“Citizen identification”: online learning supports highly accurate species identification for insect-focussed citizen science.

Running Head Online public learning of species ID

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Abstract

1. Citizen science is widely used in ecological research. Data verification of citizen collected data continues to be an issue, and confirming accurate species identification reported by citizens can be especially difficult.
2. Here, we determine the efficacy of using remote learning to identify UK social wasp (Vespinae) species. Citizen scientists (N = 559) collected wasps and identified specimens to species level using a series of online videos and support material.
3. A pre-identification and post-identification questionnaire, and a post-identification assessment test, obtained both qualitative and quantitative data for engagement and changes in identification skills. Some (13.5%) of the participants sent their samples in for expert verification of species identification.
4. Self-assessed skill ratings increased from 2.2/5 pre-identification to 3.5/5 post-identification process. Identification accuracy was high, with 85.6% of assessment test images and 96% of the verified specimens being identified correctly. In previous years, face-to-face public ID workshops with expert trainers yielded an identification accuracy of 91.3%. Eighty-seven percent of participants reported enjoying the experience and would take part again.

5. Remote learning of identification skills in non-specialists can produce greater identification accuracy than face-to-face expert-led workshops, with lower resource requirements and enhanced engagement.

Keywords: citizen science, identification, Vespinae, social wasps

Introduction

Citizen science has become an important method in ecological and biodiversity research (Dickinson *et al.*, 2010; Ellwood *et al.,* 2017; McKinley *et al.*, 2017) from short-term one-day "bioblitzes" (Parker *et al*., 2018; Aristeidou *et al*., 2021) to long-term species monitoring programmes (Chandler *et al.*, 2017; Lloyd *et al*., 2020). Citizen science has broadened research scope and capacity, but also strengthened the relationship between the public, the natural world and the scientific process (Schuttler *et al.*, 2018; Adler *et al.*, 2020). Despite these benefits, citizen science data can be problematic. While some studies have suggested the quality of data is comparable to that collected by professionals (Lewandowski and Specht, 2015; Flesch and Belt, 2017), citizen-collected data can be low quality, unreliable and difficult or impossible to verify (Lukyanenko *et al.*, 2016; Burgess *et al*., 2017; Jiménez *et al*., 2019). Data obtained through citizen science should be expert-verified whenever possible, but this is likely to be costly and time-consuming (Dickinson *et al*., 2010; Bonter and Cooper, 2012).

Ecological citizen science often relies on species identification, and accurate identification is therefore crucial (Austen *et al*., 2016; Elphick, 2008; Farnsworth *et al*., 2013) with species misidentifications being especially detrimental (e.g. Hunt, 2015). Species identification can be difficult (Crall *et al*., 2011; Pyšek *et al*., 2013) and relying on non-specialist citizen scientists for accurate species identification can present many challenges. This is particularly the case in entomological studies where species can be very difficult to identify without expert skills and equipment (Gardiner *et al.,* 2012; Ratnieks *et al.*, 2016; Hansen *et al.*, 2019). Nevertheless, widespread concerns about declining insect numbers, especially pollinators (Hallmann *et al.*, 2017; Forister et al., 2019), has brought insect monitoring to the fore in citizen science studies (Richter *et al.*, 2018; Falk *et al.*, 2019).

In 2017, a citizen science project called the Big Wasp Survey (BWS) was set up (by SS and AH) to better understand social wasp (Vespinae) diversity and distribution through the UK, and has since run annually. The project asked members of the public to collect wasp samples from their gardens using a funnel trap made from a plastic drink bottle filled with beer. Wasps collected were sent to the project team for identification and counting. To help process samples, members of the public were invited to attend expert-led wasp identification and sorting workshops. Whilst workshops are beneficial for identification, public engagement and education, they are also resource-intensive and inefficient. For example, the identification process for the 2018 study began in September 2018 and was finished by June 2019; 10 months after it started. Covid-19 restrictions imposed in March 2020 in the UK meant that public identification workshops were uncertain to run, and so we asked previous BWS participants to collect wasps and identify them at home using a series of specially-created species identification training videos and supplementary material. Participants submitted species identifications and a subset of participants were asked to post in specimens for expert verification. Our study allowed us to address two aims. First, we aimed to assess how effective our learning materials were in building confidence in wasp identifications and whether the experience was a positive one for the participants (Aim 1). Second, we assessed to what extent identification of wasps by citizen scientists at home, without real-time expert assistance or any professional equipment, can generate accurate and reliable data on insect identification (Aim 2). The BWS currently requires limited lethal sampling, which is a contentious area (Drinkwater *et al.*, 2019), but self-taught identification would be possible in some taxa without lethal sampling (e.g. Coccinellinae).

Methods

A website was created through which participants could create a personal account and upload their specimen data. The website included species identification training videos (n = 9), which were filmed using an iPhone 8 and edited using iMovie. Videos ranged from 26 seconds to 123 seconds in length, with one introductory tutorial and eight species-specific identification videos for each of the social wasps trapped in previous runs of the BWS (available via https://www.bigwaspsurvey.org/identification/). Videos showed how to handle specimens, and highlighted the main morphological features that would need to be examined to identify specimens to species level. As well as videos, participants were provided with a photographic key, which highlighted the main differences between the species in side-by-side picture comparisons. Though there are nine species of social wasp found in the UK, *Vespula austriaca* (Panzer) and *Dolichovespula norwegica* (Fabricius) were not included in this study as previous BWS data showed that the likelihood of encountering these species at the time of sampling is very low. Participants were advised that if a specimen was caught that did not match a species in the identification videos or photographic chart, then they should contact the team for assistance and verification.

Participants

The 1264 participants who took part in the 2019 BWS were invited via email to participate in the 2020 study. They were informed that, unlike previous years, they would need to identify their catch themselves. Of these, 559 signed up to take part, setting 683 traps (Figure 1). These traps provided the wasps for the participants to identify.

Figure 1 The number of participants involved in each stage of the project.

Pre- and Post-Identification Questionnaire

Participants completed a pre-identification and a post-identification questionnaire. Pre-identification, participants were asked if they had previously attended a BWS sorting workshop. If they had, they would have received prior wasp identification training and therefore may have a higher level of experience than those who had not attended. The pre-identification questionnaire also asked participants to rate how confident they were distinguishing between wasps and similar-looking flying insects (e.g. bees and hoverflies) on a scale of 1-5 (1 = 'not at all confident', 5 = 'very confident'). They were additionally asked to rate their knowledge of wasp identification to species level on a scale of 1-5 (1 = 'no knowledge', 5 = 'expert knowledge'). The use of emojis has been shown to be effective for clarifying online communications (Kaye *et al.*, 2017; Novak *et al.*, 2015; Willoughby and Liu, 2018) and so these were incorporated into the questionnaire to reduce misunderstanding over the 5-point rating scales.

The same questions were asked in the post-identification questionnaire in order to obtain a qualitative value for the participants' self-assessed improvement in species identification. They were also asked to rate the helpfulness of the identification materials on a scale of 1-5 (1 = 'very unhelpful', 5 = 'very helpful'), and to provide feedback on the extent to which they enjoyed the experience and whether they would choose to participate again.

Post-Identification Test

A multiple-choice test was provided post-identification to assess participants' actual identification abilities after undertaking identification. The test presented four questions, each with three pictures of one species (Figure 2). Participants were asked to identify the species based on the pictures provided. For each question, all seven species were listed (*Vespula vulgaris* (Linnaeus), *Vespula germanica* (Fabricius), *Vespula rufa* (Linnaeus), *Dolichovespula media* (Retz), *Dolichovespula saxonica* (Fabricius), *Dolichovespula sylvestris* (Scopoli) and *Vespa crabro* Linnaeus)), but only one was the correct answer.

Figure 2 An example of a question in the post-identification test.

Specimen Verification

Of the 683 traps, 415 traps set by 229 participants contained wasps. We randomly selected 60 (ca.25%) of those participants who had captured and identified wasps and asked them to post their samples to the BWS team for verification. As per previous BWS runs, these participants were asked to wrap their specimens in aluminium foil, place them in a padded envelope, and encouraged to post 1st class to ensure the specimens arrived in good condition.

On delivery, specimens were stored in 100% ethanol in airtight plastic liquid containers labelled with the trap registration number and subsequently identified to species level by microscopic examination.

Results and Discussion

We tested how effective our training materials were in improving participants' confidence in identifications (Aim 1) by comparing their self-assessment scores from the pre and post-questionnaires. Pre-identification, the confidence rating for participants' ability to distinguish between wasps and similar-looking flying insects averaged 4.0 (out of a possible maximum of 5) (SD = 1.08), with a mode of 5/5, whereas the rating for knowledge of wasp identification to species level averaged 2.2/5, (SD = 1.27), with a mode of 1/5. Post-identification, the confidence rating for knowledge of wasp identification to species level increased to an average of 3.5/5 (SD = 0.95), with a mode of 4/5. This suggests that taking part in the BWS improved people's confidence in identifying the insects to species level.

Qualitative questionnaire responses suggested that participants found the materials useful and effective and that it had been a positive experience (Aim 1). The identification material averaged a helpfulness score of 4.4/5 (SD = 0.83), with a mode of 5/5. The videos were described as "extremely clear" and "easy to follow" with some participants commenting that their length (26 seconds – 123 seconds) meant they were "short and to the point" and "short – easy to watch". Of the 209 participants who completed the post-identification questionnaire, 183 participants (87.6%) said they enjoyed the experience and would like to do it again, with comments such as "I hope you repeat this next year", "self-identification is the way forward" and "I'm feeling empowered for the future". Of the remaining 26 participants, 12 (5.7%) said they neither liked nor disliked the experience and may or may not do it again, 10 (4.8%) said they did not enjoy the experience but may give it another go, and 4 participants (1.9%) said they enjoyed the experience but would not do it again. Overall, participants were extremely positive about their experience and found the resources helpful and effective in helping them identify their specimens.

The self-identification process achieved high accuracy results in both the post-identification test and the verified samples. Of the 559 participants that initially signed up, 448 (80.1%) completed the pre-identification questionnaire (Figure 1). Of the 448 participants who completed the pre-identification questionnaire, 209 participants (46.7%) went on to complete the post-identification questionnaire and online identification test. Many participants dropped out before completing the post-identification questionnaire as they did not catch wasps in their traps and so did not have the opportunity to identify any specimens. In the post-identification online test, 89% (n = 186) of participants correctly identified *Vespula germanica*, 83.3% (n = 174) correctly identified *Dolichovespula media*, 80.4% (n = 168) correctly identified *Dolichovespula sylvestris* and 89.5% (n = 187) correctly identified *Vespula vulgaris.* The average accuracy achieved in the post-identification test was 85.6%. For each question, with the exception of Question 1 (*Vespula germanica*), all 7 potential answers were selected as the answer at least once. *Vespula* spp. were most commonly mistaken as other *Vespula* spp.; *Vespula germanica* in particular was most commonly misidentified as *Vespula vulgaris* (16/209 = 7.7% identified as *V. vulgaris*), which was the same case in the 2018 BWS workshops. *Dolichovespula sylvestris* was most commonly misidentified as *Vespula rufa* (16/209 = 7.7% identified as *V. rufa*), which is most likely because these are the only two species with a single pair of yellow spots on their thorax.

In addition to the online identification tests, 802 wasp specimens were received from 31 participants for verification. Some of the specimens (n = 18) were unidentifiable due to decomposition and were discarded. Three participants miscounted the total number of specimens in their samples and these samples were also discarded. The remaining specimens (n = 726) were verified, and of these, 96% (n = 697) had been identified correctly. One honeybee (*Apis mellifera*) was found, which had been incorrectly identified as *Vespula rufa*. Two participants missed wasp specimens in their bycatch (3 *Vespula germanica* and 3 *Vespa crabro* were found); these specimens were not included in the total number of wasps for accuracy calculations.

Forty-two of the 448 (9.4%) participants who completed the pre-identification questionnaire had previously attended a BWS workshop; of these, 22 (52.4%) went on to complete the post-identification questionnaire and test. These participants had an average test accuracy of 88.5% (cf. total overall average 85.6%). Only four participants who sent their samples for verification had previously done a workshop; of these, two got 100% (one identified two specimens, the other identified three), one identified 97/98 specimens correctly and the other 13/14 (accuracy = 98%).

The usefulness of citizen-collected data depends on its accuracy and validity (Delaney *et al.*, 2008; Kosmala *et al*., 2016). Our results demonstrate that when given appropriate training material, high species identification accuracy (96%) can be achieved by non-specialists. Additionally, we show that remote learning identification is effective for educating and engaging the public. Participants' self-assessed identification ratings increased 60% (from 2.2/5 to 3.5/5), the identification material received a helpfulness rating of 4.4/5, and 87.6% of participants said they enjoyed the remote learning experience and wanted to do it again.

Based on these results, we conclude that remote learning is an effective tool for accurate species identification in citizen science. It should be noted, however, that Vespinae form a small and distinctive guild of insects that are relatively large in size compared to others. Remote learning and self-identification may therefore not be as straightforward for projects looking at a longer list of target taxa, or taxa with microscopic characteristics. These types of projects would benefit from using citizen science as a means of data collection; however, for species-level identifications, further expertise may be required.

Not only did the remote learning process improve the self-assessed identification ratings, but the accuracy achieved in the verified samples was 4.7% higher than that achieved at the 2018 public sorting workshops (91.3% (Walsh, 2019)). At these workshops, participants were provided with microscopes, photographic identification keys, and access to experts for assistance. In the 2020 study, participants identified the wasps at home using their own equipment with minimal expert input, so the increase in identification accuracy is notable. However, it may be that the subset of participants who sent in wasps to be verified were those who were most motivated and may have been more likely to identify the wasps correctly. We are unable to say whether this was the case but regardless our results add to existing research (Fuccillo *et al.*, 2015; Katrak-Adeforowa *et al.*, 2020) that indicates high accuracy levels can be achieved through low-input training methods. The improved accuracy may reflect the fact that some people perform worse under pressure (Toma, 2017; Bucciol and Castagnetti, 2020) and being in the presence of experts at public workshops may decrease participants' confidence in their abilities and their accuracy. This is similar to the 'white coat syndrome' (Pioli *et al.*, 2018) where some people experience higher blood pressure in a clinical environment than they do in other settings, such as their home. Our results suggest that if citizen scientists are given more space, time and the appropriate resources, then they can accurately identify complex species without expert assistance and may perform better on their own. What is more, remote learning is much more time- and cost-efficient than using public workshops or face-to-face training. Using remote learning and self-identification in identification-based projects could greatly reduce time and resource requirements for such projects and thus improve their long-term sustainability. Of course, not all projects will be suitable for this approach. We knew in advance which species would be found, and those species form a small group of that are relatively straightforward to identify. We would recommend that if projects want participants to identify species remotely the consider project design carefully (to limit the pool of potential species) and invest in developing clear identification resources tailored to potential participants in terms of level and presentation.

Some (n = 9) participants remarked that they would have preferred written description or additional photographic material over video tutorials. This highlights the need for consideration of the VARK (visual, auditory, reading/writing and kinaesthetic) model of learning styles for citizen science projects. The VARK model divides types of learners into four categories: visual (those who learn through image-rich teaching materials), auditory (those who learn by listening), reading/writing (those who learn using descriptive textual material) and kinaesthetic (those who learn through experiencing physical involvement) (Lujan and DiCarlo, 2006; Prithishkumar and Michael, 2014). We suggest that all four VARK model learner types are accommodated if possible to maximise volunteer engagement and potentially further increase accuracy. Additionally, a few participants (n = 4) commented that we used good/perfect specimens in our video tutorials, yet often the specimens they caught had deteriorated in the traps, making features difficult to identify, which may have affected the accuracy of identification. This finding is similar to that of studies that used photos for species identification (Daume and Galaz, 2016; Katrak-Adeforowa *et al.*, 2020), which found that using low quality images reduced identification accuracy. We therefore suggest additional training materials that help participants identify non-ideal specimens would further improve overall accuracy.

In conclusion, we have shown that citizen scientists can be trained effectively in insect identification, without access to experts or professional equipment and, in general, they find this an enjoyable experience. Taken together, these provide encouraging evidence that citizen science projects can empower members of the public in science activities, and provide an excellent outreach opportunity for online training in specialist skills. Finally,, we have shown that the data can be extremely accurate, meaning that citizen scientists offer a largely untapped potential for gathering high-quality data on a scale that would otherwise be difficult for a small team of scientists to obtain.

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Conflicts of Interest

The authors declare no conflicts of interest.

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