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The promises and challenges of archiving insect behavior and natural history in a changing world

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Abstract

Insect behavioral ecologists are not routinely archiving their behavioral media files and natural history observations. This is especially problematic because most behaviors are not preserved by the physical specimens stored in typical natural history collections. Improving the reporting and archiving of insect behavior and natural history data holds the promise of allowing scientists to track real-time responses of animals to global change and will preserve aspects of natural history that might otherwise be lost due to extinctions. Here we argue that behavioral ecologists should work to preserve and archive raw media files and field notes related to behavior and natural history of their study organisms. One major mechanism to incentivize archiving of such data would be for journals to develop policies for archiving of natural history data that is the focus of the paper or ancillary information collected about study subjects. Buy in from researchers, journals, and funding agencies will be needed to make substantial changes in data archiving.

Keywords

extended specimen; data archiving; reproducible science; insect declines; anthropogenic change

Introduction

Descriptions of insect behavior have a long history extending back to Aristotle's *Historia Animallium*. In modern times, the accumulated knowledge of behavioral diversity within and among species have been key data for studies of insect ecology and evolution including the genetic and neurological basis of behavior, the evolutionary origin of behavioral novelty, and the ecosystem wide consequences of insect behavior [1–4].

Insect species are undergoing an unprecedented period of immense global change in terms of climate, loss of biodiversity, land use patterns, pesticide use and invasive species [5–8]. This rapidly changing world is likely to affect how insects interact with each other and with their environment (hereafter "behavior") [9,10] as well as species distribution or abundance,

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Conflicts of interest

We have no conflicts of interest to declare.

life history, social system, diet, or habitat (hereafter “natural history data”)[11–15]. To understand how insects are responding to these diverse challenges, it is more important than ever to document present day behavior and natural history and to archive these data in data repositories. The historical collection and preservation of physical specimens stored in natural history collections have shown the power of this approach [16,17] by allowing subsequent researchers to answer questions that were impossible to imagine at the time of collection [18,19]. While physical specimens and their associated metadata can preserve some aspects of an animal’s natural history or ecological interactions [20], by their very nature specimens mostly do not preserve records of behavior (but see [21] for an example of insect architecture). In addition, there are novel challenges that must be addressed to facilitate the long-term documentation and archiving of behavioral and natural history data. In many cases, behavioral data are being collected or observed by researchers as part of ongoing scientific studies, but there are still outstanding issues regarding prioritizing which data to collect, incentivizing researchers to add these data to public data archives, and funding expenses associated with curating and managing archived data. Even for well-studied species or groups, there is relatively little behavior and natural history data stored on public archives [22], meaning that without changes to scientists’ behavior we are likely to miss the opportunity to document real-time changes to animal behavior in response to global change. The goal of this opinion piece is to raise awareness among behavioral ecologists and others working on insects to the need for greater documentation and archiving of insect behavior and associated natural history data. Here we discuss (1) the types of data that behavioral ecologists regularly collect, (2) how these data may be useful for future research, and finally (3) steps to improve the state of archiving and preservation of behavioral data.

Types of data behavioral ecologists are collecting but often not archiving

Insect behavioral ecologists collect a wide range of data including video and audio files, observations and annotations of behavior, and contextual socioecological and life history data about subjects (Fig 1). Increasingly scientists are depositing datasheets used for statistical analyses in repositories such as Dryad (https://datadryad.org/) [23], although there is still room for improving the reusability of these datasets [24]. While there have been no formal studies of the rate of data archiving of insect behavior (but see [25]), raw behavioral data including original multimedia files, individual level annotations of behavior, and contextual natural history data are rarely being archived.

We present two examples to illustrate how a wide range of insect behavioral and natural history data are vulnerable to loss. We searched Google Scholar for papers with the phrase ‘cricket song’ published between 2015–2020 which mentioned recording songs in the methods and examined the first 10 papers. Only one paper examined provided sound files for the recordings in the supplemental material and those files provided were only a small sample of all the recordings used in the study. Of course, the problem is not specific to cricket research; to compile WASPnest [26], a comparative database of cooperative nest founding rates among Polistine paper wasp species, we collected observations of cooperative nesting behavior from published papers and from unpublished field observations by wasp researchers. Nearly 25% of the 25,000 nest observations in the dataset were from unpublished data showing the magnitude of data being collected by researchers that may

otherwise go unreported. The lack of standardization in reporting cooperative nesting behavior made it labor intensive to collect data and nesting information was haphazardly reported. For example, 28.6% of nest observations in peer reviewed journals aggregated data over 2 or more years, limiting the utility of this data for time-series analyses. Clearly, we all (the two of us included) have a lot a room for improvement!

How might archived behavior data be used?

Repositories of behavioral and natural history data will have many uses for addressing a wide range of questions – many of which we are unlikely to be able to anticipate. Archived insect behavioral data can be used in teaching or outreach, enabling data to reach a wider and more diverse audience, and data archiving offers the opportunity for digital repatriation of behavioral ecology data collected in other countries [27–31]. Most importantly, in the coming years many insect species are likely to go extinct [32] taking with them the opportunity to study their behavior, making it all the more pressing that we archive behaviors and natural history data that we do observe and record.

A lack of data archiving today will make it harder to identify and track changes in behavior or life history in the future. Regular documentation and archiving of behaviors can allow researchers to reconstruct the speed and timing of behavioral changes. For example, archived recordings of white crowned sparrow songs were instrumental in demonstrating a recent North America-wide shift in song [33,34]. Recent changes in song have been captured among cricket populations in Hawaii in response to an invasive parasitoid fly [9,35]. Without archiving what we observe today, we will be left to infer the course of change rather than documenting it in real time.

Better documentation and archiving of behavioral and life history data will also facilitate phylogenetic comparative studies. In comparison with the relatively large amount of data on avian and mammalian behavior and life history traits [36–38], even well studied insect taxa frequently lack information on behavior for most species even at a course categorical level [22]. Descriptions and recordings of behavior, however, can be powerful data in a comparative context. This is true both in the case of socio-ecology or life history data as well as the specific behaviors of an insect.

Future technological advances may allow archived data to be reanalyzed. One recent example are the new machine learning algorithms such as DeepLabCut [39]. These programs track individuals and describe behaviors based on their posture and have the potential for high throughput fine-grained analyses of behavior. Similarly, using machine learning techniques it is possible to reconstruct the evolution of behavioral modules and examine how behaviors change through detailed comparisons of posture and movement data from recordings done from many species [40]. A recent example of the utility of archived video data comes from birds of paradise, where researchers used archival footage to study the evolution of movement patterns that make up sexual displays [41]. Archiving raw behavioral data will allow researchers to reexamine data in light of future theoretical or methodological developments.

How can we improve archiving of behavioral and natural history data?

There are many ways that the field of behavioral ecology could improve the archiving and preservation of behavioral and life history data. Given the lack of basic data for so many insect species [22,42], it would be wonderful to see more biodiversity expeditions with the express purpose of documenting, recording and preserving social and ecologically relevant behaviors associated with specimens [28,43]. While we are very much in support of such efforts and encourage funding bodies to consider the importance of funding the collection of extended specimen data for insect behavior, here we want to emphasize the steps we may take right now in our day-to-day research programs to increase insect behavior data archiving.

Typically, when behavioral ecologists set out to record behaviors it is with the goal of ultimately publishing the work in a scientific journal. With that in mind, then, we might consider three classes of data: (1) data that is the direct topic of a publication, (2) ancillary behavioral and life history data that we collect about our subject but is not the direct focus of a publication, and (3) observations and experiments that never lead to a publication. For all three classes of data, researchers should strive to follow the FAIR principles of scientific data management, ensuring that data is Findable, Accessible, Interoperable, and Reusable [44].

1. Data that is directly related to a paper

Rich multimedia descriptions of the behaviors are increasingly easy to capture but visual depictions of animal behavior have decreased in scientific journals [45]. An obvious way to improve archiving of behavioral and natural history data is to make compliance with archiving a requirement of publication in journals. Mandated data archiving increases data longevity, reproducibility, and access [46–48]. Data archiving policies vary across journals, but typically require archiving of sufficient data to repeat the analyses in the paper, rather than raw data files (Fig 2). At present, archiving original records of behavioral data – whether raw multimedia files or the scored annotations – or any associated natural history data is not required in any major journal in the field of animal behavior or ethology. Not only is this a potential problem for reproducibility and the prevention of fraudulent science, but these practices fail to safeguard the data we collect from loss due to hardware failure, outdated file formats, or the retirement of researchers.

We argue here that journals and perhaps more importantly the associated scientific societies can implement policies to radically improve behavioral data archiving and to develop policies to prioritize what data to archive (Box 1). While straightforward in theory to upload media files to archival storage, we recognize that in practice there are number of issues stemming from the large file sizes of media files, especially video. Popular data repositories charge higher fees for archival storage of large datasets and media files are indeed large file sizes, and these repositories are not integrated with media players making it difficult to browse data. Natural history media collections such as the Fonoteca Zoologica of the Museo Nacional de Ciencias Naturales in Madrid (http://www.fonozoo.com), the Macaulay Library at Cornell University (https://www.macaulaylibrary.org), or the Borror Laboratory of Bioacoustics at Ohio State University (https://blb.osu.edu) could serve as repositories for

such data, though would need substantial investment from funding bodies to be able to properly store such large amounts of video [17]. For experimental studies, it may be practical to archive only representative samples of trials or recordings rather than all of the raw media files, instead prioritizing the archival of recordings of natural behaviors. Though there are potential long-term data accessibility issues, one stop-gap solution would be for journals to have dedicated channels on platforms such as YouTube (http://youtube.com) or iNaturalist (https://www.inaturalist.org) that would allow authors to upload media files. Similarly, labs could take the same approach and have a lab-specific media repository just as many labs today have Github code repositories. At a minimum, one could imagine a requirement for a small amount of exemplar or representative unedited video or audio files used in a study to be presented in supplemental files or uploaded to existing data repositories. We strongly encourage journals to develop policies that explicitly address the archiving of media files and associated metadata used in research [49] and recommend that reviewers and journal editors help to enforce these policies.

2. Ancillary natural history data collected but not the main subject of a paper

As part of observing, handling and collecting animals, researchers generally record additional information about life history, social systems, environmental conditions or other natural history data. While the type of data collected varies among organisms and researchers, this information may not be reported unless it is the specific focus or included in a statistical test reported in the paper. Again, journal policies, reviewers, and scientific societies have the potential to make a large impact on the availability of natural history data by developing best practices for recording and documenting information. Ancillary data will likely vary across taxa, therefore specific priorities for data collection could be developed by working groups for specific taxa or research questions. For example, studies using wild animals might report GPS location, habitat description, and date of collection; animal behavior studies could describe the social and environmental context of the organism using the STRANGE framework [50] recently adopted by *Ethology* [51].

3. Natural history data and recordings that never make it into publications

Inevitably anyone working in behavioral ecology will generate data that never turns into a publication. The amount of such data that exists in the field notes, lab notebooks, and hard drives of behavioral ecologists is hard to estimate but is clearly substantial. In addition to the monetary costs of archiving data, researchers must also be incentivized to make such data available. One relatively underutilized option is publishing larger datasets as data papers, such as in the journal *Data in Brief* or as a data paper in *Ecology*. In recent years, a number of taxon-specific databases have been published as data papers, which can serve as the basis of a variety of analyses [22,26,52–54]. Analyses of the ecology and evolution of cooperative nest founding behavior in paper wasps were able to make use of field reports published in articles as well as unpublished data [55]. Data papers simply describe and outline the details of a dataset and have the benefit of making the data accessible to a larger audience and allowing the original researcher to be cited.

Beginning the discussion on behavior and natural history data archiving

There are many potential benefits of archiving behavioral recordings and natural history data – not just of insects but all taxa - though we will only realize these benefits if behavioral ecologists and related communities support systematic preservation. We recognize that there are substantial issues that need to be overcome and many questions to be addressed for such a vision to become reality (Box 1). These issues are being tackled in the scientific community more broadly, though behavioral ecologists need to figure out how our field will address these problems. Insects are an incredible group of organisms and we will all benefit from recording, documenting and preserving more aspects of their amazing behavioral and natural history diversity.

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Box 1:

Outstanding issues for behavioral ecologists to tackle relating to archiving behavior and natural history diversity

What data to archive

- How much raw data (*sensu* Fig 1) should be deposited with papers? Should archiving natural behavior be prioritized over lab experiments?

Enforcement of data archiving policies

- Should compliance with data archiving standards be enforced by journals, reviewers, scientific societies and/or funding bodies? When should files be available? How long might researchers reasonably embargo their data files? Should exceptions to data archiving policies be made for long-term studies?

Cost of data archiving

- Should costs for data archiving be part of grant data management plan? Should these costs be paid by authors or included in publication fees?

Data collection and archiving priorities

- Are certain behaviors understudied but in need of preservation? Which taxa are least represented and in need of directed efforts to collect and archive behavioral and natural history data?

Data from other sources

- Is there a role for industries in preserving natural history and behavior related media? Natural history media companies (e.g. the BBC) and internet video sharing companies (e.g. YouTube) have expertise and capabilities for storing media that differ from academics. Might scientific societies work to forge academic-industry partnerships to preserve behavioral and natural history media?
- How can citizen scientists be encouraged to deposit and archive well-documented behavioral and natural history media?

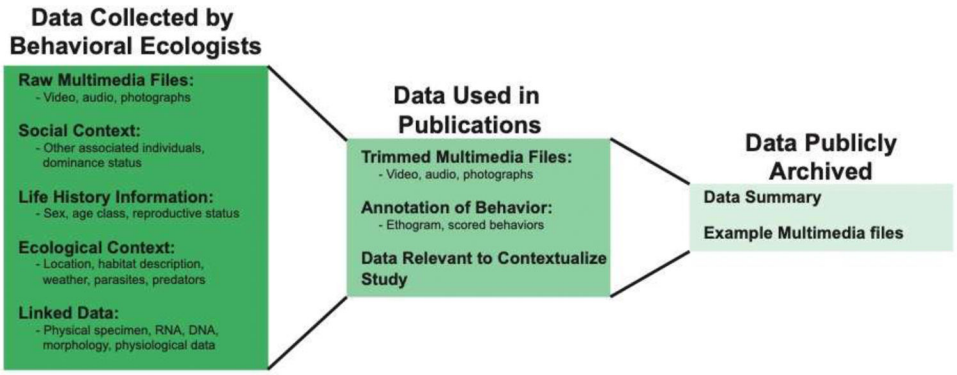

Figure 1:

Schematic of data collected in many typical behavioral ecology settings versus what is used in publications and ultimately posted in repositories at present. The amount of data is winnowed down at each step. Much more data is collected than is publicly archived, leading to a loss of natural history and behavioral media.

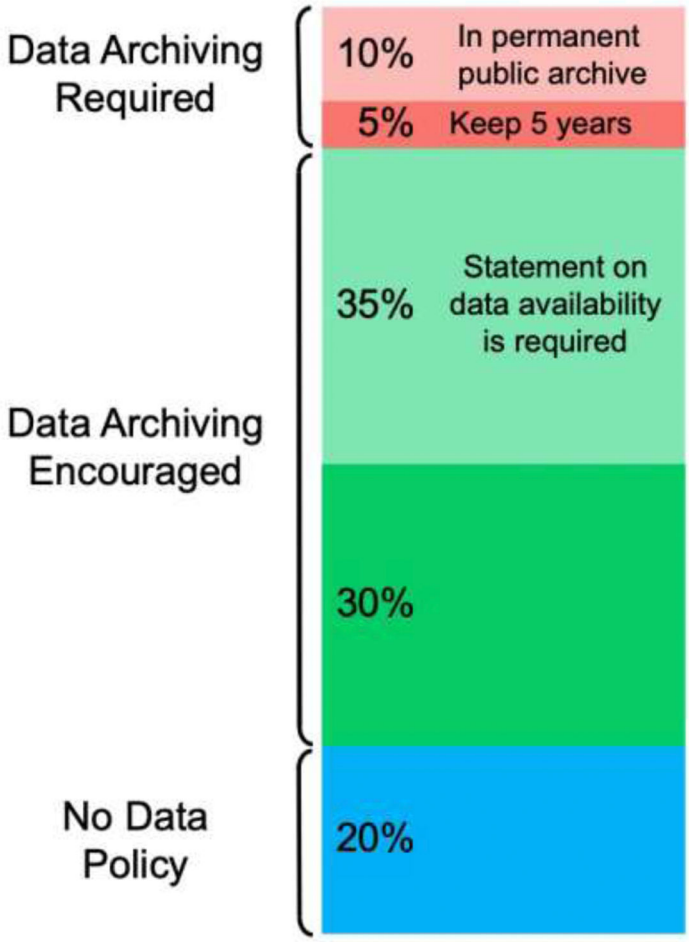

Figure 2:

Archiving policies vary by journals. The figure considers the policies for the top 20 journals listed under ‘Animal Behavior and Ethology’ on GoogleScholar.