The importance of cities in protecting imperiled species

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Abstract

Habitat loss and alteration from urbanization threaten global biodiversity, and municipal decision-making therefore affects the persistence of many imperiled species. Using Canada as a case study, we quantified the overlap between critical habitats of imperiled species in large urban areas. Of these species, 14% were urban-restricted, and ~28% of these species, spanning nine taxonomic groups, had more than 75% of their mapped critical habitat in Canadian metropolitan areas. To explore municipal engagement in biodiversity conservation, we assessed the consideration of imperiled species in publicly available plans and strategies for 42 of the largest Canadian metropolitan areas. Over half of cities (72%) mentioned imperiled species in biodiversity or official plans and half (52%) outlined actions for these species. While biodiversity conservation is one of many competing priorities in cities, given their significant overlap with critical habitat, cities can play a large role in protecting and increasing public awareness of imperiled species.

Introduction

Urbanization is one of the leading causes of habitat loss globally and is accelerating as human populations increase (Simkin et al., 2022). As many urban areas are biodiversity hotspots (Ives et al., 2016), lands and waters within and around urban boundaries can overlap with habitats deemed critical for species at risk of extinction (hereafter imperiled species; Soanes & Lentini, 2019). For some endemic species, urban boundaries entirely overlap with known range extents or critical habitat areas (Aronson et al., 2014; Lepczyk et al., 2023; Soanes & Lentini, 2019). Consequently, species conservation within urban areas is increasingly imperative.

There is no strict, global definition for the degree of urbanization that constitutes a "city" (United Nations Statistics Division, 2017). Yet, about half of the global human population currently lives in cities and other densely populated urban areas, and that number is expected to continue to increase (Zlotnik, 2004). The effects of urbanization on biodiversity are well-documented (Mcdonald et al., 2008; McKinney, 2006). Nevertheless, urban biodiversity is one of the primary ways through which people connect with nature and gain conservation awareness (Schwarz et al., 2017). Urban nature also provides important ecosystem services to urban residents. In this context, cities have an opportunity to play a pivotal role in the protection of imperiled species by strengthening conservation measures while also increasing public awareness of environmental issues (Simkin et al., 2022). However, because municipal authorities must work to balance infrastructural, environmental, cultural and economic needs within urban areas, integrating biodiversity conservation is one of many competing priorities and can pose a significant challenge.

In Canada, urban areas are concentrated in the most biodiverse regions (Coristine et al., 2018). Cities take up a very small portion of Canada's land mass, and municipal conservation efforts are inconsistent and not integrated across Canadian cities (Olive, 2014). In this way, highly altered urban ecosystems can be seen as a "lost cause" (Kowarik, 2018). Habitat loss caused by increasing urbanization and residential development has a disproportionately large impact on imperiled species compared to other threats (McCune et al., 2013; Venter et al., 2006).

Over 80% of the Canadian population lives in an urban area (Statistics Canada, 2022b). Evidence from surveys in Toronto and Vancouver in 2013 suggests that urban Canadians have little awareness of endangered species and do not feel responsible for their protection (Olive, 2014). Nevertheless, Canadians in general are strongly committed to conservation in principle (McCune et al., 2017). Thus, we posit that cities in Canada may have underrecognized and undervalued opportunities to improve protection for large numbers of imperiled species and involve Canadian urbanites - over 80% of the Canadian population - in conservation.

Existing federal protection for imperiled species in Canada is granted by the Species at Risk Act (SARA). Once assessed and listed under SARA, the critical habitat of an imperiled species is defined to the extent possible in a recovery strategy (Species at Risk Act [SARA], 2002). Critical habitat is protected on federal lands (SARA, 2002), but these cover on average <8% of the ranges of Canadian imperiled species (Bolliger et al., 2020). Terrestrial critical habitat can also be protected on non-federal lands through an emergency order, though there are only two species with active emergency orders at the time of writing (Western Chorus Frog (*Pseudacris triseriata*) and Greater Sage-Grouse (*Centrocercus urophasianus*); Government of Canada,

2025). Some provinces and territories have additional imperiled species legislation, of varying effectiveness (Gordon et al., 2024; Ray et al., 2021).

In Canada, municipal jurisdiction is strongly influenced by provincial policies. Although addressing environmental issues at local branches of government has been considered to be most effective (Gilbert et al., 1996), municipalities have limited jurisdiction over the protection of species and habitats. Nevertheless, local governments directly influence activities and processes that have significant effects on imperiled species and their habitat (Mallet, 2005) by implementing protection policies (Hodge et al., 2021), and by managing and regulating land-use planning (K. Thompson et al., 2019), infrastructure (e.g., transportation systems, stormwater conveyance), and greenspaces (Lam & Conway, 2018).

The important role of cities and local/regional authorities in preventing biodiversity loss is reinforced in several documents and ratifications of the United Nations, including target 12 of the Kunming-Montreal Global Biodiversity Framework (United Nations Convention on Biological Diversity, 2022). Despite their central role in policy-making, the United Nations does not yet fully recognize cities as stakeholders (Szörényi & Leroy, 2023). In Canada, there is a general lack of research connecting urban areas, municipal conservation policy, and imperiled species (Olive, 2014). To better understand these connections, we explored how frequently or explicitly biodiversity conservation is considered in municipal planning across Canada.

In this data-driven perspective, we used Canada as a case study to assess the importance of cities for conservation of imperiled species and explore how the urgent need to conserve biodiversity

82 was reflected in municipal biodiversity policies. Our objectives were to: a) determine the degree
83 to which the mapped critical habitat and range extents of Canada's imperiled species overlap
84 with urban areas; and b) quantify the consideration of imperiled species conservation and
85 management in biodiversity plans and official city plans from large Canadian urban centres.
86

87 **In Canada, habitat for several species at risk of extinction is restricted to urban areas**

88 We assessed the degree to which habitat for imperiled species intersects with Canadian cities by
89 quantifying the overlap between the mapped critical habitat and ranges of federally listed,
90 imperiled species, and census metropolitan areas (hereafter CMAs) and census subdivisions
91 (hereafter cities). We focused our analyses on species that have been assessed as imperiled in
92 Canada (e.g., those assessed as Special Concern, Threatened or Endangered) and listed under
93 SARA. CMAs are defined as an area with at least 100,000 people, comprising one or more cities
94 that surround an urban core with a population of at least 50,000 residents (n = 156, Statistics
95 Canada, 2021, 2023). CMAs often contain rural or non-urban areas that have not yet become
96 urbanized, but are under direct pressure from urban sprawl (Statistics Canada, 2022b). Many
97 cities are contained within CMAs and cities were included because they are more densely
98 urbanized (n = 446; Statistics Canada, 2023).

99 Critical habitat is defined as habitat necessary for the survival or recovery of an imperiled
100 species, and contains areas a species depends on for its life processes (Environment and Climate
101 Change Canada [ECCC], 2023). Mapped critical habitat is only identified for species listed as
102 Endangered or Threatened, and can be based on occupancy data, habitat characteristics and/or
103 functions, biophysical characteristics (ECCC, 2023; Lefebvre et al., 2018). We overlaid the
104 mapped critical habitat of 273 listed species with CMAs and cities using ESRI ArcGIS Pro

(3.2.0). We found that for 77 of these imperiled species, >75% of mapped critical habitat overlapped with CMAs (Figure 1). Thirty-eight (14%) species' mapped critical habitats were urban-restricted, overlapping >99% with urban areas (Table 1). The mapped critical habitat of fourteen imperiled species overlapped with cities by >75%, with habitat of four species overlapping by >99% (Figure 2).

At the time of writing, critical habitat had not been defined or mapped for 249 species, and SARA does not require mapping of critical habitat for species of Special Concern. Therefore, we also analyzed urban overlap with species' range extents (n = 488 species; ECCC, 2023b). Range extent represents all areas where a species may occur, including potentially unsuitable habitat (see Appendix A). Proportionally fewer species had range extents overlapping with CMAs and cities in Canada than for critical habitat. Forty-five imperiled species had range extents that overlapped by ≥75% with CMAs, nine of which overlapped by >99% (Figure S1A). Six species' range extents overlapped by >75% with Canadian cities (Figure S1B). None of these range extents overlapped completely with Canadian cities, but the range extents of the silver hair moss (*Fabronia pusilla*), Virginia goat's-rue (*Tephrosia virginiana*) and bird's-foot violet (*Viola pedata*) overlapped with Canadian cities by 98%, 97%, and 91%, respectively.

Thirteen CMAs and seven cities overlapped ≥75% with the critical habitat of at least one imperiled species (Figures 3 and S2). The Victoria CMA was built in the Garry Oak ecosystem

in southwestern British Columbia, which has dwindled to less than 5% of its original size within Canada (Garry Oak Ecosystems Recovery Team, n.d.). This ecosystem is home to over 100 imperiled species (Garry Oak Ecosystems Recovery Team, n.d.) and much of the remaining Garry Oak ecosystem occurs within the Victoria CMA, which contains >75% of the critical habitat of 22 species (Fig. 3). The city of Windsor, Ontario, which has similarly high overlap with imperiled species (Fig. 3), is in the planning stage of creating the first urban national park (Parks Canada Agency, 2024).

High overlap between an imperiled species' habitat and a city or CMA does not indicate that this species occurs or has critical habitat within a downtown core or urban matrix. However, it does indicate significant responsibility for a city (or cities) to support that species' recovery. For example, Blanding's turtles (*Emydoidea blandingii*), occur in cities in Ontario such as Ottawa, Pickering, Barrie, and Brantford (ECCC, 2018). The most heavily urbanized parts of these municipalities are not used directly by turtles, but they live within city boundaries, and thus rely on local governments to institute much-needed protection against threats such as development and transportation corridors (ECCC, 2018). In another example, nugget moss (*Microbryum vlassovii*) has two mapped critical habitats in Canada that fall completely within the boundaries of Penticton and Kamloops, British Columbia. Roadway maintenance, a municipal responsibility, is a potential threat to *M. vlassovii* in both cities (City of Kamloops, 2025; City of Penticton, 2025; COSEWIC, 2006). While *M. vlassovii* does not depend on urban structures for its survival (ECCC, 2012), the cities of Penticton and Kamloops maintain direct jurisdictional influence over the natural areas that support this species, and can therefore directly influence the species' persistence and recovery.

Planning for imperiled species management is limited in Canadian cities

Few Canadian cities have a dedicated strategy with detailed goals to protect biodiversity and address related environmental issues (hereafter biodiversity strategy) (ICLEI Canada, 2018). To assess municipal strategies and policies that address imperilled species, we searched for biodiversity strategies for 42 Canadian core cities (the municipalities with the highest population within each CMA; Statistics Canada, 2022a). We conducted a Google search using the names of each city and the following terms: "biodiversity strategy," "biodiversity plan," "conservation strategy," "conservation plan," "environmental plan," or "environmental strategy". If the strategy did not appear in Google searches, we then searched on the city's website. If the city did not have a publicly accessible biodiversity plan, we used Google searches using the city name AND "official plan" to access the official city plan, which are comprehensive documents focusing on multiple aspects within the city (policy, transit, land use, infrastructure, etc.). For cities in Québec, we translated these search terms to French. We then reviewed each biodiversity plan or official city plan for the following information: a) mention of imperiled species or SARA, b) a list or number of imperiled species in the city, or examples of imperiled species in the city, and c) implemented or anticipated actions to protect imperiled species and/or biodiversity in the city. For the plans that identified anticipated actions, we assigned standardized categories to the actions using the IUCN-CMP categories, version 2.0 (IUCN-CMP, 2016).

Seventeen core cities (40.5%) had a dedicated biodiversity strategy, and 12 (70.6%) of these strategies listed or mentioned imperiled species. These cities were generally more populous than those whose biodiversity strategies don't mention imperiled species (Figure S3), suggesting that

resource availability in smaller cities may limit the development of biodiversity planning for imperiled species. Six cities identified actions within their biodiversity strategies (35.3%). Twenty-five cities (59.5%) did not have a dedicated biodiversity strategy, but 24 of these cities (96%) included biodiversity-related policies and actions within their city's official plan.Of these 24 cities, 19 (79.2%) listed or mentioned imperiled species. Thirteen official plans (66.6%) described actions for imperiled species conservation.

Of the six cities (Calgary, Ottawa, Toronto, Vancouver, Hamilton, and Windsor) with biodiversity strategies that described actions to protect imperiled species, the level of detail in those actions varied. Some actions were broad and ambitious, for example, Calgary's "Our BiodiverCity" plan states: "Develop and implement management plans for all status species in Calgary parks and open space" (City of Calgary, 2015). Similarly, Windsor's Environmental Master Plan states: "Continue to implement Species at Risk protection measures in all areas of Windsor and develop strategies to improve their status" (City of Windsor, 2017). Other actions were more detailed, such as Hamilton's Five-Year Biodiversity Action Plan, with actions such as "Preserve and enhance City managed dune habitat along the Lake Ontario shoreline by reducing erosion through maintaining dedicated beach access, leaving deadwood and developing a Dune Management Plan" (City of Hamilton, 2024).

The median number of actions identified in official plans was five, while the median number of actions for biodiversity strategies was 32. Types of actions identified in dedicated biodiversity strategies were more varied than those identified in official city plans (Figure 4). Actions identified in official plans were often policies, zoning, standards, or by-laws. Biodiversity

196 strategies often included actions involving community engagement and awareness, research and
197 monitoring, training for conservation and municipal professionals, and direct land/water
198 management, including removing invasive species and/or planting vegetation. All of these
199 actions are important for protecting and recovering imperiled species (Binley et al., 2025), and
200 biodiversity strategies included a broader scope of actions for cities to implement. Nonetheless,
201 specific actions are an important component of effective conservation of imperiled species
202 (Green et al., 2019; Possingham et al., 2000), so cities can maximize their impacts by
203 considering both broad strategies and specific actions when planning for biodiversity.
204
205 We note that these summaries of conservation plans do not fully represent what happens in
206 practice (i.e., implementation), and imperiled species conservation may be included in other
207 government documents, regulations, and policies, as well as initiatives led by other types of
208 organizations (e.g. environmental non-governmental organizations). For example, in the official
209 plan for Victoria, British Columbia, one action is to "Develop and maintain an Urban Forest
210 Master Plan to enhance the urban forest on public and private land" (City of Victoria, 2013). The
211 Urban Forest Master Plan details many actions intended to protect and improve the urban forest
212 in Victoria (City of Victoria, 2013), which were not captured in this case study.
213
214 We also note that the policies included in official plans are based on provincial policies. For
215 example, cities in Ontario are required to implement policies identified in the Ontario Provincial
216 Planning Statement (hereafter OPPS; Government of Ontario, 2024) developed for Natural
217 Heritage Systems. While all policies set out in the OPPS set a required minimum standard, they
218 must be considered in complement with each other (Government of Ontario, 2024), which can

allow cities to prioritize aspects of the OPPS as long as the city policy does not conflict with policies in the OPPS. Therefore, even though the actions identified in official plans have regulatory power, they may not be tailored to the municipality and the local ecology. It is unclear whether this approach may limit the efficacy of protection for imperiled species within these jurisdictions.

At the time of writing, three additional cities in Canada (Gatineau, Kingston, and Québec City) have committed to creating biodiversity strategies in accordance with Kunming-Montreal Global Biodiversity Framework target goals. Kingston will release its Biodiversity Conservation Strategy in 2026 (City of Kingston, 2023), and Gatineau has published a preliminary version of its biodiversity strategy (Ville de Gatineau, 2023). The development of specific biodiversity strategies, with detailed actions and timelines, could improve the ability of municipalities to protect wildlife in their city, and can increase accountability for those actions.

Conclusion

Our analysis revealed that critical habitat and range extents for imperilled species in Canada (i.e., those listed as Special Concern, Threatened, or Endangered under the federal Species at Risk Act) overlaps substantially with Canadian CMAs and cities. Given cities only comprise 0.14% of Canada's land area (Statistics Canada, n.d.; World Bank, n.d.), municipal and regional governments have a disproportionately large responsibility for imperilled species conservation and protection in relation to their land area. Despite their importance in protecting imperiled species, we found that municipal strategies and planning for conservation are still limited. We found 20 cities had municipal strategies that outlined specific actions for imperiled species. Since

the federal and provincial governments are often limited in their capacity to protect imperiled species due to land tenure issues (Scheele et al., 2018), municipal governments could fill this gap in protection. Of course, cities often have competing priorities, of which conserving imperiled species is only one. Supporting municipalities in developing and implementing plans has the potential to improve protection initiatives for the 14% of species whose critical habitats are limited to urban areas. Adequate funding from provincial/state and federal agencies is required to provide capacity and resources for urban biodiversity conservation.

Non-governmental organizations and other community and volunteer-based programs are also crucial for imperiled species conservation in urban areas (Olive & Penton, 2018). For example, the conservation of a population of Jefferson Salamanders (*Ambystoma jeffersonianum*) in Kitchener, Ontario, illustrates how community leadership can result in political engagement and action. Jefferson salamanders experienced high road mortality along Stauffer Road in Kitchener, which they must cross during the breeding season to lay their eggs in vernal pools (C. Thompson, 2015). Local grassroots organizations, concerned citizens and environmental groups spearheaded an operation to close this road during the spring, to protect the salamanders when they are most vulnerable (C. Thompson, 2015). The municipal government then agreed to temporarily close this road once a year during migration. Another example is the Bird-Friendly Cities certification program, funded by the federal government, which unites concerned community groups and municipalities to reduce threats to birds in urban environments (Nature Canada, n.d.).

Many aspects of our Canadian case study are applicable on a global scale. A similarly high proportion of imperiled species were restricted to urban areas in Australia (Soanes & Lentini, 2019). As the global population increases, so does the proportion of people living in urban areas worldwide (Cohen, 2006; Montgomery, 2008). As such, it is more important than ever for municipal and regional governments to know which species' habitats fall within their jurisdiction, and to implement imperilled species protection into urban planning and expansion. More studies on urban, imperilled species, spanning developed and developing regions, and considering the overlapping needs to people and biodiversity, can inform policies to improve biodiversity conservation and human well-being in urban areas worldwide. Moreover, additional efforts to recognize and further develop the role of urban and regional planners and managers in conservation are required (e.g., formal training, sharing of successes and failures), given their potential to serve as key actors in protecting and restoring biodiversity.

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Tables

Table 1. Species with mapped critical habitats overlapping >99% with Canadian Metropolitan Areas (CMA).

Common Name	Scientific Name	Taxonomic Group	% Overlap
Poor Pocket Moss	*Fissidens pauperculus*	Lichens & Mosses	100
Western Harvest Mouse (*dychei* subspecies)	*Reithrodontomys megalotis dychei*	Mammals	100
Dwarf Sandwort	*Minuartia pusilla*	Vascular Plants	100
Fragrant Popcornflower	*Plagiobothrys figuratus*	Vascular Plants	100
Muhlenberg's Centaury	*Centaurium muehlenbergii*	Vascular Plants	100
Prairie Lupine	*Lupinus lepidus*	Vascular Plants	100
Tall Bugbane	*Actaea elata*	Vascular Plants	100
Round-leaved Greenbrier (Great Lakes Plains population)	*Smilax rotundifolia*	Vascular Plants	100
Nugget Moss	*Microbryum vlassovii*	Lichens & Mosses	100
Colicroot	*Aletris farinosa*	Vascular Plants	100
Dense Spike-primrose	*Epilobium*	Vascular Plants	100

	densiflorum		
Deltoid Balsamroot	*Balsamorhiza deltoidea*	Vascular Plants	99.99
Vesper Sparrow (*affinis* subspecies)	*Pooecetes gramineus affinis*	Birds	99.99
Streambank Lupine	*Lupinus rivularis*	Vascular Plants	99.99
Kellogg's Rush	*Juncus kelloggii*	Vascular Plants	99.99
Brook Spike-primrose	*Epilobium torreyi*	Vascular Plants	99.99
Rayless Goldfields	*Lasthenia glaberrima*	Vascular Plants	99.99
Tall Woolly-heads	*Psilocarphus elatior*	Vascular Plants	99.99
Rosy Owl-clover	*Orthocarpus bracteosus*	Vascular Plants	99.99
Howell's Triteleia	*Triteleia howellii*	Vascular Plants	99.99
Taylor's Checkerspot	*Euphydryas editha taylori*	Arthropods & Molluscs	99.99
Coast Microseris	*Microseris bigelovii*	Vascular Plants	99.99
Blue-grey Taildropper	*Prophysaon coeruleum*	Arthropods & Molluscs	99.99
Ord's Kangaroo Rat	*Dipodomys ordii*	Mammals	99.99
Seaside Bone	*Hypogymnia heterophylla*	Lichens & Mosses	99.98
Horsetail Spike-rush	*Eleocharis*	Vascular Plants	99.98

	equisetoides		
Hine's Emerald	*Somatochlora hineana*	Arthropods & Molluscs	99.97
Seaside Birds-foot Lotus	*Lotus formosissimus*	Vascular Plants	99.97
Bearded Owl-clover	*Triphysaria versicolor*	Vascular Plants	99.97
Townsend's Mole	*Scapanus townsendii*	Mammals	99.97
Bear's-foot Sanicle	*Sanicula arctopoides*	Vascular Plants	99.97
Golden Paintbrush	*Castilleja levisecta*	Vascular Plants	99.96
California Buttercup	*Ranunculus californicus*	Vascular Plants	99.94
Spotted Wintergreen	*Chimaphila maculata*	Vascular Plants	99.93
Coastal Giant Salamander	*Dicamptodon tenebrosus*	Amphibians	99.76
Slender Bush-clover	*Lespedeza virginica*	Vascular Plants	99.41
Willowleaf Aster	*Symphyotrichum praealtum*	Vascular Plants	99.29
Prothonotary Warbler	*Protonotaria citrea*	Birds	99.07

473

Figures

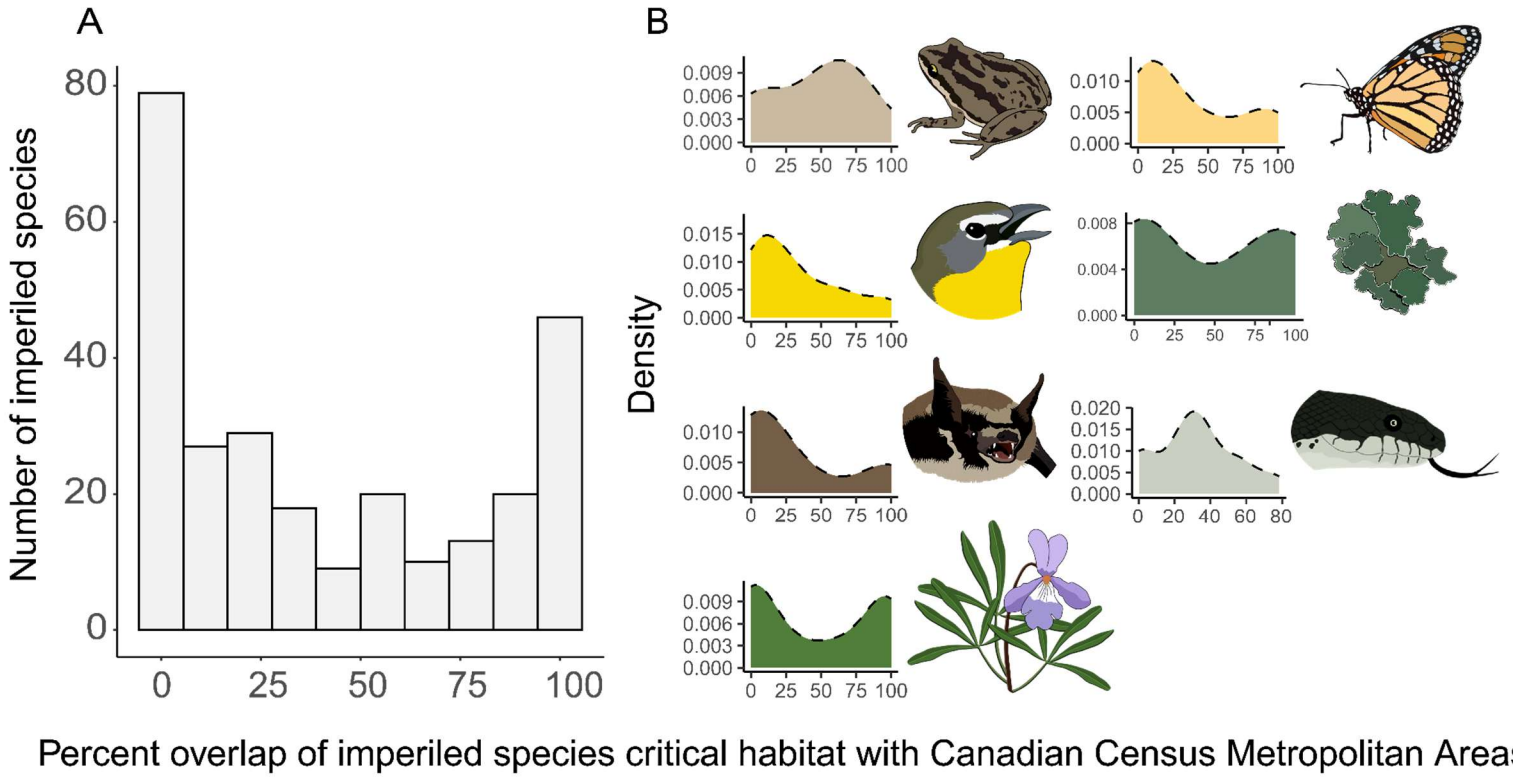


Figure 1. **A.** Frequency distribution of percent overlap between mapped critical habitat for imperiled Canadian species and Canadian Metropolitan Areas (CMAs - areas with at least 100,000 people comprising one or more cities, surrounding a core city) across 7 taxonomic groupings. **B.** Density plots of percent overlap between imperiled species critical habitat and CMAs across 7 taxonomic groups (clockwise from top-left: Amphibians, Arthropods & Molluscs, Birds, Lichens & Mosses, Mammals, Reptiles, and Vascular Plants. Note: illustrations of Yellow-breasted Chat, Boreal Forest Lichen, Little Brown Myotis, Gray Ratsnake, and Bird's Foot Violet adapted with permission from photographs by: Guy Babineau, Robert Cameron, the US Fish & Wildlife Service, Robert Tervo, and the US National Park Service, respectively.

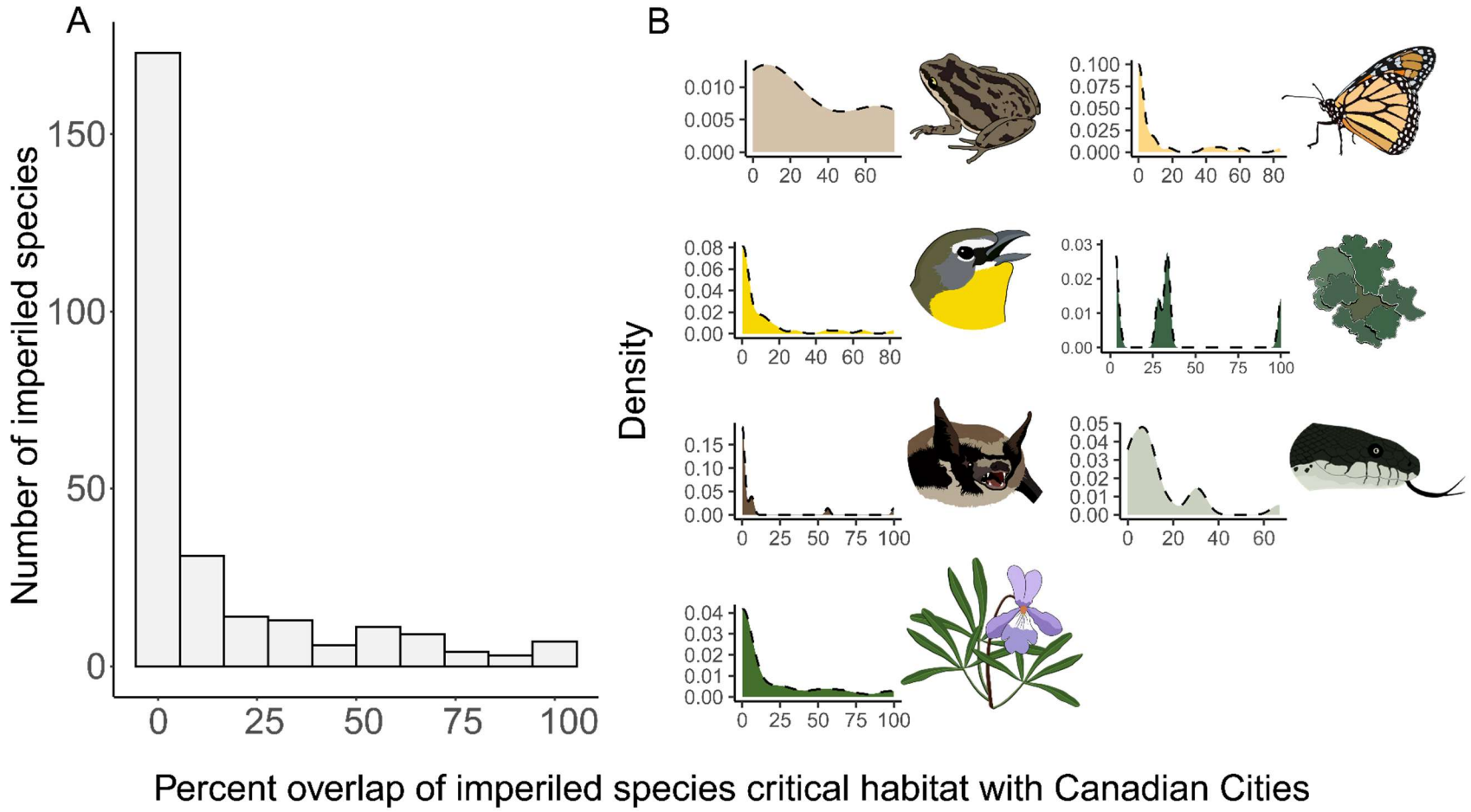


Figure 2. **A.** Frequency distribution of percent overlap between imperiled species critical habitat and Canadian cities across 7 taxonomic groupings. **B.** Density plots of percent overlap between imperiled species critical habitat and Canadian cities across 7 taxonomic groups (clockwise from top-left: Amphibians, Arthropods & Molluscs, Birds, Lichens & Mosses, Mammals, Reptiles, and Vascular Plants. Note: illustrations of Yellow-breasted Chat, Boreal Forest Lichen, Little Brown Myotis, Gray Ratsnake, and Bird's Foot Violet adapted with permission from photographs by: Guy Babineau, Robert Cameron, the US Fish & Wildlife Service, Robert Tervo, and the US National Park Service, respectively.

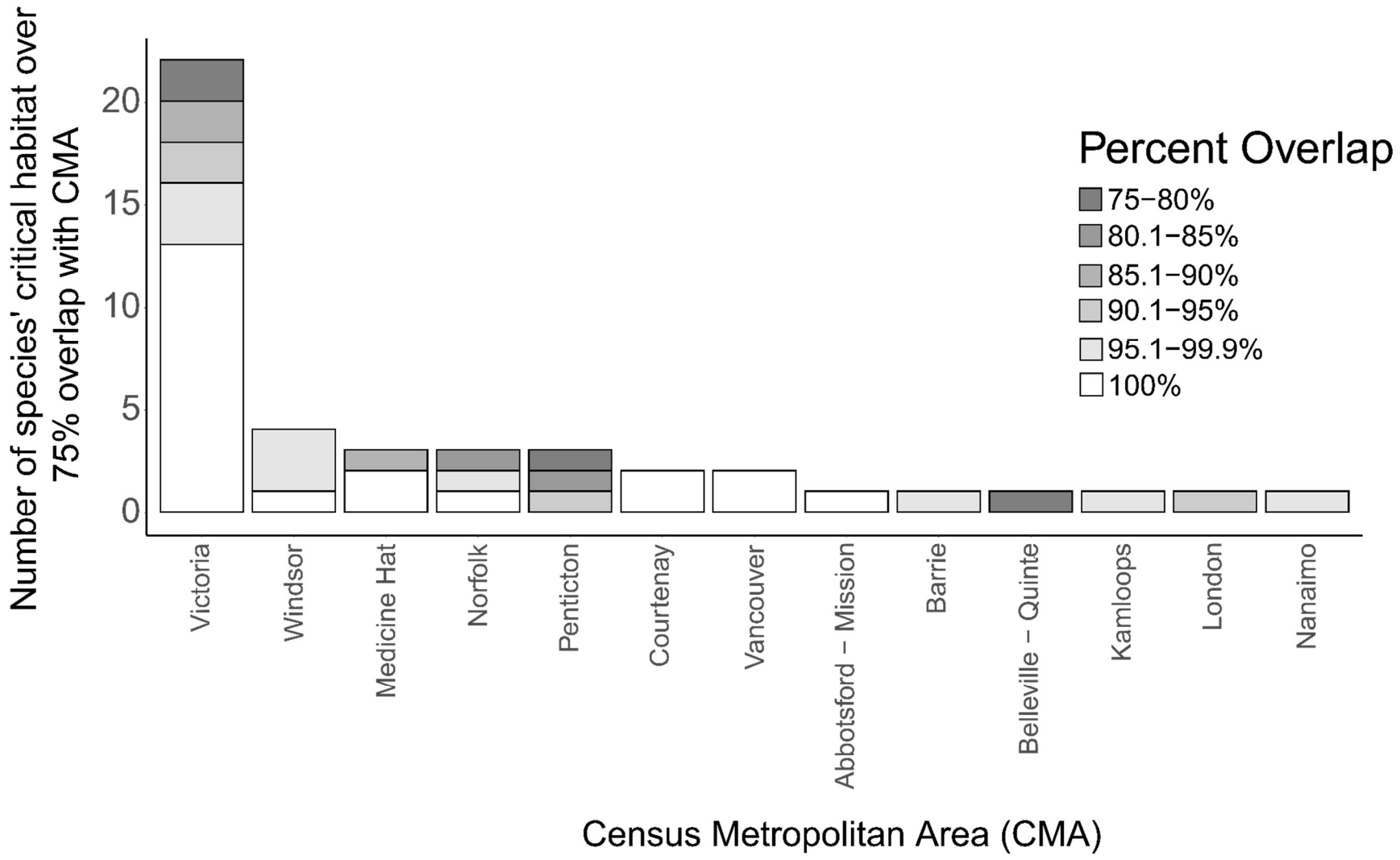
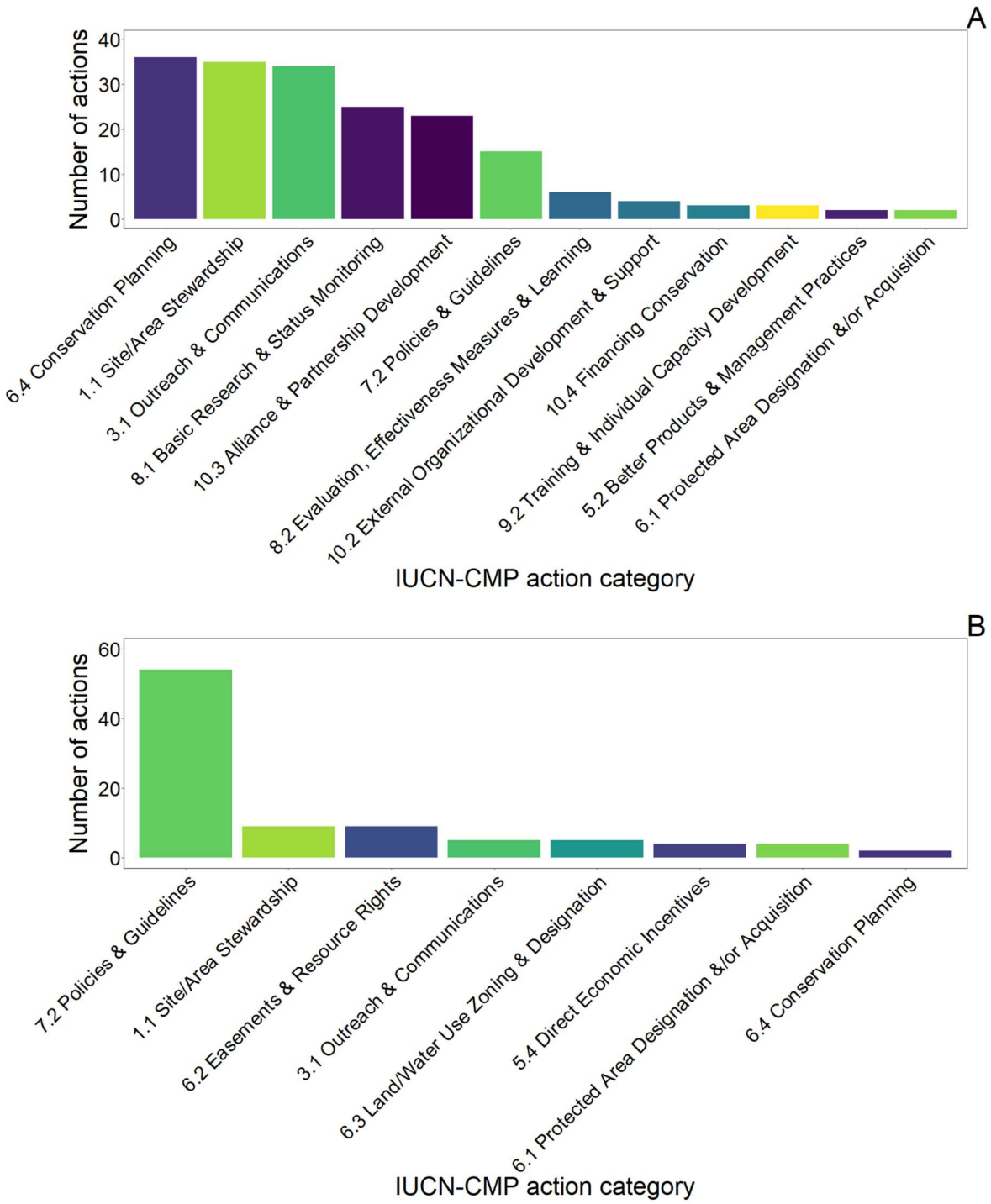


Figure 3. Canadian census metropolitan areas that overlap >75% with the mapped critical habitat of Canadian imperiled species and the number of mapped critical habitats by percentage.



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492 Figure 4. Distribution of action categories identified in municipal biodiversity strategies (A) and official city plans

493 (B). Action categories were assigned using IUCN-CMP standardized action categories, version 2.0 (IUCN-CMP,

494 2016).

Appendix A

Critical Habitat: distinctions and limitations

It is important that we consider our results within the context of the current state of range and critical habitat mapping for Canada's imperiled wildlife, and how this is reflected in the data used in our analysis.

Canada's Species at Risk Act (hereafter the Act) defines critical habitat as "the habitat [...] necessary for the survival or recovery of a listed wildlife species [...]" (Species at Risk Act, 2002, c 29, s 2.1). The Act requires that critical habitat be designated, "to the extent possible", in the recovery strategies for all threatened, endangered, and extirpated species listed (Species at Risk Act, 2002, s 11(2d). The process of defining and mapping critical habitat is complex, and has been criticized for its procedural inefficiency and ineffectiveness in supporting the conservation of imperiled species in Canada (Lefebvre et al., 2018; Bird & Hodges, 2017). Most egregious is the fact that many threatened, endangered and extirpated species remain without any designated critical habitat. In a review conducted by Bird & Hodges (2017), it was found that, as of 2015, 37.1% of threatened, endangered, or extirpated species (including aquatic species), had any form of mapped critical habitat. Furthermore, only 11.8% of these species maintained *fully* mapped critical habitat in their recovery strategy, with the remaining 25.3% of species' mapped critical habitat being considered *partial* and needing further study (Bird & Hodges, 2017).

In addition to the limited extent of current critical habitat designations, the way critical habitat is mapped spatially must also be considered. For example, many critical habitats are mapped as large, landscape-level polygons (e.g. 100 x 100km) that, using available data on the species in

question, have been determined to include some habitat(s) known to be occupied and/or suitable for its recovery or survival. While these large polygons do contain occupied and suitable habitat for the species in question, the exact location of these habitats is not known, and instead indicate "the general geographic area within which critical habitat is found" (ECCC, 2016b, Figure 4., sec. 6.3). This broad-scale approach to critical habitat mapping is used when species are known to be sparsely distributed, or abundant only at a very local-scale, over a relatively large area (ECCC, 2016b). By their nature, critical habitat designations mapped as large polygons contain significant amounts of land that are unoccupied or unsuitable for the species in question, rather than having occupied or suitable habitat over its entire span (ECCC, 2016b). In contrast, some critical habitats are mapped as small, site-level polygons (1 x 1km), defined as a parcel or patch of occupied and suitable habitat with a small surrounding area (ECCC, 2016b).

The current state of critical habitat designations in Canada impacts how we interpret our results. The most important impact is the fact that the extent of spatial overlap between currently mapped critical habitats and urban boundaries does not reflect the true overlap, and is likely quite conservative. As such, the inclusion of currently mapped critical habitat for threatened, endangered, and extirpated species in our analysis is especially illustrative since we found that the critical habitat of several species maintain high percent overlap (>75%) with urban cities (CMAs) and cities, 77 and 14, respectively. With less than 40% of listed species in Canada having any mapped critical habitat, only 11.8% of which are considered full rather than partial, it is very likely that the true overlap between urban cities and Canadian imperiled species is significantly higher than what was discovered during our analysis (Bird & Hodges, 2015).

We must also be mindful of what percent overlap between mapped critical habitat and urban areas can actually tell us about the relationship between urban areas and imperiled species. This is especially important since the land included inside mapped critical habitat polygons is not entirely composed of habitat suitable or necessary for each species' recovery (ECCC, 2016b). For example, a 92% overlap between an endangered species' mapped critical habitat and a City does not explicitly mean that 92% of that species' critical habitat is overlapped by an urban boundary, especially if said species' critical habitat is mapped at a landscape-level scale. However, such a high percent overlap does indicate that critical habitat is very likely to occur within that city's boundaries. Furthermore, since many critical habitat designations are based on occupancy data (Lefebvre et al., 2018), we can also consider high percent overlap between mapped critical habitat and urban boundaries as being indicative that both the imperiled species and its critical habitat occurs on lands under the jurisdiction of cities.

Range extent data is important to include in our analysis for several reasons. Firstly, it provides spatial data for a much more exhaustive list of imperiled species in Canada compared to mapped critical habitat (488 vs. 273 species, respectively). For instance, range extent data includes species that are not currently listed as threatened, endangered, or extirpated, such as those listed as species of special concern or not at risk, or those with no status. Despite being more exhaustive in its coverage of imperiled wildlife, range extent data is much more broad that that of critical habitat. Much of the data used to define these range extents are drawn from NatureServe's Ecosystem-based automated range maps (EBAR maps), which "combine biodiversity data with expert knowledge to populate ecoshapes [...] with species presence information" and which "represent the geographic extent where a species *may* occur"

(NatureServe Canada, 2023, para. 1; NatureServe Canada, 2023, para.16). Many range extents cover large geographic areas, limiting our confidence that an overlap between these ranges and urban boundaries represents a legitimate overlap with areas where a species is known to occur.

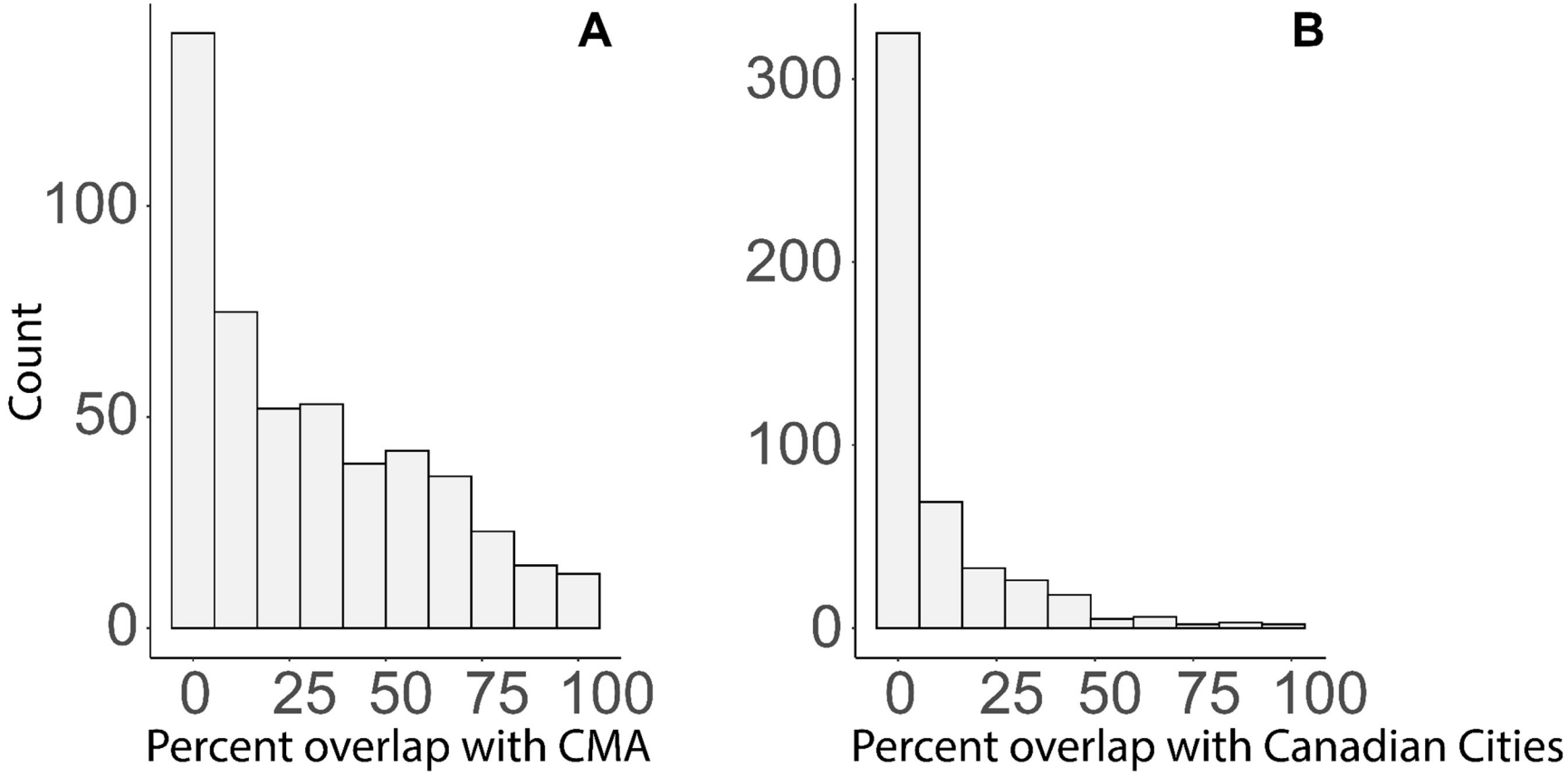
For our purposes, range extent boundaries can be used in a way that is similar to critical habitat. If the modeled range extent of a threatened species maintains 98% overlap with cities, we can argue that:
a) the species in question likely has a relatively limited range in Canada and/or
b) much of the area where the species may occur in Canada falls within the jurisdiction of one or several cities.

Including both mapped critical habitat and range extents allows for the most exhaustive analysis possible given the available data on imperiled species in Canada. High percent overlap between a species mapped critical habitat and cities is indicative of said species occurring and maintaining habitat critical to its recovery within urban jurisdictions. Given the limited scope of mapped critical habitat currently in Canada, revealing that a significant number of species' critical habitat are overlapped by urban areas also allows us to project that the true degree of overlap is much higher, since current critical habitat data is limited in the number of species covered, and is only partial for most currently mapped species. Species' range extents, while being broad spatially and not necessarily indicating the occurrence of a species over an entire geographic span, are useful in that they cover a more exhaustive list of imperiled species in Canada. If a species' range extent is highly or even completely overlapped by n cities, we can be confident that the conservation and recovery of that species will depend on the policies and actions of cities,

planners, and non-governmental organizations since said species is very likely to occur on land under their jurisdiction.

Despite the potential limitations of currently mapped range and critical habitat data in Canada, it is highly relevant and illustrative in describing which species are most likely to occupy and maintain suitable habitat within the boundaries of major urban municipalities across Canada, and to show that any estimate of overlap is likely to be much higher as more critical habitats are designated across Canada.

595 **Supplementary figures**



596

597 Figure S1. **A.** Frequency distribution of percent overlap between imperiled species projected range and Canadian census metropolitan areas (CMAs) across 7
598 taxonomic groupings. **B.** Frequency distribution of percent overlap between imperiled species projected range and Canadian cities areas across 7 taxonomic
599 groupings.

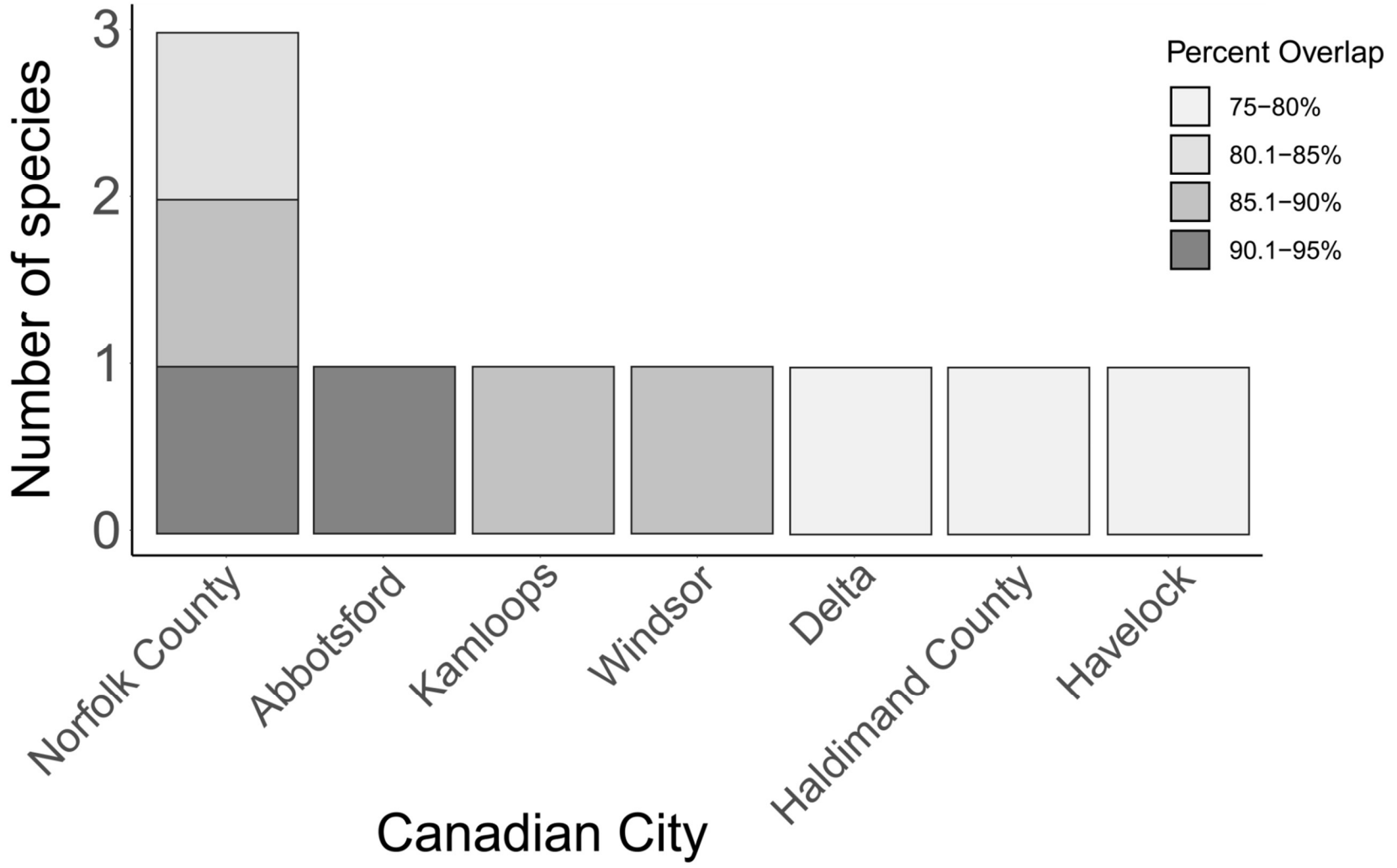
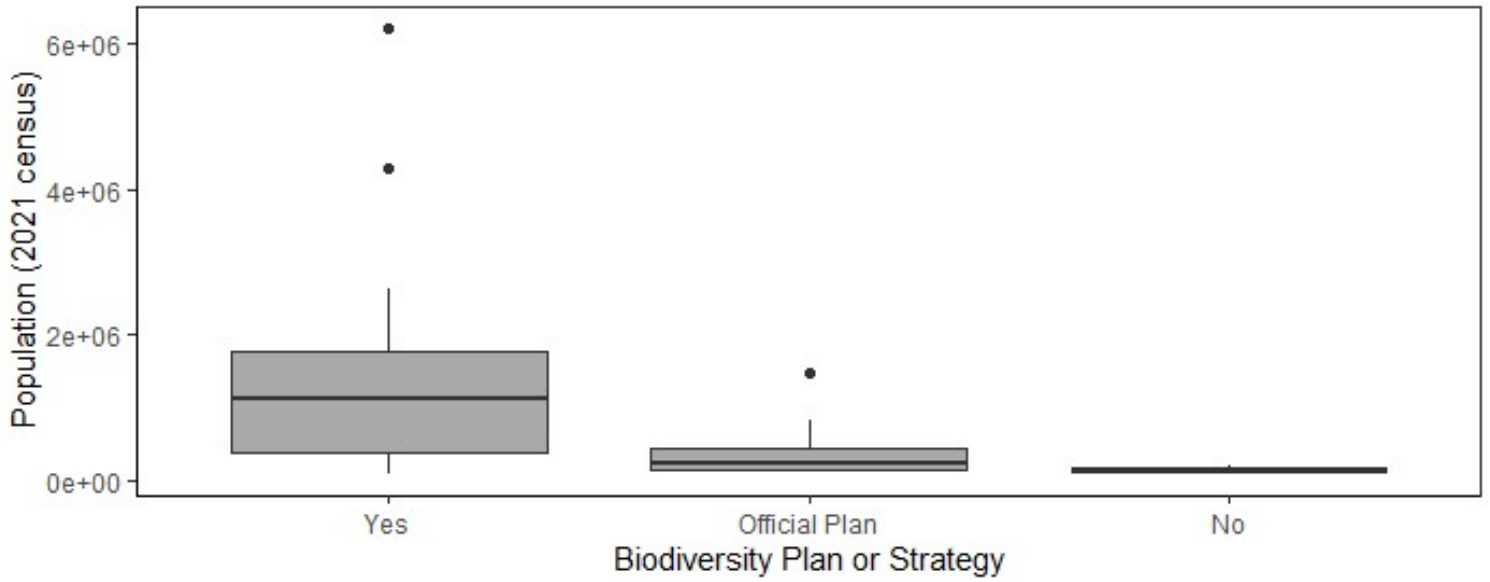


Figure S2. Canadian cities (urban cores) that overlap >75% with the mapped critical habitat of imperiled species and the number of species with mapped critical habitat that overlap >75% for each city.



604

605 Figure S3. City biodiversity strategies or official plans mentioning imperiled species based on population. The population median for cities that mention
606 imperiled species within their biodiversity plan or official plan is 1,126,398; for cities that do not mention imperiled species it is 130,613; for cities with no
607 dedicated biodiversity strategy it is 249,217.