A review of existing citizen science approaches to monitoring farmland biodiversity

Deliverable D25 (D3.8)

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SHOWCASE

SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity

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Preface

This report was researched and written between April and December 2021 by researchers at the Swedish University of Agricultural Sciences (SLU), with support from partners at the University of Reading (UK), De Vlinderstichting (Netherlands), and Centre National de la Recherche Scientifique (CNRS, France). The report consists of a review of existing 'citizen science' approaches to monitoring biodiversity on farmland, in which we introduce a typology of five different types of approach, and highlight the strengths and weaknesses of these. This forms part of the project "SHOWCASing synergies between agriculture, biodiversity and Ecosystem services to help farmers capitalising on native biodiversity" (SHOWCASE). SHOWCASE aims to encourage the widespread uptake of biodiversity-friendly farming practices across Europe, both through identifying effective incentives for farmers, and gathering further evidence of the ecosystem services provided by increased levels of biodiversity. The project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.862480. In particular, this report fulfils Deliverable 3.8 within SHOWCASE: "A review of existing citizen science approaches to monitoring farmland biodiversity, including an overview of the different statistical approaches to handling citizen science data". We at SLU are grateful to all SHOWCASE partners for their contributions.

Summary

Biodiversity monitoring is carried out in order both to track large-scale biodiversity trends, and to assess the effectiveness of actions aiming to promote biodiversity. Over the past two decades, 'citizen science' approaches to such monitoring have seen a huge increase in popularity. Citizen science refers to the contribution of members of the public to scientific research, with biodiversity being one major area of focus within this. The SHOWCASE project recognises the potential of engaging farmers in farmland biodiversity monitoring, due both to the importance of farmland for biodiversity, and the potential to influence their attitudes towards biodiversity-friendly farming practices.

This report provides a review of citizen science approaches that are, or have been, used to monitor biodiversity on farmland. While later project tasks will empirically test ways to engage farmers in such monitoring, this is a means of 'setting the scene' with an overview of existing, relevant approaches. In the report, we highlight the strengths and weaknesses of different types of approach, with a focus on the level of participation by farmers and members of the public, and the types and quality of the biodiversity data collected.

In total, we identified 110 different citizen science projects or programmes with at least a partial focus on farmland. These were identified through three complementary approaches: A literature search using Web of Science; asking SHOWCASE project partners about relevant programmes they were aware of; and a Google search for farmland-specific approaches. This was not an attempt to produce an exhaustive review of *all* existing citizen science-based monitoring schemes. Rather, we aimed at covering the major categories of approaches that involve volunteers in biodiversity monitoring, in order to identify their respective strengths and weaknesses.

Based on the 110 programmes identified, we set out a typology of citizen science approaches to farmland biodiversity monitoring based on the overall aim of the initiative. The five identified programme types are: Measuring general biodiversity trends (Type A); Measuring general trends for specific species/taxa (Type B); Measuring general *farmland* trends for specific taxa (Type C); Measuring the effects of farming-related activity on biodiversity (Type D), and; Engaging farmers (or testing methods with farmers) (Type E). The five identified types represent a progression towards increasing relevance for farming communities. Between types A and D, there is also a progression towards focused data collection that enables analysis of the effects of specific farmland practices on (often specific aspects of) biodiversity.

The key strengths and weaknesses of the five programme types can be summarised with reference to three key 'trade-offs' between different priorities of citizen science programmes: Data collection vs farmer/volunteer engagement; Size of programme vs specific focus of data, and; Systematic vs opportunistic data collection.

Having also provided an overview of the different statistical approaches to dealing with biodiversity monitoring data collected by citizen scientists, the report concludes with a series of recommendations for future citizen science approaches to monitoring farmland biodiversity. A key, overarching aim is to ensure clarity of the programme aims. Subsequent recommendations are then arranged according to the broad aims that may be held by a given programme: Collecting data on general biodiversity trends; collecting data on the effects of specific farming practices on (often specific aspects of) biodiversity; and approaches where engagement of farmers is the *main* aim. These recommendations emphasise balancing these aims within a given project – for example, increasing engagement with farmers while gathering large volumes of data on general trends.

List of abbreviations

AES	Agri-environment Scheme
BTO	British Trust for Ornithology (UK NGO)
CNRS	Centre National de Recherche Scientifique (SHOWCASE partner, France)
CS	Citizen Science
EU	European Union
GWCT	Game and Wildlife Conservation Trust (UK NGO)
H2020	Horizon 2020 (EU funding stream)
JNCC	Joint Nature Conservation Committee (UK government advisory group)
NGO	Non-governmental organisation
OPAL	Open Air Laboratories (former UK citizen science organisation)
RSPB	Royal Society for the Protection of Birds (UK NGO)
UK	United Kingdom
SLU	Sveriges Lantbruksuniversitet/Swedish University of Agricultural Sciences

1 Introduction

Biodiversity monitoring is carried out in order both to track large-scale biodiversity trends, and to assess the effectiveness of actions aiming to promote biodiversity. Over the past two decades, 'citizen science' approaches to such monitoring have seen a huge increase in popularity. Citizen science refers to the contribution of members of the public to scientific research, with biodiversity being one major area of focus within this. Citizen science can reduce costs compared to monitoring conducted by professional biologists, as well as enable the collection of volumes of data that would previously have been impossible. It can also, however, be seen as an opportunity to engage new audiences with science and biodiversity.

The SHOWCASE project recognises the potential of engaging farmers in farmland biodiversity monitoring, due both to the importance of farmland for biodiversity, and the potential to influence their attitudes towards biodiversity-friendly farming practices. While later project tasks will empirically test ways to engage farmers in such monitoring, this report 'sets the scene' with an overview of existing citizen science approaches to farmland biodiversity monitoring. In doing so, the report fulfils Deliverable 3.8 within SHOWCASE: "A review of existing citizen science approaches to monitoring farmland biodiversity, including an overview of the different statistical approaches to handling citizen science data".

This report, then, provides a review of citizen science approaches that are, or have been, used to monitor biodiversity on farmland. We highlight the strengths and weaknesses of different types of approaches, with a focus on the level of participation by farmers and members of the public, and the types and quality of the biodiversity data collected. This was not an attempt to produce an exhaustive review of *all* existing citizen science-based monitoring schemes. Rather, we aimed at covering the major categories of approaches that involve volunteers in biodiversity monitoring, in order to identify their respective strengths and weaknesses.

In total, we identified 110 different citizen sciences projects or programmes with at least a partial focus on farmland. These were identified through three complementary approaches: A literature search using Web of Science; asking SHOWCASE project partners about relevant programmes they were aware of; and a Google search for farmland-specific approaches. These methods are detailed in Chapter 2.

Based on the 110 programmes identified, we set out a typology of citizen science approaches to farmland biodiversity monitoring based on the overall aim of the initiative. The typology is introduced in Chapter 3, and the five programme types are then analysed in Chapters 4 and 5. The five identified programme types are:

- Measuring general biodiversity trends (Type A)
- Measuring general trends for specific species/taxa (Type B)
- Measuring general *farmland* trends for specific taxa (Type C)
- Measuring the effects of farming-related activity on biodiversity (Type D)
- Engaging farmers (or testing methods with farmers) (Type E)

The five identified types represent a progression towards increasing relevance for farming communities. Between types A and D, there is also a progression towards focused data collection that enables analysis of the effects of specific farmland practices on (often specific aspects of) biodiversity.

The key strengths and weaknesses of the five programme types can be summarised with reference to three key 'trade-offs' between different priorities of citizen science programmes:

- **Data collection vs farmer/volunteer engagement**: Engagement of farmers increases across the five programme types identified above – for example, becoming face-to-face and more personalised, rather than occasional engagement with an online portal. Programmes whose *main* aim is farmer engagement (Type E), as well as types where the aim is to engage a large number of people (Types A-C), tend not to provide rigorous or systematic data. Those that attempt high levels of engagement (with small numbers of farmers) *and* data collection that can be used to draw specific links between biodiversity and agricultural practices (Type D), can also be somewhat resource-heavy when it comes to this engagement. In many cases, data collection in programmes of this type could simply be carried out by researchers themselves.

- **Size of programme vs specific focus of data**: Programmes identified in this report vary considerably in terms of their size and scale of coordination, and this has clear implications for the type of data collection that is enabled. Generally, as programmes increase in size, their focus becomes less specific and systematic, making it more difficult to draw links between specific farming practices or interventions, and trends relating to specific aspects of biodiversity. Programmes in Type D enable the clearest analysis of links between farming practices and biodiversity trends, but as highlighted above, tend to be more resource-heavy, as well as engaging fewer people.

- **Systematic vs opportunistic data collection**: The extent to which data collection is 'opportunistic' or 'systematic' varies across and even within the different programme types, from those where volunteers submit records on any species at any time or place (Type A), to those where the indicator species/taxa are specified, and sites are carefully selected due to the presence of a particular habitat type or farming practice (Type D). The clear advantage of the systematic selection of sites is that it enables links to be far more easily drawn between farming practices and effects on particular aspects of biodiversity. It is, however, far more time-consuming and resource-intensive for those coordinating the programme, while allowing participants to choose their own sites potentially makes it easier to engage them.

These strengths, weaknesses and 'trade-offs' are explored in more detail in Chapter 7. Before this, and with particular relevance to the trade-off 'systematic vs opportunistic data collection', Chapter 6 provides an overview of the different statistical approaches to dealing with biodiversity monitoring data collected by citizen scientists. The report concludes with a series of recommendations for future citizen science approaches to monitoring farmland biodiversity, based on the trends identified in this review. The first, overarching recommendation is to **ensure clarity of programme aims**.

Subsequent recommendations are then arranged according to the broad aims that may be held by a given programme. These can be summarised as follows.

For citizen science approaches aiming to collect data on **general biodiversity trends**:

- Raise awareness of non-farmland-specific programmes among the farming community.
- Add farmland-specific elements to data collection/submission protocol.

- Keep methods simple and engaging.
- Consider degree of expertise required and volunteer availability.
- Provide identification resources (and/or training).
- Provide local contacts for providing training/support.

For citizen science approaches aiming to gather data on the **effects of specific farming practices on (often specific aspects of) biodiversity**:

- Consider whether citizen science is the best approach.
- Consider whether engaging farmers is feasible/important.
- Ensure data collection remains simple (if engaging volunteers).

Finally, for citizen science approaches where **engagement of farmers** is the *main* aim:

- Provide more feedback to farmers.
- Encourage partnerships between farmers and volunteers.
- Consider more “co-created” approaches (those where farmers participate in all stages of the research progress, including design).
- Consider relevance of monitoring to both biodiversity and agricultural production.

2 Methods

This chapter outlines the key methods used in this review. Broadly, we were looking to gather examples of different type of programmes employing citizen science approaches to biodiversity monitoring on farmland. From this, we then aimed to develop a typology of approaches that would illustrate the variety among these, as well as to identify the key strengths and weaknesses of those approaches. This required a wide-ranging search that would draw upon as wide a range of information and expertise as possible. We therefore used the following three separate methods in this review:

- A literature search using Web of Science
- Contributions from SHOWCASE partners
- A Google search for farmland-specific programmes and approaches

When identifying programmes, our key criteria were that these must:

- Take place on *farmland* (but not necessarily exclusively – i.e. farmland could be just one of a number of landscape/habitat types included in the programme);
- Focus specifically on *biodiversity* or components thereof*,* and;
- Involve monitoring carried out by *non-professionals*.

All programmes identified were added to a spreadsheet (set up using GoogleDocs) that included a series of questions to be addressed for each programme. These are further detailed in section 2.4 below, and all contributed to the following overarching questions that ran through this review:

- What citizen science approaches can be/have been used to monitor farmland biodiversity?
- What are the key features of these approaches?
- What do we know about the strengths and weaknesses of the programmes?

It is important to note that despite the range of methods employed, this review should be considered illustrative rather than exhaustive. That is, while we have identified a significant number of programmes that has enabled the development of a typology, there are likely to be further programmes (which at least partly cover farmland) that have remained unidentified. This is owing to factors such as language, our broad search criteria, and the geographical scope of the expertise at our disposal. This is discussed further in the Limitations section (2.5).

The following sub-sections provide more detail on the methods identified above.

2.1 Web of Science literature search

We used Web of Science to conduct a wide-ranging literature search for academic papers that referred to programmes that met the criteria identified above. These could be papers

that specifically discussed the advantages or challenges of engaging non-professionals in farmland biodiversity monitoring (there were only a small number of these), or papers that simply drew upon data gathered through such approaches. Below, we outline the various stages to this literature search, and the search terms used.

2.1.1 Narrow title search

We began with an approach that we felt would quickly identify the most relevant articles – that is, those containing current debates or discussions around citizen science on farmland. We did this by searching only the titles of articles, using the following narrow search terms:

```
TI=((farm* OR agri* OR agro*) AND (“citizen scien*”′)
```

This returned 26 journal papers. Most of these were relevant to this review, at least in terms of a broad discussion of the strengths and weaknesses of citizen science approaches to farmland biodiversity monitoring.

2.1.2 Author keyword search

We then performed an author keyword search using the same terms as above, in order to broaden the range of relevant papers. The search terms were therefore as follows:

```
AK=((farm* OR agri* OR agro*) AND (“citizen scien*”))
```

This returned 55 papers, including the 26 identified through the previous step.

2.1.3 Wider author keyword search

Following the narrow searches described above, we performed a wider author keyword search. This accounted for the relatively recent emergence of the term ‘citizen science’, and attempted to cover the numerous related terms that may have a similar meaning. These included ‘public science’, ‘community science’, ‘civic science’, and phrases including words such as ‘volunteer’, ‘participatory’, and ‘public engagement’. We also considered the specific taxa that may have been referred to instead of the generic ‘biodiversity’, and based these on the indicator species/taxa identified as part of the SHOWCASE project. These included birds, beetles, syrphids/hoverflies, butterflies, and earthworms. We ensured that our search terms would cover different forms of the relevant words – for example, ‘hoverfly’ and ‘hoverflies’, ‘citizen science’ and ‘citizen scientist’ - by including asterisks next to the root forms of the words (for example, ‘hoverfl*’, ‘citizen scien*). We also entered two-word phrases in speech marks so that the words were identified only when they appeared together, in that order (for example, “citizen scien*”, “public engag*”). Our wider author keyword search, then, used the following search terms:

AK=((farm* OR agri* OR agro*) AND (biodivers* OR wildlife* OR conservation* OR species* OR taxa OR ecosystem* OR habitat* OR bee* OR pollinat* OR bird* OR beetle* OR vascular plant* OR butterfly* OR syrphid* OR hoverfly* OR earthworm*) AND ("citizen scien*" OR "public scien*" OR "civic scien*" OR "community scien*" OR participat* OR "public engag*" OR volunteer* OR non-professional* OR collectiv* OR farmer-led OR "farmer* led" OR monitor*))

This search returned 326 papers, including a number of relevant papers that had not been previously identified. Many, however, did not meet all of our search criteria, as described below.

2.1.4 Sorting papers for relevance

Having identified the papers through the above searches, the next step was to read the abstracts of these in order to determine which were relevant. To reiterate our search criteria, 'relevant' in this instance means that papers described or referred to an approach to biodiversity monitoring that: Takes place on *farmland* (not necessarily exclusively); focuses specifically on *biodiversity*, and involves monitoring carried out by *non-professionals*.

In practice, these criteria served to reduce considerably the number of relevant papers. This was largely because many of the papers included one or two of the above three elements, but not all. For example, they may describe a programme of biodiversity monitoring on farmland, but where monitoring had been done by professionals; or a programme where farmers had participated in some form of monitoring, but the focus had been on testing new agricultural technologies, rather than on biodiversity. A significant number of papers also presented general considerations for engaging farmers in conservation programmes or Agri Environmental Schemes (AESs), but did not describe a specific monitoring programme. Such papers were not included in our literature database, but some were relevant for subsequent discussion (see Chapters 6 and 7). In total, 27 relevant programmes, from 36 different papers (9 of the programmes were referred to in more than one paper) were identified through this method, as described in the following chapter.

2.2 Partner contributions

While this task was led by SLU, SHOWCASE partners at the University of Reading (UK), De Vlinderstichting (Netherlands) and Centre National de la Recherche Scientifique (CNRS, France) were all named as contributors to this task. We therefore asked these partners to add to the database any programmes that, to their knowledge, involved farmland biodiversity monitoring carried out by non-professionals. The approach to this aspect of the task was agreed in an online meeting, and all partners were sent a document explaining the process and the various questions making up the database. This method had the advantage of drawing upon the in-depth knowledge of national contexts held by SHOWCASE partners (most programmes identified were in partners' home countries, with a few exceptions) to identify relevant programmes that had not (yet) been referred to in the academic literature. This method resulted in a total of 71 programmes being added to the database.

2.3 Google search

We employed this method once the results from the literature search and partner contributions had been gathered. Through this method, we aimed to identify only *farmland-*

specific programmes, in order to identify any clearly relevant schemes that we had missed through our previous searches. These previous searches had identified many programmes that included farmland as one of a number of possible landscape or habitat types covered, but where in fact there was little reference to monitoring taking place on farmland. We predicted that a wider Google search would be likely to identify many more programmes of this type, and that there was little to be gained from this in terms of identifying the key features, and strengths and weaknesses, of such programmes. It was for this reason that we narrowed our Google search terms to focus on farmland-specific schemes. Through this method, we did find many references to the same programmes identified through the literature search and partner contributions. We also, however, identified 12 programmes that we had not previously identified.

Our search was conducted using Google in “incognito” mode and with all “cookies” erased to avoid previous search history to influence the results. We used the following search terms, and followed the first 10 pages of results from each:

citizen science project farm biodiversity
farm* AND bird* AND count*
farm* AND bird* AND monitor*
farm* AND bird* AND survey*
farm* AND bird* AND count* OR monitor* OR survey*
farm* AND pollinat* OR bee* AND count* OR monitor* OR survey*
farm* AND flower* AND count* OR monitor* OR survey*
farmer AND scien* AND biodiversity AND partnership OR cooperat*
farmer AND biodiversity AND count* OR monitor* OR survey*
farmer AND scientist AND partnership AND biodiversity
farm* science* work together monitor*
farmer* AND bird* citizen scien*
farmer AND conservation AND count* OR monitor* OR survey*
farmer AND wildlife AND count* OR monitor* OR survey*
farm* AND butterfly* AND count* OR monitor* OR survey*
farm* AND insect* AND count* OR monitor* OR survey*
farm* AND beetle* AND count* OR monitor* OR survey*
farm* AND plant* AND count* OR monitor* OR survey*
farm* AND hoverfly* AND count* OR monitor* OR survey*
farm* AND worm* AND count* OR monitor* OR survey*
farm* AND earthworm* AND count* OR monitor* OR survey*

2.4 Database questions

As previously noted, all programmes identified were added to a spreadsheet (set up using Google Docs) that included a series of questions to be addressed for each programme. These questions, then, ran throughout all three of the methods used in this review. The questions were explained clearly to partners contributing to this task in the information document sent to them, and consisted of the following.

- Introduction/aims/brief description
- References to the programme (e.g. Academic articles, other)
- Scale of organisation
- Who coordinates the programme? (e.g. national recording scheme, or locally-specific?)
- Who uses the data collected (if known)? (e.g. Government agency, NGO, university, researchers)
- Does the programme aim to monitor farmland specifically? (e.g. Government, NGO, researchers - if known)
- Does the programme aim to monitor farmland specifically?
- Who does the monitoring? (e.g. farmers, citizen scientists, ecologists?)
- How do farmers/the farming community participate, if at all? (e.g. monitoring, receiving feedback from recorders)
- If farmers are involved in the programme, who engages with them (e.g. ecologists, citizen scientists)?
- What species/taxa are monitored?
- Does the programme aim to monitor: a) General biodiversity trends (e.g. of a certain species at national/local scale); b) The effects of something on biodiversity (e.g. an intervention, farming method, or policy); c) Both; d) Other (please specify)
- What types of methods are used? (And/or types of data collected?)
- Approximately how many sites are covered by the programme?
- How frequently is monitoring carried out?
- How long has the programme been running? (Or if no longer running, how long did it run for?)
- At what stage/s of the process are volunteers involved? (e.g. recording/submitting results, study design, data analysis):
- What does the data enable? (e.g. Identifying national trends, farm-level assessment of conservation measures)
- What are the strengths of the programme, to your knowledge/in your opinion? (e.g. data quantity/quality, farmer participation)

- What are the weaknesses of the programme, to your knowledge/in your opinion? (e.g. data quantity/quality, farmer participation)

2.5 Limitations

As previously noted, although wide-ranging, this review should be considered illustrative rather than exhaustive. That is, there are likely to be other citizen science programmes, at least partly covering farmland, that have not been identified here. Despite this, we are confident that this review has been sufficiently broad in scope to enable us to draw significant insights from the programmes identified. The following limitations, however, should be acknowledged:

- Our literature search was limited to author keywords (as well as article titles). When working to refine the search terms, we found that widening the fields in which we searched (for example, to abstract, or "topic") tended to return many thousands of results. Even using the narrow search terms identified in section 2.1.1 within these wider fields returned more results than were practical to sort through for relevance. While we were confident that our search terms were refined yet broad enough to identify the majority of relevant articles, it is possible that a small number of others would have been identified had we searched in wider fields.

- It is also possible that further programmes exist that are not farmland-specific, but nonetheless include farmland to a limited extent. When gathering examples of programmes from the UK in particular, it became apparent that there were large numbers of non-farmland-specific schemes that listed farmland as one of the habitats or landscape types covered, but where in fact there was little reference to monitoring taking place on farmland. With our UK partners, we agreed that since these programmes were already in the majority and did not differ much from each other, there was little to be gained or learned from continuing to add programmes of this nature to the database. It is possible, then, that there is some inclusion of farmland in the programmes not included here, but this is likely to be minimal, and/or have little information on it.

- Language-wise, our Web of Science and Google searches were limited to results in English. This was expanded to Swedish, Dutch and French for the partner contributions, but only to these languages. It is therefore likely that a considerable number of relevant programmes exist in other countries that do not have information, nor related academic papers, in English.

3 Overview of programmes identified

This chapter provides a quantitative summary of the programmes identified using the methods described in the previous chapter. In particular, we detail the number of programmes identified through each method (section 3.1), the geographical spread of the programmes (3.2), whether the programmes are farmland-specific or not (3.3) and the species/taxa monitored (3.4). In section 3.5, we then provide an introduction to the typology used to classify the programmes identified, which is then used in the following two chapters. Section 3.6 provides an overview of the main types of data collection methods used in the programmes identified. Again, these are referred to throughout the following chapters. Finally, we briefly acknowledge links between the programmes identified here, and the EU H2020 project EuropaBON, which has several partners in common with SHOWCASE (3.7).

3.1 Number of programmes identified

We identified a total of **110** programmes that met our search criteria – that is, programmes that took place at least partly on farmland, that aimed to monitor biodiversity, and that involved non-professionals in data collection. Of these:

- **27** programmes were identified through the Web of Science literature search, from a total of 36 papers meeting our search criteria (9 of the programmes were referred to in more than one paper). The papers identified are listed in Appendix 2.

- **71** programmes were identified through input from SHOWCASE partners, as well as four further programmes that had already been identified in the literature review (partners were able to provide additional details on the programme in these cases).

- **12** programmes were identified through the Google search. As noted previously, this method also returned links to many of the projects already identified through the literature search and partner contributions, but the 12 referred to here were those that had not been previously identified. As also previously noted, our search terms here were narrower as we attempted to identify only farmland-specific programmes.

All identified programmes are listed in Appendix 1.

3.2 Geographical spread

Across the programmes identified, there is a considerable geographical spread. When looking at *all* identified programmes, including those identified through partner contributions, there was a very clear weighting towards the countries in which those partners are based. This was particularly so for the UK, with 51 of the 110 identified programmes being based there. The next most numerous are the Netherlands with 12, and Sweden with 10.

The particularly high number of UK schemes, even compared to the other partner countries, can be considered a likely reflection of the fragmented nature of citizen science there, with NGOs tending to provide their own platforms or monitoring programmes that focus on a particular species. Additionally, many of the UK-based programmes were identified through the National Biodiversity Network (NBN) website, which includes a search tool for identifying biological recording schemes. Many of the programmes identified through NBN listed farmland as one of several habitat types covered, but were not farmland-specific, and did not include information on how farmland was covered. It is therefore not necessarily the case

that the UK is more advanced or active than other countries in terms of their development of farmland-specific citizen science. It is also important to reemphasise the further limitations of this search – namely, that partner contributions were limited to the UK, Sweden, the Netherlands and France, and that our literature and Google searches were limited to English (further details in section 2.6).

Given these limitations, it is perhaps more insightful to consider only the programmes identified through the literature search and Google search elements of this review. The countries in which these programmes are based are displayed in the table below. This shows a more balanced geographical spread, although with the highest number of programmes still in the UK (probably owing to the Google search being conducted in English).

Finally, it should be noted that in the table below, several programmes operate in more than one country (for example, the North American Breeding Bird Survey covers the USA, Canada and Mexico), and in these cases, each country has been counted in the table.

Table 3A: Location of programmes identified through the literature search and Google search elements of this review.

Country	Number
UK	9
France	6
USA	3
Germany	3
Austria	2
Switzerland	2
Ireland	2
Spain	2
Canada	2
Italy	2
Sweden	1
Various/ EU-wide	1
Australia	1
Mexico	1
Taiwan	1
South Africa	1
New Zealand	1
Denmark	1
Hungary	1
Bulgaria	1
Belgium	1

3.3 Farmland-specific or non-farmland-specific

Of the programmes identified, **45 focused on farmland biodiversity specifically**. The remaining 65 made some reference to including farmland as one of several habitat or landscape types, but this was not their sole focus. The prevalence of non-farmland-specific programmes is in spite of our search terms being tailored to identify schemes that covered farmland, and as noted in section 2.6, there are likely to be many more of these in reality

(albeit programmes that only cover farmland to a limited extent). This is due to our decision during the review process, that there was little to be gained from continuing to identify programmes that were clearly not specifically farmland-oriented.

In relation to the above, it is important to note that there was considerable variation within the non-farmland-specific programmes in terms of the extent to which farmland *is* covered. That is, although many programmes listed farmland as being included but make no specific further mention of it, others mentioned relatively high levels of farmland coverage, and/or materials designed to encourage farmers' involvement. The farmland focus within non-farmland-specific programmes was demonstrated most clearly through the literature search, where several of the identified papers drew farmland-specific data from national monitoring programmes that were not farmland-specific.

Finally, it is important to emphasise that despite the prevalence of non-farmland-specific programmes, 45 farmland-specific programmes represents a significant number of this type of initiative.

3.4 Species/taxa monitored

The table below provides a summary of the taxa or species monitored across all the identified programmes. These are then broken down by programme type over the following two chapters.

Table 3B: Species/taxa monitored in the identified programmes.

Species/Taxon	Number
Birds	33
General/wide categories	16
Bees and other key pollinators	15
Butterflies	11
Plants/flowers*	10
Insects (in general)**	5
Flowers	4
Moths	3
Hedgehogs	2
Dragonflies and damselflies	2
Trees	2
Reptiles/amphibians	1
Ladybirds	1
Diptera	1
Bats	1
Beetles	1
Myriapods & isopods	1
Fungi	1
Bryophytes	1
Hemiptera and heteroptera	1
Collembolla (springtail)	1
Freshwater flatworms	1
Earthworms	1
Soil organisms	1
Weeds	1
Brown hares	1

*Note that of the programmes monitoring “plants/flowers”, 4 of the 10 programmes focused on flowers specifically. These are included as one category due to a number of programmes aiming to monitor “plants/flowers” generally.
**Note also that programmes monitoring “Insects (in general)” are those where a particular species of insect is not specified (unlike programmes that focus on a narrower category of insect, such as butterflies, bees/pollinators, moths, and dragonflies/damselflies.

While the table demonstrates considerable variety in terms of the species/taxa that are monitored, there is also considerable disparity in terms of the number of programmes covering each. Birds are clearly the dominant taxon, with pollinators and butterflies also being the focus of a relatively large number of programmes. The category “General/wide categories” refers to general biodiversity recording platforms where participants submit opportunistic records of any species identified (sometimes these are in slightly narrower but still very broad categories, such as mammals). Many of the taxa covered by just one programme are UK-based recording schemes run by NGOs focused on a particular species. Finally, it should be noted that in cases where a programme covers several different species, these are all counted in the table above (this is also the case in the subsequent chapters, where the species/taxa recorded are listed under each programme type).

3.5 Introduction to the typology of programme types

In the following two chapters, we set out a typology of citizen science approaches to farmland biodiversity monitoring based on the overall *aim* of the programmes identified. This, we felt, was the overarching factor that best accounted for the key differences between programmes – for example, the methods used, the level of farmer engagement, and the scale at which the programmes are coordinated. The five types of programme comprising this typology are identified and defined below:

- **Type A - Measuring general biodiversity trends**: These are mostly large-scale and opportunistic programmes that encourage submission of records on any species, in any location and habitat type. Examples include large-scale online recording platforms such as iSpot and iRecord. These programmes are not farmland-specific – that is, they may cover farmland, but there is no specific reference to or focus on this.

- **Type B - Measuring general trends for specific taxa**: These programmes also aim to measure mostly national-level trends, but focus on a particular species. These programmes employ a mix of opportunistic submission of records, and methods such as transect counts, that are carried out on particular sites. Again, these programmes may cover farmland, but there is no specific reference to or focus on this. Typical examples of this programme type include national bird or butterfly surveys.

- **Type C - Measuring general farmland trends for specific taxa**: These programmes are similar to Type B, but with a specific focus on farmland. As far as we could tell, these programmes all focused on a particular species or taxa, and may include, for example, annual farmland bird counts. As with the above types, these programmes are most commonly coordinated on a national scale.

- **Type D - Measuring the effects of farming-related activity on biodiversity**: These programmes are more focused and generally smaller-scale than types A to C, beginning with a particular intervention or farming practice, and attempting to determine its effects on biodiversity (or often particular components thereof). Examples include regular bird counts in small woodlands planted on farms in the past

twenty years, and pollinator counts on areas of farmland that have been managed in different ways.

- **Type E - Engaging farmers (or testing methods with farmers)**: These are programmes where the data collected is secondary to the engagement of farmers – that is, farmers are closely engaged with and encouraged to carry out biodiversity monitoring on their land, but the data collected is not necessarily used for research purposes. These include monitoring set up for the purposes of testing citizen science methods with farmers, and monitoring tools set up for farmers to engage them with the biodiversity on their land.

Below is a summary of the number of each type of programme identified through this review. Type B – programmes focused on specific species/taxa, without being specifically focused on farmland - is by some distance the most common type of programme. Given that our search terms and approach were aimed at identifying farmland-specific schemes, however, we were able to also identify a significant number of programmes that enable data on particular farming practices and their effects on biodiversity (Type D).

Table 3C: Number of identified programmes in each programme type.

Programme Type	Number
Type A: Measuring general biodiversity trends	9
Type B Measuring general trends for specific species/taxa	56
Type C: Measuring general farmland trends for specific taxa	12
Type D: Measuring effects of farming-related activity on biodiversity	26
Type E: Engaging farmers (or testing methods with farmers)	7

Of the following two chapters, Chapter 4 covers the first two programme types detailed above – the general or non-farmland-specific programmes. Chapter 5 then covers the farmland-specific programmes – Types C, D and E. The different types of methods summarised in the following sub-section also run through these different types of programme.

3.6 Methods overview

This section provides an overview of the types of methods used in the various programmes identified. These are then explored in more detail in the following chapters, with reference to the different types of programme (from the above typology) in which they are most commonly used. The key types of methods are:

- **Method Type 1 - Opportunistic counts**: This refers to participants submitting records that are not site or time specific. They may, for example, see a bee pollinating a flower, and submit a record of it regardless of the time or location. Records may therefore only be submitted once at a particular location, and there is a

high chance that sightings will be concentrated in areas that are popular with visitors. It is therefore complicated to draw conclusions from data obtained through this method type (see discussion on statistical approaches to handling data of this kind – Chapter 6). Instead, programmes employing this method are largely designed to engage the public with a particular species, or with biodiversity more generally.

- **Method Type 2 - Point/route/transect counts with no extra step:** These are by far the most common method type identified, with 68 of the relevant programmes employing them. These methods consist of the participant counting the number of a particular species or taxon (or several of these) seen, either along a set route, at a particular point, or in a particular area (transect). Most commonly, the same count will then be carried out at regular intervals and at the same time/s of year, in order to gather longitudinal data on that point, route or area. There is considerable variation within this method type, although the basic method is the same. There is, for example, variation in the size of the areas covered – from a single flower-patch, to a distance of one kilometre along a road. There are also several programmes where sites are selected systematically – for example, where a species is already known to be abundant, or in order to ensure a spread of habitat types – although in the majority of programmes, it is the participants who select the site. Finally, there is also variation in what is being counted and by what means – standout examples include using powerful torches to count brown hares at night, and counting bats using ultrasound. These programme, however, all have in common that the participant does not perform any extra step before performing the count, in contrast to method type 3.

- **Method Type 3 - Point/route/transect counts with an extra step**: In this method type, similarly to type 2, participants count the number of a particular species or taxon seen along a set route, at a particular point, or in a particular area. The difference, however, is that participants are required to carry out an extra step in the data collection process before carrying out the count. This therefore adds an extra level of commitment to participants' involvement (although the increase is often fairly minimal). Examples include earthworm counts where participants are required to dig holes and/or spray mustard on the ground in order to draw worms out, installing "footprint tunnels" as part of a hedgehog survey, and methods such as pan traps for pollinators, and light traps for moths.

- **Method Type 4 – Others**: Across the programmes identified, there were only five that did not employ any of the previous three method types (possibly aside from those that were 'unclear' – see below). These are captured by this fourth method type. These other methods are malaise traps, recording details of trees such as age and girth rather than the number of trees in a particular area, using technology to identify the DNA of all species present - or which had been present - in farm dams, and two programmes where farmers are asked to answer questions about biodiversity on their land – that is, rather than any data being physically collected.

- **Unclear**: Finally, there were ten programmes where there was no clear information on the methods used. This was due to – for example – needing to sign up to the programme in order to receive information on it, or methods that were determined according to the needs or interests of particular farmers.

The table below shows the total number of programmes employing each method type. It should be noted that in cases where a programme includes more than one method, all methods have been counted.

Table 3D: Number of identified programmes employing each method type.

Methods Type	Number
Method type 1: Opportunistic counts	23
Method type 2: Point/route/transect counts with no extra step	68
Method type 3: Point/route/transect counts with extra step	10
Method type 4: Other	5
Unclear	10

3.7 Links to H2020 EuropaBON project

This Deliverable can also be linked to the EU H2020 project EuropaBON (Europa Biodiversity Observation Network: integrating data streams to support policy) which aims to address issues around spatially and temporally fragmented biodiversity monitoring data, taxonomic biases and lack of integration in Europe by designing an EU-wide framework for monitoring biodiversity and ecosystem services. Common partners to both Showcase and EuropaBON include the University of Reading, De Vlinderstichting, and Pensoft. A deliverable of interest within that project is D3.1: “Inventory of current European network for monitoring; web-based database”, where there is likely to be a degree of overlap with the programmes identified in this review. Other deliverables of interest within EuropaBON include D3.3: “Report on identification of current monitoring workflows and bottlenecks”; and D4.2: “Report on potential of novel technologies for biodiversity monitoring”. We believe that the citizen science approaches highlighted in this review, and in particular the overview of statistical approaches for dealing with biodiversity monitoring data collected by citizen scientists in Chapter 6, are of potential relevance to those Deliverables.

4 Non-farmland-specific programmes

This chapter presents the key characteristics of identified programmes that do not pertain specifically to farmland – those in programme types A (measuring general biodiversity trends) and B (measuring general trends for specific species/taxa). These programmes all make some mention of including farmland within them, but are not set up to record farmland biodiversity specifically.

In this and the following chapter, our analysis of each type of programme is arranged under the same set of headings. These reflect the questions set out in our database, and are as follows:

- Coordination and scale: Who coordinates the programme (this is usually either an NGO, researchers or a university, a government agency, or a combination of two of these), and the scale at which it is coordinated (that is, international, national, regional or more locally-specific).

- Methods: The methods that are commonly used in the monitoring, with reference to the four types set out in the previous chapter.

- Citizen scientist and farmer involvement: Whether monitoring has been carried out by farmers or other volunteers, and how those participants are involved. This can vary from simply collecting and submitting results, to helping to design the programme.

- What is monitored: The species/taxa that the programmes commonly focus on.

- Data availability/quality: The number of years of data that is typically available, the number of sites on which data are collected, and how often data is collected (for example, annually, or twice per month).

- Examples: We then provide descriptive examples of each programme type.

- Summary: What does this type of programme enable?: Finally, we provide a summary of the strengths and weaknesses of each programme type.

4.1 Type A: Measuring general biodiversity trends

Type A consists of mostly large-scale and opportunistic programmes that encourage members of the public to submit records of sightings of any species, in any location or habitat type, either through a website or smartphone app. Our review identified 9 programmes of this type. These programmes are open to all and therefore may cover farmland, but there is no specific reference to or focus on this. A key feature of this type of programme is that data collection is opportunistic, with no systematic selection of sites or habitat types. It is therefore challenging to draw any links between land use and biodiversity trends. These programmes are, however, valuable in that they offer an accessible means of engaging many people with biodiversity, and provide large volumes of data from which general trends can be observed.

4.1.1 Coordination and scale

All nine programmes in type A are organised on a large scale. Two programmes at least – iSpot (based in the UK) and iNaturalist (based in the USA) – are international in scope, enabling records to be submitted from any country. Otherwise, the programmes are all organised at a national scale. Nearly all programmes in this type are coordinated by NGOs, universities or research centres, or a partnership between the two. Such partnerships typically consist of the university maintaining the database and managing the data, and the NGO providing the website and communicating the programme to the public.

Table 4A: Coordination of programmes in Type A by type of organisation.

Organisation Type	Number
NGO/university partnership	4
University/government partnership	1
NGO	2
University	2

4.1.2 Methods

The majority of these programmes employ opportunistic counts, with participants submitting records at any time or place, as often or infrequently as they choose. The methods used in two of the programmes – the hedge-focused survey run by Open Air Laboratories (OPAL), and the programme run by the Freshwater Habitats Trust - are closer to being point counts. These programmes focus on hedges and ponds respectively, and are therefore a little more specific in terms of the type of habitat they cover. They are, however, not focused on any specific species, and participants can choose any hedge or pond to which they have access.

Table 4B: Number of programmes in Type A employing each method type.

Method Type	Number
Method type 1: Opportunistic counts	6
Method type 2: Point/route/transect counts with no extra step	2
Method type 3: Point/route/transect counts with extra step	0
Method type 4: Other	0
Unclear	1

4.1.3 Citizen scientist and farmer involvement

Monitoring in this type of programme is all carried out by volunteers, who can choose how much or little time they commit to the activity. Engagement is limited to the submission of records through an app or website, as well as engagement with the materials provided – for example, the identity guides provided on the app or website, or in the case of the OPAL hedge-focused survey, a booklet offering a simple guide to tree/shrub species found in hedges and a guide to the monitoring activity. As previously noted, there is no specific mention of farmer involvement in any of the schemes. Since the programmes are open to anyone, however, it is almost certain that there is at least a small number of farmers who participate. There may also be monitoring carried out by volunteers, on or at the edges of farmers' land.

4.1.4 What is monitored?

Generally, programmes in Type A allow volunteers to record anything they see, often with the aid of a form of identification guide, or in some cases an online community to help with identification. Some programmes offer a slightly narrower focus than this. Nature's Calendar in the UK, for example, and its Swedish equivalent Naturens Kalendar, include different monitoring resources (or "calendars") for birds, flowers, fungi, and insects, among other taxa. Volunteers can then select from a long list of species within each of these. Mammal Mapper, meanwhile, an app run by the mammal society (UK), focuses only on mammals. This is, however, still a very broad category, and record submission is still purely opportunistic.

4.1.5 Data availability/quality

With all but one of the programmes in this type, the date at which they were established, and therefore how many years of data are available, is unclear. It is clear, however, that they are generally fairly recent initiatives, being largely established in the internet age (or in many cases, since the advent of smartphones). Unlike some of the other programme types (mainly Type D), these programmes are open-ended, rather than operating within set dates. The exception to this is the hedge-focused survey run by Open Air Laboratories (OPAL, UK), which ran for only two years between 2010 and 2012. There is also little information on the number of sites covered by these programmes, although due to the scale at which they operate, it can be assumed that many thousands of sites are covered (though not necessarily repeatedly or on more than one occasion), and this volume of data can be considered a major advantage of the opportunistic data collection that these programmes enable (see also section 6.2). Finally, with all programmes, as previously stated, frequency of data collection is as often or infrequently as volunteers choose.

4.1.6 Examples

The following are illustrative examples of programmes in Type A:

iSpot (UK/international)

This website and app are run by the UK's Open University, and are described as an online "community", rather than platform or programme of study. The website and app aim to help anyone to identify anything they may observe in nature. Participants upload their observations of wildlife, often accompanied by a photo, and are then helped by other users to identify the species. There is also a "species browser" to help participants with identification, arranged into categories such as birds, mammals, insects, worms and slime moulds. Via a map, they can also look at the records that have been submitted recently, in order to get a sense of how common the species is in that area (the map includes international records, but by far the largest number of records are in the UK). Similar examples are iNaturalist (USA and international), and Artportalen, or "the species portal" (Sweden). https://www.ispotnature.org/

Mammal mapper (UK)

This website and smartphone app is similar to iSpot, but with a particular focus on mammals. There is, however, a greater focus on recording "*where* you are looking for animals, or 'effort'". This, they argue, helps address the problem that "in the past, it has been difficult to understand if gaps in records are caused by a true absence of animals in those locations, or if it is simply an artefact of nobody recording in those areas". As well as simply submitting a record in one place, the platform also includes the option of recording along routes (chosen by the user). The identification guide has greater details on mammals than a more general platform such as iSpot, providing detailed lists of mammals in a range of categories, such as rodents, carnivores, and even-toed ungulates.

https://www.mammal.org.uk/volunteering/mammal-mapper/

Naturen's Kalendar (Sweden)

Similarly to Nature's Calendar in the UK, this programme aims to monitor changes in phenology, – that is, the timing of events in nature - especially during spring. There are separate "calendars" – or recording categories - focused on (for example) birds, flowers, fungi, and insects, but volunteers can then select from a long list of species within each of these in order to help them with identification. Any member of the public can record sightings, which then appear on an interactive map. Users of the website can then select a particular species whose sightings can all be viewed on the map. Recordings might include the first daffodils flowering in spring, or the first appearance of migratory birds. With this focus on phenology of common species, over time Naturen's Kalendar will help to build up a picture of how those species are affected by climate change.

https://www.naturenskalender.se/

4.1.7 Summary: What does this type of programme enable?

There are two key advantages of this type of programme (Type A). Firstly, their accessibility and ease of use make them a valuable educational tool for participants, and enable widespread public engagement with biodiversity. Secondly, they enable the collection of large volumes of data that would not be possible without them. That volume of data, along with the scale of these programmes, enables analysis of general trends on a national and even international scale.

The opportunistic and general nature of records submitted through these platforms, however, makes it difficult to draw any conclusions beyond these large-scale trends. Even analysing these broad trends can be complicated, due to a potential bias towards certain types of habitat or landscape, and for inaccuracies due to volunteers' lack of training (although these are perhaps offset by, respectively, Mammal Mapper's "effort" filter, and the

presence of an online community in the case of iSpot, as discussed in the examples). The advantages and challenges of the types of opportunistic data collected through these programmes is explored further in Chapter 6 (section 6.2).

Additionally, for the purposes of our review, there is a clear lack of focus on farmland within these type of programmes. Given their accessibility and ease of use, these programmes should not be disregarded in terms of their potential to engage farmers with citizen science and biodiversity. For greater levels of engagement and/or more focused data collection, however, other types of programme would be required.

4.2 Type B: Measuring general trends of specific species/taxa

Programmes of this type also aim to measure mostly national-level trends, but unlike those in Type A, focus on a particular species or taxa. These taxa vary considerably, with everything from bryophytes to dragonflies to birds being the focus of different programmes. In keeping with the general trends set out in Chapter 3, however, there was a particular prevalence of programmes focused on birds, butterflies and pollinators.

Our review identified 56 programmes of this type, making it by some distance the most common type. There are, in fact, likely to be many more than this, but a decision was made to stop adding more such programmes to the database (see section 2.6). The prevalence of these non-farmland-specific programmes was in spite of our focus on identifying farmland-focused programmes in our search terms and communications with project partners.

These programmes employ a mix of opportunistic submission of records (method type 1), and more commonly, point, route or transect counts (method type 2) that are carried out on particular sites. As with Type A, these programmes may cover farmland, but there is no specific reference to or focus on this. It should be noted, however, that within this type, there was considerable variation within the non-farmland-specific programmes in terms of the extent to which farmland *is* covered. That is, although many programmes listed farmland as being included but make no specific further mention of it, others mentioned relatively high levels of farmland coverage, and/or materials designed to encourage farmers' involvement. The farmland focus within non-farmland-specific programmes was demonstrated most clearly through the literature search, where several of the identified papers drew farmland-specific data from national monitoring programmes that were not farmland-specific.

4.2.1 Coordination and scale

The scale of organisation of programmes of this type is overwhelmingly large-scale or national. Four programmes in this type involve submission of results relating to a particular species or taxa through a more general platform such as iSpot (in Type A). There is therefore some overlap between these programmes and those in Type A (at least in terms of the database in which records are kept), although they still represent separate programmes due to their species-specific focus. These programmes are considered "international" because they contribute to international datasets, but the four programmes themselves are all based in the UK. The two programmes that can be considered "regional" take place in two fairly large and major regions – Friesland (Netherlands) and Cataluña (Spain).

Table 4C: Coordination of programmes in Type B by scale.

Scale	Number
International	4
National	50
Regional	2
Local	0

In terms of coordination of the programmes, the vast majority of programmes in this type are managed by NGOs. A further significant number consist of partnerships between NGOs and universities. As with programmes in Type A, these partnerships often consist of the university providing and maintaining the database, and the NGO providing the website and promoting the programme among the general public.

Table 4D: Coordination of programmes in Type B by type of organisation.

Organisation Type	Number
NGO	40
University or research centre	10
University/NGO partnership	3
Government agency	1
University/government partnership	2

4.2.2 Methods

Point/route/transect counts with no extra step in the data collection (method type 2) are clearly the most common type of method used in this type of programme, as demonstrated in the table below. Broadly speaking, these consist of participants counting the number of a particular species or taxon (or several of these) seen, either along a set route, at a particular point, or in a particular area (transect). The count will often then be repeated at regular intervals and at the same time/s of year, in order to gather longitudinal data. There is, however, considerable variation within the type of method within programmes in Type B. Diverse examples include recording bird sightings on fixed routes along roads (Coordinated Avifaunal Road Count, South Africa), flower-insect timed counts (UK Pollinator Monitoring Scheme, UK, and Great Sunflower Project, USA), and counts of the numbers of orchids on designated sites (Danish Orchid Monitoring Programme, Denmark).

Table 4E: Number of programmes in Type A employing each method type. Note that several of the programmes in this type included more than one method, meaning that the numbers in the above table add up to more than the total number of programmes in this type.

Method Type	Number
Method type 1: Opportunistic counts	16
Method type 2: Point/route/transect counts with no extra step	32
Method type 3: Point/route/transect counts with extra step	3
Method type 4: Other	2
Unclear	5

There is also variation in terms of the selection of sites on which the counts are carried out. Although information on this was often scarce, it is clear that with some programmes, sites are selected systematically by the coordinating organisation. These include the UK Pollinator Monitoring Scheme (UK), where sites are allocated to volunteers from a set of sites that "have been randomly allocated within cropped and non-cropped land". In two other programmes, Floraväktare (Sweden) and the Danish Orchid Monitoring Programme (Denmark), monitoring takes place on sites where the relevant species are already known to be abundant. In the majority of remaining programmes, it appears that volunteers are free to select a site themselves, meaning that data collection is somewhat less systematic.

As well as programmes using point, route, or transect counts, there are also a number of programmes using the same opportunistic recording methods as in Type A (method type 1). Data collection in these programmes is still not site or time-specific, but the programmes are designed to gather data on and/or raise awareness of a particular species or taxa – particularly those that are considered threatened. Such taxa include birds (Ornitho, Spain), bryophytes (British Bryological Society Recording Scheme, UK), moths (British Leaf-miner Moths Recording Scheme, UK), and hedgehogs (Hedgehog Street, UK).

Three of the programmes, meanwhile, employ method type 3 - counts with an extra step in the data collection process. These are, firstly, the UK Pollinator Monitoring Scheme (UK), which uses pan trapping; secondly, the Irish Hedgehog Survey (Ireland), which involves placing "footprint tunnels" on a site to indicate the presence of hedgehogs; and thirdly, the Dutch Macro-moth Monitoring Scheme (Netherlands), which uses light traps. Finally, the "others" (Method type 4) are firstly, recording *details* of trees - such as girth, location, species and access - instead of their quantity (Ancient Tree Inventory, UK); and secondly, Malaise traps (Insect Biome Atlas, Sweden/Madagascar).

4.2.3 Citizen scientist and farmer involvement

In the vast majority of programmes of this type (51, from a total of 56), data collection is carried out by volunteers, and we can assume that the vast majority of these are not farmers. In the five remaining programmes, it has been clearly stated (either by contributing project partners or academic articles) that farmers are included among these volunteers. These include Coordinated Avifaunal Roadcounts (South Africa), the Dutch Macro-moth Monitoring Scheme (Netherlands), and the EU Pollinator Monitoring Scheme (multiple countries). In all other programmes, there is some mention of farmland being one of the types of habitats monitored, but no specific mention of farmers being involved, or being targeted to encourage their involvement. It can therefore be assumed that there is far less engagement with farmers in this type of programme than in Types C, D and E.

It is also clear across these programmes that volunteers' involvement is almost entirely limited to data collection. That is, the programmes are designed by NGOs or universities, with volunteers simply asked to submit data through a website or app. With regard to the skill level of volunteers, ten of the schemes within this type emphasise that the volunteers are "skilled ornithologists" or similar – there may of course be a number of others that involve mostly skilled volunteers, but this is not listed as a requirement at the outset. Programmes in Type D place a greater emphasis on skills among volunteers.

4.2.4 What is monitored?

In keeping with the general trends across this review as a whole, there was a particular prevalence of programmes focused on birds, butterflies and pollinators within this

programme type. The table below gives some examples of the other species or taxa recorded in the various schemes.

Table 4F: Species/taxa monitored in Type B programmes.

Species/Taxon	Number
Birds	12
Butterflies	7
Bees and other key pollinators	6
Moths	3
Plants/flowers	2
Insects (in general)	2
Hedgehogs	2
Dragonflies and damselflies	2
Plants (general)	2
Trees	2

As well as those in the table above, other programmes focused on (for example): reptiles/amphibians, ladybirds, bats, trees, beetles, fungi, bryophytes, collembolla (springtail), and freshwater flatworms (each of these had one programme focused on them).

4.2.5 Data availability/quality

This programme type included the longest-running recording schemes, with various programmes having been running for a number of decades. The longest-running of these dated back to 1966 (North American Breeding Bird Survey, USA/Canada/Mexico), with several others commencing in the late 1960s or 1970s. With long-running schemes, it should be noted that there is probably a high turnover of volunteers, meaning it is unavoidable that there will be some missing data. There will therefore not necessarily be records for the same site going back to 1966 (for example), and particular sites may in fact only have a few years of data gathered (ter Braak et al. 1994, see also section 6.1). Also in relation to timescale, almost all programmes of this type are ongoing rather than timebound. In Types C and D, there are more schemes that were or are timebound in this way – that is, they collect data for a set number of years, and then stop. Programmes in Type B therefore tend to have very substantial volumes of data associated with them.

In the largest number of programmes of this type, data are collected annually. There are also a significant number of programmes where data are collected as and when volunteers choose – these programmes correspond with those employing opportunistic counts (Method type 1). Typical of this programme type, then, are large volumes of data that are collected regularly but infrequently. There are, however, also a fairly significant number of programmes requiring a greater time commitment from volunteers. There are, for example, seven programmes where data are collected 2-4 times per month during a season (typically summer), or monthly during a season.

Table 4G: Frequency of data collection in Type B programmes.

Frequency of Data Collection	Number
Chosen by volunteers	12
Annual	20
Twice during a season	5
Monthly or 4-5 times during a season	4
2-4 times per month during season	7
Several times within 1 week, annually	1
Once ever	1
Unclear	8

4.2.6 Examples

The following are illustrative examples of programmes in Type B:

X:Polli-Nation (UK)

This pollinator-focused programme offers two recording schemes, as well as a range of education and training materials. Of the two recording schemes, one is based on photo submission (BeeWatch, which uses AI and other computing science tools to generate automated feedback), and one based on a standardised timed survey of small plots chosen by the volunteers (a continuation of the earlier, school-based Polli:Nation project). The project is coordinated by researchers form the UK's Open University, and our UK SHOWCASE partners report that farmland is relatively well-represented within it. Furthermore, the well-developed survey and interpretation materials have potential to be used in a farming context. The programme generates large-scale species distribution data, but its wider aims are to engage and train people to recognise species, and to change how they think about and care for local green spaces.

https://plantingforpollinators.org/pfp/index.php?r=user/auth

Irish Hedgehog Survey (Ireland)

Like the X:Polli-Nation project described above, this new programme engages participants through two methods: Opportunistic recording and submission of sightings, and a more focused "local area survey", in which volunteers select an area of 1km^2 to monitor. For five nights in a row, volunteers place ten "footprint tunnels" within this area, and check them each morning for signs of hedgehogs. The programme is coordinated by National University of Ireland in Galway, where researchers have also attempted to gather farmland-specific information on hedgehogs from farmers through a questionnaire. Rather than asking farmers to gather data themselves, the questionnaire asks simple questions around whether they have seen hedgehogs on their land, as well as for details on the type of farming and habitats found there. The questionnaire element of this programme has been included as part of programme Type D. https://www.irishhedgehogsurvey.com/

Suivi Temporel des Oiseaux Communs (France)

This is France's national breeding bird survey, in which volunteers annually carry out ten counts at fixed points within a randomly selected square. The squares are selected by those coordinating the project – a partnership between the French Natural History Museum, the NGO Ligue pour la Protection des Oiseuax (LBO), and the government agency Office Français de la Biodiversité. This is a very typical example of a programme within this type – in fact, the literature search element of our review identified similar national bird monitoring programmes in the UK, Italy, Hungary, Bulgaria, Germany, Spain, North America, and Sweden. This demonstrates that some analysis of farmland-specific trends is possible in these programmes, as many of the papers identified were able to isolate farmland-related data gathered through them. This also suggests a degree of farmer involvement in these programmes, although there is usually no specific reference to this. National bird monitoring programmes typically follow the same methods, following guidelines set out by the Pan-European Common Bird Monitoring Scheme. They are also typically long-running, with the French survey dating back to 1989.

https://www.vigienature.fr/fr/suivi-temporel-des-oiseaux-communs-stoc

4.2.7 Summary: What does this type of programme enable?

As with programmes in Type A, programmes of this type generally involve simple methods that encourage large numbers of participants, thereby acting as an educational tool. They also provide large volumes of data at a national scale, and unlike in programmes in Type A, this data pertains to a specific species or taxa. Although data are relatively general and non-habitat-specific, it is clearly possible to draw some broad farmland-related conclusions from them, as demonstrated by a number of papers identified in the literature review aspect of this task (which often drew upon data from national breeding bird surveys). The inclusion of farmland within these programmes also suggests some level of farmer involvement, although we found no clear reference to this. The identification of biodiversity trends (both farmland-related and more general) through this type of programme is often possible due to their long-running nature, and the subsequent longitudinal nature of the data. It should be noted here, though, that data collected over many years do not necessarily pertain to exactly the same site (particularly in cases where volunteers choose the site themselves), with high volunteer turnover a probably feature of this type of programme.

Although some analysis of farmland-specific trends is possible through such programmes, however, the data collected still tend to be very general compared to those in more farmland-specific programmes (particularly Type D), and involve a high degree of estimation. Calvi et al. (2018) illustrate this in a paper evaluating the benefits of agri-environment schemes (AESs) to farmland bird populations, which uses data from the Italian breeding bird survey. These authors accept that due to a “lack of knowledge about the exact location of AES implementation within sampling units” (p.66), they can only estimate that bird population trends in an area may be due to the AESs that they know to exist within that area. That is, they do not have data on exactly what conservation actions have been taken at the individual farm level. Other limitations of this type of programme include the potential bias towards ‘exciting’ plots selected by volunteers (although not in cases where sites are selected by those coordinating the programme), and the potential for inaccuracies due to the impracticality of providing training for such large numbers of volunteers. Finally, although there is likely to be a degree of farmer involvement in these programmes, this does not extend beyond the collection and submission of data to include any sort of feedback that links the data collected to their own farming practices.

5 Farmland-specific programmes

This chapter now explores the farmland-specific citizen science approaches to biodiversity monitoring identified through this review – that is, those that begin with the aim of gathering data on farmland biodiversity in particular, and/or of engaging farmers specifically in biodiversity monitoring. These farmland-specific programmes are categorised into three types in this review – those that aim to measure general farmland trends for specific taxa (Type C), measure the effects of farming-related activity on biodiversity (Type D), and engage or test methods with farmers (Type E). These types are explored in turn in this chapter. As with the previous chapter, sections on each programme type are structured under the following headings: Coordination and scale; Methods; Citizen scientist and farmer involvement; What is monitored; and Data availability/quality. We then provide descriptive examples of each programme type, and a summary of what is enabled by each type of programme.

5.1 Type C: Measuring general trends on farmland specifically

These programmes are similar to Type B in that they tend to be coordinated on a large scale and aim to gather data general trends, but have a specific focus on farmland. All the programmes identified in this review were, like Type B, focused on a particular species or taxa. Owing to their farmland-specific focus, these programmes are far less numerous than those in Type B, with this review identifying just twelve of this type.

5.1.1 Coordination and scale

As with Type B, these programmes are mostly coordinated by NGOs, although there is also a degree of university or researcher involvement. As will be discussed in the following section, however, the involvement of researchers, tends to increase in programme Type D.

Table 5A: Coordination of programmes in Type C by type of organisation.

Type of Organisation	Number
NGO	7
University/NGO partnership	1
University or research centre	2
University/NGO partnership	1
Government agency	2

Also similarly to Type B, all programmes of this type are organised on a national scale, with the exception of one programme that is limited to the region of Friesland (Bond Friese Vogelwachten, Netherlands). It should also be noted that although national in scope, two of the programmes have clearly-stated region-specific elements – for example, support provided by a regional representative (Swiss Brown Hare Monitoring, Switzerland, and RSPB Farmland Bird Count, UK).

5.1.2 Methods

As with Type B, data collection in this programme type is dominated by point, route and transect counts with no extra step in the data collection process. Across the programmes

identified, these vary from counting arable weeds along a 100 metre-long transect (Inventea Åkerogräs, Sweden), to counting hares at night using powerful spotlights (Swiss Brown Hare Monitoring, Switzerland), to bird counts similar to the national programmes in type B (e.g. BTO/JNCC Winter Farmland Bird Count, UK). With regard to the selection of sites within this method type, this was not clear in any of the programmes identified. It is likely, however, that farmers select the sites themselves in most cases, as the programmes are all coordinated at a large scale with little mention of interaction or direct communication with farmers.

Table 5B: Number of programmes in Type C employing each method type.

Method Type	Number
Method type 1: Opportunistic counts	0
Method type 2: Point/route/transect counts with no extra step	8
Method type 3: Point/route/transect counts with extra step	2
Method type 4: Other	1
Unclear	1

In two programmes within this type, volunteers employ an extra step in the data collection process (method type 3). These are the On-farm Earthworm Survey (UK), where farmers dig holes in order to count earthworms, and Observatorio de Biodiversidad Agraria (Spain), which includes pitfall traps as one of its key methods. The one programme in the "other" category (method type 4) is the questionnaire for farmers that forms part of the Irish Hedgehog Survey (Ireland). Here, farmers are asked to answer questions about the prevalence of hedgehogs in different habitat types on their farm, without actually conducting any sort of count.

5.1.3 Citizen scientist and farmer involvement

Clearly, with the farmland-specific focus of this type of programme, there is considerably more involvement of farmers than in the other programme types discussed up to now. In the largest number of Type C programmes, it is mainly farmers that carry out the monitoring. Those that are categorised as "volunteers and/or farmers" in the table below are programmes that take place on farmland, but where there is no mention of who the "volunteers" are. In these cases, the volunteers are still likely to be farmers, although no information on this is available. It is also likely that even if they are not primarily the ones carrying out data collection, farmers will still have greater awareness of the programme than in Types A and B – for example, simply by allowing citizen scientists access to their land.

Table 5C: Summary of who carries out data collection in Type C programmes.

Who collects the data?	Number
Volunteers	2
Volunteers and/or farmers	5
Farmers	7
Unclear	1

Despite the greater levels of farmer involvement, however, this involvement is largely limited to the collection and submission of data in these programmes. That is, in large-scale programmes such as these, the tendency is for those collecting the data to follow standard, externally-defined protocols, without having any input into determining the questions to be addressed, or the indicator species to be identified. There are two exceptions to this within

programmes of this type. Interestingly, two of these are cases where farmers are not required to carry out the monitoring themselves, meaning that it is likely to be mostly volunteers that do so. The two programmes are firstly, the RSPB Farmland Bird Count (UK), where farmers receive "targeted feedback" based on the results of monitoring, and secondly, the Curlew Task Force (Ireland), in which farmers were represented at meetings that helped determine the approach taken to a national survey of curlews on farmland. The third programme that involves further communication with farmers is the GWCT Partridge Count (UK), where farmers also receive advice on how to improve habitats for the target species.

5.1.4 What is monitored?

As with other programme types, birds are the focus of more than half of the programmes in Type C (7), with two focusing on specific species of bird – the grey partridge, and the curlew. The remaining programmes all focus on different, separate species and taxa. These are weeds, plants/flowers, earthworms, soil organisms, hedgehogs, pollinators, and brown hares, all of which are the focus of one programme.

5.1.5 Data availability/quality

With farmland-specific programmes such as these, despite their national-level coordination, we can assume that generally, fewer sites are covered than in programmes in Types A and B. There is, however, a lack of information on exactly how many sites are covered across all these programmes. These programmes are also generally more recent than those in Type B, and therefore have years' worth of data to draw upon. The one exception to this is the GWCT Partridge Count (UK), which according to its website, has been running since 1933. Others still provide significant longitudinal data, with some programmes running from the 1990s, and others from the early 2000s. As with Type B, we can also assume a high turnover of volunteers (mostly farmers in this case), meaning that data going back to 1933 (for example) does not necessarily pertain to the same site. Also like Type B, however, these programmes are still mostly ongoing rather than time-limited.

Finally, the frequency of data collection within this programme type appears to be much more varied than in Type B. There is not a very clear picture of this, however, with the highest number of programmes being listed as "unclear" in this respect.

Table 5D: Frequency of data collection in Type B programmes.

Frequency of Data Collection	Number
Chosen by volunteers	1
Annual	1
2 x/year	1
3 times in a season (winter)	1
Monthly or 4-5 times during a season (spring)	1
Once ever	2
Unclear	6

5.1.6 Examples

The following are illustrative examples of programmes in Type C:

Observatorio de Biodiversidad Agraria (Spain)

The Observatory of Agricultural Biodiversity (OBA) is currently a pilot programme involving just 16 participants, but ultimately aims to develop into a large-scale monitoring network of agricultural biodiversity that can evaluate the impacts of agricultural management. It aims to achieve this through citizen science involving farmers and others working in agricultural areas. Its coordinators – the NGO Fundación Global Nature - hope that this will enable the collection of large quantities of data while simultaneously engaging farmers with the biodiversity on their land. There are currently three surveys carried out as part of the pilot programme: a pollinator survey that monitors flower visitation rates and also involves the construction of 'bee hotels'; a survey of soil fauna using pitfall traps and earthworm counts; and a plant survey using $4m^2$ plots. Our SHOWCASE partners in Spain identified this as a promising programme if it can be scaled up as planned. https://oba.fundacionglobalnature.org/

Big Farmland Bird Count (UK)

This programme is similar to the many national bird surveys that make up programme Type B, but with a specific focus on farmland and the engagement of farmers. It is also more recent than many of those programmes, having started only in 2014. Since then, however, participation has expanded so that over 1,800 farmers took part in 2021, between them recording over 130 species across 2.5 million acres. Participants undertake one count during a specific time period during winter (between 5th and 21st February). They are asked to spend around 30 minutes recording the species and number of birds seen on one particular area of a farm (preferably somewhere close to where supplementary feeding takes place), as well as provide information on the types of habitat and cropping on and adjacent to the count site. The focus on farmer engagement is clear in the advice that "counting should take place at first light as this is when the birds are most active. However, it is more important that you take part, so timings should suit you". The programme is run by the Game and WIldlife Conservation Trust (GWCT) – an NGO that also runs a more species-specific monitoring programme, the Partridge Count.
https://www.bfbc.org.uk/

Swiss Brown Hare Monitoring (Switzerland)

This programme involves the counting of brown hares in agricultural areas carried out by volunteers, and subsequent data is drawn upon in a paper by Zellweger-Fischer et al. (2011). The extent of farmer involvement in the programme is unclear, but there is a clear focus on agricultural areas - Zellweger-Fischer et al. (2011) describe the project as a response to the decline of brown hare populations due to agricultural intensification. The methods employed in this programme are unusual in that the counts take place at night using high-powered spotlights and binoculars, and volunteers are required to drive slowly along pre-determined routes that were then repeated with each subsequent count. The programme ran from at least 1992 to 2008, and the website of the Swiss NGO Vogelwarte suggests that at least a similar scheme is still in operation.

https://www.vogelwarte.ch/en/projects/habitats/terminated-projects/monitoring-and-promoting-the-brown-hare-in-switzerland

5.1.7 Summary: What does this type of programme enable?

For the purposes of this review, the clear advantage of this type of programme over those in Types A and B is that they enable the collection of more specific, but still large-scale, data about farmland and species in relation to farming practices. This is despite these programmes generally including fewer sites and fewer years' worth of data than those in Type B. It appears that in many cases, participants are asked to provide more targeted information on the types of habitat found on monitoring sites. Data may therefore still be general and wide-ranging, but it appears that links can at least begin to be drawn between farming practices and biodiversity trends. This is demonstrated, for example, in Zellweger-Fischer et al's (2011) paper on the Swiss Brown Hare Monitoring programme (see section 5.1.6 above), where they draw links between brown hare population trends, and the intensification of farming. Despite the farmland-specific focus, however, the data gathered through these programmes still relate to rather general trends. They may not, therefore, enable conclusions to be drawn on the effects of a specific farming practice with trends relating to a specific species. Programmes with more specific research questions require more targeted and smaller-scale programmes, such as those in Type D.

Another key benefit of this programme type is the engagement of a large number of farmers, either through carrying out monitoring themselves, simply by engaging with volunteers to allow them access to their land, or the programmes and their associated communication tools being set up to appeal to farmers specifically. As has been noted, however, this engagement is still somewhat minimal, with only a few programmes mentioning any engagement with farmers beyond the collection and online submission of data.

5.2 Type D: Measuring effects of farming on biodiversity

These programmes are those that begin with a more specific research question, and aim to measure the effects of a particular farming-related activity on a particular aspect of biodiversity. They are generally smaller-scale than programmes in Types A to C, starting with a particular intervention or farming practice, and determining its effects over a number of carefully-selected sites. Sometimes, these programmes are set up for the purposes of a particular study, and reported on in subsequent papers (as identified through the literature search element of this review). A total of 26 programmes of this type were identified in this review.

5.2.1 Coordination and scale

Despite there still being a substantial number of NGO-run schemes, programmes of this type demonstrate a much-increased involvement of universities and research centres compared to Types A to C, with thirteen of the programmes involving universities in some stated capacity. This can be seen in the relatively high number of programmes of this type that form the basis of focused academic papers.

Table 5E: Coordination of programmes in Type D by type of organisation.

Organisation Type	Number
NGO	8
University/NGO partnership	1
University or research centre	11
NGO/government partnership	2
Government agency	2
University/government/NGO partnership	2

In terms of the scale at which these programmes are organised, many still operate at a national level, although this perhaps creates a false impression of the number of sites covered by them. In fact, those operating at a national level are often still small in terms of the number of sites, as well as being more focused on a particular habitat type or type of intervention than programmes in Types B and C. The few exceptions to this include the Observatoire Agricole de la Biodiversité (France), where “1,216 farmers monitored biodiversity in 2,382 fields between 2011 and 2017” (Billaud et al. 2020, p.262). Methods used in this programme do, however, appear precise enough to enable the effects of specific farming practices to be identified, as demonstrated in Billaud et al.’s (2020) paper. The one programme of international scope is the development of a biodiversity assessment scheme reported on by Tasser et al. (2019). This took place in five different countries across the Alps, but in fact included just 44 sites at which data were collected. Even with the tendency for national and international programmes tending to be smaller in terms of number of sites, there is still a much higher proportion of locally-coordinated schemes within this programme type.

Table 5F: Coordination of programmes in Type B by scale.

Scale	Number
International	1
National	14
Regional	3
Local	9

5.2.2 Methods

Again, the methods used in this type of programme are dominated by point, route or transect counts. It is assumed that given the specific focus of these programmes, site selection is in most cases more systematic than in Types A to C, although in fact this is often not explicitly stated. Within this method type, a variety of interventions or farming practices form the basis of the investigation. These include regular bird counts in small woodlands planted on farms in the past twenty years (English Farm Woodland Bird Monitoring Scheme, UK), bird counts in unique areas of mixed farmland (Northumberland Coast Farmland Bird Monitoring Scheme, UK), farm dams (EnviroDNA, Australia, and Taoyuan farm ponds project, Taiwan), a range of conservation methods (Swedish Volunteer Farmer Alliance, Sweden), bird nesting boxes (Songbird Farm Trail, USA), and different harvest dates (Enquête Busards-Milans, France). In all cases, however, a standardised counting method follows the intervention or selection of sites.

Table 5G: Number of programmes in Type D employing each method type.

Method Type	Number
Method type 1: Opportunistic counts	1
Method type 2: Point/route/transect counts with no extra step	22
Method type 3: Point/route/transect counts with extra step	4
Method type 4: Other	2
Unclear	0

The extra steps in the data collection process employed by four of the programmes are: Light traps in order to monitor butterflies and macro moths (Insect monitoring by farmers on agricultural land, Netherlands); Spraying mustard to encourage earthworms to the surface (one of several methods used by the Observatoire Agricole de la Biodiversité, France); Mapping using an online tool before data collection (Grasslander, Canada); and pan traps used in an “Expert-assisted citizen science program” in agricultural high schools (France). Those categorised as “other” (method type 4), meanwhile, are the National Honey Monitoring Scheme (UK), where beekeepers are asked to provide information in the form of a questionnaire, and EnviroDNA (Australia), where participants use technology to detect the DNA of a range of species that are or have been present in farm dams.

Overall, the methods employed are largely similar, and no more complicated, than in programme Types B and C. The key difference, however, is in the selection of sites. That is, in starting with the aim of investigating the effects of a particular intervention or farming practice on a particular aspect of biodiversity, the sites included are likely to have been carefully selected as examples of particular habitat types or places where a particular intervention has taken place. This leads to data that can more clearly demonstrate links between farming practices and biodiversity trends, even if the actual monitoring techniques are similar to those in larger-scale, more general citizen science programmes.

5.2.3 Citizen scientist and farmer involvement

Overall, engagement of farmers is significantly higher in programmes of this type than in others, although in the highest number of programmes, data collection is still carried out by volunteers. In programmes that employ volunteer-led monitoring, however, it is still likely that farmers engage with the programme to some extent. This may include contact with researchers as farmers agree to be part of the programme, granting volunteers access to their land, and face-to-face contact with volunteers as they make regular visits to the farm. In this type of programme, there are also more references to farmers receiving feedback from volunteers or researchers on the results of monitoring, and what this means for their farming practices.

Table 5H: Summary of who carries out data collection in Type D programmes.

Who Collects the Data?	Number
Volunteers	13
Volunteers and/or farmers	3
Ecologists and farmers	1
Farmers	9
Unclear	0

In programmes where farmers carry out data collection themselves, it should be noted that their role still tends to be that of a participant in someone else's research project (at least officially or according to how the programmes are reported on). That is, while in some cases farmers may be involved in mapping the study site, or providing further details of it to researchers or volunteers, their role thereafter tends to be one of simply collecting and submitting data. This indicates that these programmes are not set up on farmers' own terms – that is, it is not farmers who are setting the questions or deciding *what* needs to be monitored and to what end. It is still very much ecologists and conservation NGOs who are setting the agenda. "Contributory" approaches such as this, in which participants simply collect data that contribute to a study designed by others, are in fact the most common across citizen science as a whole (Roy et al. 2012: Follett and Strezov 2015), and indeed also in Types A to C in this review. Some of the programmes in Type E, however, can be seen to be shifting this tendency towards more "co-created" approaches – those where the target community themselves play a key role in the identification of the phenomena to be studied. Despite the "contributory" nature of Type D programmes, however, there may still be more informal types of engagement by farmers, such as speaking with volunteers or researchers, or as noted above, receiving feedback on the data collected. The examples in section 5.2.6 detail some of the type of involvement that occur in these programmes.

Two programmes in this type are notable in that data collection is carried out by farmers in combination with ecologists or volunteers. One such programme is the biodiversity assessment scheme developed in Tasser et al's (2019) study, where farmers were given the option to accompany ecologists when carrying out data collection, with a view to them developing the skills to be able to do this themselves in future. This programme is labelled "ecologists and farmers" in the table above. In the programme Birds on Farms (Australia), farmers often accompany volunteers to carry out monitoring. The programme's website describes this as being part of an "informal training session". This is labelled "volunteers and/or farmers" in the table above. In the other programmes of this type (Zone Atelier Plaine et Val de Sèvre, France, and English Farm Woodland Bird Monitoring Scheme, UK), both farmers and other volunteers contribute to data collection, but do so separately.

Particularly across the programmes referred to in academic articles, there is a greater emphasis on volunteers receiving training, or having existing skills, in this type of programme. There are, for example, references to “300-400 trained local volunteers” (Enquête Busards-Milans, France), “trained observers” (ARGOS Farmland Bird Monitoring Scheme, New Zealand), “experienced birdwatchers” (Birds on Farms, Australia), and “skilled birdwatchers” (Swedish Volunteer and Farm Alliance, Sweden), and those forming part of a University’s “Master Gardener” programme (Squash bee flower visitation study, USA). The greater emphasis on skills is likely due to the smaller scale of programmes of this type. That is, while the methods used are not necessarily more complex than in other programme types, the small number of study sites means that there is less “room” for observer error, and a greater need for accuracy in the data collected.

5.2.4 What is monitored?

As with other programme types, birds, and to a lesser extent bees, are the main taxa covered by this type of programme. While many of the bird-focused programmes are still somewhat general, being focused on common bird species for the particular habitat type under investigation, three of them have a more species-specific focus than those in Types B and C (Enquête Busards-Milans, France; Grasslander, Canada; and Strathspey Wetland and Wader Initiative, UK). Likewise, four of the pollinator-focused programmes also focus on specific species of bee (Observatoire Agricole de la Biodiversité, France; Squash bee flower visitation study, USA; and National Honey Monitoring Scheme, UK).

It is also notable that there are a greater number of programmes where more than one species/taxon is monitored within the same plot. This is perhaps enabled by the greater emphasis placed on skilled volunteers in this type of programme, as noted in the previous sub-section. Given this tendency, the total number of species/taxa listed in the table below is higher than the number of programmes in this type.

Table 5I: Species/taxa monitored in Type D programmes.

Species/Taxon*	Number
Birds	12
Bees	7
Butterflies	4
Plants/flowers	4
Insects (in general)	2

*As well as the species/taxa in the table above, Type D includes one programme each focused on spiders, mammals, invertebrates, bats, earthworms, ants, dragonflies, hoverflies, amphibians, fish, and moths. One programme – EnviroDNA in Australia – monitors any species whose DNA is detected in farm dams.

5.2.5 Data availability/quality

There is a clear tendency for programmes of this type to include fewer data collection sites than those in Types A to C. The number of sites in Type D programmes is commonly less than 100, with a few small pilot programmes even consisting of ten sites or fewer. Additionally, in terms of number of years of data available, a higher number of Type D programmes are time-limited, with many taking place over three seasons, for example.

Overall, based on the information available, data collection is not necessarily more frequent in this type of programme than in Types B and C. There appears to be a more varied picture in this respect across programmes of this type, with examples being monthly (4 programmes) annually (2 programmes), every two years over a six-year period (1), three times in spring for two years (1), once for the purposes of a study (2), and three or four times per year (3). It is likely that this variation reflects the range of specific research questions addressed in programmes of this type, meaning that data collection methods are tailored accordingly.

As previously noted, these programmes are by definition more focused in terms of what is being monitored in relation to what type of habitat or intervention, meaning that fewer sites and less longitudinal data, combined with a similar frequency of data collection, does not necessarily equal lower data quality.

5.2.6 Examples

The following are illustrative examples of programmes in Type D.

Birds on Farms (Australia)

This project currently covers the state of Victoria, but is in the process of expanding into New South Wales. It is a bird monitoring programme that facilitates data collection by volunteers on privately-owned land (including farms). Methods consist of bird counts carried out quarterly, and sites are carefully selected to include different types of habitat (such as remnant native forest, planted native trees, native grassland or pasture, and orchards and cropland) in cooperation with the NGO BirdLife Australia. This, according to the programme's website, enables more targeted questions to be addressed, such as "How do bird assemblages differ between the various habitats found on these properties and has this changed over time?", and "How does land management influence these bird assemblages?" Significantly for SHOWCASE, the project emphasises partnerships between volunteers and farmers/landowners, who often carry out the surveys together "as part of an informal training session". The programme appears to offer a good balance between farmer engagement and systematic data collection.

https://birdlife.org.au/projects/woodland-birds-for-biodiversity/birds-on-farms-wl

Development of a biodiversity assessment scheme (Tasser et al. 2019, Alps)

This project was developed as part of a study by Tasser et al. (2019), and took place in five countries across the Alps - Austria, Switzerland, Italy, France, and Germany. Despite this international focus, it was still a relatively small project, covering just 44 farms. Significantly, the assessment scheme was developed with farmers, mainly through workshops to help determine the indicator species to be counted. Farmers were then also given the chance to assist researchers with data collection as a means of evaluating the "non-expert applicability" of the survey methods, with 13 of the 44 participants doing so. Data collection during the fieldwork period consisted of 235 plant surveys, 201 flower colour surveys and 200 butterfly surveys. Based on this study, Tasser et al. (2019) emphasise the need for farmers to receive extensive training in order to carry out the data collection in such an assessment scheme, and potentially, for some aspects of the data collection to be done by professionals.

Tasser, E., Rüdisser, J., Plaikner, M., Wezel, A., Stöckli, S., Vincent, A., Nitsch, H., Dubbert, M., Moos, V., Walde, J. and Bogner, D., 2019. A simple biodiversity assessment scheme supporting nature-friendly farm management. Ecological Indicators, 107, p.105649. https://doi.org/10.1016/j.ecolind.2019.105649

Squash bee flower visitation study (Appenfeller et al. 2020, USA)

Appenfeller et al. (2020) detail a citizen science project developed specifically for their study, in which data collection was carried out by volunteers with existing specialist knowledge, on farms across Michigan. There is no mention of farmer involvement in data collection, although presumably there was some communication with farmers in order to set up the study. The study focused on the squash bee - a specialist pollinator of pumpkins, squashes, and gourds, and therefore an important farmland bee species – and how its "flower visitation frequency varies according to crop management". This was a relatively large study for its type, with 291 pollinator surveys carried out by 59 volunteers. The authors were thus able to draw strong links between specific agricultural practices and pollinator abundance.

Appenfeller, L.R., Lloyd, S. and Szendrei, Z., 2020. Citizen science improves our understanding of the impact of soil management on wild pollinator abundance in agroecosystems. PloS one, 15(3), p.e0230007. https://doi.org/10.1371/journal.pone.0230007

Observatoire Agricole de la Biodiversité (France)

France's Farmland Biodiversity Obervatory (FBO) aims to "offer protocols for observing ordinary biodiversity to interested farmers, with a view to better understanding ordinary biodiversity in an agricultural environment and its links with practices". Farmers collect data through four such protocols, each focused on a different indicator species: bees, earthworms, bats and invertebrates. As well as monitoring and submitting results, farmers provide information "about the landscape surrounding the field and their agricultural practices", which according to related academic papers (Billaud et al. 2021; Deschamps and Demeulenaere 2015) enables links to be drawn between biodiversity trends and farming practices. The programme appears to represent a good balance between the possibility for such focused analysis, and large-scale data collection carried out by farmers.
https://www.observatoire-agricole-biodiversite.fr/

Northumberland Coast Farmland Bird Monitoring (UK)

This is a very small and targeted programme that has begun by pairing ten trained volunteers with ten farmers in order to carry out surveys of breeding and overwintering birds (although it appears to be mainly the volunteers who have carried out the surveys). Coordinated by the government agency Natural England, the project has been specifically developed for the mixed farming system in this particular area of Northern England, which is not typical of UK farming as a whole. It therefore enables an analysis of the effects of this particular type of land use system on bird populations. Volunteers visit allotted farms four times per year to carry out the bird counts. Data so far extends back to 2015, but there are future plans to "employ a Master's Degree student to analyse it against cropping, climate and agri-environment data".
https://www.northumberlandcoastaonb.org/farmland-bird-monitoring/

Swedish Volunteer and Farmer Alliance (Sweden)

SVFA was primarily a conservation initiative focused on promoting the implementation of various conservation measures at farm level, which were then followed by data collection carried out by volunteers (particularly relating to birds). In total, the project involved almost 300 farmers spread across Sweden's key agricultural areas, along with volunteer birdwatchers recruited through the NGO BirdLife Sweden. Conservation measures included "skylark plots" (Josefsson et al. 2017) – small areas of arable land left unploughed to provide habitats for skylarks - and subsequent monitoring aimed to assess the effectiveness of these. Although monitoring was carried out by volunteers, farmers themselves implemented the conservation measures, which resulted in close collaboration between these participants.

https://birdlife.se/projekt/tidigare-projekt/lantbrukare-och-fagelskadare/

5.2.7 Summary: What does this type of programme enable?

As citizen science approaches to monitoring farmland biodiversity, programmes of this type have two key advantages over other types. Firstly, there is far greater potential to draw links between biodiversity trends and specific agricultural practices. This is made possible by the specific research questions they tend to begin with, and the subsequent careful selection of sites and participants. Secondly, mostly due to their smaller scale, such programmes allow for higher levels of farmer engagement. A high proportion of these programmes involve farmers themselves in data collection, but even if this is done by volunteers, there is still potential for informal forms of engagement, such as agreeing to be part of the study, or talking to volunteers or researchers during their visits. Particularly encouraging are programmes such as Birds on Farms (Australia), where farmers often accompany volunteers to carry out data collection, with a view to developing the necessary skills to continue it themselves. Despite their more specific focus, these programmes still largely employ simple methods, which also helps with effective participant engagement. Some papers reporting on programmes of this type point to an increase in farmers' knowledge of or interest in biodiversity after involvement – although admittedly this is often an informal observation that is secondary to the article's main argument, rather than being studied in any systematic way (e.g. Shaw 2017; Tasser et al. 2019).

While these programmes enable more focused data analysis, however, they are less suitable for analysing large-scale trends than programmes in Types B and C. This is due to their smaller number of sites, and tendency to focus on a specific type of habitat or farming type. Additionally, the tendency for these programmes to be time-bound rather than ongoing, or only recently established, can result in a lack of longitudinal data compared with other types of recording scheme.

Programmes of this type are also potentially more resource-heavy when it comes to engagement of volunteers, due largely to the greater emphasis on expertise. The smaller number of sites in these programmes leaves less 'room' for observer error, which creates a need either to provide (sometimes quite extensive) training for volunteers, or to recruit

volunteers with pre-existing skills and knowledge. Training provision entails a considerable use of resources, while recruitment of those with existing skills means there is less potential for engaging new audiences with biodiversity. In a sense, the smaller scale of these programmes means that there is a less of an argument for using citizen science approaches within them than in programme Types A to C. In those programmes, involvement of the public enables the collection of volumes of data that would never otherwise be possible, whereas in this type, it is often possible for researchers to collect the data themselves. Indeed, our literature search returned a number of small-scale studies of farmland biodiversity where this was the case. There are, however, clear potential benefits to the closer engagement of farmers that these programmes enable, in the form of increased interest in biodiversity, and willingness to adopt more biodiversity-friendly farming practices (although clear evidence or testing of this remains somewhat limited).

Finally, farmers' engagement is potentially increased when they are given greater input into the aims and design of a study/programme, as in the Type E programmes explored in the following section. As highlighted in this section, farmers' role in Type D programmes still tends to be that of a participant in someone else's research project, rather than having any further input. If farmer engagement is the aim of such programmes, then this may be seen as a further disadvantage.

5.3 Type E: Engaging or testing methods with farmers

In these programmes, the primary aim is the engagement of farmers, and/or testing research methods that may help to engage farmers. They are still 'citizen science' in that non-professionals are engaged in some form of data collection, but the data collected are not necessarily used for research purposes, and are secondary to this primary aim. Our review identified seven programmes of this type – all except one in the UK. One of these is a series of protocols tested for the purposes of a study, with recommendations made for the wider use of these methods (Garratt et al. 2019), while others consist of monitoring tools set up for farmers to engage them with the biodiversity on their land (e.g. Cool Farm Tool, LEAF Simply Sustainable resources, both UK).

5.3.1 Coordination and scale

As with other programme types, the highest number of programmes of this type are coordinated by NGOs. There are, however, key differences in how some of the programmes are run. The Innovative Farmers programme, for example (see examples in section 5.3.6) is itself a type of NGO (a "not for profit membership network", according to its website), but its main purpose is to enable farmers themselves to set up "field labs" in order to test interventions or innovations. While the scheme as a whole is NGO-run, then, these individual field labs are farmer-led, with help from researchers as required. Of the other programmes, two are coordinated by government agencies – monitoring tools provided by the government's Farmland and Wildlife Advisory Group (FWAG) within the UK Government's Department of Environment, Food and Rural Affairs (DEFRA); and MonVia monitoring tools, under development by the German Ministry of Agriculture. The programme run by researchers is the series of protocols tested in Garratt et al.'s (2019) paper.

Table 5L: Coordination of programmes in Type A by type of organisation.

Organisation Type	Number
NGOs	4
Researchers	1
Government	2

In terms of organisational scale, the majority of programmes (six of seven) are organised on a national scale. With this programme type, however, programmes often still involve only small numbers of farms, or involve many unconnected small groups of farmers working together on specific monitoring projects.

5.3.2 Methods

When looking at the methods employed in this type of programme, in several cases this was unclear. This was either due to needing to register for the programme in order to receive resources (Cool Farm Tool, UK), or methods being determined once the questions to be addressed had been decided (Innovative Farmers and Farmer Clusters, UK). The programme including an extra step in the data collection process is Garratt et al's (2019) study, which includes pan trapping as one of the methods used. Of the remainder, the dominant methods used were again point/route/transect counts – typically, farmers choosing an area of their farm and being encouraged to monitor what is there, among taxa to be determined by the farmer him or herself.

Table 5K: Number of programmes in Type E employing each method type.

Method Type	Number
Method type 1: Opportunistic counts	0
Method type 2: Point/route/transect counts with no extra step	4
Method type 3: Point/route/transect counts with extra step	1
Method type 4: Other	0
Unclear	3

In terms of the selection of sites to be monitored, in most cases this is done by farmers themselves. In some cases such as Innovative Farmers, presumably this is done in consultation with a researcher (see examples in section 5.3.6). In a sense, the chosen site is irrelevant in this programme type, as they are not aimed at collecting high quality data. For the purposes of engaging farmers, however, it may make a significant difference to their developing interests and motivations whether the site is already rich in biodiversity or not.

5.3.3 Citizen scientist and farmer involvement

Farmers carry out data collection in all seven identified programmes of this type. In two of these, others also contribute to the data collection, at least in some cases. In the monitoring methods described in Garratt et al.'s (2019) paper, researchers and "volunteer non-experts" also collect data, separately to farmers. The Farmer Clusters programme, meanwhile, may also involve volunteers or researchers in data collection, depending on the particular "cluster". Overall, however, there is a far higher level of farmer engagement in these programmes, including in the design and planning of the monitoring. This is detailed in the examples in section 5.3.6.

5.3.4 What is monitored?

The protocols described in Garratt et al's (2019) paper all focus on pollination, so involve monitoring pollinators, insects and plants/flowers. In all the remaining schemes, farmers decide themselves what is to be monitored, sometimes from a list of options provided through the programme. We can therefore assume that a wide variety of species/taxa are monitored through these programmes.

5.3.5 Data availability/quality

All programmes are unclear in terms of the number of sites monitored, aside from Garratt et al.'s (2019) study, which took place on 13 field sites. As noted elsewhere, however, these programmes have primarily been set up to engage farmers, and are not necessarily coordinated with a view to collecting significant volumes of ecological data. Even if some programmes include high numbers of sites, then, it is likely that participants are not measuring the same thing on all these sites.

Data across all these programmes are either collected once for the purposes of a particular study, or as little or often as farmers choose. There is limited information on the number of years of data available, but all are presented as recent or innovative programmes, so this is presumably fairly limited in all cases.

5.3.6 Examples

The following are illustrative examples of programmes in Type E:

LEAF Simply Sustainable Biodiversity (UK)

This is a booklet that forms part of the "Simply Sustainable" series of resources provided by the NGO Linking Environment and Farming (LEAF). The booklet aims to "help farmers monitor, manage and enhance biodiversity through the adoption of Integrated Farm Management (IFM)", and details a series of simple steps to be taken towards this. Monitoring and identifying key species, on a site chosen by farmers themselves within their own farm, are the first two of these steps. Unlike Farmer Clusters and Innovative Farmers, there is no research question underlying this monitoring - the idea is simply to begin by identifying the biodiversity on their land (or a particular part of it). As far as can be determined by the programme's website, the data then does not contribute to any wider dataset or scientific study. https://leaf.eco/farming/simply-sustainable-series

Farmer Clusters (UK)

This programmes aims to bring farmers together in “clusters”, in order to "work more cohesively together in their locality", aided by an advisor or facilitator. Monitoring forms part of the programme, but is not linked to a particular study or wider dataset, with farmers instead setting up a programme themselves (including applying for funding through the scheme), and potentially recruiting volunteers. The programme’s website includes advice on how to design a monitoring programme in order that data are collected as systematically as possible. As part of this, farmers are encouraged to adopt methods that enable them to contribute to a national survey, so there is at least potential for these programmes to contribute to wider datasets (most likely those in Types B or C). This programme is very significant in that it offers farmers a high degree of agency in terms of deciding the overall purpose of the data collection, and what is to be monitored – “on their own terms”, as described on the website. The programme is “hosted by” the Game and Wildlife Conservation Trust (GWCT), with a number of other organisations (mostly conservation-focused NGOs) acting as partners. The first clusters were established in 2015, and there are now roughly 120 of them across the UK. https://www.farmerclusters.com/

Innovative farmers (UK)

Similarly to Farmer Clusters, Innovative Farmers is, according to its website, “a network of farmers and growers who are running on-farm trials, on their own terms”. The programme is part of the Duchy Future Farming Programme, which in turn is funded by the Prince of Wales’s Charitable Fund through the sales of organic products in the supermarket chain Waitrose. Like Farmer Clusters, the emphasis is on farmers coming together to devise and coordinate a monitoring scheme, which they do through “field labs”. There are now 132 field labs across the UK that are either still running, or have concluded. These can focus on “any issue that makes farm businesses more sustainable and resilient”. Interestingly given farmers’ freedom to choose the monitoring topic, few of these field labs appear to focus on biodiversity specifically. A search for “biodiversity” in the database of field labs returns only five results, with only one of these focused on a specific aspect of biodiversity (“Investigating the aspects that make farms successful or unsuccessful for breeding waders”). The remaining four mention biodiversity alongside soil and animal health. This suggests that, for engaging farmers with biodiversity through monitoring programmes, indicators with greater relevance to agricultural productivity (such as earthworms) may act as an effective starting point. https://www.innovativefarmers.org/

Testing protocols for monitoring pollinators and pollination service (Garratt et al. 2019, UK)

This is a study led by researchers at the University of Reading, in which the authors test the willingness and (self-reported) ability of farmers, and other types of participants, to carry out pollinator monitoring using a series of protocols. The study involved three different recorder groups - "research scientists", "volunteer non-experts", and farmers – testing three different protocols: transect surveys, pan trapping, and "pollination service assessments". The methods were tested in three different locally-specific habitat types: oilseed rape fields, field bean fields, and an apple orchard, in three different areas of the UK. The authors report that all three recorder groups (including farmers) were able to successfully use the protocols in the field. They also generally considered the process "enjoyable", and said they would be willing to participate in a "wider scheme" using such methods. They also point to the potential need for "training and capacity building if these methods are to be rolled out more widely". This study therefore offers encouraging evidence that high quality data collection can be linked with widespread farmer engagement, although hints at the increased time and funding required (for training provision, for example) if such programmes are to be upscaled.

Garratt, M.P.D., Potts, S.G., Banks, G., Hawes, C., Breeze, T.D., O'Connor, R.S. and Carvell, C., 2019. Capacity and willingness of farmers and citizen scientists to monitor crop pollinators and pollination services. Global Ecology and Conservation, 20, p.e00781. https://doi.org/10.1016/j.gecco.2019.e00781

5.3.7 Summary: What does this type of scheme enable?

The clear advantage of this type of programme is the engagement of farmers. This happens either through "co-created" approaches (Follett and Strezov 2015) that begin with farmers' own identification of the research question, through resources aimed at farmers specifically, that help them make the link between biodiversity and agricultural practices, or through testing monitoring methods for farmers specifically (Garratt et al. 2019). From a data collection perspective, however, the very clear disadvantage of these programmes is that they do not (yet) appear to contribute to any wider scientific study or dataset. This is due either to programmes that encourage farmers to monitor purely for their own learning, or "field labs" or "clusters" that consist of only a few farms. Combining such high levels of farmer engagement with data that is 'useful' from an academic perspective, is a key challenge for farmland biodiversity monitoring programmes going forward. This is touched upon further in the Summary and Recommendations chapter (Chapter 7).

6 Statistical approaches for dealing with biodiversity monitoring data collected by citizen scientists

The previous two chapters have briefly summarised what is enabled by the five types of programme identified in this review, focusing largely on data collection methods, farmer/volunteer engagement, and how the programmes are coordinated. This chapter now goes somewhat 'behind the scenes' to look more closely at what happens to the data produced by these programmes, with a particular focus on how they are analysed.

How biodiversity data collected by citizen scientists can be analysed depends both on the nature of the data and the aim of the monitoring or the analysis. The aim of biodiversity monitoring is typically to assess general trends in biodiversity (as in programme Type A), or trends for certain species or groups of species, depending on large-scale drivers (Types B or C), or to evaluate the effects of a specific driver or specific types of management, interventions or other actions aiming to promote biodiversity (Type D). Here, we focus on biodiversity monitoring that aims to detect and assess changes or trends in biodiversity over time.

6.1 Systematically collected data

Two main categories of citizen science-collected data used for biodiversity monitoring are data collected through systematic monitoring schemes, and opportunistically collected data. As highlighted elsewhere, the extent to which data collection is 'opportunistic' or 'systematic' varies across the different programme types identified in this review. While there is some variation within Types B and C, this can largely be viewed as a spectrum ranging from programmes where volunteer submit records on any species at any time or place (Type A), to those where the indicator species/taxa are specified, and sites are carefully selected due to the presence of a particular habitat type or farming practice (Type D).

Large-scale monitoring programmes, such as national monitoring programmes of birds or butterflies (Type B), are designed to yield data that can be used to estimate trends in biodiversity. The design typically consists of large numbers of sites that are visited each year (or with some other regular interval), and where species are observed using standardised methods (PECBMS 2021; Pollard and Yates 1993). Hence, the data consists of time-series of species occurrences or abundances at multiple sites over a span of multiple years. One challenge is that the data are often incomplete. Because monitoring is conducted by citizen scientists on a voluntary basis, it is unavoidable that there will be some missing data – for example, when some sites have not been monitored every year and hence some year-site combinations are missing (ter Braak et al. 1994). Another factor that needs to be taken into account is that that the observations at a given site and a given year might not be independent of the observations from the same site the previous year (i.e. serial correlation). This can for example occur for birds, who live for more than one year, such that the same individuals are observed at the same site during multiple years. Specific statistical methods have been developed to estimate trends for this type of data, for example TRIM (Trends and Indices for Monitoring data) (Pannekoek and van Strien 2005). TRIM implements a type of Poisson regression for count data, and imputes missing data based on both site and year effects, under the assumption that changes observed in monitored sites also apply to sites that were not monitored in a given year (Pannekoek and van Strien 2005). This method has been further developed - for example, to estimate non-linear trends (Soldaat et al. 2007). TRIM is widely used to calculate trends for national data, and is used to evaluate the progress towards national biodiversity targets – for example, in Sweden (Green et al. 2021).

It is also used to calculate trends at a European scale, such as the EU Butterfly indication for grassland species (van Swaay et al. 2019).

6.2 Opportunistically collected data

Another common type of data collected by citizen scientists is opportunistic biological records. This is typically data on species observations reported by volunteers through reporting systems such as Artportalen, iNaturalist, and others in Type A. As such, the data consists of records of observed species at a given location and time point. The main advantage of using opportunistic biological records is the large amount of data available (see also section 4.1.5). Comparisons between opportunistic and systematically collected data from citizen scientists have found that they tend to show similar trends, even though the correlation is weak and there is high variability in the agreement of trends at the species level (Snäll et al. 2011). The non-systematic nature of opportunistic records means that there are several challenges in using it to estimate biodiversity trends (Isaac et al. 2014). One problem is that observers typically only record what they observe, and rarely what they *do not* observe. Hence, it is difficult to know if the absence of a given species in the data is because the species is truly absent from the site, or because the recorder observed it but chose not to record it. The latter might often be the case for very common species, which tend to be under-reported compared to their actual occurrence (Snäll et al. 2011). Applying complete checklists for reporting opportunistic records, where observers report all the species they detect and identify, makes it possible to separate non-detections from other reasons for not recording a given species. This can significantly improve the reliability of trends in species occupancy and distribution (Johnston et al. 2021).

Some of the additional challenges that need to be overcome are: First, that recording intensity - the number of visits by recorders to a given site - varies from year to year: Second, the spatial coverage is uneven – that is, recorders tend to visit more accessible locations (Mair and Ruete 2016), or locations with high numbers of species or rare species; Third, the sampling effort - the time spent at a given location - varies over time and between recorders, and the records from a given site might originate from different recorders in different years, and: Fourth, recorders might differ in their ability to detect or identify the species of interest (Isaac et al. 2014). There have been many attempts to develop methods and models to overcome these challenges. A frequently used approach is to filter the data, so that only sites with a minimum number of species or sites with records from a minimum number of days or years are included (Ruete et al. 2020). Other approaches have used the estimated trend in all species together as an indirect measure of how recording intensity varies over time (Telfer et al. 2002), or statistically tried to control for uneven sampling between locations by adding the study site as a random effect in the statistical model (Roy et al. 2012). Rapacciuolo et al. (2021) identified four main approaches to increase the usefulness of opportunistic biological data to derive indicators of biological change. These were: Reverse-engineering survey structure: Borrowing strength across taxa; Modelling the observation process, and: Integrating standardised data sources. “Reverse-engineering survey structure” implies filtering the data as described above and aggregating observations across space and time to reduce the variability and uncertainty. “Borrowing strength across taxa” means estimating the likelihood of false absence for a focal species from observations of additional species. An example is that if several commonly observed species were not observed during an observation event, this could indicate that the absence of a focal species is the result of a low observation effort. “Modelling the observation process” is the attempt to include measures of variation in observer effort, for example the time spent searching, directly within statistical models (Rapacciuolo et al. 2021). “Integrating standardised data sources” means that opportunistically collected data is combined with systematically collected data into the same statistical model (Isaac et al. 2020).

There have also been calls to attempt to make opportunistic biological records more systematic, by for example, including checklists to facilitate the recording of absences (Johnston et al. 2021; Pocock et al. 2017), asking volunteers to visit all habitats, train observers to reduce variability in skills, and collect data on environmental covariates (Altwegg and Nichols 2019).

Isaac et al. (2014) compared different types of statistical approaches to estimate trends from opportunistic biological records, and found that most approaches could account well for uneven sampling effort over time, but that other forms of variation in recorder activity were more difficult to account for. Statistical models for citizen science data are however a rapidly developing field of research. There are ongoing efforts to develop statistical models that attempt to account for sampling effort and species detectability (e.g. Johnston et al. 2021; Rapacciuolo et al. 2021), and combining different types of citizen science data (Isaac et al. 2020). Such models will continue to be developed and refined, but there will always be larger uncertainties associated with opportunistic data than systematically collected data.

It is also important to note that the usefulness and robustness of opportunistic records also depends on the type of trend one tries to estimate. Occupancy-detection models that estimate trends in species distributions (i.e. presence or absence per site) have been demonstrated to give relatively reliable results (Altwegg and Nichols 2019; van Strien et al. 2013). Hence, using opportunistically collected biological records to estimate trends in species distributions or occupancy typically gives much more robust estimates than estimates of the change in the numbers of individuals.

6.3 Targeted data

Citizen science data are more rarely used to evaluate effects of specific management options or interventions aiming at increasing biodiversity (see Type D programmes identified in this report), but especially with the development of results-based payments to farmers, this is likely to become more common in the future. There are a few different types of data that can be used to evaluate the effects of an intervention (Christie et al. 2019; Josefsson et al. 2020). The simplest type of data consist of observations collected only after the interventions was collected (i.e. “After”-data). A better option is to compare observations before and after the intervention was established (“Before-After”). Alternatively, it is common to substitute space-for-time, and compare sites with the intervention with sites without the intervention (“Control-Impact”). The reliability of such data increases when control and impact sites are monitored over time. The type of data that has the highest reliability is when both sites with and without the intervention are compared both before and after the intervention was established (“Before-After-Control-Impact”) (Christie et al. 2019). Except for the “After”-only data, which cannot give any information on biodiversity change, there are well-developed statistical approaches to analyse these types of data using generalised linear mixed models (e.g. McDonald et al. 2000). Generalised linear mixed models, where one tests the interaction between time (e.g. year) and treatment (intervention vs. non-intervention), perform much better than older approaches that compare “differences of differences” – that is, first calculate the difference between intervention and non-intervention for each time point, and then assess the trend in this difference over time (McDonald et al. 2000).

7 Summary and Recommendations

This chapter provides a summary of the strengths and weaknesses of different citizen science approaches to monitoring farmland biodiversity, with reference to three key 'trade-offs' between different priorities that may be held by these programmes. It does so with continued reference to the five programme types detailed in the previous chapters. Based on these trade-offs, and with reference to related literature, we then provide a series of recommendations for programmes using citizen science approaches to farmland biodiversity monitoring, arranged according to the overall aim/s of the programme.

7.1 Summary of strengths, weaknesses, and trade-offs

This section provides a discussion of three 'trade-offs' between different priorities of citizen science programmes: Data collection vs farmer/volunteer engagement, size of programme vs specific focus of data, and systematic vs opportunistic data collection. This acts as a summary of the strengths and weaknesses of the five programme types identified in this review.

7.1.1 Data collection vs farmer/volunteer engagement

Environmental citizen science generally aims both to gather new scientific data, and to engage new audiences with science and the natural world. The SHOWCASE project carries similarly dual goals – aiming to encourage biodiversity-friendly farming both through gathering further evidence of the benefits of biodiversity to farming, and through exploring new ways to influence the attitudes of farmers. Research in various sub-fields of citizen science has long accepted that these two aims constitute something of a 'trade-off' (Paul et al. 2014; Aceves-Bueno et al. 2017; Specht and Lewandowski 2018).

Trade-offs between data collection and farmer/volunteer engagement can be seen in the five programme types explored here. In short: Programmes whose main aim is farmer engagement (Type E), and types where the aim is to engage a large number of people (Types A-C), tend not to provide rigorous or systematic data. Those that attempt to combine high levels of engagement (with small numbers of farmers) with data that can be used to draw specific links between biodiversity and agricultural practices (Type D), can be somewhat resource-heavy when it comes to this engagement.

If engagement of large new audiences is the priority, then clearly it is programmes in Type A that best enable this. With programmes such as iSpot, many thousands of people are encouraged to notice new things in nature, submit their sightings to the online platform, and identify it with the help of identity guides and a knowledgeable online community. The opportunistic and general nature of records submitted through these platforms, however, makes it difficult to draw any conclusions beyond these large-scale trends (and even then, data are often biased towards certain popular areas or habitat types). The engagement, meanwhile, is minimal and restricted to online feedback. There is no direct engagement with scientists, or involvement in other stages of the research process, both of which have been identified as beneficial from the point of view of changing attitudes through engagement in citizen science (Falk et al. 2012; Silva et al. 2015; Ballard et al. 2017).

Towards the other end of the spectrum are programmes in Type D, which are required for addressing more specific research questions. These programmes enable more focused data collection - for example, determining the effects of a particular farming practice, intervention, or habitat type, on a particular aspect of biodiversity. Although farmer engagement still tends

to be restricted to data collection and submission of results in programmes of this type, it is usually far greater than in Type C (and A and B). A high proportion of these programmes involve farmers themselves in data collection, but even when this is done by volunteers, there is still potential for informal forms of engagement, such as agreeing to be part of the study, or talking to volunteers or researchers during their visits. Others involve farmers accompanying knowledgeable volunteers to carry out data collection, as a means of informal training. This engagement, however, is more time-consuming and resource-heavy in programmes of this type, due to a need for greater precision in data collection, and therefore, potentially an increased need for training for farmers or other volunteers. It could be argued that the smaller scale of these programmes means that there is less of a need for citizen science approaches within them than in programme Types A to C. The benefits of this engagement, however, are potentially significant. With this in mind, those designing such schemes must be clear that that farmer/volunteer engagement is a major aim of the programme, to be treated with similar importance to data collection.

At the far end of this spectrum are programmes in Type E, where farmer engagement is the clear priority. In these programmes, engagement is maximised through (for example) farmers' involvement in the design and implementation of studies "on their own terms", and contact with researchers to explore topics specific to their interests. In other programmes in this type, such as the LEAF Simply Sustainable resources (UK), farmers are provided with farm-specific resources to help them carry out monitoring on a site of their choice. In most or all programmes of this type, however, the data are not immediately 'useful' for scientific research purposes - that is, they do not contribute to any wider data set or study.

Type C programmes might be seen as potentially the best compromise in terms of this trade-off. They enable the collection of large volumes of farmland-specific data, as well as the engagement of large numbers of farmers through more targeted resources, with minimal expenditure of resources. There are, however, limitations in both respects. The data gathered, despite being farmland-specific in nature, still relate to fairly general trends. Engagement of farmers is also fairly minimal, with only a few programmes mentioning any engagement beyond the collection and online submission of data.

7.1.2 Size of programme vs specific focus of data

This trade-off relates to the type of data collected and what it can be used for, regardless of the engagement aspect of the programmes explored above. Programmes identified in this report vary considerably in terms of their size and scale of coordination, and this has clear implications for the type of data collection that is enabled. Generally, as programmes increase in size, their focus becomes less specific and systematic, making it more difficult to draw links between specific farming practices or interventions, and trends relating to specific aspects of biodiversity – for example, the effects of wildflower strips on pollination, or the effects of recently-planted woodlands on farmland bird populations. Data of this type are most clearly enabled by programmes in Type D, which generally take place on small numbers of sites in locally-specific agricultural landscapes that have been carefully selected for the presence of a particular habitat type or farming practice. The smaller number of sites, however, make these programmes less suitable for analysing large-scale trends than programmes in Types B and C, while their tendency to be time-bound rather than ongoing results in a comparative lack of longitudinal data.

Programmes in Types B and C enable the collection of large volumes of data, usually on an ongoing basis rather than being time-bound. This enables longitudinal analysis of large-scale trends, usually at a national scale. Analysis is, however, largely limited to these general trends. This is slightly less the case in Type C programmes, given their farmland-specific

focus. From some of the papers identified through the literature search element of this review, it is clear that links can at least begin to be drawn between farming practices and biodiversity trends through this type of programme. These include where farmers have provided details of the habitat types present, or type of farming practiced, on their land (Zellweger-Fischer et al. 2011). Type B programmes – those that are species or taxa-specific, but not farmland-specific - also appear to enable some analysis of farmland-specific trends. This may include, for example, linking bird population trends shown by a national bird survey to agri-environment schemes (AESs), through the authors' own knowledge of the presence of those schemes in a given area (Calvi et al. 2018). It is clear, however, that a higher degree of estimation is involved in this type of analysis, resulting in potential inaccuracies.

Finally, while Type A programmes enable the collection of volumes of data that would have been impossible before their development, it is even more difficult to draw any conclusions beyond these large-scale trends. This is due largely to the opportunistic nature of the records submitted, as explored in the following sub-section.

A few of the programmes represented in this review represent a good balance between the possibility for analysis of the effects of farming practices on biodiversity, and large-scale data collection. One such programme is Observatoire Agricole de la Biodiversité (France), which combines data collection by farmers at a national scale with well-developed yet accessible species/taxa-specific protocols. Farmers are also required to provide details of their agricultural practices and the surrounding landscapes (Billaud et al. 2020).

7.1.3 Systematic vs opportunistic data collection

Another, related trade-off is that between opportunistically-collected data, and data that has been gathered more systematically. The extent to which data collection is 'opportunistic' or 'systematic' varies across the different programme types. In Type A programmes, volunteers submit records on any species, at a site and time of their choosing. In many programmes in Types B and C, the species/taxa to be monitored are specified, as well as the time/s of year and frequency at which monitoring should be carried out, but sites are still chosen by volunteers. This can result in a potential bias towards 'exciting' sites selected by volunteers – for example, nature reserves, scenic areas, or sites where particular species are already known to be abundant. Type D programmes are generally far more systematic, with both indicator species/taxa specified, and sites carefully selected due to the presence of a particular habitat type or farming practice.

The clear advantage to the systematic selection of sites is that it enables links to be more easily drawn between farming practices, and effects on particular aspects of biodiversity. It is, however, far more time-consuming and resource-intensive for those coordinating the programme - requiring them to visit sites themselves, for example - and potentially limits the number of sites that can be covered. There are cases where a balance has been struck, however. In the BTO Breeding Bird Survey (UK, Type B), for example, sites are allocated by the coordinating NGO, but these are one-kilometre squares selected from the national grid. This selection method helps to counter bias towards particular types of site or habitat, but is still somewhat limited in terms of the level of detail known about each site. This tension is also offset to an extent by programmes where participants are asked to submit details of the site at which data are collected. This was a particularly common feature of farmland-specific programmes in Type C.

7.2 Recommendations

This section provides a series of recommendations for future citizen science approaches to monitoring farmland biodiversity, based on the trends identified in this review. These are arranged according to the broad aims that may be held by a given programme. These aims are summarised as data on general trends, data on the effects of farming practices, and engagement of farmers. While these aims are used as a starting point, many of the recommendations deal with how to balance this aim against others – for example, how to maximise engagement with farmers in large-scale programmes aimed at gathering data on general trends.

First, however, there is one overarching recommendation to be kept in mind:

- **Ensure clarity of programme aims**: Engagement of volunteers (or in the case of this review, farmers) can be a time-consuming and resource-heavy process, particularly where training is required, and particularly in smaller-scale programmes set up to address a specific question, such as those in Type D. Additionally, in this type of programme, citizen science may not always be the best approach to data collection – indeed, there are many such programmes where researchers carry out the monitoring themselves. There is therefore a need to be clear about whether a citizen science approach is needed in the first place, and if so, the extent to which volunteer/farmer engagement is an aim of the programme. Essentially the question is: Is there a commitment to engaging farmers or volunteers, or do you just need the data? If engagement is a major aim, then considerable emphasis will need to be placed on this aspect of the programme in order to balance it with high quality data collection.

  In the case of larger-scale programmes, there is a clearer case for using citizen science approaches, which enable the collection of far higher volumes of data than would be possible otherwise. However, those coordinating these programmes should be realistic about the limitations of these programmes when it comes to drawing links between specific farmland practices, and specific biodiversity trends.

7.2.1 Data on general trends

The following are recommendations for citizen science approaches to monitoring farmland biodiversity that aim to gather large-scale data on general biodiversity trends:

- **Raise awareness of non-farmland-specific programmes among the farming community:** This review has identified a large number of programmes that do not focus specifically on farmland. It is likely that most or all of these cover farmland or engage farmers to some extent, but most appear to contain no information on this. This at least suggests that there is little or no attempt to engage the farming community specifically in these programmes. Given the importance of farmland for biodiversity, this appears to be a missed opportunity. At relatively little cost, programmes could tailor resources in order to appeal to or provide information for farmers. Steps could also be taken to build relationships between citizen scientists and farmers – for example, where monitoring is taking place on or at the edges of farmland.

- **Add farmland-specific elements to data collection/submission protocols:** In relation to the above recommendation there may also be a need to make small

changes to the information that participants provide when submitting data. This could take the form of additional questions when participants are asked to provide information about the data collection site. Such information could include identification of farmland-specific habitat types, or questions about the type of farming practiced on a particular site. This may increase the possibility of drawing farmland-related conclusions from data gathered through non-farmland-specific programmes.

- **Keep methods simple and engaging**: The vast majority of programmes identified in this review engage volunteers in simple data collection methods that require relatively little time commitment. It is important that this trend is maintained, in order both to ensure as little inaccuracy in data collection as possible, and to maximise the chances that volunteers enjoy a positive experience and continue to participate.

- **Consider degree of expertise required and volunteer availability:** Depending on the species/taxa to be monitored in a given programme, there will be huge variation in terms of the available volunteers with the necessary identification skills. The prevalence of bird monitoring programmes, for example, may be partly explained by the prevalence of keen birdwatchers with a highly-developed bird identification skills. In contrast, it may be more difficult to find volunteers with a good knowledge of fungi, bryophytes or diptera, to name a few of the taxa covered by programmes identified in this review. Lack of available expertise may result in a need for more training provision, and potentially more targeted efforts to attract volunteers. There is also a consideration around the benefits of attracting new audiences – for example, engaging those with little existing knowledge in bird monitoring programmes. Again, this would require further training provision.

- **Provide identification resources (and/or training)**: Related to the recommendation to employ simple data collection methods is the benefit of accessible information for volunteers on the species they are recording. This may include, for example, a simple identification guide to the different types of pollinators that may be observed on a given site, either as part of an app, on a website, or in resources to be sent to volunteers. Failing this, at the very least, it is important that there are clear links to a relevant online identification guide. This accessibility of information ensures a smoother experience for volunteers, and helps to ensure accurate data collection. As noted above, training provision, if feasible, will also help develop volunteers' identification skills, and/or enable the engagement of new audiences.

- **Provide local contacts for providing training/support:** This review has noted the lack of direct engagement with farmers and other volunteers in national-scale programmes in Types A to C. This may be countered by providing local or regional contacts in programmes of this type who would, for example, provide training, or feedback to farmers, on the trends observed. This is something that is done already by some, but by no means all, of the programmes identified here. These contacts could potentially be volunteers too – for example, in Type C programmes, a knowledgeable farmer who is experienced at collecting data through the programme.

7.2.2 Data on the effects of farming practices

The following recommendations are for citizen science approaches to monitoring farmland biodiversity that aim to gather more focused data on the effects of specific farming practices on (often specific aspects of) biodiversity:

- **Consider whether citizen science is the best approach**: As noted above, there is arguably a question around the need for citizen science as a means of data collection in this type of programme, compared to those operating at a larger scale. This is because the focused and small-scale nature of the study often means it is often possible for the researchers themselves to collect all data. If engagement of volunteers *is* a major aim, however, then considerable emphasis needs to be placed on this aspect of the programme in order to balance it with high quality data collection.

- **Consider whether engaging farmers is feasible/important**: In relation to the recommendation above, if citizen science is deemed to be the most suitable means of data collection, then who are the most suitable volunteers? If there is an existing pool of citizen scientists with the relevant identification skills, then the most feasible option may be to engage these volunteers. There are, however, clear potential benefits to engaging farmers themselves in data collection, as a means of engaging them with biodiversity and encouraging them to consider new biodiversity-friendly measures in response to the data collected. This may, however, may require further training provision (although of course farmers may also have pre-existing identification skills). As will be further highlighted below, setting up partnerships between volunteers and farmers may provide a means of drawing on existing expertise whilst also engaging farmers.

- **Ensure data collection remains simple (if engaging volunteers)**: As noted in this report, programmes in Type D did not necessarily employ more complicated methods than those in other programme types. This was despite the specific research questions addressed in these programmes, the more systematic selection of sites, and the greater emphasis on volunteer expertise. As with the related recommendation in section 7.2.1, it is important that this trend is continued, for reasons of both accurate data collection, and volunteer experience.

7.2.3 For engagement of farmers

Finally, this sub-section provides recommendations for citizen science approaches to monitoring farmland biodiversity where engagement of farmers is the priority:

- **Provide more feedback to farmers**: As noted in the database by one SHOWCASE project partner in reference to one of the identified programmes, the species monitored “is declining which is demotivating volunteers. There is too little effort to improve conditions, it is just monitoring”. This suggests the importance of not only engaging farmers in monitoring, but also providing some form of feedback based on the results of data collection. This may take the form of advice on new measures that could be taken to improve habitats for the species in question, while also maintaining agricultural productivity. There is potentially even more benefit if this advice can be made more targeted and personalised – as demonstrated in programmes in Type E, where researchers provide advice to farmers running “field labs”.

- **Encourage partnerships between farmers and volunteers**: This is one cost-effective way to ensure the personalised feedback discussed above, or at least face-to-face conservations that encourage engagement with biodiversity. Particularly encouraging programmes identified in this review include Birds on Farms (Australia), where farmers and land managers often accompany volunteers on bird counts on their land. This sets up a relationship between farmers and those with a different but

relevant area of expertise, and acts as informal training whereby farmers learn how to carry out the monitoring themselves. While researchers can only engage personally with a relatively limited number of farmers, involving volunteers appears to offer relatively low-cost way of upscaling such engagement. This will be a major focus of Task 2.6 within the SHOWCASE project, which aims to test different ways of engaging farmers in farmland biodiversity monitoring. A key further question here is whether involvement in *monitoring* specifically is important for influencing farmers' attitudes to or engagement with biodiversity. Alternatively, it may be that simply engaging with ecologists or citizen scientists through an AES, or project such as SHOWCASE, is a sufficient influence in this respect.

- **Consider more "co-created" approaches**: A clear trend throughout the programmes identified in this review has been the lack of farmer or volunteer engagement beyond the collection and submission of data. The exceptions to this are largely those in Type E, which represent more "co-created" approaches to farmland biodiversity monitoring. Co-created approaches are those where the target community plays a key role in the identification of the phenomena to be studied, and the design of the study, rather than simply collecting data to address a set of externally-developed questions (Roy et al. 2012; Follett and Strezov 2015). These stand in contrast to "contributory" approaches, in which participants simply collect data that contribute to a study designed by others – most programmes outside of Type E are of this type. Given the SHOWCASE aims around engaging farmers with biodiversity, increasing farmers' 'ownership' of monitoring programmes through more co-created approach appears to represent a desirable direction of travel. This does, however, create challenges that perfectly exemplify the 'trade-off' between data collection and volunteer engagement discussed in section 7.1.1.). Allowing participants more input into the research design process requires a certain degree of 'letting go' by researchers, whose priority would otherwise be the efficient collection of data in order to address what they see as a key 'gap' the literature on a given topic. Notably, in most programmes of this type identified in this review, the data collected are secondary to the engagement of farmers, and do not contribute to any wider study or dataset. This suggests that considerable effort is required to gather data that is useful both for academic research, and that responds to farmers' own interests and priorities. Such an approach, however, would surely result in higher levels of engagement among farmers, not least through the increased relevance of the programme to them.

- **Consider relevance of monitoring to both biodiversity and agricultural production**: In relation to the above recommendation, it is notable that in the Type E programme Innovative Farmers (see examples in section 5.3.6), only one of the 132 "field labs" set up by farmers had biodiversity as its only focus. Only four others mentioned biodiversity in their key aims, alongside soil and animal health (although it should be noted that trials forming part of the Farmer Clusters programme – also Type E – are somewhat more biodiversity-focused). There is perhaps an argument that aspects of biodiversity that more clearly relate to agricultural productivity, such as earthworms, may act as a better starting point for engaging farmers with biodiversity in general. This is a potential consideration for future farmland-specific biodiversity monitoring programmes.

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Appendix 1: Identified programmes

The table below lists all programmes identified through this review. For each programme, we list the country in which it is based, the type of programme it can be categorised as (see section 3.5 for an introduction to this typology), and the method by which they were identified. We also provide a brief summary of the programme, and either the programme website, or a reference to the main academic paper through which they were identified.

Programme name	Country	Type	Identified through	Summary/Website or main reference
Squash bee flower visitation study	USA	D	Lit search	Developed for a study in Michigan where citizen scientists collected and submitted data on an important farmland wild bee species – the squash bee. *Appenfeller, L.R., Lloyd, S. and Szendrei, Z., 2020. Citizen science improves our understanding of the impact of soil management on wild pollinator abundance in agroecosystems. PloS one, 15(3), p.e0230007.*
The Great Sunflower Project	USA	B	Partners	Encourages members of the public to conduct a count of numbers of pollinators visiting a flower - in gardens, schools grounds, parks, etc. https://www.greatsunflower.org/
Songbird Farm Trail	USA	D	Google search	Mostly a conservation scheme encouraging farmers to install nest boxes, but also includes monitoring, which is described on the website as citizen science. https://www.wildfarmalliance.org/songbird_farm_trail
North American Breeding Bird Survey	USA/ Canada/ Mexico	B	Partners	“Each year thousands of citizen scientists skilled in avian identification collect data on BBS routes throughout North America". https://www.usgs.gov/centers/eesc/science/north-american-breeding-bird-survey
iNaturalist	USA/ International	A	Partners	Website/App enabling members of the public to submit wildlife sightings, which can then be shared with "fellow naturalists" and experts/scientists. https://www.inaturalist.org/
GrassLander	Canada	D	Google search	Small scheme set up by a professor and Masters student, surveying eastern meadowlark and bobolink on farmland. One of the aims is encouraging farmers to delay "haying" in order to improve the survival chances of the birds. https://www.wlu.ca/news/spotlights/2017/july/laurier-based-citizen-science-project-tracking-threatened-birds-on-farmland.html
Bird Survey forming part of Taoyuan Farm Ponds Project	Taiwan	D	Lit search	“The Bird Survey in Taoyuan’s Farm Ponds Project is a systematic citizen science project founded in 2003. This project aims to identify existing and potential irrigation ponds that are important for creating waterbird refuges”. *Chao, S.H., Jiang, J., Wei, K.C., Ng, E., Hsu, C.H., Chiang, Y.T. and Fang, W.T., 2021. Understanding pro-environmental behavior of citizen science: an exploratory study of the bird survey in Taoyuan’s farm ponds project. Sustainability, 13(9), p.5126.*

Coordinated Avifaunal Roadcounts (CAR) project	South Africa	B	Lit search	A national scheme, but used to draw conclusions about one species - the blue crane - in agricultural areas. Volunteers - including farmers – carry out bird counts along roads. *Young, D.J. and Harrison, J.A., 2020. Trends in populations of Blue Crane Anthropoides paradiseus in agricultural landscapes of Western Cape, South Africa, as measured by road counts. Ostrich, 91(2), pp.158-168.*
ARGOS farmland bird monitoring scheme	New Zealand	D	Lit search	Monitoring scheme that aims "initially to establish baseline information on community composition and species distribution and abundance in relation to different farming systems and locations". *MacLeod, C.J., Blackwell, G., Weller, F. and Moller, H., 2012. Designing a bird monitoring scheme for New Zealand's agricultural sectors. New Zealand Journal of Ecology, 36(3), pp.0-0. (See also Weller 2012)*
Birds on Farms	Austra-lia	D	Google search	CS project, in Victoria but expanding into NSW and elsewhere, where volunteers count birds on privately-owned land (including farms). "Sometimes these surveys are undertaken in conjunction with the landholder as part of an informal training session." https://birdlife.org.au/projects/woodland-birds-for-biodiversity/birds-on-farms-wl
EnviroDNA	Austra-lia	C	Partners	A citizen science project investigating farm dam biodiversity in West Gippsland, Victoria: Landholders and other Landcare locals went in search of wildlife DNA, using innovative technology called environmental DNA (eDNA). https://www.youtube.com/watch?v=494Q2_34WK8&t=45s
Svensk Dagfjärilsöv-ervakning	Sweden	B	Partners	Monitoring population trends of butterflies in Sweden. https://www.dagfjarilar.lu.se/
Swedish Volunteer and Farmer Alliance	Sweden	D	Partners	SVFA "aimed to moderate negative farmland bird population trends, by promoting the implementation of conservation measures at the farm level" (and included monitoring carried out by volunteers). https://birdlife.se/projekt/tidigare-projekt/lantbrukare-och-fagelskadare/
Floraväktare ("Flora guardians")	Sweden	B	Partners	Monitoring populations of rare plant species. Volunteers count individuals of certain plant species at selected sites each year. https://svenskbotanik.se/floravaktarna/
Svensk fågeltaxering	Sweden	B	Partners	Monitoring population trends of all bird species breeding in Sweden. https://www.fageltaxering.lu.se/
Rädda bina ("Save the bees")	Sweden	B	Partners	Garden owners can create wildflower meadows, "bee-friendly plantations", or bee nests, and then observe the effects of their actions https://raddabina.nu/om-operation-radda-bina-2021/
Insect Biome Atlas	Sweden	B	Partners	Large-scale mapping on insect diversity. https://www.insectbiomeatlas.com/
Artportalen	Sweden	A	Partners	Website enabling members of the public to submit wildlife sightings. Similar to e.g. iNaturalist. https://www.artportalen.se/

Vinterfåglar inpå knuten	Sweden	B	Partners	Volunteers observe birds at their bird feeders one weekend each winter. https://vinterfaglar.se/
Naturens kalender	Sweden	A	Partners	Aims to monitor changes in phenology, i.e. timing of events in nature (especially during spring). Similar to "Nature's Calendar" (UK). https://www.naturenskalender.se/
Inventea åkergräs	Sweden	C	Partners	Monitoring of weeds on arable land. https://svenskbotanik.se/inventera-akergras/
Danish National Orchid Monitoirng Programme	Den-mark	B	Lit search	Annual counts of orchids on particular sites, by volunteers. "Orchids have been monitored annually for more than 30 years from 440 selected orchid sites". *Damgaard, C., Moeslund, J.E. and Wind, P., 2020. Changes in the abundance of Danish orchids over the past 30 years. Diversity, 12(6), p.244.*
Italian Common Breeding Bird monitoring programme	Italy	B	Lit search	Nationally-organised common bird monitoring scheme. The paper below uses data from it to explore the influences of agri-environment schemes on farmland birds. Similar to other schemes of this type. Calvi, G., Campedelli, T., Florenzano, G.T. and Rossi, P., *2018. Evaluating the benefits of agri-environment schemes on farmland bird communities through a common species monitoring programme. A case study in northern Italy. Agricultural Systems, 160, pp.60-69.*
Swiss Brown Hare Monitoring	Switzer-land	C	Lit search	Counting of brown hares in agricultural areas carried out by volunteers. At night, using spotlights and binoculars. *Zellweger-Fischer, J., Kéry, M. and Pasinelli, G., 2011. Population trends of brown hares in Switzerland: the role of land-use and ecological compensation areas. Biological conservation, 144(5), pp.1364-1373.* https://www.vogelwarte.ch/en/projects/habitats/terminated-projects/monitoring-and-promoting-the-brown-hare-in-switzerland
Hungarian Common Bird Monitoring Scheme	Hungary	B	Lit search	National bird monitoring scheme using point count methodology. *Nagy, S., Nagy, K. and Szép, T., 2009. Potential impact of EU accession on common farmland bird populations in Hungary. Acta Ornithologica, 44(1), pp.37-44.*
National Common Bird Monitoring Scheme Bulgaria	Bulgaria	B	Lit search	National bird monitoring scheme using line transect methdology, carried out by volunteers. *Spasov, S., Hristov, J., Eaton, M. and Nikolov, S.C., 2017. Population trends of common birds in Bulgaria: Is their status improving after the EU accession. Acta Zoologica Bulgaria, 69(1), pp.95-104.*
Biodiversitäts monitoring mit Landwirt-Innen	Austria	D	Lit search	"A nationwide network of more than 700 Austrian farmers and 12 agricultural schools regularly observe rare plants and animals in their own species-rich grasslands". *Shaw, B.J. 2017. Citizen Science–Harnessing the Expertise of Farmers to Monitor Biodiversity in Austrian Meadows (Book chapter).*

German Common Breeding Bird Survey	Ger-many	B	Lit search	"Initiated in 1989 to monitor common bird species and has been continued since 2004 on 1 km² sample plots" *Aue, B., Diekötter, T., Gottschalk, T.K., Wolters, V. and Hotes, S., 2014. How High Nature Value (HNV) farmland is related to bird diversity in agro-ecosystems–Towards a versatile tool for biodiversity monitoring and conservation planning. Agriculture, ecosystems & environment, 194, pp.58-64.*
National odonatology survey	Ger-many	B	Lit search	"Database… compiled and revised in a citizen science project of the (Association of German-speaking odonatologists) for the distribution atlas of Odonata in Germany". *Goertzen, D. and Suhling, F., 2019. Urbanization versus other land use: Diverging effects on dragonfly communities in Germany. Diversity and Distributions, 25(1), pp.38-47.*
MonViA monitoring tool (under develop-ment)	Ger-many	E	Google search	"MonViA's development and implementation of a Citizen Science-based Monitoring tool aims to facilitate the voluntary participation of farmers…. to document biodiversity indicators on farms, to be mindful of nature and actively promote biodiversity through agriculture". https://enrd.ec.europa.eu/evaluation/knowledge-bank/citizen-science-based-monitoring-agricultural-biodiversity-tool_en
1m2 gardens (part of landscape observatory BEL-landscape)	Belgium	D	Lit search	Scheme in which volunteers maintain a 1-metre-squared area of land to monitor ecosystem services provided by different crops. Not 100% about biodiversity but the project as a whole is about "functional agricultural biodversity (FAB)". https://www.bel-landschap.be/
Suivi Temporal des Oiseaux Communs	France	B	Lit search	National breeding bird survey. *Jiguet, F., Devictor, V., Julliard, R. and Couvet, D., 2012. French citizens monitoring ordinary birds provide tools for conservation and ecological sciences. Acta Oecologica, 44, pp.58-66.* https://www.vigienature.fr/fr/suivi-temporel-des-oiseaux-communs-stoc
Observatoire Agricole de la Biodiversite	France	D	Lit search	The Farmland Biodiversity Obervatory aims to "offer protocols for observing ordinary biodiversity to interested farmers, with a view to better understanding ordinary biodiversity in an agricultural environment and its links with practices". *Billaud, O., Vermeersch, R.L. and Porcher, E., 2021. Citizen science involving farmers as a means to document temporal trends in farmland biodiversity and relate them to agricultural practices. Journal of Applied Ecology, 58(2), pp.261-273.* https://www.observatoire-agricole-biodiversite.fr/

Various projects forming part of the Zone Atelier Plaine & Val de Sèvre (ZA PVS)	France	D	Lit search	An LTSER (long-term social and ecological research) project in an experimental agricultural area that involves collaborative research with farmers. *Bretagnolle, V., Berthet, E., Gross, N., Gauffre, B., Plumejeaud, C., Houte, S., Badenhausser, I., Monceau, K., Allier, F., Monestiez, P. and Gaba, S., 2018. Towards sustainable and multifunctional agriculture in farmland landscapes: lessons from the integrative approach of a French LTSER platform. Science of the Total Environment, 627, pp.822-834.*
Enquête Busards-Milans	France	D	Lit search	Farmland monitoring scheme in France focused on a specific species, the Montagu's harrier – a ground nesting raptor. *Santangeli, A., Arroyo, B., Millon, A. and Bretagnolle, V., 2015. Identifying effective actions to guide volunteer-based and nationwide conservation efforts for a ground-nesting farmland bird. Journal of Applied Ecology, 52(4), pp.1082-1091.*
Pollinator-focused citizen science programme with agricultural high schools	France	D	Lit search	"An expert-assisted citizen science program where teachers from 20 French agricultural high schools collected bees, which were identified to species level by a panel of expert bee taxonomists." *Le Féon, V., Henry, M., Guilbaud, L., Coiffait-Gombault, C., Dufrêne, E., Kolodziejczyk, E., Kuhlmann, M., Requier, F. and Vaissière, B.E., 2016. An expert-assisted citizen science program involving agricultural high schools provides national patterns on bee species assemblages. Journal of Insect Conservation, 20(5), pp.905-918.*
Catalan Butterfly Monitoring Scheme	Spain (Cata-luña)	B	Lit search	Monitoring scheme carried out by trained observers, not restricted to but including farmland. *Lee, M.S., Comas, J., Stefanescu, C. and Albajes, R., 2020. The Catalan butterfly monitoring scheme has the capacity to detect effects of modifying agricultural practices. Ecosphere, 11(1), p.e03004.*
Ornitho (Cataluña)	Spain (Cata-luña)	B	Lit search	Web-based monitoring tool collecting opportunistic bird records. *Sardà-Palomera, F., Brotons, L., Villero, D., Sierdsema, H., Newson, S.E. and Jiguet, F., 2012. Mapping from heterogeneous biodiversity monitoring data sources. Biodiversity and Conservation, 21(11), pp.2927-2948.*
Observatorio de Biodiversidad Agraria	Spain	C	Partners	"A commitment to creating a monitoring network of agricultural biodiversity that can evaluate the impacts of agricultural management. Its great potential resides in citizen or participatory science, that is, the collection of information will be massive and involving its protagonists, those who are on the field." (Partner communication). https://oba.fundacionglobalnature.org/

Development of Biodiversity assessment scheme	Alps region (5 countries)	D	Lit search	Biodiversity assessment scheme developed with farmers for the sake of this study. Including workshops to agree upon the indicators, then research carried out (with 13 out of 44 farmers participating). *Tasser, E., Rüdisser, J., Plaikner, M., Wezel, A., Stöckli, S., Vincent, A., Nitsch, H., Dubbert, M., Moos, V., Walde, J. and Bogner, D., 2019. A simple biodiversity assessment scheme supporting nature-friendly farm management. Ecological Indicators, 107, p.105649.*
Pan-European Common Bird Monitoring Scheme	Various	B	Lit search	"The Pan-European Common Bird Monitoring Scheme (PECBMS)'s main goal is to use common birds as indicators of the general state of nature using large-scale and long-term monitoring data on changes in breeding populations across Europe..." *Herzog, F. and Franklin, J., 2016. State-of-the-art practices in farmland biodiversity monitoring for North America and Europe. Ambio, 45(8), pp.857-871.*
Testing protocols for monitoring pollinators and pollination service	UK	F	Lit search	The authors test the willingness and (self-reported) ability of farmers, and other types of participants, to carry out particular monitoring techniques involving pollinators. *Garratt, M.P.D., Potts, S.G., Banks, G., Hawes, C., Breeze, T.D., O'Connor, R.S. and Carvell, C., 2019. Capacity and willingness of farmers and citizen scientists to monitor crop pollinators and pollination services. Global Ecology and Conservation, 20, p.e00781.*
BTO Breeding Bird Survey	UK	B	Partners	The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is the main scheme for monitoring the population changes of the UK's common and widespread breeding birds. Main method = 1km^2 counts. https://www.bto.org/our-science/projects/bbs
Big Farmland Bird Count	UK	C	Partners	Similar to the many national bird surveys that make up programme Type B, but with a specific focus on farmland and the engagement of farmers. https://www.bfbc.org.uk/
RSPB Farmland Bird Survey	UK	C	Partners	Farmers can choose to be part of this project, in which "volunteers undertake surveys to monitor population trends of priority bird species, and we provide targeted advice to ensure appropriate conservation management". https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/advice/get-a-farmland-bird-survey/
BTO/JNCC winter farmland bird survey	UK	C	Partners	Survey of birds on farmland in winter. Took place between 1999 and 2003. 1km square counts carried out by "volunteer surveyors". https://www.bto.org/our-science/publications/research-reports/winter-farmland-bird-survey
GWCT Partridge Count	UK	C	Google search	Monitoring scheme of a typical farmland bird, mostly carried out by farmers. https://www.gwct.org.uk/partridge
English Farm Woodland Bird Monitoring Scheme	UK	D	Google search	Focused, time-bound scheme in 2019, assessing how well birds have colonised new "farm woods" planted since 1999. https://www.bto.org/our-science/projects/english-farm-woodland-bird-survey-0

Northumberland Coast farmland bird monitoring	UK	D	Google search	Small farmland bird monitoring scheme, starting by pairing 10 volunteers with 10 farmers. Specifically developed for mixed farming system there, which is not typical of UK farming. https://www.northumberlandcoastaonb.org/farmland-bird-monitoring/
Cool Farm Tool	UK	F	Google search	A tool for farmers to monitor greenhouse gases, water (quality), and importantly, biodiversity. https://coolfarmtool.org/coolfarmtool/biodiversity/
LEAF simply sustainable biodiversity	UK	F	Google search	A booklet to help farmers monitor, manage and enhance biodiversity “through the adoption of Integrated Farm Management (IFM)." https://leaf.eco/farming/simply-sustainable-series
FWAG farmland monitoring tools	UK	F	Google search	Like the above two, appears to be a monitoring tool for farmers, but just to help them see the benefits - not part of a citizen science scheme. http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZW.09SIPKQGA1M4TJ
UK Butterfly Monitoring Scheme	UK	B	Partners	National scheme not restricted to farmland, and where data is carried out by volunteers, who choose their own site to monitor. https://ukbms.org/
Wider Countryside Butterfly Survey	UK	B	Partners	Stemming from the National Butterfly Monitoring Scheme, the WCBS is more targeted, focusing on “under-recorded habitats such as farmland, plantation woodland, uplands and urban green spaces”. https://butterfly-conservation.org/our-work/recording-and-monitoring/wider-countryside-butterfly-survey
X:Polli-Nation	UK	B	Partners	Brings together BeeWatch and OPAL Polli:Nation schemes, and lots of clever tools. Aims to increase interest in pollinators, their recording and creation of habitat. https://plantingforpollinators.org/pfp/index.php?r=user/auth
Strathspey Wetland and Wader Initiative	UK	D	Partners	Partnership scheme aiming to create wader-friendly habitat, in partnership with farmers and crofters. “The project work is guided by a comprehensive survey which takes place every five years”. https://cairngorms.co.uk/caring-future/cairngorms-nature/priority-species/strathspey-wetlands-wader-initiative/
Farmer Clusters	UK	F	Partners	Monitoring forms part of this programme, which brings farmers together in clusters to "work more cohesively together in their locality", aided by an advisor or facilitator. https://www.farmerclusters.com/advice/monitoring-species/farmer-cluster-wildlife-surveys/
BeeWalk	UK	B	Partners	Gathers data on the abundance of bumblebee species in the UK. https://beewalk.org.uk/
Short-haired Bumblebee Reintroduction Project	UK	D	Partners	Project aimed at re-introducing the short-haired bumblebee. Working with farmers, conservation groups and smallholders in a particular area - Dungeness and Romney Marsh in Kent/East Sussex. Includes monitoring carried out by "trained volunteers". https://www.bumblebeeconservation.org/short-haired-bumblebee-reintroduction-project/

Mammal Mapper	UK	A	Partners	App enabling members of the public you to record signs and sightings of mammals in the UK, in any kind of habitat. https://www.mammal.org.uk/volunteering/mammal-mapper/
UK Pollinator Monitoring Scheme	UK	B	Partners	National recording scheme enabling the public to carry out pollinator surveys, using either a ten-minute count or a 1km square survey that includes 'cropped' and 'non-cropped' land. https://www.ceh.ac.uk/our-science/projects/uk-pollinator-monitoring-scheme
National Moth Recording Scheme	UK	B	Partners	Nationwide scheme run by Butterfly Conservation. Volunteers submit records of "any larger (macro) moth", in any habitat. https://butterfly-conservation.org/our-work/recording-and-monitoring/national-moth-recording-scheme
Record Pool	UK	B	Partners	National recording platform for collecting information on reptiles and amphibians in the UK. https://www.recordpool.org.uk/
UK Ladybird Survey	UK	B	Partners	Recording scheme focused on ladybirds. Partly a response to the 'invasion' of the harlequin ladybird. Members of the public simply record sightings and enter them online. https://www.coleoptera.org.uk/coccinellidae/recording
Nature's Calendar	UK	A	Partners	National recording platform focused on a wide range of species/taxa and their phenology, helping to understand "how wildlife is affected by weather and climate change." https://naturescalendar.woodlandtrust.org.uk/what-we-record-and-why/species-we-record/
Soldierflies and Allies Recording Scheme	UK	B	Partners	National recording scheme that "collates biological records for 11 related Diptera families, using the information to promote enjoyment, study and conservation of the species and their habitats". https://www.brc.ac.uk/soldierflies-and-allies/
Rare Arable Flowers App	UK	B	Partners	App specifically focused on wildflowers on arable land. Presented mostly as an educational tool with an ID guide and "information about the management of arable land for the benefit of rare plant species". https://www.brc.ac.uk/app/rare-arable-flowers-app
iSpot	UK/international	A	Partners	Website and app run by Open University. Describes itself as an online "community" rather than platform or programme of study. Participants upload their observations of wildlife, often accompanied by a photo, and are then helped by other users to identify the species. Also includes an ID guide. https://www.ispotnature.org/
iRecord	UK	A	Partners	Website/app enabling members of the public to submit wildlife sightings. https://www.brc.ac.uk/irecord/
On-farm earthworm survey	UK	C	Partners	Pilot study which mobilised farmers to assess over 1300 ha farmland soils in spring 2018. https://www.globalsoilbiodiversity.org/blog-beneath-our-feet/2019/3/22/4ewwexsdm77v9qxyrp1hswhzvg605h

OPAL hedge-focused survey	UK	A	Partners	Asked participants to examine hedges and the biodiversity found in them, using i.d guides/instruction materials provided by OPAL. https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/opal/BIODIVERSITY-16pp-booklet_legacy.pdf
Open Farm Sunday Pollinator Survey	UK	D	Partners	One-off count in which volunteers were invited to farms to carry out pollinator surveys (2012). http://cehsciencenews.blogspot.com/2012/12/citizen-scientists-ensure-success-of.html
Hedgehog Street	UK	B	Partners	The BIG Hedgehog map helps us to understand where hedgehogs are in the UK and where they are missing from. https://bighedgehogmap.org/
Innovative farmers	UK	F	Partners	"Innovative Farmers is a network of farmers and growers who are running on-farm trials, on their own terms". https://www.innovativefarmers.org/
National Plant Monitoring Scheme	UK	B	Partners	Monitors plant diversity using grid squares. Focuses on natural habitats, but does include farmland (confirmed by email). https://www.npms.org.uk/
National Honey Monitoring Scheme	UK	D	Partners	Aims to use beehives to monitor long-term changes in condition and health (e.g. plant diversity) of UK countryside. Focuses on the impact of pathogens, pesticides, and plant diversity on honey production and bee health. https://honey-monitoring.ac.uk/
National Bat Monitoring Programme	UK	B	Partners	Aims to monitor UK bats to discover how they are doing and the factors that are important for their survival. https://www.bats.org.uk/our-work/national-bat-monitoring-programme
Ancient Tree Inventory	UK	B	Partners	Aims to monitor ancient trees in the UK in order to protect them. Volunteers record details rather than quantity. https://ati.woodlandtrust.org.uk/add-a-tree/
UK beetle recording schemes	UK	B	Partners	Aims to monitor UK beetles to discover how they are doing and the factors that are important for their survival. https://www.coleoptera.org.uk/recording-schemes
Bees, wasps, & ants recording schemes	UK	B	Partners	Aims to monitor UK bees, wasps, & ants to discover how they are doing and the factors that are important for their survival. https://www.bwars.com/content/submitting-your-records
British Bryological Society Recording Scheme	UK	B	Partners	Aims to monitor UK bryophytes to discover how they are doing. https://www.britishbryologicalsociety.org.uk/recording/
British Bugs Recording Schemes	UK	B	Partners	Aims to monitor UK hemiptera & heteroptera to discover how they are doing. http://www.britishbugs.org.uk/recording.html
Dragonfly and Danselfly Recording Schemes	UK	B	Partners	Aims to monitor UK Odonata to discover how they are doing. https://british-dragonflies.org.uk/recording/monitoring/

Collambolla Recording Scheme	UK	B	Partners	(Listed on National Biodiversity Network but little information). http://urweb.roehampton.ac.uk/collembola/
Conker Tree Science Recording Scheme	UK	B	Partners	Aims to monitor conker trees & pest damage from leaf miner, previously looked at moth abundance, and at bird predation of minors. http://www.conkertreescience.org.uk/home
Freshwater Habitats Trust	UK	A	Partners	Aims to monitor freshwater habitats. Mostly submitting records any time or place. https://freshwaterhabitats.org.uk/projects/pondnet/
Freshwater Flatworm Recording Scheme	UK	B	Partners	(Unclear. Listed on National Biodiversity Network but little information). https://nbn.org.uk/members/freshwater-flatworm-recording-scheme-2/
Fungus Conservation Trust Recording Group	UK	B	Partners	Aims to monitor UK fungi to discover how they are doing. http://www.abfg.org/page/local-groups/42/
British Leaf-miner Moths Recording Scheme	UK	B	Partners	Aims to monitor UK leaf-miners to discover how they are doing. http://www.leafmines.co.uk/html/nlls.htm
Lacewings & Allies Recording Scheme	UK, Ireland	B	Partners	Aims to monitor Neuroptera, Megaloptera, Raphidioptera and Mecoptera of the British Isles to discover how they are doing. https://lacewings.myspecies.info/
Fungal Recording	UK, Ireland	B	Partners	Aims to monitor fungi of the British Isles to discover how they are doing. https://www.britmycolsoc.org.uk/field_mycology/fungal_recording
British myriapod & isopod group recording schemes	UK, Ireland	B	Partners	Aims to monitor myriapods & isopods of the British Isles to discover how they are doing. https://www.bmig.org.uk/page/centipede-recording-scheme
Diptera recording schemes	UK, Ireland	B	Partners	Aims to monitor diptera of the British Isles to discover how they are doing. https://dipterists.org.uk/home
Curlew Task Force	Ireland	C	Partners	"The Curlew Task Force was established… to reverse the decline of the Curlew as a breeding species in Ireland". Part of the work of the task force was a national survey of breeding curlew. Also included input from farmers in the identification of indicators. https://www.npws.ie/research-projects/animal-species/birds/curlew-task-force
Irish Hedgehog Survey	Ireland	B	Google search	Engages participants through two methods: Opportunistic recording and submission of sightings, and a more focused “local area survey”, in which volunteers select an area of 1km2 to monitor. For five nights in a row, volunteers place ten “footprint tunnels” within this area, and check them each morning for signs of hedgehogs. https://www.irishhedgehogsurvey.com/

Farmer-specific questionnaire within Irish Hedgehog Survey	Ireland	C	Google search	Through this programme, researcher also gathered farmland-specific information on hedgehogs from farmers through a questionnaire. Rather than asking farmers to gather data themselves, the questionnaire asks simple questions around whether they have seen hedgehogs on their land, as well as for details on the type of farming and habitats found there. https://www.irishhedgehogsurvey.com/farmer-questionnaire
Meadow bird agreement with agri-environment cooperatives	NL	D	Partners	"The results-based element of the scheme requires participants to map and monitor meadow bird nests on their land as a proxy for the number of breeding meadow birds on site.... Farmers are responsible ultimately for counting and monitoring of the meadow bird nests in conjunction with local conservation volunteers". https://ec.europa.eu/environment/nature/rbaps/fiche/meadow-bird-agreement-agri-environment-cooperative_en.htm
Bescherming Boerenlandvogels	NL	C	Partners	Farmers are trained to monitor and farm in a bird-friendly manner. Also, volunteers go out for at least half a day every week to monitor in a fixed setting: that means in the same place, at the same farm". https://groenbezig.nl/boerenlandvogels
Bond van Friese Vogelwachten	NL	C	Partners	Volunteer conservation initiative involving birdwatchers and including surveys. https://www.friesevogelwachten.nl/nl
EU Pollinator Monitoring Scheme (EU-PoMS)	EU	B	Partners	Aims to develop a cost-effective Core Scheme for monitoring essential pollinators (wild bees, butterflies, hoverflies, moths, rare and threatened pollinator species) across the EU using standardised methods. https://ec.europa.eu/jrc/en/science-update/proposal-eu-pollinator-monitoring-scheme-eu-poms
European Butterfly Monitoring Scheme (eBMS)	Europe (22 countries)	B	Partners	Joint initiative of Butterfly Conservation Europe and the Centre for Ecology & Hydrology. https://butterfly-monitoring.net/
Dutch Butterfly Monitoring Scheme	NL	B	Partners	National butterfly monitoring scheme with the main policy aim to identify species population trends at national level, but increasingly trends are analysed at more regional levels. https://www.vlinderstichting.nl/wat-wij-doen/meetnetten/meetnet-vlinders
Dutch Macro-moth Monitoring Scheme	NL	B	Partners	National macro-moth monitoring scheme with the main policy aim to identify species trends in abundance and/or distribution at national and regional (and where possible local) levels. https://www.vlinderstichting.nl/wat-wij-doen/meetnetten/meetnet-nachtvlinders
Dutch Dragonfly Monitoring Scheme	NL	B	Partners	National dragonfly monitoring scheme with the main policy aim to identify species trends in abundance and/or distribution at national level. https://www.vlinderstichting.nl/wat-wij-doen/meetnetten/meetnet-libellen

Dutch Agricultural Scheme for Dragonflies (Agrarisch meetnet libellen)	NL	D	Partners	AML involves about 25 volunteers and professionals counting the dragonfly green hawker (Aeshna viridis) along a fixed route at the banks of ditches. This project is operating across four provinces, and aims to compare the effect of traditional land-use practises with nature friendly agricultural schemes. https://www.vlinderstichting.nl/agrarisch-meetnet-libellen/
Monitoring insects in Friesland (Argustelling)	NL	B	Partners	The Wall Brown (Lasiommata megera) and the Green Hawker (Aeshna viridis) are important target species in the Management of Agriculture and Landscape. Dutch Butterfly Conservation encourages farmers and other people to volunteer in counting these species on their own land or in their surroundings. https://www.vlinderstichting.nl/wat-wij-doen/projecten/resultaat/argustelling
Dutch Bumblebee Monitoring Scheme	NL	B	Partners	Nationwide bumblebee monitoring by citizen scientists in collaboration with the Dutch Monitoring Scheme and using the same transects. https://www.bestuivers.nl/meetnethommels
Pollinator Monitoring of Bird-friendly cropland	NL	D	Partners	Bird cropland consists of lucerne or red clover crop strips alternating with strips of herb-rich mixtures to benefit farmland birds. Pollinator monitoring was conducted to evaluate the value of this practice for bees and hoverflies. https://www.vlinderstichting.nl/wilde-bijen-in-groninger-vogelakkers
Farmer Insect Monitoring on Agricultural Land (BIMAG)	NL	D	Partners	In order to involve farmers in enhancing insect diversity, a monitoring project targeting macro-moths and butterflies has been initiated as a collaborative project between farmer organisations and Dutch Butterfly Conservation. https://www.vlinderstichting.nl/bimag/
ANLb Policy Monitoring for Amphibians and Fish	NL	D	Partners	This programme aims to support provinces and agri-environment associations in monitoring and evaluating the effectiveness of agri-environment policy. https://www.vlinderstichting.nl/bimag/

Appendix 2: Literature search full references

The following is a list of all papers identified through our Web of Science literature search, and the programmes to which they refer.

Appenfeller, L.R., Lloyd, S. and Szendrei, Z., 2020. Citizen science improves our understanding of the impact of soil management on wild pollinator abundance in agroecosystems. *PloS one*, *15*(3), p.e0230007. (Pollinator monitoring techniques on farmland, developed for this study)

Aue, B., Diekötter, T., Gottschalk, T.K., Wolters, V. and Hotes, S., 2014. How High Nature Value (HNV) farmland is related to bird diversity in agro-ecosystems–Towards a versatile tool for biodiversity monitoring and conservation planning. *Agriculture, ecosystems & environment*, *194*, pp.58-64. (German Common Breeding Bird Survey)

Billaud, O., Vermeersch, R.L. and Porcher, E., 2021. Citizen science involving farmers as a means to document temporal trends in farmland biodiversity and relate them to agricultural practices. Journal of Applied Ecology, 58(2), pp.261-273. (Farmland Biodiversity Obervatory/Observatoire Agricole de la Biodiversite, France)

Brereton, T., Roy, D.B., Middlebrook, I., Botham, M. and Warren, M., 2011. The development of butterfly indicators in the United Kingdom and assessments in 2010. *Journal of Insect Conservation*, *15*(1), pp.139-151. (UK Butterfly Monitoring Scheme)

Bretagnolle, V., Berthet, E., Gross, N., Gauffre, B., Plumejeaud, C., Houte, S., Badenhausser, I., Monceau, K., Allier, F., Monestiez, P. and Gaba, S., 2018. Description of long-term monitoring of farmland biodiversity in a LTSER. *Data in brief*, *19*, pp.1310-1313. (Zone Atelier Plaine et Val de Sevre, France)

Bretagnolle, V., Berthet, E., Gross, N., Gauffre, B., Plumejeaud, C., Houte, S., Badenhausser, I., Monceau, K., Allier, F., Monestiez, P. and Gaba, S., 2018. Towards sustainable and multifunctional agriculture in farmland landscapes: lessons from the integrative approach of a French LTSER platform. *Science of the Total Environment*, *627*, pp.822-834. (Zone Atelier Plaine et Val de Sevre, France)

Calvi, G., Campedelli, T., Florenzano, G.T. and Rossi, P., 2018. Evaluating the benefits of agri-environment schemes on farmland bird communities through a common species monitoring programme. A case study in northern Italy. Agricultural Systems, 160, pp.60-69. (Italian Common Bird Monitoring Programme)

Campedelli, T., Calvi, G., Rossi, P., Trisorio, A. and Florenzano, G.T., 2018. The role of biodiversity data in High Nature Value Farmland areas identification process: A case study in Mediterranean agrosystems. *Journal for nature conservation*, *46*, pp.66-78. (Italian Common Bird Monitoring Programme)

Chao, S.H., Jiang, J., Wei, K.C., Ng, E., Hsu, C.H., Chiang, Y.T. and Fang, W.T., 2021. Understanding pro-environmental behavior of citizen science: an exploratory study of the bird survey in taoyuan's farm ponds project. Sustainability, 13(9), p.5126. (Bird Survey forming part of Taoyuan Farm Ponds Project)

Damgaard, C., Moeslund, J.E. and Wind, P., 2020. Changes in the abundance of Danish orchids over the past 30 years. *Diversity*, *12*(6), p.244. (Danish National Orchid Monitoring Programme)

Deschamps, S., & Demeulenaere, É. (2015). L'observatoire agricole de la biodiversité. Vers un ré-ancrage des pratiques dans leur milieu. Études Rurales, 195, 109–126. (Farmland Biodiversity Obervatory/Observatoire Agricole de la Biodiversite, France)

Gaget, E., Fay, R., Augiron, S., Villers, A. and Bretagnolle, V., 2019. Long-term decline despite conservation efforts questions Eurasian Stone-curlew population viability in intensive farmlands. *Ibis*, *161*(2), pp.359-371. (Zone Atelier Plaine et Val de Sevre, France)

Garratt, M.P.D., Potts, S.G., Banks, G., Hawes, C., Breeze, T.D., O'Connor, R.S. and Carvell, C., 2019. Capacity and willingness of farmers and citizen scientists to monitor crop pollinators and pollination services. Global Ecology and Conservation, 20, p.e00781. (Pollinator monitoring techniques involving farmers, developed for this study)

Gerits, F., Messely, L., Reubens, B. and Verheyen, K., 2021. A social–ecological framework and toolbox to help strengthening functional agrobiodiversity-supported ecosystem services at the landscape scale. *Ambio*, *50*(2), pp.360-374. (1m2 gardens – part of landscape observatory BEL-lanscape, Flanders)

Gillings, S., Newson, S.E., Noble, D.G. and Vickery, J.A., 2005. Winter availability of cereal stubbles attracts declining farmland birds and positively influences breeding population trends. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1564), pp.733-739. (BTO/JNCC UK winter farmland bird survey)

Goertzen, D. and Suhling, F., 2019. Urbanization versus other land use: Diverging effects on dragonfly communities in Germany. *Diversity and Distributions*, *25*(1), pp.38-47. (National odanatology survey, Germany)

Herzog, F. and Franklin, J., 2016. State-of-the-art practices in farmland biodiversity monitoring for North America and Europe. Ambio, 45(8), pp.857-871. (Pan-European Common Bird Monitoring Scheme)

Hsu, C.H., Chou, J.Y. and Fang, W.T., 2019. Habitat selection of wintering birds in farm ponds in Taoyuan, Taiwan. *Animals*, *9*(3), p.113. (Bird Survey forming part of Taoyuan Farm Ponds Project)

Jerrentrup, J.S., Dauber, J., Strohbach, M.W., Mecke, S., Mitschke, A., Ludwig, J. and Klimek, S., 2017. Impact of recent changes in agricultural land use on farmland bird trends. *Agriculture, Ecosystems & Environment*, *239*, pp.334-341. (German Common Breeding Bird Survey)

Jiguet, F., Devictor, V., Julliard, R. and Couvet, D., 2012. French citizens monitoring ordinary birds provide tools for conservation and ecological sciences. *Acta Oecologica*, *44*, pp.58-66. (French Common Breeding Bird Survey)

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