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Entomological Collections - Their Historic Importance and Relevance in the 21st Century

Mark Colvin

Abstract: This article provides information on the relevance of entomological collections and collecting. It also reviews recent literature and provides the reader with a perspective on the reasoning behind the responsible collecting of specimens and the formation of a collection, and provides examples of the use of such specimens.

Sir David Attenborough with Wallace's Giant Bee *Megachile pluto*
Photo © OUMNH

"*Due to the care of past curators, we can (for example) still handle specimens actually from Linnaeus's personal cabinets, as well as others collected and prepared by later giants in the history of biology, Raffles, Darwin and Wallace among them. Ownership of these collections in trust carries an obligation to maintain them in good state and to make them accessible to enquirers and research workers at home and abroad.*" - Earl of Cranbrook, taken from Paine (1992).

The aim of this article is to provide what I hope is a balanced and thought-provoking personal view on both the historic importance, and contemporary relevance, of entomological collections and collecting. It is not, by any means, intended to present a position endorsed by any individual or organization, or to encourage collecting without appropriate research based justification or consideration of the Invertebrate Link (Joint Committee for the Conservation of British Invertebrates) code (see sidebar). Rather, its fundamental objective is to enlighten readers in a subject that is frequently controversial, due to a lack of understanding of the reasons for collecting and killing specimens, which consequently generates diverse and conflicting opinions.

The Invertebrate Link (JCCBI) Code

The Invertebrate Link (JCCBI) code is applicable to all terrestrial and freshwater invertebrates in the UK - not just insects. The code, out of necessity, defines certain activities that should be avoided or restricted but it equally emphasises the need to collect invertebrates in order to gain valuable information, much of which can aid conservation. There are currently 36 member organisations, including the leading conservation charities, entomological societies and statutory agencies, represented on the committee (Invertebrate Link (JCCBI), 2002).

What use is a library that stops acquiring books?

Entomological collections, indeed any collection of natural history specimens, are libraries of natural objects such as insects, mammals, birds, plants and fungi. Such items are collected and preserved because they form a rich foundation upon which to study the natural world by, for example, providing the basis for identification of organisms, mapping their distribution and providing the means for facilitating research led conservation. By storing the physical object and not only an image or description of the natural organism, natural history collections aim to maximize the possibilities for new scientific discoveries (Dincă et al., 2011; Pittino, 2006).

Within biodiversity research, taxonomists and evolutionary biologists are the traditional users of natural history collections. But the result of their work is only one part of these collections' value. For environmental research, agriculture, genomics, climate studies, epidemiology, ecological niche modeling for conservation, public health, and many other areas of research, collections have become indispensible and several such studies are considered later in this article. Crucially, collections will continue to answer questions that are unrelated to the reasons for their original establishment (Ownes and Duin, 2008; Society for the Preservation of Natural History Collections, 2010).

Not just a load of dead insects ...

The essential work of the entomological curator
Photo © Mark Colvin

Photomicrography and the digital recording of historic specimens
Photo © Mark Colvin

Natural history collections worldwide house an estimated 3 billion preserved specimens together with their collective data. This represents an immense knowledge base of global biodiversity (Ownes and Duin, 2008).

Museum specimens, particularly well-represented taxa such as butterflies and beetles, can provide us with data for investigating the effects of climate change, habitat modification and loss due to anthropogenic activity and the resulting distributional changes over time, often spanning many decades. Although many historic specimens housed in museums and private collections will be unsuitable for molecular research (due to their age, methods of preparation or preservation) there are still many that can provide scientists with valuable data.

For example, in the case of the Adonis Blue butterfly *Polyommatus bellargus*, researchers amplified microsatellite DNA from museum specimens over 100 years old to examine population changes over time (Harper et al., 2006) and were able to extract data from specimens where the populations had become extinct through habitat loss. Another example involves the British Swallowtail butterfly, *Papilio machaon*, where researchers undertook a morphometric study that showed populations at the Norfolk sites and those at Wicken Fen (Cambridgeshire) differed in several wing characteristics; Norfolk specimens were also generally larger. These differences were most marked between 1890 and 1920, but a study of more recent specimens showed that these differences were almost lost. Differences in size give little indication of selection pressures operating on individuals, whereas differences in shape may be far more informative, since these may reflect changes in function (Dempster et al., 1976). It is impossible to do more than speculate at what changes in shape mean in terms of an animal's biology, but one characteristic that is likely to be influenced by shape is mobility.

In Norfolk the swallowtail butterfly is a strong flyer and adults are frequently seen outside of their fen habitat. There is no way of knowing whether the Wicken race was as mobile as the Norfolk race, but selection pressures against emigration must have been high, since there was no other suitable breeding habitat within 160 km. If one assumes that the two populations originated from a single East Anglian stock, then it is probable that differences arose after the Wicken population became isolated. It is tempting to believe that the reduced size of the habitat available to the butterfly at Wicken led to selection against mobility and that this resulted in changes in body shape (Dempster et al., 1976).

More recently, it has become possible to extract nucleic acids from dry insects, in order to undertake DNA analysis and associated studies, without causing external morphological damage (Gilbert et al., 2007); an important consideration with extremely rare or 'type' specimens - the specimen(s) on which the description and scientific name of a new species is formally based.

Providing methodologies are scientifically robust, most reputable natural history museums will provide access to specimens to researchers for both traditional and molecular research. Traditional research includes morphological studies (the branch of biology dealing with the study of the form and structure of organisms and their specific structural features), and data mining (extracting verifiable data from a specimen's data label(s) and the computational process of discovering patterns in large data sets). Molecular research includes population genetics (the study of the distributions and changes in genetic makeup in a population), barcoding (a taxonomic method that uses a short genetic marker in an organism's DNA to identify it as belonging to a particular species) and molecular systematics (the use of molecular genetics to study the evolution of relationships among individuals and species).

Example Areas of Research

Population Genetics

Population genetics considers changes in the distribution and genetic makeup of a population as it is subject to the four main evolutionary processes of natural selection, genetic drift (the change in allele frequencies), mutation and gene flow (the transfer of genes between populations).

By sampling genetic material from specimens of the Adonis Blue butterfly, *P. bellargus* over 100 years old, and then comparing the results with samples taken from the same site and from other extant populations 200 generations later, Harper et al. (2006) were able to show that dramatic changes in gene frequencies have occurred over time, which is indicative of substantial genetic drift, extinction or recolonisation (Slatkin, 1977). This serves to reinforce the enormous potential of museum specimens in well-represented taxa, such as butterflies, for examining the effects of population change spanning many decades.

Collections are therefore extremely useful when studying evolutionary change and anthropogenic influences over a long period of time, as they provide genetic material from historic populations against which contemporary information can be considered (Ownes and Duin, 2008; Anon, 2013).

Agriculture and Public Health

Collections are not only potential sources of information related to pests of agriculture and forestry, but also for vectors of veterinary and human diseases. Collections also house many potential natural enemies, parasitoids and predators of pests, which are accessible to researchers for study. Most parasitoid species have, in fact, been described by taxonomists using material residing in our natural history collections. Collections can also be used to help predict pest distribution from the reconstruction of invasion history, to forecast areas where crop damage or vector-borne human disease may occur, to enable research into insecticide resistance, and to develop taxonomic keys for farmers that allow them to identify pest species more easily (Ownes and Duin, 2008; Hartley et al., 2006).

Biodiversity Distribution Modeling

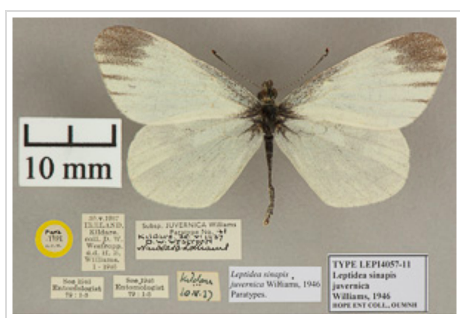
Most species distribution models are founded on the concept of a species niche - the environmental conditions that define the range in which a species can exist. These models can define the relationship between the presence of a species and a set of environmental factors. Such relationships can then be extrapolated to other locations based on the suitability of habitat and geographic range.

In the case of prominent arthropod-borne diseases, models can help by mapping the anticipated global range of vectors and consequently the potential areas of disease expectancy. Specimens from collections can be used to add species distribution to these models as they are analysed. Other application areas include the prediction of the impact of climate and environmental change on the distribution of organisms, and long-term conservation planning. Modeling has become an increasingly important tool for ecologists, environmental managers and planners (Clark Labs, 2014; Ownes and Duin, 2008; Sinclair et al., 2010).

Taxonomy and Genomics

Uncovering cryptic biodiversity is essential for understanding evolutionary processes and patterns of ecosystem functioning, as well as for nature conservation. European butterflies are arguably the best-studied group of invertebrates in the world. The discovery, some twenty years ago, of a cryptic species within the Wood White, *Leptidea sinapis*, was a significant event and, since then, these butterflies have become a model to study speciation. Cryptic species are not separable based on their external morphology but can often be distinguished by dissection of the male and / or female genitalia. In addition, genetic data also supports species level separation.

In the 1940s Williams investigated the identity of the Irish Wood White *Leptidea sinapis*. From looking at subtle differences between voucher specimens, he came to the conclusion that Irish examples were distinct from those found on mainland Britain and, as such, proposed that the Irish butterfly should be given the status of subspecies, which he named *juvernica*.



Paratype of *Leptidea sinapis juvernica* as named by Williams
Photo © OUMNH

Across Europe, seven species of *Leptidea* have now been described: *sinapis*, *reali*, *juvernica*, *duponcheli*, *amurensis*, *morsei* and *lactea*. The last three are essentially Asian species but *duponcheli*, a butterfly of Eastern Europe and Asia Minor, is found very locally as far west as the South of France. *L. sinapis* appears quite widespread on the continent as well as occurring in both Britain and Ireland. In the 1970s and 1980s Réali, and later Lorković, undertook research involving dissections of *sinapis*. They concluded that *sinapis* was not a single species but was really two cryptic species. Both species looked identical to the naked eye, did not interbreed and only upon dissection of their genitalia were they found to be separable. The new species was named *Leptidea reali*, Réal's Wood White.

More recent investigations of museum specimens by Spanish and Russian lepidopterists (Dincă and colleagues) have thrown further light on the identity and distributions of the Wood Whites across Europe, using techniques based on chromosome counts and DNA analysis. Their conclusions are that *reali* is not in fact a single species but is itself made up of two distinct species - now named *reali* and *juvernica*. They are separate entities from *sinapis*. Therefore, with the benefit of access to museum specimens, what was previously thought to be a single species of Wood White is, in fact, three species - *sinapis*, *reali* and *juvernica* (Dincă et al., 2011; Sachanowicz et al., 2011; Butterfly Ireland, 2014).

Increasingly, we are seeing taxonomies being based on, or strongly supported by, DNA sequencing research. Whilst this is primarily a laboratory-based discipline, traditional museum specimens play an important supporting function. If taxonomy is to be based on molecular data, then the identity of the organism from which the data is derived is of fundamental importance. The storage of 'voucher' specimens (see sidebar) is therefore essential for the future study and revision of taxonomies (Godfrey, 2011). This is of particular importance with 'type' specimens.

Voucher Specimens

A 'voucher specimen' is any specimen, usually but not always a preserved example, that serves as a basis of study and is retained as to verify and validate the associated data e.g. where, when and who caught it. 'Specimen' may mean the whole organism or a part thereof e.g. part of a plant. Vouchers are usually placed in a publicly accessible collection although, even if they are not, they remain vouchers (Animal Ethics Infolink, 2014).

Conservation

British specimens of the Large Blue *Maculinea arion*
Photo © Mark Colvin

Maculinea arion, the Large Blue, is a habitat specialist, like the rest of the genus Maculinea and many other members of the tribe Polyommatini (the blues). Ugelvig et al. (2011) describe the use of microsatellite markers in order to suggest that *M. arion* is less sensitive to genetic erosion via population bottlenecks than previously thought, and that managing clusters of high quality habitat may be key for their long-term conservation.

The ecological niche of a species can be described as the set of conditions and resources necessary for an organism to maintain a viable population (Graham et al., 2004). Ecological niche modeling (a process of predicting the distribution of a species - historic, current and future) is an important tool for conservation assessment as it allows us to predict the 'ecological niche' requirements of a species (Ownes and Duin, 2008). Being able to accurately forecast organisms requirements is critical in reintroduction programmes, especially those involving defined habitat specialists. Species such as the Adonis Blue, *P. bellargus*, and Large Blue, *M. arion*, are maintained by grazing disturbance: these species occupy a very confined ecological niche and they have very strict requirements concerning the vegetation structure and, for *M. arion* at least, the presence of the ant host species (Polus et al., 2007). Understanding these requirements and being able to accurately map suitable locations for release is essential and, in part, is possible due to the data that is housed in our collections (Gaubert et al., 2006; Johnson et al., 2011).

The British psammodiines (lesser dung beetles) are psammophilous (sand-loving) in habitat choice and often restricted in their distribution. Due to a lack of specific research on the species, their true distribution and conservation status is unclear. *Brindalus porcicollis* (Illiger) is one such species, which, until recently was believed to be extinct in the UK. Mann and Booth (2000) confirmed, through examining all known specimens and their data housed in UK collections, that the locality of the original collectors was a small patch of sandy beach, and not as had been published in the literature - several locations in the 'Plymouth area'. This data also provided the authors with the times of appearance for this rare beetle. The notebooks and data from voucher specimens allowed the authors to pinpoint the exact locality and the time of year to undertake fieldwork, which consequently proved successful.

In another paper, this time by Mann and Barclay (2009), the identification and status of the two-spot pot beetle *Cryptocephalus biguttatus*

(Scopoli) was discussed. Following confusion in the recent literature, new characters were used to separate two superficially similar species, *C. biguttatus* and *C. bipunctatus*. Through re-identification of specimens deposited as vouchers in museums and private collections, from most known localities dating back 190 years, the authors were able to verify that *C. biguttatus* had been over-recorded due to misidentifications. This rare beetle occurred in fewer sites than previously thought and so its conservation status was far more precarious than originally believed.

Growing concerns about declines in both managed and wild bee colonies, and the associated loss of pollination services, has increased the urgency to identify the underlying causes. By sampling pollen loads on the bodies of voucher specimens that were collected between 1870 and 1950 - prior to the onset of agricultural intensification in The Netherlands - Scheper et al. (2014) were able to evaluate the historic pollen choices of wild bees and how their populations had changed during the twentieth century. Their research enabled them to show that the fate of the bees, in part, was often linked to that of their preferred, and declining, wild plants they depended on.

Environmental Monitoring

Natural history collections are used for monitoring changes in our natural environment by analysing levels of contamination in a particular territory or region. They serve as an archive of anthropogenic impact on nature and are key components of environmental impact assessments e.g. for landscape planning. Conventional collections can be used for environmental monitoring but for a systematic monitoring programme an environmental specimen bank (an archive of representative samples which are collected at regular intervals and in an identical manner) provides a more appropriate platform for study (Ownes and Duin, 2008).

Species New to Science

Genitalia dissection - a key requirement in many areas of research
Photo © Mark Colvin

One of our only truly endemic insects, the lesser dung beetle *Psammoporus insularis* (Pittino, 2006) was only recently described as a species new to science. Pittino examined over 602 specimens from most of the major European collections. However, this new species was only discovered from specimens held in the National Museum Wales, Cardiff in their British beetle collection, some of which were collected over 100 years ago. This beetle still survives today, and is widespread in Britain with a primarily northwestern distribution where it lives on sandy riverbanks and river shingle (Pittino, 2006).

Although insect species new to science are discovered regularly, new mammal species are exceedingly uncommon, and new carnivorous mammals especially so. The Olinguito, *Bassaricyon neblina* (Helgen, 2013), a small South American mammal, has evaded the scientific community for all of modern history. Nearly two-dozen preserved samples - mostly skulls or furs - were mislabeled in museum collections across the United States. Visits to eighteen different museum collections and the examination of roughly 95 percent of the world's Olingo specimens (a closely related species) turned up voucher specimens that actually came from the Olinguito. Many experts still believe that many more unknown species may be hiding in scientific collections (Stromberg, 2013).

Biological Recording

A prime example of the relevance of vouchers is stated in Mann and Barclay (2009). In this instance, over-recording of the beetle *C. biguttatus* had occurred due to the confusion between this rare species and a colour variety of a more widespread one. The authors examined voucher specimens in numerous collections (public and private), as well as the associated paper archives, and from this resolved the identification problem and reassessed its distribution and conservation status.

Another excellent example is in the field of re-interpretation of a species as taxonomic changes occur, in part due to increased understanding of taxonomically important characters, but also through technological improvements in research methods e.g. high magnification microscopes, computer analysis and molecular techniques. This was certainly the case in the Wood White (*Leptidea*) butterflies (Dincă et al., 2011; Sachanowicz et al., 2011), where examination of genitalia characters and statistical analysis aided in the separation of the three cryptic species mentioned earlier.

Conclusion

Natural science collections underpin our understanding of the planet and the life that lives on it. Type specimens lodged in museums are what define every species known, with reference specimens providing a way for researchers to check species identifications and piece together the complex history of life and relationships between organisms. Collections provide a historical baseline for understanding past population distributions, to better understand current distributions and to predict future trends. This allows us to make sense of our changing planet and raise awareness of how we influence it (Natural Sciences Collections Association, 2014).

Our knowledge and understanding of the entomological world continues to grow and, for the most part, this is through responsible collecting, which often requires specimens to be killed and preserved. Although this is less likely, though not unnecessary with the Lepidoptera, we should not, therefore, instinctively label those brandishing a net and undertaking collecting as irresponsible. Providing collecting is carried out following well-established ethical guidelines, and undertaken to better understand and conserve our global biodiversity, then I consider collecting to be a vital tool in furthering our scientific knowledge.

The vouchers and data that researchers accumulate over the course of their lives will have scientific value long into the future. I am sure when Williams collected Wood Whites in the 1940s he would not have thought his specimens would be used for taxonomic and conservation research in the 21st Century. What would have happened if Williams had only drawn or photographed his white butterfly?

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