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Editorial

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Editorial

Toward a brighter future for entomological collections

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Entomology collections, and natural history collections more generally, are critical research infrastructure. Specimens and metadata such as specimen labels, field notebooks, images, dissections, genetic sequences, and host plant data (to name a few) enable team science to examine biological diversity through time and study the impacts of humans on landscapes and climate (Johnson et al. 2023). However, some do not grasp the connection between drawers of insect specimens and modern science driven by advances in computational methods, molecular biology, and big data. Scientific specimens are key to connecting large-scale research questions within and among entomology and other disciplines.

Although entomological specimen metadata are the connecting point for our understanding of species and their biotic and environmental interactions, these data are typically not available in a digital format, essentially hidden in collection drawers. Consequently, researchers must visit, hand sort, examine, transcribe the associated metadata, and then analyze it. As an example of the continuing value of this procedure, analyses of host records from specimen label data revealed nonoverlapping host use, which provided insights into management strategies (Rudolph and Wiman 2023).

The research potential of easily accessible insect label data (and other metadata) is unlimited. Illumination of hidden data has enabled the reconstruction of paleoenvironments (Marshall et al. 2018) and the discovery of connections between agricultural practices, climate change, and insect biodiversity declines (Outhwaite et al. 2022). Furthermore, One Health practitioners can track spread of parasites and disease through time (Harmon et al. 2019) and model future outbreaks. Unfortunately, most specimen label data are brought to light haphazardly, project by project.

To make entomology collections accessible to researchers and the public, investments are needed to digitize metadata and prevent the loss of specimens (the primary data). The National Science Foundation (NSF) has supported transcribing specimen data and associated metadata this past decade. Yet, only about 5% of US entomological collections are fully digitized (Cobb et al. 2019). Importantly, no collection is too regional or small to contribute to this digital knowledge network. Digitization and conservation of existing regional and academic-based collections prevent irreversible data loss. Although the 2018 fire that destroyed much of the National Museum of Brazil was heartbreaking, quietly we continue to lose entomology collections to pests, poor environmental conditions, or disinvestment. We hold these specimens in trust for future generations, and we owe it to them to preserve this irreplaceable research infrastructure.

Periodically, the need for this research infrastructure is questioned. The most recent assault on collections (Byrne 2023) questioned the need for collecting and collections because of new technologies. Certainly, new technologies have immensely increased our understanding of the natural world. But imagine a newly discovered insect species represented by a single individual. Would we take some notes on it, preserve a leg for DNA, and then discard the specimen? Nachman et al. (in press) document the importance of continued collecting and preservation of scientific specimens in museums. There is still much discovery work ahead for entomologists!

Species discovery continues to impact our discipline especially for emerging pests like the soybean gall midge. The advent of large-scale integrative taxonomy (Hartop et al. 2022)—combining bulk sampling, molecular mini-barcodes, and bioinformatics—promises the next leap in tackling hyper diverse, poorly described groups like phorid flies. If researchers pair these advances with artificial intelligence to create species' descriptions and monographic treatments, biodiversity discovery will thrive as long as well-trained entomologists ground truth the results.

So far, I have been stressing research innovations in entomological collections. Transformation is occurring regarding "who" does this work and how they work together. Team science is here. Those involved with research collections are increasingly diverse with complementary skills. Team science extends to and includes the public, who are enthusiastic about their favorite arthropod—native pollinators, ladybugs, and butterflies. Popularization through *iNaturalist* and other apps enables public access to appreciating biodiversity. The promise of recruiting the next generation of biodiversity scientists hinges on increasing access points (Fischer et al. 2021). In addition, Eurocentric insect collections rarely incorporate Indigenous knowledge into their collections. Although becoming common place to engage Indigenous people in annotating and enriching anthropological collections with their knowledge, entomology and other biological research collections have been slow to recognize its

importance. Liggins et al. (2021) suggest how to enhance molecular sequence databases of molecular sequences with Indigenous knowledge. This approach could be translated to entomology database practices.

The promise of a bright future for entomological collection-based research rests upon all entomologists. During your entomology career, you have relied on a collection or collection-based specialist—for your research, education, or public outreach. Please pay forward! Your stakeholder support has a bigger impact than the voice of those who steward collections daily. The collections occupy an important space, in our buildings and in our future research questions. With your advocacy, entomology research collections will be around to inspire, educate, and answer the novel research questions of future generations.

With your support, the Entomological Collections of the Future could look like this:

In a welcoming workspace, students, collections staff, and researchers worked on various projects in the Dame Miriam Rothschild Museum. The imaging team was evaluating workflows for digitizing a large, historical collection of odonates and frozen samples. The collection manager was meeting with representatives from a local Tribe. Their discussion centered on incorporating the Tribe's knowledge and associated cultural practices into museum records and public exhibits. In the adjacent conference room, biodiversity researchers and students discussed with international colleagues via virtual conferencing how best to integrate new micro-ecological data into existing natural history databases on insect pollinators. A graduate student reviewed a thesis chapter correcting AI-generated taxonomic descriptions of springtails, a worldwide synthesis of known fossil, extinct, and extant Collembola. The collection assistant checked environmental conditions inside the rooms and within cabinets, in between ordering new insect cabinets and collecting supplies for the next grant-funded expedition. In the breakroom, a museum adjunct professor celebrated with the museum curator that the Dean has prioritized funding for the new roof and classroom addition to accommodate the surge in students interested in biodiversity careers.

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