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**Do amateurs and citizen science fill the gaps left by scientists?**

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Abstract:

The diversity of insects is tremendous and so is the effort needed to assess it in order to better understand insect ecology as well as their role for the functioning of ecosystems. While the interest of academics and naturalists for these species has always existed, it is only recently that such interest started to reach society more generally. From insect taxonomy and distribution to the collection of large range and long scale monitoring data, the involvement of non-academics in research outputs is growing. Is this a sign of scientists not being able to meet expectations or of science getting more and more entrenched in society? We argue for the latter, highlighting the opportunities that such involvement of amateurs in insect science represent for insect conservation.

23

## 24 **Introduction:**

25 The diversity of insects is huge, with more than one million described species (Roskov et al.,  
26 2019). Hence, the effort needed to assess (Stork, 1998) and relate this diversity to insects'  
27 roles in the functioning of ecosystems (Price, 1997) is tremendous. While the interest of  
28 academics and naturalists for these species has always existed, it is only recently that such  
29 interest started to reach society more generally (IPBES, 2016). This came with the rising  
30 concern of insect decline largely popularized by the fate of pollinators (Buchmann & Nabhan  
31 1996; Hall & Martins, 2020). Since then, research effort to characterize this decline and  
32 associated causes and consequences is growing (Didham et al., 2020). In what follows, we  
33 investigate to what extent amateurs may help professional scientists fill the gaps of  
34 knowledge on insects, and how this joint effort may be an opportunity to better entrench  
35 science in society.

36

37

## 38 **Role of non-professionals in the knowledge of insect diversity, distribution and** 39 **taxonomy**

40 Since the end of the XXth century, the development of online taxonomical and bibliographical  
41 databases, digital photography, and social media where people can share photos and help  
42 each other identifying them has given a new momentum to the input of amateurs to the  
43 knowledge of biodiversity, and in particular insects (Marshall 2008). Skilled amateurs provide  
44 pictures for identification atlases, sometimes in the framework of targeted searches for rare  
45 taxa triggered by professional taxonomists, or are enrolled in citizen science projects to map  
46 occurrences of threatened insect species (Campanaro et al., 2017; Zapponi et al., 2017). In  
47 this context, the XIXth century amateur who was a bug collector is now often a digital  
48 photography collector. Other initiatives are open to anyone interested, skilled or not, and aim  
49 at recording insect occurrence data, often without a protocol or sampling plan. They gather a  
50 huge quantity of data on insect distribution, either targeting specific insect groups (moths or  
51 ladybirds for instance [https://butterfly-conservation.org/our-work/recording-and-](https://butterfly-conservation.org/our-work/recording-and-monitoring/national-moth-recording-scheme)  
52 [monitoring/national-moth-recording-scheme](https://butterfly-conservation.org/our-work/recording-and-monitoring/national-moth-recording-scheme)  
53 <https://www.coleoptera.org.uk/coccinellidae/home>), or any organism, including insects (e.g.  
54 <https://www.inaturalist.org/>; <https://www.ispotnature.org/>).

55 However, the contribution of amateurs to the knowledge on insects, and in particular  
56 taxonomical knowledge, is not restricted to projects driven by professional biologists. Non-

professionals, i.e. people who do not hold a position in which they are remunerated for performing taxonomy, are known to take a significant part in the building of taxonomical knowledge: for instance, between 1998 and 2007, they described 62% of new species from Europe, 70% of which being insects, and authored 54% of European species synonymizations (Fontaine et al., 2012). Amateur contributions extends far beyond charismatic groups such as butterflies or seashells: between 1998 and 2007, they described 53% of new European Diptera, 57% of Coleoptera, and 84% of Orthoptera. Similar figures showing the importance of amateur contributions to insect taxonomy are found in other parts of the world, for instance French Guyana, where non-professionals provided 65% of new insect records between 2008 and 2013, and collected 74% of new species holotypes (Brûlé & Touroult, 2014). The importance of their contribution is such that the synergy between amateurs and professionals in insect systematics has been qualified as « a backbone of the primary research on biodiversity » (Audisio 2017), and that the decline in their numbers will have an impact upon information generated on insects, and hence on their conservation (Hopkins & Freckelton, 2006). For this reason, a better integration of amateurs in academic teams, with formalized collaborations, training for the use and interpretation of technological tools such as DNA sequencing and help in securing grants has been advocated to solve the Taxonomic Impediment (Fontaine et al., 2012; Coleman, 2015)

Amateurs also make significant contribution to the scientific knowledge of insects by donating books and article collections to museum libraries. This was recently analyzed for the contribution of a local Canadian entomologist, whose entomological book and article collection is now hosted by the Macdonald Campus Library from McGill University, and includes many titles not found in any other Canadian university library (Waters & MacKenzie 2018). Similarly, amateurs have produced insect collections, sometimes of high scientific value, which may be lost forever unless there is a coordinated effort to register those private collections and find the funding to acquire them and secure their preservation (Fischer et al., 2021).

#### **Amateurs, scientists and long-term insect surveys**

Except managed honeybees, for which numerous national agricultural administrations collected data for decades, and agricultural or silvicultural pests for which some monitoring programs started early on (e.g. Watt & Hicks 2000, Bell et al. 2015), time series of insects are scarce. However, such data are highly needed in the current context of a potential insect Armageddon (Leather, 2017, Wagner et al. 2021). Despite recent studies relying on relatively short time series from academic origins (Sanchez-Bayo & Wyckhuyse 2019, van Klink et al. 2020, Crossley et al. 2020, Høye et al. 2021, Schowalter et al. 2021), most of our knowledge

on insect temporal trends comes from the analysis of insect records from collections (e.g. Beisemeijer et al 2006, Ollerton et al. 2014, Powney et al. 2019, Soroye et al. 2020, Duchenne et al. 2020). Such data and in particular historical collections or records, allowing turning the clock back enough to minimize the shifting baseline issue (Pauly 1995), have been collected and curated largely thanks to numerous non-professional but passionate entomologists (Brunelle 1997). Although natural history museums were also involved in collecting and are in charge of preserving such precious specimens, the contribution of amateurs and associated entomological societies must be acknowledged. For example, the UK Bees, Wasps and Ants Recording Society (BWARS), with ca. 500 members, is thought to have one of the most detailed available databases on these taxa for a single country, with records going back a century (Beisemeijer et al. 2006, Ollerton et al. 2014, Powney et al. 2019). Although associated from the start to academics, it largely relies on non-professionals for data collection and curation. The same is true for the UK hoverfly recording scheme whose data were also recently analysed (Beisemeijer et al. 2006, Powney et al. 2019).

However, though invaluable, such insect occurrence data, also called opportunistic data, are most commonly collected with unknown protocol and observation pressure, which make statistical analyses a difficult task (van Dooren, 2016; Didham et al., 2020). For this reason, large range and long-term monitoring schemes following standardized protocols have been launched, in order to produce abundance data while minimizing sampling biases. These schemes, managed by academic institutions and/or entomological societies, rely heavily on the participation of volunteers to reach data collection with large spatiotemporal coverage. The earliest schemes relied on skilled naturalists, such as the UK Butterfly Monitoring Schemes, launched in 1976, which now compiles species temporal series of species abundance for over more than 4000 locations in the United Kingdom with roughly as many participants (<https://www.ukbms.org/>). Another striking example is the Krefeld Entomological Society in Germany, with ca. 50 members, which provided the data for the iconic Hallmann et al. study (2017), showing a 75 percent decline in flying insect biomass since 1989 (Bruch et al. 2013). Here again, many of the members are hobbyists as the same time as being world experts on their favorite insects. At the onset of the XXIst century, new schemes have been opened to the general public (Silvertown, 2009), with dedicated protocols suited for participants with no prior knowledge of insects. For instance, the French Garden Butterfly Count, launched in 2006, has reached more than 10,000 participants (Fontaine et al., 2016). Since then, numerous participatory monitoring schemes are flourishing, targeting other groups attractive to the general public, such as dragonflies, moths or pollinators (e.g. <https://www.vlinderstichting.nl/wat-wij-doen/meetnetten/meetnet-libellen>;

[ecology.org.uk/gms2019](https://ecology.org.uk/gms2019); <https://www.spipoll.org/>), or documenting flower-insect interactions (Deguines et al., 2012).

In addition to providing the material for numerous scientific articles and books on various aspects of insect ecology, protocolled monitoring data are also used to produce indicators as official statistics to inform governmental agencies on biodiversity trends and help them set and assess the outcome of conservation policies (Brereton et al. 2011). Such citizen science, associating academics, entomological societies and volunteers to monitor biodiversity and provide accurate indicators to stakeholders, if not free, is recognized as being cost effective and less vulnerable to funding variances (Couvét et al. 2008, Levrel et al. 2010, Mackechnie et al. 2011).

### **Amateurs involved in insect citizen science help entrench science in society**

Enlarging the communities of amateur insect researchers has significant and important consequences on insects' conservation (Oberhauser & Prysby, 2008), but also on the relationships between science and the society.

First, insect citizen-science projects make insects more real and relevant for the society. It has already been shown that some amateurs increase their entomological knowledge and modify their gardening practices to be environmentally-friendly (Cosquer et al. 2012, Deguines et al. 2018, 2020). Although current press coverage of insect decline remains weak (Althaus et al. 2021), involving amateurs and publicizing the results of these large spatial and temporal scientific surveys of insects can make insects more visible in public space, as exemplified by the hundreds of news stories, thousands of tweets and dozens of policy documents related to the Hallmann et al. study (2017) on insect decline in Germany (<https://www.altmetric.com/details/27610705>).

Secondly, insect citizen-science projects provide opportunities for volunteers to be in close contact with insects in their habitats, to experience nature (Clayton et al. 2017): when observing insects in their garden to collect scientific data, volunteers are physically involved in data collection, standing up on tiptoes or squatting down, feeling too cold or too hot. They use all their senses, vision of course, but also hearing, touching, smelling, even tasting. They are also emotionally involved in their experiences: curious or anxious, disgusted, enjoying themselves, happy and proud, they can feel all these emotional states during their citizen-science experiences. Finally, they often pay attention to all interactions between the natural living beings they focus on and spontaneously adopt context-dependent situated perspectives (see Bang 2015), in which they also relate to the objects of their inquiry. Collecting insects' citizen-science data enlarges volunteers' perceptions of nature.

161 Third and consequently, amateurs involved in insect citizen science monitoring programs  
162 learn different ways to do science (Trumbull et al., 2000): they converge with scientists in  
163 taxonomic identification and ecological scientific knowledge on biodiversity functioning, but  
164 they complete this knowledge with embodied knowledge, by being physically involved in their  
165 discovery of insects. Such embodied knowledge has been progressively disqualified in  
166 western science, which legitimates distancing and decontextualizing ways to describe nature,  
167 considered to be the only way to reach objectivity (Medin and Bang 2014). Yet, embodied  
168 and practical knowledge is of prominent importance to re-link theory and practice (Macintyre  
169 Latta & Buck 2008), and amateurs challenge scientists in their scientific norms and world  
170 visions.

171 Finally, in joining citizen-science programs, amateurs enter a community of participants with  
172 which they exchange during meetings or via dedicated social networks. The presence of  
173 scientists in these communities can be an important motivation for volunteers to legitimate  
174 their participation (Cosquer et al. 2012). But these enlarged communities with scientists and  
175 non-scientists who share interests in insect knowledge and conservation represent also new  
176 arenas that force scientists to quit a socially comfortable sphere, to present and share their  
177 knowledge with other social spheres, and to be challenged by people who do not have the  
178 same worldviews.

## 180 **Perspective**

181 Rather than filling a gap left by scientists, we argue that amateurs contribute with scientists to  
182 increase knowledge on insects, with citizen science projects currently favoring the  
183 complementarity between their contributions and helping to entrench science and insect  
184 conservation issues in society (IPBES, 2019). If the embodied knowledge of amateurs,  
185 relating scientific knowledge to emotions and feelings, is recognized as key for them to care  
186 about insects, one has to recognize that such embodied, emotional and close relationships  
187 with natural living elements is also key to the motivation and creativity of academics: « After  
188 spending 32 of my 41 years in the field, I'm still agog at life's splendour. The beauty I see as I  
189 search for dragonflies on expeditions in Gabon or watch birds around Stellenbosch on my  
190 way to work can be so absurd it makes me laugh, so diverse it makes me gasp for air, so  
191 intense that I binge-watch as if there is a cliff-hanger in every impression. » (Dijkstra, 2016).  
192 Citizen-science, in making scientists and non-scientists close together, may help modern  
193 science to enlarge their world visions, toward more relational epistemologies (Bang 2015).

194 Such a vision might be challenged by the recent and fast developments of identification  
195 systems based artificial intelligence (AI) that make automatic species identification from

196 pictures or sounds increasingly accurate, rapid and reliable (Høye et al. 2021). These AI  
197 systems are already used in programs collecting opportunistic occurrence data (e.g. the  
198 obsidentify app aiming at identifying all species from pictures including insects  
199 <https://observations.be/>). Such technology also leads to the development of sensors for  
200 biodiversity monitoring, including insects (Ärje et al. 2020), offering potentially better  
201 sampling than amateurs can provide. Amateurs can contribute to such AI-based identification  
202 development by constituting huge training databases of annotated pictures, but it is not clear  
203 whether automatic identification help amateurs to learn how to identify species. Likewise  
204 sensors question the need for amateur involvement in biodiversity observations, and thereby  
205 the opportunity to experience nature. While being a fascinating opportunity, AI is  
206 transforming the current collaboration between amateurs and scientists, and some thinking is  
207 needed to use such technology in a way the truly benefits both scientists and amateurs in  
208 their quest to know and conserve insects.

209

210



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