Species Knowledge Review:
Shrill carder bee *Bombus sylvarum* in England and Wales

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Bombus sylvarum, Nashenden Down nature reserve, Rochester (Kent Wildlife Trust)
(Photo credit: Dave Watson)

Executive summary

This report aims to pull together current knowledge of the Shrill carder bee *Bombus sylvarum* in the UK. It is a **working document**, with a view to this information being reviewed and added when needed (current version updated Oct 2019). Special thanks to the group of experts who have reviewed and commented on earlier versions of this report.

Much of the current knowledge on *Bombus sylvarum* builds on extensive work carried out by the Bumblebee Working Group and Hymettus in the 1990s and early 2000s. Since then, there have been a few key studies such as genetic research by Ellis et al (2006), Stuart Connop's PhD thesis (2007), and a series of CCW surveys and reports carried out across the Welsh populations between 2000 and 2013.

Distribution and abundance
Records indicate that the Shrill carder bee *Bombus sylvarum* was historically widespread across southern England and Welsh lowland and coastal regions, with more localised records in central and northern England. The second half of the 20th Century saw a major range retraction for the species, with a mixed picture post-2000.

Metapopulations of *B. sylvarum* are now limited to five key areas across the UK: In England these are the Thames Estuary and Somerset; in South Wales these are the Gwent Levels, Kenfig–Port Talbot, and south Pembrokeshire. The Thames Estuary and Gwent Levels populations appear to be the largest and most abundant, whereas the Somerset population exists at a very low population density, the Kenfig population is small and restricted. Less is known about the Pembrokeshire population but it does not appear to be thriving in a manner equivalent to the

Thames Estuary or Gwent populations. It is possible a sixth population on Salisbury Plain may still remain in very low numbers, but this population is likely to have now been lost.

In general, there is reasonably good distribution data for the Shrill carder bee, although the comparatively frequent discovery of new populations and reappearance of old ones suggests that the species may be easily overlooked in a landscape if not searched for specifically. *Bombus sylvarum* has been recorded on 29 BeeWalk transects to date (BBCT's national bumblebee recording scheme which measures abundance) but there are gaps in coverage, with the majority of active transects in the Thames Estuary area, and there is currently insufficient BeeWalk data to reliably assess and monitor populations.

Bombus sylvarum populations in the UK are isolated and found in very fragmented habitats. As a result, they are vulnerable to inbreeding and loss of genetic diversity, which can lead to the production of diploid males (resulting in sterile or inviable offspring) and reduced resilience in populations, increasing the risk of local extinctions.

To enable the long-term conservation of *Bombus sylvarum* it is important to be able to define when conservation success has been achieved. Currently, there is no clear method for attempting to define or record when a viable population has been achieved. A combination of monitoring techniques, in addition to BeeWalk, needs to be employed. Methods are discussed below.

Species ecology

Bombus sylvarum is one of the last species of bumblebee to emerge from hibernation in the UK, with new colonies being established by a single queen usually in late May (although in some years there are sightings in April). Workers from the colony can be seen from June to September and sometimes October, and males and daughter queens appear from late August. Overwintering for queens begins in late September/October.

Bombus sylvarum appears to have wide dietary breadth of forage species that it utilises overall, but with a narrow dietary breadth at a given time of year and depending on the forage available on a particular site. It should be noted that marked differences in behaviour are displayed between different populations as regards use of forage. In terms of forage preference the plant families Fabaceae, Lamiaceae, Orobanchaceae and Asteraceae are all important, however there a big differences between locations and over time (and between plants utilised for pollen vs nectar collection).

Generally nests have been found on the surface or just below ground, and are associated with rough long grass with a litter layer. However, there is still little data and varying descriptions of *B. sylvarum* nest sites, despite many searches. Currently only broad habitat types with a suite of microhabitat features can be used to ensure that nesting habitat is present. More research is needed to better understand Shrill carder bee nesting preferences. More knowledge is also required to fully understand the preferences of *B. sylvarum* in choosing its hibernation sites.

Bombus sylvarum has been observed predominantly in open areas, often tall grasslands, with a scruffy element to them, plus a litter layer and varied forage. They have been found to be associated with a variety of open, flower-rich habitats (particularly late flowering) and habitat mosaics, including but not exclusive to: traditionally managed hay meadows and pastures, chalk downland, sand dunes, brownfield sites, field ditches, coastal and floodplain grazing marsh, sea walls and saltmarsh edges. There is a need for nesting habitats to be close to flower-rich areas for forage. Given the variety of habitats used by this species, there is still a lack of understanding of their relative importance.

It is suspected that *B. sylvarum* has a low dispersal distance in comparison to common species of bumblebee, therefore a precautionary approach should be taken when accounting for dispersal. However, very little is known on forage and dispersal distances (or timing) for this species, and the effect of barriers, and so more research is needed.

There is no specific evidence of problems with pests or pathogens specific to *Bombus sylvarum*, but no research has been done on this. The species is not known to host cuckoo bumblebees. However, there are a range of parasites, parasitoids and pathogens which affect bumblebees in general. These parasites and diseases are likely to be able to affect the Shrill carder bee as well, although their lower densities may reduce their impact compared with commoner bumblebees.

Bombus sylvarum is determined to have a west-Palaearctic distribution (Williams, 1998) with a narrower climatic niche in Western Europe then their more common cousin *B. pascuorum*. Williams *et al.* (2007) found *B. sylvarum* to be associated with warmer and drier areas of Western Europe, with much of the losses towards the cooler areas (e.g. northern Britain).

Threats

Similar to many bumblebee species in the UK, loss of habitat is a key threat for *Bombus sylvarum*, particularly the loss of flower-rich habitat mosaics that provide all the life cycle requirements (foraging, nesting, hibernation) for resilient populations. It is likely that threats will vary both temporarily and spatially at different scales, meaning each key site and population will have unique threat attributes.

Drivers for habitat loss include:

- Inappropriate management (e.g. badly timed cutting, over-grazing, use of fertiliser)
- Lack of management (resulting in degradation or loss of habitats / grass dominance / scrub encroachment / invasive species)
- Development (e.g. housing, industry, roads) – major threat in heavily populated and/or industrial areas such as the Thames Estuary (e.g. Tilbury expansion) and parts of south Wales (e.g. M4 relief road, Gwent Levels Solar Farm).
- General land-use change – such as agricultural intensification, pesticide use on a previously untreated site, managed realignments* (*although these can sometimes offer opportunity for new habitat creation).

Small, isolated populations and the loss of genetic diversity are other key threat factors.

A complexity of threats are likely to be acting on the species in the UK, from habitat change; climatic changes (e.g. phenological shifts impacting foraging, drought, flooding); pesticides, pathogens, and possible competition with imported bumble bees or honey bees. The majority of threats may coalesce around their impacts on colony size, number and viability.

To define a threat analysis, an initial exercise was undertaken in June 2019 involving members of staff from BBCT, Buglife and Natural England, and facilitated by the IUCN. A PESTLE analysis was also undertaken at the workshop, which considers the Political, Economic, Social, Technological, Legal and Environmental factors that could impact on populations, positively or negatively. The results of the workshop are outlined in this report.

Knowledge gaps
This knowledge review also highlights several knowledge gaps that vary in their ease and importance to address. Critical knowledge gaps:

- Deepening our understanding of threats to *Bombus sylvarum*
- Acquiring new knowledge on the extent of loss of genetic diversity across the population
- Learning about the preferred types of nesting/ hibernating habitat
- Understanding the extent to which habitat fragmentation is impacting the population (a gap which could be partly filled through genetic studies)

Other knowledge gaps identified include: impacts of inappropriate land management, pathogens, imported honeybees and/or bumblebees, loss of foraging habitat at colony level, and competition for forage/nest sites. There is also a lack of consistent standardised monitoring of the conservation management techniques for this species.

Conservation and management
Bombus sylvarum is listed as a priority species of conservation concern under Section 41 in England (NERC Act 2006), and Section 7 in Wales (Environment (Wales) Act 2016). It was a UK Biodiversity Action Plan species and was listed as Notable b (Nationally Scarce Nb) by Falk (1991). Natural England and BWARS are currently in the process of updating its threat status for Great Britain, this should hopefully be finalised by the end of 2019. *Bombus sylvarum* is also a qualifying feature for a number of Sites of Special Scientific Interest.

It has been suggested that *B. sylvarum* requires at least 10-20 sq.km of suitable habitat for an individual population to be viable (Bumblebee Working Group 1998, 2000). A viable metapopulation structure would presumably require multiple habitat matrices across a much wider landscape. Management recommendations for *B.sylvarum* tend to focus on ensuring plentiful flower-rich habitat with suitable forage is available from April to late September/October, in addition to providing undisturbed nesting habitat.

There are a range of conservation projects currently being delivered across England and Wales but only one is focused solely on the Shrill carder bee (Back from the Brink, ends March 2020), others have a general bee/invertebrate or habitat focus but provide benefits to *B. sylvarum,* and some have *B. sylvarum* as one of several target species. In addition, there is management for the species through individual landowner management activities, including on several nature reserves (e.g. RSPB), and to some extent through agri-environment agreements.

The Bumblebee Conservation Trust (BBCT) are undertaking the main targeted standardised surveys for this species across its distribution via BeeWalk, plus ad hoc surveys and specific research or monitoring projects, which are site focused. Some other organisations are also doing targeted monitoring for Shrill carder bee, such as the RSPB on some reserves.

Community engagement
The Shrill carder bee is an appropriate species for community engagement with good opportunities to use it as flagship species to champion threatened bumblebee conservation, as well as for the habitats it is associated with; engaging professionals as well as the wider public with its conservation. Several projects have been taking concerted action to raise awareness (e.g. Making a Buzz for the Coast, Bee Wild West Wales, Back from the Brink), with positive results.

Contents

Introduction

This report aims to pull together current knowledge of the Shrill carder bee *Bombus sylvarum* in the UK. It is a **working document**, with a view to this information being reviewed and added when needed.

Much of the current knowledge on *B. sylvarum* builds on extensive work carried out by the Bumblebee Working Group and Hymettus in the 1990s and early 2000s, which in turn was built in part on Paul Williams' PhD thesis (1985). Work was also undertaken on *B. sylvarum* in South Essex and Canvey Wick for English Nature which included mark and recapture studies and pollen analyses (Harvey, 2000; 2001). Since then, there have been a few key studies such as genetic research by Ellis et al (2006), Stuart Connop's PhD thesis in South Essex (2007), and a series of CCW/NRW reports and surveys carried out across the Welsh populations between 2000 and 2013.

Historic account

Records indicate that *Bombus sylvarum* was once historically widespread across southern England and Welsh lowland and coastal regions, with more localised records in central and northern England (Fig 1). The second half of the 20th Century saw a major range retraction for the species, with a mixed picture post-2000.

Sladen (1912) said *Bombus sylvarum* was 'widely distributed in England & Ireland and common in a good many places' and the same was indicated by the New Naturalist Bumblebees (1950), as well as Hallett indicating good populations in Wales in the 1930s.

By the publication of the 'Bumblebees of the British Isles', *B. sylvarum* was scarce (Alford, 1980). Analysis of these records showed that *B. sylvarum* was one of the Southern Local Species characterised by having been lost from the Central Impoverished Region of Britain (Williams, 1982), for which the most likely explanation was considered to be post-1940 habitat conversion and reduction in food resources (Williams, 1986). *Bombus sylvarum* was classified as Nationally Notable B (present in 31-100 hectads UK-wide; superseded by Nationally Scarce) in Falk's 1991 status review. More recently, the Bumblebee Working Group (BWG) estimated a 90% range decline between the pre-1970 confirmed distribution and results of intensive searches carried out between 1990 and 2001, and a 75% decline between the periods 1970-90 and 1990-2001 (Edwards, 2001 *in* Benton, 2006). The species was declared not present in Cornwall in 2005 (last recorded 1971).

In 1997, Bumblebee Working Group surveys found low records of individuals (1 in Kent, 1 on Salisbury Plain and 2 at Margam Moors), although it was noted that due to the weather conditions of the year all species of bumblebees were found to be at lower densities. It was accepted, through evidence, that *B. sylvarum* was present on the Somerset levels but surveying was not possible due to flooding. In 1998, the BWG confirmed a total of six key areas or sub-populations across the UK. In 2003, surveys of the Gwent levels found workers widely across the site (Pavett, 2004).

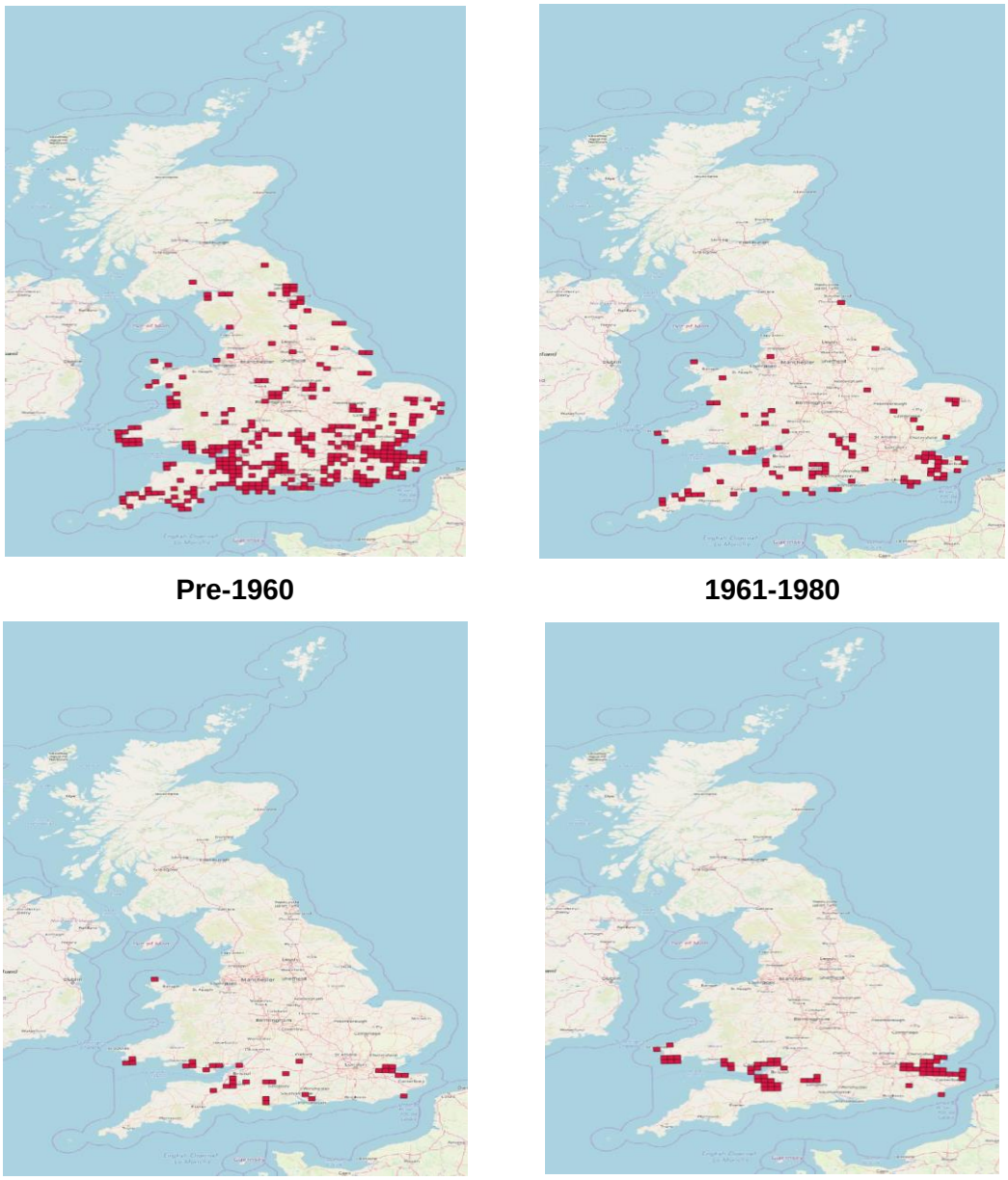


Fig.1 – Records of *B. sylvarum* in the UK demonstrating range retraction over time despite increasing recording effort. Data courtesy of BWARS (incl. iRecord records), BBCT, and NBN Atlas partners.

Current populations – distribution, abundance, genetics

Distribution

Metapopulations of *B. sylvarum* are now limited to five key areas across the UK: In England these are the Thames Estuary and Somerset; in South Wales these are the Gwent Levels, Kenfig–Port Talbot, and south Pembrokeshire.

(NB. 'Key areas' here are defined as apparently-separate populations, though these are difficult to define as the areas vary greatly, and the genetic links between population areas are not known (though see Ellis et al 2006). For the purposes of this report, where there are clear gaps in records between known population areas of >20 miles, we have defined these as separate).

It is possible a sixth population on Salisbury Plain may still remain in very low numbers, but this population is likely to have now been lost. The most recent record is more than a decade old (2008) despite bumblebee surveys being carried out in several areas of the Plain in most years, several with a specific focus on *B. sylvarum*; however substantial parts of the Plain are difficult to access - as a result it is difficult to establish presence/absence. Further surveys were undertaken in 2018 and 2019 as part of the Back from the Brink project and *B. sylvarum* was not found.

There have been observations of the Thames Estuary population starting to spread northwards up the Essex coast, and to some extent westwards towards London since 2000 (see below). A few individuals were seen in the Dungeness/Lydd/Romney Marsh area of south Kent during 2011-12, but there have been no sightings since and this area is heavily surveyed for bumblebees as part of the BBCT Short-haired Bumblebee Reintroduction and Fifth Continent Green Lanes projects.

Fig. 2

GB records of *Bombus sylvarum* 2010-19

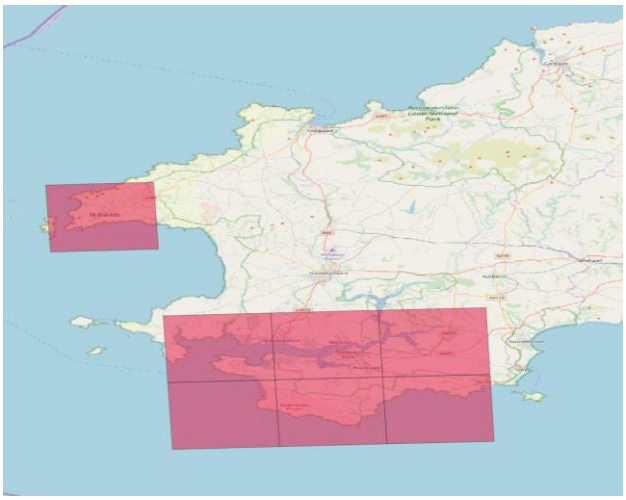
(Data from BWARS (inc. iRecord records), BBCT, BRERC, KMBRC, CCW/NRW, Kent Field Club, NT, SERC, & WWBIC)

Summary of recent distribution data:

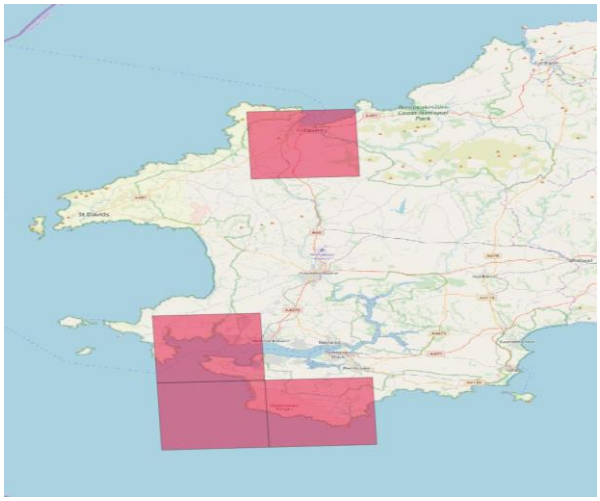
NB. Likely to reflect recorder effort to some degree. Maps represent 10km grid squares with B. sylvarum records in the given time periods, data as for the national map (Fig.2).

Pembrokeshire:

- Main population found on MOD land at Castlemartin Range east (Stack Rocks, St Govan's Head) and Castlemartin Range west (Linney and Linney head). Habitat at Linney may have declined with low numbers recorded there in 2018. *Bombus sylvarum* queen recorded near Carew Farm on Castlemartin Trail in 2012.
- Confirmed sighting at Amroth in 2017
- Confirmed records at Wyndrush Farm, Redberth in recent years
- Numerous records north of Castlemartin Range since 2012 at National Trust's Gupton Farm (low numbers), Valero Refinery (particularly around Kilpaison), and Somerton Farm.
- The area is in general relatively well-surveyed for bumblebees, but there appears to have been little recording on the MOD ranges in recent years.



Pembrokeshire 2000-2009

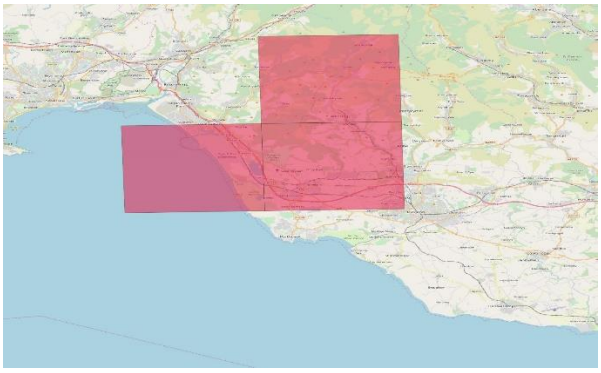


Pembrokeshire 2010-2019

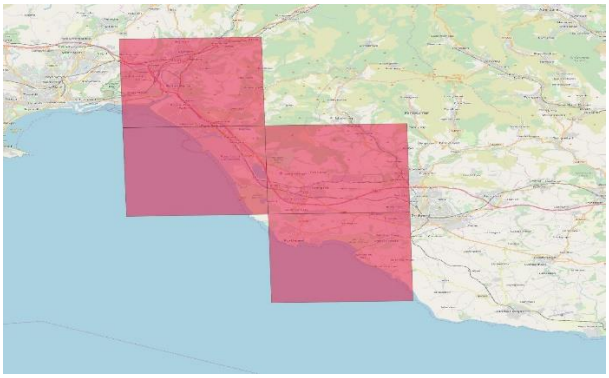
Gwent and Glamorgan:

- From 2003 to 2014 a comprehensive series of reports were commissioned by CCW/NRW, on the status of *B. sylvarum* on the Gwent Levels and surrounding areas, and at Kenfig and Port Talbot. These and other reports are summarised in Appendix 1.
- Important sites include Kenfig Burrows NNR (Bridgend), Newport Wetlands and Great Traston meadows (Gwent Levels)
- Ecological reports for the M4 Relief Road highlighted importance of brownfield land at TATA steel.
- Records north of Newport at Glebelands (E. Meloy, pers comm 2017),
- In 2016 a queen was recorded at Central Valley Nature Reserve in Ebbw Vale by Gwent Wildlife Trust staff, and later in the summer a male was recorded by BBCT staff. The site is approximately 16 miles north from nearest records on Gwent Levels, no records have been confirmed since despite some searches.

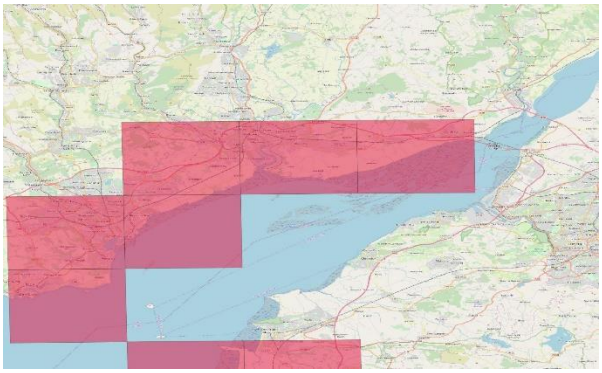
- Recorded at Dow Corning, Barry Docks, west of Cardiff by Wildlife Trust and BBCT in 2016 and 2017. Historic records at Lavernock Point near Penarth.
- The Gwent Levels SSSIs are well known as hotspots for *B. sylvarum* and the species is consequently well-recorded here on an annual basis. Kenfig is less well-recorded, but a BeeWalk transect was established at the site in 2019 and immediately recorded the species.



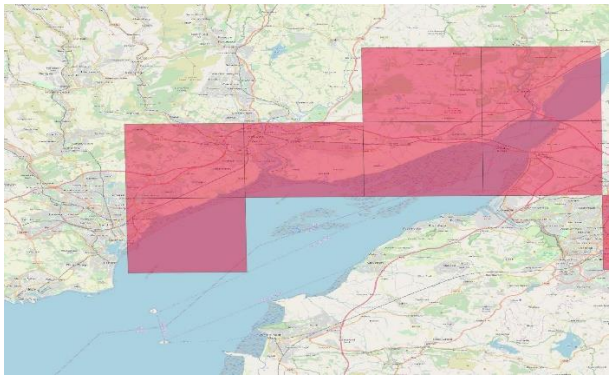
Kenfig 2000-2009



Kenfig 2010-2019



Gwent 2000-2009

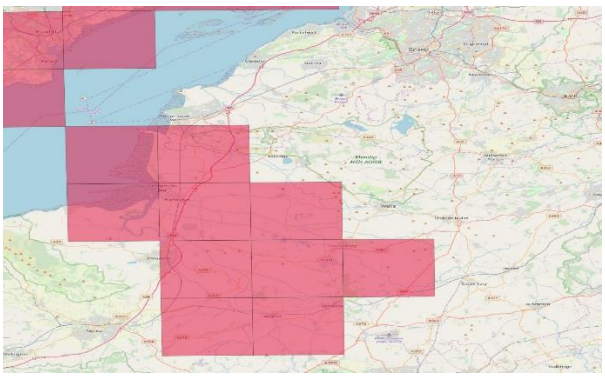


Gwent 2010-2019

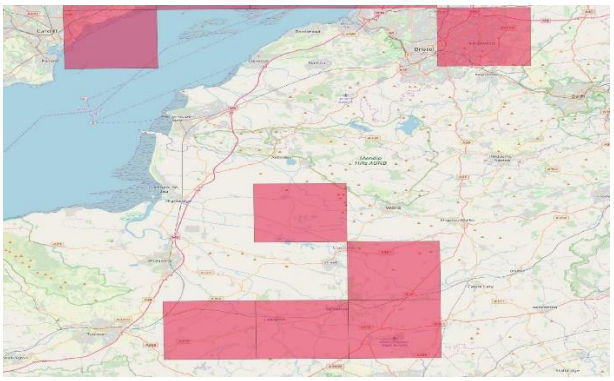
Somerset:

- The Somerset population was historically centred around the Avalon Marshes complex and RSPB Ham Wall. This population has been extensively surveyed since 2011 for BBCT's BeeWalk scheme (as well as by the Recorders of the Avalon Marshes (ROAM) volunteer group and site & BBCT staff). The species has only been found once in the area since 2013 (one record at Catcott in 2017) and it is no longer thought to be present.
- In 2012, a new population was discovered around Lytes Cary Manor, a National Trust property approx.12 miles southeast of the Avalon Marshes complex. Surveying of likely sites around the Manor has revealed a population which is relatively extensive, but which occurs at a very low population density.
- In recent years (2017 onwards) the population at Lytes Cary has been recorded in much lower numbers than in previous years. For example, 109 individuals recorded in 2016 compared to 25 in 2018.

- Sightings in south Somerset have been primarily found between Curry Rivel on the western side and Lytes Cary on the eastern side (approx. 12 mile stretch). Interestingly, many of the sightings have followed the path of the Taunton to Reading rail line leading to speculation that dispersal is aided by the rail. In 2018, a new site (Perry Bridge Farm) was discovered 4 miles northeast of Lytes Cary at East Lydford/Lovington by BBCT.
- In 2019, two new sites were discovered in the Curry Rivel area: Six workers and a queen were recorded on the eastern edge of West Sedgemoor (Somerset Shrill Carder Group), and Patrick Saunders recorded *B. sylvarum* (5 workers and 7 males) on the outskirts of Muchelney (east of Curry Rivel) whilst carrying out targeted Shrill carder bee surveys in Somerset for BBCT.
- Other previously known sites for *B. sylvarum* have not had any individuals recorded for several years. For example Green Down, a nature reserve owned by Somerset Wildlife Trust northwest of Lytes Cary (and the original reintroduction site of the large blue butterfly), where Shrill carder bee was last recorded in 2017 despite several more recent surveys.
- Surveys by the Somerset Shrill Carder Group (SSCG) have been taking place since 2014 in areas of known floral resources, although these are primarily in areas where access is freely available such as nature reserves and where landowners have actively engaged with the group. Surveying has also been undertaken by BBCT, particularly since the start of the Back from the Brink Shrill carder bee project in 2017 which has seen a more coordinated approach along with the SSCG and more private land searches following the interest of farmers getting involved with the project. It appears that the Somerset population covers a large area, but exists at a very low population density. Intensive, repeated surveying is often required to confirm presence at each site, and some sites have individuals recorded at a rate of one every few years despite annual surveying. This would explain why records are made in various different locations each year; it does not however, explain the recent and serious reductions in numbers at Lytes Cary Manor, that has received similar surveying effort since it began in 2014.



Somerset 2000-2009



Somerset 2010-2019

Thames Estuary (Essex):

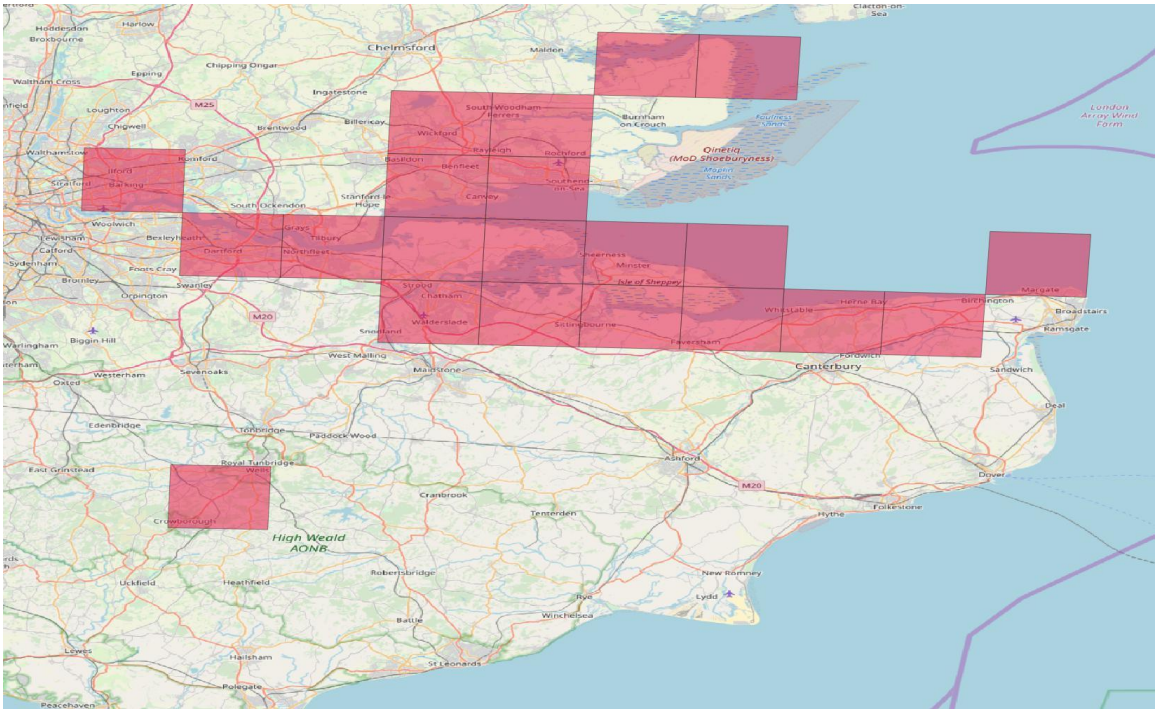
- Important sites include Canvey Wick, Rainham Marshes, Hadleigh Park and East Tilbury Silt Lagoons.
- Since 2000, range extensions have been documented along the Essex coast: *B. sylvarum* recorded at MOD Foulness (2011), Dengie peninsula (2009), Tollesbury Wick (2007) and as far as Mersea Island / East Mersea in 2010 – a shift in range of approx. 30km (Benton

et al 2012). It is suggested this range expansion has been heavily dependent on sea wall habitat (Benton pers comm - in Gardiner 2012) which can act both as a forage source and/or as a leading line for dispersing individuals (Stuart Connop, pers. comm.).

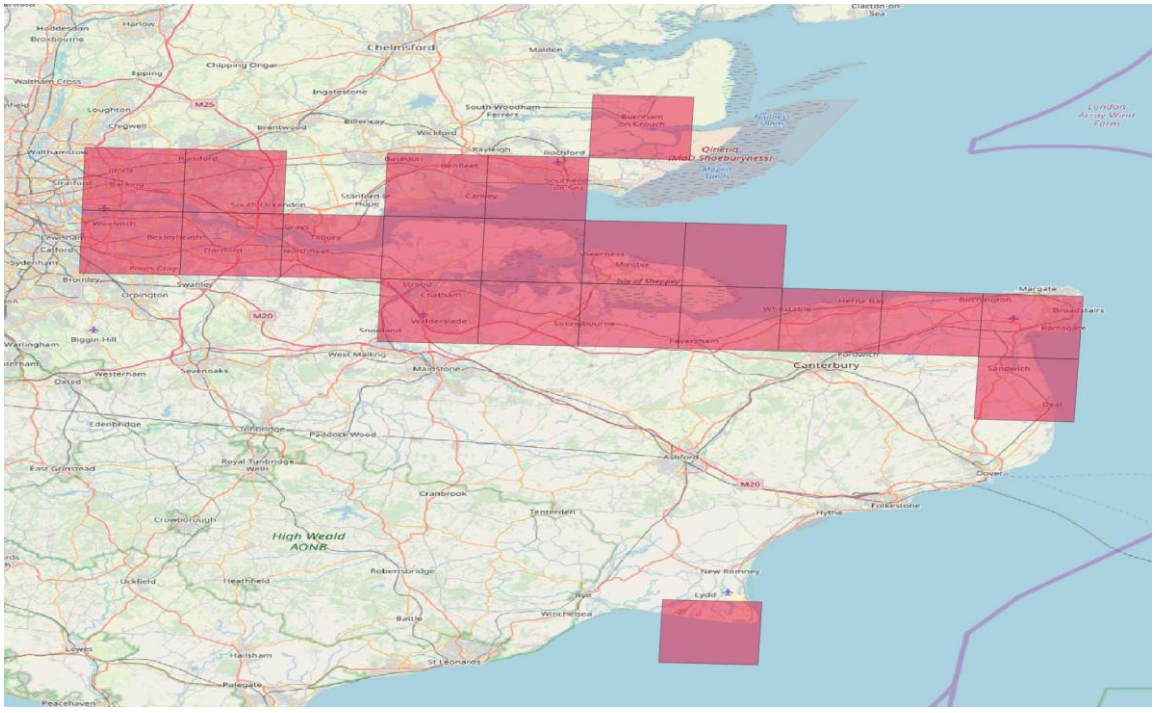
- Range extensions have also occurred westwards towards London, (see http://www.essexfieldclub.org.uk/portal/p/Species+Account/s/Bombus+sylvarum). However, these seem to be experiencing only limited success: an individual was observed at Barking Riverside in 2012 but none were found in subsequent years, and the remnant population at Thames Barrier Park appears to be no longer present, nor has *B.sylvarum* been observed on neighbouring brownfield sites around the royal docks (Stuart Connop, pers. comm).
- The area is well-surveyed for bumblebees and has been the subject of considerable recording effort through the Back from the Brink project in recent years

Thames Estuary (Kent):

- Important sites include RSPB Cliffe Pools and RSPB Northward Hill (Hoo peninsula), plus multiple sites along the north Kent coast from Dartford (Long Reach Sewage Treatment Works) to Seasalter. Records from 2018/19 suggest *B. sylvarum* is widespread in the Sittingbourne area (e.g. South Swale NNR, Milton Creek Country Park) and Isle of Sheppey (e.g. Leysdown Coastal Park, coast between Sheerness and Minster) (Rosie Earwaker pers comm).
- Further west, there have been consistent sightings of *B. sylvarum* between 2012- 2019 at Crossness Nature Reserve (Thames Water) / Erith Marshes in the London Borough of Bexley since the species was first recorded there in 2012.
- *B. sylvarum* worker recorded at RSPB Seasalter near Whitstable in 2015. During the BWG surveys, this was the most easterly reliable location for the species (Mike Edwards pers comm). There have been recent records (2014-2019) 12 miles further east at Reculver (Geoff Allen pers comm; Bex Cartwright pers comm), which represents the eastern-most extent of the main North Kent population. This cluster of records is 10km from the nearest records to the west in South Swale and Seasalter levels/Graveney Marshes, and is separated by the heavily built-up areas of Whitstable and Herne Bay.
- Important new populations of *B.sylvarum* have been discovered in 2018 and 2019. In 2018, the species was recorded at a Woodland Trust arable reversion site (Victory Wood) 2km south of Seasalter levels and just south of A299, and also at adjacent Ellenden Farm and Wildlife Trust managed nature reserve (Wraik Hill). Subsequent surveys have revealed a significant population with spring queens foraging in gardens adjacent to the sites and an impressive count of 121 individuals on one day's surveying at Victory Wood in August 2019.
- Two records from Sandwich Bay area in East Kent 2009-2013 (Geoff Allen pers comm) including one suspected diploid male (Nikki Gammans pers comm), suggesting a small remnant but likely inbred population. The most recent accepted record from this area is from 2017 - a spring queen foraging in the garden at Sandwich Bay Bird Observatory on 29/4/19 (which was seen on two subsequent days, presumably the same individual).
- In 2005, two workers recorded at North Foreland/Foreness Point in Margate (11 miles north of Sandwich Bay), however this site has been surveyed by BBCT multiple times in last few years, with no subsequent sightings.
- The area is well-surveyed for bumblebees and has been the subject of considerable recording effort through the Back from the Brink project in recent years
- In south Kent, there were sightings at Dungeness in 2010-12 but not since, despite frequent and extensive bumblebee surveying in the area.



Thames Estuary 2000-2009



Thames Estuary 2010-2019

Abundance

In general, there is reasonably good distribution data for the Shrill Carder bee, although the comparatively frequent discovery of new populations and reappearance of old ones suggests that the species may be easily overlooked in a landscape if not searched for specifically. The BeeWalk records for this species were analysed using a log-linear model applied to monthly sighting rates (bees per kilometre walked). The overall (2010-18) population trend for the species at BeeWalk-monitored sites was positive, though variation is high. Ad hoc surveys and observations are indicating there are decreases on some sites e.g. RSPB Great Bells, Isle of Sheppey (Gomes, 2015).

Estimates of population sizes and trends of bumblebees over the shorter term can be achieved through the BBCT-run BeeWalk bumblebee monitoring scheme (www.beewalk.org.uk). This is based around the idea of repeated monthly transects, with all bumblebees seen within a 4m x 4m x 2m 'recording box' counted and identified to species (or to *Bombus* sp. where the exact ID is unclear). Several transects have been set up in or around areas where the Shrill Carder has been found, and the bee has been seen on 29 of these to date. Most notably, several transects in Kent/Essex and Somerset have had repeat sightings of the species. Unfortunately, the Welsh populations are not well represented (one record each from the Gwent Levels and Pembrokeshire populations, none (no transects) from Kenfig. There are 276 sightings of the species in total in the BeeWalk database. The BeeWalk data can also be used to construct a phenology for the species, which demonstrates the species' late-summer peak (Fig.4). However, caution needs to be taken when deriving trends from the current BeeWalk data due to the small number of transects, low densities being recorded and high variation.

BeeWalk transects may not always pick up this species especially in areas where its populations are low density, but sustainable, due to the large area of suitable habitat, especially where this is comprised of ditches within otherwise fairly extensively, managed habitat, for example. Such populations may require very long and frequent transects, taking in several km of suitable habitat (e.g. ditch edges), to be adequately surveyed. This species may also be difficult for new bumblebee surveyors as it requires a very targeted search image. It may be appropriate to combine BeeWalk transects with additional non-transect surveying across a site, particularly targeting areas with preferred forage plant species in areas with known populations of rare bumblebees such as *B. sylvarum*. This could take the form of timed searches: for example a standardised timed search method is used to monitor bumblebee populations in the US Pacific North West region (Strange et al, 2013). This combined approach could be used to monitor other Section 41 (England) /Section 7 (Wales) *Bombus* species.

Knowledge Gap:
More BeeWalk data is needed from transects across metapopulation areas to reliably assess and monitor populations. Different approaches (e.g. more intensive surveying, longer/more frequent transects/timed counts) may be needed for lower density populations scattered over large areas. There is also a lack of data regarding queen and/or reproductive nest abundance so there is a need to undertake specific surveys to monitor this.

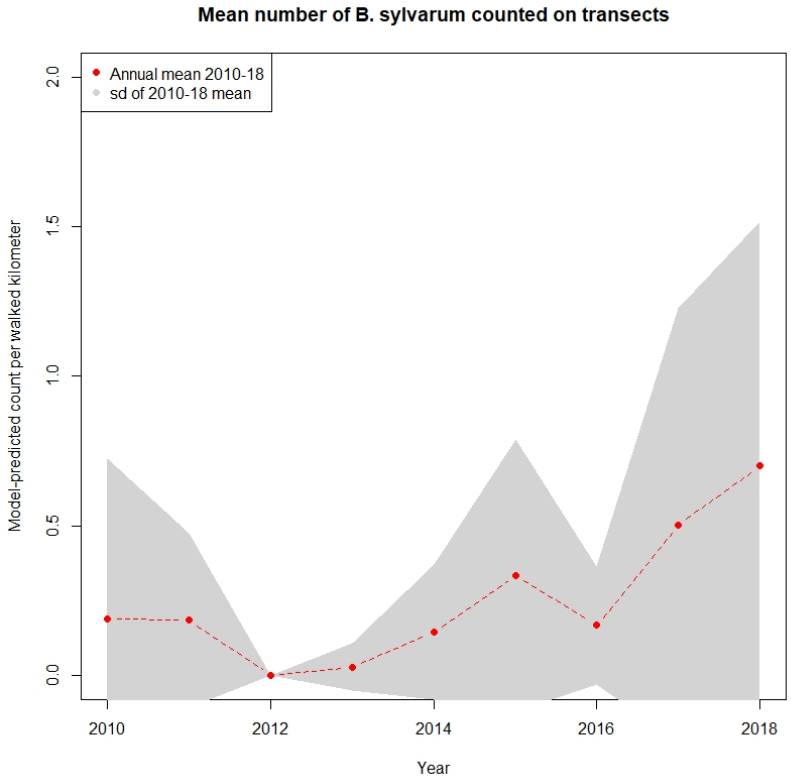


Fig.3 Abundance trends for *Bombus sylvarum* 2010-18, shown as the mean number of bumblebees counted per kilometre walked each year across transects where the species has ever been recorded (red line). The grey cloud is a measure of variability around the mean (standard deviation).

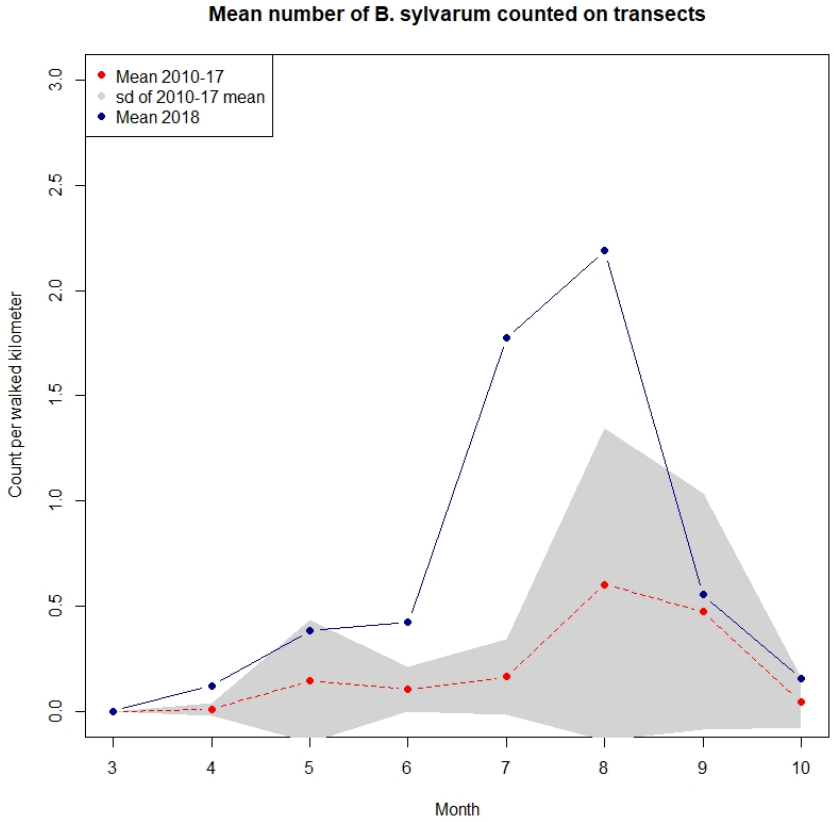


Fig.4 The mean number of *Bombus sylvarum* per kilometre per month between March and October 2018 (blue line), plotted against the average monthly abundance for the seven-year period 2010-17 (red line). The grey cloud indicates the variability of the 2010-17 average (standard deviation).

Variation, genetics and viable population size

Bombus sylvarum populations in the UK are isolated and found in very fragmented habitats. As a result, they are vulnerable to loss of genetic variation. A genetic study was carried out in 2003-4 at five UK sites (Castlemartin, Margam Moors, Ham Wall, Salisbury Plain, and Cliffe Pools; Ellis *et al.* (2006) found that effective population sizes of *B. sylvarum* were extremely low. The study estimated effective population sizes to be 21-72 nests, with a UK average of 55.2 (±5.58); these figures were stated as likely to be over-estimates in most populations (Ellis et al, 2006), although there has been subsequent debate of how effective the sampling method used for the paper was at capturing all genetic diversity within each population. The study did not include the large Gwent Levels population.

There is debate regarding minimum viable population size but, in general, populations of less than 50 nests are expected to quickly become inviable through inbreeding and even populations of up to 500 will be vulnerable to loss of genetic diversity through drift (Ellis et al, 2006). The study found significant population structuring, indicating isolated populations and thus ideal conditions for inbreeding depression, and one population (Castlemartin) showed signs of having passed through a recent genetic bottleneck. This was backed up by the finding of a diploid male at Castlemartin (Ellis et al, 2006). A suspected diploid male *B.sylvarum* was also discovered at Lydden in East Kent in 2010 (N. Gammans pers obs). Diploid male production in bumblebees can be an indicator of severe inbreeding and results in sterile or inviable offspring, significantly reducing colony fitness (Whitehorn et al, 2009). This can lead to increased extinction risk resulting from a 'diploid male extinction vortex' (Zayed and Packer, 2005).

The Bumblebee Working Group estimated bumblebee nesting densities at 1-2 successful reproductive nests per km^2, with some variation between species (BWG 1998) and that individual populations require a minimum of 10-20 km^2 of good matrix habitat to be viable (BWG 1998, 2000).

Melanic variation

Bombus sylvarum is a distinctive bee which can be identified by its pale grey-yellow colouring, black band of hair between the wings and reddish-orange tail. Most specimens found within the UK have a greyish/green tint to the hair, however the dark form *f. nigrescens* was recorded several times in Sussex (Mortimer, 1922). More recently, darker specimens have been found in 2011 at Dungeness (BWARS - N Gammans pers. comm) and at Deal (BWARS - RL Evans & ED Moss, pers. comm).

Knowledge Gap:
More genetic studies are needed for this species' conservation. Results would provide a better understanding of bottlenecks present in the UK and the relatedness between populations (e.g. Gwent and Somerset populations). Genetic analysis can also inform other key factors such as foraging and dispersal distances.

Population viability and understanding conservation success

To enable the long-term conservation of *Bombus sylvarum* it is important to be able to define when conservation success has been achieved. Currently, there is no clear method for attempting to define or record when a viable population has been achieved. Existing BeeWalks would not

provide sufficient information to do this and therefore a combination of other monitoring techniques need to be employed. It is suggested that a combination of spring queen monitoring, evidence of occupancy expansion (via regular monitoring), as well improved understanding of habitat as a proxy and genetic viability of populations; could be used to define viability. Monitoring of nest sites would be valuable too but these are difficult to find.

By far the most effective method of establishing population viability is direct monitoring through genetic methods, although this is expensive and can be difficult to implement. Monitoring of abundance (outlined under section b), especially if individuals can be identified to caste, can provide a useful adjunct to this, though it should be noted that there is no guarantee that a spring queen equates to a successful colony at the end of summer! It can be generally assumed that a population becomes more viable as it increases in size, so increased population viability can be inferred from evidence of expansion in a population from a baseline of population monitoring, using thorough repeated monitoring coverage to pick up expansions and retractions. A strategic implementation of BeeWalk could help to achieve this.

Analysing genetic viability is also important so that the general health of Shrill carder bee populations can be understood. This would not be as a regular as other monitoring but could be used intermittently to complement it. Finally, the integration of habitat monitoring could eventually be used as a proxy, therefore data should be collected at the same time as other monitoring methods, so that an evidence base is built (e.g. creation/presence of certain habitats types and features will increase *B. sylvarum* success).

Species ecology

Phenology and colony size:

Bombus sylvarum is one of the last species of bumblebee to emerge from hibernation in the UK (Williams, 1989; BWG, 1998), with new colonies being established by a single queen usually in late May (although in some years there are sightings in April). Workers from the colony can be seen from June to September and sometimes October, and males and daughter queens appear from late August. Overwintering for queens begins in late September/October.

Phenology varies across the range in the UK, with slightly later emergence and nest establishment in western populations, e.g. queens emerging in late May or June in Pembrokeshire. Emergence times also vary annually, for example *B. sylvarum* was recorded in Somerset as early as 11th April in 2017. Following this, no workers were recorded after late August (Somerset Shrill Carder Group pers. comm., 2017). Similarly, in years when the species emerges later, colonies seem to be "late" to finish as well, with workers active well into mid-September (Matt Smith pers comm, Gwent Levels) and early-mid October (Sam Page pers. obs. North Kent). Generally, compared to most other bumblebee species, *B. sylvarum* is a 'late-peaking' bumblebee species, similar to *B. humilis.*

Colonies are small compared to other bumblebee species with on average 40 – 70 workers (Sladen, 1912). Other references confirm there are usually less than 100 workers per nest (F. Smith, 1868; Hasselrot,1962; Alford, 1975) (In: Philp & Edwards 2001).

Forage:

Bombus sylvarum appears to have wide dietary breadth of forage species that it utilises overall, see references below, but with a narrow dietary breadth at a given time of year and depending on the forage available on a particular site - which can be limited by issues such as meadow cutting (reducing late forage) and invasive species (e.g. Thames Estuary, Goats-rue invasion). It should be noted that marked differences in behaviour are displayed between different populations as regards use of forage. In terms of forage preference the families Fabaceae, Lamiaceae, Orobanchaceae and Asteraceae are all important, however there a big differences between locations and over time (and between plants utilised for pollen vs nectar collection). A matrix chart of forage in relation to the key areas and the life-cycle stage (timing) could be useful to inform conservation and wider work to ensure spatial and temporal variation in forage is accounted for.

Dietary breadth:

Dietary breadth and preference can be expected to vary across the global distribution range as a function of the interaction of foraging profitability of different plants in different climates (Williams, 1985, 2005; Williams et al 2007). There are differing accounts of *B.* sylvarum dietary breadth. Forage preferences will vary dependent on the plant species available at a given site and at a given time. Dietary breadth should take account of the number of flower-visit observations and dietary preference may be understood as not just which plants are visited most, but more interestingly, which plants are visited more frequently than would be expected given their different abundances (Williams 1989, 2005).

B. sylvarum is a longer tongued species, queen tongue length is 10.6mm and workers is 8.8mm on average. Goulson and Hanley (2005) suggest that *B. sylvarum* has a broad dietary breadth, while Connop (2007) indicated that of all of the bumblebee species observed, *B. sylvarum* had the lowest dietary breadth. An explanation for why this might vary in different areas was suggested by Williams (2005) which suggests that the further a species is from its climatic optima, the more pristine its habitat needs to be for it to persist. This statement was reiterated by Connop *et al.* (2010b) stating that *B. sylvarum* has a relatively narrow dietary breadth when compared to *B. humilis* and *B. pascuorum*. In this study in South Essex, over half of the pollen collected (from 30 samples from *B. sylvarum* workers) was from Red Bartsia *Odontites vernus*. Narrow-leaved Bird's-foot Trefoil *Lotus tenuis* was the second most commonly collected pollen, making up over a quarter of the pollen collected. Smith (2013) provides pie charts to summarise forage visits for *B. sylvarum* workers and males in the Gwent Levels, and those charts indicate a wide variety of forage resources utilised, particularly by workers. Workers were seen visiting 25 species of plant, and collecting pollen from seven of these, and males were recorded on 16 plant species (Smith, 2013).

Forage preference:

Bumblebees are known to show food-plant preferences, including as a response to changing relative profitability among forage options. However, these preferences may not necessarily be related to or solely responsible for bumblebee population declines (Williams, 2005). Local experiences indicate preferences vary considerably from site to site, and region to region, as well as temporally. In south Essex, Connop (2007) presented forage preference in relation to other

Bombus species foraging rather than in relation to total available flora, and found that the most frequently visited plants were Red Bartsia and Black Horehound (for queens Black Horehound and Broad-leaved Everlasting Pea), whereas Black Horehound is uncommon in Wales for example. As with many other species of bumblebee, the Fabaceae is a particularly important family (ACG report, 2004) (Table 1). Fabaceae and Lamiaceae are the most frequently visited plant families in Connop (2007). The Scrophulariaceae (which included Red Bartsia at the time of this study, since transferred to Orobanchacaea family) and Asteraceae families were also found to be important in the Aculeate Conservation Group pollen load analysis (ACG report, 2004) (Table 1).

Table 1 – Pollen analysis by plant family for *Bombus sylvarum* (n=153) using amalgamated data for the analysis of pollen loads carried by bumblebees from 1998-2004. (ACG report, 2004)

Fabaceae %	Scrophulariaceae %	Asteraceae %	Lamiaceae %	Boraginaceae %
62.7 (96)	30.7 (47)	15.0 (23)	10.5 (16)	5.2 (8)

Smith (2010) found *B. sylvarum* workers to display similar preference in Wales with 60% of individuals recorded foraging on Fabaceae (including Narrow-leaved Everlasting Pea, Tufted Vetch and Common Bird's-foot Trefoil), a further 17% were found on knapweed (Asteraceae). Connop (2007) suggests that Red Clover may not be a particularly important forage source for *B. sylvarum* compared to its importance for other bumblebee species when other sources of forage such as Red Bartsia and Narrow-leaved Bird's-foot Trefoil are available, although in 2008 he noted this plant was of importance to queens (Connop 2008). During sea wall surveys in Essex over the last 10 years, 27% *B. sylvarum* records were recorded on red clover (Tim Gardiner, pers comm). Tufted vetch *Vicia cracca* has been noted as an important forage resource on Salisbury Plain (S. Roberts, pers comm).

Red Bartsia (*Odontites vernus*) is known to be a key forage species for *Bombus sylvarum* (BWG, 1998). Harvey (1998) suggests that Red Bartsia appears to be the most important forage plant for *B. sylvarum* in south Essex in August (also Jamie Robins, pers comm). Connop, et al (2010) found majority of pollen collected by *B.sylvarum* was from Red Bartsia. This preference has also been noted in Somerset, particularly at Lytes Cary Manor (Somerset Shrill Carder Group, 2017) and at Kenfig (Stewart and Roberts, 2014). Stewart and Roberts (2014) note that the average height of foraging for *B. sylvarum* was 21-30cm which coincides with the height of Red Bartsia. Further to this, Harvey (1998) notes that *B. sylvarum* seems to prefer flying at the height of Red Bartsia even when there is neighbouring taller vegetation.

Conversely, a BWG survey by Peter Harvey in 1999 found a large presence of *B. sylvarum* at two sites (Canvey Wick and East Tilbury Silt Lagoons) where the main worker forage was Narrow-leaved Bird's-foot Trefoil *Lotus tenuis*, and Red Bartsia was absent from both. In the Thames Estuary, Narrow-leaved Bird's-foot Trefoil is a key forage plant for Shrill carder bee, especially on sea walls. Similar to Red Bartsia, this species also likes disturbed ground. Benton found large numbers of *B. sylvarum* on *Lotus tenuis* in Sept 2007 at Tollesbury Wick in Essex, and 46% *B.sylvarum* were on *L.tenuis* during sea wall surveys in Essex (Gardiner, pers comm). Similar results were found during sea walls surveys in North Kent, with 41-57% *B. sylvarum* on *L.tenuis* (Page, 2015). At RSPB Cliffe Pools, 152 workers were recorded on *L.tenuis* in August during timed transect and forage patch counts, and 35 workers plus 1 male in September (Gomes, 2012); this matches BWG findings at the same site in the late 1990s (S Roberts, pers comm). Bombus

sylvarum, including queens, have been noted foraging on Broad-leaved everlasting pea *Lathyrus latifolius* at Canvey (S. Falk pers comm; S. Connop pers comm).

On the Hoo Peninsula in Kent, Asteraceae species such as Bristly Oxtongue and Hawkweed Oxtongue were found to be frequently used by workers and males in late summer (e.g. 18% on Bristly Oxtongue, n=60, S. Page, sea wall surveys 2013-2015; 33 workers and 2 males on Hawkweed Oxtongue at RSPB Cliffe Pools, Gomes 2012). *Bombus sylvarum* also regularly visits Sea Aster at Canvey (Matt Smith, pers comm). At Canvey workers have been recorded on Oxtongues and other *asteraceae* species including hawkbits and Catsear *Hypochaeris radicata*, on Creeping thistle *Cirsium arvense* at Wallasea, and on Bristly oxtongue *Helminthotheca echioides* at Rainham (S. Falk, pers comm). In the Gwent Levels it was noted that ruderal plants were particularly important, especially stands of Creeping thistle *Cirsium arvense* (Pavett, 2004).

Yellow Flag Iris has seen to be important on wetland Welsh sites for queens (Mike Edwards pers comm), also White Deadnettle and Comfrey have been observed to be important for queens on other sites. Queens have been recorded foraging on White dead nettle *Lamium album* at Leysdown, and numerous workers on Betony *Stachys officianalis* at Castlemartin Range (Steven Falk, pers comm.) A forage usage table is being compiled in Appendix 2 (by no means complete).

Knowledge Gap: Queen forage breadth and preferences particularly in terms of pollen collection and early forage needs, and so further research is needed on queen forage. Also forage resource relative to needs over time, as well as space, needs mapping and monitoring for key sites and simple vegetation assessment defining.

Nesting:

Generally nests have been found on the surface or just below ground, and are associated with rough long grass that have a litter layer. However, there is still little data and varying descriptions of *B. sylvarum* nest sites, despite many searches. Currently only broad habitat types with a suite of microhabitat features can be used to ensure that nesting habitat is present. More research is needed to better understand Shrill carder bee nesting preferences.

Of those found, descriptions are provided below:

According to Sladen (1912) ““*The nest is usually on the surface of the ground, but I have often found it under the ground with a short tunnel*”. Nesting has also been suggested to take place slightly under the surface of the ground with a dead leaf layer for carding material (BWG, 1998). Whilst a nest was discovered at Castlemartin on top of the ground in the middle of tussock grassland (BWG, 2000).

- Paul Williams (1985) found two nests in subsequent years at Dungeness, Kent underground inside on banks covered predominately by grass. In one of these nests, a queen of *B. jonellus* and a queen of *B. muscorum* were found dead (Williams, 1989).

- A nest studied by Claire Carvell (2000) in Castlemartin Range, Pembrokeshire: Main part of nest (thick clump of mosses, probably an old mouse nest) 8cm below the grass ‘surface’ but not below ground, in fairly open, flower-rich mesotrophic grassland, slightly south-facing and exposed to sunlight for majority of day, bare soil visible, entrance hole at side with tunnel through the grass (route taken by house bees clearing material from nest) - photos and diagram below (Carvell, 2000).

- Two nests were located in the Newport Wetlands reserve through surveys in 2009 (photo below) and 2012, both nests were underground and in areas of rough, coarse grassland (Smith, 2013).

***Bombus sylvarum* nest site, Newport Wetlands (Photo: Matt Smith, 2009)**

- A nest was found by Rosie Earwaker at Cliffe Pools, Kent in August 2017 (photos below). This was on a south-facing bank in rough, tussocky grassland next to a patch of Black Horehound (where workers were observed to be foraging). The nest site was excavated in late October 2017, but no nest could be located despite extensive excavation of the area. A single, dead queen *B. sylvarum* was found ~20cm underground, but towards the northern side of the bank, suggesting this may have been an overwintering site (Rosie Earwaker, pers. comm.) although this is not known. The excavated site consisted mainly of rubble (such as broken paving slabs and other waste material).

***Bombus sylvarum* nest site (left) and location of nest entrance (right), Cliffe Pools (Photo: Rosie Earwaker, 2017)**

- Several nests have been found at Coalhouse Fort, Essex. One situated in unimproved grassland, near a seasonally wet area with abundant Sea Aster; a further two nests were found in unimproved, tussocky grassland (Ray Reeves, via Rosie Earwaker pers comm).

- Reported sightings at Kenfig NNR and Newport Wetlands NNR in recent years (both provided with annotated photographs) show dense scrubby marginal habitat consisting of bramble and climbing legumes as well as tussocky grass.

- *Thoracobombus*, or carder bumblebees, need leaf litter and moss to build the covering of the nest. From personal observations in Germany the queens also seem to weave dead grasses to make the first stages of their nests, as well as using old summer nests of small mammals. Observations concluded the importance of permanent, relatively low-management, grassland - but not tall and tussocky as the sun needs to get to the base of the vegetation. (M.Edwards, pers comm).

- In Ireland, a site that Mark Brown sampled in The Burren in 2004 had abundant workers and nests were obviously underground. The Burren is a Karst landscape, and after foraging workers flew into holes between surface rocks, presumably to their nests as workers flew out from these sites without pollen bags (Mark Brown, pers comm).

- *Bombus sylvarum* has been reported to nest underground in Iran (Alireza Monfared in Williams and Jepsen 2015).

Knowledge Gap: is still significant regarding nesting preferences of this species, particularly in relation to specific attributes, for example litter vs no litter, and the role of certain sites e.g. ditches and sea walls, the avoidance of flooding etc.

Hibernation:

Hibernation sites suggested as under mosses in the open (BWG, 1998). The use of rank grassland and old small mammal burrows has also been suggested (Howe and Haycock, 2007). More knowledge is required to fully understand the preferences of *B. sylvarum* in choosing its hibernation sites. It is suggested that these will not be on south-facing sites, especially as it is one of the last species for queen emergence in the spring (Mike Edwards pers comm). In the Karstic lakes of Slovenia, the species has been found to overwinter in the drier, higher areas and then forage in the lower wetlands (M Edwards pers comm).

Knowledge Gap: more information needed on hibernation sites.

Broad habitat usage:

Bombus sylvarum has been observed predominantly in open areas, often tall grasslands (Wiilliams, 1988; BWG, 1998; Svensson *et al.*, 2000) both acid and damp, with a scruffy element to them, plus a litter layer and varied forage. They have been found to be associated with a variety of open, flower-rich habitats including but not exclusive to: traditionally managed hay meadows and pastures, chalk downland, sand dunes, brownfield sites, field ditches, coastal and floodplain grazing marsh, sea walls and saltmarsh edges (Williams 1988). Particularly utilising grassland and wetland sites that are late flowering (Mike Edwards pers comm). There is a need for nesting habitats to be close to flower-rich areas for forage. Given the variety of habitats used by this species, there is still a lack of understanding of their relative importance. There is also a need to understand the microhabitats in these sites and their relative importance to *Bombus sylvarum*. Key *B.sylvarum* sites do not necessarily represent the most botanically or otherwise ecologically interesting sites, and may be overlooked. For example the overgrazed horse pastures supporting Red bartsia (e.g. around Kenfig) and 'weedy' brownfield or grassland/sea wall sites.

Smith (2011) noted that on the Gwent levels *B. sylvarum* was primarily found near to the ditches and reens which, for the purpose of safety, are fenced off to livestock. The alleviation of grazing pressure and a lack of ability to be cut results in favoured plant species being able to go to flower. This suggests, as Smith (2011) states, that should other areas outside of the levels also be managed in a similar fashion and the availability of forage improved, the area would hold more potential for *B. sylvarum* to expand into.

On the Somerset levels, their persistence has been suggested to be associated with the long tradition of peat digging, particularly by hand (BWG, 2000; Julie Merritt, pers. comms.). The disturbance caused is associated with the maintenance of ruderal habitats which is in agreement of Pavett (2004) who found workers on primarily ruderal associated species and the BWG 1998 report that states that "they are often associated with early successional habitat of disturbed grassland to scrub". Many of the preferred food plants for *B.sylvarum* are early-succession ruderals or opportunists which benefit from disturbance. In the Thames Estuary, disturbance due to new sea-wall works resulted in a big upsurge of clovers (Red and Sea) and Narrow-leaved Bird's-foot Trefoil and an associated upsurge in *B. sylvarum* for several years during the time of the BWG surveys (Mike Edwards, pers. comm.). it is worth exploring whether recent population declines in the Somerset Levels and Salisbury Plain may be due to the loss of disturbance and succession to longer rank grassland (Richard Comont, pers. comm.).

In areas where *B. sylvarum* was found in Essex during surveys in August, Harvey (1998) noted that the most important habitat features seemed to be "tall very flower-rich herbage, with abundant Red Bartsia and evidence of previous abundance of clovers and other species such as *Lotus* together with the vicinity of scrub". On Thames Estuary brownfield sites forage usage alters due to invasive plants Goat's Rue and Alexanders. At RSPB Cliffe Pools where *B. sylvarum* is present in good numbers, there is a mosaic of brownfield, this is an early successional habitat, with flower-rich wet grasslands (managed for breeding waders but with rotational or light grazing to allow flowering), scrub and sea wall habitat. Peter Harvey (2015) observes that large patches of flowers are used more frequently and are much more important than widely distributed floral resources for *B.sylvarum*. While Connop agrees *B.sylvarum* is more frequently observed on large flower patches, he argues it is hard to conclude whether or not this is because they are easier to find on these patches as it concentrates numbers (S Connop pers comm).

Newport Wetlands reserve in the Gwent Levels contains significant stretches of wide flower rich verges around wetland and reedbed habitat across the reserve. The site benefits from very low nutrient soils due to the creation of the reserve on PFA deposits from Uskmouth power station. Reserve staff (NRW) who are very familiar with *B. sylvarum* habitat needs are clearing sheltered areas to create wet meadows which are cut every other year in October to encourage ruderal and tall grassland habitat.

On the Castlemartin peninsula in Pembrokeshire, *B. sylvarum* is known to occur on the extensive flower-rich grasslands of the MOD's Castlemartin Range. Although in recent years concerns have been raised that a lack of grazing in some areas is resulting in the reduction in quality of grassland habitat, and in addition the dry rank grassland is at greater risk of fire spreading and damaging habitat. In recent years, records have been found at industrial sites to the north of Castlemartin range at Valero refinery, the records have occurred on varied habitats across the site which can be characterised as a mosaic of scrub, wet grassland, tall dry grassland, bare ground, ruderal, ditches and banks.

Monitoring of Countryside Stewardship field margins by Mike Edwards, has recorded only of two farms where a non-*pascuorum* Thoracobombus species (*B. humilis/B. ruderarius*) used such

margins. On both farms there were considerable sections of permanent flower-rich grassland, cut only in late summer/autumn. However, Ted Benton has recorded rare carder species foraging in pollen and nectar margins close to sea wall habitat in Essex (e.g. Dengie peninsula) (S Page pers comm) and *B.sylvarum* has been recorded foraging on Countryside Sterwardship field margins as well as pollen and nectar strips in Somerset (Henry Lang farm) (Daisy Headley, pers. comm.).

Mobility – forage and dispersal distances:

It is suspected that *B. sylvarum* has a low dispersal distance in comparison to common species of bumblebee, therefore a precautionary approach should be taken when accounting for dispersal (S Connop pers comm); although other Thoracobombus are known for long range dispersal. Generally it is questionable whether bumblebees are able to disperse long distances through habitat that is severely unsuitable for them (Williams et al, 2017).

Connop *et al.* (2010a) suggest that *B. sylvarum* workers have a minimum average forage distance of 231m from the nest, when compared with *B. humilis*. The maximum foraging distance was 2280m, while the majority of workers foraged from the same forage patches or those less than 1km apart. The study found that sisters from the same nest were more likely to be found foraging from the same patch, which suggests that they are more vulnerable to forage loss. Osborne *et al.* (2008) described them as 'door-step' foragers, due to their tendency to fly only a few 100m away from the nest. However, forage distance is likely to be locality-specific and vary considerably between different types of sites and populations (Charman et al, 2010). Proximity to the climatic optima may be a factor in foraging behaviour (Williams, 2005), and therefore may explain differences in foraging behaviour between different populations. Based on Greenleaf 2007, which provided a formula to calculate a maximum foraging distance based on body size, these are 6.78km for queens and 2.1km for workers (Stuart Roberts pers comm).

A recent molecular study of the Tree bumblebee *Bombus hypnorum* suggests that short worker foraging distances (103.6m) coupled with high nest densities (which vary greatly from year to year) are associated with its rapid range expansion in the UK (Crowther et al, 2019). The authors state that low foraging distances are not an autoecological characteristic - but rather indicate that workers in the study population are able to forage more profitably at shorter forage distances (but are capable of foraging at much longer distances).

Connop (2007) hypothesises that one potential reason for the *B. sylvarum* population in south Essex being largely coastal could be due to the coast and other large water bodies acting as leading lines for dispersal. Benton suggests that the sea walls in Essex provide an important dispersal corridor for *B. sylvarum* along the coast (Gardiner 2012). However, it may also simply be a reflection of the restriction of the habitat resource in this area (Mike Edwards pers. comm.) and further study is needed.

Barriers such as roads may not be a big issue for this species, a mark recapture study at Roscommon Way (Connop, 2013) showed that individuals will cross over roads, and *Bombus terrestris* have appeared to cross over estuaries (Stuart Connop pers. comm.). *Bombus sylvarum* was one of the species under-represented in road kills on Dungeness relative to its local abundance (Williams 1985), suggesting either that it is less likely to cross roads or less likely to get killed doing so.

Lepais et al (2010) stated that 'rare bumblebee species appear unable to regularly disperse over distances greater than 10km'. In 2004, a *B. sylvarum* male was captured in Groombridge near Tunbridge Wells in Kent, 35-40km away from the main (and nearest) N Kent population (Geoff Allen, pers. comm.). The specimen was found on 13th June which is relatively early to see males, so it may have come from a failed nest, although it is difficult to speculate.

Knowledge Gap: very little is known on forage and dispersal distances (or timing) for this species, and the effect of barriers, and so more research is needed, as this will support the recolonisation and creation/restoration methods for new/suitable forage and nesting habitat.

Habitat connectivity:

Connectivity tools could be used in combination with current data on *Bombus sylvarum* habitat size, density, quality, temporal shifts to develop more connected landscapes for the species; while collecting data to improve understanding and quality of conservation work.

In terms of understanding what an ideal connected landscape for *B.sylvarum* looks like, in some areas this species shows preference for larger sites, although in the Gwent levels it is using a lot of small linear ditch edges but these are in high number and located close together. It is unlikely that small isolated patches of habitat are beneficial to this species. There is no exact information on dispersal distances for *B.sylvarum* and more research is needed on this species and to be precautionary ideal distances of 100ms for foraging should be used. Barriers will also be important in terms of quality of landscapes for this species in reducing and affecting permeability of landscape, particularly in more industrialised areas such as the Thames Estuary. There are pre-existing connectivity tools such as 'Condatis' that could be used to define and explore connection opportunities in landscapes. Using data on habitat size, density, quality, temporal shifts to define ideal conditions based on current understanding; at the same time collecting data to improve data on requirements. 'Connectivity' for this species will need to take account of resources on a micro-habitat scale in order to understand appropriate conservation actions.

Knowledge Gap: better habitat requirement data to underpin connectivity analysis

Disease & pathogens:

There is no specific evidence of problems with pests or pathogens specific to the Shrill carder bee, but no research has been done on this. The species is not known to host cuckoo bumblebees. However, there are a range of parasites, parasitoids and pathogens which affect bumblebees in general. These parasites and diseases are likely to be able to affect the Shrill Carder as well, although their lower densities may reduce their impact compared with commoner bumblebees.

Several diseases affecting, and first described from, honeybees can be found in bumblebees (Durrer & Schmid-Hempe 1994, Genersch et al 2006, Singh et al 2010, Peng et al 2011, Evison et al 2012, Levitt et al 2013, Fürst et al 2014, Graystock et al 2013, Li et al 2014, Ravoet et al 2014, McMahon et al 2015). Pathogenicity to bumblebees for most of these diseases is not yet precisely known, but bumblebees infected with Deformed Wing Virus (DWV) are known to

develop deformed wings (Genersch et al 2006) and suffer higher mortality (Fürst et al 2014). Bumblebees have also been found carrying the fungal pathogen *Nosema ceranae*, an emergent disease of honeybees (Paxton 2010, Graystock et al 2013, Fürst et al 2014) and emergent infectious diseases have been implicated in bumblebee declines (Cameron et al 2011, Meeus et al 2011, Fürst et al 2014, Schmid- Hempel et al 2014).

Disease transfer takes place through shedding of disease particles and direct bee-bee contact on shared flowers (Durrer & Schmid-Hempel 1994, McArt et al. 2014, Graystock et al 2015, Manley et al 2015). In DWV, the best-studied of these pathogens, the anthropogenic movement of managed honeybee stocks has been found to be the source of DWV outbreaks in bumblebees (Wilfert et al 2016, Manley et al 2019). Managed honeybees are likely to be linked to the dispersal of many diseases observed in wild bees, therefore it is reasonable to assume that the proximity of managed bees of any species may be detrimental to vulnerable populations of native bees (Fürst et al 2014, Manley et al 2015, McMahon et al 2015, Graystock et al 2016, Mallinger et al 2017).

The use of commercially reared bumblebees also represents a potential risk. These colonies have been found to contain pathogens on arrival (Graystock et al., 2013.; Murray et al., 2013; Trillo et al., 2019), including honeybee-associated parasites which can also infect bumblebees (Graystock et al., 2013), most likely as a result of honeybee pollen being fed to bumblebees during the rearing process (Goulson and Hughes, 2015). As these bees forage in the environment they risk transmitting parasites and diseases via shared flowers (Colla et al., 2006; Meeus et al., 2011; Schmid-Hempel et al., 2014). They can also compete for food resources and, if new queens become established in the wild, for nesting sites (Matsumara et al., 2004; Morales et al., 2013).ees.

Knowledge Gap: more research is needed on diseases of this species.

Climatic range and climate change:

B. sylvarum is determined to have a west-Palaearctic distribution (Williams, 1998) with a narrower climatic niche in Western Europe then their more common cousin *B. pascuorum* (Williams *et al.,* 2007). Williams *et al.* (2007) found *B. sylvarum* to be associated with warmer and drier areas of Western Europe, with much of the losses towards the cooler areas (northern Britain). The paper suggests the retreat is due to the species becoming restricted to a climatic optimum, stating: “the areas where they persist in Britain from 2000 onwards are closer climatically to the centres of their pre-decline west-European climatic niches than the areas from which they have been lost” and “it is in areas nearer the edges of their climatic niches where these species are most vulnerable to decline, although this can be ameliorated locally by high food-resource levels.” (Williams et al, 2007). *B. sylvarum* used to be found around Carlisle and has not always been restricted to the Southern England and Wales and so can be present in parts of the England that are not so warm and dry; this suggests that given sufficient resources (food and nesting habitat), it could occur further north and west. In Ireland the species is still present in the Karstic areas of the Burren in County Clare, as well as small areas of County Galway, which is wetter and more evenly warm (not hot) than south east England. *Bombus sylvarum* occurs in areas of France, Italy, Turkey, Bulgaria and Iran with warmer climates than Britain (Williams pers. comm.). It is also common in Slovenia, close to the Mediterranean - an area which is decidedly hot, with an early season (Mike Edwards pers comms). The species reaches its northern range extent in Britain

and is part of Williams' southern-continental grouping – a warming climate may well help the species (alongside others such as *B. humilis*).

A warming climate which results in warmer temperatures during the summer months may not be a significant problem for *B. sylvarum* in England and Wales. However, the impacts of climate warming, particularly increased frequency of extreme weather conditions as a result of climate change (such as intense rainfall and drought periods) may have a negative impact, especially on small isolated populations more vulnerable to stochastic events. Sea level rise and flooding events may be damaging to *B. sylvarum* populations, particularly in the Gwent Levels and Somerset levels. Unseasonally warm spring temperatures may result in emergence of queens from hibernation before sufficient suitable forage is available.

Threat analysis

Similar to many bumblebee species in the UK, loss and fragmentation of habitat is a key threat for *Bombus sylvarum*, and in particular the loss of flower-rich habitat mosaics that provide all the life cycle requirements (foraging, nesting, hibernation) for resilient populations. It is likely that threats will vary both temporarily and spatially at different scales, meaning each key site and population will have unique threat attributes.

Drivers for habitat loss include:

- Inappropriate management (e.g. badly timed cutting, over-grazing, use of fertiliser)
- Lack of management (resulting in degradation or loss of habitats / grass dominance / scrub encroachment / invasive species)
- Development (e.g. housing, industry, roads) – major threat in heavily populated and/or industrial areas such as the Thames Estuary (e.g. Tilbury expansion) and parts of south Wales (e.g. M4 relief road, Gwent Levels Solar Farm).
- General land-use change – such as agricultural intensification, pesticide use on a previously untreated site, managed realignments* *(*although these can sometimes offer opportunity for new habitat creation)*.

Small, isolated populations and the loss of genetic diversity are other key threat factors.

A complexity of threats are likely to be acting on the species in the UK, from habitat change; climatic changes (e.g. possible phenological shifts impacting foraging, drought, flooding); pesticides, pathogens, and possible competition with imported bumble bees/ honey bees. The majority of threats may coalesce around their impacts on colony size, number and viability.

Two threat factors are particularly worth noting for this species: isolation through the increasing fragmentation of habitats is leading to the isolation of populations leaving them vulnerable to the effects of inbreeding as well as single catastrophic events such as flooding and extreme weather events. Also, the loss of genetic diversity (one consequence being the development of sterile, diploid males) could well be exacerbating the threats to the species; a better understanding of genetics is a key knowledge gap in informing appropriate conservation interventions.

The drivers behind the decline and possible disappearance of the Salisbury Plain *B.sylvarum* population are unclear. The Salisbury Plain Training Area (SPTA) consists of huge expanses of flower-rich grasslands which support high insect diversity and many nationally scarce species,

including *Bombus humilis* (which appears to have similar habitat requirements to *B.sylvarum*) and several other rare bumblebee species. It is suggested that something must be preventing the specific habitat niches required for *Bombus sylvarum* - do sufficient plants of the right kind flower within the habitat mosaic at the right time? Is there sufficient litter development to provide the right nesting habitat? (S. Roberts, pers comm) - but isolation, small population size and (lack of) genetic diversity could also be factors.

To define a national threat analysis, an initial exercise was undertaken in June 2019 involving members of staff from BBCT, Buglife and Natural England, and facilitated by the IUCN. This workshop analysed and defined threats for the species, exploring drivers and linkages; this resulted in a causal flow diagram of the species threats. See Figure 5 below.

After the national threat mapping exercise, the workshop looked in more detail at threats within key Shrill carder bee population areas, ranking the degree of threat level and assigning directional change (see Table 2 below). To develop further understanding around wider system changes that could impact threats at each of the metapopulations, the workshop participants also undertook a PESTLE analysis. This analysis considers the Political, Economic, Social, Technological, Legal and Environmental factors they were aware of that could impact each metapopulation, positively or negatively (see Tables 3-9 below).

It should be noted that the following diagrams and tables provide an initial threat analysis to generate further thought and discussion, and are not comprehensive.

Knowledge gaps

The workshop participants also identified a range of knowledge gaps - that vary in their ease and importance to address. The critical gaps identified were:

- Deepening our understanding of threats to *Bombus sylvarum*
- Acquiring new knowledge on the extent of loss of genetic diversity across the population
- Learning about the preferred types of nesting/ hibernating habitat
- Understanding the extent to which habitat fragmentation is impacting the population (a gap which could be partly filled through genetic studies)

Other knowledge gaps identified included: impacts of inappropriate land management, pathogens, imported honeybees and/or bumblebees, loss of foraging habitat at colony level, and competition for forage/nest sites.

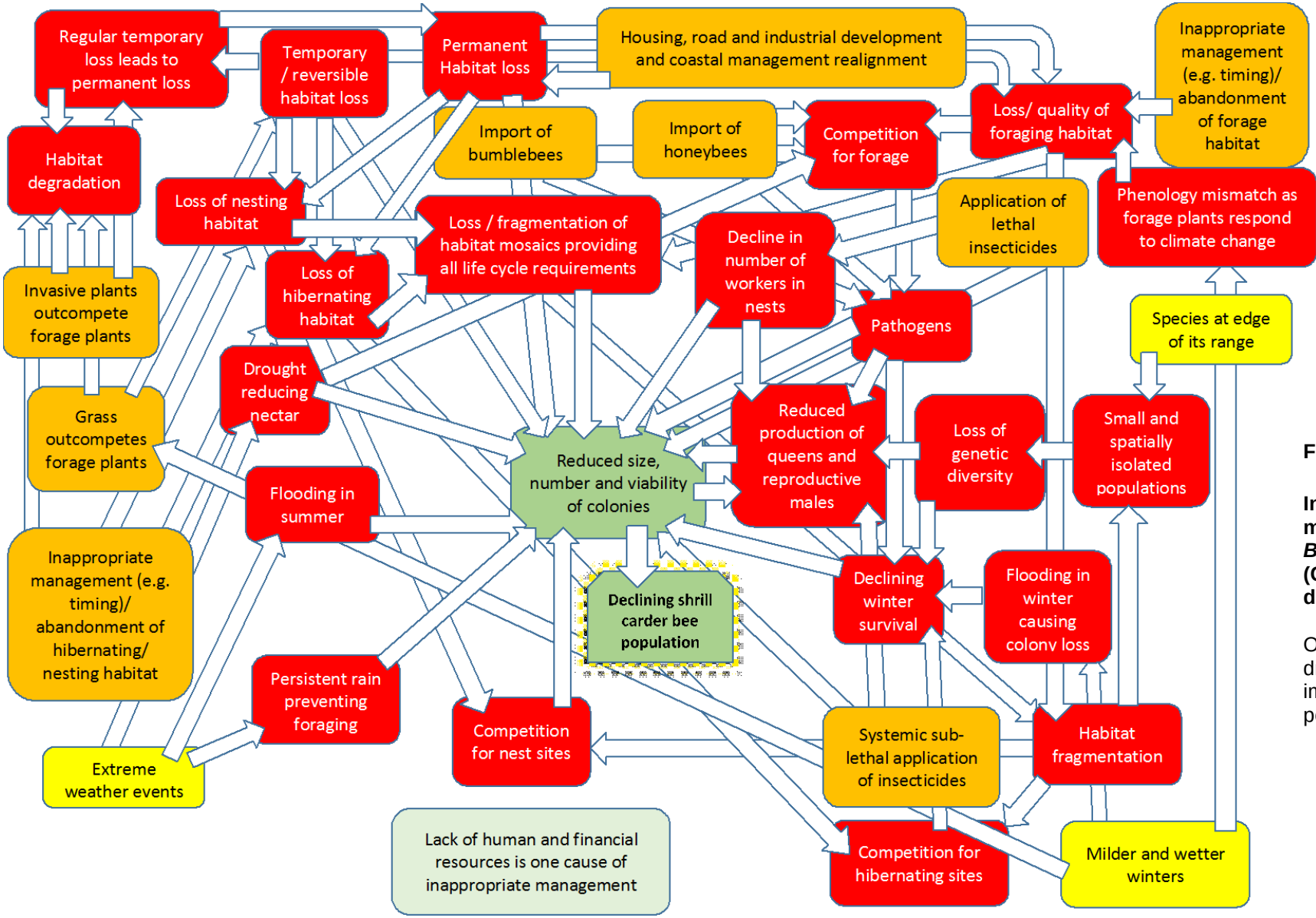


Figure 5.

Initial threat mapping for *Bombus sylvarum* (Causal flow diagram)

Orange/yellow = drivers; Red = threat impact; Green = population response.

Table 2 summarises the threat ranking for the six key population areas, highlighting the perceived degree of threat on a scale of 0-5 (0=no threat; 5=extreme threat), and presumed directional change over the next 5-10 years. Boxes are colour-coded, green signifying low threat scores (0-1), orange medium threat scores (2-3), and red high threat scores (4-5). Question marks highlight areas of high uncertainty.

Population areas / Direct threats	Salisbury Plain	Thames Estuary	Somerset	Gwent Levels	Kenfig	Pembroke-shire	'National' threat categories (average score)
Inappropriate forage management	2 →	5→	5↑	2-4	4-5 ↑	4-5 ↑?	4
Inappropriate nesting and hibernating sites management	4-5 →	3-5 →?	3-5 →?	3 ↑	3 ↑	3-4 ↑?	3.6
Industrial development (incl. wind farms)	0 →	5↑↑	1→	3 →	3-4 →	1 →	2.2
Housing development	1 →	5↑	1↑?	1-2 →	4 →	0 →	2.1
Road development	0 →	5↑	1↑↑	2-4 ↓	2 →	0 →	1.8
Coastal realignment	0 →	2↑	0→	0 →	0 →?	0 →	0.3
Herbicide usage	0? →	3 ?	3-4?	3 →	1 →	2 →	2.1
Insecticide usage	0? →	4-5?	4-5?	4 →/ ↑	0 →	2 →	2.5
Disease/ pathogens/ competition from imported bumblebees	1 ↑?	3↑	2↑?	1 →	0-1 →	0-1 →	1.3
Disease/ pathogens/ competition from imported honeybees	2 →?	3-4↑?	3↑?	1-3 →	1-3 →	1-3 →	2.4
Extreme weather events	3-4 ↑	4↑	3-4↑	4-5 ↑	4 ↑	3 ↑	3.8
Mild, wet winters	2-3 ↑	3-4↑	3-4↑	2-3 ↑	2 ↑	3 ↑	2.8
Invasive plants	1 →	4-5↑	1-2↑	3 ↑	3 ↑	1 →	2.4

PESTLE analysis

In addition to developing a prioritized threats table at the local and national level, a PESTLE analysis was undertaken to begin to identify some of the Political, Economic, Social, Technological, Legal and Environmental risks and opportunities faced (**Tables 3-9 below**). Whilst this should be considered an initial rather than comprehensive analysis, it did begin to provide additional information as to how the threats might change in the foreseeable future given these wider considerations.

Table 3. National populations- combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	4	AES post-Brexit emphasis on public good, sustainable agriculture Access to funding and staff resource for local councils - habitat management e.g. verges	Current push for pollinators means potential for more funded work due to public interest.	Pressure for 'tidy' green space	Better understanding of species genetics. Better disease screening with DNA barcoding. Precision agriculture Possible development of drones to track bees & nests (address knowledge gaps). BeeSteward modelling (e.g. impact of habitat interventions - currently being tested) but *B.sylvarum* autecology knowledge gaps = limitations of model	?	Risk of weakening legislation, including environmental standards, planning/EIA, pesticide regulations, etc. Wales Environment Act, Well-being & Future Generations Act promotes more positive use and engagement with nature.
Inappropriate nesting and hibernating sites management	3.6						
Industrial development (incl. wind farms)	2.2						
Housing development	2.1						
Road development	1.8						
Coastal realignment	0.3						
Herbicide usage	2.1						
Insecticide usage	2.5						
Disease/ pathogens/ competition from imported bumblebees	1.3						
Disease/ pathogens/ competition from imported honeybees	2.4						
Extreme weather events	3.8						
Mild, wet winters	2.8						
Invasive plants	2.3						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 4. Thames Estuary- combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	5→	Potential for bigger Brexit impact as closer to the continent. Environmental concerns may be less important there. Procedures linked to sea wall development have increased suitable habitat for *B.sylvarum*. National Park City status and Greater London Authority is big driver for Green Infrastructure and Nature-based Solutions. Biodiversity Net-Gain in housing developments.	More money for nature reserves due to location and # of visitors. High pressure on land for housing and industrial development. High redevelopment value of land means great potential for funding biodiversity net-gain and offsetting schemes Are there more financial opportunities, projects, etc. in Thames Estuary?	Risk of arson, anti-social behaviour etc. diverting resource and funds from conservation objectives. Removal of anti-social activities which can be providing the random disturbance needed to retain a site's value. Pressure for 'tidy' green space.	Precision farming, including targeted use of pesticides, etc.	?	Warmer and drier so risk of drought and associated risks (less nectar, fire). Will wetter winters lead to less drought stress and less flowery landscape? Is there a risk of mismatch between phenology of bee and flowering species? Is the area more susceptible due to microclimate? Invasive plants (e.g. Goat's rue, Alexanders, Sea buckthorn, Buddleia) threatening key sites and wider landscape
Inappropriate nesting and hibernating sites management	3-5 →?						
Industrial development (incl. wind farms)	5↑↑						
Housing development	5↑						
Road development	5↑						
Coastal realignment	2↑						
Herbicide usage	3?						
Insecticide usage	4-5?						
Disease/ pathogens/ competition from imported bumblebees	3↑						
Disease/ pathogens/ competition from imported honeybees	3-4↑?						
Extreme weather events	4↑						
Mild, wet winters	3-4↑						
Invasive plants	4-5↑						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 5. Salisbury Plain - combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	2 →	Current changes in MOD use of the land may be reducing disturbance, which could be an issue Increased activity on SPTA since reduction in availability of large training areas in Germany. Limited control over tenant farmers / graziers? Potential impact of MOD land if sold (low risk)	Changes in farming practice of the graziers on SPTA (West and East) are a threat (e.g. changes from silage cropping to grazing, stocking densities/ha, areas grazed, length of grazing periods). These are economic factors as the importance of cattle in the rural economy fluctuates. (Stuart Roberts, pers. Comm.)	Complexity of gaining access to the area as MOD land makes monitoring/ action problematic. Possibility of housing development on the periphery of the plains?	?	?	Drought reducing forage, chance of fires from lightning strikes. Lower risk of warmer mild winters impacting as chalk so porous? Not enough known in terms of potential impact of milder winters on fungal diseases, etc. Flooding wouldn't be an issue here
Inappropriate nesting and hibernating sites management	4-5 →						
Industrial development (incl. wind farms)	0 →						
Housing development	1 →						
Road development	0 →						
Coastal realignment	0 →						
Herbicide usage	0? →						
Insecticide usage	0? →						
Disease/ pathogens/ competition from imported bumblebees	1 ↑?						
Disease/ pathogens/ competition from imported honeybees	2 →						
Extreme weather events	3-4 ↑						
Mild, wet winters	2-3 ↑						
Invasive plants	1 →						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 6. Somerset- combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	5↑	Pollinator strategy acting as an opportunity Would new agri-environment schemes be positive or negative without being bound to EU regulations?	Possible conversion of current A303 into a carriageway	Range and number of landowners makes coordination of land management and access to the land problematic.	Precision farming, including targeted use of pesticides, etc.	?	Strong overlap with warmer, milder winters for flooding, as both catastrophic and long-term trends are an issue. Flooding potential to be very significant and could worsen in future. Is *B.sylvarum* already in sub-optimal areas due to flooding?
Inappropriate nesting and hibernating sites management	3-5 → ?						
Industrial development (incl. wind farms)	1→						
Housing development	1↑?						
Road development	1↑↑						
Coastal realignment	0→						
Herbicide usage	3-4?						
Insecticide usage	4-5?						
Disease/ pathogens/ competition from imported bumblebees	2↑?						
Disease/ pathogens/ competition from imported honeybees	3↑?						
Extreme weather events	3-4↑						
Mild, wet winters	3-4↑						
Invasive plants	1-2↑						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 7. Gwent Levels- combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	2-4	M4 cancellation (but road development threat remains) *B.sylvarum* now on all 8 Gwent Levels SSSIs as qualifying feature Pollinator action plan in development (also Monmouthshire) Newport council/Cardiff council owned land / WG opportunity for habitat Ongoing pressure for infrastructure development Likely intensification of agriculture post-Brexit	Allocated land for development, ABP, Tata steel unclear what's going to happen Big potential threat from industrial development as small population, relies on larger proportion of brownfield habitat. Use of pesticides as oil seed rape area. Also use of pesticides for 'spot on' treating cattle	Some housing allocations but mostly outside main areas More people moving to Newport since bridge toll, influx of people	?	?	? No known coastal realignment plans ? AES / farming changes (Brexit influence) - unknown impact
Inappropriate nesting and hibernating sites management	3 ↑						
Industrial development (incl. wind farms)	3 →						
Housing development	1-2 →						
Road development	2-4 ↓						
Coastal realignment	0 →						
Herbicide usage	3 →						
Insecticide usage	4 →/ ↑						
Disease/ pathogens/ competition from imported bumblebees	1 →						
Disease/ pathogens/ competition from imported honeybees	1-3 →						
Extreme weather events	4-5 ↑						
Mild, wet winters	2-3 ↑						
Invasive plants	3 ↑						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 8. Kenfig-Port Talbot - combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	4-5 ↑	Bridgend council handing over Kenfig NNR management but not yet agreed to whom. Influence/ pressure from Friends of group (against grazing).	Lack of funding to manage Kenfig NNR & SSSI and not targeted for SCB Tata steel closure - key brownfield site? Potential improvement area / development	Pressure for housing development at Port Talbot. Friends of group Kenfig Pressure to manage Kenfig for orchids (may conflict with *B.sylvarum*) Dog walking (impacts on management)	?	?	No known coastal realignment plans
Inappropriate nesting and hibernating sites management	3 ↑						
Industrial development (incl. wind farms)	3-4 →						
Housing development	4 →						
Road development	2 →						
Coastal realignment	0 →?						
Herbicide usage	1 →						
Insecticide usage	0 →						
Disease/ pathogens/ competition from imported bumblebees	0-1 →						
Disease/ pathogens/ competition from imported honeybees	1-3 →						
Extreme weather events	4 ↑						
Mild, wet winters	2 ↑						
Invasive plants	3 ↑						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Table 9. Pembrokeshire - combined threat analysis and PESTLE analysis

Key Sites/ Direct threats	Extract from threats table	Political factors	Economic factors	Social factors	Technological factors	Legal factors	Environmental factors
Inappropriate forage management	4-5 ↑	MOD land - key landowner. This could make the site vulnerable to complete change, e.g. should government decide to cut budgets to MOD. Land use - changed/less grazing = less forage (Landmarc graziers)	Some intensive land management north of ranges for dairy farming Bee-keeping area- possible risk of disease? Valero & RWE brownfield - large landowners / development or could revert to arable = volatile industry Tourism – opportunity? Tourism - disturbance, development pressure	?	?	?	MOD - impact of blasts - could be positive = disturbance MOD grass fires - related to lack of management = increased risk of fires, increases grass coverage
Inappropriate nesting and hibernating sites management	3-4 ↑						
Industrial development (incl. wind farms)	1 →						
Housing development	0 →						
Road development	0 →						
Coastal realignment	0 →						
Herbicide usage	2 →						
Insecticide usage	2 →						
Disease/ pathogens/ competition from imported bumblebees	0-1 →						
Disease/ pathogens/ competition from imported honeybees	1-3 →						
Extreme weather events	3 ↑						
Mild, wet winters	3 ↑						
Invasive plants	1 →						

Key: Text in red refers to potential negative factors. Text in blue refers to potential positive factors.

Conservation and management - current situation

***Conservation status* – UK, European:**

Bombus sylvarum is listed as a priority species of conservation concern under Section 41 in England (NERC Act 2006) and Section 7 in Wales (Environment (Wales) Act 2016). It was a UK Biodiversity Action Plan species and was listed as Notable b (Nationally Scarce Nb) by Falk (1991). Natural England and BWARS are currently in the process of updating its threat status for Great Britain, this should hopefully be finalised by the end of 2019.

Bombus sylvarum is listed under the IUCN as Least Concern in Europe (Rasmont et al, 2015), but is listed as Endangered in the Irish Red List (Fitzpatrick et al, 2006) and is on the Red List in various other countries including: Belgium, Denmark, Germany, the Netherlands and Czech Republic (Kosior, 2007).

The UK BAP Species Action Plan for *Bombus sylvarum* was last updated in 2010 (JNCC 2010; Appendix 3). The RSPB has a species action plan for *B. sylvarum* (last reviewed 2016). The species is identified as a qualifying feature of all eight SSSIs which make up the Gwent Levels. It is also listed as a qualifying feature of Castlemartin Range SSSI, Kenfig SSSI and Margam Moors SSSI. It is listed locally as a priority species in some agri-environment schemes (e.g. Countryside Stewardship in parts of Kent, Natural England).

Conservation management:

It has been suggested that *B. sylvarum* requires at least 10-20 sq.km of suitable habitat for an individual population to be viable (BWG 1998, 2000). A viable metapopulation structure would presumably require multiple habitat matrices across a much wider landscape. Management recommendations for *B.sylvarum* tend to focus on ensuring plentiful flower-rich habitat with suitable forage available from April to late September/October, in addition to providing undisturbed nesting habitat.

Space available to be utilised varies greatly depending on the area, with the population on the Gwent levels found by the Bumblebee Working Group to live in an area of ~9 km^2 (although the colonised area is over 27km long so this seems like an underestimation - Richard Comont, pers. comm.) whilst those that were found on Salisbury Plain have access to over 600 km^2 of habitat (BWG, 1998). The range of *B. sylvarum* in the areas surrounding Bridgend was estimated to cover 66 km^2 of which just under half (30 km^2) contained suitable foraging habitat (Stewart and Roberts, 2014). Peter Harvey notes that *B.sylvarum* seems to require much larger areas of habitat than *B.humilis* in south Essex (Harvey, 2015), this account is confirmed anecdotally by Stuart Connop based on the ability of *B.humilis* to persist on smaller more fragmented sites towards London where *B.sylvarum* does not get recorded.

Management recommendations for *B.sylvarum* tend to focus on ensuring plentiful flower-rich habitat with suitable forage is available from April to late September/October (e.g. rotational cutting/grazing, leaving uncut strips, ceasing summer grazing, rotational hedge/bank/ditch cutting, restoration or establishment of new wildflower grasslands and/or pollen & nectar margins), in addition to providing nesting habitat (e.g. rough/tussocky grass and scrubby areas left undisturbed March-October, south-facing aspect). The management of brownfield habitats to maintain mosaic

habitats (with open flowery areas alongside undisturbed nesting habitat) is also recommended (e.g. rotational vegetation clearance and disturbance).

Mosaic management:

This late emerging and 'late-peaking' species is susceptible to mid-summer cutting or grazing which restricts forage availability in late summer and early autumn when colonies are at peak numbers and producing reproductives (queens and males). It is also possible the species is also victim of 'pollinator conservation' headlines and the perception that flowers shouldn't be cut when pollinators are foraging (S. Connop, pers comm), leading to 'no cut' policies or a single late cut in autumn. However, a **mosaic of cutting times** from May through to September/October may be more beneficial for *Bombus sylvarum* to ensure continuity of forage rather than late cutting alone. For example, cutting grassland areas in May will help to encourage flowering later in the summer. Experiments at Hadleigh Park in south Essex showed that a mosaic May cut on some parts of the meadows can be very beneficial in extending the flowering season and providing late forage (Connop 2017). This type of management may also be useful for mitigating against early flowering and seed set (in relation to warming climate) by cutting to stimulate re-flowering.

Narrow-leaved Bird's-foot Trefoil:

In south Essex, Harvey (2002) notes that Narrow-leaved Bird's-foot Trefoil *Lotus tenuis* - a key forage plant for *B.sylvarum* - appears to favour seasonally-wet conditions, but can cope with reasonably dry summers with water available below the ground surface. In grasslands without disturbance the plant seems to survive for a number of years until it is out-competed by grasses and other vegetation. Harvey (2003) also notes that the very long flowering season of Narrow-leaved Bird's-foot Trefoil together with topographical and hydrological gradients across a site enables the vegetation to respond to different annual weather conditions to provide extended availability of forage. Seeding and plug trials on trial plots at Canvey Wick demonstrated that Narrow-leaved Bird's-foot Trefoil can be re-established by seeding but by far the most extensive *L. tenuis* areas present in 2003 were adjacent to these trial plots, where vehicular disturbance had opened up previously closed species poor grassland (Harvey, 2012). There could therefore be real gains to be made on the site by deliberately disturbing certain areas of species poor grassland to expose the underlying sandy substrate, allowing the development of a flower rich vegetation with areas of Narrow-leaved Bird's-foot Trefoil. The use of disturbance to deliberately produce variation in topography and hydrology could also help ensure that Narrow-leaved Bird's-foot Trefoil areas are in flower over different parts of the season. It should be noted that site suitability for management through ground disturbance needs to be carefully considered.

Hadleigh Park invertebrate conservation analyses:

Results from a three year study of the south Essex populations of *B. humilis* and *B. sylvarum* (Connop, 2007), and a study on foraging behaviour and dietary breadth (Connop et al., 2010) were fed into fed into an experimental programme of forage creation at Hadleigh Park. The site, which runs between South Benfleet and Hadleigh in south Essex, was selected due to its suitability for a bumblebee habitat improvement program. The site has received Higher Level Stewardship funding for management of habitat. Monitoring has demonstrated that habitat interventions have increased the area of suitable forage and nesting habitat. The study concludes that soil inversion plus green haying and the subsequent late hay cut proved to be an effective and rapid method of habitat creation created suitable forage areas for *B. sylvarum* and *B. humilis*. The study also found that a combination of an early (May) hay cut on some established forage areas, along with the later hay cuts on other areas, was an effective method of creating a mosaic

of forage during the peak foraging season and for creating more abundant forage in late summer. Continued monitoring to determine the long-term success of this project is recommended.

Sea wall management:

Small scale studies have been carried out to compare Environment Agency cutting regimes and timings on sea wall flood defences in the Thames Estuary. Gardiner and Vetori (2015) found that species richness and abundance of bumblebees on one-cut sea wall in mid-late September (20 *B.sylvarum* recorded) were higher than two-cut plots which were cut in June and August (0 *B.sylvarum* recorded); these two-cut sections also had correspondingly lower forage plant species richness. Sea wall monitoring surveys on the Hoo Peninsula in north Kent found that abundance of *B.sylvarum* was higher in sections receiving two cuts where an early (spring) and late (autumn) cut was being carried out, compared to sections with summer sea wall cutting (Page, 2015).

Knowledge gap: Robust research is needed on the impact of targeted management for *B.sylvarum,* including for queens (e.g. white dead nettle planting) and population level monitoring.

Current projects

There are a range of conservation projects currently being delivered across England and Wales but only one is focused solely on *B. sylvarum* (Back from the Brink), others have a general bee/invertebrate or habitat focus but provide benefits to *B. sylvarum,* and some have *B. sylvarum* as one of several target species. In addition, there is management for the species through the agri-environment schemes in England and Wales, as well as individual landowner management activities, including on several nature reserves.

Hymettus has worked closely with farmers, local authorities, policy makers and land managers on *B. sylvarum*.

Back from the Brink 'Shrill carder bee recovery project' (BBCT & Buglife) – Part of the wider Natural England and Rethink Nature-led 'Back from the Brink' partnership in England. Focus on Somerset and the Thames Estuary. Activities include: surveys and monitoring (via BeeWalk), landowner advisory work, development of a species action plan to inform future targeted conservation. The Shrill carder bee Back from the Brink project ends in March 2020.

Making a Buzz for the Coast (BBCT) – landscape-scale project focussing on the Kent coast from Dartford to Deal. Multiple elements including: habitat restoration & creation for priority bumblebee species including *Bombus sylvarum* (with partners including RSPB, Kent Wildlife Trust, Thames Water, Thanet district council), landowner advice, bumblebee identification training and promotion of recording (BeeWalk, iRecord), and public engagement/awareness raising. Three-year delivery phase to Autumn 2020.

Bee Wild West Wales (BBCT) – Focus on recording and monitoring across west Wales, including areas supporting *B. sylvarum.* Surveys have taken place at target sites in south Pembrokeshire. Targeted conservation work parties and land management advice at Castlemartin Range, and Valero refinery/Greenhill farm to north of Castlemartin range. Project ended in Dec 2018.

Short-haired bumblebee reintroduction project (BBCT, Natural England, RSPB (and formerly Hymettus)) – although focused on another species, the activity to increase flower rich diversity within the Romney Marsh and Dungeness area which spans from Hythe, Kent to the High Weald in East Sussex and north to Ashford, has resulted in benefits for lots of other rare bumblebees and provides important learning for other conservation initiatives.

Living Levels: Pollinating the Levels (BBCT, Buglife, RSPB) – NLHF funded landscape project across Gwent Levels led by RSPB (Living Levels), BBCT and Buglife are jointly delivering Pollinating the Levels. Includes targeted habitat management, restoration and creation for *B. sylvarum,* as well as monitoring and bumblebee identification training. Three year delivery phase to Dec 2020.

Important Invertebrate Areas (IIA) (Buglife) - identified the broad-scale IIA network ahead of fine-scale mapping in 2018/19. However, IIAs do not account for aculeates (and any other invertebrates) not treated by recent status reviews, as a result there are significant invertebrate areas missing in Wales (and elsewhere), including the Gwent Levels and the north Castlemartin peninsula.

B-lines (Buglife) – mapped outline of an IIA / a B-lines network for the Thames Estuary and parts of south Wales.

Planning work (Buglife) – site protection through engaging with planning applications to protect the best sites and/or improve mitigation outcomes.

Essex sea wall management (EA, Tim Gardiner) **–** e.g. Canvey Wick, Dengie, Goldhanger, Paglesham – rotational cutting / sea wall annual cut mid-Sept & rotational on berm.

Sites with active management for Shrill carder bee, including Lytes Cary National Trust, RSPB Thames Estuary reserves, Wildlife Trusts reserves, Natural Resources Wales reserves, MOD Pembrokeshire, Valero (Pembs), Landfill restoration Thurrock Cory.

Management through agri-environment payments – in England, there are some NGO managed sites that are receiving agri-environment payments of *B. sylvarum* habitat in North Kent and the Thames Estuary, and a private farm BBCT is working with in Somerset is actively managing for *B.sylvarum* under a Countryside Stewardship agreement*;* in Wales, *Bombus sylvarum* is a target species under Glastir but take up through the scheme is unknown.

Surveys, Monitoring and Research

BBCT are undertaking the main targeted standardised surveys for this species across its distribution via BeeWalk (BBCT's national bumblebee monitoring scheme), in addition to ad hoc surveys and specific research and monitoring projects, which are site focused. However, there are significant gaps in BeeWalk coverage (particularly for the Wales and Somerset populations) and more BeeWalk data is needed from transects across metapopulation areas to reliably assess and monitor *B.sylvarum* populations. Some other organisations, such as RSPB, are also doing targeted monitoring for Shrill carder bee on some reserves such as RSPB Cliffe Pools and Rainham Marshes.

BeeWalk (BBCT) – *B. sylvarum* has been recorded on 29 BeeWalk transects since the scheme was established in 2009, and on 20 transects during 2019. Twenty-two of the 29 transects remain active. Of these, only one is in Wales (Monmouthshire), four in Somerset (three of these are at Lytes Cary) and the rest are in the Thames Estuary area. There are plans to establish more transects in areas with low coverage to target the species, particularly in Wales through a new Skills for Bees Cymru project. The number of BeeWalk transects in the Thames Estuary area has increased significantly over the last two years, mainly as a result of the Making a Buzz for the Coast and Back from the Brink projects which have been actively promoting long-term monitoring of *B.sylvarum* and other rare bumblebee populations through BeeWalk.

Fig.6 BeeWalk transects recording *Bombus sylvarum.* All transects with *B.sylvarum* records, 2009-2018; no *B.sylvarum* records in 2012. Pembrokeshire transects no longer active. (2019 data not yet processed as field season ongoing.)

Other surveys – Recording and survey days are taking place at some key locations on an ad hoc basis, mainly through the above projects. Some other organisations, such as RSPB, are also doing targeted monitoring for Shrill carder bee on some reserves such as RSPB Cliffe Pools, Rainham Marshes and South Essex Marshes.

Road verges for bumblebee conservation: a green infrastructure opportunity or an ecological trap? UEA/BBCT/Highways Agency PhD examining the important of road verges for bumblebee conservation, October 2018 - 2021.

Knowledge Gap:
There is a lack of consistent standardised monitoring of the conservation management techniques for this species to understand the benefits and the pitfalls.

Resources

Hymettus produced a factsheet on bumblebees (including *B. sylvarum*) as part of the '*Aculeate Information Sheets: How the habitat requirements of BAP aculeates relate to their HAP'* series. http://hymettus.org.uk/downloads/Grassland_Bumblebee_info_sheet.pdf

BBCT has produced a Shrill carder bee factsheet, as well as an 'ID card' (pocket sized laminated card for use as identification reference and directing people to submit photographic records on iRecord). These are also available in Welsh.
https://www.bumblebeeconservation.org/wp-content/uploads/2017/08/BBCT037-Shrill-Carder-bee-Leaflet-02.17.pdf

Buglife has produced a Species Management factsheet for Shrill carder bee and Brown-banded bee, and a factsheet on 'Managing brownfields for scarce bumblebees'.
https://www.buglife.org.uk/sites/default/files/Shrill%20and%20Brown-banded%20carder%20bee%20species%20management%20sheet.pdf
https://www.buglife.org.uk/sites/default/files/Species-Management-Shrill-carder-bee-and-Brown-banded-carder-bee-OCT-2018.pdf
https://www.buglife.org.uk/sites/default/files/Managing%20brownfields%20for%20scarce%20bumblebees_0.pdf

Shrill carder bee and community engagement

The Shrill carder bee is an appropriate species for community engagement with good opportunities to use it as flagship species to champion threatened bumblebee conservation, as well as for the habitats it is associated with; engaging professionals as well as the wider public with its conservation.

Except for a degree of understanding in the local areas where the species occurs, currently there is generally a lack of public engagement with this species, although several projects have been taking concerted action to raise awareness (e.g. Bee Wild West Wales, Making a Buzz for the Coast), with positive results. People are generally very enthusiastic about bumblebee conservation and this species is a good candidate species for engagement as it is a threatened species that is relatively easy to identify (and verify through photographs). It also has a unique name and quirky characteristics as well as a good conservation story. It could be used with a professional audience to get better conservation for certain habitats types and influence planning decisions (e.g. Buglife planning work; M4 expert witness statement, Dr Richard Comont, BBCT); as well as supporting conservation for wider threatened bumblebees and action in the SSSIs where it occurs. More widely, Shrill carder bee can be used to engage members of public to increase understanding of bumblebee conservation and support their monitoring (with adequate training), with opportunities on key tourist sites, nature reserves as well as gardens across its range.

As part of the Species Champions project, which pairs at-risk species with elected politicians, there are currently two Shrill carder bee species champions: In Wales, Delyth Jewell AM for South Wales East (Plaid) and in England, Thangham Debbonaire MP for Bristol West.

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Appendix 1: Survey reports for *Bombus sylvarum* with summary of findings

Authors / report	Year (publ.)	Summary of findings
Bumblebee Working Group Report	1997	The establishment of a Bumblebee Working Group to execute the Biodiversity Action Plan initiative for scarce and declining species of bumblebee is reported. Searches of potential localities for the Short List species *Bombus sylvarum* are reported. Confirmation of the acute conservation status of this bumblebee is reported. The future direction of research under this programme is suggested. It was decided to concentrate on re-surveying for the species at as many post-1970 sites and selected pre-1960 ones as possible in order to establish the 1997 distribution and identify suitable areas for more intensive autecological research. Survey of these sites was to be carried out during August 1997 by teams under the leadership of designated lead surveyors who were familiar with the bee. Details of each site survey were recorded in a standardised way. Survey areas included: Salisbury Plain and adjacent areas, Dorset downland, Chiltern Hills and Somerset levels; North Kent Marshes and Dungeness; East Sussex Downs, South Essex, Portsdown Hill. North Cornwall was a possible area but there was insufficient time in the 1997 programme. A worker was found in Kent near Sittingbourne, a worker was found on Salisbury Plain near Tilshead and two queens were found during June in the course of other survey work at Margam Moors near Swansea.
Bumblebee Working Group Report	1998	Searches for the southern target bumblebees, *Bombus humilis, B. ruderatus, B.subterraneus* and *B. sylvarum* were carried out between June and August 1998. It was decided to concentrate on further searches of areas where the species had been sighted during 1997 in order to try and locate a suitable study population for more detailed work in 1999. Several promising areas had been identified during the 1997 programme and it was decided to carry out further searches at these, as well as some which had come to our notice since then. The general areas searched were: Essex; Kent; Salisbury Plain and Dorset; Somerset; South Wales coast. The 1998 searches found many more individuals of this species than the 1997 searches and confirmed the existence of three more populations at Kenfig/Margam Moors, Newport Levels, Somerset Levels, Salisbury Plain Training Area and the higher ground at the fringes of the North Kent and South Essex Marshes, a total of six populations. The Kenfig population was the study of some preliminary autecological investigation during 1998.
Bumblebee Working Group Report	1999	In the south of the UK the research programme concentrated on *Bombus sylvarum*, although data for *B. humilis* was also collated. Individual projects were based in: South Essex; North Kent coast; Dungeness/Romney Marsh; Salisbury Plain Training Area; Somerset Levels; North Cornwall; South Wales coastal areas. Further foraging data was collected for all species and a large series of pollen samples was collected from worker bumblebees at study sites throughout the UK. Experimental management of farmland margins was commenced in Kent and adjacent to Salisbury Plain Training Area. A series of meetings with agri-environment advisers and site managers was held throughout the winter months. These were followed by a series of field identification meetings. Many papers concerned with bumblebees were gathered together and a literature search was commenced.
Harvey, P.R.	1999	1998 fieldwork: The author visited fourteen sites in Essex to search for *Bombus sylvarum* including potential sites in North Essex where there are old records for the species (ITE 1980). *Bombus sylvarum* was only found at two sites, both in south Essex, Wat Tyler C.P. where it was recorded in 1993 and a new site at Benfleet Downs. At Wat Tyler two workers and one male were seen on the 9th August 1998 and then over 20 workers were seen on the 12th August.
Bumblebee Working Group Report	2000	BWG 2000 Work programme included: A detailed study of *B. humilis* and *B. sylvarum* at Castlemartin and Kenfig was carried out. Further distributional studies of B. sylvarum were made in Somerset. Further distributional studies of all bumblebees were made on Salisbury Plain TA and a further survey visit made to a set of good

		unimproved meadows to the west of Kidderminster which had first been visited in 1999. 200 artificial nest boxes were made, deployed and monitored in various sites throughout the UK. Research into restoring bumblebee habitat and monitoring the effects of this were continued at Cholderton, Hants and on Romney Marsh. Liaison with relevant conservation bodies and land-owners was continued. Further pollen samples were collected and sent to for analysis. Preliminary analysis of the 1997/8 samples was carried out. Research project not under the BWG were carried out on the foraging and distribution of B. sylvarum in south Essex.
Carvell, C.	2000	Studies of the distribution and habitat requirements of *Bombus sylvarum* (the Shrill Carder Bee) and other bumblebees at Castlemartin Range, Pembrokeshire and Kenfig National Nature Reserve, Glamorgan and surrounding areas. Report for Countryside Council for Wales, Bangor.
Poole, A.	2000	Nest site study (Annex in Carvell 2000) Not yet sourced
Bumblebee Working Group Report	2001	No field research could be undertaken at the start of the 2001 season as a consequence of the restrictions imposed for the Foot and Mouth epidemic. This gave an opportunity to travel to southern Germany to look at early-season bumblebee (in particular *B. sylvarum* and *B. humilis*) ecology. Further distributional studies of *B. sylvarum* in Kent and Somerset were carried out. The research on *B. sylvarum* and *B. humilis* in southern Essex was continued (not a BWG project, but in full consultation with BWG).
Bumblebee Working Group Report	2002	Further distributional studies in North Kent, surveys on The Isle of Sheppey, at Murston and on the Hoo Peninsula (Cliffe Poools) were completed in 2003. These surveys confirmed the continuing presence of B. sylvarum on the Hoo Peninsula and gave an idea of the size of the population at Cliffe Pools RSPB Reserve. They confirmed the species' continued presence at Murston, Lower Swale NR (Kent Wildlife Trust) and the Elmley area of Sheppey, giving a much better idea of the size of the population in the Elmley area (which is narrowly separated from Murston by The Swale). The research on *B. sylvarum* and *B. humilis* in southern Essex continued (not a BWG project, but in full consultation with BWG). Monitoring of *B. sylvarum* (Wales) and *B. distinguendus* (Scotland) (not BWG projects, but liasion with BWG is to be maintained). Survey work on Salisbury Plain found Bombus sylvarum on isolated occasions and never more than one or two individuals. Altogether, it was found in three out of nine sample sites and only found on two occasions in one sample site. The low numbers/density of this species was rather surprising as the forage plants in many of the areas we were sampling were in very good overall condition for bumblebees.
Pavett, M	2003	Recording of B. sylvarum in the Gwent Levels; study which first highlighted *B. sylvarum* population in Gwent Levels.
Aculeate Conservation Group	2005	B. sylvarum recorded at RSPB Minsmere, an area it had been considered absent from and where it is unlikely that they have been missed in the intervening years as they have been visited quite well.
Howe, M, Haycock, B	2007	Castlemartin Range: Field tests conducted Aug 2007, 16 individuals seen on 4 transects.
CCW Contract Science Report No. 919 (Smith, 2010)	2010	Significant numbers were found during surveys in the Gwent Levels east of the River Usk (Magor & Undy SSSI, Whitson SSSI, and Newport Wetlands NNR) in 2009
Connop, S., Hill. T., Steer, J. & Shaw, P.	2010a	Minimum mean foraging distances calculated using microsatellite analysis of 150 *B. sylvarum* workers, in south Essex.
Connop, S., Hill, T., Steer, J. & Shaw, P.	2010b	The role of dietary breadth in national bumblebee (Bombus) declines: Simple correlation? Biological Conservation, 143, 2739-2746. 3yr study on foraging behaviour of *B. humilis* and *B. sylvarum* at sites in south Essex, 2003 to 2005. Transects recording flower visits, and pollen samples taken.

Connop, S.	2007-2011	Hadleigh Park bumblebee habitat improvement: experimental forage plot surveys. Floral surveys and timed bee counts were carried out to assess the value of green haying as a management technique for quickly generating substantial areas of suitable wildflowers for foraging *Bombus sylvarum* and *Bombus humilis* at Hadleigh Country Park, south Essex.
CCW Contract Science Report No. 972 (Smith 2011)	2011	Low numbers of *B. sylvarum* were found between Magor and Chepstow, and were not recorded at key grassland sites such as Caerwent. However, these surveys did identify several new sites on the eastern end of the Gwent Levels, and at inland locations outside of the Gwent Levels. The report also documents records at urban localities at Newport Docks and Maesglas landfill site.
Gardiner, T	2012	Sea wall surveys in Essex (June): *B. sylvarum* recorded on red clover, narrow-leaved bird's foot trefoil, tufted vetch and oil seed rape (field adjacent to bank). Transect counts: 7 *B.sylvarum* recorded on uncut folding (Paglesham); Mean 5.3 *B.sylvarum* per kilometre on unmown bank; 0 on mown bank (Tilbury Marshes).
Gomes, B (RSPB)	2012	RSPB Cliffe Pools bumblebee survey, Aug & Sept 2012. Timed transects & timed counts. Large numbers of *B.sylvarum* recorded. Narrow-leaved Bird's foot-trefoil *Lotus tenuis* was the dominant flowering plant and the main forage species utilised by B.sylvarum. 152 workers were recorded foraging on *L.tenuis* in August, and 35 workers (plus 1 male) in September. Other key species utilised by these bees e.g. Red Clover and Red Bartsia had passed their flowering peak and much more patchy in distribution. Similarly, Black Horehound had mostly finished flowering at the times of visits. (Red bartsia = 8 workers. Black horehound = 9 workers. Red clover = no records.) Asteraceae were visited by mainly males of all species but also by workers. Hawkweed oxtongue – 34 sylvarum workers plus 2 males (August/Sept, 12 nectaring). The high proportion of visits to Lotus may have demonstrated a preference for foraging on this species but may also have been a result of the limited availability of other forage resources in the late summer/autumn. It appears, however, to be of major importance to both B.sylvarum and B.humilis in the autumn, at a time when other key species such as Red Clover are at the end of their flowering season.
Connop, S.	2013	Roscommon bumblebee research project. University of East London. Roscommon, Canvey Island, Essex. Included nest searches and mark recapture studies. *B. sylvarum* noted foraging along sea wall in significant numbers.
CCW Contract Science Report No. 1030 (Smith 2013)	2013	Surveys on the west of the Gwent Levels at Rumney & Peterstone SSSI, and in the east at Nash & Goldcliff SSSI, found *B. sylvarum* to be widely distributed on those SSSIs. This status is summarised as follows: 'Newport Wetlands (542 individuals at 18 sites in 2009), Nash & Goldcliff (381 at 32 sites in 2009), Rumney and Peterstone (305 at six sites in 2003), Whitson (300 at one site in 2003; 87 at 29 sites in 2009), St.Brides (220 at two sites in 2003) and Redwick & Llandevenny (61 at 20 sites in 2009). Numbers on Magor & Undy and Magor Marsh (5 individuals) are too small to merit this status unless considered part of a wider Gwent Levels population'.
NRW Evidence Report No. 23 (Stewart & Roberts 2014)	2014	Survey work undertaken in the Kenfig-Port Talbot area in 2013, with 101 individuals recorded across 49 transect sites. The range of *B. sylvarum* was estimated to be 66km2 with half of that area providing suitable forage habitat. The largest concentrations of records were found at the northern margins of Kenfig NNR and fields on the periphery of the NNR.
Gardiner, T & Vetori	2015	Sea wall mowing in Essex: Transect monitoring results for 2013 and 2014 indicated that the species richness and abundance of bumblebees on the one-cut sea wall in

		mid/late September (20 sylvarum recorded) were higher than the two-cut plots which were mown in June and August (0 sylvarum recorded) and had correspondingly lower forage plant species richness.
Gomes, B (RSPB)	2015	RSPB Great Bells Farm bumblebee survey, August 2015. *B. sylvarum* not recorded on timed transects but individuals were seen on an isolated *Buddleja davidii* bush and on Black Horehound *Ballota nigra*. This species was recorded much less frequently than in 2010. *NB. Not accessed 2010 survey report.*
Page, S (BBCT)	2015	Sea wall surveys on Hoo Peninsula, Kent in 2013, 2014 and 2015 (early July, early Aug, early Sept repeat surveys). 12 transects across 6 sections (based on cutting management regimes). - 2013: 17 *B. sylvarum* (6% total records); plus 11 workers/1 male outside survey - 2014: 21 *B. sylvarum*, all workers (9% total records) - 2015: 22 *B. sylvarum*, all workers (6% total records); plus 1 queen outside survey Only 1 sylvarum recorded in early July surveys (across all years). Peak numbers in in 2013 and 2014 were in early Sept surveys, whereas in 2015 similar numbers of sylvarum were recorded across August & Sept. Abundance of *B.sylvarum* was higher in sections where an early and late cut was being carried out (rather than summer sea wall cutting). Narrow-leaved bird's-foot trefoil = 47% records in 2013; 57% records in 2014; 41% in 2015. Bristly oxtongue and autumn hawkbit = September forage.
Connop, S, and Nash, C	201	Hadleigh Park invertebrate conservation analyses 2017. London: University of East London. Long term study (surveys from 2007-2011, 2015-2017), includes May cut trials, annual timed count comparisons, green-haying experiment analyses.

Appendix 2: Known forage plant species used by *B. sylvarum*

(NB. This list is a working document and is by no means complete.)

Plant family	Forage species	Caste	Season	References	Notes/regions
Aizoaceae	Iceplant *Mesembryanthemum crystallinum*			Smith (2013)	Gwent Levels
Asteraceae	Dandelion *Taraxacum spp*	Queens	Spring	Rosie Earwaker, pers comm (2018 surveys)	Thames Estuary
Asteraceae	Common knapweed *Centaurea nigra*	Workers	Mid / late summer	Smith (2010) Gardiner T, pers comm	17% workers on *Centaurea nigra* in 2009 surveys - Gwent Levels (Smith, 2010). Connop, et al (2010) Thames Estuary
Asteraceae	Creeping Thistle *Cirsium arvense*		Late summer	Pavett, (2004); Smith, (2010), Page (2015), Connop, et al (2010)	Gwent Levels, Thames Estuary
Asteraceae	Sunflower *Helianthus annuus*	Workers and males	Late summer	Gwent Levels, Smith, 2010 and 2011.	Gwent Levels
Asteraceae	Common fleabane *Pulicaria dysenterica*	Males		S. Lynch	Wales
Asteraceae	Common ragwort *Senecio jacobaea*	Males		Smith (2013) Gardiner, pers comm Gomes (2012), Connop (2007)	Gwent Levels Thames Estuary
Asteraceae	Marsh thistle *Cirsium palustre*			Smith (2013)	Gwent Levels
Asteraceae	Sow-thistle *Sonchus sp.*			Smith (2013) Gomes (2012)	Gwent Levels; RSPB Cliffe Pools
Asteraceae	Spear thistle *Cirsium vulgare*			Smith (2013), Connop (2007)	Gwent Levels
Asteraceae	Teasel *Dipsacus fullonum*			Gomes (2012)	RSPB Cliffe Pools
Asteraceae	Hawkweeds / hawkbits / hawksbeard			Page (2015) Gomes (2012) Gardiner, pers comm	Thames Estuary
Asteraceae	Bristly oxtongue *Helminthotheca echoides*		Late summer	Page (2015) Gardiner, pers comm	Thames Estuary Page - BBCT sea wall surveys 2013-2015 - 18% records on bristly oxongue (n=60 sylvarum)
Asteraceae	Hawkweed oxtongue *Picris hieracioides*			Gomes (2012), Page 2015	RSPB Cliffe Pools
Asteraceae	*Picris echioides*			Connop (2007)	
Asteraceae	Sea aster *Tripolium pannonicum*	Males		Gomes (2012)	RSPB Cliffe Pools
Balsaminaceae	Himalayan balsam *Impatiens glandulifera*			Smith (2013)	Invasive species; Gwent Levels

Boraginaceae	Comfrey *Symphytum spp*	Queens (and workers)	Spring	S. Lynch, pers.comm	Magor Marsh and Newport Wetlands
Brassica	Oil seed rape *Brassica napus*		June	Gardiner (2012)	Thames Estuary
Brassica	Perennial wall rocket *Diplotaxis tenuifolia*			Gomes (2012), S Page	Thames Estuary
Convolvulaceae	Large Bindweed *Calystegia silvatica*		Late summer	Smith, 2013	Gwent Levels
Dipsacaceae	Devil's-bit Scabious *Succisa pratensis*		Late summer	Howe and Haycock, 2007	Castlemartin Range
Dipsacaceae	Field scabious *Knautia arvensis*			Connop, et al (2010)	
Fabaceae	Common Vetch *Vicia sativa*	Queens	Spring	Connop (2007), Rosie Earwaker, pers comm (2018 surveys)	Thames Estuary
Fabaceae	Narrow-leaved everlasting pea *Lathyrus sylvestris*	Workers	Mid summer	Smith (2010)	Gwent Levels & Newport Wetlands
Fabaceae	Common Bird's-foot trefoil *Lotus corniculatus*	Workers	Mid / late summer	Smith (2010) Page S (2015), Connop (2007)	
Fabaceae	Greater bird's-foot trefoil *Lotus pedunculatus*		Mid / late summer		
Fabaceae	Narrow-leaved bird's-foot trefoil *Lotus tenius*			Connop, et al (2010) Benton et al (2012) Gardiner (2012) Page S (2015), Connop (2007)	Thames Estuary - key forage plant (especially on sea walls); Benton - large numbers on *L.tenuis* in Sept 2007, Tollesbury Wick; Gomes 2012 - 152 workers were recorded foraging on L.tenuis in August, and 35 workers (plus 1 male) in September; Gardiner, pers comm- 46% sylvarum sea wall records from last 10yrs on *L.tenius. Connop, et al (2010) ~40% of pollen samples taken from B. sylvarum.*
Fabaceae	Tufted vetch *Vicia cracca*	Workers	Mid / late summer		Gwent Levels Thames Estuary Salisbury plain
Fabaceae	Hairy vetch *Vicia villosa*	Queens	Spring	Connop (2007)	Essex
Fabaceae	*Vicia tenuifolia*	Workers		Connop (2007)	Essex
Fabaceae	Red clover *Trifolium pratense*			Gardiner (2012; pers comm) Page S (2015) Benton et al (2012), Connop, et al (2010), Connop (2007)	

Fabaceae	Strawberry clover *Trifolium fragiferum*			Page S (2015)	
Fabaceae	Meadow vetchling *Lathyrus pratensis*			Smith (2013)	
Fabaceae	Broad-leaved everlasting pea *Lathyrus latifolius*	Queens		Connop (2008); S Falk, pers comm	Canvey
Fabaceae	White clover *Trifolium repens*			Smith (2013) Benton et al (2012) Connop, et al (2010)	
Fabaceae	Lucerne *Medicago sativa*			Gardiner, pers comm	Thames Estuary
Fabaceae	Bladder senna *Colutea arborescens*	Queens	Late Spring	Connop (2008)	South Essex
Fabaceae	Ribbed melilot *Melilotus officinalis*	Workers		Connop (2007)	
Fabaceae	Goat's-rue *Galega officinalis*	Queens, Workers		Connop (2007)	
Lamiaceae	White Dead-nettle *Lamium album*	Queens	Spring	Rosie Earwaker, pers comm (2018 surveys); Benton et al 2012; S. Page pers comm, Connop (2007)	Thames Estuary
Lamiaceae	Red Dead-nettle *Lamium purpureum*	Queens	Spring	Rosie Earwaker, pers comm (2018 surveys)	Thames Estuary
Lamiaceae	Ground-Ivy *Glechoma hederacea*	Queens	Spring	Rosie Earwaker, pers comm (2018 surveys)	Thames Estuary
Lamiaceae	Black horehound *Ballota nigra*	Queens, workers		Gomes (2012), Page (2015), Benton et al 2012, Connop, et al (2010), Connop (2007)	Thames Estuary; This species is uncommon in Wales
Lamiaceae	Marsh woundwort *Stchys palustris*			Smith (2013)	
Lamiaceae	Selfheal *Prunella vulgaris*			Smith (2013)	
Lamiaceae	Common sage *Salvia officinalis*			Connop (2007)	
Lamiaceae	*Lavandula* spp.	Workers		Connop (2007)	
Lamiaceae	Water mint *Mentha aquatic*			Smith (2013)	
Lythraceae	Purple loosestrife *Lythrum salicaria*				
Onagraceae	Great willowherb *Epilobium hirsutum*			Smith (2013)	

Orobanchaceae	Red bartsia *Odontites vernus*	Workers	Late summer	BWG, 1998; Somerset Shrill carder bee Group, 2017; Stewart and Roberts, 2014; J Robins, pers comm; Gomes, 2012	All regions Connop, et al (2010) found majority of pollen collected by B.sylvarum was from Odontites verna.
Rosaceae	Apple *Malus spp*	Queens	Spring	Connop, et al (2010)	Thames Estuary
Rosaceae	Bramble *Rubus fruticosus agg.*		Mid summer	Smith (2013), Gomes (2012), Connop (2007)	All regions
Scrophulariaceae	Butterfly bush *Buddleia davidii*			Smith (2013)	
	Woody nightshade *Solanum dulcamara*			Smith (2013)	
Vipers bugloss *Echium vulgare*	Vipers bugloss *Echium vulgare*		Early summer (June)	BWG 1998	Kenfig NNR