Biodiversity and Conservation

Bee (Hymenoptera: Apoidea: Anthophila) roadkill across Texas, United States of America, compared with other studies

Supplement

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Materials and methods

Roadkill surveys and sampling design

Texas roadkill surveys for Spring 2020 comprised five trips, ranging from three to five days long each (22 days total), that were conducted every other week between 30 March and 28 May 2020. The Autumn 2020 field season consisted of a total of five trips, ranging from four to five days long each (24 days total), were conducted about every other week between 12 October and 24 November 2020. Similarly, in Spring 2021, a total of six trips, ranging from one to five days long each (26 days total), were conducted approximately every other week between 22 March and 21 May 2021.

Three different categories of localities for transects were established based on criteria outlined below: Dispersed, Adventitious, and Special Adventitious. In the Spring 2020 and Spring 2021 field seasons, Dispersed localities were spaced by at least 60 road km and up to 100 road km apart at maximum (~37–62 road mi; approximately every 80 road km / 50 road mi on average) and at roadside milkweed stands when feasible. In Autumn 2020, the distance between Dispersed localities was reduced to every 25 road km to 50 road km at maximum (~15–31 road mi; approximately every 38 km or 23 mi on average). During all field seasons, Adventitious localities were designated between the Dispersed localities, either once or twice a day when time allowed, and when either a large milkweed stand and/or less common milkweed species was observed along the road. Special Adventitious localities were only sampled in Autumn 2020, upon request by the Texas Department of Transportation (TxDOT), and primarily to provide additional monarch roadkill data.

Localities for transects were not located within urban areas (e.g., cities) and measurements between transect sites did not include distances driven through urban environments. All roadside transects measured 100 m long by 1 m wide. Transect sites were never surveyed more than once, within or between field seasons. Most localities were sampled with a transect on a single side of the road. Localities were also periodically sampled with transects on both sides of the road (i.e., two-sided road transects), when at least one side had a milkweed stand (during Spring field seasons) and/or as time allowed. In general, when only one side of the road was sampled at a locality, the transect was on the right side of the vehicle based on the direction being driven (i.e., the passenger's side of the vehicle). Handheld Global Positioning System (GPS) units were used to record approximate geographic centroids for each transect to generate a spatially explicit dataset. The side(s) of road sampled were assigned to the nearest cardinal direction (i.e., north, south, east, and/or west) they faced. Cardinal directions were frequently estimated in the field based on the road orientation and direction of travel, in comparison to cell phone Google Maps data. Cardinal directions were also assigned, corrected, or standardized as needed using visual assessment of the transects' geographic centroids, road orientation, and the direction of travel as indicated by adjacent transect numbers in Google Earth. For simplicity of data curation, since there were only two sides of the road at each locality, the transect data from north and west sides, and the transect data from south and east sides of roads, were arbitrarily combined into "North" and "South" categories, respectively. Roadkill was counted on both sides of the road for 27 of the 508 total roadkill transects in this study. Six of the 27 two-sided transects had at least one transect with bees, and the North or West transect had an average 25% more bees than the South or East transect (range -100% to 100%). Most transects were North or West, and we conservatively estimated the roadkill to be equal on both sides of the road for estimating roadkill rates per 100 m.

Sample processing and specimen identification

The contents of each individual bag of roadkill sample materials were placed in a shallow foam tray and sorted by taxon using forceps. The parts of individual bee specimens were reassociated as frequently as possible (i.e., when they were available). This allowed a total number of individuals of each taxon in a sample to be counted before being returned to the bag. When whole or nearly complete bee specimens were not present for all or any individuals in a sample, counts were based on the greatest body parts available for the taxon (e.g., heads, thoraxes, sets of wings). In two instances (i.e., in Spring 2021 samples for transects 3AT37 and 4AT18), we were unable to confirm if the body parts available for the native bee taxa in the samples belonged to multiple individuals or not. To be conservative and avoid overcounting the number of individuals represented in these samples, we assumed that all the parts belonged to single individuals.

Bee specimens recovered in Autumn 2020 and Spring 2021 were determined by SKK in 2023 using an Olympus SZ51 Stereo Microscope equipped with an Olympus SZ2-ILST LED Illuminator Stand (Olympus Corporation, Tokyo, Japan). Bee specimens recovered in Spring 2020 were primarily determined by KWW. SKK identified Spring 2020 *Apis* specimens and reexamined all the season's samples to ensure bee specimens were accounted for, adding and reconfirming KWW's determinations as needed. SKK and KWW used previously determined bee specimens in the Texas A&M University Insect Collection (TAMUIC) as reference material.

SKK identified most bee specimens to family, tribe, or genus level using Michener et al. (1994). Additional genus keys were used for metallic green halictids (Maffei 2021) and Lithurgini (Gonzalez et al. 2013), and a subgenus key was used for *Centris* (Michener 2007). Species-level identifications were accomplished using a variety of taxon-specific resources, specifically: *Bombus* spp. (Colla et al. 2011; Koch et al. 2012; Williams et al. 2014; Texas Parks and Wildlife Department 2023), *Xylocopa* spp. (Mitchell 1962), *Agapostemon* spp. (Roberts 1972; Portman et al. 2022), *Augochloropsis* spp. (Portman et al. 2022), *Lithurgopsis* spp. (Snelling 1986), and *Centris* (*Paracentris*) spp. (Snelling 1984).

We follow classification based on Michener (2007), with exceptions based on the following recent studies. We follow Bossert et al. (2019) for subfamilies within Apidae, Freitas et al. (2023) for generic classification within Eucerini, Moure and Melo (2007) for generic classification within Lithurgini, and Williams et al. (2008) for subgeneric classification within *Bombus*. Within genera, taxon concepts were applied based on recent revisions and other taxonomic works: *Agapostemon* (Mitchell 1960; Roberts 1972; Portman et al. 2022), *Augochloropsis* (Mitchell 1960; Portman et al. 2022), *Lithurgopsis* (Snelling 1986), *Centris* (Snelling 1974, 1984), *Diadasia* (Timberlake 1941; Adlakha 1969), *Melissodes* (LaBerge 1961; Mitchell 1962), *Triepeolus* (Rightmyer 2008), *Dieunomia* (Cross 1958), *Nomia* (Mitchell 1960; Ribble 1965), *Megachile* (Mitchell 1937), *Osmia* (Sandhouse 1939; Michener 1949; Mitchell 1962; Rust 1974), *Xylocopa* (Hurd 1961; Mitchell 1962), and *Bombus* (Franklin 1913; Mitchell 1962; Milliron 1971, 1973a, b; Labougle 1990; Williams et al. 2014).

Notably, undescribed *Augochloropsis* spp. are present in Texas (Portman et al. 2022). Determinations past genus level were not made for Spring 2021 *Augochloropsis* specimens. However, determined Spring 2020 specimens are included at species-level [all *Augochloropsis* (*Paraugochloropsis*) *metallica sensu lato* (Fabricius 1793)] as they were identified prior to the publication of Portman et al. (2022). For clarity, females of *Agapostemon* (*Agapostemon*) *angelicus* and *Ag.* (*Agapostemon*) *texanus* are "morphologically indistinguishable" from one another (Portman et al. 2022). Thus, while these two taxa are distinct species, we follow Portman et al.'s (2022) recommendation in reporting them as a single morphospecies because they both occur in Texas and only female specimens were represented at this taxonomic level in roadkill samples. Additionally, we treat *B. pensylvanicus* and *B. sonorus* as distinct species as in other works (e.g., Franklin 1913; Warriner 2012), which is supported by a recent analysis of molecular data for Texas populations (Beckham et al. 2024). However, since these bumble bee taxa are also frequently treated as conspecifics or subspecies (e.g., Milliron 1973a; Williams et al. 2014), we opted to address them together as *B. pensylvanicus sensu lato* in our dataset as well. Please refer to Warriner (2012) for additional citations pertaining to *B. pensylvanicus* and *B. sonorus* in Texas; further study of the group will refine understanding of their phylogenetic relationships and geographic distributions.

Cross-study comparisons

Of the 2,334 roadkill Anthophila collected in Knoxville, Tennessee by Russo (2025), 24 bees identified only to family level or higher (2 Halictidae and 22 Anthophila) were excluded from analysis, leaving 2,310 bees to consider. We extrapolated Tennessee bee roadkill per 0.75 km transect to 1 km, calculated the mean and standard deviation roadkill per km over sample dates, and then multiplied this mean and standard deviation by the sample size to obtain annual seasonal mean and standard deviation of bee roadkill, which was not originally reported.

Utah bee roadkill per taxa per driving route from Wilson et al. (2024) was calculated multiplying relative abundance of bees per driving route (their Table 2) by average bee roadkill estimates per route (their Table 1), before summing over all routes to calculate roadkill relative abundance per taxa. Utah bee roadkill data (their Table 1) was also used to calculate both average and minimum estimated numbers of bees hit per day per route by multiplying bees per car per km per route by estimated average or minimum number of daily cars during the bee flight period per route. The weighted mean values for Utah average and minimum estimated numbers of bees hit per day per route were first calculated for the multiple instances of some routes, using the mean route kilometers for each route as a weight. Then, the route-distance weighted mean for Utah estimated average and minimum numbers of bees hit per day per route was calculated and multiplied by the 3,461 km total of all driving routes and the number of days per season (total annual = 180, spring = 83, summer = 97) to yield total average and minimum estimated roadkill over Utah driving routes for various seasons.

Washington vehicular bee sweeper roadkill per kilometer was calculated by dividing the total kilometers surveyed per year into the bees captured as given in Table 1 of Vinchesi et al. (2018).

Qualitative comparisons of roadkill bee taxa at various taxonomic levels among this study and other studies were made using Microsoft Excel pie charts.

Roadkill sampling methodologies and iNaturalist data

For the iNaturalist (2025a) occurrence data of the 23 bee genera among the Texas and Utah roadkill studies, we used accepted genus or species level identifications with the following criteria: (1) iNaturalist research grade quality species identifications, which have at least two agreeing identifications; (2) genus level verified occurrence data with two confirming genus identifications, which is equivalent to research grade quality for species level identifications, but is not available for genus level identifications; and (3) verified occurrence data with an identification to at least genus by bee taxonomist John S. Ascher (ident_user_id=johnascher; https://www.inaturalist.org/people/johnascher). Observations with two or more agreeing genus identifications were most easily identified from non-research grade observations with at least two agreeing identifications in the downloaded tabular data (num_identification_agreements>1). Where only one agreeing identification was reported for a non-research grade identification (num_identification_agreements=1), we examined the online iNaturalist record to verify whether there still may be more than one agreeing identification for the genus, such as where one user identification may be the genus *Agapostemon* and another user identification may be of a particular *Agapostemon* sp. that remains unconfirmed. For accepted bee genus observations with duplicates for a given location, we kept the observation with research grade quality or with the highest number of agreeing genus identifications.

The Histogram Bin Ratio Weighting (*HBRWt*) sample bias correction method of Tracy et al. (2022) was used to adjust the iNaturalist occurrence records for the 23 bee genera according to human population density bias, considering how the distribution of occurrences of the larger Hymenoptera target group (verified observations with at least one identification) required numerical adjustment to match the distribution of random points within bins of human population density throughout the contiguous five state area of Utah, Colorado, Arizona, New Mexico, and Texas (Fig. S1). Data for each genus with at least two agreeing identifications were separately thinned to 1 km to reduce spatial autocorrelation, and the random and target group data were also thinned to 1 km. The proportions of *HBRWt* adjusted occurrences among the 23 bee genera were then compared between the roadkill survey areas in Utah and Texas (Fig. S1, Table S3).

Results

Texas roadkill relative abundance

Texas roadkill was greatest for the family Apidae and was estimated at 4.3M for autumn and spring 2020 (the following roadkill estimates in parentheses are all for 2020) (Table S4). Apidae roadkill in Texas was dominated by the subfamily Apinae (2.4M), including *Apis mellifera* (1.5M), *Xylocopa virginiana* (0.8M), *X. micans* (0.7M), *Bombus pensylvanicus* (0.3M), *Centris* sp. (0.18M), *B. griseocollis* (0.15M), *C. atripes* (black-legged oil digger), *C. caesalpiniae* (Caesalpinia oil digger), *B. impatiens,* and *B. sonorus*, followed by the long-horned bees subfamily Eucerinae (0.2M), including *Diadasia rinconis* (cactus bee), *Melissodes tristis* (dark-faced longhorn bee), and *Triepeolus pencilliferus*. Minor roadkill was estimated for the subfamily Anthophorinae, *Anthophora* (common digger bees). The family Halictidae (1.3M) was the next most common among Texas roadkill, dominated by *Agapostemon angelicus/Ag. texanus* (1M), and including *Augochloropsis metallica* (metallic epauletted-sweat bee) (0.15M), *Ag. splendens* (brown-winged striped sweat bee), *Augochloropsis* sp., *Dieunomia nevadensis* (Nevada nomia), and *Nomia nortoni* (Norton's alkali bee). Less common bee roadkill families included Andrenidae (e.g., *Andrena* sp.) (0.3M) and Megachilidae (0.3M), including *Osmia subfasciata* (0.15M), *Lithurgopsis littoralis* (cactus wood-borer bee), *Megachile inimica* (hostile leaf-cutter bee), and *O. texana* (Texas mason bee), with minor representation by Colletidae (*Colletes* sp.) (Figs. 2, 6c, 7a, 9a; Table S4).

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Figures

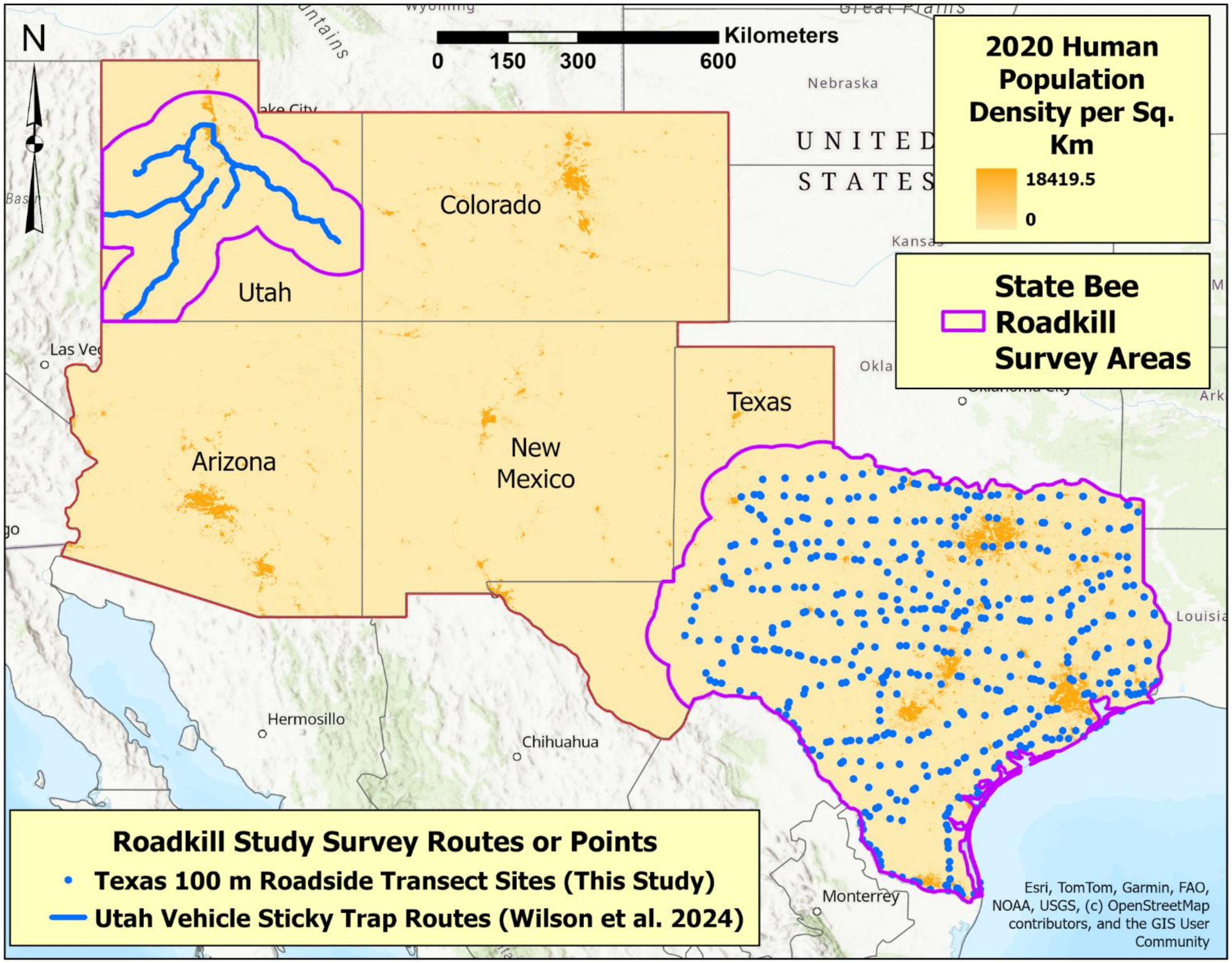

Fig. S1 Bee roadkill survey areas in Texas (this study), showing 100m roadside transects, and Utah (Wilson et al. 2024), showing roadway survey routes for vehicle-mounted sticky traps, including associated 70 km buffer roadkill survey areas over a background raster of 1 km resolution 2020 population density (CIESIN 2022) for five state area that was used in calibrating weightings for human population sample bias adjustments of iNaturalist (2025a) data

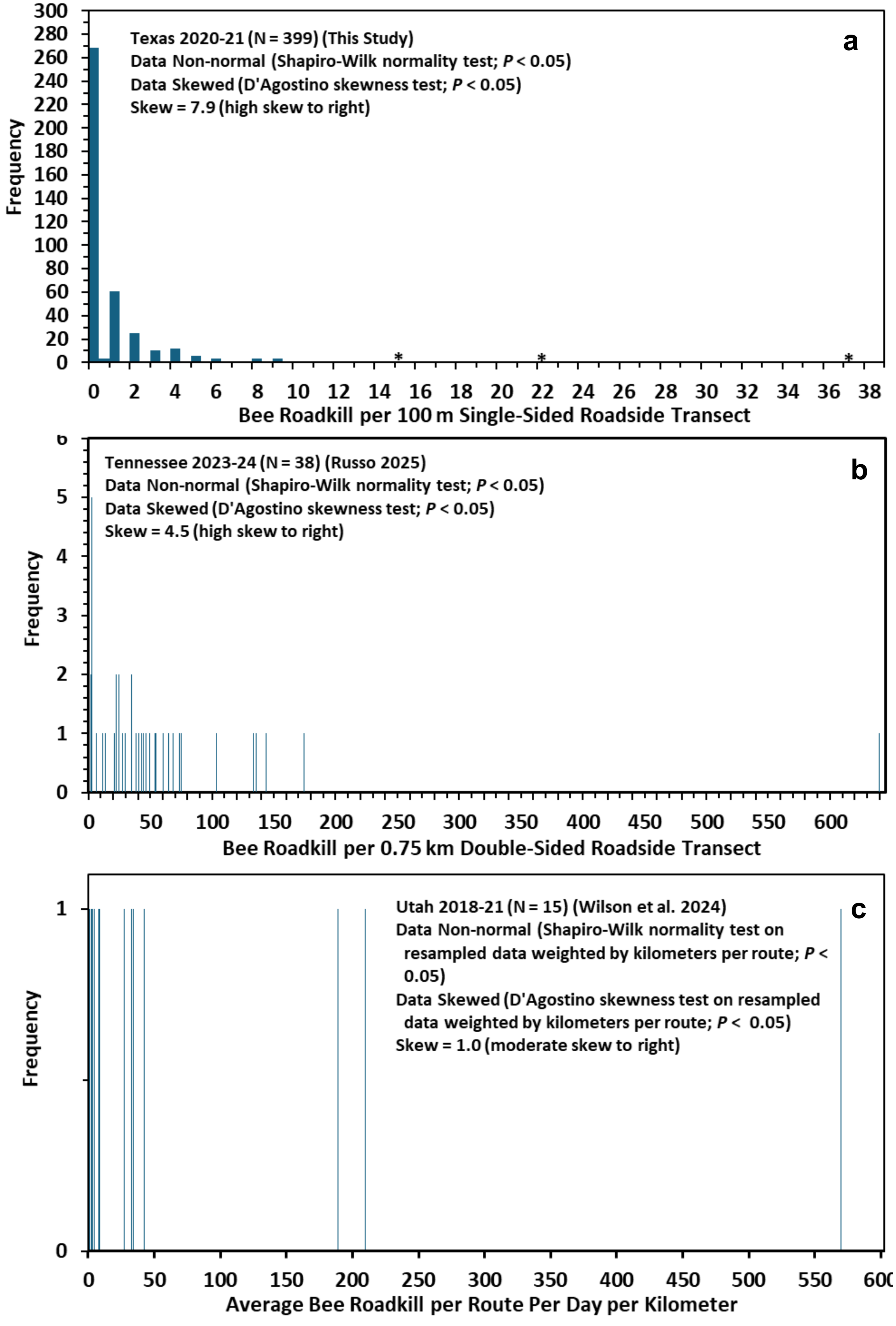

Fig. S2 Frequency histogram of values for bee roadkill per transect for (a) Texas (this study) and (b) Knoxville, Tennessee (Russo 2025) (asterisk indicates a value of "1"), and (c) average bee roadkill per driving route per day per kilometer for Utah (Wilson et al. 2024)

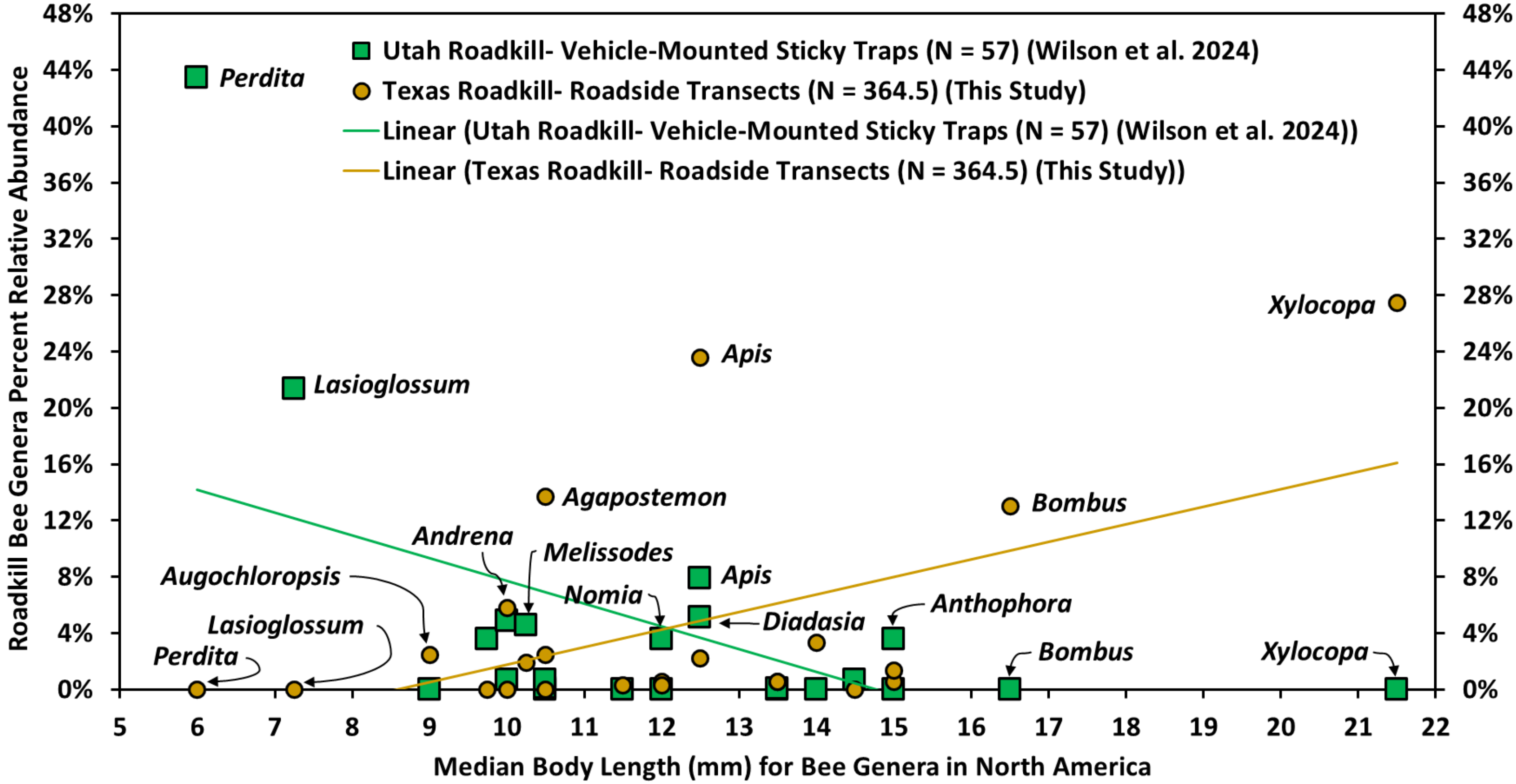

Fig. S3 Scatterplots of identifiable roadkill bee genera relative abundance versus median body length for genera in North America from Utah vehicle-mounted sticky traps (Wilson et al. 2024) and Texas roadside transects (this study). Only more abundant bee roadkill genera are labeled (N = number bees; see Tables S2–4 for data; see Fig. 10a for bar chart of data)

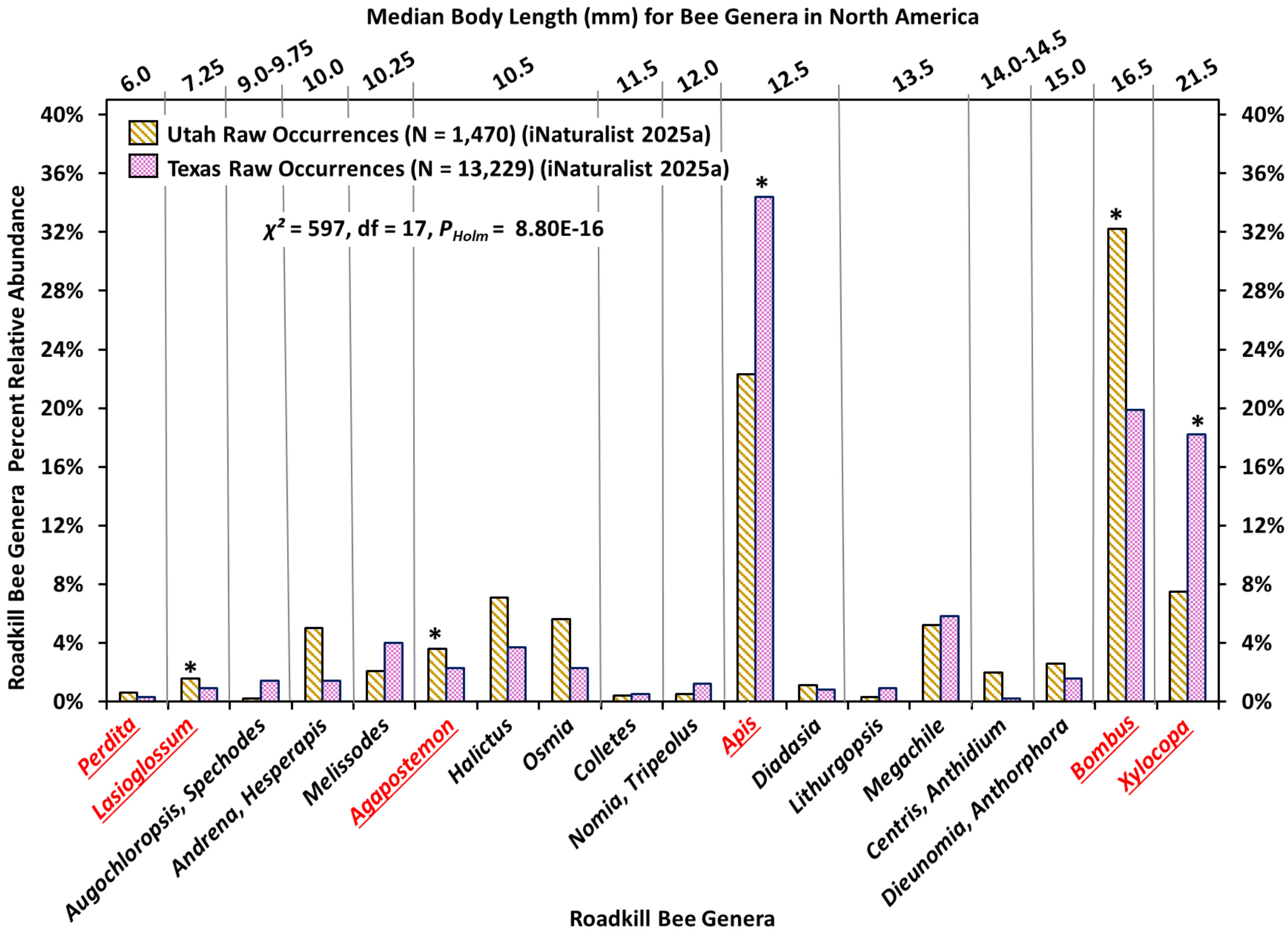

Fig. S4 Bee roadkill genera relative abundance according to median body length in North America from confirmed iNaturalist (2025a) genus sample raw occurrences for Utah and Texas (N = number bees). Asterisk in the six red underlined genus groups indicates significant difference in relative abundance among all genera for Utah versus Texas ($P_{Holm} < 0.05$; Chi-square test for independence with Holm's correction, followed by proportion tests with Holm's correction) (see Tables S2–4 for data; see Fig. 10b for same chart with sample bias adjusted data)

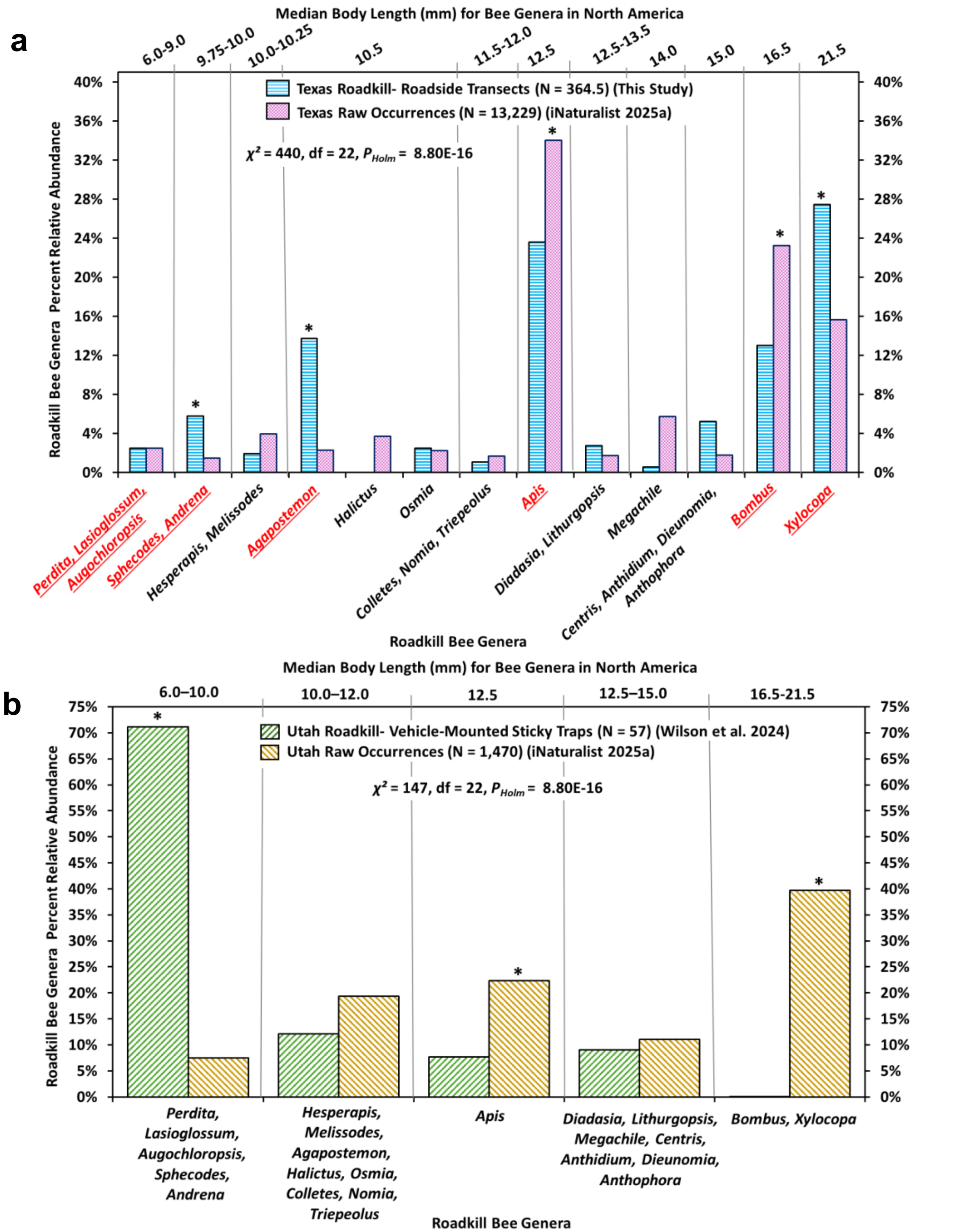

Fig. S5 Bee roadkill genera relative abundance according to median body length in North America for roadkill from (a) Texas roadside transects (this study) or (b) Utah vehicle-mounted sticky traps (Wilson et al. 2024) and confirmed iNaturalist (2025a) raw genus occurrences for (a) Texas and (b) Utah (N = number bees). Asterisk in (a) six red underlined genus groups or (b) any genus group indicates significant difference in roadkill versus occurrence relative abundance among all genera ($P_{Holm} < 0.05$; Chi-square test for independence with Holm's correction, followed by proportion tests with Holm's correction) (see Tables S2–4 for data; see Fig. 11 for same charts with sample bias adjusted data)

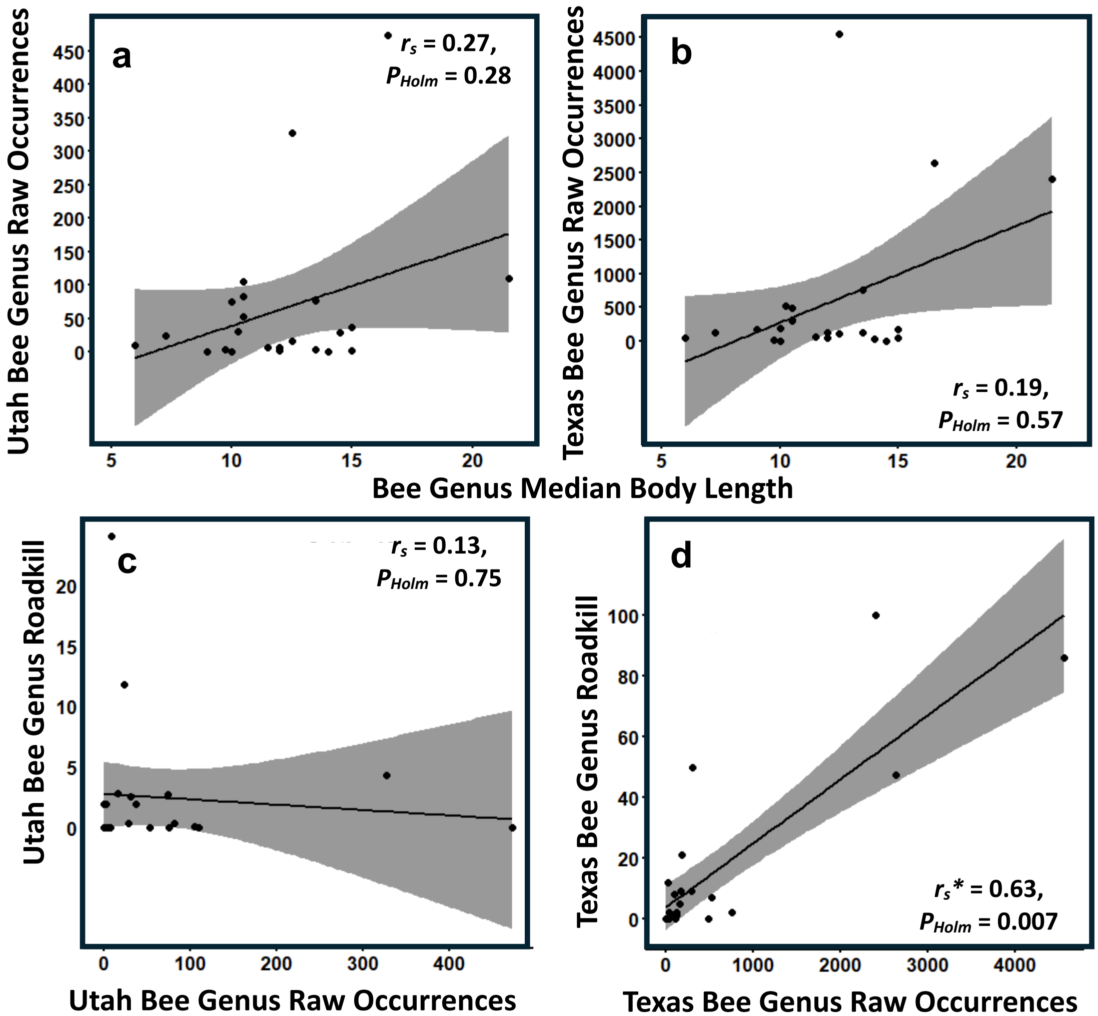

Fig. S6 Spearman's rank-order correlations (r_S) for 23 bee genera between bee genera median body lengths (mm) and (a-b) raw occurrences (iNaturalist 2025a) in (a) Utah and (b) Texas; and (c-d) roadkill counts and raw occurrences for (c) Utah and (d) Texas. Asterisk indicates significant r_S ($P_{Holm} < 0.05$) and shaded areas represent 95% confidence intervals (N = number bees) (see Tables S2–4 for data; see Fig. 12c–f for same charts with human population density sample bias adjusted data)

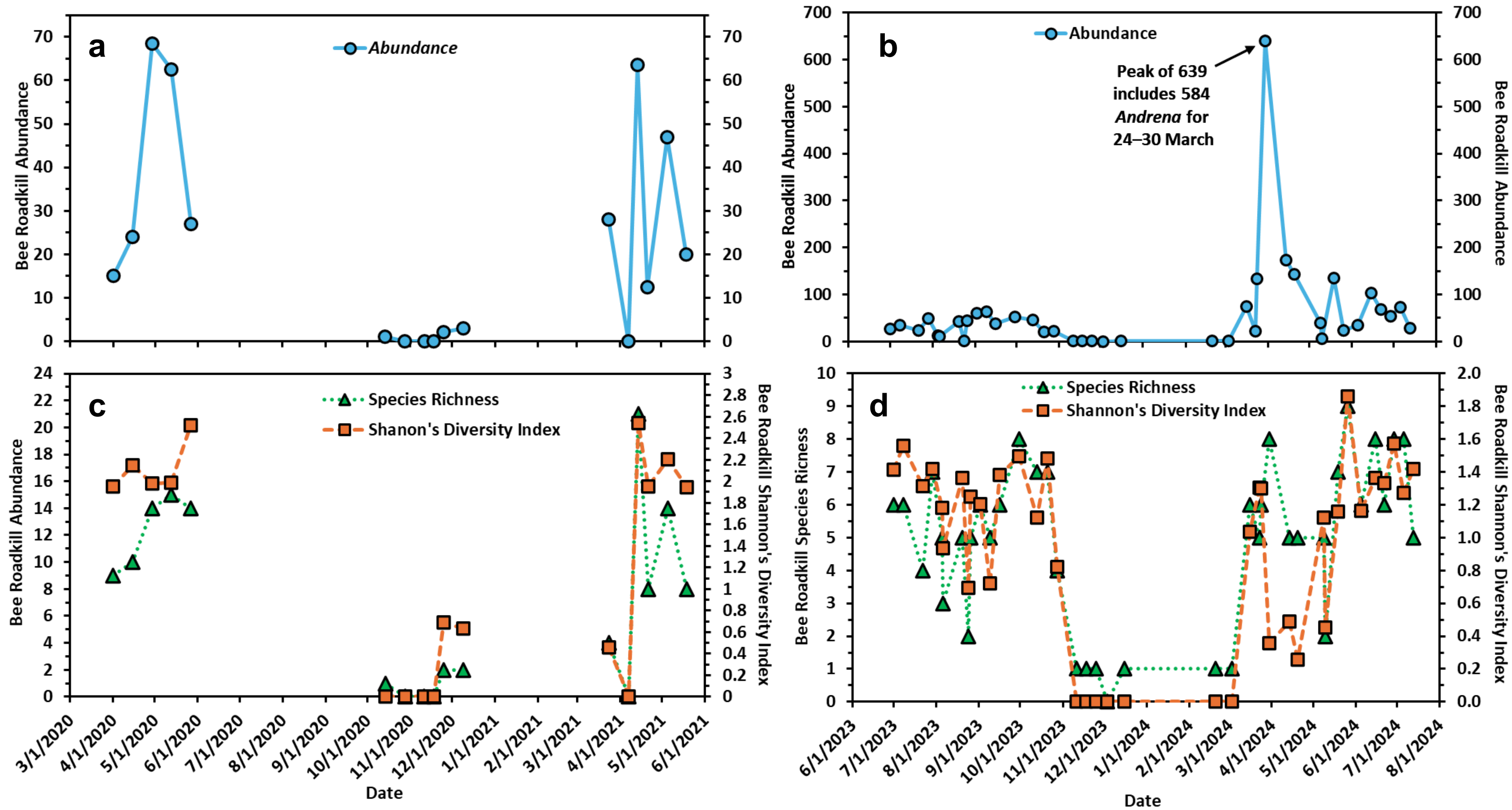

Fig. S7 Bee roadkill seasonal (a–b) abundance and (c–d) species richness and Shannon's diversity index for taxonomic units from (a,c) Texas weekly totals (this study, N = 374) and (b,d) James White Parkway Bridge, Knoxville, Tennessee (N = 2,310) (Russo 2025)

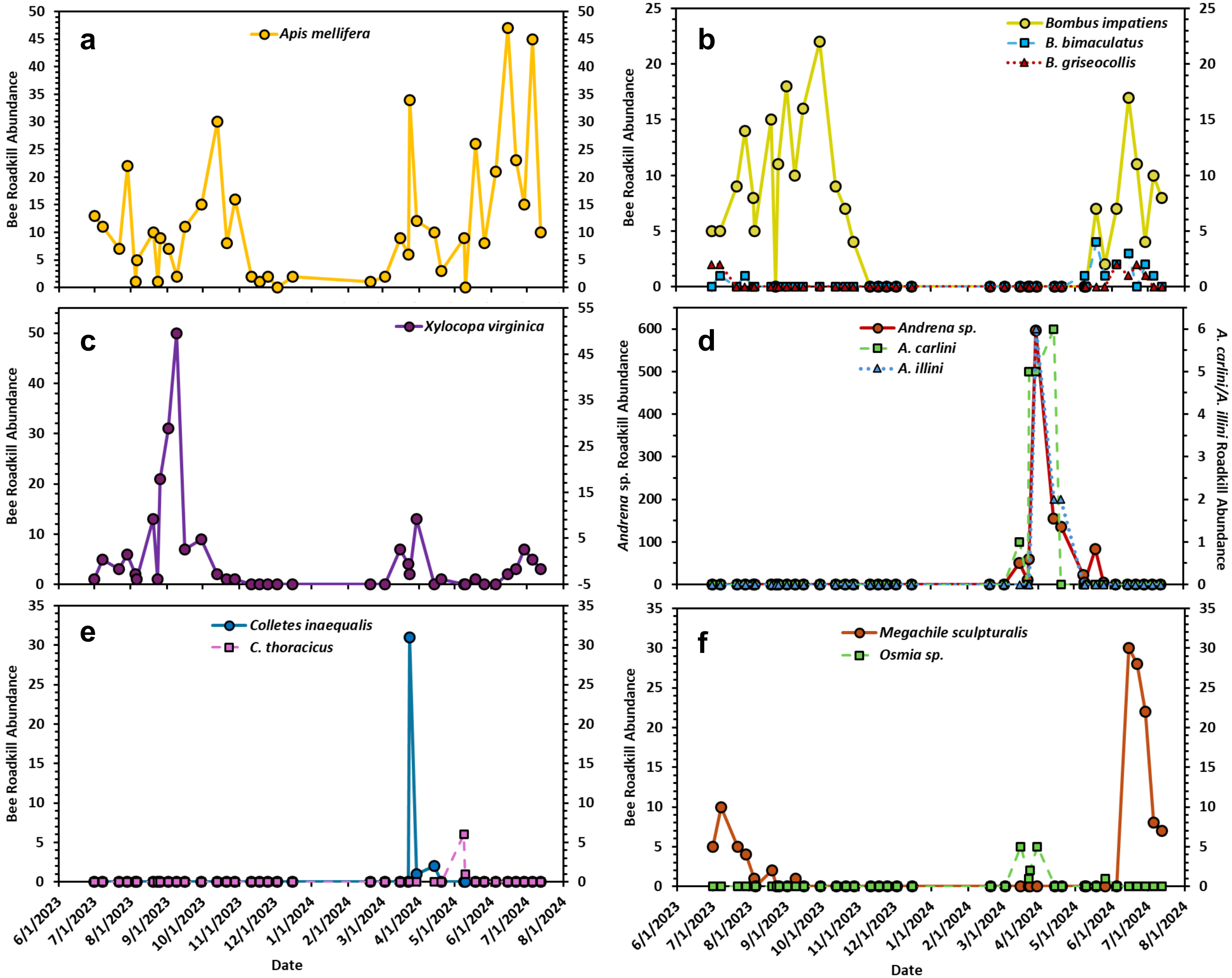

Fig. S8 Bee roadkill seasonal abundance from Knoxville, Tennessee (Russo 2025): (a) *Apis mellifera*, (b) *Bombus* spp., (c) *Xylocopa virginica*, (d) *Andrena* spp., (e) *Colletes* spp., and (f) *Megachile sculpturalis* and *Osmia* sp.

Tables

Table S1 Taxonomic authorities for insect species mentioned in manuscript or Table S4 (alphabetized by order, genus, species).

Order: Genus: Species	Family: Subfamily: Tribe
Hymenoptera (Epifamily Anthophila)	
Agapostemon angelicus Cockerell, 1924	Halictidae: Halictinae: Halictini *sensu lato*
Ag. splendens Lepeletier, 1841	Halictidae: Halictinae: Halictini *sensu lato*
Ag. texana Cresson, 1872	Halictidae: Halictinae: Halictini *sensu lato*
Apis mellifera L., 1758	Apidae: Apinae: Apini
Augochloropsis metallica (Fabricius, 1793)	Halictidae: Halictinae: Augochlorini
Bombus affinis (Cresson, 1863)	Apidae: Apinae: Bombini
B. cullumanus (Kirby, 1802)	Apidae: Apinae: Bombini
B. franklini (Frison, 1921)	Apidae: Apinae: Bombini
B. fraternus (Smith, 1854)	Apidae: Apinae: Bombini
B. griseocollis (DeGeer, 1773)	Apidae: Apinae: Bombini
B. impatiens Cresson, 1863	Apidae: Apinae: Bombini
B. pensylvanicus (DeGeer, 1773)	Apidae: Apinae: Bombini
B. sonorus Say, 1837	Apidae: Apinae: Bombini
B. suckleyi Greene, 1860	Apidae: Apinae: Bombini
B. terrestris (L., 1758)	Apidae: Apinae: Bombini
Centris atripes Mocsáry, 1899	Apidae: Apinae: Centridini
C. caesalpiniae Cockerell, 1897	Apidae: Apinae: Centridini
C. thoracicus Smith, 1853	Colletidae: Colletinae
Colletes inaequalis Say, 1837	Colletidae: Colletinae
Diadasia rinconis Cockerell, 1897	Apidae: Eucerinae: Emphorini
Dieunomia nevadensis (Cresson, 1874)	Halictidae: Nomiinae: Dieunomiini
Lithurgopsis littoralis Cockerell, 1817	Megachilidae: Lithurginae: Lithurgini
Megachile cypricola Mavromoustakis, 1938	Megachilidae: Megachilinae: Megachilini
M. inimica Cresson, 1872	Megachilidae: Megachilinae: Megachilini
M. rotundata (Fabricius, 1787)	Megachilidae: Megachilinae: Megachilini
M. sculpturalis Smith, 1853	Megachilidae: Megachilinae: Megachilini
Melissodes tristis Cockerell, 1894	Apidae: Eucerinae: Eucerini
Nomia melanderi (Cockerell, 1906)	Halictidae: Nomiinae: Nomiini
N. nortoni Cresson, 1868	Halictidae: Nomiinae: Nomiini
Osmia subfasciata, Cresson, 1872	Megachilidae: Megachilinae: Osmiini
Perdita meconis Griswold, 1993	Andrenidae: Panurginae: Panurgini
Triepeolus penicilliferus (Brues, 1903)	Apidae: Nomadinae: Epeolini
Xylocopa micans (Lepeletier, 1841)	Apidae: Xylocopinae: Xylocopinae
X. virginica L., 1977	Apidae: Xylocopinae: Xylocopinae
Lepidoptera (Superfamily Papilionoidea)	
Danaus plexippus (L. 1758)	Nymphalidae: Danainae: Danaini

Table S2 Bee genera body length ranges in North America north of Mexico for taxa found in Utah and Texas roadkill studies

	Body Length (mm)			Body Length Ranges for North	
Taxon: Family, Genus	Minimum	Maximum	Median	American Subgenera North of Mexico	References
Apidae					Michener 2007
Anthophora	6	24	15	*Anthophoroides* 10-13 mm, *Clisodon* 9-13 mm, *Heliophila* 6-10 mm, *Lophanthophora* 11-20mm, Melea 13-17 mm, *Mystacanthophora* 9-16 mm, *Paramegilla* 9.5-24 mm, *Pyganthophora* 12-16 mm	Michener 2007
Apis	10	15	12.5		LeBuhn 2013
Bombus	10	23	16.5		LeBuhn 2013
Centris	9	19	14	*Acritocentris* 15-19 mm, *Centris* 12-24 mm, *Paracentris* 9-15 mm, *Xerocentris* 9-17 mm	Michener 2007
Diadasia	5	20	12.5		Michener 2007
Melissodes	6.5	14	10.25	*Apomelissodes* 9-14 mm, *Callimelissodes* 7.5-16 mm, *Eumelissodes* 8-16 mm, *Heliomelissodes* 9-17 mm, *Melissodes* 7.5-16 mm, *Psilomelissodes* 11-13 mm, *Melissoptila* 6.5-13.5 mm	Michener 2007
Triepeolus	7	17	12		LeBuhn 2013
Xylocopa	13	30	21.5		Michener 2007; LeBuhn 2013
Halictidae					
Agapostemon	7	14	10.5		Michener 2007
Lasioglossum	3.5	11	7.25	*Dialictus* 3.5-8 mm, *Hemihalictus* 5.5-7.5 mm, *Sphecodogastra* 7-11mm	Michener 2007
Halictus	7	14	10.5	*Nealictus* 10-13 mm, *Odontalictus* 7-14 mm, *Protohalictus* 9-13 mm	Michener 2007
Sphecodes	4.5	15	9.75		Michener 2007

Table S2 Bee genera body length ranges in North America north of Mexico for taxa found in Utah and Texas roadkill studies

Taxon: Family, Genus	Body Length (mm) Minimum	Maximum	Median	Body Length Ranges for North American Subgenera North of Mexico	References
Augochloropsis	5	13	9		Michener 2007
Dieunomia	7	23	15		Michener 2007
Nomia	8	16	12	*Acunomia* 8-16 mm	Michener 2007
Andrenidae					
Andrena	3	17	10	LaBerge 1977: Thysandrena 6-11, Rhacandrena 7-10, Euandrena 6-11; Bouseman and LaBerge 1978: Melandrena 7-17; LaBerge 1980: Andrena 6.5-14; LaBerge 1985: Dactylandrena 9-13 mm, Notandrena 6-8 mm, Archiandrena 7-12 mm, Anchandrena 6-12 mm, Erandrena 9-11 mm, Belandrena 7-10mm, Iomelissa 7-11 mm, Holandrena 3-11 mm, Conandrena 8-11 mm, Genyandrena 8-10mm Oligandrena 7.5-13 mm, Augandrena 6-10mm; LaBerge 1986: Leucandrena 8-14; Ptilandrena: 6-11; LaBerge 1989: Simandrena 5-12; Thorp and LaBerge 2005a: Onagandrena 8-15 mm; Thorp and LaBerge 2005b: Heserpandrena 6-10 mm	LaBerge 1977; Bouseman and La Berge 1978; LaBerge 1980, 1985, 1986, 1989; Thorp and LaBerge 2005a, b
Perdita	2	10	6		Michener 2007
Megachilidae					
Lithurgopsis	8	19	13.5		Michener 2007
Megachile	7	20	13.5	*Argyropile* 9-16 mm, *Chelostomoides* 7-17 mm, *Leptorachis* (*M. petulans*) 8-17mm, *Litomegachile* 8-17mm, Megachile 7-20mm, *Megachiloides* 9-17mm, *Melanosarus* 10-16 mm, *Neocheylnia* 6.5-10 mm, *Pseudocentron* 8-16 mm	Michener 2007

Table S2 Bee genera body length ranges in North America north of Mexico for taxa found in Utah and Texas roadkill studies

Taxon: Family, Genus	Body Length (mm) Minimum	Maximum	Median	Body Length Ranges for North American Subgenera North of Mexico	References
Osmia	4	17	10.5	*Acanthosioides* 6-14 mm, *Cephalosmia* 8-17 mm, *Diceratosmia* 4-8 mm, *Helicosmia* 7.5-15 mm, *Melanosmia* 6-14 mm, *Mystacosmia* 8-12 mm, *Trichinosmia* 9-10 mm	Michener 2007
Anthidium	11	18	14.5	*Callanthidium* 11-18 mm	Michener 2007
Colletidae					
Colletes	7	16	11.5		Michener 2007; LeBuhn 2013
Mellitidae					
Hesperapis	4	16	10	*Amblyapis* 4-9 mm, *Carinapis* 7-16 mm, *Disparapis* 8-14 mm, *Hesperapis* 4-7 mm, *Panurgomia* 7-15 mm, *Xeralitoides* 7-10mm, *Zacesta* 4-7 mm	Michener 2007

Table S3 Bee genera median body lengths and roadkill and occurrence frequency counts in Utah and Texas study areas (Fig. S1)[a]

		Roadkill Frequency (%)		2018–2021 Occurrence Frequency (iNaturalist 2025a)			
				Raw		Normalized Human Population Sample Bias Adjusted (*HBRWtN*)[b]	
Genus	Median Body Length (mm)[a]	Utah Vehicle-Mounted Sticky Traps (Wilson et al. 2024)	Texas Roadside Transects (This Study)	Utah	Texas	Utah	Texas
Perdita	6	18 (35.3%)	0 (0.0%)	9 (0.6%)	43 (0.3%)	17.7 (0.8%)	70.9 (0.6%)
Lasioglossum	7.25	11 (21.6%)	0 (0.0%)	24 (1.6%)	120 (0.9%)	54 (2.5%)	137.9 (1.1%)
Augochloropsis	9	0 (0.0%)	9 (2.5%)	0 (0.0%)	173 (1.3%)	0 (0.0%)	169.8 (1.3%)
Andrena	9	3 (5.9%)	21 (5.8%)	3 (0.2%)	11 (0.1%)	3.9 (0.2%)	11.5 (0.1%)
Sphecodes	9.75	1 (2.0%)	0 (0.0%)	74 (5.0%)	188 (1.4%)	149.3 (7.0%)	194.6 (1.5%)
Hesperapis	10	1 (2.0%)	0 (0.0%)	0 (0.0%)	2 (0.0%)	0 (0.0%)	3.5 (0.0%)
Melissodes	10.25	4 (7.8%)	7 (1.9%)	31 (2.1%)	529 (4.0%)	40.5 (1.9%)	323.9 (2.6%)
Agapostemon	10.5	0 (0.0%)	50 (13.7%)	53 (3.6%)	309 (2.3%)	62.3 (2.9%)	423.2 (3.4%)
Halictus	10.5	1 (2.0%)	0 (0.0%)	105 (7.1%)	494 (3.7%)	89.3 (4.2%)	304.8 (2.4%)
Osmia	10.5	1 (2.0%)	9 (2.5%)	82 (5.6%)	298 (2.3%)	177.1 (8.4%)	190.3 (1.5%)
Colletes	11.5	0 (0.0%)	1 (0.3%)	6 (0.4%)	62 (0.5%)	14.5 (0.7%)	68.4 (0.5%)
Nomia	12	1 (2.0%)	2 (0.5%)	1 (0.1%)	39 (0.3%)	0.2 (0.0%)	67.2 (0.5%)
Triepeolus	12	0 (0.0%)	1 (0.3%)	7 (0.5%)	123 (0.9%)	10.9 (0.5%)	126.5 (1.0%)
Apis	12.5	5 (9.8%)	86 (23.6%)	328 (22.3%)	4,556 (34.4%)	260.9 (12.3%)	3,898.1 (31.0%)
Diadasia	12.5	2 (3.9%)	8 (2.2%)	16 (1.1%)	107 (0.8%)	32.3 (1.5%)	179.8 (1.4%)
Lithurgopsis	13.5	0 (0.0%)	2 (0.5%)	4 (0.3%)	124 (0.9%)	13.9 (0.7%)	152.9 (1.2%)
Megachile	13.5	1 (2.0%)	2 (0.5%)	76 (5.2%)	766 (5.8%)	115.1 (5.4%)	689.7 (5.5%)
Centris	14	0 (0.0%)	12 (3.3%)	0 (0.0%)	24 (0.2%)	0 (0.0%)	40.1 (0.3%)
Anthidium	14.5	1 (2.0%)	0 (0.0%)	29 (2.0%)	7 (0.1%)	19.2 (0.9%)	8.1 (0.1%)
Dieunomia	15	0 (0.0%)	2 (0.5%)	1 (0.1%)	41 (0.3%)	3.5 (0.2%)	66.3 (0.5%)
Anthophora	15	1 (2.0%)	5 (1.4%)	37 (2.5%)	168 (1.3%)	101.7 (4.8%)	242.2 (1.9%)
Bombus	16.5	0 (0.0%)	47.5 (13.0%)	474 (32.2%)	2,639 (19.9%)	830.9 (39.2%)	3,113 (24.7%)
Xylocopa	21.5	0 (0.0%)	100 (27.4%)	110 (7.5%)	2,406 (18.2%)	122 (5.8%)	2,097.1 (16.7%)
Totals		**51 (100%)**	**364.5 (100%)**	**1,470 (100%)**	**13,229 (100%)**	**2,119.1 (100%)**	**12,579.9 (100%)**

[a]Median body lengths from Table S2. Texas roadkill frequency from Table S4.

[b]Sample bias adjusted Utah and Texas data were normalized to equal the total of raw Utah and Texas data, which was 14,499.

Table S4 Texas bee (Hymenoptera: Anthophila) taxa roadkill frequency per 0.1 km transect per one side of road, roadkill percent, and estimated roadkill extrapolated along both sides roads in survey areas for combined road classes per season and year (Fig. 1a)

Roadkill Bee Taxon: Family, Subfamily, Tribe, Genus/Species (where available)	Season/Year (N transects) Roadkill Frequency; Roadkill Percent[a]; Estimated Roadkill[b] per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c] Autumn 2020 (90)	Spring 2020 (121)	Spring 2021 (188)	Total Roadkill Frequency; Total Roadkill Percent per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]
Apidae	***[5; 83.3%; 182,254]***	***[134; 68.0%; 4,095,681]***	***[130.5; 76.3%; 2,584,106]***	***[269.5; 72.1%]***
Anthophorinae, Anthophorini				
Anthophora sp.	0; 0%; 0	0; 0%; 0	5; 2.9%; 99,008	5; 1.3%
Apinae	*(4; 66.7%; 145,804)*	*(72.5; 36.8%; 2,215,947)*	*(69; 40.4%; 1,366,309)*	*(145.5; 38.9%)*
Apini				
Apis mellifera	4; 66.7%; 145,804	45; 22.8%; 1,375,415	37; 21.6%; 732,658	86; 23.0%
Bombini	{0; 0%; 0}	{21.5; 10.9%; 657,143}	{26; 15.2%; 514,841}	{47.5; 12.7%}
Bombus pensylvanicus	0; 0%; 0	11; 5.6%; 336,213	6; 3.5%; 118,809	17; 4.5%
B. griseocollis	0; 0%; 0	5; 2.5%; 152,824	8; 4.7%; 158,413	13; 3.5%
B. impatiens	0; 0%; 0	2; 1.0%; 61,130	5; 2.9%; 99,008	7; 1.9%
B. sonorus	0; 0%; 0	1.5; 0.8%; 45,847	1; 0.6%; 19,802	2.5; 0.7%
B. sp.	0; 0%; 0	2; 1.0%; 61,130	6; 3.5%; 118,809	8; 2.1%
Centridini	{0; 0%; 0}	{6; 3.0%; 183,389}	{6; 3.5%; 118,809}	{12; 3.2%}
Centris atripes	0; 0%; 0	0; 0%; 0	3; 1.8%; 59,405	3; 0.8%
C. caesalpiniae	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
C. sp.	0; 0%; 0	6; 3.0%; 183,389	2; 1.2%; 39,603	8; 2.1%
Eucerinae	*(0; 0%; 0)*	*(7; 3.6%; 213,953)*	*(10; 5.8%; 198,016)*	*(17; 4.5%)*
Emphorini	{0; 0%; 0}	{4; 2.0%; 122,259}	{4; 2.3%; 79,206}	{8; 2.1%}
Diadasia rinconis	0; 0%; 0	3; 1.5%; 91,694	0; 0%; 0	3; 0.8%
Dia. sp.	0; 0%; 0	1; 0.5%; 30,565	4; 2.3%; 79,206	5; 1.3%
Eucerini	{0; 0%; 0}	{3; 1.5%; 91,694}	{6; 3.5%; 118,809}	{9; 2.4%}
Melissodes tristis	0; 0%; 0	2; 1.0%; 61,130	0; 0%; 0	2; 0.5%

Table S4 Texas bee (Hymenoptera: Anthophila) taxa roadkill frequency per 0.1 km transect per one side of road, roadkill percent, and estimated roadkill extrapolated along both sides roads in survey areas for combined road classes per season and year (Fig. 1a)

Roadkill Bee Taxon: Family, Subfamily, Tribe, Genus/Species (where available)	Season/Year (N transects) Roadkill Frequency; Roadkill Percent[a]; Estimated Roadkill[b] per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]			Total Roadkill Frequency; Total Roadkill Percent per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]
	Autumn 2020 (90)	Spring 2020 (121)	Spring 2021 (188)	
Mel. sp.	0; 0%; 0	0; 0%; 0	5; 2.9%; 99,008	5; 1.3%
Eucerini sp.	0	1; 0.5%; 30,565	1; 0.6%; 19,802	2; 0.5%
Nomadinae, Epeolini	*(0; 0%; 0)*	*(1; 0.5%; 30,565)*	*(1; 0.6%; 19,802)*	*(2; 0.5%)*
Triepeolus penicilliferus	0; 0%; 0	1; 0.5%; 30,565	0; 0%; 0	1; 0.3%
Epeolini sp.	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
Xylocopinae, Xylocopini	*(1; 16.7%; 36,451)*	*(53.5; 27.2%; 1,635,216)*	*(45.5; 26.6%; 900,972)*	*(100; 26.7%)*
Xylopcopa micans	0; 0%; 0	24.5; 12.4%; 748,837	4; 2.3%; 79,206	28.5; 7.6%
X. virginica	1; 16.7%; 36,451	27; 13.7%; 825,249	38.5; 22.5%; 762,361	66.5; 17.8%
X. sp.	0; 0%; 0	2; 1.0%; 61,130	3; 1.8%; 59,405	5; 1.3%
Halictidae	***[1; 16.7%; 36,451]***	***[42; 21.3%; 1,283,721]***	***[25.5; 14.9%; 504,940]***	***[68.5; 18.3%]***
Halictinae	*(0; 0%; 0)*	*(37; 18.8%; 1,130,897)*	*(22; 12.9%; 435,635)*	*(59; 15.8%)*
Halictini *sensu lato*	{0; 0%; 0}	{32; 16.2%; 978,073}	{18; 10.5%; 356,428}	{50; 13.4%}
Agapostemon angelicus/*Ag. texanus*	0; 0%; 0	28; 14.2%; 855,814	17; 9.9%; 336,627	45; 12.0%
Ag. splendens	0; 0%; 0	3; 1.5%; 91,694	1; 0.6%; 19,802	4; 1.1%
Ag. sp.	0; 0%; 0	1; 0.5%; 30,565	0; 0%; 0	1; 0.3%
Augochlorini	{0; 0%; 0}	{5; 2.5%; 152,824}	{4; 2.3%; 79,206}	{9; 2.4%}
Augochloropsis metallica	0; 0%; 0	5; 2.5%; 152,824	0; 0%; 0	5; 1.3%
Au. sp.	0; 0%; 0	0; 0%; 0	4; 2.3%; 79,206	4; 1.1%
Nomiinae, Dieunomiini	*(0; 0%; 0)*	*(3; 1.5%; 91,694)*	*(1; 0.6%; 19,802)*	*(4; 1.1%)*
Dieunomia nevadensis	0; 0%; 0	2; 1.0%; 61,130	0; 0%; 0	2; 0.5%
Nomiini	{0; 0%; 0}	{1; 0.5%; 30,565}	{1; 0.6%; 19,802}	{2; 0.5%}
Nomia nortoni	0; 0%; 0	1; 0.5%; 30,565	0; 0%; 0	1; 0.3%

Table S4 Texas bee (Hymenoptera: Anthophila) taxa roadkill frequency per 0.1 km transect per one side of road, roadkill percent, and estimated roadkill extrapolated along both sides roads in survey areas for combined road classes per season and year (Fig. 1a)

Roadkill Bee Taxon: Family, Subfamily, Tribe, Genus/Species (where available)	Season/Year (N transects) Roadkill Frequency; Roadkill Percent[a]; Estimated Roadkill[b] per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]			Total Roadkill Frequency; Total Roadkill Percent per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]
	Autumn 2020 (90)	Spring 2020 (121)	Spring 2021 (188)	
N. sp.	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
Unidentified Subfamily				
Halictidae sp.	1; 16.7%; 36,451	2; 1.0%; 61,130	2.5; 1.5%; 49,504	5.5; 1.5%
Andrenidae	***[0; 0%; 0]***	***[11; 5.6%; 336,213]***	***[11; 6.4%; 217,817]***	***[22; 5.9%]***
Andreninae				
Andrena sp.	0; 0%; 0	11; 5.6%; 336,213	10; 5.8%; 198,016	21; 5.6%
Unidentified Subfamily				
Andrenidae sp.	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
Megachilidae	***[0; 0%; 0]***	***[10; 5.1%; 305,648]***	***[3; 1.8%; 59,405]***	***[13; 3.5%]***
Lithurginae, Lithurgini				
Lithurgopsis littoralis	0; 0%; 0	1; 0.5%; 30,565	1; 0.6%; 19,802	2; 0.5%
Megachilinae	*(0; 0%; 0)*	*(9; 4.6%; 275,083)*	*(2; 1.2%; 39,603)*	*(11; 2.9%)*
Megachilini	{0; 0%; 0}	{1; 0.5%; 30,565}	{1; 0.6%; 19,802}	{2; 0.5%}
Megachile inimica	0; 0%; 0	1; 0.5%; 30,565	0; 0%; 0	1; 0.3%
Meg. sp.	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
Osmiini	{0; 0%; 0}	{8; 4.1%; 244,518}	{1; 0.6%; 19,802}	{9; 2.4%}
Osmia subfasciata	0; 0%; 0	5; 2.5%; 152,824	0; 0%; 0	5; 1.3%
O. texana	0; 0%; 0	1; 0.5%; 30,565	0; 0%; 0	1; 0.3%
O. sp.	0; 0%; 0	2; 1.0%; 61,130	1; 0.6%; 19,802	3; 0.8%
Colletidae	***[0; 0%; 0]***	***[0; 0%; 0]***	***[1; 0.6%; 19,802]***	***[1; 0.3%]***
Colletes sp.	0; 0%; 0	0; 0%; 0	1; 0.6%; 19,802	1; 0.3%
Unidentified Family				
Anthophila sp.[a]	0	1	0	1

Table S4 Texas bee (Hymenoptera: Anthophila) taxa roadkill frequency per 0.1 km transect per one side of road, roadkill percent, and estimated roadkill extrapolated along both sides roads in survey areas for combined road classes per season and year (Fig. 1a)

Roadkill Bee Taxon: Family, Subfamily, Tribe, Genus/Species (where available)	Season/Year (N transects) Roadkill Frequency; Roadkill Percent[a]; Estimated Roadkill[b] per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c] Autumn 2020 (90)	Spring 2020 (121)	Spring 2021 (188)	Total Roadkill Frequency; Total Roadkill Percent per Smallest Taxon ***[per Family]*** *(per Subfamily)* {Per Tribe}[c]
Totals from Smallest Taxa	**[6; 100%; 218,705]**	**[197; 100%; 6,021,262]**	**[171; 100%; 3,386,070]**	**[374; 100%]**
	Spring-Autumn 2020			
2020 Totals	**203; 100%; 6,696,345** (from Table 1)			

[a]Single unidentified bee (Anthophila) from spring 2021 not included in percentage calculations, estimated roadkill, or totals.
[b]Roadkill estimated from multiplying (Percentage Roadkill per Bee Taxon) x (Overall Mean Bee Roadkill per Side of 0.1 km Roadside Transect from Table 1) x (2 Sides per Road) x (10 Sides of 0.1 km per Kilometers of Road) x (Total Kilometers of Surveyed Road Classes in Survey Area from Table 2). Roadkill per kilometer for each taxon can be estimated by dividing (Roadkill Frequency) / (Number of Transects per Season) and then multiplying by (2 Sides per Road) x (10 Sides of 0.1 km per Kilometers of Road). For example, Spring 2020 roadkill per kilometer for *B. pensylvanicus* is (11/121)*2*10 = 1.82.
[c]Subtotals for various taxa categories are only given if there is more than one taxon in their subcategories.

Table S5 Bee and bumblebee community species abundance, species richness and Shannon's Diversity in various habitats over US[a]

Taxa/ Sample Method[b]	Location	Habitat	Period	Sample Locations (n)	% Bees Identified to Species (% Identified to Genus)[c]	Community Characteristic Range (Average): Abundance (N)	Species Richness (*S*)	Shannon's Diversity (*H′*)	Source
Bees									
Blue Vane Traps	Pikes Peak Forest Dynamics Plot, Colorado	Montane Forest	20 April–4 Sep 2017 (four 3–6 day periods)	1 (pooled over 4 periods)	73% (100%)	934	41	2.53	Table 1 of Rhoades et al. 2018
Bowl Traps	TNC Boardman Grasslands Preserve, Oregon	Arid Grassland	June–Sep 2014–2016 (2 mos. periods, except June–July 2014)	18 (pooled over 8 periods)	68% (100%)	839-3,254 (1,624.5)	13-32 (22.9)	0.7-1.4 (1.2)	Tables 1, S1 of Smith DiCarlo et al. 2018
Bowl Traps	Boise Mountain, Boise National Forest, Idaho	Montane Forest	July 2016, 2018	2 (pooled over 2 periods)	72% (100%)	119-345 (232)	17-38 (27.5)	2.99-3.44 (3.22)	Table 2 of Foote et al. 2020
Bowl Traps	Central Iowa	Soybean and Fruit/ Vegetable Farms	1 July–24 Sep 2015, 15 June–9 Sep 2016	2 (pooled over 2 periods)	100% (100%)	335-1,102 (718.5)	32-36 (34)	2.24-2.54 (2.4)	Table S3 of St. St. Claire et al. 2020
Netting and Bowl Traps	Southern Iowa/ Northern Missouri	Grass-lands	Late May–Early August 2015–2016	3 grassland types (pooled 4 sites each)	69% (100%)	291–625 (454)	26–41 (34.7)	2.28–2.37 (2.32)	Supplemental Table 1 of Stein et al. 2020
Netting and Bowl Traps	Chicago, Illinois	Urban/ Suburban	June–Aug 2018 (four samples each urban vs suburban)	2 (pooled sites over 4 periods)	93% (100%)	1,073-1,280 (1,176.5)	55-71 (63)	2.95-3.54 (3.25)	Table S4 of Gruver and CaraDonna 2021
Netting and Blue Vane Traps	Western South Carolina	Peach Orchards	Early March–First Week April 2021, 2022	2 (pooled over 2 periods)	100% (100%)	273-378 (325.5)	15-20 (17.5)	1.76-2.29 (2.03)	Table 1 of Tayal et al. 2025
Overall Range (Overall Average) of Averages (n = 7)					**% Species: 68%–100% (82.1%)**	**232–1,264.5 (5,465)**	**17.5–63 (34.37)**	**1.2–3.25 (2.42)**	

Table S5 Bee and bumblebee community species abundance, species richness and Shannon's Diversity in various habitats over US[a]

Taxa/ Sample Method[b]	Location	Habitat	Period	Sample Locations (n)	% Bees Identified to Species (% Identified to Genus)[c]	Community Characteristic Range (Average) Abundance (N)	Species Richness (*S*)	Shannon's Diversity (*H'*)	Source
Bumblebees									
Netting	15 US States	Agricul-tural to Semi-natural	26 June – 10 Aug, 2015	31	100% (100%)	78–163 (105.0)	2–9 (5.0)	0.05–2.01 (0.96)	Appendix 3 Table of Strange and Tripodi 2018
Netting and Release/Field Identification/ Photography	Minneapolis-St. Paul Metropolitan Area, Minnesota	Roadsides	6 visits, 15–30 August 2018	78 (with bees)	86% (100%)	5,304	13	1.5	Table 2-1 of Evans et al. 2019
Netting and Release/Field Identification/ Photography	Southern Minnesota	Roadside Vegeta-tion	18 May–24 Aug 2021	3 vegetation types (pooled 19 sites each)	85% (100%)	205-993 (527.7)	9-10 (9.3)	1.37-1.66 (1.55)	Table S1 of Darst et al. 2023

[a]Species abundance, species richness, and Shannon's Diversity based on smallest identified taxonomic units. Calculations from provided lists of counts for all species/taxonomic units.
[b]Dependent on habitat type, bowl traps often favor detecting more species of Halictidae and sometimes Megachilidae, and sometimes disfavor detecting species of Apidae (Larson et al. 2024).
[c]Genera with individuals that were often difficult to identify to species included *Lasioglossum*, *Andrena*, *Melissodes*, *Nomada*, and *Agapostemon*.