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**The 'Targeting Revisits Map'
and evaluation of its impact on recorder behaviour**

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Summary

Opportunistic, also called unstructured, biological recording provides valuable data for mapping species distributions and trend analysis. However, these data are spatially unevenly distributed and so it is valuable to consider targeted recording in which people make records at times and places that optimally add value to the overall dataset.

Here we developed an interactive map-based tool to show recorders where records would be particularly valuable. These Targeting Revisits Maps were developed for Orthoptera, craneflies, ground beetles and soldierflies in 2020 and 2021. For the target grid squares, we selected squares that had been visited during one year in the past, because when these squares were revisited (i.e. records from two or more years) they would be included in datasets for occupancy trend modelling.

We evaluated the impact of the Targeting Revisits Maps during this trial by assessing patterns in recording and qualitative feedback from recorders and recording scheme organisers.

In this trial the promotion of the Targeting Revisits Maps was relatively limited but feedback from recorders (n = 20) was very positive. Changes in the patterns of recording was consistent with the Targeting Revisits Maps having an effect but was not conclusive. Recording scheme organisers were positive about the Maps and the concept of targeted recording, but they raised concerns about whether the definition of the target was optimal and whether there could be unintended effects on recorders' behaviour.

Overall, we recommend that the Targeting Revisits Maps continue to be developed, promoted and evaluated prior to their potential wider use for other taxa.

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1 Introduction

The evidence for the importance of volunteer involvement in biodiversity monitoring ('citizen science') is unequivocal: we would know much less about biodiversity distribution, abundance and change without the contribution of volunteers. For instance, volunteers contributed data supporting a large amount of evidence in the UK's State of Nature report (Hayhow *et al.* 2019) and the Defra Biodiversity Headline Indicators in the UK (Roy *et al.* 2012). For the wealth of unstructured data, occupancy models allowed the production of trends for several thousand species in the UK (Outhwaite *et al.* 2019) for the assessment of drivers of biodiversity change in the UK (Hayhow *et al.* 2019; Outhwaite *et al.* 2020).

There are different ways in which people can undertake recording and so contribute to biodiversity citizen science (Table 1; Kelling *et al.* 2019; Pocock *et al.* 2015, 2017). Structured sampling is an approach to gain high-quality records through carefully designed sampling strategies, both in terms of when and where people go but also the protocol through which they record. This typically requires a high level of commitment and so only a portion of the number of potential recorders take part. In contrast, unstructured recording, also called opportunistic recording, is a way of harnessing the value of records made by the many people who record nature in their spare time as and when they choose. It requires careful statistical analysis to account for biases in the data (Isaac *et al.* 2014). Approaches such as occupancy modelling are valuable for analysing these occurrence data (Altwegg & Nichols 2019; Guillerá-Arroita *et al.* 2014), although they may not be suitable for all unstructured data (Pescott *et al.* 2019). Semi-structured sampling covers a wide range of approaches that seek to control for different aspects of recording effort that are unaccounted for in unstructured recording, and so make the data more valuable for analysis (Kelling *et al.* 2019). This can be done by providing a simple protocol for people to follow (e.g. timed counts) or by allowing people to document their recording effort (e.g. using a smartphone app to record distance travelled). Semi-structured sampling is valuable, but it does not solve the problem that recording tends to be spatially biased and clustered in its distribution (Boakes *et al.* 2016; Geldmann *et al.* 2016). Here we describe and evaluate an approach that we have developed for spatially targeted recording to seek to address this limitation, while also providing the flexibility desired by many recorders.

Table 1. Different approaches to undertaking biodiversity sampling with citizen science.

Type of sampling	Protocol	Targeted spatial coverage	Description	Examples
Structured	Yes	Yes	People follow a protocol, or submit measures of recording effort, at times and places dictated by project organisers	Breeding Bird Survey ; UK Butterfly Monitoring Scheme
Semi-structured	Yes	No	People follow a protocol, or submit measures of recording effort, at times and places of their choosing	Flower-Insect Timed Counts in the UK Pollinator Monitoring Scheme ; Big Butterfly Count ; SeaWatch Foundation
Unstructured (also called opportunistic or haphazard)	No	No	People make records at times and places of their choosing without following a set protocol	Biological recording through National Schemes and Societies supported by the BRC
Spatially targeted (or adaptive)	No	Yes	People make records at times and places that optimally add value to the overall dataset	Gap-filling for local or national species atlases (e.g. Breeding Bird Atlas ; Targeting Revisits Map ; DECIDE)

The principle of adaptive sampling has been around for a long time in biodiversity monitoring (Lindenmayer & Likens, 2009). It recognises that allocating recording effort conditional on previous records (in particular previous detections) can increase the performance of estimators from modelling (Mackenzie & Royle 2005; Pacifici *et al.* 2016; Thompson 2004), so augmenting the survey design based on the latest information can help to optimally achieve a particular target (e.g. the maximal reduction in uncertainty for a parameter estimate). Typically adaptive sampling has been considered for designing and updating sampling undertaken by professional, contracted researchers, although recently a few examples exist of it being considered for biodiversity monitoring by volunteers (i.e. for citizen science (Callaghan, Poore *et al.* 2019; Callaghan, Rowley *et al.* 2019; Xue *et al.* 2016)). This idea has been developed further with the concept of ‘digital twins’ in environmental science, in which monitoring is designed to be responsive to current circumstances of the model (e.g. current uncertainty in model outputs (Blair 2021)).

When applying the concept of adaptive sampling to citizen science, one major challenge is providing tools to influence the decisions in where people choose to record. This is because, as volunteers, they are not obliged to follow an adaptive sampling design, and their recording choices are likely to be affected by home location, site access, or their own recording preferences.

Unstructured, or opportunistic, recording in the UK is organised through National Recording Schemes and Societies covering more than 80 taxonomic groups (Pocock *et al.* 2017). These schemes collate and verify records of where different species have been recorded.

Occupancy modelling uses information from biological records to infer non-detections and estimate probability of detection; this is a valuable way to make use of the wealth of these opportunistic records (Guillera-Arroita 2017; Outhwaite *et al.* 2020). From these models annual occupancy rates, and hence trends, across the set of visited sites can be estimated (Outhwaite *et al.* 2018). In the specific occupancy models currently used by the UK Centre for Ecology & Hydrology (Outhwaite *et al.* 2018), records are only included in the analysis if they are from sites (i.e. 1 km grid squares) that have been visited in more than one year. This means that a substantial number of records (typically 20–60% of the total, depending on the taxonomic group) are discarded from the dataset prior to analysis (Pocock *et al.* 2019).

Adaptive sampling design depends on “maximizing a defined utility function that quantifies the usefulness of a particular design in estimating some value of interest related to the monitoring objective being considered” (Kang *et al.* 2016). This utility function can be more, or less, complex. The particular constraint that our occupancy models only use data from sites visited in more than one year means that if sites that have been visited in only one year in the past are revisited, then both the current and the historical records can be included in the dataset for analysis. The number of sites visited in more than one year therefore provides a simple utility function for adaptive sampling in this citizen science. The impact of this would require further investigation: more records are assumed to be better to produce more accurate and/or precise trends, although we note that this is not necessarily the case, especially if less well-recorded squares are a biased sample of the landscape. More species with more accurate and precise trends would support better assessment of biodiversity and evaluation of the impact of interventions to support biodiversity (Burns *et al.* 2016).

Here we developed an interactive map-based tool: the Targeting Revisits Map. We developed these interactive maps to inform recorders how to improve the information content of unstructured biodiversity datasets, based on increasing the number of sites (i.e. 1 km grid squares) with visits in more than one year by re-recording species at sites that had only been visited in one year in the past (since 1990). We constructed the maps for four different taxonomic groups in 2020 and 2021 and assessed the impact of the maps in this trial using a mixed methods approach, with patterns in recording and qualitative feedback from recorders and recording scheme organisers.

2 Methods

2.1 Development of the Targeting Revisits Map

The aim of the Targeting Revisits Map was to provide map-based information to support recorders' decisions on where to record, be updated in real time based on records submitted to iRecord (and its linked websites and apps), and provide a strong incentive, via colour changes, to indicate the changing status of squares. The intended impact was for recorders to incentivise visits to less well-visited squares. It was developed using R Shiny (Chang *et al.* 2021).

Most biological recording schemes in the UK are defined by taxonomic groups (Pocock *et al.* 2015). We developed a short list of biological recording schemes with which to trial the Targeting Revisits Map by selecting those that actively promoted the use of iRecord to recorders, have organisers who were considered likely to support and promote new recording approaches, and where the taxa have good and reasonably accessible identification guides. For this trial, we also focused on recording schemes with a moderate number of recorders (estimated to be one to several hundred recorders annually) because we believed that this was where we would have greatest impact; too few recorders and there

was less chance to influence an individual, too many recorders and the impact on the data would have been relatively small.

From initial conversations with several schemes, we selected to work with the recording schemes for Orthoptera (termed “grasshoppers” in the Targeting Revisits Map, although also including bushcrickets and crickets: Orthoptera), soldierflies (Diptera: Stratiomyidae), crane flies (Diptera: Tipuloidea & Ptychopteridae) and ground beetles (Coleoptera: Carabidae). We developed the Targeting Revisits Map for Orthoptera in 2020 and developed it for the three other recording schemes in 2021. We attempted to develop a Targeting Revisits Map for ladybirds (Coleoptera: Coccinellidae) in 2021, but our current solution with R Shiny did not work for this much larger dataset, although it could undoubtedly be made to work with technical developments in the future.

The Targeting Revisits Map used species records from the recording scheme since 1990 that had been verified and incorporated into the recording scheme datasets. These squares were plotted on a 1 km grid and coloured according to their status (Figure 1; Table 2). The colours were selected from the ‘PiYG’ colour-blind friendly colour ramp (Harrower & Brewer, 2003) and were selected to show the previous year’s history and need for this year (Table 2; Figure 2). Colours were selected so that there was a striking colour change between ‘targets for revisits’ and ‘successful revisits’. Clicking on a square created a pop-up box giving details of the species that had been recorded there, the number of past visits, the number of years in which visits had been made (Figure 1).

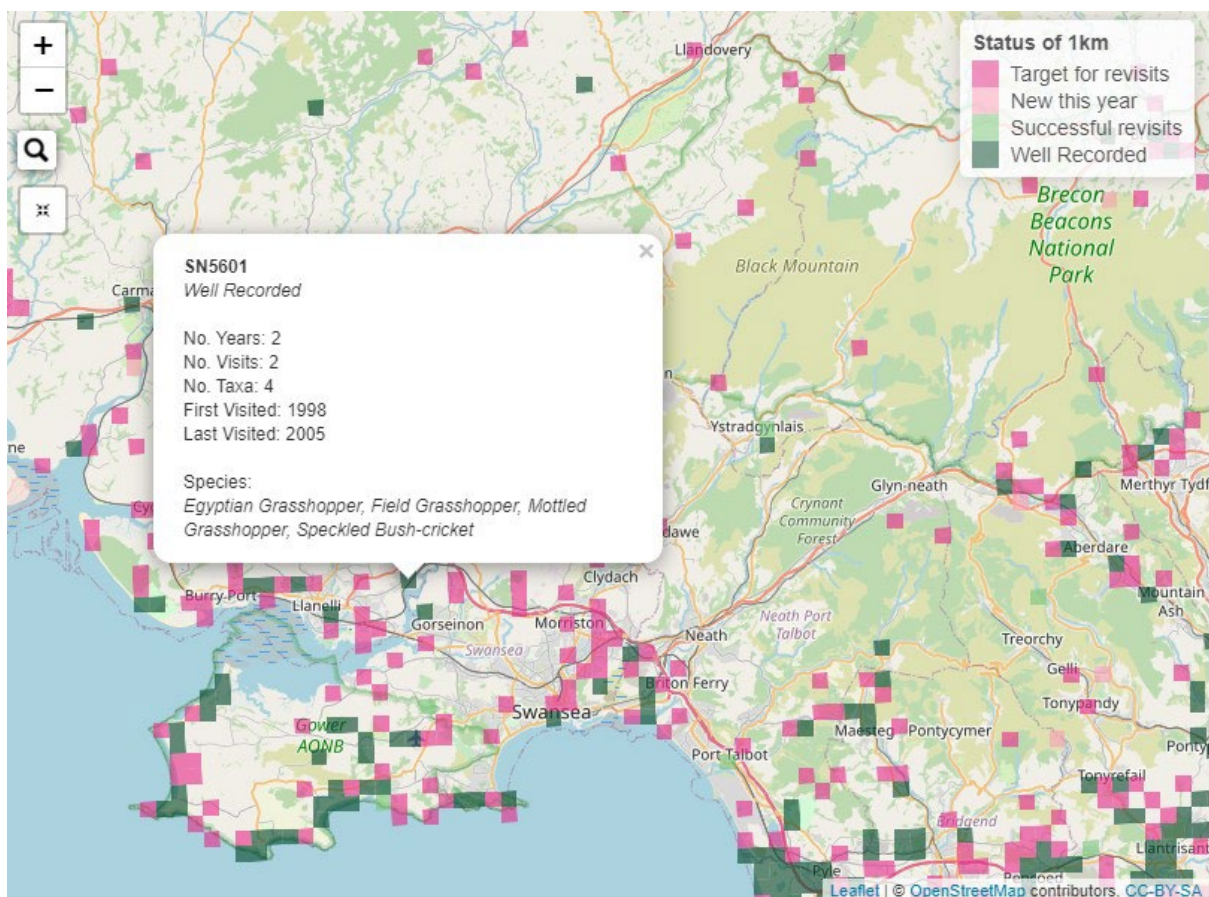


Figure 1. A snapshot of the Targeting Revisits Map for grasshoppers for south Wales showing the information that is available in the pop-up box accessed by clicking on a grid square.

Table 2. Description of the status of the 1 km squares in the Targeting Revisits Map, with a summary of the colours used to indicate status.

Status	Description	Colour of 1 km square on tool
Well-recorded	Sites that already have records of species in the taxonomic group from multiple years – these are already included in our trend analysis but, of course, records from these sites continue to be valuable.	Dark green
Successful revisits	Sites that used to only have records of species in the taxonomic group from a single year, but since this year have visits from multiple years and will now be included in our trend analysis.	Light green
Targets for revisits	Sites that have records of species in the taxonomic group from only one year in the past – if these sites are revisited then they can be included in our trend analysis.	Dark pink
New in that year	Sites that, for the first time, have records of species in the taxonomic group from this year. Next year these will become targets for revisits.	Light pink
Unrecorded	Sites that, so far, do not have any records of species in the taxonomic group in our database.	No colour

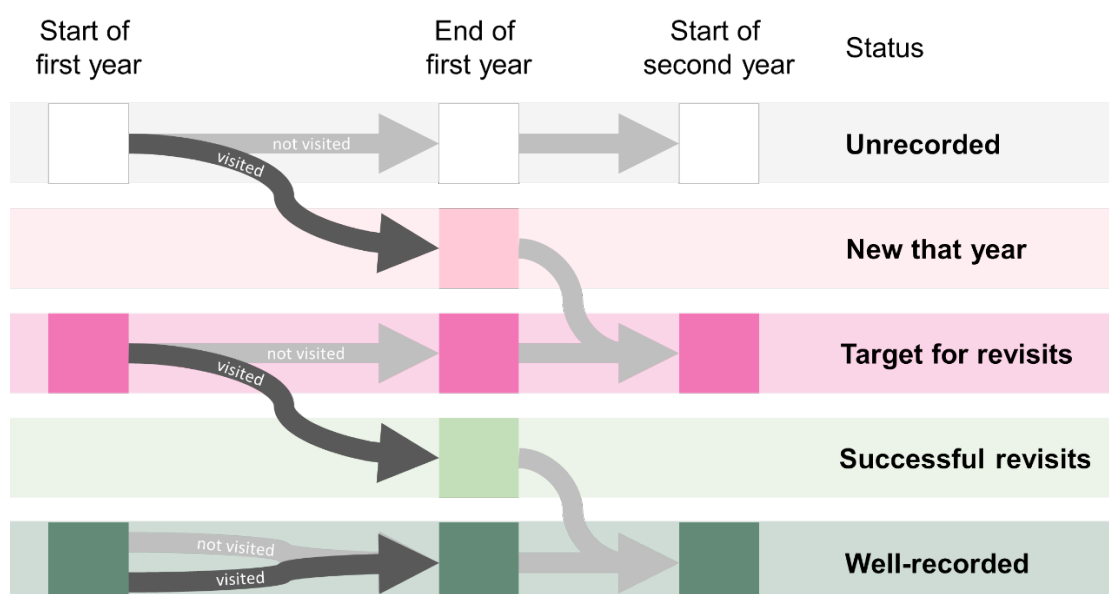


Figure 2. The transitions between the different states for grid squares within a year and between years, showing the outcomes for squares that are visited or not visited.

A simple message was given to recorders on the website: “you can increase the amount of data for analysis by revisiting squares that have records from only one year in the past – and so to turn the bright pink ‘targets for revisit’ to dark green, ‘well recorded’ squares”. Once per

day, the tool updated its database of records from records submitted to iRecord. These recent records were unverified (i.e. had not been reviewed by experts), but we decided that it was best to provide real-time feedback on the submitted records; there was often a substantial delay (days to months) between making a record and having it verified by an expert in iRecord, but good feedback supports volunteer motivation (Geoghegan *et al.* 2016).

The grasshoppers Targeting Revisits Map was launched on 21 August 2020. On 30 July 2021 the Targeting Revisits Maps for soldierflies, crane flies and ground beetles were launched, and that for grasshoppers was refreshed with the verified records from 2020. In both years they were promoted via a [news item](#) on the Biological Records Centre website (updated in 2021) and links in social media, especially via Twitter (using the hashtag #targetingrevisits for promotion). Unfortunately, the Maps were launched and promoted later in the season in 2021 than intended, so they were only available after the flight period of many soldierflies.

2.2 Evaluation of the Targeting Revisits Map

We conducted evaluation of the Targeting Revisits Map using a mixed methods approach, combining qualitative and quantitative sources of information. For quantitative assessment, we assessed the change in the total number of squares in the dataset, and the number of squares added, by their status. We also assessed the proportion of squares that changed status, in particular the proportion of newly visited squares that were successful revisits, compared to those already well-visited and those that were newly visited. We embedded a Google Analytics tracker in the Targeting Revisits Maps for Grasshoppers because it allowed us to monitor the number of people who accessed the webpage. For the qualitative assessment, we invited users of the Targeting Revisits Map to complete a feedback form giving their opinion of the tool (Appendix A1.1), and separately we invited the organisers of the four recording schemes to respond to four evaluation questions (Appendix A1.2).

3 Methods and Results

3.1 Evaluation based on change in status of squares

The total number of grid squares with records increased for all taxa across the four years from 2018 to 2021 (Figure 3a). The number of grid squares with records added that year also increased across the four years (Figure 3b). The greatest increases were after the introduction of the Targeting Revisits Maps. This reflects the overall increase in recording over time, as facilitated by ease of access to smartphone apps and web-based recording tools such as iRecord.

The increase in records added from visits in past years was striking (grey bars in Figure 3b); this was due to recorders sharing records made in previous years with the National Recording Schemes. Anecdotally, we believe that this was, at least partly, due to people submitting records during the COVID-19 restriction on use of leisure time. However, we also know of instances where the increasing visibility of the records on the Targeting Revisits Maps (and hence recording gaps) led recorders to pass existing records on to the National Recording Schemes. The increasing visibility of records supported data mobilisation.

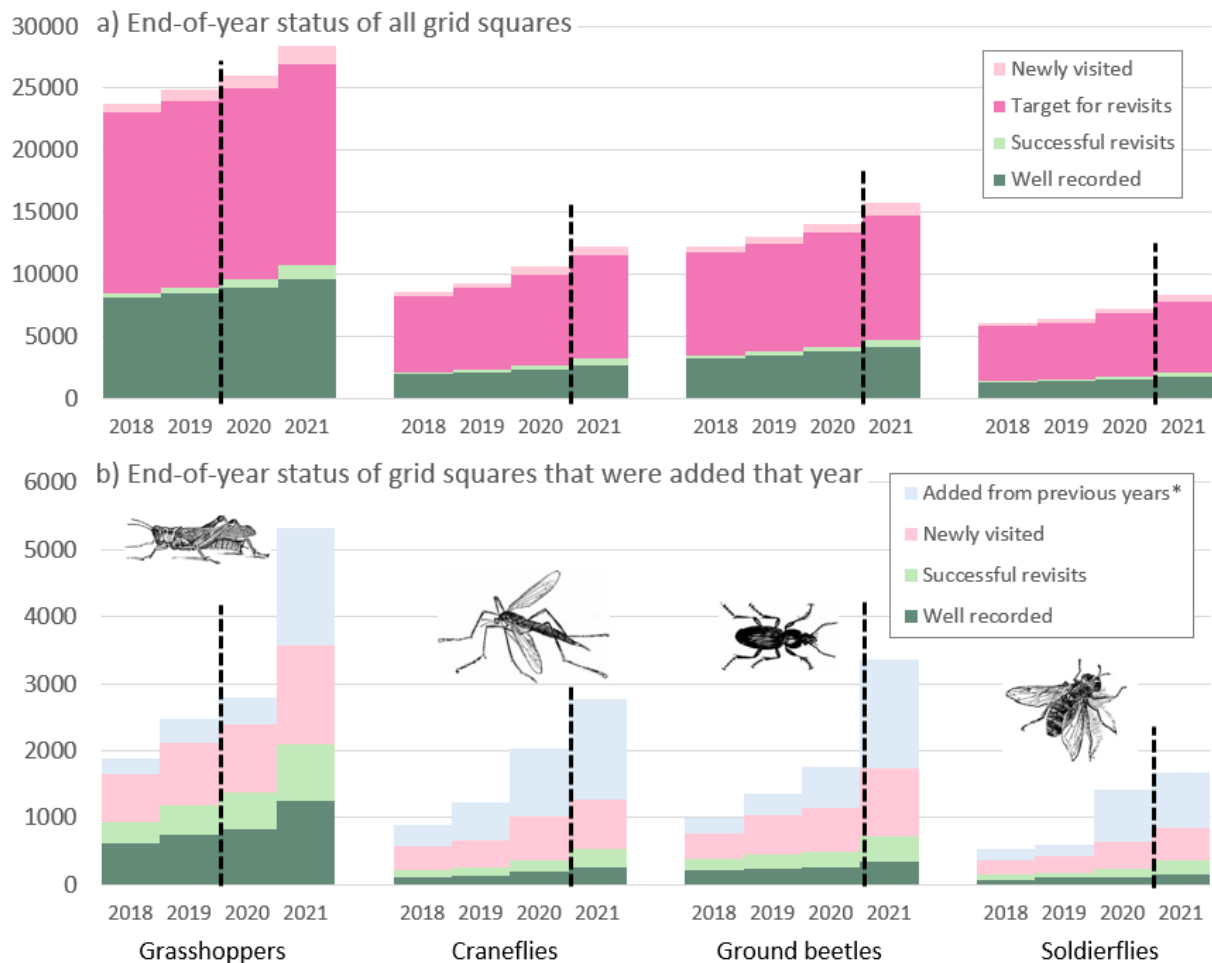


Figure 3. The overall increase in (a) the number of squares with records and (b) the number of grid squares added across the years, for grasshoppers, crane flies, ground beetles and soldierflies. The dotted line shows when the Targeting Revisits Map was introduced. (* The colour indicates the status at the end of the year except for 'added from previous years': these records were retrospectively added to the database. They could have had any status but are aggregated for clarity.)

The number of successful revisits did increase over time, particularly after the introduction of the Targeting Revisits Maps (Figure 3b), but this is better assessed as changes in the proportion of squares visited (Figure 4), rather than the overall number of squares, to account for the increasing number of records throughout the period. Evaluating the importance of changes in these proportions is challenging because they are interlinked (if proportions of two classes go up, the third must go down). Also, the opportunity for change in status changes over time because, in particular, the total number of targets for revisits increases over time (Figure 3a).

Despite this, we can see that the proportion of visits that were successful revisits was highest, for all taxa, during the years in which the Targeting Revisits Map was available, although the size of the difference was small (Figure 4b). The proportion of visits that were to newly visited, and already well-recorded squares, did not show a consistent effect (Figure 4a and c). The proportion of targets that were successfully revisited were also highest in the years in which the Targeting Revisits Map was available (3.4–5.2%), compared to previous years (1.7–3.0%; Figure 4d). Therefore, these results support the hypothesis that the Targeting Revisits Maps had a demonstrable impact on patterns of recording.

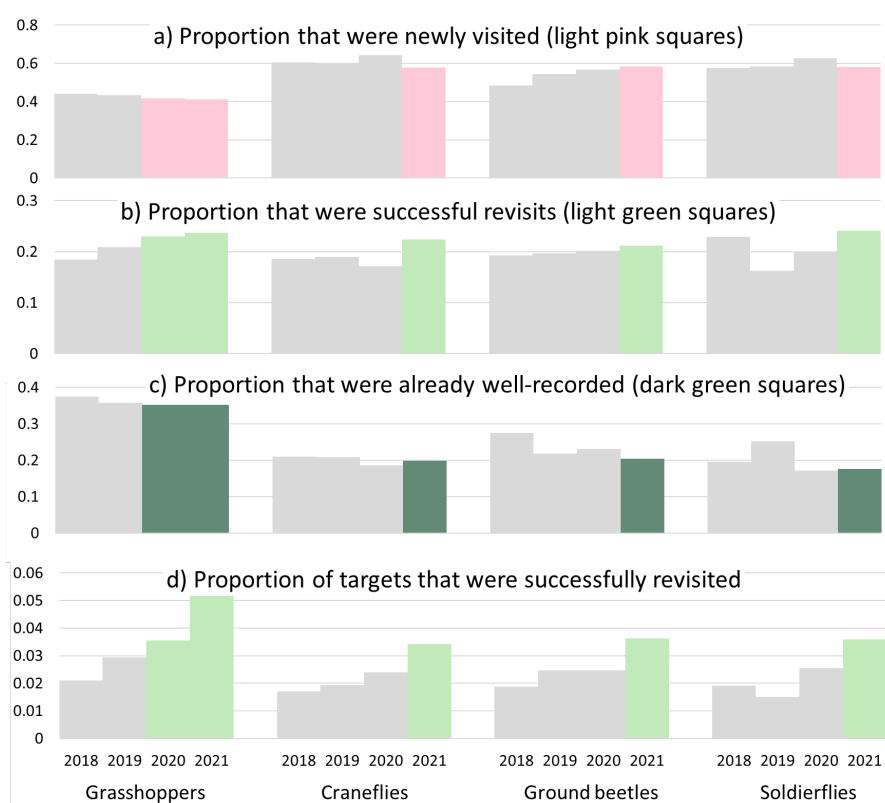


Figure 4. Proportion of squares visited that year according to the status at the end of the year, for grasshoppers, craneflies, ground beetles and soldierflies. Years in which the Targeting Revisits Map was available for the taxa are coloured.

3.2 Visits to the Targeting Revisits Tool webpage

The Targeting Revisits Map for grasshoppers has had 1537 unique page views since its launch (17 August 2020 to 17 January 2022). The peaks from midsummer followed the launch/re-launch of the Targeting Revisits Map, but also coincided with the peak recording season for Orthoptera in late summer (Figure 5).



Figure 5. Numbers of page views of the Targeting Revisits Map for grasshoppers from its launch on 17 August 2020.

3.3 Feedback from participants

We asked a set of evaluation questions in an optional feedback survey. Users of the Maps were invited to participate in the feedback survey via a link on the Map webpage and a Biological Records Centre blogpost. By February 2022 we had received 20 responses to the survey.

Most respondents to the survey submitted records via iRecord frequently (78%), and the remainder submit records occasionally. Most submit a few records each year of the target

taxa (65%), with some submitting many per year (25%) and the remainder only rarely. Most respondents thought that the information in the Targeting Revisits Map was very likely to influence their recording and would influence 'some' rather than 'a lot' of their recording activity (Figure 6). The messaging around the Targeting Revisits Map was focussed on encouraging people to revisit squares that had only been visited in one previous year, and indeed most respondents were very motivated to visit these squares (Figure 7a). Their response to visiting well-recorded squares was more mixed, although most people had some motivation to visit these squares (Figure 7b), possibly because they were local, or because this provided easily accessible information on the species being present, and possibly because they recognised the value of further revisits (e.g. to detect change). Respondents were very or somewhat motivated to visit blank squares (Figure 7c). The Targeting Revisits Map differs from several similar tools (e.g. the NBN Atlas) in that the lack of records are for the whole taxonomic group and not for an individual species, and so it provided a clear visual indication of places lacking records, and so where 'gap filling' was beneficial.

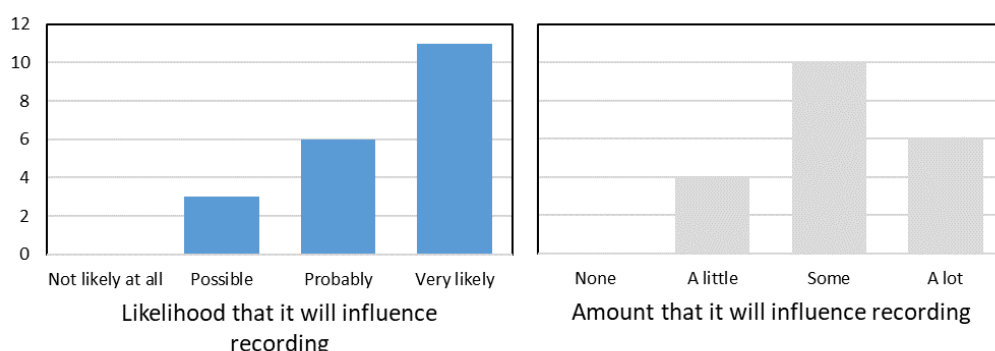


Figure 6. The number of people responding about how likely and how much the Targeting Revisits Map was thought to influence future recording behaviour.

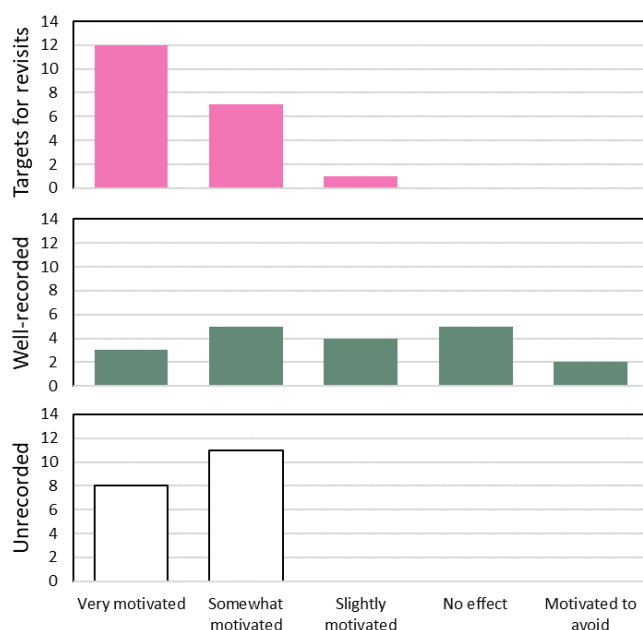


Figure 7. How the information in the Targeting Revisits Map would influence respondents' motivation to visit and submit records from: (a) (top) targets for revisits (pink on the map); (b) (middle) well-recorded squares (green on the map); and (c) (bottom) unrecorded squares (blank on the map).

Respondents provided open responses to the question: “why you think the Targeting Revisits Map is, or is not, useful”. They described how the Targeting Revisits Maps: (a) help recording to be more useful; and (b) encourage more recording; by (c) providing good feedback to recorders; and they described (d) future opportunities and challenges. One respondent summed up the impact of the Targeting Revisits Map by explaining that *“being able to see how impactful my recording can be, and directing me to where recording could have the greatest impact, is immensely powerful and motivating... I'm definitely more likely to make an active effort to record species where I can see the outputs like this coming from the data I've submitted”*. Another recorder said: *“I can see that on 3 maps... I have already helped to turn the square... from pink to pale green this year, and it's great to think that any additional records I make here will strengthen the BRC data. It also makes me realise that there are many local sites that I could visit to help fill in the gaps... I have tended to assume that my area is very well covered, but I can see from that maps that isn't always the case and it makes me feel that my small contribution is valuable.”*

- a. **Helping recording to be more useful.** Many people described how it enabled their recording to be useful: *“It shows where it would be most useful to target recording efforts”* and that it *“helps recorders... target their efforts on under-recorded areas rather than the popular nature reserves...”*. This was because *“fundamentally, we want our recording to be useful”*.
- b. **Encouraging more recording.** The responses also indicated that the Targeting Revisits Map does not simply support targeted recording but would support *more* recording: *“Orthoptera are not my usual 'target' taxa but maps like this will remind and encourage me to include them in my site lists. Also, if I spotted a square close to me or convenient to visit during fieldwork, I would be more likely make an effort to visit and collect records.”* The comments indicated that the Targeting Revisits Maps support recording for less frequently recorded taxa: *“Shows me the value of recording species which I might not think are 'worth' recording, by showing how under-recorded most species/areas are. Gives me a target to fill in gaps in the map/missing species.”* The potential to support more recording appears to be particularly the case for taxonomic groups that are relatively accessible for recording by general naturalists (i.e. with species are not too difficult to sample or identify, and with good identification materials), but are currently not very well recorded. Of course, this also depends upon having verifiers able to support data flow, and hence maintain recorder motivation (Baker et al. 2021). One person noted that it gives them *“a reason to record these groups, which are not insects I would necessarily be looking out for... learning a few new species to ID would be a motivator for me.”*
- c. **Provided good feedback.** The ease with which the summary information is accessed appeared to be important to respondents: *“Quick and easy to see what has been recorded previously”*, *“really helpful to see which species are recorded, even in well-recorded squares”*, *“The tool is very useful as it appears to be updated daily so you can see which squares need coverage”*. The fact that the change in status was clearly communication was also important: *“Very motivational for targeted recording, particularly the immediate feedback loop of the colour change.”* The ease of visualisation also revealed to one local recording organisation that their data were not assimilated with the national recording scheme, and so the Targeting Revisits Map prompted them to share data. As one person noted *“it gives something back to recorders so thank you”*, which suggests that the existing feedback to recorders about the value of their data is, perhaps, not as good as it could be.
- d. **Future opportunities and challenges.** Respondents raised several opportunities and challenges for the future of the Targeting Revisits Maps. They said that it would be valuable to integrate it with iRecord (especially *“if it 'popped-up' after entering the*

record”), and to get the 1 km squares and their status as a downloadable list, rather than making it solely map-based. Some of the suggestions were for the Targeting Revisits Maps to perform more like the National Biodiversity Network Atlas (*“being able to... quickly show distributions (ideally with a year range option) for any chosen species”*). If developed for other taxa, then for some *“e.g. Sawflies there would be so many unrecorded squares it would be difficult to know where to start”* indicating that it could be valuable to have additional targets to help recorders prioritise their recording. The approach of targeting based on optimally improving spatial models is an approach that is being tested in the current [DECIDE](#) project.

3.4 Feedback from scheme organisers

The national recording scheme organisers had lightly promoted the Targeting Revisits Map via social media (especially Twitter), and a few talks. Overall, they thought that the concept of targeting was valuable: *“do we just want more records from as many places as possible, or is a targeted approach needed to avoid wasted effort?”*. They felt that the easily accessible map-based overview was very beneficial, and it was valuable that the Maps made the direct link between the data and its use in trend analysis, thus closing the link between an individual’s recording and the value of their records. The Targeting Revisits Maps provide a motivation to recorders that is different to the current information. Any support to encourage recording, whether revisits or gap-filling, is valuable for smaller recording schemes with few recorders and for which *“every record is important”*.

The recording scheme organisers did not yet have evidence on who was most likely to be influenced by the Targeting Revisits Map but felt that it would appeal to some more than others. It could appeal to those with a more competitive sense of recording and intermediate recorders who have capacity to explore and record in new areas local to them.

One organiser said that *“revisiting squares with a few old records is also likely to generate new location data for species not recorded on the previous visit”*. However, a couple of the organisers raised concerns about the target used in the Targeting Revisits Maps. The Maps had a clear, single target (encouraging people to record in squares that had records from only one year in the past) and a strong visual indicator of success (*“turning pink squares green”*), but this is contingent on one aspect of one type of analysis (the occupancy modelling used in the Biological Records Centre). It therefore assumes that the occupancy models and their outputs are suitable for these data, although this was queried by one organiser. Many of the targets for revisits were in species-poor habitats, and arguably it would be better to encourage revisits to squares that were known (or predicted) to be more species-rich. Although records of common species are important, two organisers suggested that asking people to look for species in species-poor squares would *“not be the best use of recorders’ time”* because it would simply result in more records of ubiquitous species rather than the rarer habitat specialists. However, it was also acknowledged that this could also raise awareness about these species amongst people who have not previously recorded them, and so suggests the opportunity to personalise tools such as this, based on recording behaviour of the recorder viewing them (e.g. seeing a personalised set of recommendations once logged into iRecord). Going further, there was some concern that the Targeting Revisits Maps could unhelpfully change people’s recording behaviour. After all, a single record of a common species in a grid square is enough (with the current Maps) to change it from a target for revisits to well-recorded, so people could simply travel around ‘ticking off’ a single species in lots of squares or devote excessive recording effort until they make a single record. One organiser knew of a recorder who was frustrated that their visit to a target square did not result in any records, so the square remained pink, although this reflects a larger question of the challenge of reporting zeroes when recording effort is not controlled or reported. One way to responding to these concerns would be to change the criteria for

defining a ‘target for revisits’, and so it would be valuable to engage further with the schemes to discuss this.

The scheme organisers supported the continuation of the Targeting Revisits Maps and believed that it would generate more interest over time. The Targeting Revisits Maps could provide a live summary of how many squares change status through the year. It could also be integrated with iRecord, so recorders can be given immediate feedback how their visit compares with older records. It would be good to let recorders know how this has contributed to improvements in trend analysis and, ultimately, conservation outcomes. Two of the scheme organisers would welcome further engagement about how the targets could be defined to be more appropriate (e.g. weighting towards species-rich squares or a better definition of what counts as a successful revisit). However, even if we adapted the way that targets were defined in response to this feedback, it would be important to follow the endorsement that *“targeting needs to be kept simple and clearly explained (which it [currently] is)”*.

4 Discussion

4.1 Reflection on the evaluation of the Targeting Revisits Maps

Here we developed a new tool that identified spatial targets for biological recording through the presentation of a clear, easily accessible map that was updated in real time, had a simple definition of targets and provided contextual information about past records. Qualitative feedback from volunteer recorders indicated that the Targeting Revisits Maps were positively received and likely to influence their future recording and recording scheme organisers were positive that this tool would encourage more, and more targeted, recording.

There is a long history of providing biological recorders with feedback about where records are valuable, but in our experience this has been almost entirely focussed on gap-filling. This can be simple messaging (e.g. recording in places with no records such as the “Gaps in the Maps” project (Northamptonshire Biodiversity Records Centre 2021)) or more complex, as in the British Trust for Ornithology’s web-based tool to guide gap-filling based on the proportion of species present but not confirmed to be breeding (British Trust for Ornithology, n.d.). However, they rarely have such a direct, timely link to the data input as our Targeting Revisits Maps, and we focused on a specific analysis-led need (increasing the number of sites with records made from more than one year for use in occupancy modelling).

The response from the volunteer recorders was encouraging about the impact of the tool, even though recorders will have a wide range of motivations for taking part (West *et al.* 2021). Most people submitted records only occasionally for the taxon of interest, so they did not represent the most active recorders, but they were strongly motivated to change their recording behaviour and visit both targets for revisits and unrecorded grid squares. In the future it would be valuable to explore whether the keenest recorders or less active recorders are the optimal targets for the Targeting Revisits Maps, both in terms of their motivations and flexibility to be influenced, and in terms of the overall impact on the outputs of analysis of the data. Questions like this have been explored in other citizen science projects (Rallapalli *et al.* 2015). This shows that there is great potential in using simple tools to support people’s recording behaviour, and the value of providing clear, persuasive visual information (Pandey *et al.* 2014). In this case, it was clear that the simple and honest messages in the Targeting Revisits Maps aligned closely with people’s interest in spending their time for biological recording well. Their responses also suggested that Targeting Revisits Maps encourages more recording overall, as well as recording in under-recorded places.

As we anticipated, quantitative evaluation of the Targeting Revisits Maps was challenging because any effect was likely to be small against the variability and increase in current recording. It was also affected by the dramatic effects of COVID-19 lockdowns on recording behaviour (e.g. Basile *et al.* 2021), and limitations on local and international travel could have influenced recording behaviour throughout 2020 and 2021, even once lockdown restrictions had been relaxed. However, the current evidence supported the hypothesis that the Targeting Revisits Maps positively influenced the dataset. We anticipate that another year's data (especially providing the Targeting Revisits Maps from the start of the recording season) and comparison with data from recording schemes without the Targeting Revisits Maps will provide a stronger BACI (before, after, control, intervention) design for evaluation.

One of the major challenges with targeted recording is the definition of the target. Biological recording data has multiple uses, from producing atlases (and gap-filling) to spatial modelling and trend analysis (Powney & Isaac 2015). Different users (including recording scheme organisers, and recorders themselves) will have different priorities at different times. The feedback from recording scheme organisers suggests that while the targets in the Targeting Revisits Maps could be adapted, the simplicity, clarity of the target of success, and its direct link to a call to action is one of the reasons for the positive feedback from volunteer recorders. It would also be valuable to use simulations to test the impact of these different approaches to targeting on the precision and accuracy of the trends. This is ultimately the way of assessing how changes in recording would lead to improved trends and, hence, improved management for biodiversity.

There was some concern that the Targeting Revisits Maps could cause unintended biases in the data. It will be valuable to consider ways of testing this, for example, comparison in the number of species per visit in squares with different statuses, to understand the risk posed by these concerns.

4.2 Next steps for the Targeting Revisits Maps

Overall, the Targeting Revisits Maps demonstrate the effectiveness of a simple visual tool that provides real-time feedback to biological recorders.

Several activities will be valuable for further work in 2022:

- Promote the Maps more strongly. Publicity around the Targeting Revisits Maps has been relatively limited so far. Developing the Maps early in 2022 to allow them to be advertised to, and by, the relevant recording schemes will be important to further test their uptake by recorders. Promotion should be focussed on recorders, so including recording scheme newsletters and journals, as well as a major investment in social media.
- Gather feedback from more recorders and gather stronger quantitative evidence of the impact that this tool is having on the data. This will need to include comparison with the counterfactual situation of recording schemes that are similar but do not have Targeting Revisits Maps in place.
- Test for potential biases in the data collected in response to the Targeting Revisits Maps. For instance, whether species lists are shorter than expected in sites visited in response to the Targeting Revisits Maps. It may be possible to assess whether bias is present or not by comparing the species composition of sites with different recording statuses, and/or by asking an additional question in the feedback survey.
- Explore different definitions of the target. Given the different ways in which it would/could define the 'targets for revisits', it would be important to engage with the recording schemes involved in this trial about the best, simple metrics to use to target

people's recording that meets the needs of recording scheme organisers, as well as the needs of those who undertake occupancy modelling. In doing this, the criterion for a 'target' could be refined and could include habitat characteristics, although it will be vital to keep the messaging and visual communication simple.

- More schemes could be engaged in the future, so it would be valuable to identify potential schemes, based on the number of recorders, availability of identification guides and verifiers, and suitability of taxa to benefit from occupancy modelling.
- Engage Natural History Societies. They organise regular field meetings throughout the year and could use the Targeting Revisits Maps to plan where to go. Naturalists may submit records to the relevant national recording schemes but frequently organise their activities as part of a local natural history society.
- Develop a technical solution that works efficiently for high volume datasets (e.g. the ladybird recording scheme dataset).
- Explore the impacts of the Targeting Revisits Maps and related spatial targeting approaches, such as [DECIDE](#), on other areas of work relevant to the TSDA partnership (e.g. assessing biodiversity interventions, providing wider spatial and taxonomic coverage of recording, linking with habitat recording).
- Investigate closer integration with tools such as iRecord and NBN Atlas.
- Engage verifiers about whether prioritising records for verification (e.g. based on their status in the Targeting Revisits Map) would be useful and how it could be implemented.
- Investigate market segmentation for tools such as the Targeting Revisits Maps. For instance, recorders who have a lot of species expertise could be directed more towards some squares (e.g. species-rich squares), whereas those who have less expertise could be directed to squares that are expected to be less species-rich, but for which records would still be valuable.

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Appendix 1

A1.1 Evaluation questions for recorders

Thank you for taking time to give feedback on the Targeting Revisits Map.

We hope that you have enjoyed exploring the Targeting Revisits Map. This is an opportunity to tell us what you think of it and how you think it might affect your recording.

This feedback survey is optional. The results will be used to inform how we can best support biological recorders like you and help to get better data on trends in insects. By filling in this survey you give us permission to use the information you provide for evaluation of the Targeting Revisits Map.

1. Which Targeting Revisits Map have you used? (*Grasshoppers; craneflies; ground beetles; craneflies*)
2. Do you think that the Targeting Revisits Map is valuable for recorders like you?
3. Please briefly describe why you think it is, or is not, valuable.
4. What is the likelihood that the information in the Targeting Revisits Map will influence your recording of the species in the Map that you have used? (*Not at all likely; Possibly; Probably; Very likely*)
5. How much of your recording of these species do you think will be influenced by the information provided by the Targeting Revisits Map? (*None; A little; Some; A lot; I don't know*)
6. Given the information presented in the Targeting Revisits Map, how motivated are you to visit and submit records of these species from: (*Very motivated to record in these squares; Somewhat motivated to record in these squares; Slightly motivated to record in these squares; The map has no effect on my motivation; Motivated to avoid recording in these squares*)
 - a. Targets for revisits? (Bright pink on the map)
 - b. Well recorded squares? (Bright green on the map)
 - c. Unrecorded squares? (Blank on the map)
7. How frequently do you submit records of species in the taxonomic group for the Targeting Revisits Map that you used? (*Never; Rarely - only in some years; Occasionally - a few records each year; Frequently - many records each year*)
8. How frequently do you submit biodiversity records (e.g. via iRecord or other activities)? (*Never, Rarely - a few records per year, Occasionally - a few records in most months, Frequently - many records in most months*)
9. Do you think a tool like the Targeting Revisits Map would have long-term effects on your biological recording? Please briefly describe if so and how.
10. Does the information in the Targeting Revisits Map influence your recording or your motivation in other ways? If so, please briefly explain how and why.
11. Please state the county (e.g. Oxfordshire or Pembrokeshire) where you do most of your recording.
12. Do you have any other comments about this tool or support for biological recorders that are relevant for us at the Biological Records Centre?
13. Please give your name. (This is so that we can count the number of individuals who fill in this survey. You can fill in this survey more than once if you chose. We will not associate your name with any of your results during our analysis.)

A1.2 Evaluation questions for recording scheme organisers

We are interested in evaluating the Targeting Revisits Map and would like feedback from you as recording scheme organisers.

This feedback survey is optional. The results will be used to inform how we can best support biological recorders like you and help to get better data on trends in insects.

By filling in your answers you give us permission to use the information you provide to evaluate the Targeting Revisits Map. We will acknowledge you in the report and may use anonymised comments within the report.

1. Have you actively promoted the Targeting Revisits Map to your recorders? If so, can you briefly describe how, and why you wanted to do so?
2. Thinking about the impact on biological recorders:
 - a. Do you think a tool like the Targeting Revisits Map is beneficial for biological recorders of your taxa. If so, how?
 - b. Do you think a tool like the Targeting Revisits Map is detrimental for biological recorders of your taxa. If so, how?
 - c. Do you think that there is variation in the impact across the types of recorder (from beginner to expert)?
3. Thinking about the impact on biological recording datasets
 - a. Do you think a tool like the Targeting Revisits Map could be beneficial for your datasets. If so, how?
 - b. Do you think a tool like the Targeting Revisits Map could be detrimental for your datasets. If so, how?
4. Have you had feedback from your community of recorders? How have they responded, and do you have specific comments to share?
5. Would you like to see continued support for the Targeting Revisits Map? If so, are there changes that you would like to see?
6. Do you think that the concept of 'targeting' is valuable for biological recorders?
7. Do you have any other comments?