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Systematic Map Protocol

Title
What evidence exists on wild-bee trends in Germany? Research protocol for a systematic map

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Corresponding author's email address
anne-christine.mupepele@biom.uni-freiburg.de

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Background
Wild bees have inspired scientists and citizens by their fascinating diversity, beautiful appearance and the benefit humans obtain via plant pollination (Klein et al. 2018). They receive a widespread public attention and were used in recent popular petitions from the civil society in Germany campaigning for a reversal of insect decline (Süddeutsche Zeitung 2019). Their interaction with flowering plants has been researched intensively over the past decades (Jordano et al. 2003; Garibaldi et al. 2013; Potts et al. 2016; Benadi and Pauw 2018). The decline of wild-bee and in more general pollinator diversity has been documented worldwide and is assumed to hold true for Germany (Biesmeijer et al. 2006; Potts et al. 2010; Schwenninger and Scheuchl 2016). Nevertheless, information on wild-bee trends from the country that has launched the current political debate on declining insects (Hallmann et al. 2017; Seibold et al. 2019) are scarce and knowledge about German wild-bee communities is scattered. In Germany there are a range of entomological, in general locally organised associations, and 16 regional governments responsible for nature protection measures and potentially storing wild-bee records. Collecting and synthesising this knowledge is a tedious task, but promises to substantially increase the knowledge about wild-bee population trends in Germany. The scope of the study is to identify trends in wild-bee populations in Germany. Therefore, we aim to identify data available on temporal trends of wild-bee communities, predominantly in agricultural areas, but also in urban areas and forests. The systematic map results will be used by practitioners specifically targeting conservation actions for wild bees and allow them to identify suitable habitat types in the past, present and future most particularly in Germany, but even across Europe.

Theory of change or causal model
Wild bee populations change over time and we hypothesise that changes are caused by changes in air temperature, precipitation, landscape structure (composition and configuration, small landscape features), land use types, and land use intensity (pesticides, fertilisation, mowing frequency in agricultural areas; tree cover density in forests; imperviousness density in urban places). We expect trends to differ between ‚federal states' as relevant legislation differs between them. Further potential causes of wild-bee population trends may arise from the systematic map effort. All causes will be analysed in a systematic review following this systematic map.

Stakeholder engagement
The protocol was initiated on a workshop with stakeholders, most particularly representatives of the German public authorities from local and regional levels. The workshop was part of the sMon project (=‘Analysing trends in German species data’) from the German Centre for Integrative Biodiversity Research in Halle, Jena, Leipzig, Germany (https://www.idiv.de/en/smon.html). Stakeholders’ motivation to contribute to the sMon workshops is usually their goal to see their data used, as some of the authorities are required by law to collect data, such as the case for bees for which particular permissions and reporting is required if an individual wants to collect bees for research or other purposes. Alternatively, stakeholders are interested in getting to know more about how to conserve biodiversity in Germany. In this particular case, they consider it useful to synthesise knowledge on wild bees, as these are currently in all political debates about insect conservation.

Objectives and review question
Identify long-term trends of wild-bee communities in Germany and link them to environmental variables to inform conservation action. 1. Did diversity change over time? 2. Do diversity trends differ between landscape type (agricultural areas, forests, urban places) and geographical area (federal states of Germany)? This is a subset of research questions that we originally published in a research protocol on osf (Mupepele et al. 2021). These two research questions will be addressed in this systematic map. A subsequent systematic review will follow up on this and answer the additional research questions published in the systematic review protocol on osf.

Definitions of the question components
Research Question (1): - Population(s): wild bees in Germany. - Intervention/exposure(s): no intervention/exposure(s). - Comparator(s): no comparators. - Outcome(s): We identify whether and where (within Germany) bee populations change over time. Research Question (2): - Population(s): wild bees in Germany. - Intervention/exposure(s): different landscape types. - Comparator(s): no comparators. - Outcome(s): We identify whether and where (within Germany) bee populations change over time according to different landscape types and geographical areas.

Search strategy
Sources of data about wild-bee diversity and abundance are searched. In Germany, the conservation status of wild bees is frequently reported in multiple German-language journals from entomological grey literature. Therefore and in addition to peer-reviewed literature (Bullet Points 1 and 2), we intensively searched the grey literature (Bullet Points 3 to 7). Literature in German and English is considered. All methods are based on the standards of the Collaboration for Environmental Evidence (Collaboration for Environmental Evidence 2018). We have searched for literature in the following sources: 1. Published and peer-reviewed literature from bibliographic databases 2. Peer-reviewed journals publishing in German: ‘Natur und Landschaft’ and 'Naturschutz und Landschaftsplanung' 3. Contributions and German-language journals from entomological associations in Germany (see osf protocol, Mupepele et al. 2021, https://osf.io/wa84v) 4. References from the book: ‘Wildbienen Deutschlands’ (Westrich 2019) 5. Public authorities (‘Behörden’) 6. Specialists searches, stakeholder contacts 7. Databases and data repositories

Bibliographic databases
Published and peer-reviewed literature is searched from Web of Science databases and Scopus with a search string that covers potential data sources (as the search string is overlong, it cannot be included here; see osf protocol, Mupepele et al. 2021, https://osf.io/wa84v). We have only searched for studies that are either covering the term 'Germany' or one of the federal states in keyword, title or abstract or with at least one co-author affiliated to a German institution. Given that we concentrate our review on Germany, we had to restrict the search term to an otherwise unmanageable amount of literature. From our knowledge and based on feedback from our

stakeholders, we do not expect to find any more studies relevant for our review without restricting the search term that way.

Web-based search engines
A web-based scoping search (with the keywords: 'bee AND Germany AND trend') demonstrated that we covered all relevant grey and peer-reviewed, data-providing literature sources. Therefore, additional web-based search engines are not included in the final search.

Organisational websites
Databases and data repositories include the Global Biodiversity Information Facility (GBIF) and the Conservation Evidence Synopses (https://www.conservationevidence.com/). German entomological associations occassionally provide relevant data, but this would be additionally published in reports and annual reviews that we have all screened unter Point 8, Bullet Point 3.

Comprehensiveness of the search
Four benchmark publications were identified and covered by the search string used in the Web of Science and Scopus search: [1] Klug OB. 1965. Die Hymenopteren am Tuniberg, im Mooswald und Rieselfeld; eine vergleichend faunisitisch-ökologische Untersuchung dreier extremer Biotope des südlichen Oberrheintales. Berichte der Naturforschenden Gesellschaft zu Freiburg i Br 55: 5–225. [2] Tscharntke T and Steffan-Dewenter I. 1998. Bioindication using trap-nesting bees and wasps and their natural enemies: community structure and interactions. Journal of Applied Ecology 35: 708–719. [3] Flügel H-J. 2007. Bienen (Hymenoptera Aculeata: Apidae) vom Halberg bei Neumorschen (Nordhessen, Fuldatal). Philippia 31: 29–36. [4] Papanikolaou AD, Kühn I, Frenzel M, and Schweiger O. 2017. Landscape heterogeneity enhances stability of wild bee abundance under highly varying temperature, but not under highly varying precipitation. Landscape Ecology 32: 581–593.

Search update
After the search is completed, no further search update is planned during the conduct of the review.

Screening strategy
All literature is first screened by title and abstract. If title and abstract are not allowing an exclusion based on one of the non-fulfilled eligibility criteria, the full-text is read. All relevant information is then extracted from the full-text and directly entered to a SQL database.

Eligibility criteria
The following inclusion criteria have to be fulfilled for a study or dataset to be included in our database. - Population: Wild bees, i.e. Hymenoptera of the families Apidae (excluding the domestic honey bees), Megachilidae, Halictidae, Colletidae, Andrenidae, Melittidae (Peters et al. 2017). - Geographic scope: Germany in its geographic extension of 2020. - Outcome measure/Data requirements: Occurrence as presence-absence or abundance, but no model or opinion-based data. - Temporal scale: Data from at least two either consecutive or more distant years at the same location and with the same sampling protocol, i.e. method, need to be given. - Study designs: Observational and experimental data on presence or abundance are included. - Sampling method: All approaches (e.g. flower visitor, unsystematic walk, transect walk) are included, but need to be equal across years in one data set and have to be transparently documented.

Consistency checking
A test for consistency of study inclusion between researchers at title and abstract level was performed (Kappa test, Cohen 1960). All researchers involved in the screening evaluate the first 100 studies of the list extracted from bibliographic databases, in random order of studies. The screening

results are compared with regard to inclusion or exclusion of studies based on the eligibility criteria, and all disagreements are discussed.

Reporting screening outcomes
The outcomes of screening are reported in a ROSES diagram. A list of all articles will be provided with the systematic map (included articles and also excluded articles with reasons for exclusion).

Study validity assessment
As part of the systematic map, the validity of individual studies is not planned to be assessed.

Consistency checking
N/A

Data coding strategy
Data extracted from the full texts will be the wild bee diversity/abundance and all 'effect modifiers' i.e. environmental predictors that could influence the wild bee diversity/abundance. They will be directly entered into a database using a custom form developed with R Shiny (Chang et al. 2020). The database will consist of data sheets on the study, covariates and wild bee data.

Meta-data to be coded
All information relevant for a bibtex entry, such as study type, authors, title and publication year, will be entered into the Study Table. Information on the geographical and methodological context of the studies will be entered into the Covariates Table with a link to the respective entry in the Study Table. These infomation include the taxonomic group covered (i.e., species, genus, family), the geographic scope (i.e. the state in Germany, such as Bavaria or Hesse), detailed GPS coordinates if available, the land use, information on the sampling frequency, methods, period covered and measure (e.g. biweekly net sweeping from April to August given as abundance per species), and the start and end years of data collection. All information on wild bee populations will be entered into the Data Table with links to the Study and Covariates Tables. These information include quantities and standard deviations such as abundance per species per year, the sample size, the year, and data ID with a link to the raw data folder if available.

Consistency checking
A test for consistency between researchers in coding data while entering them to the database will be performed (Kappa test, Cohen 1960). All researchers involved in the screening will evaluate the first 100 studies of the list extracted from bibliographic databases, in random order of studies. The resulting data entries in the Study, Covariates and Data Tables will be compared and all disagreements will be discussed.

Type of mapping
The systematic map will include descriptive analyses providing an overview on studies, covariates and wild bee data, as compiled in the database. The database will be provided as part of the systematic map.

Narrative synthesis methods
The evidence base will be synthesised in tables, diagrams and maps, including descriptive statistics, for example on the taxonomic groups, sampling methods, locations, land use context, and years covered by the studies. These will be presented together with a textual description and synthesis of spatially and temporally differentiated wild bee trends.

Knowledge gap identification strategy

The analysis of the information compiled in the database will reveal knowledge gaps in research on wild bee trends in Germany. By synthesising these information, knowledge gaps will be identified and discussed, for example, with regard to taxonomic groups, sampling methods, locations, land use context, and years covered in previous studies.

Demonstrating procedural independence
Decisions regarding inclusion of the work of any members of the review team are taken by other team members based on the inclusion criteria.

Competing interests
The authors declare that they have no competing interests.

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Author's contributions
ACM: conceptualisation; data curation; formal analysis; writing – original draft preparation; writing – review and editing. NH: conceptualisation; data curation; formal analysis; writing – original draft preparation; writing – review and editing. PD: conceptualisation; writing – review and editing. AMK: conceptualisation; writing – review and editing.

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Authors and Affiliations

Name	Country	Affiliation
Anne-Christine Mupepele	***Germany***	***Nature Conservation and Landscape Ecology, University of Freiburg***
Niels Hellwig	Germany	Thünen Institute of Biodiversity, Braunschweig
Petra Dieker	Germany	Thünen Institute of Biodiversity, Braunschweig
Alexandra-Maria Klein	Germany	Nature Conservation and Landscape Ecology, University of Freiburg

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