Trends in global insect abundance and biodiversity: A community-driven systematic map draft protocol

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1. Background

Recent studies documenting declines in insect abundance and biodiversity, especially from Western Europe (e.g., Conrad et al. 2006, Shortall et al. 2009, Schuch et al. 2012, Hallman et al. 2017, Powney et al. 2019), have raised concerns of a global insect conservation crisis with potentially dire consequences. The circa 5.5 million insect species globally (Stork 2018) play diverse, critical roles in their communities; some are important pollinators, some are herbivores, others decomposers, and most are prey for organisms at higher trophic levels. From greater than 75% declines in insect biomass over three decades in Germany (Hallman et al. 2017), to range contractions in butterflies in the United Kingdom (Thomas et al. 2004), to diversity and abundance declines in North America (Forister et al. 2010, Young et al. 2017, Loboda et al. 2018) and more anecdotal reports from the Neotropics (Janzen and Hallwachs 2019), insect abundance and biodiversity may be under siege as much as vertebrate abundance and biodiversity (Dirzo et al. 2014).

Recent calls for more primary study data (Thomas et al. 2019, Montgomery et al. in review), however, have brought attention to the relatively limited conclusions we can draw from available primary studies because they are usually conducted at local or regional scales across only a few years. Only a small fraction of described insect species have any population monitoring programs, and the widespread lack of baseline data for insect populations, high inter-annual variation in insect population levels, potential publication biases, and the limited geographic scope of current findings are all obstacles to interpretation of reported insect declines (Wagner 2019). Moreover, the relative contributions of the diverse drivers of declines in abundance and biodiversity remain unclear. To better understand these phenomena, we need to identify and fill data gaps and conduct better syntheses of the data that already exist.

Evidence synthesis incorporates information from multiple sources to inform decisions on a specific issue. Systematic reviews and meta-analytical statistical tools are commonly employed in evidence synthesis, and are valuable for the study of insect declines because of their ability to identify and rigorously synthesize large bodies of primary literature. Systematic mapping is a relatively recently-developed form of evidence synthesis (Peersman 1996, Clapton et al. 2009, James et al. 2016). Unlike systematic reviews, which typically aim to provide answers to specific questions related to impacts and effectiveness, systematic maps aim to describe the nature of evidence bases, producing searchable databases of studies on a broad subject, commonly acting as the first step in the evidence synthesis pathway (e.g. Haddaway et al. 2015). Systematic maps can be used to highlight knowledge gaps and knowledge clusters, helping to direct efforts towards funding and conducting necessary primary research, whilst also facilitating rapid synthesis of groups of similar studies, for example using meta-analysis. Here, we aim to provide the first community-driven systematic map which will engage large numbers of participants and stakeholders to quickly synthesize literature on a topic requiring urgent attention.

1.1. Stakeholder engagement

This topic was suggested by a group of subject and evidence synthesis experts in response to growing concern within the community about insect conservation and public discussion of global insect declines. In order to develop a well-designed protocol, screen and extract data from an expansive volume of evidence, and include a global body of literature, we will recruit a large group of community members to drive the review. To identify stakeholders, we will develop a database of potentially interested community members and organizations and will request suggestions from community members for additional stakeholders. The stakeholder engagement and identification plan is in a supporting document (Grames and Montgomery, 2019).

2. Objective of the review

We aim to assemble a thorough set of evidence relating to global insect population trends which will be used to populate a detailed, interrogable systematic map database. We will visualize this database using interactive evidence atlases, heat maps and other diagnostic plots in a narrative synthesis. Our systematic map will address the following review questions:

2.1. Primary research question

Where are knowledge gaps and knowledge clusters in interannual temporal trends of insect abundance, biomass, diversity, and geographic range?

2.2. Secondary research question(s)

What knowledge gaps warrant further funding and attention in the form of primary research studies? What knowledge clusters exist that might be amenable to quantitative synthesis?

2.3. Question components: POCS statement

Population: We will include studies of native insects in all terrestrial, aerial, and freshwater habitats globally. We will exclude 1) invasive species and 2) species that are subject to intentional population manipulation (e.g. crop pests managed with herbicide, managed pollinator stocks, and species that are targets of conservation interventions).

Outcomes: We are interested in studies that test for changes in four outcome measurements for insects: 1) geographic range 2) species occurrence and abundance 3) species richness and other diversity indices and 4) biomass.

Comparator: The comparator will be the previous year(s) in the study. All studies must be time series with multiple (2 or more) years. We will not place any restrictions on the time the study was conducted or on the timeframe over which observations were made other than that data points must be at least 6 months apart to avoid repeated samples within the same season. To account for differences in comparator timeframes, we will code for continuous versus snapshot surveys with the length and time steps included in the time series (section 3.3).

Space: We are only interested in field studies conducted in a natural setting (i.e. not simulations, mesocosms, greenhouse, or laboratory studies), but make no restrictions on the geographic space where a study was conducted.

3. Methods

3.1. Searching for articles

We will use a search strategy that targets bibliographic databases, organizational and governmental websites, thesis databases, and other grey literature sources to capture as much of the global evidence base as possible. In lieu of searching trial registries, we will search pre-print servers that house ecological and environmental studies. Because we are designing this review as a community-driven systematic map, we will accept suggestions of studies or datasets we may have missed from any stakeholders interested in the review and we will also contact expert researchers and decision-makers (including policy-makers and practitioners) in the field for their suggestions. We will also solicit unpublished studies from entomology listservs. For studies that meet inclusion criteria, we will extract the reference lists and cross-reference them with studies returned by our search using the R package litsearchr (Grames et al. 2019); new studies retrieved in this manner will be added to the library.

Because the databases we are searching have different rules for truncation, search string length, and formatting, we will adapt our main search to develop specific search strings that match the formatting of each search system. For the English searches in large bibliographic databases with known search rules (e.g. BIOSIS Citation Index, Scopus, etc.), we will use a full Boolean search string with truncation to word stems if stems are at least four letters long. For non-English searches, we will not use truncation and instead will search with complete words and phrases. For databases or websites that have limited search capabilities (e.g. JSTOR), we will develop a shorter search string that contains only the most critical search elements. For each database or website searched, we will record the version of the search string used.

3.1.1. Search term identification and selection

We will use the method implemented in litsearchr (Grames et al., 2019) to identify search terms. We will use the naive search (Table 1) to capture a highly relevant set of articles from BIOSIS Citation Index (1926-2019), Zoological Record (1864-2019), and Scopus (1788-2019) and will use litsearchr to build keyword co-occurrence networks and extract potential search terms.

All terms suggested by litsearchr will be reviewed in duplicate to select relevant terms; additional terms not identified by litsearchr will be added manually based on consultation with experts. Because we anticipate that some studies will not include higher order taxa in their title, abstract, and keywords, EMG will build a detailed list of all known insect taxa at the family level or above by compiling scientific and common names, along with taxonomic synonyms and out-of-use names, from BugGuide.net, iNaturalist, Encyclopedia of Life, the Global Biodiversity Information Facility, and the Catalogue of Life. This will be added to the final search terms included in the insect concept category.

Insects	(insect OR insects OR insecta OR "Megaloptera" OR "Alderflies" OR "Dobsonflies" OR "Fishflies" OR "Zoraptera" OR "Angel Insects" OR "Neuroptera" OR "Antlions" OR "Owlflies" OR "Lacewings" OR "Mantidflies" OR "Hymenoptera" OR "Ants" OR "Bees" OR "Wasps" OR "Sawflies" OR "Psocodea" OR "Barklice" OR "Booklice" OR "Parasitic Lice" OR "Coleoptera" OR "Beetles" OR "Microcoryphia" OR "Bristletails" OR "Lepidoptera" OR "Butterflies" OR "Moths" OR "Trichoptera" OR "Caddisflies" OR "Blattodea" OR "Cockroaches" OR "Termites" OR "Odonata" OR "Dragonflies" OR "Damselflies" OR "Dermaptera" OR "Earwigs" OR "Siphonaptera" OR "Fleas" OR "Diptera" OR "Flies" OR "Orthoptera" OR "Grasshoppers" OR "Crickets" OR "Katydids" OR "Notoptera" OR "Ice Crawlers" OR "Rock Crawlers" OR "Mantodea" OR "Mantids" OR "Ephemeroptera" OR "Mayflies" OR "Protorthoptera" OR "Primitive Winged Insects" OR "Mecoptera" OR "Scorpionflies" OR "Hangingflies" OR "Zygentoma" OR "Silverfish" OR "Raphidioptera" OR "Snakeflies" OR "Phasmida" OR "Stick Insects" OR "Plecoptera" OR "Stoneflies" OR "Thysanoptera" OR "Thrips" OR "Hemiptera" OR "True Bugs" OR "Cicadas" OR "Hoppers" OR "Aphids" OR "Strepsiptera" OR "Twisted-winged Insects" OR "Embiidina" OR "Webspinners")
	AND
Population responses	(("species distribution" OR "geographic distribution" OR range OR "population dynamics" OR abundan* OR occurrence OR occupanc* OR diversity OR biodiversity OR "species richness" OR "species presence" OR biomass OR survey* OR demography OR "population trend")
	NEAR/2
Over time	(expansion* OR contraction* OR shift* OR "time series" OR "over time" OR "long-term" OR "long term" OR reduction OR interannual OR "multi-year" OR trend* OR temporal or spatiotemporal OR "repeated measures" OR "long-running" OR "population trend" OR monitor* OR annual))

Table 1. Naive search terms. These terms will be combined into a Boolean search string to retrieve a set of highly relevant articles, from which potential search terms will be extracted using litsearchr.

3.1.2. Evaluating the comprehensiveness of the search

To estimate the comprehensiveness of our search strategy, we will ask for community input on our proposal to generate a benchmark list of articles that should be returned by our search. EMG will check to see which of the articles from the community-generated list are indexed in BIOSIS Citation Index (1926-2019), Zoological Record (1864-2019), and Scopus (1788-2019). For benchmark articles that are indexed, EMG will check to see if they are returned by our search string using litsearchr. If any of the benchmark articles are not returned, we will determine what terms are missing and will incorporate them into our search string.

We will supplement the community generated-list with the articles included in a recent, non-systematic review on a similar topic (Sanchez-Bayo and Wyckhuys, 2019). After reviewing the articles included in the supplemental material for Sanchez-Bayo and Wyckhuys (2019), EMG recorded 78 studies that were included in the references and seven additional studies that were not found in the references section but had primary study data included in the supplemental material. Of the 78 studies with references, 76 are indexed in BIOSIS Citation Index, Zoological Record, and/or Scopus and should be retrieved by our search strategy. The seven studies without references were not included in our list because they could not be uniquely identified since the Sanchez-Bayo and Wyckhuys (2019) supplemental material only included first author last name and year.

3.1.3. Platforms, databases, and websites

We will generate a list of platforms, databases, and websites to search that may include relevant studies. Because this is a community-driven map, we will accept suggestions from the community for additional platforms or databases to search. For databases that the review team does not have access to, we will request search results from community members who do have access. The current list of platforms, databases, and websites to search is being built at http://s.uconn.edu/4p3.

3.1.4. Languages

For the electronic search, we will search bibliographic databases in English and non-English languages and search organizational and regional databases or websites in English and applicable regional languages. For example, we will search the Serbian Citation Index in English and Serbian, but not in Korean.

To identify non-English language articles on our review topic, we used get_language_data() in litsearchr to query a dataset based on Ulrich's global serials directory. The function estimates a count of non-English academic journals that are tagged as being about topics related to the review; we had it estimate the number of journals related to agriculture, biology, crop science, entomology, conservation, ecology, forestry, and environmental science. We will search in all languages returned that have at least five non-English language journals (Table 2).

3.1.5. Assembling search results

For bibliographic databases, we will export results in .bib or .ris format and import them using revtools v0.3.0 (Westgate, 2018). For grey literature, EMG will write scraping functions to assemble results into a database and convert them to .bib files. We will use a combination of revtools and custom deduplication functions that are in development by EMG to deduplicate all search results and write the library to a .bib file. We will import the full library to Zotero, which we will use to convert the library to an EndNote XML file. This xml file can then be uploaded to SysRev.com to make the inclusion and exclusion process open to the community.

Number of Journals	**Languages**
100+	Russian (247)
50 - 100	Mandarin (89), Spanish (75), Indonesian (66)
25 - 50	Portuguese (48), German (38) French (34), Korean (34), Polish (33), Ukrainian (33)
10 - 25	Persian (17), Japanese (14), Czech (13), Serbian (11), Turkish (11)
5 - 10	Slovak (7), Croatian (6), Italian (6), Belorussian (5), Hungarian (5)
< 5	Slovenian (4), Danish (3), Dutch (3), Norwegian (3), Arabic (2), Bosnian (2), Finnish (2), Lithuanian (2), Swedish (2), Estonian (1), Icelandic (1), Latvian (1), Malay (1)

Table 2. Counts of journals published in non-English languages that may contain articles related to the topic of the review. This indicates which non-English languages should be searched to retrieve published and unpublished data because the journal counts can be used as a proxy for the volume of studies available in a language.

3.1.6. Search update

If the review takes more than two years to complete, we will redo our search to retrieve newly published studies.

3.1.7. Supplementary searches

We will screen the bibliographies of all relevant review articles that we find during screening to identify additional studies that we may have missed during our searches. We will also consider any article suggested by stakeholders that were not retrieved by the other search methods.

3.2. Article screening and study eligibility criteria

3.2.1. Screening strategy

To determine if articles are relevant to the systematic map, we will first screen articles by title and abstract. For screening abstracts in this review, we will make use of the Open Access review management tool SysRev (https://sysrev.com/)—a state-of-the-art review management and task allocation technology. Articles that meet inclusion criteria or that do not provide sufficient information to tell if they meet inclusion criteria will be retained to the next stage and reviewed at the full text stage if it is still unclear whether my meet criteria. Articles for which the abstract or full text is not available but that may be relevant based on the title will be requested through the community members working on the review or through interlibrary loan. All unobtainable articles will be described in a database that outlines the reason the full text could not be obtained.

3.2.2. Consistency checking and procedural independence

Prior to screening articles, community members will complete a brief training module to assess their agreement with a set of articles screened by the core review team for inclusion or exclusion at the title and abstract level. Community members whose application of eligibility standards is not in agreement with the pre-screened articles will be given automated feedback on discrepancies in their coding compared to the inclusion and exclusion criteria and prompted to repeat the training module with a different set of articles. After completing training, community members will be added to the review project on SysRev.

All articles will be screened in duplicate at all stages. Any discrepancies will be resolved by a third party. In no circumstances will an author of a potential paper be allowed to make decisions on screening that paper. If community members screening articles on SysRev come across a paper on which they are a co-author or have another conflict of interest (e.g. it is written by a close colleague), they will skip screening that article, leave a note declaring their conflict of interest, and a different community member or member of the review team will be responsible for assessing it.

3.2.3. Eligibility criteria

To meet our eligibility criteria, a study must match, at a minimum, the population, outcome, comparator, and study design elements of our question components. This means that the study must include measures of non-managed insect population trends and must be a time series with data points from at least two years, though years do not need to be consecutive. The way in which insect population trends are measured is not important so long as the measured outcome is abundance, range or geographic distribution, occupancy or occurrence, biodiversity indices, species richness, or biomass. Because we are only interested in non-managed insect populations, experimental studies of pesticide effectiveness or conservation interventions specifically designed to alter insect populations will not be included. We will not restrict included studies by study design or perform critical appraisal, which is an optional component of systematic maps (James et al. 2016) and will be the focus of follow-up studies once the systematic map has been created and knowledge clusters are identified. Additionally, studies must include primary research that presents data; this criterion excludes perspectives and commentaries with no original data, reviews and prior meta-analyses, and purely theoretical papers.

3.2.4. Reasons for exclusion

We will provide at least one reason for exclusion for all articles, regardless of the stage at which they are excluded. To save time, at the title and abstract screening stages, the reason marked may be simply "not relevant" for studies that clearly do not match our POCS statement (e.g. because they are byproducts of broad search terms). At the full text stage, a more detailed reason must be given for exclusion, though only one reason needs to be given if a study does not meet multiple criteria. Ideally, a detailed reason will also be given at the abstract stage, particularly if it is not readily apparent why a study does not match our POCS statement.

3.3. Data extraction and coding

All studies will be coded for a predefined list of variables; if a study does not report some of this information or it is otherwise unobtainable, those fields should be filled in with "not reported." This ensures that each study is coded for all variables and that variables are not inadvertently omitted.

For each included study, we will describe the population, the timeframe of the data collection, the location, the outcome variables measured, and other predefined variables. We will also record additional reporting measures from studies to assess the state of the literature (e.g. whether biomass measures are reported to family for at least the largest 50% of biomass, etc.).

3.3.1 Variables to code:

- *Response/outcome type.* We will record which of the four outcome types the study measures: 1) geographic range 2) species occurrence or abundance 3) species richness or other diversity indices and 4) biomass.
- *Geographic location.* We will record the most detailed geographic location possible, ideally latitude and longitude, but in cases where that information is not provided, we will record less precise locations (e.g., town or region). We will also record the standardized geographic unit according to the World Geographical Scheme for Recording Plant Distributions (Brummitt 2001).
- *Time-series length*. We will record both the number of temporal points and the time between each point.
- *Time of study*. We will record the years the study was conducted and the time of year (month and day) that data were collected.
- *Habitat type.* We will classify the habitat type into one of the nine terrestrial biomes in Kendeigh (1961) or one of three freshwater ecosystems: lentic, lotic or wetlands.
- *Scale of study*. We will record the spatial scale of the study as one of the following categories: local, landscape, regional, or continental, and will record the number of sampling sites.
- *Number of species studied.* We will record the number of taxa included in each study when it is reported in studies or can be surmised from tables.
- *Species/taxonomic group*. We will record the taxonomic rank of each study organism down to the lowest taxonomic level possible (stopping at species level).

- *Insect sampling method.* Because the type of trap or sampling method used determines the insect community sampled, we will record how insects were sampled. Common methods include sampling by: sweep net, branch, Berlese funnel, Lindgren trap, malaise trap, and pitfall trap.
- *Causes proposed.* We will record what cause(s) the authors propose (if any) for any observed trends.
- *Causes tested.* We will record what the authors test (if any) as the proposed cause(s) for any observed trends.
- *Focus of the study*. We will record whether insects were the focus of the study, or whether insect data was collected as a byproduct of another study (e.g. studies of invertebrate food availability for nesting birds).

3.3.2. Consistency checking and procedural independence

All articles will be coded in duplicate and any discrepancies will be resolved by a third party. As with study screening, no one will be allowed to code an article on which they are an author or have another conflict of interest.

3.4. Study mapping and presentation

The primary product of this systematic mapping process will be a detailed systematic map database that describes each study across multiple variables described above. We will further visualize this database using the following:

- An evidence atlas that displays the studies in the map on cartographical space in an interactive geographical information system

- A series of heat maps that cross-tabulate categorical variables to highlight evidence gaps and clusters for a set of key variable pairs, for example: country and insect order, study methods, insect order, etc.
- Diagnostic plots that display details of the evidence base in histograms, bar charts and scatterplots

We will then synthesize the evidence base narratively to describe its nature, focusing on the spread of studies over subjects, space and time.

3.4.1. Knowledge gap and cluster identification

We will make use of spatial, temporal and subject classifications across the evidence base in the form of the visualizations above to identify subtopics, insect groups, time periods, and regions for which there is an underrepresentation of evidence (evidence gaps) or for which there is sufficient evidence to allow a full systematic review (evidence cluster). Evidence clusters will be discussed in consultation with stakeholders that include researchers and decision-makers to identify high priority topics that warrant quantitative synthesis (i.e. meta-analysis).

Declarations and competing interests

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References

Brummitt, R.K. (2001). World Geographical Scheme for Recording Plant Distributions, Edition 2. Biodiversity Information Standards (TDWG). http://www.tdwg.org/standards/109

Clapton, J., Rutter, D., & Sharif, N. (2009). SCIE Systematic mapping guidance. 151.

Conrad, K. F., Warren, M. S., Fox, R., Parsons, M. S., & Woiwod, I. P. (2006). Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. Biological Conservation, 132(3), 279–291. https://doi.org/10.1016/j.biocon.2006.04.020

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J., & Collen, B. (2014). Defaunation in the Anthropocene. Science, 345(6195), 401–406. https://doi.org/10.1126/science.1251817

Forister, M. L., McCall, A. C., Sanders, N. J., Fordyce, J. A., Thorne, J. H., O'Brien, J., ... & Shapiro, A. M. (2010). Compounded effects of climate change and habitat alteration shift patterns of butterfly diversity. Proceedings of the National Academy of Sciences, 107(5), 2088-2092. https://doi.org/10.1073/pnas.0909686107

Grames, E.M., & Montgomery, G.A. (2019). EntoGEM stakeholder engagement plan. Zenodo. http://doi.org/10.5281/zenodo.2725233

Grames, E., Stillman, A., Tingley, M. & Elphick, C. (2019). litsearchr: Automated search term selection and search strategy for systematic reviews. R package version 0.1.0. https://doi.org/10.5281/zenodo.2551701

Haddaway, N. R., Hedlund, K., Jackson, L. E., Kätterer, T., Lugato, E., Thomsen, I. K., … Söderström, B. (2015). What are the effects of agricultural management on soil organic carbon in boreo-temperate systems? Environmental Evidence, 4(1). https://doi.org/10.1186/s13750-015-0049-0

Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … de Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLOS ONE, 12(10), e0185809. https://doi.org/10.1371/journal.pone.0185809

James, K. L., Randall, N. P., & Haddaway, N. R. (2016). A methodology for systematic mapping in environmental sciences. Environmental Evidence, 5(1). https://doi.org/10.1186/s13750-016-0059-6

Janzen, D. H. & Hallwachs, W. (2019). Perspective: Where might be many tropical insects? Biological Conservation, 233, 102–108. https://doi.org/10.1016/j.biocon.2019.02.030

Loboda, S., Savage, J., Buddle, C. M., Schmidt, N. M., & Høye, T. T. (2018). Declining diversity and abundance of High Arctic fly assemblages over two decades of rapid climate warming. Ecography, 41(2), 265–277. https://doi.org/10.1111/ecog.02747

Montgomery, G. A., R. Dunn, R. Fox, E. Jongejaans, S. Leather, M. Saunders, C. Shortall, M. Tingley, & D.W. Wagner. (2019). Is the Insect Apocalypse upon us? How to find out. In review.

Peersman, G. (1996). A descriptive mapping of health promotion studies in young people. London, UK: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Powney, G. D., Carvell, C., Edwards, M., Morris, R. K. A., Roy, H. E., Woodcock, B. A., & Isaac, N. J. B. (2019). Widespread losses of pollinating insects in Britain. Nature Communications, 10(1). https://doi.org/10.1038/s41467-019-08974-9

Randall, N. P., & James, K. L. (2012). The effectiveness of integrated farm management, organic farming and agri-environment schemes for conserving biodiversity in temperate Europe - A systematic map. Environmental Evidence, 1(1), 4. https://doi.org/10.1186/2047-2382-1-4

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation, 232, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Schuch, S., Wesche, K., & Schaefer, M. (2012). Long-term decline in the abundance of leafhoppers and planthoppers (Auchenorrhyncha) in Central European protected dry grasslands. Biological Conservation, 149(1), 75–83. https://doi.org/10.1016/j.biocon.2012.02.006

Shortall, C. R., Moore, A., Smith, E., Hall, M. J., Woiwod, I. P., & Harrington, R. (2009). Long-term changes in the abundance of flying insects. Insect Conservation and Diversity, 2(4), 251–260. https://doi.org/10.1111/j.1752-4598.2009.00062.x

Stork, N. E. (2018). How many species of insects and other terrestrial arthropods are there on Earth? Annual Review of Entomology, 63, 31-45. https://doi.org/10.1146/annurev-ento-020117-043348

Thomas, C. D., Jones, T. H., & Hartley, S. E. (2019). "Insectageddon": A call for more robust data and rigorous analyses. Global Change Biology. https://doi.org/10.1111/gcb.14608

Thomas, J. A., Telfer, M. G., Roy, D. B., Preston, C. D., Greenwood, J. J., Asher, J., … Lawton, J. H. (2004). Comparative losses of British butterflies, birds, and plants and the global extinction crisis. Science, 303(5665), 1879–1881. https://doi.org/10.1126/science.1095046

Wagner, D. (2019). Threats to insects in the Anthropocene. In review.

Young, B. E., Auer, S., Ormes, M., Rapacciuolo, G., Schweitzer, D., & Sears, N. (2017). Are pollinating hawk moths declining in the Northeastern United States? An analysis of collection records. PLOS ONE, 12(10), e0185683. https://doi.org/10.1371/journal.pone.0185683