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DATA ARTICLE

The list of vascular plants for the city of Toronto

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Abstract

1. Urban areas have become epicentres for applied ecological and conservation research and policy. Yet, most urban areas have surprisingly little consolidated information about their biota, including species-at-risk and invasive species.
2. I used multiple data sources to compile a list of vascular plants for the greater metropolitan Toronto region. This data not only includes taxonomic information but also global and national status ranks, growth from, native status, threatened status, abundance estimates and year of first observation for non-indigenous species.
3. The list includes 1937 taxa from 146 families, of which 822 are non-indigenous. The majority of native species were ranked as abundant and widespread both globally and provincially. However, non-indigenous species ranks were bimodal, likely to be either extremely restricted in the province, or very widespread.
4. This database provides a robust list of plant taxa in Canada's largest city. It will inform global urban ecology analyses and local and regional management and policy.

KEYWORDS
biodiversity inventory, flora, invasive species, non-indigenous species, rare species, urban ecology

1 | INTRODUCTION

Urban areas are of increasing scientific and management interest (Aronson et al., 2017; Lepczyk et al., 2017) because of both the impacts of human activity on ecosystems and the realization of the contributions of biodiversity to the delivery of services and benefits to people. Central to understanding both the impacts of urbanization and the potential benefits of biodiversity for urban ecosystem function, and service delivery is an accurate accounting of the species that occur in cities. Even though we know that cities can harbour important biodiversity elements (Lepczyk et al., 2017) most city species lists are built from limited and incomplete sampling. Furthermore, cities are hotspots for the importation, establishment and spread of non-indigenous species (Cadotte, Yasui, Livingstone, & MacIvor, 2017). Thus, cities have an extremely important role to play in biodiversity conservation, but more accurate information about their biota are needed.

Toronto is Canada's largest city and supports a human population of about 6.4 million in the larger metropolitan region and covers almost 6,000 km^2. Toronto sits on the north shore of Lake Ontario and covers a range of different habitat types including ravines, meadows, deciduous forests, wetlands and planted conifer forests. Toronto lies in the transitional zone between the mixed-wood plains and boreal shield ecoregions, and so is naturally situated in a biodiverse region, which is not uncommon for cities to be found in disproportionately biodiverse regions (Schwartz, Thorne, & Viers, 2006).

In the past decade, the city of Toronto has adopted a series of ambitious biodiversity and natural area management policies (City of Toronto, 2019). Yet sound municipal urban ecology policy and management require robust data on the taxa inhabiting a city, especially about the abundances of rare and invasive species. To ensure that adequate data is available for policy, management and urban ecological analyses, I created a master plant taxa list for the Greater Toronto

Area, which includes information about the global and provincial statuses, estimates of abundance and time since introduction for non-indigenous species.

2 | MATERIALS AND METHODS

The Toronto plant list, excluding non-vascular plants, was compiled from several different species lists and crossed referenced for taxonomic verification. Six different plant lists that are actively updated were used, including

1. A list of species compiled through the Cadotte lab research within and around the city of Toronto (e.g. Arnillas & Cadotte, 2019; Livingstone, Isaac, & Cadotte, 2020).
2. A list of the vascular plants for the Rouge National Urban Park, supplied by park staff, that included 861 taxa,
3. The plant list compiled by the Royal Ontario Museum – ROM (Royal Ontario Museum, 2018) with the 1548 species recorded from the City of Toronto extracted.
4. A biological inventory of vascular plants provided by the Toronto Region Conservation Authority from their ravine and woodlot monitoring program, which included 790 species.
5. A list of plant observations was downloaded on 21 October 2019, from the Global Biodiversity Information Facility – GBIF (Global Biodiversity Information Facility, 2020) from a polygon drawn around the greater Toronto area (−79.67285 43.48641,−78.84888 43.88364,−79.27734 44.0497,−79.80469 43.82026,−79.67285 43.48641), which included 1881 taxa.
6. A collation of natural history observations provided by Toronto resident Ken Sproule (http://toronto-wildlife.com/Plants/plants_family.html), which included 488 species.

Species from these sources were checked against the Taxonomic Name Resolution Service (http://tnrs.iplantcollaborative.org/index.html), and further uncertain designations were cross-referenced with the Canadensys database of vascular plants (https://data.canadensys.net/vascan/search?lang=en) to confirm presence in Canada and the currently accepted taxonomic name.

Species were then cross-referenced with the list of plants for the province of Ontario available through the Ministry of Natural Resources and Forestry's Natural Heritage Information Centre (https://www.ontario.ca/page/natural-heritage-information-centre) to provide up-to-date information on the provincial and national rank and risk (Committee on the Status of Endangered Wildlife in Canada, COSEWIC) statuses as well as whether species are native or non-indigenous (introduced). Non-indigenous species are those not known to occur in the province of Ontario prior to European settlement (Myers & Bazely, 2003).

I searched for species not found in Natural Heritage Information Centre with general online queries and in the USDA Plants database (https://plants.sc.egov.usda.gov) to confirm if species have been introduced or were cultivated and present in our region. For species rankings (Bachman, Nic Lughadha, & Rivers, 2018), I simplified the coding by combining extirpated (SE and GE) and likely extirpated (SH and GH) into SE and GE, respectively. I classified unrankable (SU and GU) and unassessed species as S? and G? respectively. Furthermore, for species that have a range of rank values (e.g., S3S4) I took the more conservative conservation estimate and selected the lower bound to represent the potential conservation value. I retained the SNA and GNA, not applicable, designations for non-indigenous (introduced) species. I further performed web searches for each non-indigenous species to ascertain whether they were predominately spread as cultivated or domesticated species.

Each taxon was assigned one of nine growth form classes.

1. Herbaceous: vascular plants lacking woody tissue.
2. Graminoid: grass and grass-like plants in the Cyperaceae, Juncaceae, Juncaginaceae and Poaceae.
3. Shrub: perennial woody plants with multiple stems, usually less than 5 m tall.
4. Tree: a woody plant with a single dominant stem, usually taller than 5 m.
5. Vine: a climbing plant with long stems that usually require a surface or another plant for physical support.
6. Herbaceous/shrub: a plant that appears as an herbaceous plant in some conditions and as a shrub in others.
7. Herbaceous/vine: a plant that appears as an herbaceous plant in some conditions and as a vine in others.
8. Shrub/tree: a plant that appears as a shrub in some conditions and as a tree in others or is at the boundary between shrub and tree growth forms.
9. Shrub/vine: a plant that appears as a shrub in some conditions and as a vine in others.

In addition to species ranks and risk status, estimates of abundance from the number of occurrences of species in the ROM and the GBIF lists were included. I also created a composite abundance measure from the ROM and GBIF estimates by scaling both sets to be between 1 and 100 and taking the average of the two. Either the scaled ROM or GBIF estimates were used if the other was missing. I rounded the combined estimates to the nearest whole number. Further, the first date of observation for non-indigenous (introduced) species in the ROM list was also included.

3 | USAGE NOTES

I did not personally observe all of the species included in this list. Instead I relied on correct identifications by other botanists, ecologists and local naturalists. Based on available taxonomic and biogeographic information, I reclassified taxon names based on the likelihood of their being present in the city, and I made the following name changes (independent of taxonomic updates):

From	To
Hydrocotyle ranunculoides L.f.	*Hydrocotyle americana* L.
Eryngium yuccifolium Michx.	*Eryngium planum* L.
Mentha arvensis L.	*Mentha canadensis* L.
Nasturtium officinale W.T. Aiton	*Nasturtium microphyllum* Boenn. ex Rchb
Solanum Ptychanthum Dunal	*Solanum americanum* Mill.
Spergularia rubra (L.) C. Presl	*Spergularia media* (L.) C. Presl ex Griseb.

While the plant list includes species from both Pteridophytes (club-mosses, ferns and horsetails) and Spermatophytes (seed plants), the sources used more consistently recorded Spermatophytes, and so the list of Pteridophytes is likely to be incomplete. Furthermore, subspecies, varieties, etc., were likely to have been inconsistently identified or included, and so the taxa list underrepresents the full number of these subspecific designations present in the city. It would be prudent to analyse patterns at the species level only.

This plant list can benefit applied management and city policy by providing a baseline inventory and historical information to guide future action, and to provide better estimates of species rarity and invasion in Toronto. As an example, this list is currently being used to implement a non-native species management prioritization assessment (Potgieter, Shrestha and Cadotte, unpublished manuscript). Such lists can be utilized for global scale compendium of both urban biodiversity (e.g., https://sites.rutgers.edu/urbionet/) and urban invasions (e.g., https://cubes-labs.com/gubic/). This list has use for education and outreach to train in the identification of urban taxa.

4 | GENERAL PATTERNS

The Toronto plant list generated includes a total of 1937 plant taxa in 146 families. Most families contain few species in the city, with 105 families each containing 10 or fewer species (Figure 1). The four largest families, Asteraceae, Cyperaceae, Rosaceae and Poaceae, contained more than one-third of the Toronto species (664 species).

Of the 1937 species recorded in Toronto, more than 40% (822) are non-indigenous to the region, with a further 23 taxa of uncertain origin (Figure 2(a)). 118 of these non-indigenous species are purported to be cultivated species. The remaining 1092 species are recorded as native to the region. The native species were mostly of a secure conservation status both globally (with 90% of native taxa classified as G4 or G5; Figure 2(b)) and provincially (with 85% of native taxa being classified as S4 or S5; Figure 2(c)). Only 14 taxa are listed under COSEWIC as species at risk (COSEWIC, 2011).

Most Toronto plants were herbaceous (60% or 1154 species), followed by graminoids (17% or 324 species) (Figure 2(d)). Shrubs (8.1% or 157 species) and trees (7.6% or 147 species) made up about equal proportions of the species list. The remaining five growth form categories all contained fewer than 5% of the species (Figure 2(d)).

Unlike for native species status ranks that were strongly skewed to 4 and 5, the status ranks of non-indigenous species were bimodal (Figure 2(e)) with about equal representation at modes SE1 and SE5. Thus, non-indigenous species were most likely to be either very infrequent or widespread. Furthermore, the data includes first year of record in the ROM herbarium records for these non-indigenous species. With the exception of the 1970s, where there appears to be a large sampling effort, species are fairly evenly distributed through time (Figure 2(f)). It is important to note that the data for year of first record is available for only 343 of the non-indigenous species.

The two estimates of species abundance from the number of records in the GBIF and ROM species lists are strongly correlated (Figure 3), and most strongly when the GBIF records were log-transformed, ($r = 0.62$, $P < 0.001$). Indicating that these two measures can provide potentially reliable abundance estimates and justifies combining them.

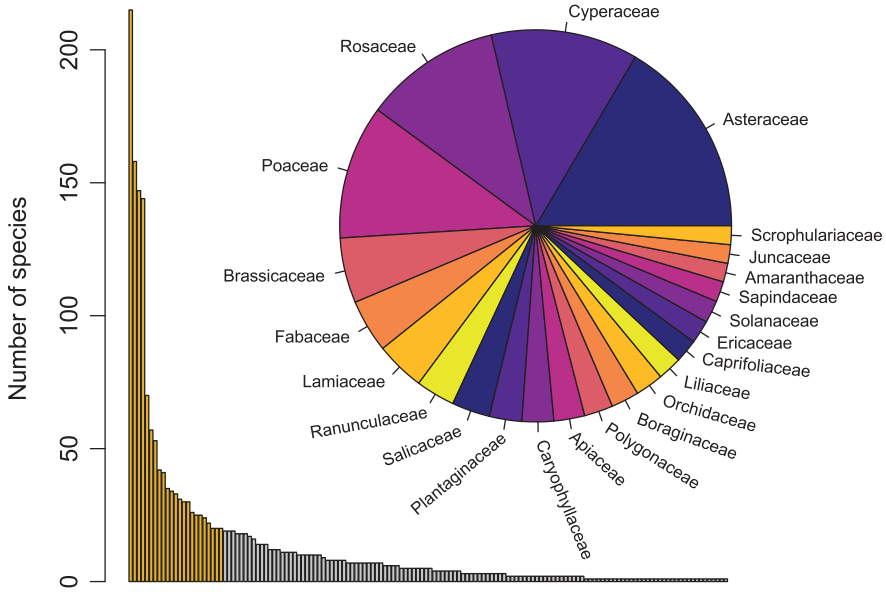

FIGURE 1 The distribution of family sizes for the 146 families in the Toronto plant list. The bars in gold are the 23 families with 20 or more species. The breakdown of these 23 families is shown in the pie chart

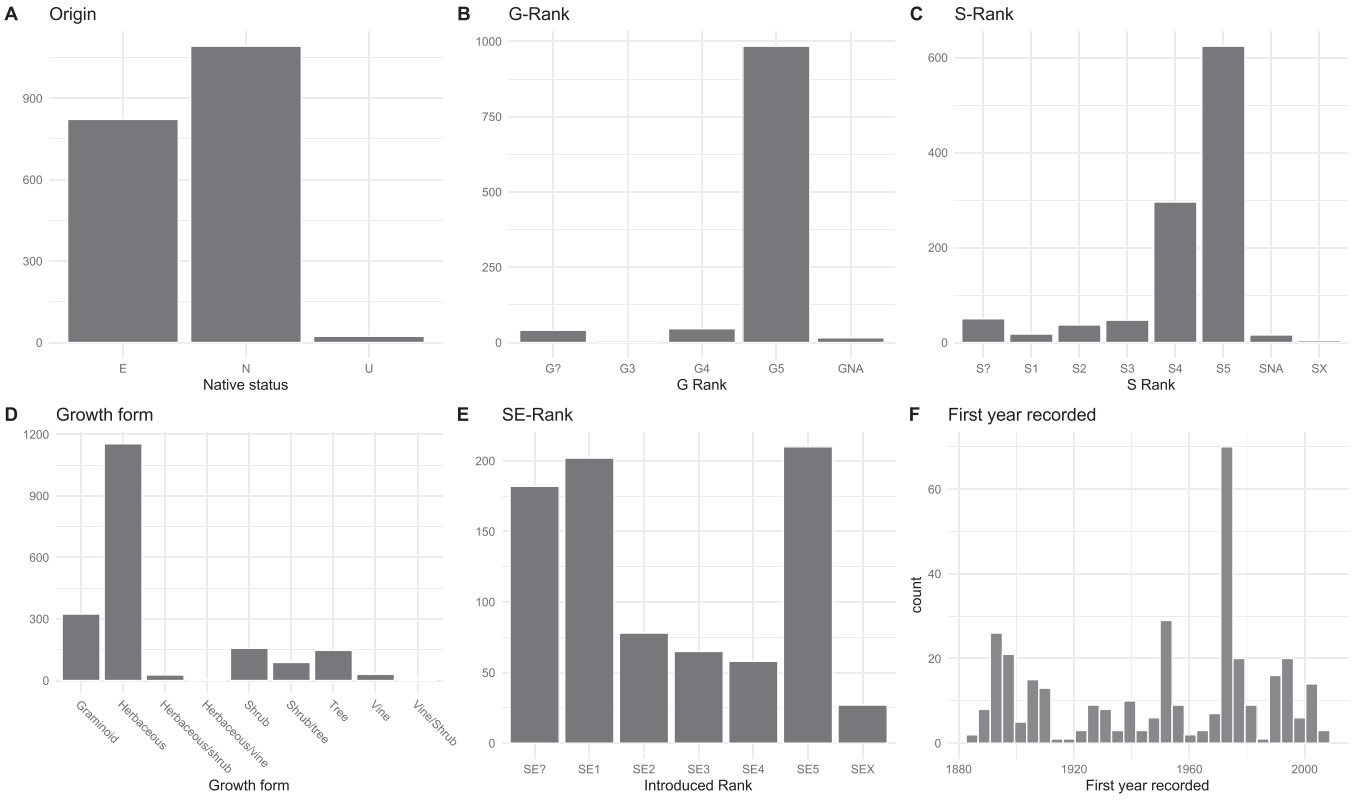

FIGURE 2 Summary plots from the distribution of plants of Toronto database, including. The native status of the taxa (a); the global rank, G-rank (b); the Ontario provincial ranking, S-rank (c); the nine growth form categories (d); the non-indigenous (introduced) ranking, SE-rank (e); and finally, the first year non-indigenous taxa were recorded by the Royal Ontario Museum herbarium (f)

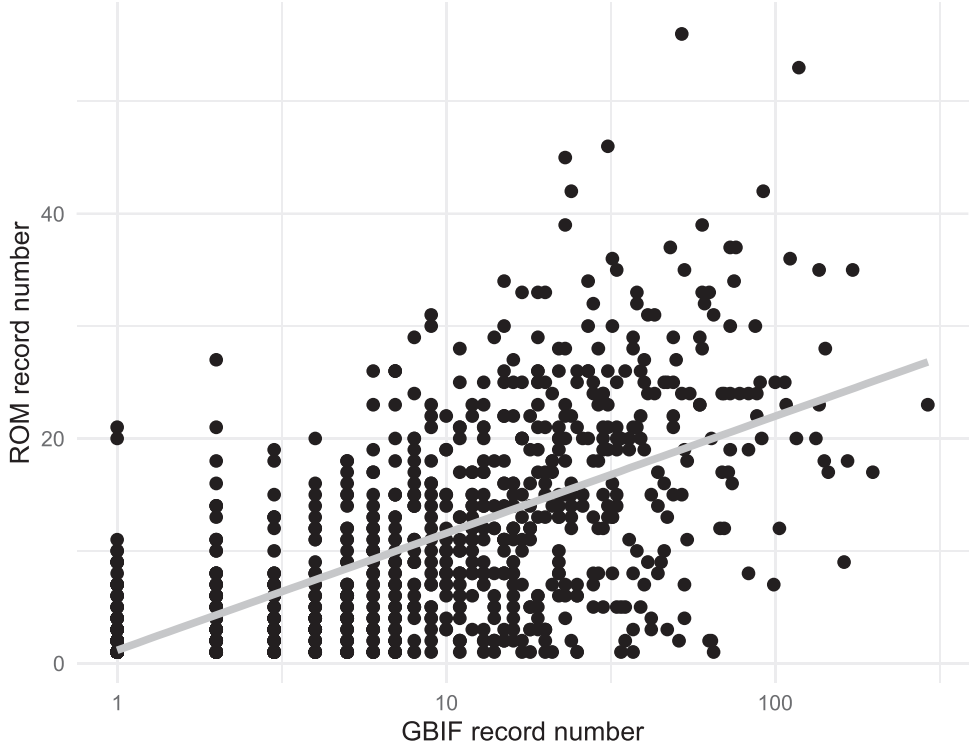

FIGURE 3 The positive correlation between two estimates of abundance

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DATA AVAILABILITY STATEMENT

The Toronto plant list version of record is available on the Dryad data repository (Cadotte, 2020), and a live and periodically updated version is available at: https://cubes-labs.com/plants-of-toronto/.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/2688-8319.12036.

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