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Documenting Persistence of Most Eastern North American Bee Species (Hymenoptera: Apoidea: Anthophila) to 1990–2009

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abstract: The status of wild bees, the major group of pollinators in most biomes, has gained recognition as an important ecological and economic issue. Insufficient baseline data and taxonomic expertise for this understudied group has hindered efforts to assess the conservation status of the majority of wild bee species. To more objectively address their current conservation status, we drew upon museum collections and the expertise of melittologists (biologists studying non-*Apis* bees) to compile a complete list of bee species for eastern North America, discriminating those which have and have not been detected during the past 20 years. The vast majority (95% of about 770 eastern North American bee species) have been found again, at least once since 1990. The remaining 37 species were rarely collected before 1990 as well. Some may truly be at risk (or lost). Others are undoubtedly data deficient due to inadequate knowledge of their biology or hosts, or the geographic regions and local habitats where they occur. Distributional and ecological patterns among these missing species are discussed. Most were recorded in the region only from peripheral areas or areas known to be undersampled by recent collectors, such as the southeastern United States. Others are characterized by specialized life histories or they cannot be identified routinely in the absence of taxonomic revisions. Clearly, most eastern North American bee species have persisted until recent times, with no evidence of widespread recent extinctions. An absence of well-documented global extinctions of bee species does not warrant complacency regarding pollinator conservation, as our qualitative method does not lend itself to documenting range contractions, range fragmentation, or declines in abundance and species richness in local bee communities.

key words: Collection data, bees, invertebrate, rarity, extinction, museum specimens, database

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Introduction

Wild bees (Hymenoptera: Apoidea: Anthophila) are increasingly appreciated as an ecologically and economically valuable group of insects, some of which are at risk (Brown and Paxton, 2009). Bee taxa vary greatly in their life history characteristics, phenologies, distributions, and morphologies, so they are not expected to respond uniformly to most ecological threats. Multiple challenges exist to determining the status of these vital pollinators (NAS, 2007). Most species are difficult to identify. For many genera, species identification requires an experienced bee taxonomist with access to both relevant literature and a comprehensive reference collection. For some of the most commonly-collected taxa, species-level taxonomy is still being analyzed through integrated studies of morphology and DNA sequences such as DNA barcodes (e.g., Gibbs, 2010, 2011). Many species are restricted in their geographical distribution, habitat tolerances, floral preferences, and, for cleptoparasites, host species, which may constrain their population size or make them elusive. The wealth of information held in most museum collections has been largely inaccessible because collaborative digitization of bee specimen data across multiple collections has only begun (Schuh *et al.,* 2010). As a consequence, native bees along with other arthropods are usually overlooked in conservation efforts and assessments of species at risk (May *et al.,* 1995). Although some insects have recently gone extinct or been locally extirpated, rare insects are hardly ever included in assessment lists (Dunn, 2005). Of the few insect species listed globally, most are from colorful and charismatic taxa, such as butterflies, dragonflies, and tiger beetles (e.g., IUCN, 2010). Even among bees, the species which have attracted the most widespread conservation attention have been the commercially important and widely introduced honey bee (*Apis mellifera* L.) (e.g., Van Engelsdorp *et al.,* 2008) and the large, showy, and familiar bumble bees (*Bombus* spp.) (Williams and Osborne, 2009).

In North America, feral and managed European honey bees and some (native) bumble bee species have suffered dramatic declines (Colla and Packer, 2008; Cameron *et al.,* 2011), but they are not representative of the other 3500 plus species in the United States and Canada. It might be expected that the regional bee fauna as a whole may also show signs of long-term decline. A relatively small-scale pair of studies in southern Illinois near Carlinville shows how much of a bee fauna may persist in a changing landscape. Marlin and LaBerge (2001), revisiting sites and floral hosts studied 75 years earlier (Robertson, 1929), found "no evidence of a marked decline in the species composition of this rich bee community…." Although natural areas had decreased and farming had become more intensive, local landowners maintained a diversity of habitats that provided hosts and nesting areas for most of the 214 species of bees collected by Robertson that could be identified. The accumulation of local or regional biodiversity studies such as Robertson (1929) and Marlin and LeBerge (2001), as well as the combined scientific expertise of researchers from a broad geographic area, can develop the wealth of data needed to assess the conservation status of wild insects (Regnier *et al.,* 2009). Here, we bring together scientific expertise and data from many bee collections (supplemented by additional field observations including those documented by vouchered images), to assess the persistence of all bee species known historically from eastern North America. The result is a list of those species that have and have not been detected during the past two decades (1990–2009).

Table 1. Institutions of the authors of this study with approximate size of bee collection. Many additional collections were examined by one or more of these authors, including many minor collections and major collections such as the Smithsonian, but the collections listed received the most thorough scrutiny.

Institution	Author (s)	Estimated size of bee collection (# specimens)
Missouri Department of Conservation	M. Arduser	25,000
American Museum of Natural History	J. S. Ascher	450,000
USDA Bee Biology and Systematics Lab	T. Griswold, M. G. Rightmyer, J. Cane	1,000,000
York University, Packer Bee Collection	S. Colla, J. Gibbs, C. Sheffield	200,000
Cornell University Insect Collection	J. Gibbs	200,000
Archbold Biological Station Invertebrate Collection	M. Deyrup	220,000
USGS Patuxent Wildlife Research Center	S. Droege	130,000
University of Florida, Hall Bee Collection	H. G. Hall	12,000
Central Texas Melittological Institute	J. Neff	40,000
Indiana State University	R. P. Jean	40,000
M. Veit Collection	M. Veit	5000
University of Wisconsin-Green Bay	A. Wolf	5,900

Methods

A list of bees occurring east of the Mississippi River in the United States and east of Manitoba in Canada was extracted initially from the Discover Life Bee Species Species Guide and World Checklist (Ascher and Pickering, 2010). It consisted of about 770 species. This subcontinental region was chosen because it is relatively well-sampled and because no other comparably large region in North America has identification keys available for all of its genera. Two regional monographs (Mitchell, 1960, 1962) are the foundation for recent comprehensive species-level identification guides by multiple authors. All 770 species were scored for detection during the past two decades (1990–2009). This 20-year time period was chosen because surveys of the eastern fauna have greatly expanded since the early 1990's after a preceding lull, and because these recent surveys were conducted largely by melittologists who are still active and available for consultation. This proved to be important, because many of the most comprehensive bee surveys remain unpublished and employed varied and complex methodologies. It is important to note that while we restricted our study to bee species found historically east of the Mississippi River, we used records from throughout North America to establish recent presence. Thus, several eastern species were found during the study period only from west of the Mississippi. Our conclusions pertain to persistence of species that occur in eastern North America, but are not restricted to eastern populations of these species.

The initial list of species was distributed to melittologists at various North American institutions (Table 1) and more widely to online bee monitoring listservs. From these, the confirmed records from 1990–2009 were compiled. Most of these records were based on specimens in collections curated by or visited by melittologists, plus additional samples sent for identification by ecologists and others. Many of the more significant specimen records have been or soon will be published and/or digitized and made publicly available online.

As recently detected species were confirmed, the shrinking list of unrecorded species was iteratively reviewed until no more changes were suggested. The confirmed list was evaluated by the authors and other experts on particular taxa and regions to ensure that species were not erroneously recorded due to misidentifications. Information on life history, pollen specialization, geographic distribution, and historical status for each remaining species was then compiled from available literature and unpublished data available to the participants.

Results

The majority of the 770 bee species, representing almost all species known to occur in eastern North America, have been detected at least once within the past 20 years. A total of 37 valid (or at least nominally valid) bee species (Table 2) occurring in eastern North America have not been collected or observed anywhere in the past 20 years, representing ca. 5% of the fauna recorded historically from this region. The exact number of bee species in the region remains uncertain due to the existence of many undescribed species and sexes, lack of revisions for several genera and species groups, and delays between discovery and publication of synonymies and other taxonomic changes.

Regarding the 37 bee species not recorded after 1990, general patterns emerge from a consideration of their taxonomic status, identifiability, life histories, and geographic distributions. Many species on the undetected list belong to unrevised or incompletely-studied genera. Moreover, several are known from only from one or a few type specimens. Identification of other species is difficult or controversial (e.g., *Epeolus banksi* Cockerell, *Epeolus vernalis* Mitchell, *Lasioglossum wheeleri* Mitchell, *Melissodes pilleata* LaBerge, and *Sphecodes* spp.); this alone may explain their lack of recent records. Shared life history parameters group other undetected species together. Nearly half (16 species) are known nest cleptoparasites of other bee species. These belong to the genera *Epeolus, Nomada, Triepeolus* (Apidae), *Sphecodes* and possibly *Lasioglossum* (*L. wheeleri*; see Gibbs, 2010, 2011) (Halictidae), and *Stelis* (Megachilidae). Many bee cleptoparasites are best found around nests of their hosts, but the hosts are not known for most of the cleptoparasites in question, thereby hindering their detection. Some of the listed non-parasitic species are thought to be oligolectic - members of bee genera that commonly collect pollen only from a limited number of related plant species (Table 2). These bees are restricted to locations in which their host plant(s) are found, which can be patchy and therefore overlooked by general collectors, even if these bees are locally numerous at optimal sites for their host plants and nests.

Geographic patterns emerge regarding the distributions of the species on the undetected list (Table 2). Few species are restricted to the middle latitudes, while over half are from the Deep South and, of those, eight are known only from peninsular Florida. A few species only enter the margins of eastern North America, being primarily from the Great Plains and further west, and nine species are northerly in distribution. Such geographic patterns may reflect true patterns of rarity such as restriction to isolated sandy areas in the South or prairie remnants in the Great Plains and adjacent Midwest (Droege *et al.,* 2009). However, as few melittologists live or work in those regions where many of the unrecorded but identifiable species occur, species restricted to those areas may be simply undersampled. All species on the unrecorded list were historically uncommon

Table 2. List of bee species not recorded from 1990–2009 ([1]Known only from type specimen, [2]Ecological aspects inferred from close relatives).

Species	Distribution	Ecological Notes[2]
Andrena daeckei Viereck	NJ, PA	ground nesting, possibly oligolectic on Ericaceae
Andrena ignota LaBerge	SC[1]	ground nesting, possibly oligolectic on Asteraceae
Andrena irrasus LaBerge	IL, KS, NE, NM, SD, WY	ground nesting, possibly oligolectic on Asteraceae
Andrena mendica Mitchell	GA, IL, IN, MA, NC, OH, TN, VA	ground nesting
Colletes andrewsi Cockerell	CO, ND, NE, SD, WI, MAN	ground nesting, possibly oligolectic on *Heuchera*
Colletes ciliatus Patton	CO, IA, IL, KS, NE VA	ground nesting
Colletes titusensis Mitchell	FL	ground nesting
Epeolus banksi Cockerell	MD, NC, VA	cleptoparasite
Epeolus canadensis Mitchell	MI, NY, NS, ONT, QUE	cleptoparasite
Epeolus vernalis Mitchell	FL, GA, NC	cleptoparasite
Hylaeus flammipes (Robertson)	FL[1]	cavity nesting, probably polylectic
Hylaeus volusiensis Mitchell	FL	cavity nesting
Lasioglossum dubitatum (Mitchell)	NY[1]	ground nesting
Lasioglossum stuartense (Mitchell)	FL[1]	ground nesting
Lasioglossum wheeleri (Mitchell)	MA[1]	possible social parasite
Melissodes manipularis (Smith)	FL, GA, NC, SC	ground nesting, probably oligolectic on Asteraceae
Melissodes pilleata LaBerge	NC	ground nesting, probably oligolectic on Asteraceae
Nomada aquilarum Cockerell	AK, MN, ND NM, WI, WY,ALB, MAN, NWT, SAS, YUK	cleptoparasite
Nomada augustiana Mitchell	AL, GA, NJ	cleptoparasite
Nomada seneciophila Mitchell	AL, FL, GA, NC TN	cleptoparasite
Osmia laticeps Thomson	ME, MI, MAN, NS, ONT, QUE, YUK + Palearctic	cavity nesting, probably polylectic
Perdita krombeini Timberlake	FL	ground nesting, probably oligolectic
Perdita mitchelli Timberlake	AL, FL, MS, NC	ground nesting, probably oligolectic
Perdita townesi Timberlake	GA, FL. NC, SC	ground nesting, probably oligolectic
Pseudopanurgus helianthi Mitchell	IN	ground nesting, probably oligolectic on Asteraceae
Sphecodes crawfordi Mitchell	NC[1]	cleptoparasite
Sphecodes exaltus Mitchell	NC[1]	cleptoparasite
Sphecodes nigricorpus Mitchell	CT[1]	cleptoparasite
Sphecodes paraplesius Lovell	RI[1]	cleptoparasite
Sphecodes smilacinae Robertson	IL,MN	cleptoparasite
Sphecodes trentonensis Cockerell	NY[1]	cleptoparasite
Stelis permaculata Cockerell	CO, IL, MD, NH, TX, VA, WI, WY, ONT, QUE	cleptoparasite
Trachusa crassipes (Cresson)	FL, GA, NC	ground nesting
Trachusa dorsalis (Lepeletier)	AL GA, NC, NJ, MS,	ground nesting
Triepeolus mitchelli Hurd	NC[1]	cleptoparasite
Triepeolus monardae Mitchell	FL, GA, NC	cleptoparasite
Triepeolus nigrihirtus Mitchell	NC, TX	cleptoparasite

(based on number of specimens in collections), in many cases rare, and often known only from the type series or even a single holotype specimen.

Discussion

It has been suggested that thousands of small, understudied, and cryptic species have gone extinct completely unnoticed (McKinney, 1999). We know little of North American bee faunas prior to the work of E. Cresson and others in the mid-19th century, so any losses prior to then caused by ecological upheaval in and following the colonial and early post-colonial eras and the introduction of managed honey bees, are unknown. Using a collaborative method, we have established that at least 95% of eastern North American bee species recorded historically (into the 20th century) have persisted into the last two decades. From this effort, we are left with a short list of undetected bee species from this region deserving further study to distinguish artifactual from genuine rarity. Our findings are consistent with a comprehensive analysis of global dragonfly and damselfly species (Order Odonata) by Clausnitzer *et al.* (2009). These authors asserted that extinction risks for insects (approximately 1 of 10 species of dragonflies and damselflies) seem to be less than expected based on extrapolation of rates from other taxa, such as vertebrates. A recent comprehensive assessment of extinction risk in freshwater crabs (Cumberlidge *et al.,* 2009), on the other hand, concluded that 1 in 6 species have an elevated risk of extinction, the majority of which are endemics with restricted ranges. These recent analyses exemplify an increasing interest in assessing the conservation status of invertebrate species. At the same time, these analyses showed inconsistent patterns of vulnerability among invertebrate groups, and even for the case of the freshwater crabs, no extinctions have been documented.

We show here that by querying relatively few experts, including those with access to institutions housing historical insect collections, we could achieve a rapid, inexpensive, yet informative status assessment for a large and diverse group of insects that is not amenable to traditional evaluative protocols. Our strategy allows for efficient pooling of information from across a variety of sources, thereby ensuring high taxonomic quality as well as the extensive geographic and temporal scope that is required to make broad and reliable assessments. It should be noted that this rapid assessment merely establishes persistence of a species somewhere in its range (including outside the area of interest) after 1990 (although the vast majority were recorded ca. 2005-present when our collecting activity was greatest). It does not document losses to eastern North American populations of more widely distributed species or losses taking place after 1990. Some species that were historically widely distributed and numerous were detected in our study but have certainly declined since 1990, notably several species of formerly common bumble bees evaluated through intensive, focused studies (Colla and Packer, 2008; Cameron *et al.,* 2011).

Our list of undetected species consists largely of bees that were uncommon before 1990, which are difficult to identify, have parasitic life styles, limited distributions, and/or pollen specialization on predictive host plants. These bees are rarely encountered, and even less frequently identified, even by active collectors and taxonomic specialists. For example, as of 1960, there were six recognized parasitic species in the taxonomically daunting subgenus *Dialictus* (including *L. wheeleri*) described from eastern North America (Mitchell, 1960). These species are social parasites that reside in the nests of their hosts (Wcislo, 1997). Now, 51 years later, after a large-scale revision of the group, there are eleven parasitic *Dialictus* known east of the Mississippi, with the five new species being found in relatively well-sampled states such as Massachusetts, Maryland, and New York (Gibbs, 2011). All of these species have been collected in the last 6 years but, despite examination of tens of thousands of *Dialictus* by J. Gibbs and colleagues, only 23 specimens, for the five species combined, have been found. In some cases, only two specimens exist, and these were collected decades apart.

Other bees on the list are geographically isolated or peripheral with respect to the location of the most active collectors and identifiers of bee species. Such biogeographical gaps in our knowledge are illustrated by consideration of *Hesperapis oraria* Snelling and Stage, the only member of tribe Hesperapini found in the southeastern United States. This oligolectic bee of the northern Gulf Coast was only discovered 15 years ago despite being locally numerous and conspicuously different from any other bee in the area (Cane *et al.,* 1996). Previous non-detection of such a distinctive species makes it conceivable that failure to detect many other species can be an artifact of gaps in sampling and expertise. Although some species unrecorded since 1990 may have become extinct or extirpated, more likely these missing species were simply undetectable because they persist in very low numbers or at few localities, or at localities not frequented by the authors or the relatively few other active bee collectors. One such example is *Epeoloides pilosulus*, which would otherwise be on this list had it not been recently rediscovered first in eastern Canada (Sheffield *et al.,* 2004) and then in New England (Wagner and Ascher, 2008). Before then this species had been considered potentially extinct (Michener, 2000) due to lack of records for nearly half a century. The combination of its cleptoparasitic lifestyle and specialization on hosts which are themselves floral specialist on *Lysimachia* (declining in some areas) likely contribute to the continued rarity of *E. pilosulus* (Sheffield *et al.,* 2004). Finally, detection is a function of collecting and subsequent identification efforts. In Indiana, a fairly well studied Midwestern state, approximately 200 bee species were listed for the state in the late 1950's (Montgomery, 1957), but the addition of approximately 35,000 specimens since 1957 (20,000 of these netted at flowers or bowl trapped during 1998–2009) and additional identification work in several historical collections has doubled that total to over 400 confirmed bee species (Jean, 2010). Many of the species added based on recent collections or newly detected in older undetermined material were rarities represented by fewer than ten individuals. This example shows that full documentation of state and regional bee faunas requires both added sampling from more areas and habitats and further efforts to identify existing specimens in all relevant institutions.

We must learn more about the taxonomy, identification, distribution, life history, and population dynamics of these 37 undetected species before we can confidently determine reasons for their absence from recent collections. For now, they should be included into Natural Heritage databases (URL: http://natureserve.org/aboutUs/index.jsp (Accessed 11 October 2011)) for all states where the species has been recorded. Known taxonomic and identification difficulties and sampling biases should be noted for each case so that these can be addressed and so rarity in collections will not be misconstrued as necessarily entailing extinction or endangerment. It will be particularly valuable to develop sampling and identification protocols designed to maximize detection of rarely encountered species. Both focal surveys and unbiased, standardized monitoring can be used to survey bee communities, document community differences, and ultimately discover changes in relative abundance and community composition (Williams *et al.,* 2001).

By compiling data from many knowledgeable contributors, we have established that the vast majority (>700) of bee species recorded historically from eastern North America, including all historically numerous species, persisted in eastern North America to 1990–2009. We have not compiled precise abundance data, nor can we verify that the bees documented during the study period have persisted in sustainable populations. However, we can state that they remained detectable despite the limited, opportunistic, and geographically patchy nature of surveys by our relatively few contributors. We have also flagged the small minority of undetected bee species and noted taxonomic, identification, and sampling biases that must be overcome if we wish to efficiently locate them and evaluate their conservation status. Since these "missing" species are not randomly distributed geographically, and in some cases share ecological traits, our results suggest floral and (for cleptoparasitic bees) bee hosts, regions, and habitats that are appropriate targets for intensive surveys and conservation assessments. Our results highlight the need for additional taxonomic and life history studies of many groups, and the need to employ diverse sampling methods, including those optimal for detecting taxa of particular interest.

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