**Preliminary assessment of the conservation status of
medicinal plant species in Canada**

Journal:	<i>Botany</i>
Manuscript ID	cjb-2021-0090.R2
Manuscript Type:	Article
Date Submitted by the Author:	04-Aug-2021
Complete List of Authors:	Erland, Lauren; The University of British Columbia Okanagan, Chemistry Turi, Christina ; The University of British Columbia Okanagan, Chemistry Murch, Susan; The University of British Columbia Okanagan, Chemistry
Keyword:	Canadian native species, conservation, Canadian medicinal plant, Natureserve database, botanical commodity
Is the invited manuscript for consideration in a Special Issue? :	Ethnobotany and Ethnopharmacology of the Americas

SCHOLARONE™
Manuscripts

Preliminary assessment of the conservation status of medicinal plant species in Canada

Lauren A E Erland¹, Christina E Turi¹, Susan J Murch^{1*}

¹Chemistry, University of British Columbia, Kelowna, BC, Canada

* Corresponding Author, susan.murch@ubc.ca

Draft

9 Abstract

10

11 Natural health products in North America are a 9.6 billion US dollar industry that has seen
12 increased demands particularly in products for immune support and anti-viral supplements in
13 response to the Covid-19 pandemic. It has been estimated that $\approx 40\%$ of the plant raw materials
14 used in natural health products are wild-harvested each year but exact data is missing for many
15 species. Our data show that there are at least 1445 medicinal plant species harvested for
16 commercial products in Canada and 1217 of these are native species. Medicinal plants and non-
17 timber forest crops are also increasingly impacted by climate change as suitable growing areas
18 migrate. In order to ensure long term species survival in the wild, it is necessary to generate
19 accurate information about distribution of wild populations, need for conservation and
20 sustainable method development. Our objective was to provide a preliminary assessment on the
21 conservation status of Canadian medicinal plants by analysis of the available data resources.

22

23

24 Keywords

25 Canadian medicinal plant, Canadian native species, conservation, Natureserve database,
26 botanical commodities

Introduction

Medicinal plants are used widely both as traditional medicines and natural health products. Consumption of natural health products in North America represents a 9.6 billion US dollar industry, which increased by 8.6 % in 2019 and has seen a significant spike in value in 2020 as people search for immune boosting and alternate medicines in the face of the COVID-19 pandemic (Smith et al. 2020). Many native North American species including: elderberry (*Sambucus nigra* L. and *Sambucus canadensis* L.; \$107.5M USD), echinacea (*Echinacea* spp.; \$120.1M USD), cranberry (*Vaccinium macrocarpon* L.; \$88.9M USD), and black cohosh (*Actaea racemosa* L; \$28.1M USD) contribute significantly to this value (Smith et al. 2020). While the American Herbal Product Association (AHPA) 2020 tonnage report reports wild and cultivated harvest values for 40 botanical commodities, no such resource is available for the Canadian natural health product industry, leaving the impacts of wild harvest unknown in Canada (AHPA 2020).

Canada is experiencing climate change at rates of two to four times the global average and northern ecosystems are expected to bear the brunt of the harshest changes (Government of Canada 2019). Globally it has been estimated that as high as 27% of plant species red listed by the International Union for the Conservation of Nature (IUCN) species are threatened, with 2.2% of the 91 Canadian species assessed in the study having being identified as threatened (Brummitt et al. 2015). The species at risk act (SARA) lists three extirpated, 45 endangered and 42 special concern plant species (SARA, 2021). It has been estimated that Canada is home to more than 5,000 vascular and more than 1,000 non-vascular plant species, with only 74% of Canada's

native plant species have been assessed for conservation status overall (Canadian Endangered Species Conservation Council, 2016).

Cultivating commercially important medicinal species is one way to ensure that species are not overharvested, and wild populations are secure but these methods are not available for all species. In particular, the following species may be at risk due to overharvest for commercial products: bloodroot (*Sanguinaria canadensis* L.), American ginseng (*Panax quinquefolis* L.), black cohosh (*Actaea racemosa* L.), blue cohosh (*Caulophyllum thalictroides* (L.) Michx), eyebright (*Euphrasia* spp.), false unicorn root (*Chamaelirium luteum* (L.) A.Gray), goldenseal (*Hydrastis canadensis* L.), lady's slipper orchid (*Cypripedium* spp.), *Lomatium* spp., osha (*Ligusticum* spp.), slippery elm (*Ulmus rubra* Muhl.), bethroot (*Trillium* sp.), true unicorn root (*Aletris farinosa* L.), virginia snakeroot (*Aristolochia serpentaria* L.), and wild yam (*Dioscorea* spp.)(COSEWIC 2021; UPS 2021). Recent increases in commercial demand for products made from some native Canadian species such as black huckleberry (*Vaccinium membranaceum* Douglas ex Torr), Labrador tea (*Rhododendron groenlandicum* (Oeder Kron & Judd), and Arctic willows (*Salix arctica* Pall.) may pose risks to wild populations that have yet to be investigated. The objective of the current study was to collate the available data on Canadian medicinal plant diversity, commercial use, and conservation status to identify knowledge gaps and areas of potential concern. We assessed Canadian records in the Natureserve database, the AHPA Herbs of Commerce, Moerman's Ethnobotanical database and the available Conservation Data Centers (CDCs). These data provide a preliminary glimpse of medicinal plant diversity and use in Canada and provide recommendations for areas in need of further study.

Methods

Medicinal Plants Classification

Two selected datasets were generated from the available databases: Dataset #1 - A comprehensive list of known medicinal taxa in Canada (Supplementary Table 1) and Dataset #2 - Canadian medicinal plant species listed in the AHPA Herbs of Commerce (HoC; Supplementary Table 2). The comprehensive list of all known Canadian medicinal taxa (2703 total) were acquired from the Native American Ethnobotany Database (<http://herb.umd.umich.edu/>) in Fall 2016. The database contains ethnobotanical information for at least 3618 plant species with reported uses by 291 First Nations with territories north of the Mexican border in North America (Moerman 2009). The AHPA HoC is a listing of standardized common and scientific names for commercially utilized species (McGuffin et al. 2001). Species presence was then assessed as native or invasive using the United States Department of Agriculture (USDA) “PLANTS Database” (<https://plants.usda.gov/java/>) and applying a custom-built macro in Excel, and only native species were retained for further analysis.

Conservation Rankings

Conservation rankings and distribution were acquired by visiting the NatureServe explorer database (<http://explorer.natureserve.org/index.htm>) in Fall of 2016 and again in Winter 2021 with distribution sorted by the subnational regions. Natureserve rankings are designated as G - global, N - national and S – subnational (province, territory or region in the case of Labrador), and the conservation status designated numerically as 1 – Critically Imperiled, 2 - Imperiled, 3 - Vulnerable, 4 – Apparently Secure, 5 - Secure, NA – Not Applicable, NR - Unranked, X –

Presumed Extirpated, H – Possibly Extirpated and U - Unrankable. Additional subnational rankings were acquired from targeted Natureserve CDCs for three selected regions of special interest: British Columbia (BC) which has the greatest number of medicinal species unique to BC (BCCDC; <http://a100.gov.bc.ca/pub.eswp>; Supplementary Table 3), Nunavut where the minority of flora has been assessed (no territorial CDC data available, Natureserve Explorer data used; Supplementary Table 4) and the Northwest Territories where a majority of species have been assessed (NWT Species Infobase www.enr.gov.nt.ca/species-search; Supplementary Table 5). In all cases queries were for “All” and “Plants OR Plantae”. These lists were then cross referenced with list 1 matching by element code and only medicinal species were retained. Committee for the Status of Endangered Wildlife in Canada (COSEWIC) and SARA listing status was extracted from Natureserve Explorer and the respective CDCs where applicable.

Data Analysis

Once working datasets were compiled, logical algorithms were applied in Excel to identify specific trends and patterns in the dataset with respect to medicinal plant distribution, conservation status, and year assessed. Where conservation status was a composite e.g. S1S2, both ranks were counted. Data were plotted in QGIS (v 3.10) and Prism 9 (GraphPad, USA). Overrepresentation analysis was performed using linear regression and residual analysis as described by Turi and Murch 2013 for Natureserve national rankings and SARA listings. Data were downloaded for all species which were designated as present in Canada AND Native from Natureserve Explorer by national rank (excluding not applicable ranking) in July 2021 and combined into a single dataset. A total of 271 plant families were found to be present but only 136 families had at least 1 medicinal species present and were retained for further analysis.

Taxonomy was resolved and plant family assigned using TNRS: Taxonomic Name Resolution Service (v5.0)(Boyle et al. 2013). To investigate whether particular plant families could be considered at greater or lesser risk we performed overrepresentation and residual analysis of the number of medicinal species in each family present at each national ranking level (e.g. N1-N5, NR, NX, NU, NH and SARA listing). The total number of all native Canadian species by family was assigned as the independent variable and total number of native Canadian medicinal species by family as the dependent variable and the equation of the line of best fit was determined. Residuals were determined by calculating the expected number of species in each rank classification (Natureserve national ranks or SARA listing) using the equation of the line of best fit and the equation of the line of best fit forcing an intercept of (0,0) and subtracting expected from observed number of species at each rank level.

Results

National (Canadian) conservation ranking of Canadian medicinal plant species

Canada is home to at least 1,446 medicinal plants species with 1,220 of them assessed to be native to Canada. Our analysis found that at least 28% of Canada's vascular flora is medicinal. The greatest number of medicinal species are located in Ontario with 1042 species (Figure 1a) of which 807 (Figure 1b) are considered to be native, and of these 90 were present only in Ontario (Figure 2). BC had the greatest number of medicinal species unique to the province, of 882 total medicinal species (Figure 1a) 704 are considered native (Figure 1b) and 141 are unique to the province (Figure 2). 54% of Canadian medicinal plants have been assessed to be secure (Figure 1c, Figure 2), in comparison with only 42 % of all Canadian species (Figure

1d) while 15% are either possibly extirpated, critically imperiled, imperiled or vulnerable (Figure 1c), compared to 23 % of all Canadian species classified similarly (Figure 1d).

Examination of National Rankings data from 2016, including all Canadian medicinal species, identified that 92% of all Canadian medicinal plants have been allocated a national conservation status over the last 10 years, with 586 being assigned or having updated rankings in 2016 (Figure 3). Assessing the Canadian species which are currently deposited at the Millenium Seedbank at Kew, United Kingdom, of the total 1,446 total Canadian medicinal species (native and non-native), only about 10 % (n=120) have been deposited.

To determine if the proportions of native Canadian medicinal species by rank was reflective of the general proportion of native Canadian flora more generally, a residual analysis was performed. Both the line of best fit and the line of best fit forcing an intercept of (0,0), as a negative number of predicted species was not possible, showed similar trends (Table 1). Native Canadian medicinal species were found to be overrepresented only in the secure (N5) rank, and underrepresented in N2, N3, N4 and NNR (Table 1). Examination of native Canadian medicinal species by family as compared to overall composition of Canadian flora for species listed as N1 or N2 found that the Asteraceae and Fabaceae were both overrepresented in the imperiled (N2) to critically imperiled rank (N1) while the Cyperaceae and Poaceae were both underrepresented (Figure 4). A similar trend was also observed upon examination of SARA-listed species with the Fabaceae, Asteraceae, Gentianaceae and Asparagaceae all being overrepresented and the Orchidaecae, Cyperaceae and Orobanchaceae all being underrepresented in the SARA listing for native Canadian medicinal species as compared to all Canadian flora (Figure 5, Table 2).

165 *Subnational conservation ranking of Canadian medicinal plant species.*

166 Native Canadian medicinal species were assessed at the subnational level. Our analysis
167 identified Saskatchewan as having the highest number of S1 ranked native Canadian medicinal
168 species (9.8%), followed by Prince Edward Island (9.3%), Nova Scotia (8.1%) and Yukon
169 (7.8%; Figure 6). The number of native Canadian medicinal species assessed by Natureserve
170 varied by province. Nunavut had the lowest percent of medicinal species with 84% not yet
171 assessed (SNA, SNR, SU) while the Northwest Territories (NWT) has the lowest proportion of
172 species yet to be assessed at only 11.2 % (Figure 3b, Figure 6). A review of the native Canadian
173 species unique to each province at the subnational level found that while 35% of these species
174 were secure (S5), 39% were at risk or imperiled (S1 or S1S2) with 3 % already considered
175 extirpated (Figure 2 inset). We additionally examined how many of the 27 native Canadian
176 medicinal species unique to a single province and ranked as S1 or S1S2 have been listed by
177 SARA/COSEWIC and found only 16 or 59% of those species considered most at-risk by the
178 Natureserve Ranking are similarly listed by SARA (Table 3). Breaking this information down by
179 province shows that the number of S1 or S1S2 listed unique native Canadian medicinal species
180 by province roughly match the proportions of total medicinal species by province with Ontario
181 (72%) then BC (15%) being most represented followed by Alberta (8%) and Manitoba and Nova
182 Scotia (3% each; Table 3, Figure 2). Expanding the criteria to include all native Canadian
183 medicinal species with a critically imperiled or imperiled ranking (S1 or S2, respectively), and
184 unique to a single province identified 70 species from 34 plant families, less than half of these
185 species have been assessed by SARA/COSEWIC (32/70).

186 Nine species were identified which are unique to a single province and have not been
187 assessed (SNR or SU) - 5 in Ontario and 4 in BC; 5 of these species additionally lack a ranking

in the US (Table 4). Cross referencing of the Natureserve explorer data to BCCDC identified one, *Asaurem caudatum* Lindl., for which an assessment has been performed and included in the BCCDC database but for which the subnational ranking has not been updated in Natureserve Explorer and one species, *Solidago speciosa* Nutt., having been assessed by SARA (Table 4). The pattern of species distribution by family is similar to that at the national level with the Rosaceae being most common in this list (n=3) followed by the Asteraceae (n = 2), Apiaceae (n=1), Aristolochiaceae (n=1), Solanaceae (n=1), and Viscaceae (n=1) also represented.

A closer examination of NWT, which has the greatest percent of species assessed, Nunavut, with the lowest proportion assessed, and BC, which has the greatest number of unique species, found several unique trends. The BCCDC lists 3,500 species which meet the criteria of “Native” AND “Plants”, and of these 432 are also present in List 1. A total of 1,245 plant species are reported in the NWT Infobase with 274 also present in List 1. No species at risk are identified in either NWT or Nunavut by COSEWIC or SARA, while 96% of BC plant species have not been assessed, of the 4 that have been assessed 2.7% are threatened, endangered or of special concern. Both BC and NWT use Natureserve subnational rankings to assign provincial/territorial conservation rankings. While neither of the territories have any species listed as critically imperiled (S1), 18% of species in the NWT and more than half of all species assessed in Nunavut (12.5% of the 22% assessed) are ranked as imperiled or vulnerable, in contrast BC has 2% of species listed as S1, 0.67% are presumed or possibly extirpated, and 9.5% are imperiled or vulnerable (Figure 7).

Examination of the date status was last reviewed for NWT and BC species found that a major reassessment of BC species status was performed in 2019 with 37% of species receiving a revised status, while 96% of NWT species were reassessed in 2015 or later. A similar effort assessment effort is still needed for Nunavut.

Medicinal species of commercial value

To evaluate the assessment status of commercially traded medicinal species, species included in the AHPA HoC were assessed for their global and national rankings; 373 HoC are reported to occur in North America, of which 40% of these have not been assessed in Natureserve (GNR, GNA or GU; Figure 8a). None of the HoC species included in this analysis were ranked globally at the G2 (Imperilled) level or higher, though 2.5% are considered globally vulnerable (Figure 8a). In Canada, 238 HoC are reported to be present, with 29 present in a single province. Less than half of all the HoC species which are present in Canada are, however, native (111) but a higher proportion (19/111) of native species list as an HoC are present in a single province (Table 5). Seven species were found to be SARA listed among the AHPA HoC species and of these four are both unique to a single province and are listed as of special concern or endangered (Table 6). These include commonly recognized species such as *Panax quinquefolius* and *Hydrastis canadensis*. The most represented families in the AHPA HoC list differ from the overall distribution of medicinal species assessed to this point with the Lamiaceae being most represented followed by the Apiaceae, Asteraceae and Paeoniaceae (Figure 8d). The provinces with the greatest number of AHPA HoC species in descending order are Ontario (66%), BC (24 %), Nova Scotia, Prince Edward Island (PEI) and Quebec (3.5% each; Figure 8c). Our query of the Natureserve database found that 38% of species included in the AHPA HoC are ranked as

Critically Imperiled, Imperiled or Vulnerable at the subnational level while 35% are non-native (SNA) or have not been assessed (Figure 8b).

Discussion

As global climates continue to shift and demand for plant and plant-derived natural health products continues to grow, a centralized Canadian system which can be publicly accessed and which gathers together ethnobotanical, distribution and conservation data will be key in developing future conservation priorities including determination of sustainable harvest levels and listing of species. It should also be noted that while general distribution data is of significant value, the exact locations of data should not be publicized to minimize risk of poaching either of species which are already at risk or which may become at risk should over harvest occur. We integrated ethnobotanical, spatial distribution and conservation ranking data to assess the current conservation status of Canadian medicinal plant species. We identified more than 1,446 medicinal species known to grow in Canada, of which 882 are native. Our analysis has highlighted several key themes in both the strengths and the gaps of medicinal plant conservation data in Canada and identified several key groups of species which should be prioritized for further assessment.

Medicinal plants were overall found to be assessed at similar rates to those observed for the whole flora of Canada, and to generally be overrepresented as compared to Canada native flora overall in the secure designation. Our analysis, however, found that this was not universally true across plant families. Several families were identified which should be considered as priorities for conservation, namely those which are overrepresented in the N1, N2 and SARA

listed designations, especially the Fabaceae and Asteraceae. The Lamiaceae are also highly represented in the AHPA HoC species, and as these species are included on this list due to their commercial importance, these species should also be further considered as they may be more likely to experience commercial harvest pressure in addition to common pressures such as loss of habitat or degradation of the existing habitat through climate change or human activity. While the sustainability of medicinal plant harvest is an active area of consideration in the United States, for example with the establishment of sustainability initiatives through organizations such as AHPA (AHPA 2018), less attention has been paid to Canadian medicinal species and populations (Oliver and Leaman 2018).

A significant gap in the knowledge of the conservation status of Canadian medicinal plants is the lack of data for Nunavut (Government of Canada 2019). Overall 15% of Canadian medicinal species have not been assessed with the number of medicinal species yet to be assessed being roughly proportional to that of native Canadian plants more broadly. While most subnational regions have about 60 - 90 % of medicinal species which have been assessed, in comparison only about 10 % of Nunavut species have been assessed. This is particularly concerning as Nunavut, and Inuit Nunangat are experiencing climate change at up to four times the global average rate, making these species a potentially particularly vulnerable subset of Canadian medicinal plant diversity and an understanding of the current status of species in this environment of particular concern (Government of Canada 2019). Mapping of Nunavut flora comes with unique challenges inherent to the geography of the region; Nunavut is Canada's largest territory comprising 5% of Canada's overall landmass with most communities and regions accessible only by air. Integration of data systems into a national framework, along with

279 integration of ethnobotanical and Traditional Ecological Knowledge (TEK) surrounding these
280 plants, would further help to develop this framework. Many Nunavut species are common across
281 the NWT, Nunavut and Northern Quebec, a geopolitical region which comprises Inuit Nunangat
282 (the Inuit Homeland). Efforts in collaboration among scientists, Inuit elders and community
283 members in these regions have also generated significant knowledge including traditional
284 medicine and TEK. For example, native berries such as crowberry/blackberry (*Empetrum nigrum*
285 L.), blueberry (*Vaccinium uliginosum* L.), mountain
286 cranberry/lingonberry/partridgeberry/redberry (*Vaccinium vitis-idaea* L.), marshberry/small
287 cranberry (*Vaccinium oxycoccus* L.), bearberries (*Arctous alpina* L. Nied. and *A. rubra* Rehder &
288 Wilon Nakai, syn *Arctostaphylos* spp.) and cloudberries (*Rubus chaemaemorus* L.) represent
289 cultural, medicinal and food species which are all well documented in TEK, in communities and
290 have been integrated into the scientific literature (Black et al. 2008; Boulanger-Lapointe et al.
291 2019). Our dataset indicates that, while all of these species have been assessed and ranked in the
292 NWT as secure (S4S5 to S5), none of the rankings have considered for Nunavut. Several
293 publications have also documented traditional uses and knowledge of these species, including
294 TEK in Nunavut, and have documented potential threats to these species due to both climate
295 change and human and animal activity (Team et al. 2016; Boulanger-Lapointe et al. 2019). We
296 have utilized Moerman's Native American Ethnobotany as well as AHPA's HoC list as sources
297 to compile a list of Canadian medicinal plant species, however, we acknowledge that these
298 sources are incomplete and detailed assessments of Canadian territories are warranted. For
299 example, several species documented to be utilized by the Inuit of the Qikiqtaaluk region of
300 Nunavut are not included in this list including *Dicranum elongatum* Schwaegr., *Lycopodium*
301 *annotinum* L., *Hockenya peploides* (L.) Ehrh., *Oxytropis maydelliana* (Trautv.), *Oxyria digyna*

(L.) Hill., *Salix reticulata* L., *Saxifraga oppositifolia* L. and *Saxifraga tricuspidata* Rothb (Black et al. 2008). This is of particular concern as a direct examination of these species find only one has been assessed in Nunavut, *L. annotinum*, with an apparently secure Natureserve ranking (S4), while the rest remain unranked (SU).

The American Herbal Products Association HoC represent some of the most common commercial medicinal species (McGuffin et al. 2001). While some of these species have received significant conservation attention due to well-documented problems with unsustainable harvest (McGraw et al. 2010), and considerations such as the impacts of changing climates on wild populations (McGraw et al. 2013), unexpectedly a significant number of these species have not been assessed even at the global level with 46% of the total list of AHPA HoC 46% still unranked at the global level and 36% unranked at the subnational level within Canada. Considering only the 40 botanical commodities which were included in the AHPA Tonnage Report, more than 300K kg of dried and 19M kg fresh material was wild harvested in the United States alone in 2017 (AHPA 2020). Of the species included in the tonnage survey, 22 are species present in Canada, with 18 of those considered native or extirpated species, and it is likely that wild-harvest is also occurring (AHPA 2020). Several of the genera also include species of concern, particularly lady slippers orchid (*Cypripedium*), including the Ram's-head lady slipper (*Cypripedium arietinum* R.Br.) which is ranked as critically imperiled (S1, Nova Scotia), imperiled (S2, Manitoba & Saskatchewan) and vulnerable both subnationally (S3, Ontario, Quebec) and nationally (N3) in Canada. In addition to these species representing a priority for assessment, collection of tonnage data is important in determining the status of Canadian medicinal species. For example, *Echinacea* is a popular botanical in the US with *Echinacea*

species together representing a market value of more than \$120M in the US in 2019 alone. *Echinaceae pallida*, which was identified as a species of priority for assessment in this study as it is a popular medicinal species, is included in the AHPA Tonnage survey with approx. 18 kg of root material being wild harvested annually, however it is present in only one province, and has not been assessed (NU; Table 4). Given the limited range of the species in Canada, information on wild harvest and current populations is vital in determining the status of this species (AHPA 2020, Smith 2019).

We have examined both overall medicinal species diversity in each subnational region as well as the unique medicinal flora for each region and have identified BC and Ontario as hotspots for medicinal species diversity, with the greatest number of medicinal species and the greatest number of unique species. Species which are unique to a region, in this case a province, are inherently at higher risk than species with broader distributions. This is particularly true given the increased risk, incidence and severity of localized extreme weather events associated with climate change. For these reasons we propose that these species be considered as priority species for assessment. Nationally eight species were identified which are unranked (SU) and which occur in only one subnational region and may represent priorities for assessment.

While the above is a good start to understanding the distribution and vulnerability of Canadian medicinal plants and to prioritize specific species/ecosystems for future monitoring, these databases do not fully reflect Canadian-specific biodiversity information. Additionally, the ex situ conservation efforts to date, namely wild Canadian species represented in the Millenium Seedbank at Kew, United Kingdom are still relatively rare and further efforts are needed to

enhance these efforts, which may include establishment of a native Canadian seedbank in Canada. We propose the following three criteria which may assist in prioritizing resources for conservation assessment priority: (a) Current assessment availability or assessment date; (b) Presence in a single province or limited range and (c) Presence of a market for commercial harvest and a or b. Furthermore, while Natureserve, Natureserve Explorer and associated CDCs are a valuable resource, there is no single standard of information available at the subnational or national level. The NWT Infobase and BCCDC are functional examples for frameworks which may be employed to reconcile ethnobotanical, species distribution and plant conservation information for Canadian species within one place, as there is currently no centralized system to monitor the distribution and conservation status of medicinal flora.

Competing Interests

The authors declare no competing interests

Funding Statement

Funding support from the Natural Sciences and Engineering Research Council of Canada (NSERC) is gratefully acknowledged.

Contributor’s Statement

LAEE and CET conducted to data collection, analysis and visualization. All authors contributed to conception and design of the study and participated in writing and editing and approved the final submission.

Data Availability Statement

All data is available in the manuscript or supplementary materials

References

- American Herbal Products Association (AHPA). 2018. AHPA launches sustainability subcommittee, formalizing ongoing efforts. American Herbal Products Association. <https://www.ahpa.org/News/LatestNews/TabId/96/ArtMID/1179/ArticleID/1034/AHPA-launches-sustainability-subcommittee-formalizing-ongoing-efforts.aspx> Accessed 20 July 2021.
- American Herbal Products Association (AHPA). 2020. Tonnage surveys of selected North American wild-harvested plants, 2011-2017. Silver Spring (MD), American Herbal Products Association.
- Black, P.L., Arnason, J.T., and Cuerrier, A. 2008. Medicinal plants used by the Inuit of Qikiqtaaluk (Baffin Island, Nunavut). *Botany* **86**: 157–163. doi:10.1139/b07-052.
- Boulanger-Lapointe, N., Gérin-Lajoie, J., Collier, L.S., Desrosiers, S., Spiech, C., Henry, G.H.R., Hermanutz, L., Lévesque, E., and Cuerrier, A. 2019. Berry plants and Berry Picking in Inuit Nunangat: Traditions in a changing socio-ecological landscape. *Polar Res* 30:21 doi:10.1007/s10745-018-0044-5.
- Boundary Files, 2016 Census. Statistics Canada Catalogue no. 92-160-X.
- Boyle, B., Hopkins, N., Lu, Z., Garay, J.A.R., Mozzherin, D., Rees, T., Matasci, N., Narro, M.L., Piel, W.H., McKay, S.J., Lowry, S., Freeland, C., Peet, R.K., and Enquist, B.J. 2013. The taxonomic name resolution service: an online tool for automated standardization of plant names. *BMC Bioinformatics* **14**: 16. doi:10.1186/1471-2105-14-16.

- 394 Brummitt, N.A., Bachman, S.P., Griffiths-Lee, J., Lutz, M., Moat, J.F., Farjon, A., Donaldson,
395 J.S., Hilton-Taylor, C., Meagher, T.R., Albuquerque, S., Aletrari, E., Andrews, A.K.,
396 Atchison, G., Baloch, E., Barlozzini, B., Brunazzi, A., Carretero, J., Celesti, M., Chadburn,
397 H., Cianfoni, E., Cockel, C., Coldwell, V., Concetti, B., Contu, S., Crook, V., Dyson, P.,
398 Gardiner, L., Ghanim, N., Greene, H., Groom, A., Harker, R., Hopkins, D., Khela, S.,
399 Lakeman-Fraser, P., Lindon, H., Lockwood, H., Loftus, C., Lombrici, D., Lopez-Poveda, L.,
400 Lyon, J., Malcolm-Tompkins, P., McGregor, K., Moreno, L., Murray, L., Nazar, K., Power,
401 E., Tuijtelaars, M.Q., Salter, R., Segrott, R., Thacker, H., Thomas, L.J., Tingvoll, S.,
402 Watkinson, G., Wojtaszekova, K., and Lughadha, E.M.N. 2015. Green Plants in the Red: A
403 Baseline global assessment for the IUCN sampled red list index for plants. PLoS ONE **10**:
404 e0135152. doi:10.1371/journal.pone.0135152.
- 405 Government of Canada. 2019. Canada's Changing Climate Report. 1–444.
- 406 Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2021. COSEWIC
407 Status Reports. [Online] Available: [https://www.canada.ca/en/services/environment/wildlife-](https://www.canada.ca/en/services/environment/wildlife-plants-species/species-risk.html)
408 [plants-species/species-risk.html](https://www.canada.ca/en/services/environment/wildlife-plants-species/species-risk.html).
- 409 Canadian Endangered Species Conservation Council. 2016. Wild Species 2015: The General
410 Status of Species in Canada. National General Status Working Group.
- 411 McGraw, J.B., Lubbers, A.E., Voort, M.V. der, Mooney, E.H., Furedi, M.A., Souther, S., Turner,
412 J.B., and Chandler, J. 2013. Ecology and conservation of ginseng (*Panax quinquefolius*) in a
413 changing world. Ann Ny Acad Sci **1286**: 62–91. doi:10.1111/nyas.12032.

- 414 McGraw, J.B., Souther, S., and Lubbers, A.E. 2010. Rates of harvest and compliance with
415 regulations in natural populations of American ginseng (*Panax quinquefolius* L.). *Nat Area J*
416 **30**: 202–210. doi:10.3375/043.030.0207.
- 417 McGuffin, M., Kartesz, J.T., Leung, A.Y., and Tucker, A.O. 2001. *Herbs of Commerce*.
418 American Herbal Products Association (AHPA). Silver Spring (MD).
- 419 Moerman, D.E. 2009. *Native American Ethnobotany*. TimberPress Inc, Portland, Oregon.
- 420 Oliver LE, Leaman DJ. 2018. Protecting Goldenseal: how status assessments inform
421 conservation. *HerbalGram* 119:40–55
- 422 Species at Risk Act (SARA), Last amended April 23, 2021. Minister of Justice, Government of
423 Canada. Accessed 20 July, 2021. <https://laws.justice.gc.ca/eng/acts/S-15.3/>
- 424 Smith, T., May, G., Eckl, V., and Reynolds, C.M. 2020. US Sales of Herbal Supplements
425 Increase by 8.6% in 2019. *HerbalGram*: 54–69.
- 426 Team, I.R., Bunce, A., Ford, J., Harper, S., and Edge, V. 2016. Vulnerability and adaptive
427 capacity of Inuit women to climate change: a case study from Iqaluit, Nunavut. *Nat Hazards*
428 **83**: 1419–1441. doi:10.1007/s11069-016-2398-6.
- 429 United Plant Savers (UPS). 2021. Species at Risk. [Online] Available:
430 <https://www.unitedplantsavers.org/species-at-risk>.
- 431

Tables

Table 1. Residual analysis of native Canadian medicinal species by Natureserve Ranking.

	Observed		Expected Best Fit ($R^2 = 0.959$)		Expected Forcing (0,0)	
	Medicinal	All	# Expected Medicinal Species	Residuals	# Expected Medicinal Species	Residuals
N1	54	232	50.56	3.44	89.27	-35.27
N2	51	246	56.58	-5.58	94.66	-43.66
N3	72	366	108.16	-36.16	140.84	-68.84
N4	184	771	282.23	-98.23	296.68	-112.68
N5	779	1800	724.49	54.51	692.64	86.36
NH	3	27	-37.54	40.54	10.39	-7.39
NNR	58	334	94.40	-36.40	128.52	-70.52
NNU	4	52	-26.80	30.80	20.01	-16.01
NX	8	23	-39.26	47.26	8.85	-0.85

Table 2. Residual analysis of native Canadian medicinal taxa listed in the Species at Risk Act (SARA) by family. Note only the top 11 families are included.

	Medicinal	All	# Expected Medicinal Species	Residuals
Fabaceae	6	11	2.46	3.54
Orobanchaceae	0	10	2.24	-2.24
Cyperaceae	0	9	2.02	-2.02
Gentianaceae	3	5	1.16	1.84
Orchidaceae	0	8	1.81	-1.81
Araliaceae	2	2	0.50	1.50
Asparagaceae	2	2	0.50	1.50
Brassicaceae	0	4	0.94	-0.94
Salicaceae	0	4	0.94	-0.94
Boraginaceae	0	3	0.72	-0.72
Onagraceae	0	3	0.72	-0.72

443 Table 3. Medicinal species which are unique to one Canadian province or territory with an S1
 444 (critically imperiled) ranking
 445

Scientific Name	Rounded Global Rank ^a	COSEWIC ¹ /SARA ² Status	National Rank ^a	Subnational Rank ^a	US Rank ^a	Province or Territory
<i>Machaeranthera tanacetifolia</i> (Kunth) Nees	G5		N1	S1	N3N5	AB
<i>Oxytropis lagopus</i> Nutt.	G4	Threatened	N1	S1	NNR	AB
<i>Lupinus wyethii</i> S. Watson	G5		N1	S1	NNR	AB
<i>Fraxinus latifolia</i> Benth.	G5		N1N2	S1S2	N4	BC
<i>Adiantum capillus-veneris</i> L.	G5	Endangered	N1	S1	N5	BC
<i>Centaureum muehlenbergii</i> (Griseb.) W. Wight ex Piper	G5	Endangered	N1	S1	N5?	BC
<i>Lupinus rivularis</i> Douglas ex Lindl.	G3	Endangered	N1	S1	NNR	BC
<i>Marah oreganus</i> (Torr. ex S. Watson) Howell	G5	Endangered	N1	S1	NNR	BC
<i>Centaureum exaltatum</i> (Griseb.) W. Wight ex Piper	G5		N1N2	S1S2	NNR	BC
<i>Delphinium carolinianum</i> Walter	G5		N1	S1	NNR	MB
<i>Hydrocotyle umbellata</i> L.	G5	Special Concern	N1	S1	N5	NS
<i>Castanea dentata</i> (Marshall) Borkh.	G3	Endangered	N1N2	S1S2	N3	ON
<i>Plantago cordata</i> Lam.	G4	Endangered	N1	S1	N4	ON
<i>Baptisia tinctoria</i> (L.) R. Br.	G5		N1N2	S1S2	N4N5	ON
<i>Aureolaria virginica</i> (L.) Pennell	G5	Endangered	N1	S1	N5	ON
<i>Betula lenta</i> L.	G5	Endangered	N1	S1	N5	ON
<i>Ipomoea pandurata</i> (L.) G. Mey.	G5		N1	S1	N5	ON
<i>Phacelia purshii</i> Buckley	G5		N1	S1	N5	ON
<i>Quercus ilicifolia</i> Wangenh.	G5		N1	S1	N5	ON
<i>Tephrosia virginiana</i> (L.) Pers.	G5	Endangered	N1	S1	N5	ON
<i>Vitis vulpina</i> L.	G5		N1	S1	N5	ON
<i>Heuchera americana</i> L.	G5		N1	S1	N5	ON
<i>Hieracium venosum</i> L.	G5		N1N2	S1?	N5	ON
<i>Uvularia perfoliata</i> L.	G5		N1N2	S1S2	N5	ON
<i>Chaerophyllum procumbens</i> (L.) Crantz	G5		N1N2	S1S2	N5	ON
<i>Aesculus glabra</i> Willd.	G5		N1	S1	N5?	ON
<i>Galium concinnum</i> Torr. & A. Gray	G5		N1	S1	N5?	ON
<i>Sisyrinchium albidum</i> Raf.	G5		N1	S1	N5?	ON
<i>Triosteum perfoliatum</i> L.	G5		N1N2	S1	N5?	ON

Scientific Name	Rounded Global Rank ^a	COSEWIC ¹ /SARA ² Status	National Rank ^a	Subnational Rank ^a	US Rank ^a	Province or Territory
<i>Agastache scrophulariifolia</i> (Willd.) Kuntze	G4		N1	S1	NNR	ON
<i>Asclepias quadrifolia</i> Jacq.	G5	Endangered	N1	S1	NNR	ON
<i>Blephilia ciliata</i> (L.) Benth.	G5		N1	S1	NNR	ON
<i>Gentiana alba</i> Muhl. ex Nutt.	G4	Endangered	N1	S1	NNR	ON
<i>Pycnanthemum incanum</i> (L.) Michx.	G5	Endangered	N1	S1	NNR	ON
<i>Senna hebecarpa</i> (Fernald) Irwin & Barneby	G5		N1	S1	NNR	ON
<i>Silphium laciniatum</i> L.	G5		N1	S1	NNR	ON
<i>Solidago ulmifolia</i> Muhl. ex Willd.	G5		N1	S1	NNR	ON
<i>Viola pedata</i> L.	G5	Endangered	N1	S1	NNR	ON
<i>Camassia scilloides</i> (Raf.) Cory	G4	Threatened	N1	S1	NNR	ON

¹Committee for the Status of Endangered Wildlife in Canada

²Species at Risk Act

^aG, Global Rank; N, National; S, Subnational Rank; NR, unranked; NA, not applicable; U, Unrankable; H, possibly extirpated; X, presumed extirpated; 1, Critically Imperiled; 2, Imperiled; 3, Vulnerable; 4, Apparently Secure; 5, Secure; ? indicates an inexact numeric rank

453 Table 4. Species unique to one province but not ranked (SNR/SU)

Scientific Name	Common Name	Rounded Global Rank ^a	COSEWIC ¹ / SARA ² Status	Canada Rank ^a	Subnational Rank ^a	BCCDC ³ Rank ^a	US Rank ^a	Province	Provincial Assessment ⁴
<i>Arceuthobium campylopodium</i> Engelm.	Western Dwarf-mistletoe	G5		N4?	SNR		NNR	BC	Yellow
<i>Malus coronaria</i> (L.) Mill.	Sweet Crabapple	G5		NNR	SNR		N5	ON	
<i>Rubus leucodermis</i> Douglas ex Torr. & A. Gray	White-stem Raspberry	G5		N5	SNR		NNR	BC	
<i>Thaspium barbinode</i> (Michx.) Nutt.	Hairy-joint Meadow-parsnip	G5		NNR	SNR		N5	ON	
<i>Echinacea pallida</i> (Nutt.) Nutt.	Pale Purple Coneflower	G4		NU	SNR		N4	ON	
<i>Solidago speciosa</i> Nutt.	Showy Goldenrod	G5	Endangered	NNR	SNR		N5	ON	
<i>Asarum caudatum</i> Lindl.	Longtail Wild Ginger, BC wildginger	G5		NNR	SNR	S5 (2019)	NNR	BC	Yellow
<i>Rubus frondosus</i> Bigelow	Yankee Blackberry	G5		NNR	SU		NNR	ON	
<i>Nicotiana attenuata</i> Torr. ex S. Watson	Coyote Tobacco	G4		NU	SU		NNR	BC	Unknown

454 ¹Committee for the Status of Endangered Wildlife in Canada
455 ²Species at Risk Act
456 ³British Columbia Conservation Data Center, brackets indicate year last assessed
457 ⁴ Provincial listing by Species at Risk Ontario (SARO) or BCCDC, included where indicated
458 ^aG, Global Rank; N, National; S, Subnational Rank; NR, unranked; NA, not applicable; U,
459 Unrankable; H, possibly extirpated; X, presumed extirpated; 1, Critically Imperiled; 2,
460 Imperiled; 3, Vulnerable; 4, Apparently Secure; 5, Secure; ? indicates an inexact numeric rank
461

463 Table 5. American Herbal Products Association (AHPA) Herbs of Commerce species unique to a
 464 single province/territory.
 465

Scientific Name	Rounded Global Rank	COSEWIC ¹ / SARA ² Status	National Rank ^a	Subnational Rank ^a	US Rank ^a	Province
<i>Aletris farinosa</i> L.	G5	Endangered	N2	S2	N5	ON
<i>Apium graveolens</i> L.	GNR		NNA	SNA	NNA	NS
<i>Baptisia tinctoria</i> (L.) R. Br.	G5		N1N2	S1S2	N4N5	ON
<i>Betula lenta</i> L.	G5	Endangered	N1N2	S1	N5	ON
<i>Castanea dentata</i> (Marshall) Borkh.	G3	Endangered	N1N2	S1S2	N3	ON
<i>Collinsonia canadensis</i> L.	G5		N4	S4	N5	ON
<i>Dioscorea villosa</i> L.	G4		N4	S4	N4N5	ON
<i>Echinacea pallida</i> (Nutt.) Nutt.	G4		NU	SNR	N4	ON
<i>Equisetum telmateia</i> Ehrh.	G5		N5	S5	NNR	BC
<i>Euonymus atropurpureus</i> Jacq.	G5		N3	S3	N4N5	ON
<i>Frangula purshiana</i> (DC.) A. Gray	G5		N5	S5	N4	BC
<i>Heuchera micrantha</i> Douglas ex Lindl.	G5		N5	S5	N5	BC
<i>Hydrastis canadensis</i> L.	G3	Special Concern/Threatened	N2	S2	N3N4	ON
<i>Mahonia nervosa</i> (Pursh) Nutt.	G5		N5	S5	NNR	BC
<i>Sassafras albidum</i> (Nutt.) Nees	G5		N4	S4	N5	ON
<i>Artemisia douglasiana</i> Besser	G5		N1N2	S1S2	NNR	BC
<i>Ballota nigra</i> L.	GNR		NNA	SNA	NNA	ON
<i>Chamaelirium luteum</i> (L.) A. Gray	G5		NX	SX	N5	ON
<i>Eclipta prostrata</i> (L.) L.	G5		N1?	S1?	N5	ON
<i>Forsythia suspensa</i> (Thunb.) Vahl	GNR		NNA	SNA	NNA	ON
<i>Glehnia littoralis</i> F. Schmidt ex Miq.	G5		N3	S3	NNR	BC
<i>Lonicera japonica</i> Thunb.	GNR		NNA	SNA	NNA	ON
<i>Mentha pulegium</i> L.	GNR		NNA	SNA	NNA	BC
<i>Paeonia lactiflora</i> Pall.	GNR		NNA	SNA	NNA	ON
<i>Paeonia officinalis</i> L.	GNR		NNA	SNA	NNA	ON
<i>Salvia sclarea</i> L.	GNR		NNA	SNA	NNA	ON
<i>Stachys officinalis</i> (L.) Trevis.	GNR		NNA	SNA	NNA	PE
<i>Teucrium scorodonia</i> L.	GNR		NNA	SNA	NNA	QC
<i>Vaccinium pallidum</i> Aiton	G5		N4	S4	N5	ON

466 ¹Committee for the Status of Endangered Wildlife in Canada

467 ²Species at Risk Act

468 ^aG, Global Rank; N, National; S, Subnational Rank; NR, unranked; NA, not applicable; U,
 469 Unrankable; H, possibly extirpated; X, presumed extirpated; 1, Critically Imperiled; 2,
 470 Imperiled; 3, Vulnerable; 4, Apparently Secure; 5, Secure; ? indicates an inexact numeric rank
 471

Table 6. American Herbal Products Association (AHPA) Herbs of Commerce species listed under the Species at Risk Act (SARA).

		NatureServe Rounded Global Rank	SARA Status	Distribution
Family	Scientific Name			
Liliaceae	<i>Aletris farinosa</i> L.	G5	Endangered	ON
Betulaceae	<i>Betula lenta</i> L.	G5	Endangered	ON
	<i>Castanea dentata</i> (Marshall)			
Fagaceae	Borkh.	G3	Endangered	ON
Araliaceae	<i>Panax quinquefolius</i> L.	G3	Endangered	ON, QC
Juglandaceae	<i>Juglans cinerea</i> L.	G3	Endangered	MB, NB, NS, ON, PE, QC
Ranunculaceae	<i>Hydrastis canadensis</i> L.	G3	Threatened	ON
Agavaceae	<i>Yucca glauca</i> Nutt.	G5	Threatened	AB, SK

Figure Captions

Figure 1. (a) All medicinal plant species present in Canada by province or territory, (b) Native medicinal plant species assessed present by province or territory, where native is defined by the USDA PLANTS floristic database; (c) distribution of Natureserve conservation rankings (Percent) for all medicinal species in Canada; and (d) distribution of Natureserve conservation rankings for all Canadian species, where NNA (Not Applicable), NNR (Unranked), NH (Possibly Extirpated), NX (Presumed Extirpated), N1 (Critically Imperiled), N2 (Imperiled), N3 (Vulnerable), N4 (Apparently Secure), N5 (Secure). Shape files from Cartographic Boundary Files portrayed in Lambert conformal conic projection based on the North American Datum of 1983 (NAD83), 2016 Census, Statistics Canada.

Figure 2. Distribution of native Canadian medicinal species unique to a single province or territory. Inset, Natureserve subnational ranking of native Canadian species unique to a single province or territory where SNA (Not Applicable), SNR (Unranked), SH (Possibly Extirpated), SX (Presumed Extirpated), S1 (Critically Imperiled), S2 (Imperiled), S3 (Vulnerable), S4 (Apparently Secure), S5 (Secure). Shape files from Cartographic Boundary Files portrayed in Lambert conformal conic projection based on the North American Datum of 1983 (NAD83), 2016 Census, Statistics Canada.

Figure 3. (a) Year medicinal species possessing Natureserve national rankings were last updated and (b) proportional of species assessed by province/territory.

Figure 4. Distribution of species by family ranked as (a) N1 or (b) N2 by family where size of the bubble indicates total number of native Canadian species in a particular family and the line of best fit is the linear regression line of all species with the ranking vs all medicinal species with the designated ranking. Families above the line are families where medicinal species are overrepresented in the family for the rank level, while those below the line are underrepresented by the rank level.

Figure 5. Regression analysis of number of SARA-listed native Canadian medicinal species by family vs total SARA-listed native Canadian species where families above the line of best fit are over-represented and those under the line are under-represented. Size of bubbles indicates total number of native species present in the family in Canada and the lighter the colour the greater the number of native Canadian medicinal species in the family.

Figure 6. Percent of species by Natureserve subnational ranking in each province/territory. Darker indicates a higher proportion, for combined categories e.g. S3S5 the species is included in both S3 and S5. SNA (Not Applicable), SNR (Unranked), SH (Possibly Extirpated), SX (Presumed Extirpated), S1 (Critically Imperiled), S2 (Imperiled), S3 (Vulnerable), S4 (Apparently Secure), S5 (Secure). Shape files from Cartographic Boundary Files portrayed in Lambert conformal conic projection based on the North American Datum of 1983 (NAD83), 2016 Census, Statistics Canada.

Figure 7. Natureserve subnational rankings of native Canadian species reported to occur in the Northwest Territories (NWT; top), British Columbia (BC, middle) and Nunavut (NU, bottom),

where SNA (Not Applicable), SNR (Unranked), SH (Possibly Extirpated), SX (Presumed Extirpated), S1 (Critically Imperiled), S2 (Imperiled), S3 (Vulnerable), S4 (Apparently Secure), S5 (Secure).

Figure 8. American herbal products association (AHPA) herbs of commerce (HoC) (a) Global rank of all HoC species reported to occur in Canada (b) Subnational ranking (c) Provincial distribution of HoC unique to a single province or territory and (d) Distribution of unique HoC species where G, Global; S, Subnational, 1 (Critically Imperiled), 2 (Imperiled), 3 (Vulnerable), 4 (Apparently Secure), 5 (Secure), NR (Not Ranked), NA (Not Applicable), U (Unrankable), X (Presumed Extirpated), H (Possibly Extirpated).

Draft

534 Supplementary Materials

535
536 Supplementary Table 1. Comprehensive list of medicinal species included in the study acquired
537 from the Native American Ethnobotany Database
538 Supplementary Table 2. List of species included in the study which are included in the American
539 Herbal Products Association (AHPA) Herbs of Commerce.
540 Supplementary Table 3. Species queried for subnational ranking and conservation status in
541 British Columbia through the BC Conservation Data Centre.
542 Supplementary Table 4. Species queried for subnational ranking and conservation status in
543 Nunavut through Natureserve Explorer.
544 Supplementary Table 5. Species queried for subnational ranking and conservation status in the
545 Northwest Territories through NWT Species Infobase.
546

Draft

a

b

S1

S4

SNR, SNA, SU

S2

S5

S3

SH, SX

a

b

c

d