UK Pollinator Monitoring Scheme

UK Pollinator Monitoring and Research Partnership (PMRP)

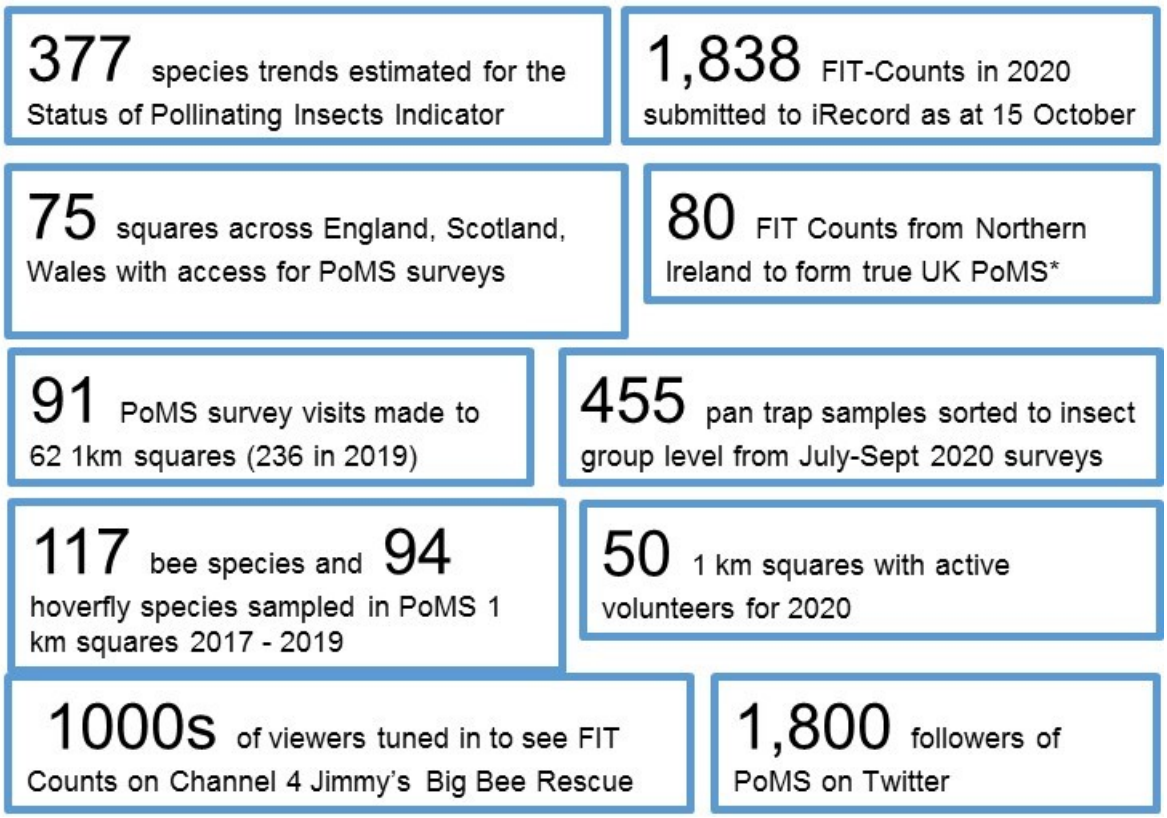
Progress Report October 2020

Claire Carvell and PMRP partners (October 2020)

A collaborative project funded by Defra, JNCC, Welsh Government, Scottish Government, DAERA NI and project partners (BE0159)

www.ceh.ac.uk/pollinator-monitoring

PoMS highlights in numbers (February 2020 – October 2020)



*FIT Counts from N Ireland include 58 submitted through the All-Ireland Pollinator Plan and 22 submitted through PoMS via iRecord.

Cover image: *FIT Count in the Scottish Highlands* (Photo: Katty Baird)

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Introduction and overview of progress

Many insect pollinators are becoming less widespread in Britain and elsewhere and we have a poor understanding of their changing abundance. This is largely due to the lack of long-term standardised monitoring of their populations. Current evidence for pollinator declines (of most species, aside from butterflies, moths and more recently, bumblebees) is derived from relatively unstructured opportunistic records of species occurrence submitted by volunteer recorders and co-ordinated by the National Schemes and Societies (NSS). These invaluable datasets make it possible to track long-term changes in pollinator distributions at the species level, but provide no direct information on abundance, population size or pollination service.

Through the project "Establishing a UK Pollinator Monitoring and Research Partnership BE0125" (Jan 2017 – April 2019) the PMRP project team established a hierarchical approach combining professional and volunteer involvement and taxonomic scope, through the integration of two new systematic surveys (forming the UK Pollinator Monitoring Scheme, PoMS) with ongoing opportunistic recording. In addition, a Pollinator Monitoring Research Advisory Group (PMRAG) was established to help support externally-funded research applications and use PoMS-derived data in research, conservation and survey planning.

This report summarises progress on the PMRP project during the second part of Phase 2 BE0159 (February – October 2020)[1]. Phase 2 retains the five core Tasks as outlined below, with elements of the implementation mechanism updated to reflect this phase of delivery.

The 2020 season has inevitably been impacted by the Covid-19 pandemic and restrictions on both volunteer recorders and PoMS team members. We have been grateful for regular liaison with PMRP funders and the wider biodiversity monitoring schemes, and the commitment of everyone to ensure consistent messaging and timely responses to changing restrictions.

Despite the restrictions, many volunteer recorders have found PoMS surveys to be a hugely positive means of engaging with nature 'close to home' and as this report demonstrates, more than double the number of FIT Counts were received by the scheme in 2020 than in 2019. The more intensive surveys of 1 km squares have incurred significant gaps in survey effort during 2020 but samples have been processed from 62 squares and analyses will aim to account for the missed surveys. Good progress has been made with the modelling of integrated datasets from different survey approaches, and outreach activities have continued online throughout the year.

Project resources that were underspent on the 1 km square survey during 2020 have been re-allocated to developing an app for FIT Counts and a new dedicated website for the UK PoMS. These aim to be launched in time for the 2021 survey season (details to be reported in the final report end of March 2021).

We are delighted to welcome the addition of DAERA as a funder of the Partnership, enabling the integration of Northern Ireland into the UK Pollinator Monitoring Scheme. During the initial phase of integration in 2020, the PMRP provided advice and survey materials for implementation of PoMS in NI, hosting a visit from a member of the NI team at UKCEH Wallingford. FIT Counts undertaken in NI and promoted via the All-Ireland Pollinator Plan[2] have been included in PoMS outputs for the first time (Task 2). A candidate set of 1 km survey squares has been selected using the same stratification and selection criteria as with GB, with the aim of securing access permission and pilot surveys during 2021 (Task 3).

With this in mind, we have therefore replaced "GB" with "UK" in most sections of the PMRP report, except where the scope of activity still covers only GB.

[1] The final report from Phase 1 (2017- 2018 surveys) was published following peer review in June 2020: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=19837&FromSearch=Y&Publisher=1&SearchText=be0125&SortString=ProjectCode&SortOrder=Asc&Paging=10

[2] https://pollinators.ie/record-pollinators/fit-count-progress/

Objectives of the UK Pollinator Monitoring and Research Partnership

To provide a hierarchical approach to monitoring combining expert and non-expert volunteer and professional recording while building capacity through existing partnerships to ensure long-term sustainability (Tasks 1 – 3);

To provide metrics and/or indicators to show how pollinator populations are changing in the UK (Tasks 1 and 4);

To establish how pollinator populations are changing in the cropped and non-cropped environment (T 3-5);

To provide access to monitoring data at full resolution and engage with external research groups and wider stakeholders to facilitate use of the data in research, conservation & survey planning (Tasks 4-5).

These objectives are delivered under the following Tasks:

Task 1) Improving robustness and understanding of population trend estimates for bees and hoverflies from opportunistic records across England, Wales and Scotland, and increasing capacity for data flow and record verification.

Task 2) Simple systematic survey (Flower-Insect Timed Counts) to engage a wide range of volunteers collecting data on abundance and flower visitation rates of pollinators across the UK.

Task 3) Undertaking new intensive systematic surveys (PoMS 1 km square surveys) of pollinators and floral resources with a core set of stratified sites across England, Wales and Scotland.

Task 4) Data management, integration and modelling to create metrics or indicators at UK and country level.

Task 5) Maintaining links with the Pollinator Monitoring Research Advisory Group (PMRAG) to help support externally-funded research applications and use project data in research, conservation and survey planning.

Task 1: Strengthening existing opportunistic recording of bees and hoverflies

Task 1.1: Improving robustness and understanding of population trend estimates from opportunistic records

Opportunistic records of bee and hoverfly species are collated by the Bees, Wasps and Ants Recording Society (BWARS) and the Hoverfly Recording Scheme (HRS) and used to estimate trends in the status and occupancy of species over time. Occupancy refers here to the area (number of 1 km grid cells across the UK) over which each species was found, hence measures changes in species' distributions.

a) The New Pollinator Indicator

The UK Status of Pollinating Insects Indicator is produced alongside other UK Biodiversity Indicators and funded directly by JNCC (https://jncc.gov.uk/our-work/ukbi-d1c-pollinating-insects/).The first Indicator published in 2015 was based on modelled trends for 213 wild pollinator species. The 2020 update of the Indicator describes changes in distribution of **377** bee and hoverfly species. Only species for which reliable trends could be estimated were included; hence species with fewer than 50 total records across the time period were excluded from the Indicator. Whether an individual species is increasing or decreasing is defined by its rate of annual change across the time period considered.

The increase in species for which robust trends can be generated has been made possible by the inclusion of additional data to 2017 for hoverflies and to 2018 for bees, as well as improvements to the modelling approach. The current indicator therefore covers the period 1980-2018 (bees) and 1980-2017 (hoverflies). This indicator is not directly comparable with the previous Indicator published in 2019 due to these increases in records and species. An additional 12 species of bee and 6 species of hoverfly now meet the criteria for inclusion, whereas 6 species have been removed due to taxonomic issues, resulting in a net increase of 11 species of bee and 1 species of hoverfly.

Between 1980 and 2017, **19% of the 377 species analysed became more widespread** (7% showed a strong increase at above a threshold of +2.8% per annum) and **49% of species became less widespread** (24% showed a strong decrease at below a threshold of -2.7% per annum, equating to a decrease in occupancy of -50% over 25 years). Over the short term, a greater proportion of species were increasing between 2012 - 2017 (46%, with 34% exhibiting a strong increase) than decreasing (43%, with 36% exhibiting a strong decrease). As expected, species show considerable variation through time and care is needed when interpreting average trends across species with contrasting ecological traits (see section b).

When combined into a composite average trend across all species, occupancy or **distribution size declined by 30% between 1980 and 2017** and the pollinator Indicator was therefore assessed as **declining** over this period (the equivalent figure from the 2019 Indicator was a decline of 31%). In the shorter term between 2012 and 2017, average occupancy declined by 2%, and the short-term trend was assessed as little change.

The Indicator is presented separately for bees and hoverflies. Of the 148 wild bee species analysed, a greater proportion of species was declining than increasing, 42% and 24% respectively between 1980 and 2018 (Figure 1). Over the short term, 40% of species were increasing and 44% declining. Averaged across bee species, the bee index was relatively stable up to 2006, before undergoing several years of decline. From 2014 onwards, there was evidence of a recovery, however, the bee index in 2018 was estimated to be 11% lower than in 1980.

With regard to hoverflies (Figure 2), the index shows a gradual decline between 1987 and 2000. In 2000, the composite index was approximately 74% of the value in 1980. The trend was relatively stable up to 2009, before declining again, ending 41% lower than the value in 1980. A greater proportion of hoverflies have declined than increased in occupancy over both the long and short term (1980 to 2017: 55% decreased and 15% increased; 2012 to 2017: 49% decreased and 44% increased). It is not clear why hoverflies show a different trend to bees, although differences in the life cycle will mean they respond differently to weather events and habitat change.

b) Further understanding trends and patterns of change (including at country level)

Understanding of these trends has been aided by PMRP discussions with scheme organisers where the species-by-species model outputs have been examined in detail. A parallel exercise to produce a “Red List for the aculeate Hymenoptera”, supported by Natural England (currently under final review), has also furthered our understanding of the species-specific trend estimates since it allows for use of multiple approaches to assessing change, along with expert opinion, to inform categories of status or threat.

The UK Indicators are presented at UK level, however under this Task we have derived country-level trends for England, Wales and Scotland. Initial analyses suggest that country-specific trends are tractable, particularly for widespread species with sufficient records in a given country that pass a given ‘precision threshold’ (indicating a “useable” model for individual species). The country level indicators are presented in the PMRP final report from Phase 1 (2017- 2018 surveys), but the preliminary statistics for Scotland and Wales suggest that declines have been less severe than in England.

For 2020, we have begun to look more closely at species-specific model outputs at country level, specifically to assess regional model robustness to known potential causes of bias (e.g. targeted or low levels of recording). The scope of this work is still being clarified in the context of other re-allocated areas of the PMRP budget, and in the light of covid restrictions on other activities.

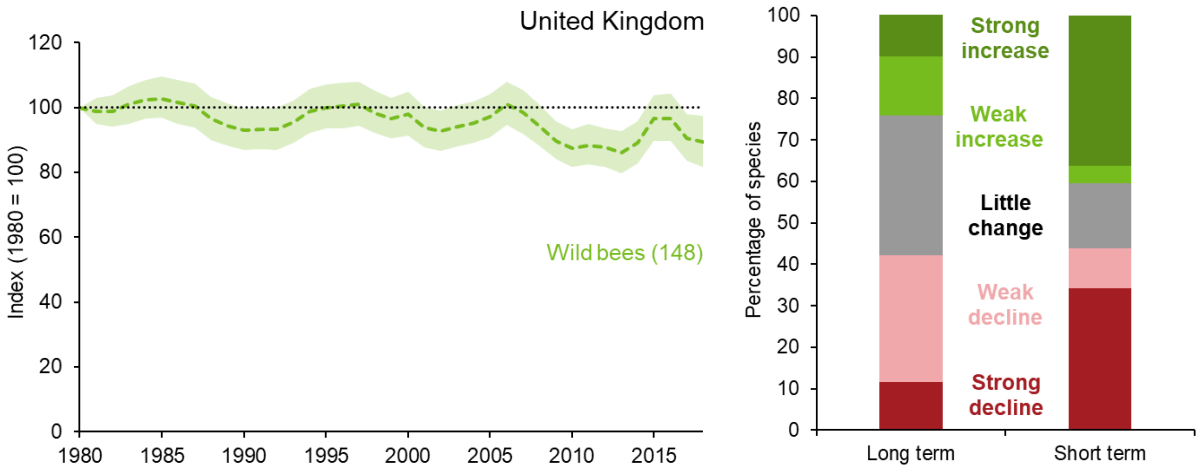


Figure 1. Change in the distribution of pollinating wild bee species (n = 148) in the UK between 1980 and 2018. The shaded region is the 90% credible intervals of the annual occupancy estimates and represents the uncertainty surrounding the annual estimates. The solid line illustrates the rescaled indicator value. The proportion of pollinating wild bee species in each trend category is based on the mean annual change in occupancy over both a) the long-term (1980-2018) and b) the short-term (2012-2018).

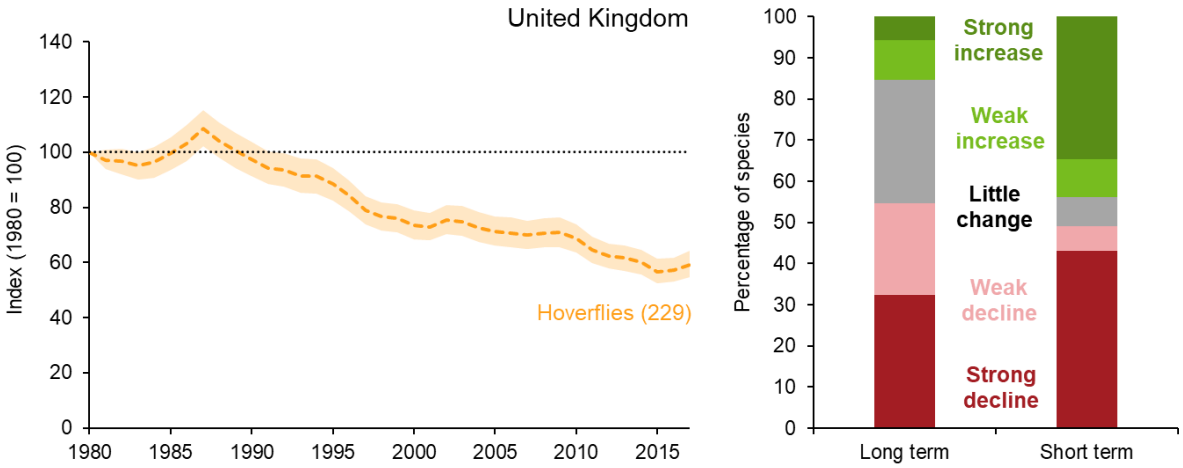


Figure 2. Change in the distribution of hoverfly species (n = 229) in the UK between 1980 and 2017. The shaded region is the 90% credible intervals of the annual occupancy estimates and represents the uncertainty surrounding the annual estimates. The solid line illustrates the rescaled indicator value. The proportion of hoverfly species in each trend category is based on the mean annual change in occupancy over both a) the long-term (1980-2017) and b) the short-term (2012-2017).

Figures taken from Gary D. Powney, Colin A. Harrower, Charlotte Outhwaite & Nick J.B. Isaac (2020) UK Biodiversity Indicators 2020: D1c. Status of pollinating Insects Technical background document. https://data.jncc.gov.uk/data/3de3abe1-d7d1-417e-9684-1348dd8b9a5a/UKBI2020-TechBG1-D1c-A.pdf

Task 1.2: Increasing capacity for data flow and record verification

The current capacity for verifying species records within BWARS and HRS is limited by the small number of dedicated volunteer scheme organisers with sufficient taxonomic expertise, and the lack of a clear route by which potential new verifiers can be identified and mentored. BWARS have identified the lack of suitable online tools for training and assessing verifiers as one of the barriers to recruiting more volunteers into the system, especially for building the capacity to verify photographic records.

Through work with Hymettus (project partners and expert entomological consultants) in 2018, we developed a detailed specification for the data structures needed to implement an **online training tool** that will capture the level of expertise of potential verifiers, allowing them to be matched to the appropriate sets of records to assist with verification of images.

During 2020 further development work has been carried out on the verification tool. We had intended to arrange some in-person workshops to test the new tool in its prototype form, but this has not been possible due to covid restrictions. However, we have been able to take advantage of updates made in summer 2020 to the photo licensing system within iRecord, which has released approximately 22,000 photos of bees to date, thanks to iRecord users choosing to make their photos available via an appropriate Creative Commons licence. A specification has now been developed to allow an API to be put in place that will enable these photos, along with the required information on date, location and verification status, to be shared with the verification tool. In addition, further work has been carried out by Hymettus with input from UKCEH staff on the statistical methods underpinning the analysis of the data captured by the verification tool.

Moving to a statistically driven technological approach over a direct-to-person training method (as currently operating within most NSS) provides a way to achieve a far greater coverage for the same initial outlay. By increasing the pool of available verifiers with known taxonomic expertise we will ultimately improve the flow of data available for modelling trends. This system will also provide a clear and more quantitative route for people who wish to increase their identification skills and so contribute to verification at levels that will increase the capacity of recording schemes such as BWARS.

Task 2: Flower-Insect Timed Counts: Simple systematic survey collecting data on abundance and flower visitation of pollinators

The name **Pollinator Monitoring Scheme – PoMS** describes the two main surveys taking place under Tasks 2 and 3 of the Pollinator Monitoring and Research Partnership.

Flower-Insect Timed Counts - **FIT Counts** - are simple systematic surveys collecting data on abundance of flower visitors and plant-pollinator interactions across a variety of habitats, and have been developed with the aim of encouraging a wide range of people to get involved in pollinator monitoring. To take part, recorders are asked to spend ten minutes counting all the insects that land on a particular flower species within a 50cm square, recording these to a broad species group (e.g. honey bees; bumblebees; hoverflies; other flies; etc).

The FIT Count approach, guidance documentation (in English and Welsh), three video guides (also on YouTube) and supporting data infrastructure within iRecord (www.brc.ac.uk/irecord/poms-fit-count) were developed and tested during 2017 and 2018, and based on positive feedback from participants, we have continued with this approach.

During the first lockdown period of 2020, which coincided with the start of the FIT Count survey on 1st April, FIT Counts were permitted to continue *in gardens and private property only*. This situation was under regular review with funders and PMRP partners, and from 5th June, in line with changing guidelines for outdoor activity in England, Scotland, Wales and N Ireland, public FIT Counts were permitted to move *beyond gardens and private property to the wider countryside and public spaces*. Due to the need for maintained social distancing and limited travel, any face-to-face training or group-based activities involving FIT Counts were not achievable, but a number of opportunities for online promotion and outreach were taken.

As well as FIT counts submitted by the wider public (here 'public' FIT counts), FIT counts were carried out as part of the 1 km square protocol (Task 3) in order to help calibrate the data and increase sample sizes ('1 km' FIT counts). Surveyors (including volunteers) of 1 km squares carried out a minimum of two counts per survey visit, once surveys were permitted to start in late July 2020.

Preliminary Results from 2020 FIT Counts as at October 2020

A total of nearly 2,000 FIT Counts have been submitted to iRecord by members of the public during 2020. Removing the few counts submitted from the Channel Isles, counts made after the end of September and counts from 1 km surveys wrongly entered in the 'public' FIT Count, but including counts from Northern Ireland, this gives a total of 1,838 counts (submitted up to 15th October). This is more than double the number of counts received in 2019. See Figure 4 for a map of 2020 count locations and Table 1 / Figure 3 for a summary and comparison with the 2018 and 2019 counts.

Table 2 shows the distribution of counts by country. As in previous years the greatest number of counts has come in from England (1,440) with a high concentration around the Peterborough area representing those involved in "Jimmy's Big Bee Count" for the Channel 4 series. Large gaps in coverage remain in the SW of England, and in large areas of Wales, North of Scotland and Northern Ireland. Not all of these gaps are currently filled by FIT Counts undertaken in 1 km squares (Figure 7).

A total of 18,970 insects was counted[3], at an average of 10.3 insects per 10-minute count. Bumblebees, honeybees, hoverflies, other flies and 'small' insects were most prevalent. It will be important to explore patterns of change at insect group level in the detailed analyses of these data.

[3] *Note that these data are unvalidated and therefore represent preliminary results that may be subject to change after formal checking and validation*

Public FIT Counts UK	2018	2019	**2020**
Number of FIT counts submitted	584	809	1,838
Total number of insects counted	5,452	10,651	18,970
Mean insects per count	9.3	13.2	10.3

Table 1. Summary of FIT Counts submitted to iRecord by members of the public 2018 and 2019 and 2020.

Figures in this table exclude the few counts submitted from the Channel Isles, and counts made after the end of September. 2019 and 2020 figures include counts submitted from the Isle of Man. *2020 figures are unvalidated* and include counts submitted from N Ireland (see Table 2).

Public FIT Counts 2020 by country – *preliminary results*	Number of counts	Total number of insects counted	Mean insects per count
England	1,440	15,970	11.1
Scotland	210	1,332	6.3
Wales	91	755	8.3
N Ireland *	80	722	9.0
Isle of Man	17	191	11.2
UK Total	1,838	18,970	10.3

Table 2. FIT Counts submitted in 2020 (as at 15th October) and broken down by country. *FIT Counts from N Ireland include 58 submitted through the All-Ireland Pollinator Plan and 22 submitted through PoMS via iRecord.

Note that these data are unvalidated and therefore represent preliminary results that may be subject to change after formal checking and validation.

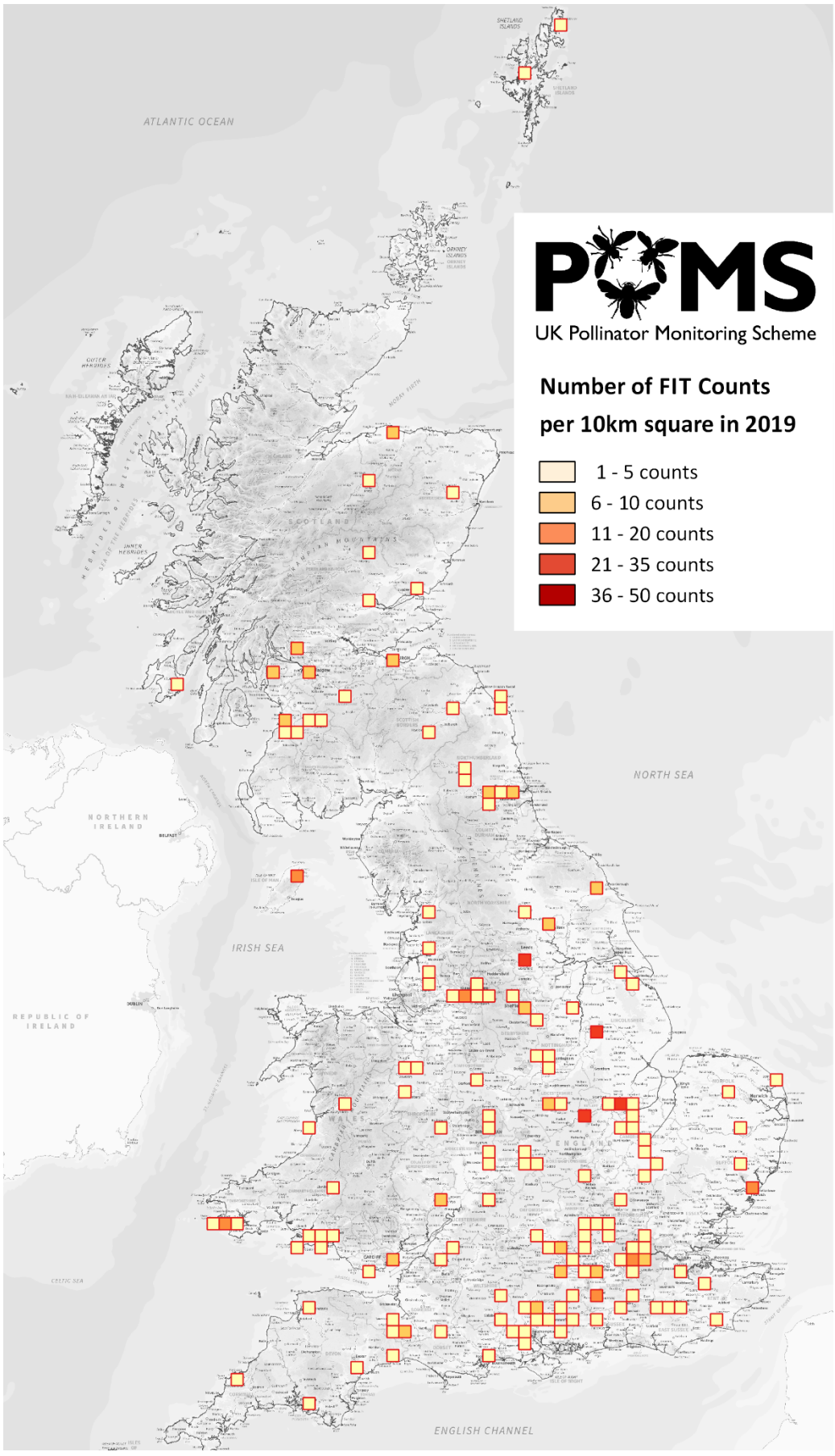


Figure 3. Map showing locations of the 809 Flower-Insect Timed Counts (FIT Counts) carried out by members of the public from April – September 2019 and submitted to iRecord as at January 2020.

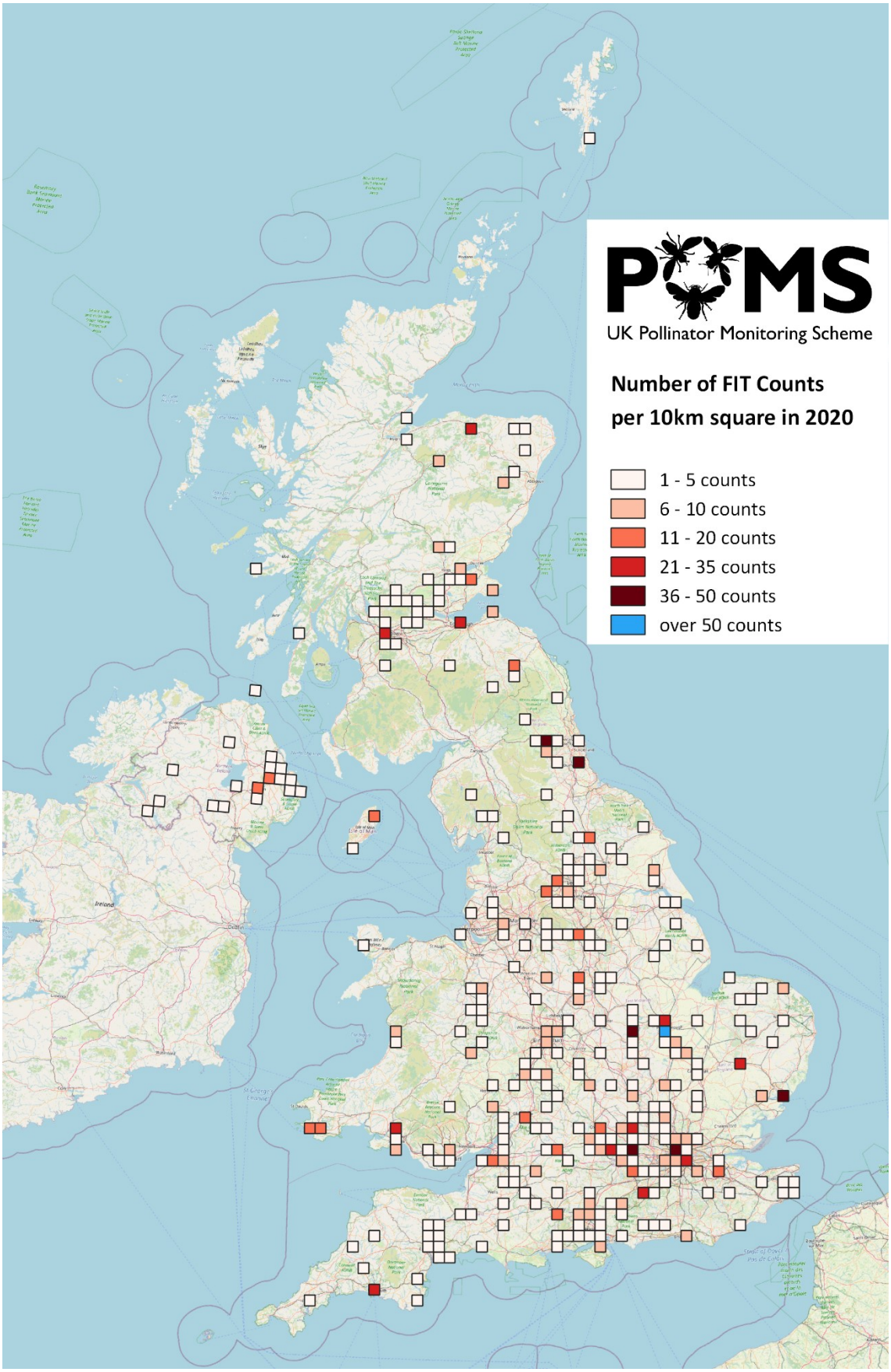


Figure 4. Map showing locations of the 1,838 Flower-Insect Timed Counts (FIT Counts) carried out by members of the public from April – September 2020 and submitted to iRecord as at 15th October 2020. Note these are *preliminary results that may be subject to change after formal checking and validation.*

Figure 5a shows the change in number of FIT Counts by month, comparing 2020 with 2019. In April 2020, five times more counts were undertaken than in April 2019, going down to double the number in May and up again to three times the number in June. We aim to examine patterns of volunteer involvement in these data, for example whether the sustained high numbers in 2020 are from 'new' FIT Count recorders who continued submitting counts through the year, or from existing recruits who had already submitted to PoMS in 2019 but undertook many more counts in 2020.

Although we have seen an increase in number of counts, it appears the average visitation rate (for total insects 2020) has not changed significantly since 2019, except for a potential dip in July and August 2020 (Figure 5b).

70% of counts were conducted in gardens in 2020, as compared with 48% in gardens in 2019, again reflecting the restrictions that were in place up until July meaning that FIT Counts were only permitted in gardens and private property.

Target flower species receiving the most counts in 2020 (of those entered up to 15th October) were Lavender, Dandelion, Buddleja and Buttercup. As in 2019, a large number of counts were conducted on "other" flowers and further counts on Ivy are likely to be added. We have produced a series of infographics generated from all public FIT Counts 2017 - 2020 showing the way in which different target flowers attract differing proportions of the various insects groups (Figure 6). These have been made available for partners and volunteers to download and use amongst their networks.

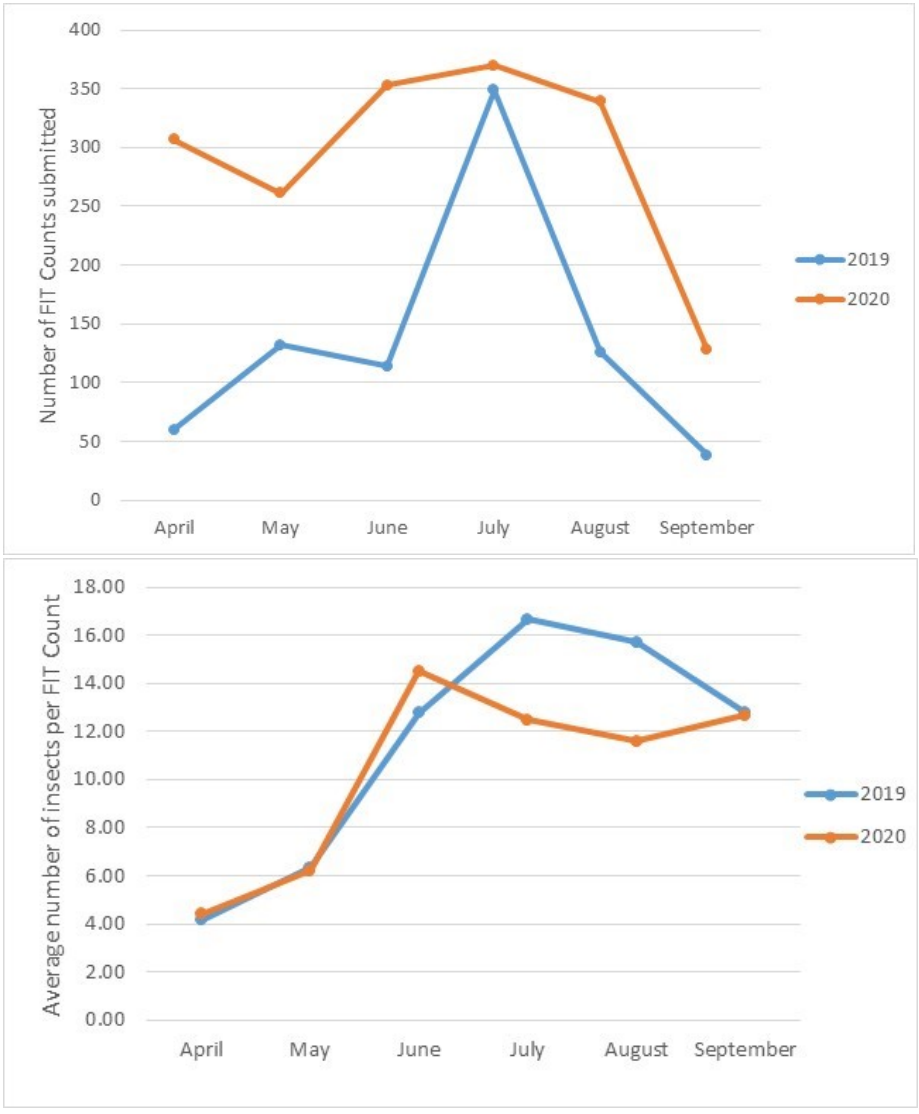
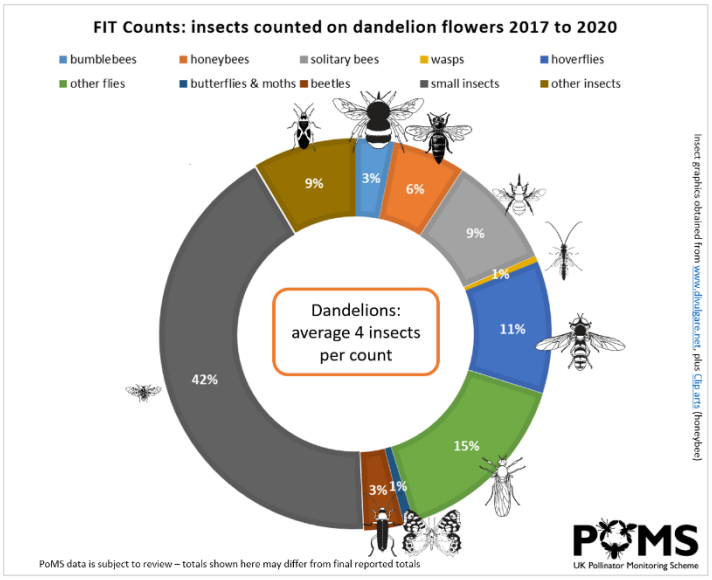


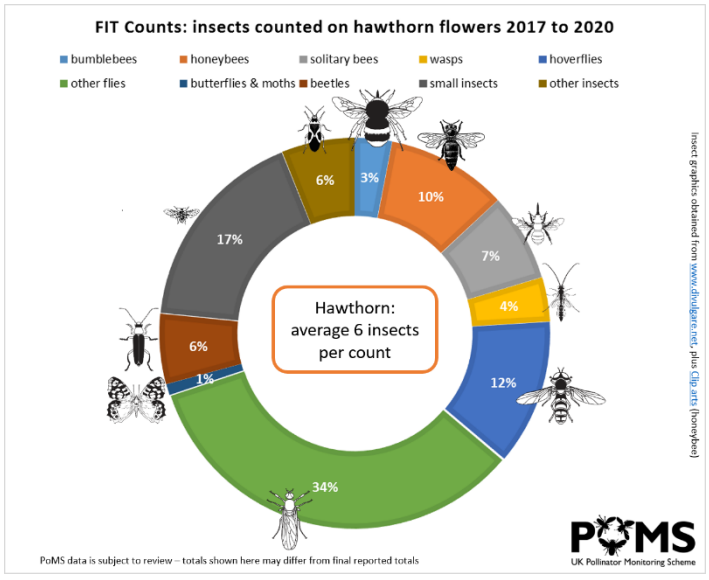
Figure 5 a (top) Number of 2020 FIT Counts by month in 2019 and 2020;

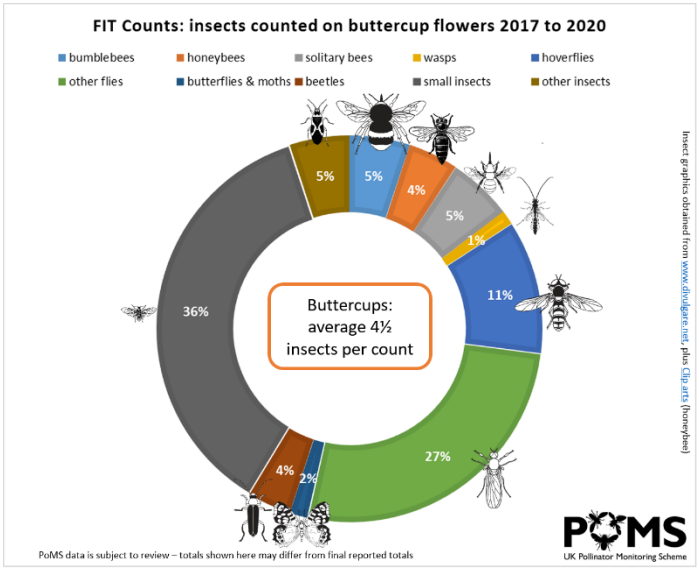
b (bottom) Average total insects per FIT Count in 2019 and 2020.

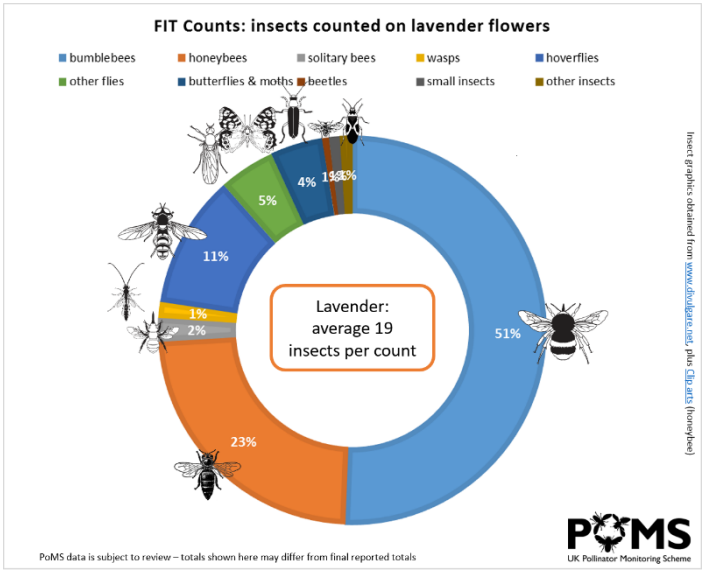
Figures include counts submitted from the Isle of Man but not from Northern Ireland.

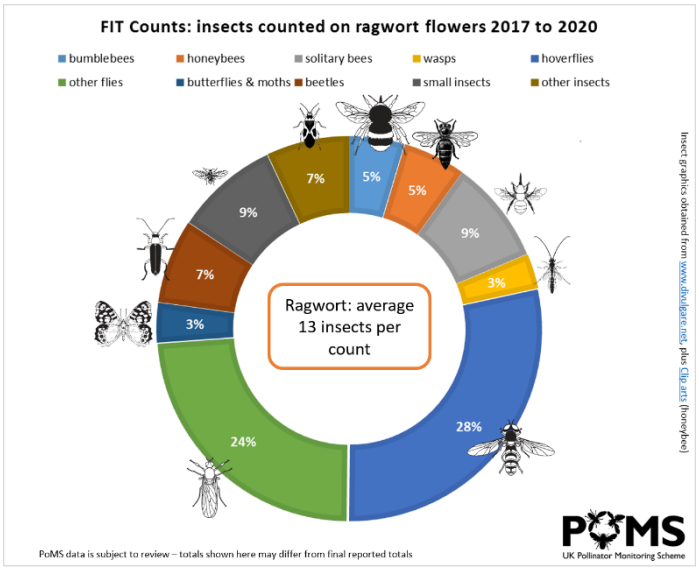
Note that these data are unvalidated and therefore represent preliminary results that may be subject to change after formal checking and validation











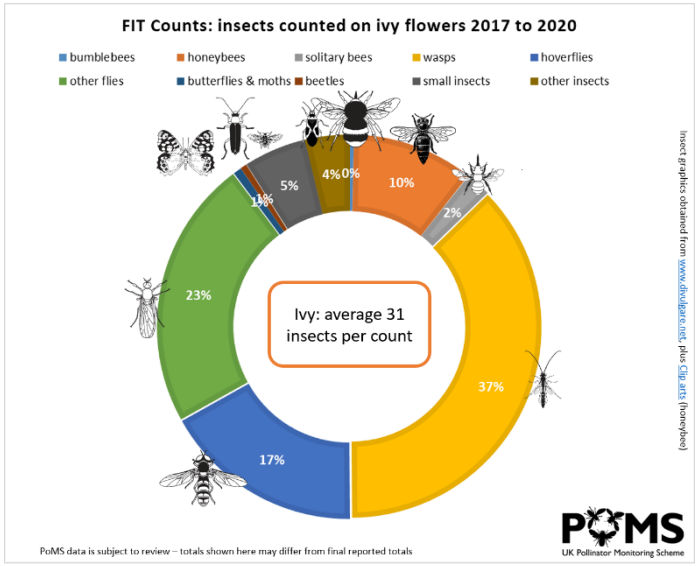


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Figure 6. Average number of insects per public FIT Count, by insect group, for six target flowers 2017-2020.

Task 3: PoMS 1 km square surveys: an intensive systematic survey of pollinators and floral resources from a network of 1 km squares

This survey has been set up to monitor the species richness and abundance of pollinating insects across a network of 75 randomly selected 1 km squares stratified across agricultural and semi-natural landscapes. All PoMS survey squares in England (36) and Scotland (22) are also included within the National Plant Monitoring Scheme (NPMS www.npms.org.uk), to benefit from co-location with their invaluable long-term data on wild plant species and changes in habitat condition. All survey squares in Wales (17) are part of the Welsh ERAMMP wider environmental monitoring framework.

Task 3.1: Field sampling 2020

The PoMS 1 km square protocol involves a set of five pan trap stations (each hosting 3 coloured bowls filled with water) being set out along a diagonal of each 1 km square and left for 6 hours, during which time the surveyor collects data on floral resources and habitats surrounding the pan traps and undertakes at least two 10-minute FIT Counts. The protocol is intended to be repeated on 4 survey visits to each square between late April and September.

As a result of national-level lockdown restrictions in place at the start of the normal survey period, and in line with other volunteer-led biodiversity monitoring schemes, the 1 km surveys were initially suspended. This resulted in no surveys being carried out between April and mid-July. On 16th July 2020, approval was confirmed from all Funders to allow 1 km square surveys to recommence in England, Scotland and Wales from late July. Communications clearly stated that surveys were to be carried out only with the full consent of landowners and in line with social distancing and current guidance appropriate to each country. All project Risk Assessments were updated to include covid-specific measures and to ensure that volunteers and PoMS staff were provided with sufficient guidance and information to carry out their surveys safely.

During 2020 a total of 91 survey visits were conducted across 62 squares between late July and late September (Table 3). 33 squares received one survey and 29 squares received two surveys, with a mean of 1.2 surveys per square overall. No landowners refused access on the basis of covid-19 concerns but four across Wales and Scotland could not be contacted to confirm permission. Surveys were conducted either by volunteers (see Task 3.4) or by one of six members of the PoMS team covering each region. Of the 13 squares not visited due to either lockdown and/or access restrictions, three were in England, four in Scotland and six in Wales (all but two of these squares being allocated to volunteers).

Country	# PoMS 1km squares	# survey visits				# samples (6hr pan traps)				# squares surveyed				Mean surveys per square			
		2017	2018	2019	**2020**	2017	2018	2019*	**2020**	2017	2018	2019	**2020**	2017	2018	2019	**2020**
England	36	59	93	113	55	295	465	565	275	36	33	35	33	1.6	2.6	3.1	1.5
Scotland	22	35	32	61	24	175	156	305	120	19	17	22	18	1.7	1.5	2.8	1.1
Wales	17	33	22	62	12	165	110	310	60	17	15	17	11	1.9	1.3	3.6	0.7
GB Total	75	127	147	236	91	635	731	1180	455	72	65	74	62	1.7	1.8	3.1	1.2

Table 3. Summary of PoMS 1 km square surveys conducted by volunteers and UKCEH PoMS team 2017 - 2020.

Task 3.2: Sample processing and identification (a summary of 2019 findings and 2020 progress)

Since our last report in January 2020, a total of 2,243 bee and 2,071 hoverfly specimens sampled in the 2019 pan traps have been identified by a team of three taxonomists. As in 2018, their determinations were quality assured by obtaining second opinions on a random subset of specimens during an end of season "lab day" hosted at UKCEH in early March (just before the national lockdown), with an additional focus on difficult species or species pairs.

All other captured specimens were identified to group level (e.g. all non-hoverfly flies as 'other flies'; solitary, social and parasitic wasps; butterflies; moths; sawflies; a group for very small insects <3mm; and 'other insects'), counted and archived in 99% ethanol in their original sample tubes at -20degC for potential downstream analysis. These samples have been catalogued within iRecord alongside their respective survey datasets.

In 2019, a national GB average of 11.8 bee and 8.9 hoverfly species (including aggregate species[4]) were sampled per 1 km square. The figures by country are: England 14 bee species and 7 hoverfly species; Scotland 4 bee and 8 hoverfly species; Wales 13 bee and 12 hoverfly species per square. Altogether, we sampled 109 bee and 78 hoverfly species across 71 PoMS 1 km squares in 2019.

It is important to note that these average species figures per square do not include the three squares which were surveyed in 2019, but for which no data were received from the volunteers. It should also be noted that while 2019 saw the highest number of survey visits and species recorded to date for PoMS, not all squares received the same number of surveys (Table 3), with a greater number of surveys through the season increasing the likely number of species sampled. Due to this unequal survey effort, a metric reporting the average number of *species per survey visit* may be more accurate than species per 1 km square when comparing species richness between countries and squares.

The total number of species (or species aggregates) sampled in pan traps on the PoMS 1 km square network between 2017 and 2019 is now at around 117 bee and 94 hoverfly species.

For 2020, all 455 samples received from the pan trap surveys have been sorted in the UKCEH lab, giving a total of 736 bee and 850 hoverfly specimens that are now with our small team of taxonomists for identification. Of these, a small number of individuals of easy to recognise species (e.g. honeybees, *Apis mellifera*) have been identified by UKCEH staff, to maximise time of the taxonomists on more challenging species. We aim to host another lab day for quality assurance checking of determinations in early 2021, but if this cannot be achieved in person then the process will be conducted remotely via exchange of material by post.

Task 3.3: Links with crop pollination

This Task aims to investigate the potential to use data collected using the PoMS 1 km survey protocol to track populations of key crop pollinators. We are utilising a recently developed comprehensive list of important UK crop pollinating bees for a number of UK crops. Combining crop visitor datasets from across the UK with ecological information, the dominant crop flower visiting bee species have been identified, as well as other species that could be important crop pollinators in the UK. Establishing such a list of crop pollinating bees is important for practitioners and policy makers to support crop pollination, conservation and species monitoring. A manuscript entitled 'Using ecological and field survey data to establish a national list of the wild bee pollinators of crops' which details the approach and presents the species lists has been submitted for publication and is currently in review.

We aim to examine the abundance and distribution of these crop pollinating species from 2019 pan trap data collected in PoMS survey squares. By comparing this with the spatial extent of different crops within the same PoMS squares, based on the UKCEH LCM+Crops maps, we will explore possible spatial mis-matches between pollinators and crops. This work has been delayed during 2020, however progress has been made with extracting data from the LCM+Crops maps on 2018 and 2019 crop coverage in and around the PoMS 1 km squares and sharing this (under Licence) with the University of Reading. Coverage of flowering crops within PoMS squares is limited and variable (for example there were 14 squares growing

[4] Where species within a taxon are difficult to separate taxonomically (e.g. the white- and buff-tailed bumblebees *Bombus terrestris* and *Bombus lucorum/magnus/cryptarum*) they are grouped to form a species aggregate.

oilseed rape in 2018 and 11 in 2019), however may be sufficient to examine the relationship between crop coverage and catches of key pollinating bees in the first instance.

As contact with growers was so limited during 2020, and priorities shifted, opportunities to actively encourage farmers to carry out FIT Count surveys were limited. It is hoped that the new FIT Count app in development and further interactions with growers (e.g. via the recent Bees Needs Champions award event) will facilitate their engagement more in 2021.

Task 3.4: Volunteer recruitment, training and retention

As a citizen science-based structured monitoring scheme with long-term aspirations, PoMS has a clear goal of ensuring that volunteers are well supported and maintaining their interest in order to maximise participation. Communication with volunteers for the PoMS 1 km square survey has continued mainly via a (part-time) Co-ordinator role based at UKCEH, including via a dedicated PoMS email account. Confirmed volunteers are put in touch with their PoMS team mentor to arrange survey visits and discuss the exchange and replacement of equipment.

News that 1 km square surveys could commence in late July 2020, following the easing of government restrictions, was communicated directly to existing volunteers via email, and to the wider network of PoMS supporters and potential new volunteers via the webpage and social media from the accounts of all PMRP partners and funders. This included publication of the map of 1 km squares to highlighting squares still available to be adopted (Figure 7).

As of October 2020, there were trained volunteers allocated across 50 PoMS squares (Table 4; Figure 7). This is a decrease of 4 allocated squares since October 2019. A number of volunteers who were in place in 2020 were not able to carry out surveys (due to lockdown and/or access restrictions) and it is not yet clear how many of these may be willing to resume in 2021. A small number of volunteers have fallen out of touch, so are assumed to no longer be available. Overall, during 2020 we lost volunteers from 15 squares and gained volunteers on 11 squares. Despite these challenges and the complexity of tracking and documenting 'volunteer status', the response from the majority of PoMS volunteers in 2020 has been extremely positive and many appreciated the opportunity to get into the countryside to undertake surveys.

Volunteer status as October 2020	England	Scotland	Wales	Total
volunteer in place, no change	21	11	7	39
volunteer in place, changed	6			6
volunteer in place, new in 2020	2	1	2	5
no volunteer, 2019 volunteer unable to continue	5	4		9
no volunteer, no change	2	6	8	16
Total	**36**	**22**	**17**	**75**

Table 4. Summary of volunteer status on PoMS 1 km squares as at October 2020.

To overcome one of the perceived barriers to uptake (travel distance to selected squares), resources were requested to offer expenses (mileage) to volunteers for travel to 1 km squares, administered through the UKCEH non-employee expenses system. This opportunity was communicated to all 1 km volunteers at both the beginning and end of the survey season, although expenses claims were received through the system from only around four volunteers in 2019 and three volunteers in 2020.

As a further means of reporting scheme findings to volunteers and receiving feedback, we organised a PoMS volunteer webinar for late March 2020. This was open to anyone, including current and potential volunteers, and had 54 attendees. It included presentations from team members and a current 1 km square volunteer. We used the on-line question/chat facility to conduct a moderated Q&A, and a recording of the webinar, together with the slides and Q&A transcript, were made available afterwards.

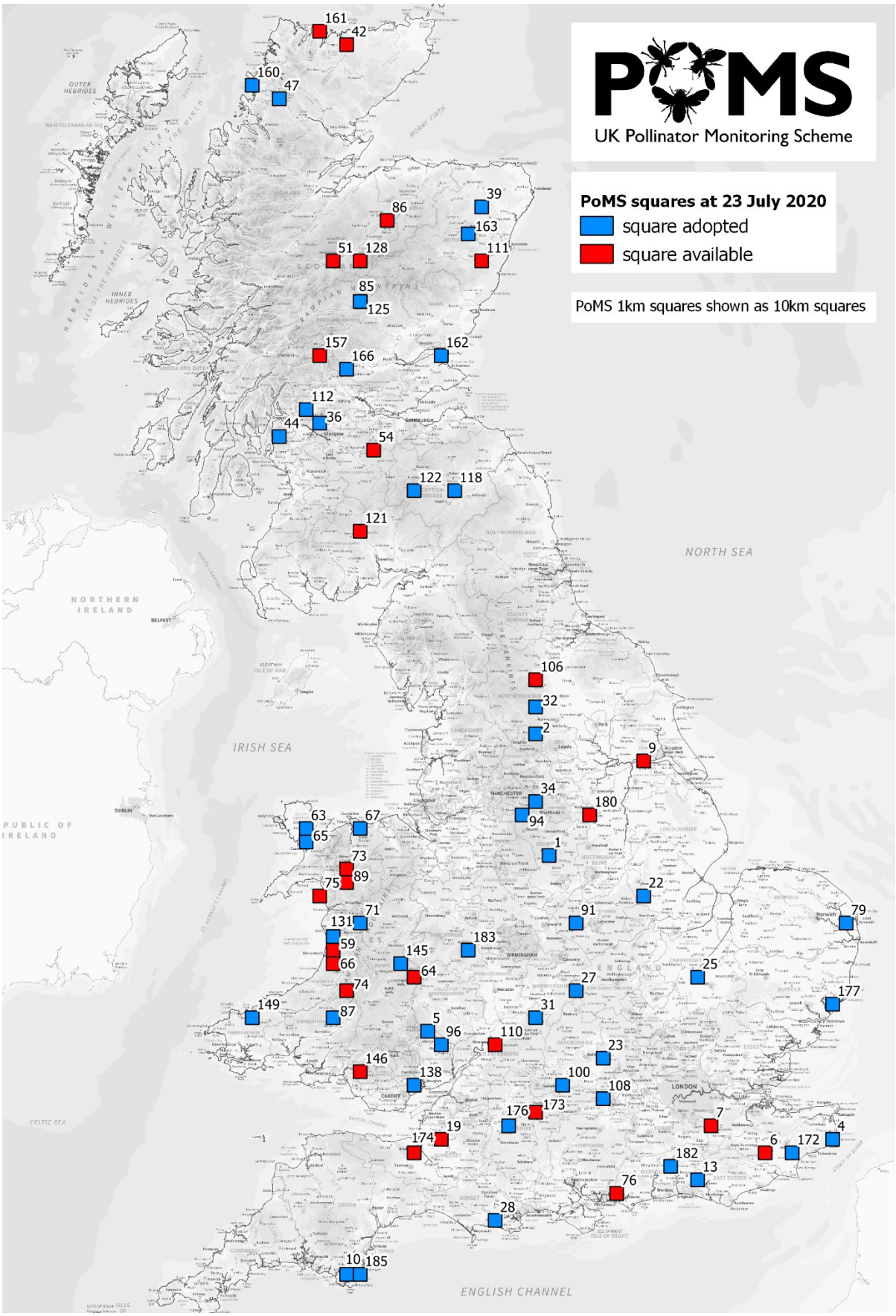

Figure 7. Allocation of PoMS 1 km squares to volunteers, showing position in July 2020, at point of surveys commencing.

Task 4: Data management, integration and modelling

Task 4.1: Data management, sharing and access

Data from the public FIT Counts and all data from the 1 km square surveys is being stored securely in the Indicia data warehouse at UKCEH. Data is entered by volunteer recorders and UKCEH surveyors via forms developed within the iRecord online recording system.

Insect specimen data from the 1 km pan trap samples is also being added to the iRecord forms, at species level for the bees and hoverflies and at species-group level for the other insects. This species data is not being made publicly visible within iRecord, so as to respect agreements with landowners. Species records generated by PoMS surveys from 2017 and 2018 have been shared with the relevant recording schemes (BWARS and HRS) following full verification, for contribution to the wider pool of pollinator occurrence data.

Verified species data from 2019 was also shared at the 1 km square resolution with the relevant landowners and volunteers for each 1 km square before the start of the 2020 survey. This took the form of a 1-page summary report containing a list of the insect and plant species recorded in their square, along with a high level summary of the national level findings across all PoMS squares. The reports have provided an effective means of engaging people and maintaining their interest through the provision of tailored feedback for their 'local' square, as well as 'benchmarking' that information against wider PoMS findings.

Full systematic datasets from the 2017 and 2018 surveys are being finalised and metadata prepared for publication under Open Government Licence (and in anonymised form) with the NERC Environmental Information Data Centre. They will be published with DOI links before the end of the current project in March 2021.

Task 4.2: Integrated modelling of structured and unstructured species record data

Under Task 4.2 we are working towards improving estimates of species occupancy using both unstructured opportunistic records (as reported in Task 1) and structured data from systematic surveys (as collected under Task 3 and other partner-led schemes). Here, we present a detailed analysis of bumblebee data from both sources that has been conducted in the current reporting period.

Occupancy detection models provide a robust framework to estimate species trends from imperfect detections. These models estimate the proportion of sites occupied by a species (the occupancy), while simultaneously estimating and accounting for variation in detection probability. Data from systematic surveys (Task 3) do not present the same biases associated with opportunistic records, for example uneven effort across surveys. Therefore data from systematic sampling has the potential to add value to the current occupancy modelling approach by reducing uncertainty in estimates of species' occupancy and improving the spatial resolution or reducing patchiness of current recording activity.

Bayesian occupancy detection models were fitted to the unstructured occurrence data from 2010 to 2016 for *Bombus* species from the Bees Wasps and Ants Recording Society (**BWARS**) and to the structured transect data from the Bumblebee Conservation Trust (BCT) **BeeWalk** from the same time period (integrated model). In order to keep the model simple, we treated the abundance data from BeeWalk as presence/absence data. The models were run for the 21 species that were present in both datasets. The same model was also fitted to the unstructured BWARS data only (BWARS-only occupancy model) so that we could compare trends in occupancy estimated by the two models. To quantify the degree of uncertainty around the occupancy estimates from the two models, we used the precision of the occupancy parameters and of the year effect on the logit of occupancy. Precision is calculated as the inverse of the parameter's standard deviation (1/standard deviation), so the higher the precision, the lower the uncertainty. Models for 15 of the 21 species completed and showed a reasonable degree of convergence (Table 5). Here we present the results for these 15 species.

Table 5. List of species for which models completed.

Species	
Bombus barbutellus	*Bombus monticola*
Bombus bohemicus	*Bombus muscorum*
Bombus campestris	*Bombus pascuorum*
Bombus distinguendus	*Bombus pratorum*
Bombus hortorum	*Bombus ruderatus*
Bombus hypnorum	*Bombus rupestris*
Bombus jonellus	*Bombus soroeensis*
Bombus lapidarius	*Bombus sylvestris*

The BWARS data accounts for more than 90% of sites (1 km squares) visited and more than 80% of the total records going into the integrated occupancy models.

Table 6. Number of sites and records that contributed to the models from the two datasets.

	Occupancy model	Integrated model
Records	32594	38975
Sites	10592	11315

Despite the relatively small number of additional sites and records from the BeeWalk data (Table 6), the results show that the value added by the standardised data goes beyond simply having more records. In some cases, the integrated model for a species converged after 200000 iterations, while the BWARS-only occupancy model showed lack of convergence after the same number of iterations – *Bombus bohemicus* is one example (Figure 8). This might be explained by the fact that the number of total records of this species doubled with the inclusion of the BeeWalk data (188 records of *Bombus bohemicus* in BWARS data and 198 records in BeeWalk data).

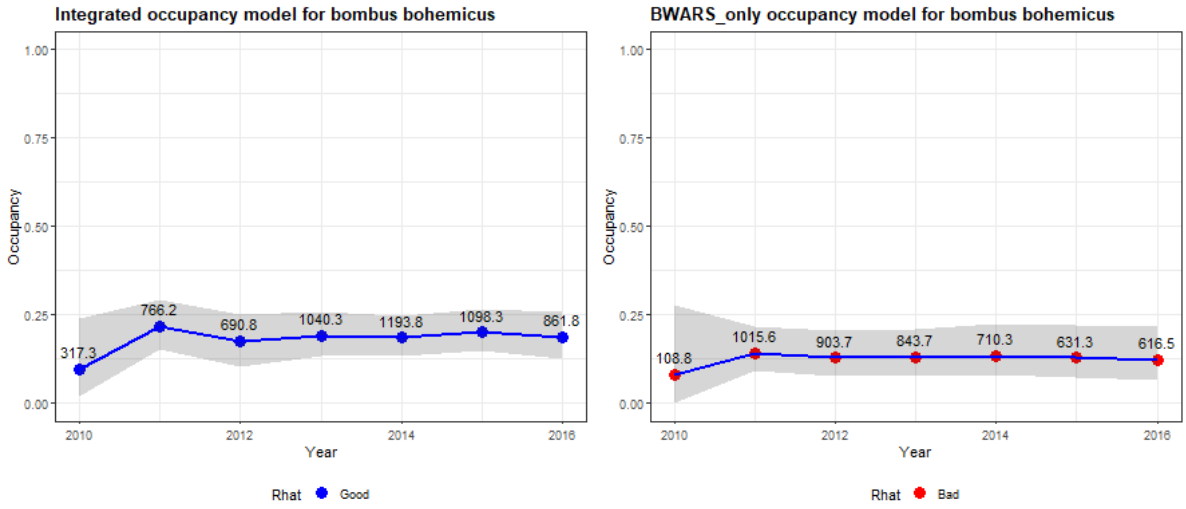

Figure 8. Occupancy trend estimated by the integrated model (left) and BWARS-only occupancy model (right) for Bombus bohemicus. Occupancy is the proportion of all sites visited that are occupied by the species. The colour of the points indicates the Rhat value and therefore convergence: blue for Rhat < 1.1 and red for Rhat > 1.1. Shaded areas are 95% Credible Intervals. Numbers are the precision with which the parameter is estimated.

In most cases, both models converged and the integrated occupancy model estimated occupancy with higher precision, as is the case with *Bombus rupestris*, where the precision of the occupancy parameter

from the integrated model is almost double that from the BWARS-only occupancy model (Figure 9). In this case, while both models estimate a similar level of decline overall (about 50% over the 5-6 years) the BWARS only model may be unable to reject the null hypothesis of no change due to its reduced precision.

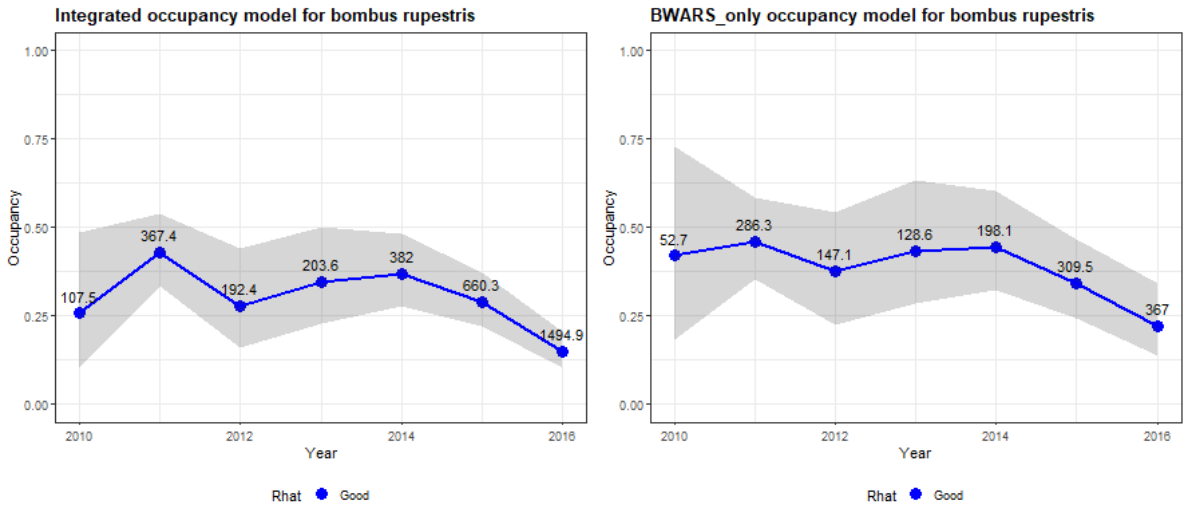

Figure 9. Occupancy trend estimated by the integrated model (left) and occupancy model (right) for Bombus rupestris. Occupancy is the proportion of all sites visited that are occupied by the species. The colour of the points indicates the Rhat value and therefore convergence: blue for Rhat < 1.1 and red for Rhat > 1.1. Shaded areas are 95% Credible Intervals. Numbers are the precision with which the parameter is estimated.

This was generally true for most, but not all species. For example, the models for *Bombus pascuorum* did not show any substantial difference in the precision of occupancy (Figure 10). *Bombus pascuorum* is a common widespread species, which has 7673 records in the BWARS dataset and 4316 records from the BeeWalk data. Both models estimated occupancy with a high precision as well as the seasonality of detection (Figure 11).

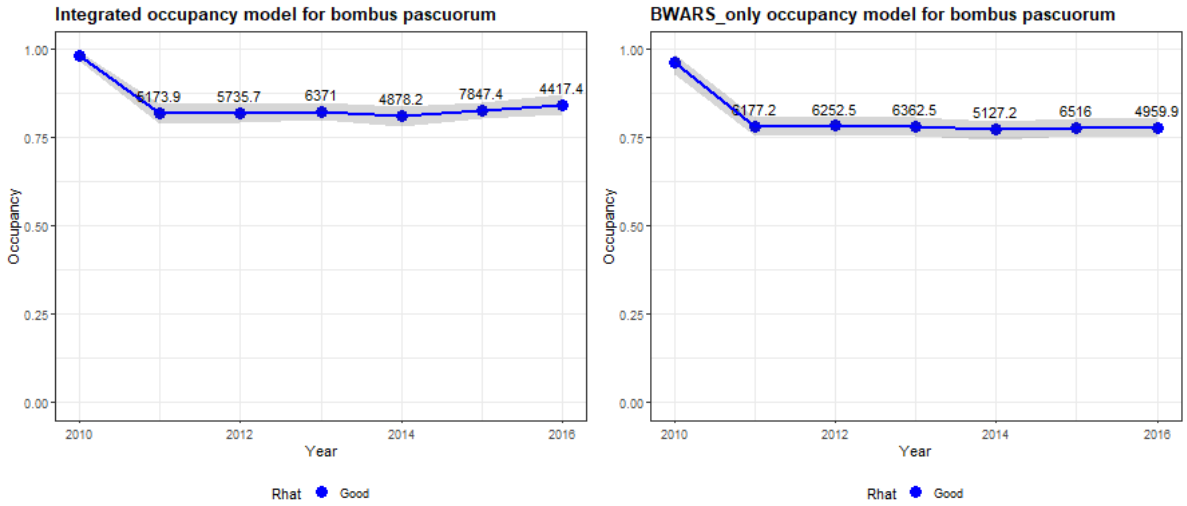

Figure 10. Occupancy trend estimated by the integrated model (left) and occupancy model (right) for Bombus pascuorum. Occupancy is the proportion of all sites visited that are occupied by the species. The colour of the points indicates the Rhat value and therefore convergence: blue for Rhat < 1.1 and red for Rhat > 1.1. Shaded areas are 95% Credible Intervals. Numbers are the precision with which the parameter is estimated.

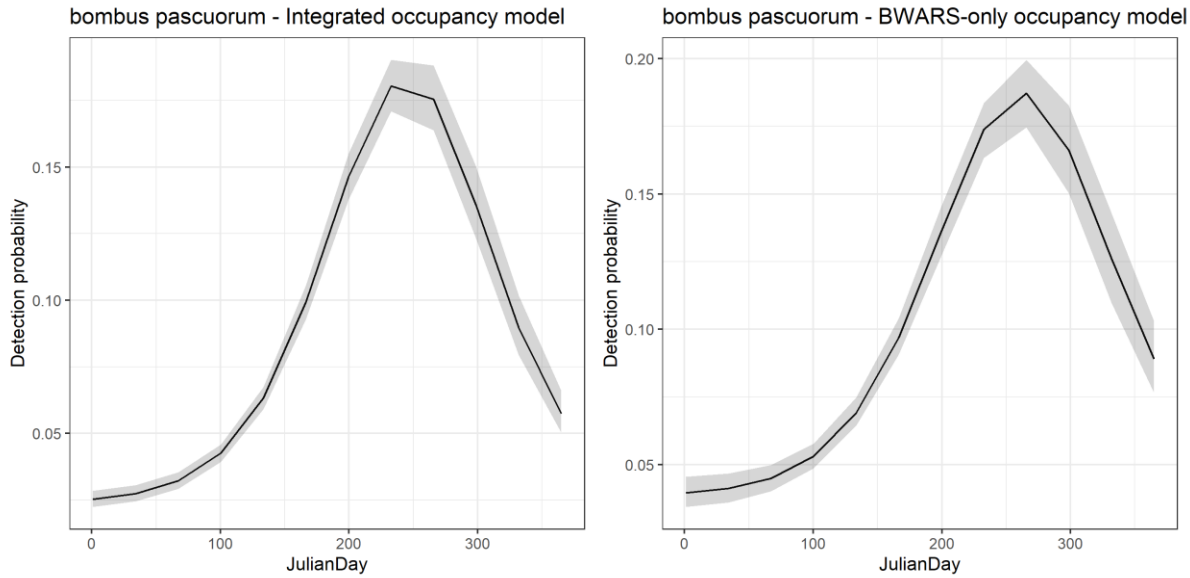

Figure 11. Detection phenology for Bombus pascuorum estimated by the integrated occupancy model (left) and by the BWARS-only occupancy model (right). Day 1 = first of January; Grey shading = credible intervals (95%).

We looked at the correlation between the precision of the year effect on occupancy (on the logit scale) from the integrated occupancy model and that from the BWARS-only occupancy model across all 15 *Bombus* species. The integrated occupancy models generally estimated this parameter with a higher precision compared to the BWARS-only occupancy models, confirming the value of the structured records in decreasing the uncertainty with which we estimate species trends (Figure 12).

Follow-on work will repeat these integrated modelling approaches using a large number of hoverfly species records from the Hoverfly Recording Scheme and structured PoMS 1 km square pan trap datasets.

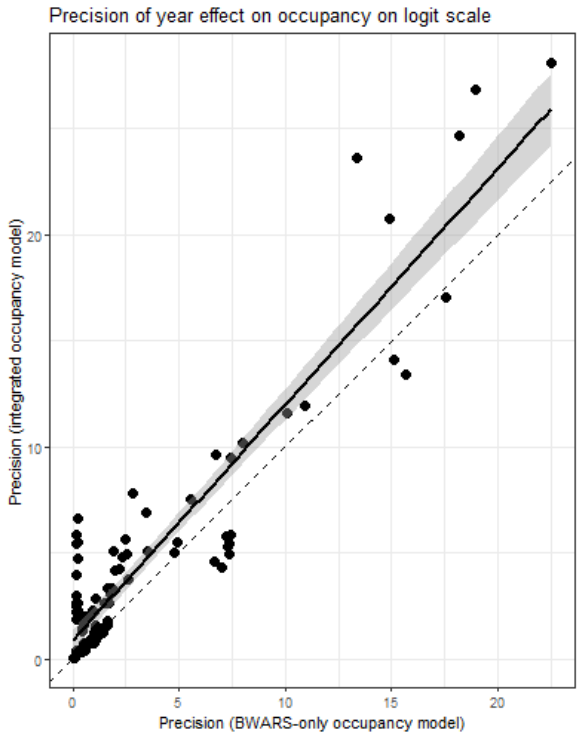

Figure 12. Correlation between the precision of parameter a (the year effect on occupancy on the logit scale) from the integrated occupancy model and the BWARS-only occupancy model. Black solid line is the regression line and grey shaded areas are 95% confidence interval. Dashed line is the 1:1 line. Points above this line are parameters that are estimated more precisely by the integrated occupancy model than by the BWARS-only occupancy model.

Task 5: Pollinator Monitoring Research Advisory Group (PMRAG)

The Pollinator Monitoring Research Advisory Group (PMRAG) was established to help identify opportunities to maximise the value of data generated by the PMRP and PoMS surveys; to highlight knowledge gaps and aim to secure external resources to address these needs. A wider stakeholder group was consulted initially during 2018 to identify overarching priorities for monitoring (in terms of pollinator groups and functions, key drivers and other research gaps). In a workshop in 2018, 14 invited academics joined project team members to review these priorities and discuss gaps and opportunities that should be a priority for the PMRP in the short-medium term.

During 2019, new research and stakeholder collaborations were established, addressing two of the themes that were considered not currently covered by PoMS: a) incorporation of molecular barcoding techniques and b) exploring more from observational FIT counts, here across a wider geographical reach. Below we provide brief updates on these two themes.

In addition, during 2019 and 2020, PMRP members Simon Potts (as Chair), Claire Carvell and Nick Isaac have been working with a group of technical experts for the European Commission on a JRC technical report entitled "Proposal for an EU Pollinator Monitoring Scheme"[5], due to be published in late 2020. This detailed report has drawn heavily on the outcomes of the PoMS design and testing phase and the implementation of current PoMS surveys in order to propose a robust yet realistic scheme that would operate across EU countries.

a) Award from the Defra DNA Centre of Excellence for novel DNA barcoding work on PoMS pan trap samples

A research collaboration with the Natural History Museum was started in 2019 to develop DNA barcoding approaches for individual bee and hoverfly specimens, pollen carried on sampled insects or suspended in the storage ethanol and whole 'bulk' samples of by-catch material from pan traps deployed on the PoMS 1 km square surveys. The aim is to help improve our understanding of insect-plant interactions and of insect community dynamics beyond the bee and hoverfly species that are currently identified from PoMS pan trap samples.

This research project involves three work packages, each of which has been impacted by a delay in the recruitment of a postdoc working at the NHM, followed by restrictions on lab use imposed by the lockdown in March 2020. Progress since July 2020 has been good, and the research team reported to the Steering Group for this project in November 2020 as follows:

1. Testing three different approaches for sampling pollen DNA from pan trap-derived samples:

   A total of 109 specimens from 2018 in one PoMS square in the south of England were screened for pollen DNA using approaches a and b:

   a) from the surface/ body hairs of the specimen (bees/ hoverflies individually tubed in ethanol after sorting in the lab): amplification of pollen DNA was successful for only 10 specimens out of 109.
   b) from the gut or nectar crop of the insect (specimens as in a): amplification of pollen DNA was successful for 103 specimens out of 109.

   c) A total of 100 ethanol samples from pan traps across 18 PoMS squares were screened for pollen DNA using the preservative ethanol in which samples are initially stored before lab sorting to pull out the different groups (this ethanol was tubed and archived from all 2018 PoMS samples with this 'eDNA' in mind): amplification of pollen DNA was successful for 96 samples out of 100.

   These findings suggest that once insects have been exposed to the pan trap 'environment' and subsequent sample tubes for storage and identification, very few pollen grains remain on the surface and body hairs. Obtaining pollen at an individual level may be more reliable from the guts

[5] Draft EU report available here: https://wikis.ec.europa.eu/display/EUPKH/EU+Pollinator+Monitoring+Scheme

(in which case both larval and adult feeding patterns may need to be taken into account when interpreting pollen types present). It may also be possible to identify pollen types associated with pan trap samples at a 'community' level via amplification from the preservative ethanol.

2. Individual and whole-community DNA-based identification:
   a) 1,333 individual bee and hoverfly specimens from across 42 PoMS squares, sampled in June-July 2018, were screened, with 1,302 successfully amplified for insect DNA and 1,125 successfully amplified for pollen DNA from the insect guts (using approach b from WP1).
   b) 210 by-catch samples of other insect groups from the same 42 squares as included in 2a) were screened, with 204 successfully amplified for insect DNA.
   DNA extractions are currently being sequenced and will be matched with both the individual specimen species-level identifications for bees and hoverflies provided by PoMS taxonomists, and with taxonomic 'species' units for the as-yet unidentified samples from other insect groups.

3. Analysis of interaction networks and community composition from the samples in 2, to identify important food sources for pollinators and map the spatial distribution of plant-pollinator associations. This will commence once results have been returned from the sequencing facility and the associated bioinformatics completed.

b) FIT Counts conducted in Ireland, Jersey, Cyprus and Chile

The FIT Count survey has now been trialled or adopted in several countries as a means of engaging members of the public in pollinator monitoring and conservation, and generating systematic data on pollinator numbers. In 2020, FIT Counts also featured in a new wellbeing experiment conducted as a result of the national lockdown. In all cases, PoMS team members have shared protocols and best practice to ensure standardisation between schemes (although each of these additional schemes is independently funded). This has included:

- FIT Counts conducted across Ireland as part of the All-Ireland Pollinator Plan (https://pollinators.ie/record-pollinators/fit-count-progress/). During 2020, more than 350 counts have been submitted to the National Biodiversity Data Centre and those from Northern Ireland shared directly with UK PoMS (as reported under Task 2).

- FIT Counts conducted on Jersey in collaboration with the Jersey Biodiversity Centre as part of the Channel Islands Pollinator Project (https://pollinatorproject.gg/pollinator-monitoring-in-the-channel-islands/).

- FIT Counts conducted during 2019 in Cyprus (under the PoMSKy Darwin Initiative project) and in Chile (as part of a pilot with the schools EXPLORA project, under the NERC-funded SURPASS project led by UKCEH), leading to a plan for UK PoMS and these two projects to collaboratively fund a new app for FIT Counts that will have the potential for global application in different languages, with focal habitats and target plant or insect lists tailored at country level.

- FIT Counts were featured as one of three citizen science surveys as part of the "Nature Up Close and Personal" experiment, run by UKCEH in partnership with the British Science Association (BSA) and University of Derby, with funding from UKRI (https://www.ceh.ac.uk/nature-up-close). This study was conceived during the initial lockdown period and looked at how nature-based activities impact our wellbeing. More than 1,700 people, 82% of them women, signed up to take part in the six-week UK study during July and August. 405 FIT Counts were done by 96 people (each participant was randomly allocated to take part in one activity over a week-long period), and 315 counts were submitted to iRecord as a result.

- When reflecting on their experiences of taking part, participants reported that levels of happiness, satisfaction and feelings of connection to nature all rose when undertaking FIT Counts and other survey activities for the Nature Up Close and Personal experiment. People were also more likely to engage in conservation activities outside the project. Analysis of survey responses will include a comparison of levels of satisfaction for those who completed the different activities.

Publications and Communications activity

The PMRP and PoMS have been presented or communicated through various online channels during 2020, as summarised in Table 7. At least 35 engagement activities have been delivered, with only around six face-face training events or talks actually cancelled or postponed altogether. A significant activity was the provision of scientific advice during and around filming to the production team for the two-part Channel 4 series “Jimmy's Big Bee Rescue” with Jimmy Doherty. FIT Counts were selected as an activity to engage members of the public and school children in measuring the impacts of habitat creation and floral plantings on bees and other pollinators in and around Peterborough. As a result, 150 FIT Counts were submitted to PoMS in both 2019 and 2020.

Scientific paper

A paper led by the University of Reading and UKCEH, with a large collaborative authorship, was published in October 2020 using findings on the value of well-designed monitoring schemes from the initial design and testing phase for PoMS (the NPPMF project). The study found the costs of running nationwide monitoring schemes are more than 70 times lower than the value of pollination services to the UK economy, and provide scientific data at a much lower cost than running individual research projects.

Breeze T.D., Bailey A.P., Balcombe K.G., Brereton T., Comont R., Edwards M., Garratt M.P., Harvey M., Hawes C., Isaac N., Jitlal M., Jones C., Kunin W.E., Lee P., O’Connor R. S., Morris R.K.A., Musgrove A., Peyton J., Potts S.G., Roberts S.P.M., Roy D.B., Roy H.E., Tang C.Q., Vanbergen A.J. and Carvell C. (2020) Pollinator Monitoring More than Pays for Itself. Journal of Applied Ecology http://doi.org/10.1111/1365-2664.13755

Further plans for PoMS communications

The PoMS newsletter planned for early March 2020 was not produced due to restrictions and delays experienced at the point of national lockdown. Materials have been refreshed and a newsletter is planned for early 2021, including a summary of results to date, a round-up of events, short blog posts from a selection of volunteers (as ‘ambassadors’ of the scheme) and updates on other wider activities.

Type of engagement activity	Number of events/ articles
Article in print	2
Article online	8
Email to team	2
Major Twitter/FB activity	2
Media radio or TV	1
Meeting attended/ talk	10
Public event/ festival	3
Targeted volunteer recruitment	5
Training event	4
Volunteer activity day	2

Table 7. Summary of communication and engagement activities at which PoMS has been promoted since January 2020.

Acknowledgements

The UK Pollinator Monitoring and Research Partnership comprises the UK Centre for Ecology & Hydrology (Claire Carvell, Helen Roy, Martin Harvey, Nadine Mitschunas, Nick Isaac, Gary Powney, Francesca Mancini, Angus Garbutt, Eleonora Fitos, Chris Andrews, Lucy Ridding), the Bumblebee Conservation Trust (Richard Comont), Butterfly Conservation (Richard Fox, Megan Lowe), British Trust for Ornithology (Dawn Balmer, Rob Jaques, Andy Musgrove), Hymettus (Paul Lee, Mike Edwards), the University of Reading (Simon Potts, Mike Garratt, Deepa Senapathi), University of Leeds (Bill Kunin) and Natural History Museum (Alfried Vogler, Huaxi Liu).

We thank our funders for their continued support and particularly for the regular communications during and beyond the lockdown period that allowed survey activities to resume: Defra (Rosie Oates, Louisa Willows), Welsh Gov (Kathleen Carroll), Scottish Gov (Jim Jeffrey), DAERA NI (Pauline Campbell) and JNCC (Paul Woodcock).

We would like to thank Jan Winder, Katty Baird and Ellen Lamborn for joining the PoMS survey team for 2020, mentoring volunteers and covering surveys on unallocated squares during what was an extremely challenging year. Taxonomists Ivan Wright, Martin Harvey, Nigel Jones and Paul Lee provided species identifications for the bees and hoverflies sampled in pan traps. Thanks to Buglife and Jimmy's Big Bee Rescue (RedSky Productions) for their help promoting PoMS at events and during the recent Channel 4 series. Finally, a huge thanks to all the volunteers and supporters of PoMS who undertook (and submitted!) FIT Counts or 1 km surveys in 2020 as well as the landowners who allowed access for PoMS surveys – the scheme could not run without their dedicated commitment.