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Bumblebees

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Summary

Since bumblebees are a group associated with cool climates, Britain supports a large proportion (~10%) of the world's bumblebee fauna. However, three of our 25 species have become extinct, and seven species are Biodiversity Action Plan (BAP) listed, a higher proportion than for any other insect group. Declines are primarily driven by habitat loss and declines in floral abundance resulting from agricultural intensification, notably the loss of ~97% of all species-rich grasslands (haymeadows, calcareous grasslands) in the last 60 years. The decline in the abundance of Red Clover, once a common fodder and ley crop and a major source of pollen and nectar for many bumblebee species, is likely to have had a significant impact. Effects of habitat degradation and fragmentation are compounded by the social nature of bumblebees and by their largely monogamous breeding system, which means that they have a very low effective population size (most bumblebees are sterile workers). Hence, populations are susceptible to chance extinction events and inbreeding. Given the importance of bumblebees as pollinators of crops and wildflowers, their declines have broad ecological and economic significance. Suggested measures for their conservation include tight regulation of commercial bumblebee use and targeted use of agri-environment schemes to enhance floristic diversity in agricultural landscapes.

Introduction

The drone of bumblebees busily collecting nectar and pollen is, for me, the sound of summer: I have fond memories of childhood days spent in our garden in Shropshire catching bumblebees and imprisoning them temporarily in jam jars. With their clumsy

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flight and large, furry, striped bodies they are among the most familiar and endearing of British insects, but like many other organisms they have not fared well in recent decades. The world bumblebee (*Bombus*) fauna consists of approximately 250 known species, largely confined to temperate parts of the northern hemisphere. Bumblebees are social insects, and the vast majority have an annual life cycle. Mated queens emerge from hibernation in spring, and attempt to found a nest in which they rear daughter workers. If all goes well, the number of workers may reach as many as 400 in some species by mid-summer, when new queens and males are reared. These leave the nest, mate and the new queens enter hibernation, while the rest of the population dies off.

An interesting consequence of the large size of bumblebees is that they must beat their wings exceedingly fast to remain in the air (~200 times per second) and it takes an enormous amount of energy to do so. Estimates of the metabolic costs of flight suggest that flying bumblebees have one of the highest metabolic rates recorded in any organism, being 75% higher than that of Hummingbirds. For comparison, a jogging human male burns the energy in a Mars bar in roughly one hour. A bumblebee of equivalent mass would burn the same energy in just 30 seconds. For this reason bumblebee survival depends on the ready availability of nectar-rich flowers, and this lies at the crux of the problems facing bumblebees in modern Britain.

Heading?

There is mounting evidence that many bumblebee species have declined in recent decades, particularly in developed regions, such as Western Europe and North America, but the most detailed records available are from Britain. The data reveal a dramatic reduction in the populations of many species during the second half of the twentieth century. Three of the 25 British species having become nationally extinct (the Apple Bumblebee, *Bombus pomorum*, Cullum's Bumblebee, *B. cullumanus* and the Short-haired Bumblebee, *B. subterraneus*) (although it should be noted that the Apple Bumblebee became extinct over 100 years ago and may never have been a resident species). A further eight species having undergone major declines (the Great Yellow Bumblebee, *B. distinguendus,* the Red-shanked Carder Bee, *B. ruderarius*, the Ruderal Bumblebee, *B. ruderatus*, the Shrill Carder Bee *B. sylvarum*, the Brown-banded Carder Bee, *B. humilis*, the Moss Carder bee, *B. muscorum*, the Bilberry Bumblebee *B. monticola* and the Broken-belted Bumblebee, *B. soroeensis*). The first six of these, along with the extinct Short-haired Bumblebee, have BAP status.

More so than for most other taxonomic groups, declines in bumblebees have potentially serious ecological and economic consequences. Many wild plants are pollinated predominantly or exclusively by bumblebees. Most bumblebees are generalist pollinators and most insect-pollinated plants use multiple pollinators, so it could be argued that loss of a few pollinator species will have little effect on plant reproduction, but simulating the effects of removal of individual pollinators from pollination networks has demonstrated that removal of highly linked pollinators (those that provide a pollination service to many different plant species) such as bumblebees produces the greatest rate of decline in plant-species diversity. Reduced pollination services can be particularly detrimental when plants are already scarce and threatened directly by the same changes in land use that threaten the bees. Hence, we ought to be particularly concerned by the state of our bumblebee fauna.

Aside from the implications for conservation, there are good financial reasons for conserving bumblebees. The yields of many field, fruit and seed crops are enhanced by bumblebee visitation. For example, field beans are largely pollinated by longer-tongued species, such as the Common Carder Bee, *B. pascuorum* and the Garden Bumblebee, *B. hortorum*, without which, yields are poor. Many crops rely primarily on honeybee pollination, but beekeeping in Britain has declined due to problems with disease (notably also in North America where, since 2006, an epidemic of unknown cause has destroyed a significant proportion of managed and almost all wild honeybee colonies). The impoverished bumblebee communities often associated with agricultural landscapes may be insufficient to replace the pollination services currently provided by honeybees, and many soft-fruit growers in Britain now buy in commercially reared colonies of the Buff-tailed Bumblebee, *B. terrestris* from eastern Europe to boost natural bee populations (although there is actually no evidence that wild bumblebee populations have fallen so low in Britain that soft-fruit crops need imported bumblebees to set a good crop).

It is pretty clear that the primary cause of bumblebee declines in Britain is the intensification of farming practices, particularly in the period from ~1945–90. The drive for self-sufficiency in the wake of the Second World War led to a number of major changes documented elsewhere in this book, some of which are particularly pertinent to bumblebees. Permanent unimproved grassland was once highly valued for grazing and hay production, but the development of cheap artificial fertilisers and new fast-growing grass varieties meant that farmers could improve productivity by ploughing up ancient grasslands. Hay meadows gave way to monocultures of grasses which are directly grazed or cut for silage. In the second half of the twentieth century, ~97% of unimproved lowland grassland was lost. Grants were introduced to grub out hedgerows, to plough and re-seed pasture and to drain marshy areas. This led to a steady decline in the area of unfarmed land and of unimproved farmland. There is evidence to suggest that bumblebee forage plants have suffered disproportionate declines. A recent study in Britain found that of 97 preferred bumblebee forage species, 71% have suffered range reductions, and 76% have declined in abundance over the past 80 years, exceeding declines of non-forage species.

On farmland, the crops themselves may provide an abundance of food during their brief flowering periods. Leguminous crops (notably clovers, *Trifolium* spp.) used to be an important part of crop rotations in much of Europe, and these are highly preferred food sources, particularly for long-tongued bumblebee species, such as the Ruderal Bumblebee and the Great Yellow Bumblebee. Since the introduction of cheap artificial fertilisers, rotations involving legumes have been almost entirely abandoned, and it is probable that this is one of the primary factors driving the decline of long-tongued bumblebees. Flowering crops such as oilseed rape may contribute to supporting bumblebee populations in arable landscapes, but in order for bumblebee colonies to thrive, they require a continuous succession of flowers from April until August, and crops alone are unlikely to provide this. Farms must contain areas of wildflowers if they are to support bumblebee populations.

Uncropped areas of farmland, such as hedgerows, field margins and borders of streams may provide flowers throughout the season, and therefore support greater numbers of foraging bumblebees than cultivated areas. However, these areas will be adequate only if there are enough of them, and if they have not been degraded by drift of herbicides and fertilisers. Insufficient flower-rich uncropped areas may lead to gaps in the succession of flowering plants, during which bumblebee colonies may starve and die. With a decline in bees, the plants that they pollinate set less seed, resulting in less forage for the bees in subsequent years. The feedback process by which mutually dependent species drive each other to extinction is known as an ‘extinction vortex’. We do not as yet know whether this process is really occurring, but it is clear that farmland provides less food for bees than it once would have done, and it seems probable that reduced pollinator abundance in turn has had negative effects on farmland plant populations.

In addition to floral resources, bumblebees need suitable nesting sites, the precise requirements for which vary between species. The carder bees (*Thoracobombus*) such as the Common Carder tend to nest in dense grassy tussocks, while other species such as the Buff-tailed Bumblebee nest underground in cavities. Both groups often use abandoned rodent nests. The loss of hedgerows and of unimproved pastures is likely to have reduced availability of nest sites for both above- and below-ground nesting bumblebee species (3). Those species that nest above ground frequently have their nests destroyed by farm machinery, particularly by cutting for hay or silage. The scarcity of weeds and field-margin flowers on modern intensive farms means that there are less seeds, and therefore less food for voles and mice. Lower populations of these mammals will lead to fewer nest sites for both above- and below-ground nesting bumblebee species.

Heading?

An obvious potential contributor to bumblebee declines is the use of pesticides, but we have very little information on whether they cause substantial bumblebee mortality. Pesticide risk assessments are routinely carried out for honeybees, but the results of these are probably not directly applicable to bumblebees since both their behaviour and physiology are different. For example, to avoid honeybees, pyrethroids are commonly applied to flowering oilseed rape in the early morning or evening, but being better able to forage in cool conditions, bumblebees are often active at this time. Laboratory and field-based bioassays appropriate to bumblebees have been developed in response to the growing use of bumblebees for the pollination of greenhouse crops, but these are not widely used and few toxicological data are available. Almost all tests conducted so far have been on Buff-tailed Bumblebees, and suggest that toxicity is similar to that found in honeybees. Tests with dimethoate and carbofuran (the latter now banned in Britain) suggest that these chemicals are selectively transported into the nectar where they can reach high concentrations. Given the large volume of nectar consumed by bumblebees, this could prove to be the most important route of exposure to pesticides.

When colonies are large, it is likely that they can tolerate the loss of some of their workers. However, in the spring, when queens are foraging, and subsequently when nests are small and contain just a few workers, mortality may have a more significant effect. Thus, spring applications of pesticides are of particular concern.

Despite risk assessments, widespread poisoning of honeybees has been reported. Such effects are obvious in domestic hives, where dead bees are ejected and form piles by the nest. It seems probable that pesticides would have similar effects on bumblebees, but they are unlikely to be noticed in most situations, since the nests are tucked away and generally not observed. However, bumblebee deaths have been reported following applications of the insecticides dimethoate or ⊠-cypermethrin to flowering oilseed rape, and of ⊠-cyhalothrin to field beans.

A growing appreciation of the damaging effects of broad-spectrum pesticides has led to the development of a new generation of more target-specific compounds. EU law now demands that oral and acute toxicity tests are carried out on honeybees prior to the registration of any new pesticide. However, there is no obligation to study sub-lethal effects on any bees, or to look at specific effects on bumblebees. Some of these substances cause no mortality in bumblebees if used appropriately, but there is evidence that supplementary trials for non-lethal effects are needed. For example, spinosad is a commonly used insect neurotoxin which, based on studies of honeybees, has been deemed harmless to bees. However, it has recently been shown that bumblebee larvae fed with pollen containing this pesticide give rise to workers with reduced ability to gather food. Screening of chitin synthesis inhibitors that are used as pesticides found that although they had no lethal effect on adult bumblebees, the use of these pesticides has strong effects on colony growth and the development of larvae. Diflubenzuron and teflubenzuron were found to be the most harmful to bumblebees, greatly reducing reproductive output at concentrations far below the recommended field concentrations. In summary, it is likely that many pesticides currently in use do impact on bumblebee populations, but hard data are largely lacking.

Heading?

A final potential threat to bumblebees is posed by the global trafficking of commercial bumblebee hives. Around 60 000 colonies of a south-eastern European sub-species of the Buff-tailed Bumblebee, *Bombus terrestris dalmitinus*, are imported each year into

Britain. Britain has an endemic sub-species of the Buff-tailed Bumblebee, *Bombus terrestris audax*. Evidence suggests that there are dangers to the British sub-species in the form of parasite transmission and competition. Also, *B. terrestris dalmatinus* and *B. terrestris audax* readily interbreed, at least under laboratory conditions, so the native sub-species could be lost through introgression.

Heading?

As a consequence of the various factors discussed above, populations of a number of bumblebee species have become increasingly small, fragmented and separated from one another by large distances. Declines appear to have followed a characteristic pattern. The last bumblebee species to disappear from Britain, the Short-haired Bumblebee, was once widespread across southern England, but declined rapidly in the years after World War II. By the 1980s, the few remaining populations were small and isolated, surviving on habitat islands (mostly nature reserves) that had escaped agricultural intensification. However, these populations subsequently disappeared, despite the protected status of the remaining habitat. The species was last recorded at Dungeness National Nature Reserve in 1988. Several other species, such as the Great Yellow Bumblebee and the Shrill Carder Bumblebee are in the late stages of a similar process, and are likely to go extinct in Britain the near future. Why do isolated populations go extinct? Understanding the consequences of the fragmentation of remnant populations of bumblebees is of great importance to conservationists, given the current distributions of many rare species.

Small populations of all organisms are inherently more vulnerable to extinction due to chance events. If these populations form part of a broader network of interlinked populations, then local extinctions can be balanced by subsequent recolonisation, but if fragmentation is severe, then extinct patches may never be re-occupied. In addition, if habitat fragmentation results in the isolation of populations, then they may face an additional extinction threat through inbreeding. Small populations inevitably lose genetic diversity over time, a process known as genetic drift, and after a few generations it becomes inevitable that all individuals within the population will be related to one another and will be genetically similar. This loss of genetic diversity and forced interbreeding between relatives usually results in a general reduction of population fitness. There are a number of reasons to believe that bumblebees may be particularly badly affected by such processes. It is the effective population size (often known as N_e) which determines the rate of genetic drift in a population, and N_e may be several orders of magnitude lower than the actual number of individuals present (because not all individuals in a population manage to produce offspring). In bumblebees, as in many other social insects, N_e depends on the number of successful colonies. Each colony contains one breeding female, the queen (ignoring occasional egg-laying by unmated workers). Queens of most bumblebee species mate only once, so each colony effectively represents two breeding individuals. Hence a flower-filled meadow may contain many foraging bumblebees and give the impression of a large population, but the vast majority are sterile; the actual number of nests present may be tiny. It seems therefore that population sizes of bumblebees may be low, making them particularly susceptible to inbreeding and to chance extinction events (for example, a hungry badger might consume several nests in a single night, and could conceivably wipe out a small population very swiftly).

Inbreeding may be especially costly to bumblebees because of their rather unusual sex-determination mechanism. Bumblebees (along with many other hymenopterans, the bees, ants and wasps) can be either haploid (have a single copy of each chromosome) or diploid (have two copies of each chromosome, the usual number in most animals including humans). Haploid individuals are produced from unfertilised eggs, diploids from fertilised eggs. In general, haploids are male and diploids are female. However, the mechanism that determines sex is actually based on a single gene: if the bee is heterozygous at this locus (it has two different alleles of the gene) it is female; if not, it is male. In large populations the sex-determining gene tends to be very variable, so diploid individuals are almost always heterozygous, and hence female, while haploids must always be male (they have only one copy of the gene). However, problems arise in small populations which have lost genetic diversity through drift. As diversity at the sex-determining locus declines, the odds of a queen mating with a male carrying the same allele as one of her own increases. If this happens, she produces a colony in which 50% of her workforce is diploid males. Diploid males have low fertility and all males do little or no work in the nest, so this is a major handicap and it seems probable that most such colonies are doomed to die off before they can produce new queens.

Diploid males represent a clear example of inbreeding depression, and have been detected in numerous wild populations of hymenopterans. Their frequency has been suggested to provide a reliable indicator of population fitness and recent modeling work has shown that diploid male production, where present, may initiate a rapid extinction vortex. However, only very recently has diploid male production been detected in naturally occurring populations of bumblebees.

Until recently, studying the population genetics of rare bee species was extremely difficult, as lethal sampling was necessary. Work in this area was greatly aided by the development of a non-lethal DNA sampling technique. This approach has recently been applied to studies of fragmented populations of some of our rarest species: The Moss Carder Bee, Shrill Carder Bee and Great Yellow Bumblebee. All three studies found high levels of population structuring, which suggests that populations are small (and hence subject to rapid genetic drift) and isolated from one another (movement of individuals between populations keeps the populations from becoming genetically different over time). All three rare species appear to have much lower genetic diversity (measured as either allelic richness or heterozygosity) than common British bumblebee species. For example, in the Moss Carder Bee, all populations >10 km apart were significantly genetically different from one another, as were some populations just 3 km apart. Low frequencies of diploid males were found in three of the 16 studied populations. Use of DNA markers can also enable us to group workers into sisterhoods and so estimate the number of colonies (and hence N_e). This has been done for remaining populations of the Shrill Carder Bee. Estimates of N_e were very low (range 21–72) suggesting that these populations are very vulnerable to loss of genetic diversity through drift, and also that they are likely to be prone to chance extinction events. Significant differentiation was found between all populations, suggesting that they are genetically isolated, which in turn suggests that if a population becomes extinct, there is little chance of the site being recolonised from elsewhere. In addition, diploid males were found at low frequency, suggesting that the surviving populations may be suffering from inbreeding.

We do not as yet have unequivocal evidence that inbreeding plays a major role in driving small, isolated populations of bumblebees to extinction, but it seems likely. If reductions in the genetic diversity of neutral markers found in rare species are indicative of reductions in the diversity of functional genes, then there will be serious consequences for population fitness and evolutionary potential. If fragmented populations of rare bumblebee species are suffering from reduced fitness through inbreeding then we must take steps to conserve what genetic diversity remains. Management strategies in vertebrates routinely consider genetic factors, and we may need to adopt similar measures in the management of rare bumblebee populations. In short, the genetic evidence suggests that the Shrill Carder Bee has a bleak and probably short future in Britain unless action is taken. Similar patterns appear to be evident in the Great Yellow Bumblebee.

Heading?

Interestingly, some bumblebee species appear to have been largely unaffected by habitat loss, fragmentation and degradation. In most of Britain, six species are widespread and common: the Buff-tailed Bumblebee, White-tailed Bumblebee (*B. lucorum*), Red-tailed Bumblebee (*B. lapidarius*) Early Bumblebee (*B. pratorum*), Garden Bumblebee and Common Carder Bee. How do these species differ from those that have declined? Based on studies of forage use, it has been argued that the rare species (which includes all seven BAP species) tend to have narrower diets, with a very large proportion of the pollen they collect being from the pea family (the Fabaceae, vetches, trefoils and clovers, many of which have deep flowers). This group seems to be primarily associated with Fabaceae-rich unimproved grasslands, a habitat which has been very largely eradicated in western Europe. In contrast, the common species tend to have broad foraging preferences and readily encompass non-native garden plants and mass-flowering crops, such as oilseed rape in their diets. It is also noticeable that the common species tend to emerge early from hibernation (February to April), and utilise spring flowers, such as bluebells, that flower early before the trees come in to leaf. In contrast, the rare species emerge later from hibernation (April to June). This would make sense if they are indeed open grassland species, since most grassland plants do not flower until mid-spring. Where nesting habitat is scarce, those species in which queens emerge early in the season may be able to monopolise available nest sites, reducing the chances of colony founding for later emerging queens. Rodent holes may limit bumblebee abundance, and it could be that the earliest emerging species monopolise nest sites.

The apparent dependency of a number of late-emerging bumblebee species on pollen from Fabaceae may prove to have a simple explanation. Fabaceae pollen tends to be rich in protein and in essential amino acids compared to the pollen of other plants frequently visited by bumblebees, such as Asteraceae (daisy family, thistles, knapweeds etc.) or Rosaceae (roses, bramble etc.). This may reflect the fact that Fabaceae are able to obtain atmospheric nitrogen via mutualistic bacteria in their root nodules, and so have a supply of nitrogen from which to build proteins that is not available to most herbaceous plant species. In turn, this explains why Fabaceae thrive in nutrient-poor unimproved grasslands, where growth of most other plant species is limited by the low fertility.

Despite the evidence that most of our rarer species tend to have narrow diets, it seems that most bumblebee species are not strongly associated with particular habitat types. For example, prior to its extinction in Britain, the Short-haired Bumblebee occurred in habitats as diverse as shingle, saltmarshes, sand dunes, and calcareous and neutral unimproved meadows (the one factor these habitats tend to share is low fertility). Although some of the rarer species do appear to exist in very specific habitats, historical records show that most once existed across a much wider range of biotopes (39). For example the Great Yellow Bumblebee now has a strongly coastal distribution in the far north and west of Britain, and several of the strongest surviving populations are found on coastal machair in the Hebrides. However, 100 years ago, this species was found across Britain at inland locations such as Warwickshire, which conspicuously lack coastal habitat, so it is clearly not a machair or coastal specialist.

The species that are rare and declining in Britain are also declining elsewhere in Europe. It seems that species such as the Shrill Carder Bee and Great Yellow Bumblebee have always had small geographic ranges across Europe, perhaps because they have narrower climatic niches. Their declines in Britain show marked latitudinal shifts, although in opposite directions (the Great Yellow has contracted northwards, the Shrill Carder southwards). This corresponds to a shift towards their range centres in Europe. It seems probable that populations that are near the edge of a species range are more susceptible to environmental degradation (e.g. declines in floral abundance), and so are the first to disappear. Indeed, the one notable feature of all the remaining sites that support Great Yellow Bumblebees in Britain (Hebrides, north coast of Caithness and Sutherland, Orkney) is climatic: they are all windy, cool, damp sites. It is possible that only under these conditions does this species have a competitive edge over other less-hardy bumblebees. Of course the likely consequences of a warming climate for this species need hardly be explained.

In recent years it has become apparent that there are major differences between bumblebee species in their foraging range. Species such as the Buff-tailed Bumblebee and Red-tailed Bumblebee have been found to forage further afield than so-called 'doorstep foragers' such as the Carder Bees. It is perhaps significant that the former two species remain ubiquitous in much of Europe, while four of the five British Carder Bee species are on the BAP list. A larger foraging range would give a greater chance of colony survival in areas where the average density of flowers is low, or where resources are highly patchy. Intensively farmed arable landscapes with occasional fields of mass-flowering crops provide just such a landscape, and it is probably no coincidence that Buff-tailed and Red-tailed Bumblebees are among the species most commonly recruited in large numbers to such crops.

Fortunately, the future for bumblebees in Britain is not all doom and gloom. Agricultural policy in Europe now places an emphasis on combining the goals of agriculture and conservation. Demand for organic food is growing rapidly, and it seems highly likely that organic farming methods (particularly reduced pesticide use and use of leguminous ley crops to boost soil fertility) will be beneficial to bumblebees and many other organisms. Subsidies are currently available for various agri-environment schemes, including maintaining and restoring flower-rich grassland. Most of the management options promote floral abundance and diversity. It has been found that a 6 m wide field margin kept free of crops and agrochemicals may contain six times as many flowering plants and ten times as many flowers than the equivalent cropped area. The effects of field-margin management options on bumblebee communities have been the focus of many studies in recent years. The most valuable form of field margin management for bumblebees has been found to be the sowing of either a wildflower meadow mix or a pollen and nectar mix, consisting of agricultural cultivars of legume species. Simple pollen and nectar mixes produce the highest flower abundance, with a seasonal succession of forage plants flowering over at least three years following sowing. Wildflower mixtures produced few flowers in the first year, but flower abundance tends to increase over time as they become established. Either seed mixture leads to a rapid increase in bumblebee species richness and abundance. The duration for which these seed mixes remain effective is likely to depend on soil fertility and fertiliser treatment of adjacent crops. If fertility is low, then wildflower mixes can theoretically persist indefinitely. In contrast, agricultural legume cultivars have been selected to grow fast and tall, but are short lived, and will probably need re-sowing within five years. The trade-off is that agricultural cultivar seed is very cheap compared to wildflower mixtures. Whichever approach is used, creation of flower strips in field margins will undoubtedly provide benefits for a broad range of other flower-visiting insects, in addition to bumblebees.

Studies of forage use by bumblebees suggest that it is not necessarily important to provide a great diversity of flowers. In studies of 15 bumblebee species across a broad range of habitats in Britain, 80% of all pollen collecting visits were to just 11 plant species. Similarly, in studies of bumblebee foraging in sown wildflower strips along field margins, 92% of visits were to just six flowering plant species. It has been found that a diverse sown wildflower field-margin option consisting of 18 herb species is no more beneficial to bumblebees than a simple sown wildflower option consisting of only three herbaceous species. All studies concur in that Red Clover is an important pollen source for many rare species and also some of the common ones (including all of the Carder Bees, the Great Yellow Bumblebee and the Ruderal Bumblebee). Studies of the only surviving population of British origin of the Short-haired Bumblebee, in New Zealand (to which they were introduced in 1895) show that this species, too, has a strong dependency on Red Clover. As mentioned earlier, one feature of the agricultural changes that have occurred in Britain is the loss of Red Clover ley crops, and this single change could have played a major role in driving declines of bumblebees. There is clear evidence that Red Clover is now much less common than it once was in Britain. Also, it is notable that parts of eastern Europe, such as southern Poland still retain high bumblebee diversity (although now declining), and their agricultural systems still include Red Clover leys, which swarm with both rare and common bumblebees.

Bumblebees not only require a suitable source of forage, but also nest and hibernation sites. A popular agri-environment scheme in Britain is the sowing of field margins with tussocky grasses, or creation of such strips across the centre of fields ('beetle banks'). These habitats attract the small mammals whose abandoned holes are used by bumblebees for nest sites, so it is likely that this form of management is of value to bumblebees. It has been found that it is possible to combine wildflowers and tussocky grasses in a single mix that provides both nest sites and flowers for bumblebees.

Heading?

Urbanisation is generally viewed by conservationists negatively, but there is evidence that gardens and urban parks are particular strongholds for some species of bumblebee. Young nests of the Buff-tailed Bumblebee placed in suburban gardens have been found to grow more quickly and attain a larger size than nests placed in arable farmland. It is likely that gardens provide favourable habitat for several bumblebee species as a result of the density, variety and continuity of flowers that they provide, and recent studies suggest that bumblebee nest densities are higher in gardens than in farmland. However, many commonly used garden plants are unsuitable for bumblebees. Artificial selection has often resulted in modern flower varieties which provide little or no reward (such as sterile F1 hybrid flowers), or which are inaccessible to insects. Similarly, some exotic plants, such as those pollinated by hummingbirds, provide rewards that are inaccessible to native species. It is clear that urban gardens can provide a refuge for several bumblebee species, but encouraging gardeners to choose their plants appropriately could make them much better. This said, it is notable that although gardens can support high densities of the common bumblebee species, rarer bumblebees do not seem to thrive in gardens, unless the gardens are immediately adjacent to high-quality semi-natural habitat (for example, Great Yellow Bumblebees commonly visit garden flowers in the Uists). The reasons for this remain unclear.

Perhaps unexpectedly, urban areas provide another benefit for bumblebees in the form of brownfield sites. Some of the strongest surviving populations of the Shrill Carder, Moss Carder and Brown-banded Carder in southern England are on brownfield sites along the Thames Estuary. These sites are often rather less than scenic, with burnt-out cars and abandoned buildings, but a combination of low soil fertility and little disturbance over several decades have often led to the development of rich wildflower swards and exceptionally high invertebrate diversity. Sadly, these sites are rarely recognised as important to biodiversity and are targeted for development. Further loss of habitat could easily prove fatal to species such as the Shrill Carder that are close to extinction in Britain.

Heading?

There is one notable bumblebee success story in Britain. In 2001, the Tree Bumblebee, *B. hypnorum*, was first recorded in the Britain (in Hampshire), having somehow crossed the channel from mainland Europe, where it is widespread. It has since spread steadily northwards as far as Hull, with unconfirmed sightings in Scotland. So far as we know, it was a natural invasion, and there is no reason to believe that it threatens our native species (the Tree Bumblebee is short-tongued and seems to thrive alongside our common species in gardens). There has been a second addition to the British Bumblebee fauna in recent years, although not the result of an invasion. Genetic and pheromonal studies provide compelling evidence that *B. cryptarum* (the Cryptic Bumblebee?), a species known from Europe and with a very similar appearance to the White-tailed bumblebee, is alive and well in Britain. It would appear to be widespread and possibly common, occurring from southern England to the Hebrides. However, it is virtually indistinguishable from the White-tailed Bumblebee, with only very subtle morphological differences in the queens, and no known morphological differences between workers or males, so it seems that this species is native, but has simply been overlooked until now. This is quite remarkable that in a country such as Britain, with a long history and tradition of entomological study, that we have been unaware of the existence of a large and abundant insect species for so long. One must wonder how many other cryptic species await identification.

Conclusion

In summary, widespread declines of bumblebee species threaten pollination services to both wildflowers and crops. It is clear from studies of population structure that most bumblebee species cannot be conserved by managing small protected 'islands' of habitat within a 'sea' of unsuitable, intensively farmed land. Large areas of suitable habitat are needed to support viable populations in the long term. Also, studies of foraging range indicate that bumblebees exploit forage patches at a landscape scale, so that the scale of management must be appropriate. An integrated approach across large areas

Figure 23.1 A Great Yellow Bumblebee worker collecting pollen from Red Clover on unimproved flower-rich grasslands on South Uist, Outer Hebrides. This is probably Britain's rarest bumblebee, and is now confined to the far north and west of Scotland (see colour plate). (Photograph by Dave Goulson.)

Figure 23.2 A Shrill Carder bee. This species is associated with flower-rich unimproved grasslands in southern Britain, a habitat which has been all but entirely eradicated leading to precipitous declines in several bumblebee species (see colour plate). (Photograph by Dave Goulson.)

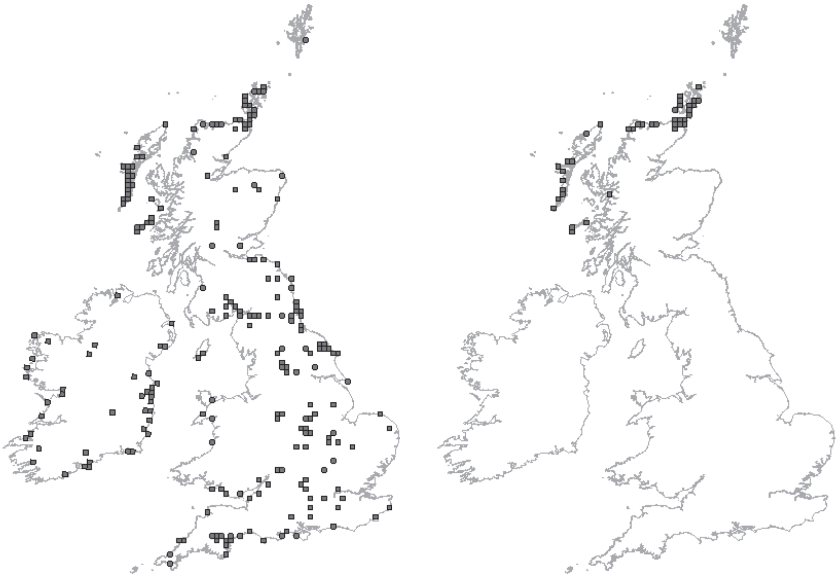

Figure 23.3 Distribution of *Bombus distinguendus:* (a) pre-2000; (b) post-2000. (Data from NBN, largely collected by the Bees, Wasps and Ants Recording Society and the Highland Biological Recording Group.

or several farms is more likely to succeed than localised efforts. Where small, isolated populations of rare species remain in habitat fragments, targeting the adjacent farms for uptake of suitable agri-environment schemes could increase the population size and so reduce the likelihood of chance extinction events and inbreeding. Similarly, such schemes could be used to provide linkage between habitat islands. Unimproved flower-rich grassland is one of the most important habitats for bumblebees, but has been largely lost to agriculture. Restoration of areas of this habitat will boost bumblebee populations and has been shown to provide improved pollination services on nearby farmed land. Substantial benefits could also be obtained by reintroducing clover ley crops into rotations, since this is a key forage source for many declining bumblebee species. Finally, long-term monitoring of bumblebee populations (not just distributions) is required in order to build up a picture of the current status of bumblebee species and to establish baselines to which future studies can refer.

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