of flies. They lay their eggs in the corpse and carefully tend to their larvae, often regurgitating food for them, and driving away any other burying beetles. If the adults perceive that there is not enough food left for their growing offspring, they will cull and consume a few of them so that the remainder can thrive.

Appendix 2 - What we can all do

This section suggests a range of actions we can all do to help invertebrate populations to recover

Actions for gardeners and allotment holders

- Grow flowers that are particularly rich in nectar and pollen to encourage pollinators such as bees, butterflies and hoverflies (For ideas, check out: **http://www.sussex.ac.uk/lifesci/goulsonlab/resources/flowers** or watch videos here: **https://www.youtube.com/channel/UCbnBys2Hl1T26dzO_nbgbiw**. Try out the Bumblebee Conservation Trust's 'BeeKind' tool to see how bee friendly your garden is: **https://www.bumblebeeconservation.org/gardeningadvice/**
- Grow food-plants for butterflies and moths, such as lady's smock, bird's foot trefoil, ivy and nettles.
- Buy or make a bee hotel: a fun project that children can get involved in.
- Dig a pond and watch how quickly it is colonised by dragonflies, whirligig beetles, newts and pond skaters.
- Create a 'hoverfly lagoon', a small aquatic habitat for hoverflies to breed in: see **https://www.hoverflylagoons.co.uk/**
- Create your own miniature wildflower meadow.
- Reduce your frequency of mowing – allow your lawn (or part of it) to flower. You may be surprised by how many different flowers are already living in your lawn.
- Try to reimagine 'weeds' such as dandelion as 'wildflowers', and let them grow. Dandelions are great flowers for bees.
- Grow your own healthy, zero-food-miles fruit and veg.

© Nick Turner

- Plant a fruit tree – available in dwarf sizes suitable for tiny gardens, they provide blossom for pollinators and fresh fruit for you. Apple, pear, plum, quince, apricot, mulberry, peach – there are heaps to choose from.
- Avoid using pesticides in your garden; they really aren't necessary. There are always organic alternatives, or you could simply leave pests alone until something comes along and eats them.
- Use companion planting to encourage pollination of veg crops and to attract natural enemies of crop pests.
- Leave a 'wild' corner for nature.
- Provide a brush pile or log pile.
- Build a compost heap and recycle kitchen scraps.

© Nick Turner

© Sarah Burgess

Actions for local authorities

- Phase out use of pesticides in urban areas, and stand alongside other large cities, e.g. Ghent, Portland, Toronto. France recently banned use of all pesticides in urban areas, by both local authorities and the public. If this is possible in France, why not the UK? Pesticide Action Network UK can provide detailed advice, including for example how to control pavement weeds with hot foam. See **http://www.pan-uk.org/pesticide-free/**
- Create wildlife areas in parks: meadows, ponds, plantings for pollinators, bee hotels.
- Plant streets and parks with flowering, native trees (e.g. lime, chestnut, rowan, wayfaring tree, hawthorn).
- Plant fruit trees in urban green spaces, providing food for pollinators and people.
- Reduce the mowing of road verges and roundabouts, sow areas with wildflowers. New road verges should be automatically sown with wildflower mixes.
- Purchase and/or dedicate land for allotments on city fringes. Recent evidence shows that allotments are the best areas in cities for pollinator diversity, while simultaneously providing healthy, zero-food-miles, no-packaging fruit and veg, and boosting the health of allotmenters (win, win, win).

Actions for government, regulators and industry

- Nature-rich development should be standard, providing real, measurable gains for wildlife, to ensure that all new developments make a demonstrable, positive contribution to nature's recovery. These should provide many functions including connectivity for wildlife, accessible green space, space for community use such as allotments, health and wellbeing benefits, effective water management and pollution and climate control. The Government, through its 25-year Environment Plan, has committed to *"embed an environmental net gain principle for development, including housing and infrastructure"* and through the National Planning Policy Framework to secure *"measurable net gains for biodiversity"* and recently consulted on the mechanics of ensuring this net gain for biodiversity.
- Incentivise new developments (particularly public facilities) to apply for and work towards Building with Nature or similar kite marks.
- Promote the inclusion in new buildings of green roofs planted with pollinator friendly plants. Some research is needed to identify suitable drought-tolerant, insect friendly plants.
- Replace neonicotinoid and fipronil insecticides in flea treatments for pets and in ant baits with pyrethroid insecticides, which are much less persistent. Also provide advice for pet owners on non-pesticide-based control methods.

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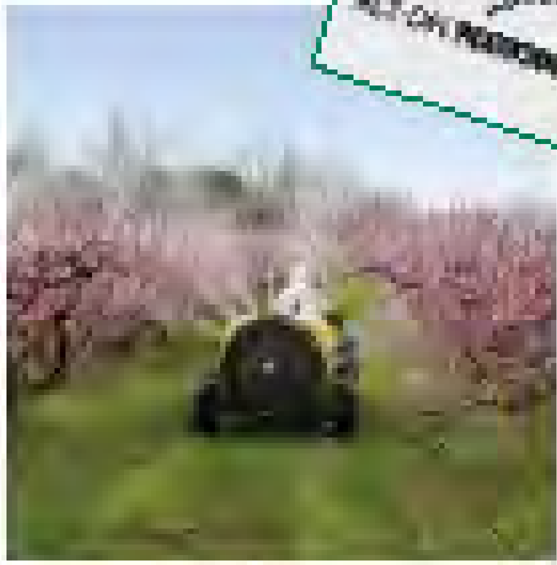

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Actions for consumers and parents

- Stop using pesticides in your garden or allotment.
- Try to buy locally grown, pesticide-free fruit and veg.
- Consider buying direct from farmers and growers who go the extra mile to avoid the use of pesticides.
- Wildlife friendly produce may be more expensive, so check out blogs that advise on cooking from scratch using seasonal ingredients, non-premium meat cuts, etc.
- Encourage your school to join the Food for Life initiative. More than a million institutional meals a day meet Food for Life standards.

Actions for GPs

- Promote the health benefits of eating fresh, seasonal, pesticide-free fruit and vegetables.
- Call for more research into the long-term health risks associated with exposure to complicated mixtures of pesticides.

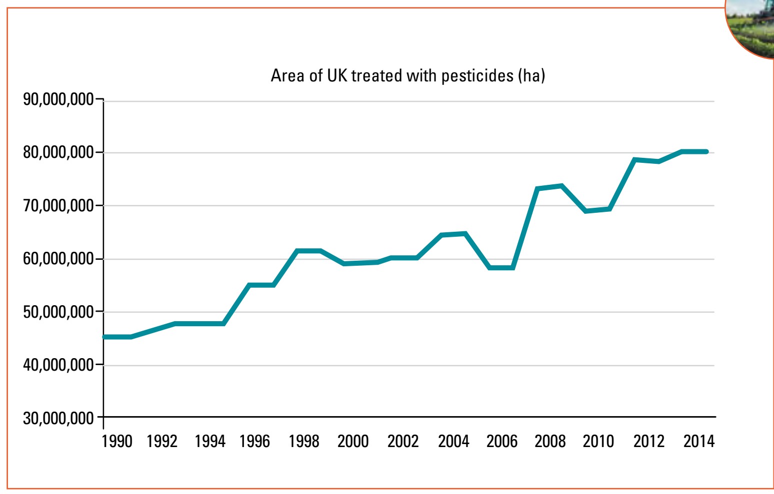
> *“Recent studies from France suggest that reductions of 40% can be achieved without reducing profitability for farms”*
>
> Lechenet et al. 2017

Appendix 3 - Pesticides

Growing use of pesticides

Every year, farmers apply more pesticides to their crops. The chart shows official Defra figures **https://secure.fera.defra.gov.uk/pusstats/** for the total area of crops treated with pesticides each year in the UK. This approximately doubled between 1990 and 2015. Given that there are only about 4.5 million hectares of arable and horticultural land, this means that on average each hectare now receives 17 pesticide applications.*

** Several active ingredients may be applied at once, so fields are not necessarily sprayed 17 times.*

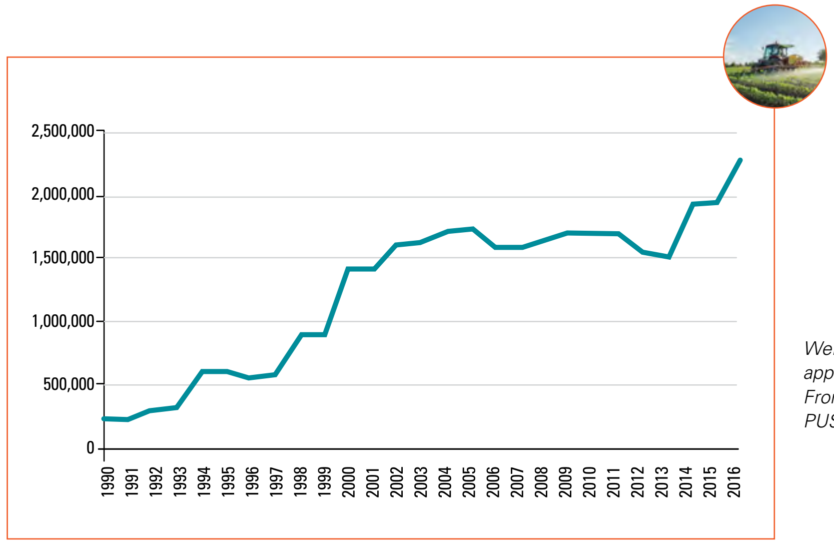


Thiacloprid

Thiacloprid is a type of neonicotinoid insecticide, a notorious group of neurotoxic pesticides implicated in the declines of bees and butterflies. Three neonicotinoids are now banned in Europe, but this one remains in use, despite evidence that it harms bumblebee colonies [Ellis et al. 2017]. Thiacloprid is widely used by home gardeners, being sold as Provado Ultimate Bug Killer. The containers it is sold in often show pretty flowers, but if you spray this on to plants that flower and are visited by pollinators then you will be giving them a dose of neurotoxin, for the chemical is systemic, travelling throughout the plant and entering the pollen and nectar. The pervasiveness of these chemicals is illustrated by a recent study from Switzerland which found neonicotinoids in the feathers of 100% of house sparrows tested, with thiacloprid being the most commonly found type of neonicotinoid [Humman-Guilleminot et al. 2019].

Glyphosate

Sold as Roundup, glyphosate is the most widely used pesticide in the world, with use in UK farming increasing year on year to 2,200 tons in 2016. This figure does not include use by local authorities or domestic gardens, both of which must be considerable but are not monitored by the Government. The main impact of glyphosate on insects is the effective removal of most ‘weeds’ from the landscape, such that crops are often close to pure monocultures. These weeds would formerly have provided food for herbivorous insects and flowers for pollinators. Outside of Europe, much use of glyphosate is associated with the growing use of “Roundup-ready” genetically modified (GM)



Weight of glyphosate applied to UK (kg). From Defra online PUSSTATS website

crops, which have been rendered immune to the effects of the herbicide. Since the introduction of these GM crops in 1996, glyphosate use globally has risen 15-fold, to 747,000 tons per year in 2014, and it continues to rise [Benbrook 2016].

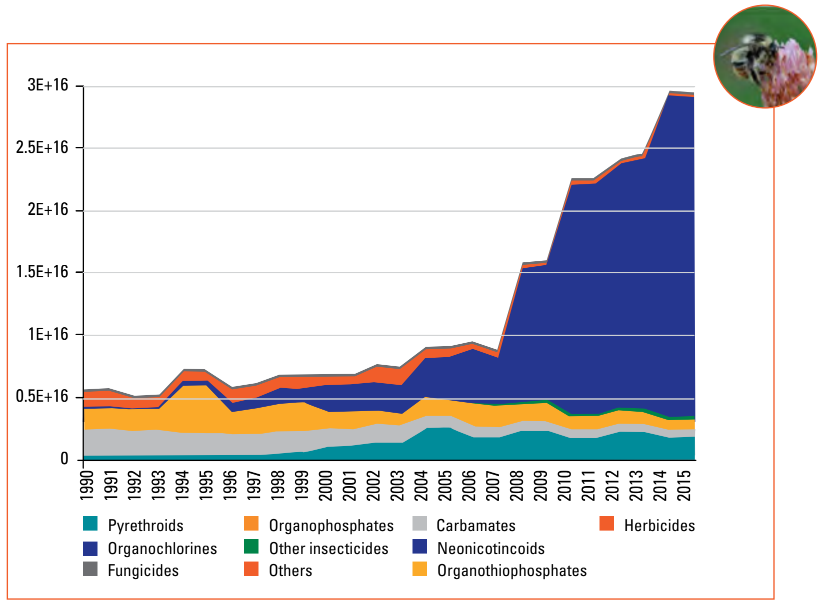
Glyphosate is considered very useful by farmers, but is far from benign. It has proved to be far more persistent that was previously thought, and is common in cereal-based foodstuffs such as bread, biscuits and breakfast cereals. A recent study found that more than 99% of a sample of 2,000 Germans had detectable glyphosate in their urine, with children tending to have more than adults [Krüger et al. 2016]. This is particularly concerning when coupled with evidence that those who are occupationally exposed to glyphosate have an elevated risk of developing a cancer called Non-Hodgkin's lymphoma [Zhang et al. 2019]. Studies have also found that low doses of glyphosate impair navigation and learning by honeybees, and also alter their gut bacteria [Balbuena et al. 2015; Motta et al. 2018].

Woodlouse killer

The gardening section of a national newspaper recently promoted "controlling" woodlice if they become too numerous in compost heaps by spraying insecticide. For those inclined to follow this advice, Vitax Ltd Nippon Wood Lice Killer, containing a general purpose pyrethroid insecticide, is available from Amazon, garden centres and DIY stores. It is advertised for outdoor and indoor use, with the claim that it is also effective against earwigs and silverfish. Quite why one would wish to kill these organisms is unclear. In compost heaps, woodlice cannot become "too numerous" as they are helping to break down the compost; the more the merrier. If woodlice and silverfish regularly turn up in numbers in your house, you have a damp problem. It is probably best to tackle that, rather than treating the symptom by dousing your house with pesticide.

Are modern pesticides safer?

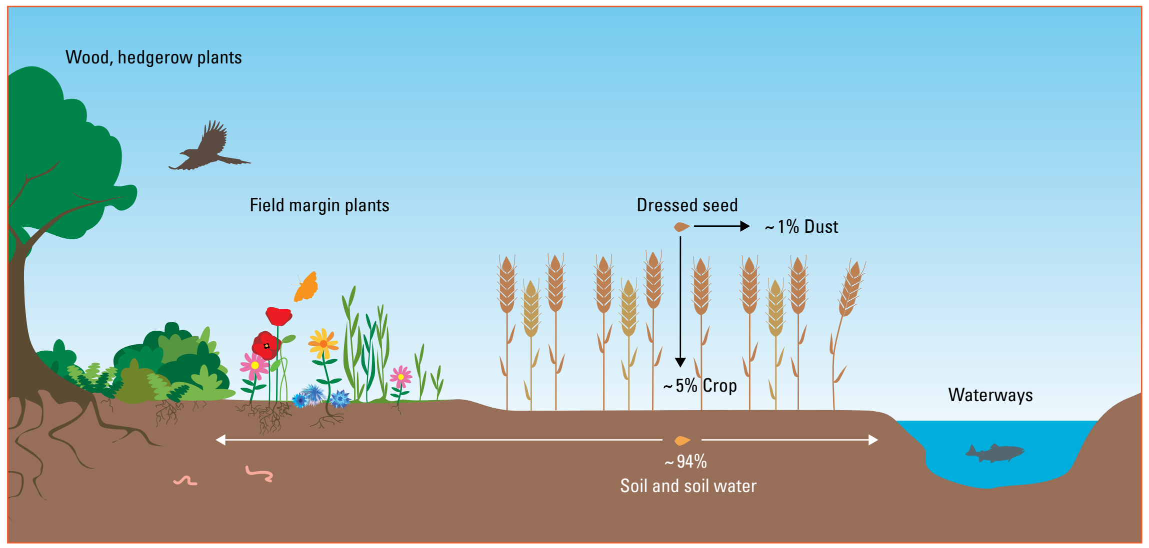
It is often argued that modern pesticides are much safer for people and the environment than older pesticides such as DDT. Is this true? The chart on the facing page shows how many honeybees one could kill with the pesticides applied to the UK each year, in the unlikely worst-case scenario that all of the pesticides applied by farmers were consumed by bees. The number of potential bee deaths has risen-six fold since 1990. The underlying explanation is that modern pesticides are much more potent than those they replaced. For example, neonicotinoid insecticides are about 7,000 times more toxic to bees than DDT is. From a bee's perspective, farmland has become a more dangerous place than it used to be.



The potential number of honeybees that could be killed by the pesticides applied to the UK each year has increased six-fold since 1990, as newer, more toxic insecticides have been adopted by farmers. [From Goulson et al. 2018, doi: 10.7717/peerj.5255].

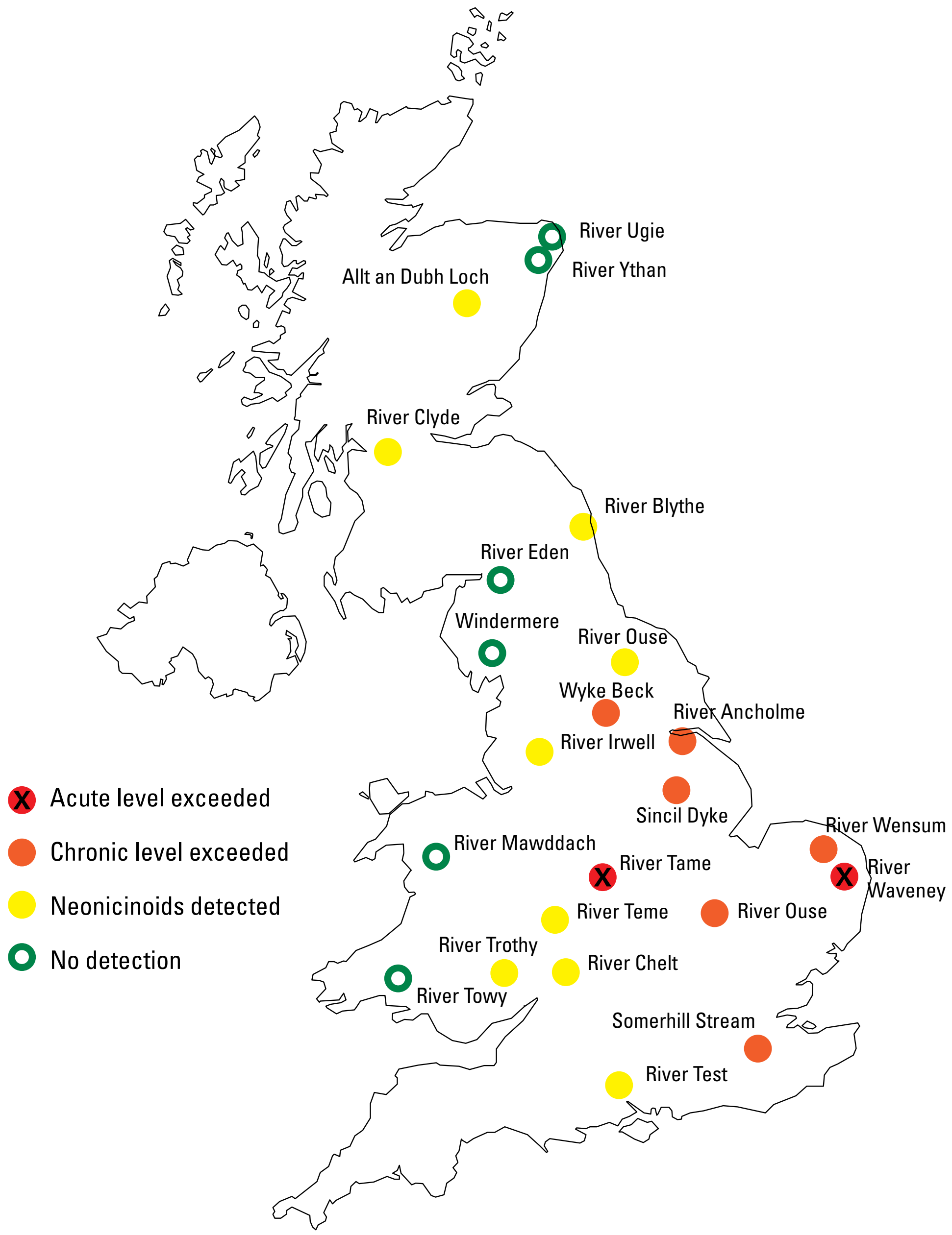
The environmental fate of neonicotinoid insecticides

The diagram below illustrates the fate of neonicotinoid insecticides when applied to crop seeds. Only 5% of the pesticide goes where it is wanted, in the crop, a figure calculated by manufacturer Bayer's own scientists [Sur & Stork 2003]. Most ends up accumulating in the soil, from where it can be absorbed by the roots of wildflowers and hedgerow plants, or can leach into streams [Wood & Goulson 2018]. There is also a fundamental problem with this mode of application, since it is necessarily prophylactic: it is impossible for the farmer to know whether the crop will be attacked by pests before he has sown the seeds. Prophylactic use of pesticides is contrary to all of the principles of Integrated Pest Management, a widely-accepted approach that seeks to minimise pesticide use.



Neonicotinoid insecticides in freshwater

Neonicotinoids are water soluble, leaching from soils into streams and rivers. They are also widely applied as flea treatments to dogs (a use not covered by the EU ban). The map reveals widespread contamination of British rivers with these pesticides, including in regions with little arable farming (it is thought that this might be from domestic pets swimming in rivers).



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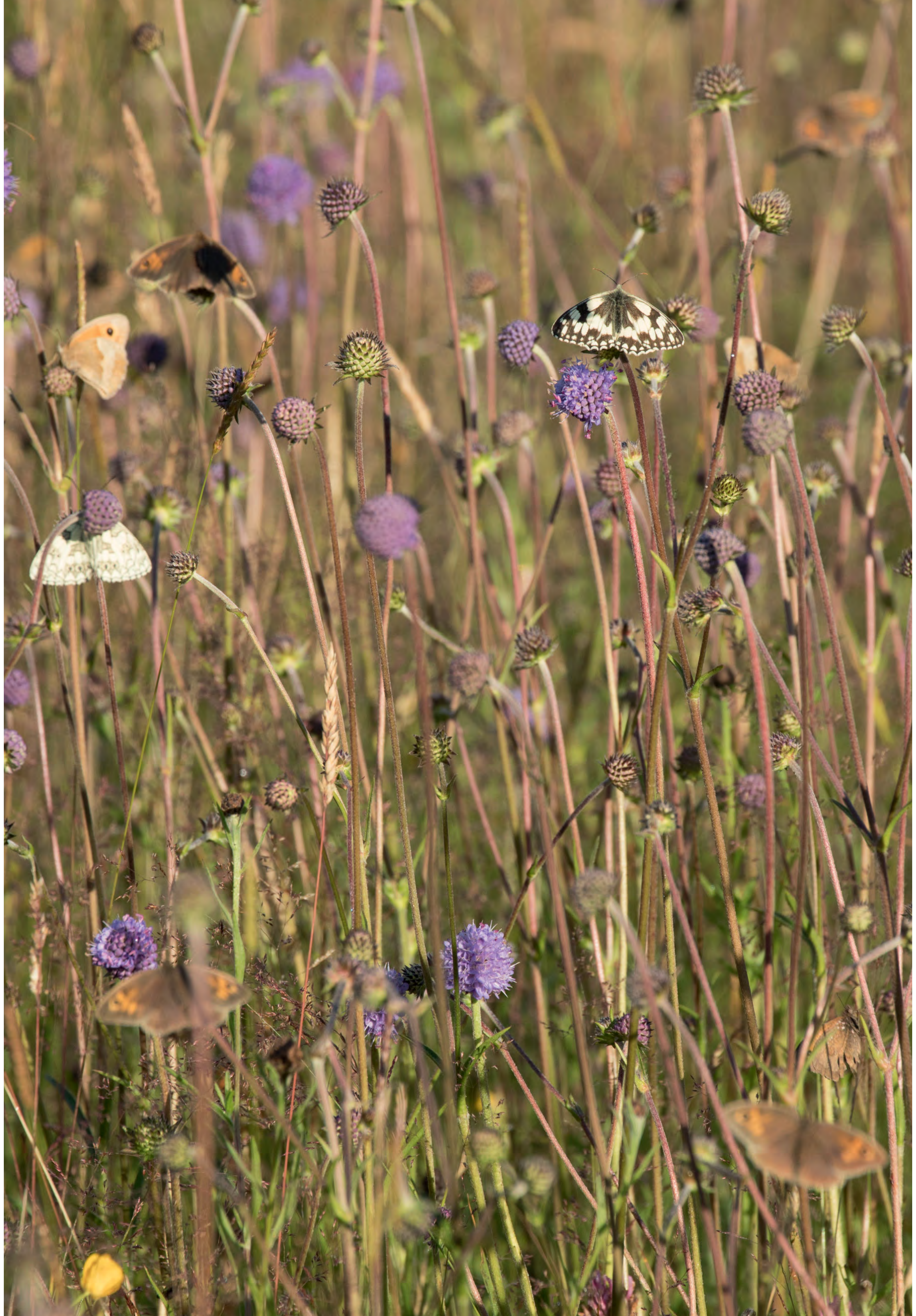

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