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Elevated extinction risk in over one-fifth of native North American pollinators

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Pollinators are critical for food production and ecosystem function. Although native pollinators are thought to be declining, the evidence is limited. This first, taxonomically diverse assessment for mainland North America north of Mexico reveals that 22.6% (20.6 to 29.6%) of the 1,579 species in the best-studied vertebrate and insect pollinator groups have elevated risk of extinction. All three pollinating bat species are at risk and bees are the insect group most at risk (best estimate, 34.7% of 472 species assessed, range 30.3 to 43.0%). Substantial numbers of butterflies (19.5% of 632 species, range 19.1 to 21.0%) and moths (16.1% of 142 species, range 15.5 to 19.0%) are also at risk, with flower flies (14.7% of 295 species, range 11.5 to 32.9%), beetles (12.5% of 18 species, range 11.1 to 22.2%), and hummingbirds (0% of 17 species) more secure. At-risk pollinators are concentrated where diversity is highest, in the southwestern United States. Threats to pollinators vary geographically: climate change in the West and North, agriculture in the Great Plains, and pollution, agriculture, and urban development in the East. Woodland, shrubland/chaparral, and grassland habitats support the greatest numbers of at-risk pollinators. Strategies for improving pollinator habitat are increasingly available, and this study identifies species, habitats, and threats most in need of conservation actions at state, provincial, territorial, national, and continental levels.

at-risk species | climate change | conservation status | threats to biodiversity | insects

Pollinating insects provide over \$15 billion of value annually to agriculture in North America (1), and together with hummingbirds and nectar-feeding bats are critical to maintaining natural ecosystems (2). Nonetheless, there is increasing evidence of general pollinator (defined as consumers of floral resources that transfer pollen) declines, and pollinating insects are among the groups most impacted by widespread insect declines (3–5). Factors implicated in pollinator declines include habitat loss, pesticide exposure, climate change, and disease (6–10). However, the taxonomic and geographic patterns of these threats to pollinators are not well understood. Further, studies of single species (11, 12) or clades (8, 13–16) as well as national and global assessments of pollinator status are taxonomically restricted with limited species-specific data (2, 17, 18).

Knowing which species are declining, where they occur, and why they are declining is critical for focusing management interventions where they will most benefit at-risk species. Yet to date, few native insect pollinators of North America other than bumble bees (*Bombus* spp., Hymenoptera) and butterflies (Lepidoptera) have been assessed for extinction risk. Lack of species status information prevents inclusion on federal threatened and endangered or species-at-risk lists as well as State Wildlife Action Plans (SWAPs), federally mandated, state-level strategies for protecting species and habitats in the United States (19, 20).

Standardized, long-term, and geographically broad monitoring data to support status assessments are absent for most North American pollinators, especially insects (5, 21), and may never become widely available (16). Instead, researchers have leveraged recent advances in the availability of digitized locality records, driven by databasing of museum collections and citizen science initiatives, to assess pollinator species status (20, 22). Approaches to status assessments generally fall into two classes: a) reporting trends in populations or distribution using locality and monitoring data (8, 10, 13, 23) or b) using extinction risk assessment methods such as the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (24) or NatureServe conservation status ranks (25) to combine information on rarity, trends, and threats to assign species to risk categories (22, 26). The former method has the advantage of providing a quantitative output whereas the latter method results in categories such as “Vulnerable” that are familiar and understood by policy makers and the public. Further, the flexible data

Significance

Pollinators are critical to maintaining terrestrial ecosystem function and the global food supply, but many are in decline. However, we have limited information identifying which species are at elevated extinction risk, limiting efforts to prioritize scarce conservation resources. We assessed the extinction risk of nearly 1,600 species of vertebrate and insect pollinators and found that more than one in five species is at risk of extinction. The major threats are climate change, agriculture, modifications to hydrological and fire regimes, and housing and urban development. These results can inform management actions to help prevent pollinator extinctions.

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requirements for extinction risk assessments can broaden the number of species that are assessable (27).

To understand better the status of North American pollinators and identify species and groups most in need of conservation action, we assessed the extinction risk of 1,579 native vertebrate and insect pollinators in mainland North America north of Mexico. We used the NatureServe ranking methodology, which has been widely adopted by US and Canadian governments (28–30), to maximize policy relevance. To provide context to help focus local and regional conservation actions, we examined state, provincial, and territorial distributions, threats, and habitat associations of each species at risk of extinction. This study is the largest, most taxonomically diverse assessment of mainland US and Canadian pollinators to date, including two vertebrate classes and four insect orders.

Results

The taxonomic groups sufficiently well known to allow comprehensive assessment comprised 0.6% (beetles)—100% (butterflies) of the estimated total species in each major grouping (Table 1). Evaluation of these species resulted in a best estimate that 22.6% (range, 20.6 to 29.6%) of assessed pollinators are at an elevated risk of extinction (i.e., those classified as Vulnerable, Imperiled, Critically Imperiled, or Historical; hereafter, “at risk;” Table 1 and *SI Appendix, Table S1*). Bees had more threatened species than other groups, with 34.7% at elevated extinction risk (range, 30.3 to 43.0%). Leafcutter (*Megachile*; 45.7% at risk, range 41.7 to 50.4%) and digger (Anthophorinae; 42.9% at risk, range 38.6 to 48.6%) bees were the most threatened bee groups assessed (Table 1). Of the 632 assessed butterflies, 19.5% (range 19.1 to

Table 1. Extinction risk of US and Canadian pollinators by taxonomic group and global conservation status rank: GH = Possibly Extinct; G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure; GU = Data Deficient

Group	Number assessed (Estimated % of total in group)	GU	G5	G4	G3	G2	G1	GH	At-risk lower est.	At-risk best est.	At-risk upper est.
Vertebrates	20 (66.7–94.1%)	0	16	1	3	0	0	0	15.0%	15.0%	15.0%
Hummingbirds	17	0	16	1	0	0	0	0	0.0%	0.0%	0.0%
Bats	3	0	0	0	3	0	0	0	100%	100%	100%
Butterflies	632 (100%)	12	336	163	81	29	11	0	19.1%	19.5%	21.0%
Metalmarks	21	3	7	5	5	1	0	0	28.6%	33.3%	42.9%
Gossamerwings	141	2	52	48	24	10	5	0	27.7%	28.1%	29.1%
Skippers	219	4	102	59	38	13	3	0	24.7%	25.1%	26.5%
Brushfoots	164	3	115	30	11	3	2	0	9.8%	9.9%	11.6%
Swallowtails	24	0	19	3	0	1	1	0	8.3%	8.3%	8.3%
Whites	63	0	41	18	3	1	0	0	6.3%	6.3%	6.3%
Macro-moths	142 (10.3–19.9%)	5	83	32	16	4	2	0	15.5%	16.1%	19.0%
Tiger and Underwing	51	1	30	9	8	3	0	0	21.6%	22.0%	23.5%
Sphinx	88	4	50	23	8	1	2	0	12.5%	13.1%	17.0%
Notodontid	2	0	2	0	0	0	0	0	0.0%	0.0%	0.0%
Borer	1	0	1	0	0	0	0	0	0.0%	0.0%	0.0%
Bees	472 (13.1%)	60	132	137	77	40	10	16	30.3%	34.7%	43.0%
Bumble	51	2	20	10	12	4	3	0	37.3%	38.8%	41.2%
Carpenter	9	0	7	2	0	0	0	0	0.0%	0.0%	0.0%
Leafcutter	127	11	33	30	19	16	2	16	41.7%	45.7%	50.4%
Digger	70	7	11	25	16	11	0	0	38.6%	42.9%	48.6%
Wool-carder	33	0	13	7	9	3	1	0	39.4%	39.4%	39.4%
Mason	139	36	28	52	13	6	4	0	16.5%	22.3%	42.4%
Squash	11	2	4	3	2	0	0	0	18.2%	22.2%	36.4%
Sweat	32	2	16	8	6	0	0	0	18.8%	20.0%	25.0%
Beetles	18 (0.6 to 0.7%)	2	7	7	2	0	0	0	11.1%	12.5%	22.2%
Checkered	10	2	2	5	1	0	0	0	10.0%	12.5%	30.0%
Hairy Flower Scarab	8	0	5	2	1	0	0	0	12.5%	12.5%	12.5%
Flower Flies	295 (40.4%)	63	107	91	29	4	0	1	11.5%	14.7%	32.9%
Eristalinae	295	63	107	91	29	4	0	1	11.5%	14.7%	32.9%
Total	1579	142	681	431	208	77	23	17	20.6%	22.6%	29.6%

Species referred to as GH to G3 are considered at risk. The best estimate (est.) of the percent of species that are at risk was the sum of GH, G1, G2, and G3 species divided by the total number of species less the number of GU species. The upper estimate of the percent at risk assumed that all GU species were at risk whereas the lower estimate assumes that none of the GU species were at risk.

21.0%) were at risk—slightly more than half the rate for bees (Table 1). Other insect groups had lower proportions of at-risk species: macro-moths, e.g., moth families with larger sized species, 16.1% (range, 15.5 to 19.0%); flower flies (Syrphidae: Eristalinae), 14.7% (range, 11.5 to 32.9%); and beetles (genera *Trichodes* and *Trichiotinus*), 12.5% (range, 11.1 to 22.2%) (Table 1). Among assessed vertebrates, all pollinating bats were at risk whereas no hummingbirds were so classified (three species have undergone long-term population decline (31) but not rapidly enough to qualify for at-risk status).

Ten bee, 11 butterfly, and two moth species were classified as critically imperiled. No pollinator assessed in this study is confidently known to be globally extinct.

All but 19 of the 1,579 species assessed regularly occur in the mainland US, and thus, the percent of species at risk there mirrors the overall results: 22.5% of all pollinators are at risk (range, 20.6 to 29.2%). The ranges of 759 assessed pollinators include Canada, where the percent at risk is much lower at 10.2% (range 9.6 to 15.2%). Full group results by nation are provided in *SI Appendix, Table S1*.

Compared to other groups of plants and animals in the mainland United States and Canada, there were proportionately more at-risk pollinator species than in birds, mammals, and squamate reptiles, but proportionately fewer at-risk species than in flowering plants and all freshwater animal groups, except damselflies and dragonflies (Fig. 1). Bees overall had about the same percentage of at-risk species as freshwater fish. However, even the most threatened bee groups, the digger and leafcutter bees, with nearly half of the species at risk, were proportionately less imperiled than freshwater and terrestrial mollusks. The pollinator group with the lowest percent threatened species (other than hummingbirds), the

beetles, had a greater percentage of at-risk species than as found in birds, albeit with greater uncertainty due to a greater percentage of Data-Deficient species.

Species richness of the pollinator groups assessed was highest in California (678 species), Arizona (677), Texas (593), New Mexico (579), and Colorado (560; Fig. 2, *SI Appendix, Table S2*). This pattern was driven by the large diversity of butterflies and bees in these states (Fig. 2). Moths had the highest species richness in Texas (84 species). Flower flies differ from other pollinator groups assessed in that they were most diverse in southern Canada. In Canada, the most species-rich province from our sample of pollinators was British Columbia (487 species; Fig. 2). Similar to overall pollinator species richness, at-risk species richness was highest in California, Arizona, and Nevada (Fig. 2). Species richness was closely correlated with the percentage of at-risk species at the state, provincial, and territorial level (*SI Appendix, Fig. S1 and Table S2*). Further, species with smaller range extents, a factor associated with higher extinction risk, were more prevalent in subnations with greater species richness (*SI Appendix, Fig. S2*); this relationship likely at least partially explains the positive correlation between species richness and percentage of at-risk species.

Threats from climate change, agriculture, modifications to hydrological and fire regimes, and housing and urban development affected the greatest number of at-risk pollinators (Fig. 3A). The primary threat varied by pollinator group, with agriculture, climate change, and development as the top threats to bees and climate change, modifications to hydrological and fire regimes, and invasive species as the top threats to butterflies and moths (Fig. 3B and C). Different regions varied markedly in the primary threat identified as afflicting pollinators: climate change was the top state, provincial,

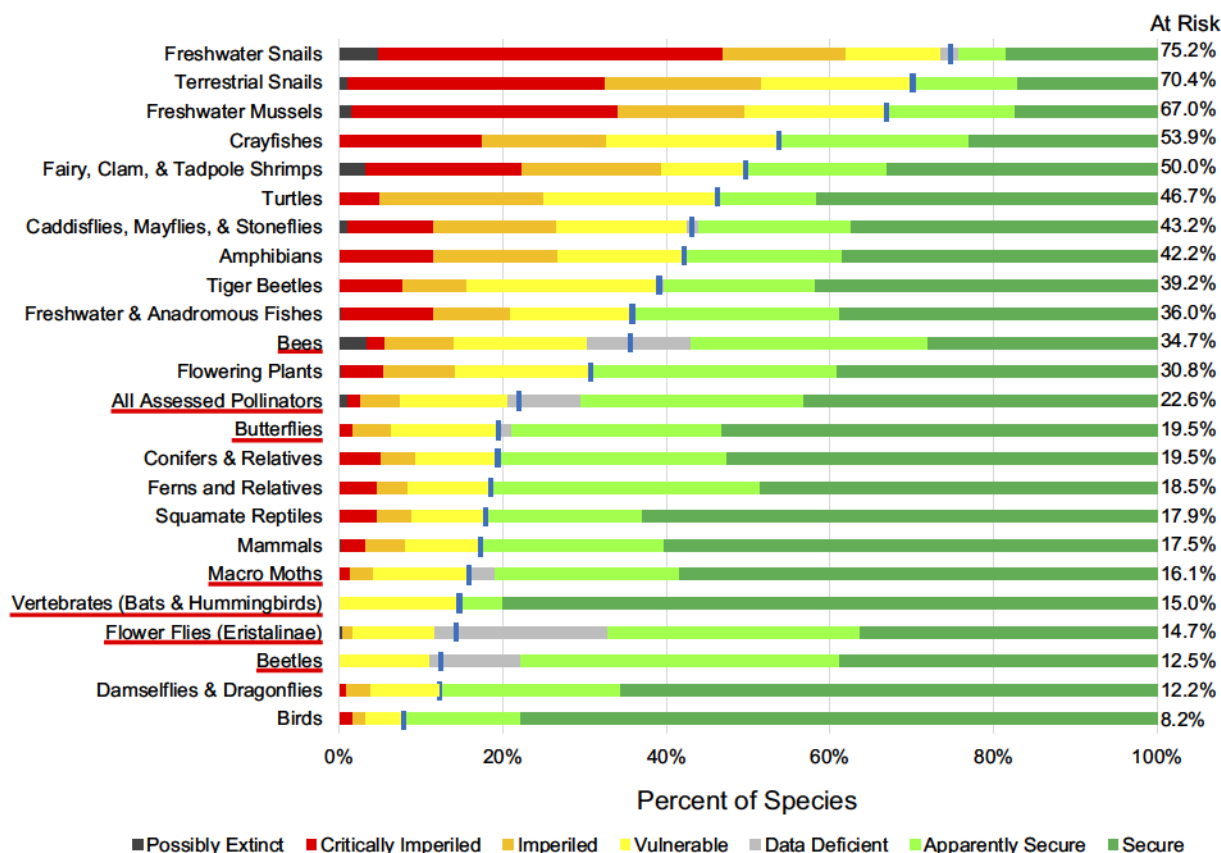


Fig. 1. Threat status of US and Canadian pollinators compared to other groups of animals and plants that have been comprehensively assessed from those with the highest to lowest percent of species at risk. Groups underlined in red are pollinators assessed in this study and include only species considered potential pollinators. Vertical blue lines indicate the best estimates of the percent of species in a group that are at risk of extinction, assuming that data-deficient species are imperiled at the same rate as data-sufficient species.

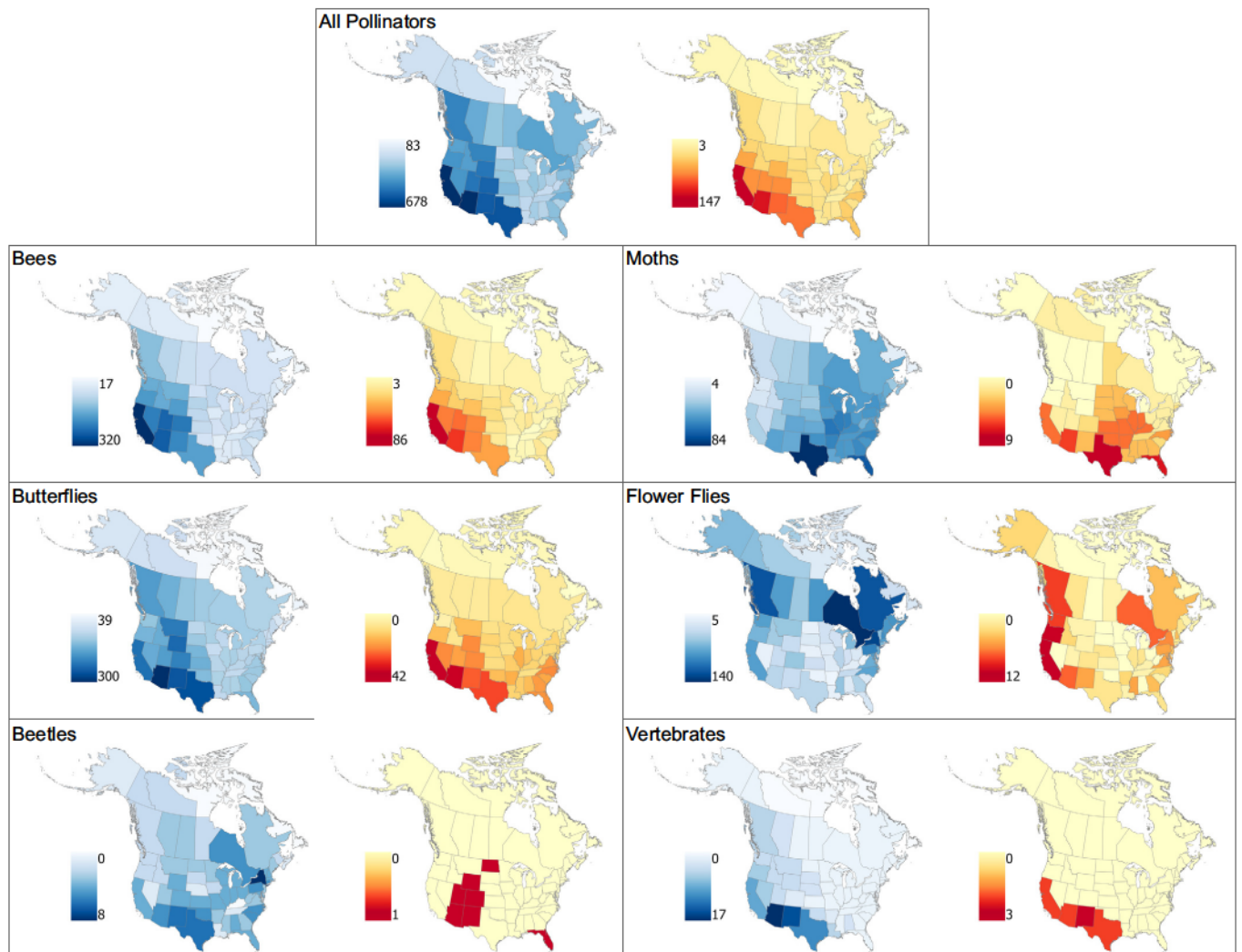


Fig. 2. Species richness (blue color maps) and richness of at-risk species (yellow-red color maps) of major pollinator groups. Note that scales vary across taxa. Maps created in ArcGIS.

or territorial level threat to at-risk pollinators in the western and northern regions, agriculture and climate change in the Rocky Mountains and Great Plains; and a mix of pollution, housing and urban development, and agriculture were the top threats in the eastern United States. (Fig. 3D). At-risk species were most likely to inhabit woodland (25 to 60% canopy cover), grassland, and shrubland/chaparral habitats, and least likely to be found in forests (> 60% canopy cover) and alpine/tundra habitats (See *Materials and Methods* for habitat definitions; *SI Appendix*, Fig. S3).

Discussion

Conservation Status of Pollinators in the United States and Canada. With the most taxonomically diverse and largest number of species assessed to date, this study helps clarify the extinction risk context for pollinators in the mainland United States and Canada. We found that more than one in five pollinators has an elevated risk of extinction with bats, bees, butterflies, and moths the most at risk. These findings expand the taxonomic breadth of previous assessments that focused primarily on bumble bees, butterflies, and moths, where researchers have documented declines at state (32, 33), regional (8, 16, 34), and continental scales (13, 23).

At-risk pollinators assessed in our study were concentrated in the southern and southwestern United States. In contrast, we found

relatively low levels of imperilment of non-*Bombus* bees in the eastern United States, corresponding with previous studies that have suggested that non-*Bombus* bees are less threatened in this region (34, 35). These findings are somewhat surprising in that the most degraded habitats in the mainland United States and Canada are in the Upper Midwest and along the Atlantic Coast, whereas some of the most intact habitat occurs in the Sonoran and Mojave Deserts (36), areas where we found pollinators were most at-risk. Two factors are likely at play. First, range extent, both an important factor in status assessments as well as a correlate of imperilment (27), tends to be smaller for the highly diverse pollinator faunas in the subnations with the greatest proportion of at-risk species (37) (*SI Appendix*, Fig. S2). Second, the most frequently cited threat to at-risk pollinators in the Southwestern states is climate change. Higher temperatures and extended droughts can impact even unaltered ecosystems (38). Insects, including pollinators, are particularly susceptible to these changes due to their small body size and ectothermic physiology (5, 39).

This study also places pollinators on the spectrum of imperilment in the wider biodiversity crisis. Outside of pollinating bats, with just three species (all Vulnerable) that represent the northern edge of a more diverse tropical fauna, the group with the highest portion of at-risk species was bees. Despite their high level of imperilment, bees had a lower percentage of at-risk species than

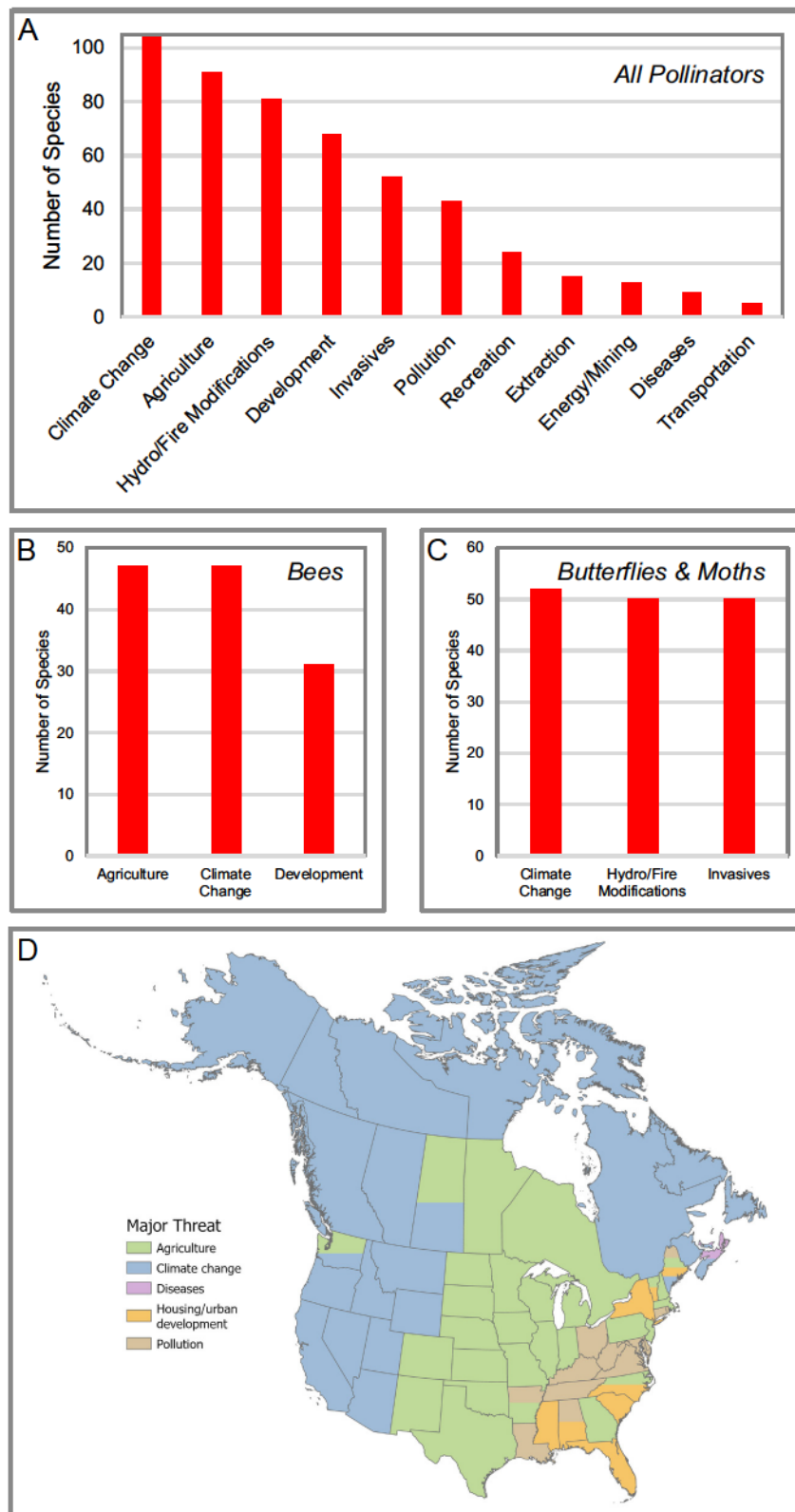


Fig. 3. Threats to pollinators. (A) Threats affecting at-risk pollinators as identified by experts (species can be affected by >1 threat). (B) Top three threats to bees. (C) Top three threats to butterflies and moths. (D) Threat affecting the greatest number of species in each state, province, or territory. Multiple colors in a state, province, or territory indicate ties. Map created in ArcGIS.

most freshwater invertebrates and vertebrates, especially mollusks, which have suffered numerous extinctions over the past century (40) (Fig. 1). However, butterflies, and the moth and bee taxa we assessed had a higher percentage of at-risk species than in birds, mammals, and reptiles, groups that receive much higher levels of

Endangered Species Act funding (41). This is especially concerning because, in addition to the high numbers of currently at-risk species, recent reports have documented declines in previously common insect species in these groups (8, 42, 43). Large-scale assessments of the conservation status of groups, as we have done

here for pollinators, are a key prioritization action for insect conservation and recovery (44).

Threats to Pollinators and Their Habitats. Threats to assessed pollinators are diverse, compounding, and include many of the same pressures long known to threaten US biodiversity (7, 42, 45). Loss and degradation of habitat caused by conversion of native habitats to agriculture, invasive plant species, and modifications of fire regimes combine to threaten many central mainland US and Canadian pollinators. Land use changes caused by urbanization similarly cause habitat loss for many pollinators. Pollution, mostly in the form of pesticides applied to crops, is increasingly recognized as a major threat to pollinators in agricultural regions (9, 10).

Many of these threats cause losses of both diverse floral resources and host plants vital for pollinator health and reproduction (3, 5–7, 42, 46). At-risk species were most likely to be found in woodland, grassland, and shrubland/chaparral habitats. These habitat types are often heterogeneous and home to higher plant and pollinator diversity but are also ecosystems that have experienced a high degree of modification and loss (5, 47).

A late Twentieth-century assessment of threats to biodiversity in the United States presciently predicted that climate change would become a major threat (45). That is now the case with pollinators, for which climate change affects more at-risk species than any other threat. Bumble bee and butterfly declines, in particular, have been linked to climate change, especially in the southwestern United States and Canada (8, 23, 48). Climate change can affect insect pollinators in many ways, including physiological stress, developmental costs, shifts in where suitable climate regimes occur, phenological adjustments (which may not be synced with shifts in required plant resources), and reproductive declines, and the development of management responses to these stresses is in its infancy (39).

Caveats. Although we included a diversity of vertebrate and insect taxa and comprehensively assessed all species of each group included, many groups of insect pollinators remain too poorly known to evaluate (Table 1). Data are too scarce to assess thousands of pollinating micromoths, flies, beetles, and wasps, for example, as well as most bee species, that occur in North America (21, 49). This is further exacerbated by the lack of targeted and opportunistic collecting and taxonomic expertise, especially in areas with high species richness, such as the desert southwest. Our results show that pollinator groups vary markedly in their degree of imperilment, and we currently have no way to predict the status of unstudied groups.

Extinction risk assessments such as the method employed here, with their focus on rarity, can be somewhat insensitive to declines in abundant species. If declines in pollinators are concentrated in common species (43), then the pollinator crisis may be larger than suggested here. Nevertheless, standardized extinction risk assessments allow comparison across disparate taxonomic groups all subject to the same potential bias. Conversely, to the degree that more common species are more likely to be represented in collections, the data we have been able to access could underrepresent the dangers to rarer species.

Until long-term, geographically broad monitoring programs and data sharing are in place for North American pollinators (21), information available for extinction risk assessments will continue to be largely limited to records from museum specimen and citizen science observation databases, research reports for selected species, and field biologist understanding of habitats, natural history, and threats. We focused on groups with readily identifiable species to limit the number of data-deficient species and bounded our estimates of the percent at risk accordingly. We note that documenting

extinction in insects and other invertebrates inhabiting continental land masses is difficult and limited research focus may result in underestimates of insect extinction (50).

Future taxonomic updates could also influence the results. For example, the subgenus *Megachiloides* accounts for 43% of the leafcutter bee species in our study area, but it is also the least known. The majority of the 50 species in the subgenus have not been taxonomically reviewed since the 1930 s, and some are only known from one sex. Most of the Possibly Extinct (GH) species in the study belong to this subgenus as do six of 11 data-deficient (GU) species in this taxon. In addition, with taxonomic updates, phylogenetics may also be used to help predict rarity. Investment in taxonomic revision of problematic groups, survey and monitoring, citizen science, and natural history studies will be key to understanding better the taxonomic breadth of declines and prioritizing investments for recovery.

Conservation Action. The imperilment status of bees and other pollinators argues for greater attention to these species in SWAPs and other conservation mechanisms such as conservation land acquisitions, forest plans, permitting for extractive activities, and pesticide regulations (3, 19, 20). In many states, species listed in SWAPs gain greater attention from land management agencies and are eligible for conservation funding. In addition, several US states now have stand-alone pollinator plans that chart habitat conservation, research, and outreach efforts to preserve native pollinators.

Mitigation of agriculture threats, such as decreasing pesticide use and increased use of wildflower strips to provide broader seasonal availability of floral resources and nesting habitat can be an effective means of pollinator conservation (51). Off-field habitat enhancements can also mitigate the impact of pesticide use and habitat loss, such as increased implementation of best practices for integrated vegetation management on rights-of-way within and near cropping systems, floral resource augmentation on adjacent solar or wind installations, and roadsides (52, 53). Further, managing these more local threats, such as those related to habitat requirements and connectivity, can mitigate the impacts of climate change (39), a major threat across much of the study area including the states with both the greatest species richness and richness of at-risk species.

The threat of agriculture also includes livestock grazing that occurs in important pollinator habitat, including grasslands, deserts, shrublands, savannahs, woodlands, open forests, and alpine tundra, areas that encompass about one-third of the US land area, particularly in the west (54). Utilizing best practices that combine grazing with the management of grasslands for plant biodiversity as well as planting floral assemblages that provide pollinator resources throughout the growing season can greatly enhance pollinator habitat (55, 56).

As home to unique boreal and arctic butterflies such as the northern ringlet, *Coenonympha tullia* (23), as well as hotspots of bumble bee and flower fly diversity, Canadian provincial and territorial governments have an important role to play in conserving these groups. Information in assessments can aid these endeavors to address geographically relevant threats to at-risk pollinators and be used by the Committee on the Status of Endangered Wildlife in Canada to identify candidates for assessment, the first step in getting species listed under Canada's Species At Risk Act (57).

Efforts to enhance pollinator habitat following generalized guidelines can successfully increase the numbers and diversity of pollinators at a site (58). Many of the pollinators attracted to these habitats are likely to be common, generalist pollinators, at least initially. Conservation of rare species, which can be crucial for maintaining pollinator services over broad temporal and spatial scales (59),

requires efforts to reduce specific pressures in geographies where at-risk species occur. With at-risk pollinators occurring in every state, province, and territory, resource managers everywhere can contribute to their conservation and, due to overlapping threats, these actions will bring wider benefits to biodiversity.

Materials and Methods

Pollinator Definition. We operationally defined a pollinator as a flower visitor that 1) consumes flower resources as an adult and 2) might contact sexual reproductive parts of the flower.

Geographic Scope. We assessed native pollinators that regularly occur in mainland North America north of Mexico. Species from Hawaii and US overseas territories were excluded unless they also occur in Canada or elsewhere in the United States. We excluded introduced or naturalized pollinator species from the study.

Selection of Taxa. We selected taxonomic groups containing pollinators that are known well enough to assign a status to at least 75% of pollinating members. The groups matching this criterion were

Hummingbirds (Apodiformes: Trochilidae)

Bats (Chiroptera)

Butterflies (Lepidoptera): families Lycaenidae (gossamerwings), Nymphalidae (brushfoots), Papilionidae (swallowtails), Pieridae (whites), Riodinidae (metalmarks), and Hesperidae (skippers)

Macro-Moths (Lepidoptera): families Sphingidae (sphinx), Notodontidae (Notodontid); subfamily Arctiinae (tiger); and genera *Catocala* (underwing), *Papaipema* (borer)

Bees (Hymenoptera: Anthophila): genera *Bombus* (bumble); *Xylocopa* (carpenter); *Anthophora*, *Habropoda* (digger); *Megachile* (leafcutter); *Osmia* (mason); *Agapostemon*, *Augochlora*, *Dieunomia*, *Nomia* (sweat, in part); *Peponapis*, *Xenoglossa* (squash)

Beetles (Coleoptera): genera *Trichodes* (checkered), *Trichotinus* (hairy flower scarab)

Flower flies (Diptera: Syrphidae): subfamily Eristalinae, all genera except *Cheilosia*, *Copestylum*, *Hiatomyia*, *Nausigaster*, *Orthonevra*, *Palpada*, and *Sphegina*, which were too poorly known to assess comprehensively.

Species in these groups that did not meet our definition of pollinators were excluded from the analysis.

Restricting the study to only taxonomic groups that we could assess comprehensively, and assessing all the species in those groups, avoided a bias toward choosing well-known or common pollinating species that would underestimate extinction risk. For example, we did not include the well-known mining bee *Andrena milwaukeeensis* or its congeners because too few of the ~550 North American *Andrena* are sufficiently well known for assessment, similarly for *Perdita*, the most speciose genus in North America.

We restricted the study to taxa recognized as full species. We note that, especially for butterflies, some described subspecies and populations are imperiled and the target of extensive conservation efforts.

Assessment Method. We used the NatureServe methodology to assess extinction risk (25). In mainland United States and Canada, NatureServe conservation status ranks are available comprehensively for many more taxonomic groups than other methods such as the IUCN Red List (22, 40, 45). NatureServe and Red List categories have been shown to be broadly congruent (60). The NatureServe method combines information on rarity (i.e., range extent, abundance) and threats to determine a score that is then modified based on population trends to calculate a global conservation status rank (G rank): GH = Possibly Extinct (known from historical occurrences only but may persist); G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure; GU = Data Deficient (insufficient information to assess). Species with a calculated rank of GH to G3 range are referred to as at risk and those in the G4 to G5 range are here termed "more secure."

When ranges of possible values are used for rarity, trend, or threat factors due to uncertainty and/or expert knowledge, the NatureServe method can result in a range rank. In all analyses, we used "rounded ranks," a simplification that

reflects the more conservative part of the rank (e.g., G1G2 rounds to a more precautionary G1). Of the species assessed, 21.3% had range ranks that were rounded. The most important impact on the analysis was rounding species ranked G3G4 to G3, classifying the species as at risk, whereas rounding to G4 would classify the species as more secure. Eighty-five species (5.4%) were categorized G3G4 and rounded to G3. Species categorized as G3G4 were spread across the major taxonomic groups examined (1 vertebrate, 23 butterflies, 5 macro-moths, 37 bees, and 19 flower flies).

Assessments were completed between 2013 and 2025 (92% were completed 2019–2025, with no temporal trend in percent at risk by assessment year; Pearson's Correlation $\rho = -0.01$, $P = 0.97$). See [SI Appendix](#) for details on the assessment methodology.

Percent At Risk. We followed the approach of Cox et al. (61) to calculate a best estimate of the percent of species at risk as the sum of GH, G1, G2, and G3 species divided by the total number of species less the number of GU species. The upper estimate of the percent at risk assumed that all GU species were at risk whereas the lower estimate assumes that none of the GU species are at risk. We calculated the percentage of at-risk pollinators for each taxonomic group, subnation (i.e., state, province, or territory), and nation. All analyses were done in Excel unless otherwise noted.

Calculating Estimated Percent Species Assessed of Total. For each major pollinator group included in this assessment: pollinating vertebrates, butterflies, pollinating macro-moths, bees, pollinating beetles, and pollinating flower flies, we estimated the total number of species, or a range of species for vertebrates, moths, and beetles, using literature and expert knowledge and then calculated the percent assessed per group. Estimation methods and sources are included in Supporting Information.

Comparing Pollinator Statuses to Other Taxa. To compare the status of pollinators with other groups of plants and animals, we downloaded status data for all valid species known to be native and regularly occurring in the mainland United States and Canada from NatureServe's central "Biotics" database on 7 July 2024, grouped species by taxonomic group and global rank, and calculated percent at risk as we did for the pollinators. The groups chosen had been comprehensively assessed (i.e., every species has been assessed), although 800 species (of 23,448 total) that were recently recognized due to taxonomic rearrangements had not yet been assessed.

Species Richness in Subnations. We documented subnational distribution across the study area of each species using the same sources as for the status assessments and then tallied the total pollinator species richness and at-risk pollinator species richness for each subnation. To better understand the relationship between species richness and at-risk species richness, we calculated a two-tailed Pearson correlation coefficient for species richness and the percent of at-risk pollinators in each subnation.

Because range extent is a known predictor of conservation status (27) and is a factor in the NatureServe methodology used, we investigated the extent to which geographic variation in range extent explained the variation found in the percent of at-risk pollinators documented in each subnation. Like the extent of occurrence in the Red List criteria, range extent is calculated as a minimum convex polygon around all known localities of the species to measure the spread of risk to a species and is therefore unaffected by included areas of unoccupied habitat (25). To calculate the average range extent of the species in each state, province or territory, we used the midpoint of the range in square kilometers of the range extent rating assigned to each species during the assessment process. For example, if a species was categorized with an "F" for range extent (20,000 to 200,000 km²), we assigned it a range extent of 110,000 km² [see (25) for more details]. We then calculated a two-tailed Pearson correlation coefficient to investigate the relationship between species richness and mean range extent for the pollinators in each subnation.

Threat Assessment. We assessed major threats impacting each group as well as operating in each subnation by tallying the number of G1 to G3 species per group that were tagged in each threat category and in each subnation, respectively.

Habitat Associations. We drew on input from scientists, literature, and habitat data compiled by Chesshire et al. (49) to identify the major habitat associations for each G1 to G3 species. The habitat association categories were 1) forests

(hardwood and coniferous, with over 60% canopy cover); 2) woodlands (hardwood and coniferous, with 25 to 60% canopy cover); 3) shrubland/chapparral (dominated by shrubs <5 m tall); 4) deserts, barrens, and flats (including dunes and other open areas); 5) grasslands (includes savannas with <25% canopy cover); 6) wetlands and riparian areas (including marshes and fens), and 7) alpine and tundra habitats. Anthropogenic habitats were not included in the analysis.

Data, Materials, and Software Availability. All study data are included in the article and/or supporting information.

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