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Notes on the nomenclature, characteristics, status, and biology of Field Thesium, Thésium des Champs (*Thesium ramosum* Hayne; Thesiaceae/Santalaceae), a potentially serious invasive plant in Alberta

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Abstract

Field Thesium (*Thesium ramosum* Hayne; Thesiaceae/Santalaceae) is an alien species in Canada, previously misidentified as *Thesium arvense* Horvátovszky or Flaxleaf (*Thesium linophyllon* L.). It is a hemiparasitic herb characterized by its many 25–50 cm long aerial stems that grow indeterminately from a caudex. Its narrow leaves extend along each aerial stem from their base into the paniculate inflorescence. The flowers are white, 4–5 mm wide, with five corolla lobes; they are perfect and occur singly, subtended by a three-parted bract at the tip of a narrow pedicel, with 60–90 such flowers along each inflorescence. Its roots develop profuse haustoria that attach to host plant roots. *Thesium ramosum* is compared to the related native genera, *Comandra* and *Geocaulon* (placed in Comandraceae or Santalaceae), which share features but differ by having determinate growth and being unbranched. *Thesium ramosum* is widespread from western Europe to western China, but in North America it is known from only three western states and Alberta, where it has established in Fish Creek Provincial Park and elsewhere in Calgary. Worldwide, many species in the genus *Thesium* are notable invasives and *T. ramosum* has the potential to be a high risk invasive in North America. Observations in the park show that it can spread rapidly and parasitize many host species. It does not have federal or provincial control status in Canada, but because it is parasitic and has potential to become widespread, it is regulated in the USA by the United States Department of Agriculture.

Key words: *Thesium ramosum*; *Thesium arvense*; Thesiaceae; Santalaceae; vascular plant; invasive hemiparasite; Alberta; Calgary; Fish Creek Provincial Park; identification; distribution

Introduction

Field Thesium (*Thesium ramosum* Hayne [J. Bot. (Schrader) 3(1): 30, t.7 (1800)]) in Thesiaceae (or Santalaceae), formerly *Thesium arvense* Horvátovsky, is a potentially invasive vascular plant species for Canada. It was first observed in 2001 by G.J. Yaki where it grew along trails in Fish Creek Provincial Park, Calgary, Alberta. He collected specimens for identification in 2003 and 2004, and the earlier collection (University of Calgary [UAC] 81466) was identified as *T. arvense* by S.V. in June 2005 using the keys for the genera and species in Santalaceae that were available in the *Flora of China* (Xia and Gilbert 2003). Specimens collected by S.V. also were submitted to the Agriculture and Agri-Food Canada National Collection of Vascular Plants in Ottawa, Ontario (DAO 806480 and DAO 806481), where S.J. Darbyshire confirmed their identification as *T. arvense*. Consultation with NatureServe (2005) at the time of identification revealed that *T. arvense* had been reported from North Dakota and Montana, but not from Canada. Hence this was the first record of this species in Canada. Since its initial observation two decades ago, the plant has spread throughout Fish Creek Provincial Park and to other locales in the City of Calgary. Considering the potential for this species to become a serious invasive plant (PPQ 2019), we here provide detailed information on the nomenclature, characteristics, occurrence, and biology that may be relevant to its control.

Species Name

A classification of Santalales was published, first as clades based on molecular phylogenetic as well as morphological data (Der and Nickrent 2008), then

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as families by Nickrent *et al.* (2010). While the Santalaceae *sensu lato* has been retained by VASCAN (Brouillet *et al.* 2010+) and other sources (The Plant List 2013; BONAP 2015; IPNI 2015; Missouri Botanical Garden 2021), it was divided into six families (Nickrent and Musselman 2004), which include in the *Flora of North America* – Volume 12 Thesiaceae Vest (Nickrent 2016a), and Comandraceae (Nickrent 2016b). Thesiaceae has two genera in North America: *Buckleya* Torrey and *Thesium* L. Comandraceae also has two genera in North America: *Comandra* and *Geocaulon*. The name *Thesium arvense* Horvátovszky [Fl. Tyrnav. Indig. 1:27. 1774] was recognized as being illegitimate by Gutermann (2009), who reported that the proper name should be *Thesium ramosum* Hayne [J. Bot. (Schrader) 3(1): 30, plate 7 (left). 1800] (IPNI 2015). Other synonyms for the species are *Linosyris ramosa* (Hayne) Kuntze, *Thesium brevibracteatum* P.C. Tam, and *Thesium parnasi* A. DC. (Czerepanov 1981; The Plant List 2013; Missouri Botanical Garden 2021; Plants of the World 2022).

Thesium has been regarded as being a most diverse and taxonomically complex genus (Musselman and Haynes 1996). The genus has 350 species worldwide, and with 190 species, it is most diverse in southern Africa and has over 90 species in the rest of Africa. Elsewhere it has 26 species in Europe, over 40 in Asia, three in South America, and one in each of Australia and North America (D.L. Nickrent and M.A. García pers. comm. 23 March 2022).

Species Description

Thesium ramosum is a perennial, hemiparasitic herb that develops from a caudex and presents many aerial stems with a rather bushy growth habit (Figure 1).

The following description and discussion of the physical features of the species and its behaviour are intended to be an expansion of the concise description of the species in the *Flora of North America* (Nickrent 2016a). It is based on observations between 2012 and 2021, and an examination of well over 50 representative and vigorous specimens from Fish Creek Provincial Park and vicinity, and from Teton County, Montana. Terminology used conforms to Nickrent (2016a) and Harris and Harris (2000).

The **caudex** is a subterranean stem with an off-white, cylindric body that is 4–9 cm long and 4–15 mm in diameter with several 0.7–1.5 cm long lobes around its base, from which 2–7 (10) cm long, spreading roots develop. These produce many fine rootlets that envelop the roots of its parasitized host and produce bell-shaped, white **haustoria** that attach to the surface of the host roots where they appear to digest the epidermis to gain access to the root sap. Typically, the root cluster is comparatively small and shallow, given the size of the mature plants.

The apex of the caudex extends only 0.6–1.5 cm above the ground, and has many **growth buds** over its surface that begin to develop by late July and persist over the winter. By mid-April of the following year these buds start to extend as medium green **aerial stems**. About 5–10 of the aerial stems grow to about 5 cm long by mid-April to early May, and to 10–12 cm by mid-May as more of the buds on the caudex develop. By mid-June they are 20 cm long, and typically by early July they are well beyond 30 cm with an average of 37 aerial branches. In more vigorous, older plants, the aerial branches may have over 100 stems that can be up to 50 cm long. At maturity the aerial stems are 1.5–1.9 mm in diameter, somewhat woody, and have about seven blunt, finely scabrid, low longitudinal ridges. Also, some of the aerial branch bases may remain green over the winter and in the spring may produce buds and aerial branch shoots. Of interest, during the major flood of June 2013 in Calgary, aerial stems that were pushed over and buried by the flood deposits along their length produced clusters of additional normal aerial stems that emerged through the sediments (E. Harder pers. comm. 22 July 2015).

The **leaves** begin to develop as the aerial stems extend. They are alternate, medium green, simple, narrowly linear, straight to slightly falcate, acute at both ends, 3.5–4.5 (9.1) cm long, and 0.9–2.9 mm wide. They have minutely serrulate margins, a finely scabrid surface, and a single midvein that is often paralleled along each side by faint side veins that extend to half the midvein's length. The leaves are sessile, or with a petiole only 1.0–4.5 mm long, and lack stipules. Young plants have leaves that extend only (3) 4–6 (8) cm into the inflorescence, but as the plants mature they develop well into the axils of the panicle branches, often as very long blades.

The **inflorescence** develops beyond the leafy portion of the young aerial stem by early June with indeterminate paniculate growth. Initially there are only single flowers on bracted pedicels along its axis, but by late June or later secondary branches develop along the axis in the lower to middle portions of the inflorescence, each with several pedicels having bracts and flowers along their length. By mid-July the inflorescence is about 20–35 cm long, and by August it becomes notably bushy and may continue growing well into October to become over 50 cm long. Occasionally in late season, the inflorescence apices become fasciated and the flowers become congested.

A narrow, (3) 10–20 mm long, thin **pedicel** supports a single three-parted bract above which is a single flower. The **bracts** are medium green, acute, 7–12 (25) mm long, 0.6–1.1 mm wide, with minutely

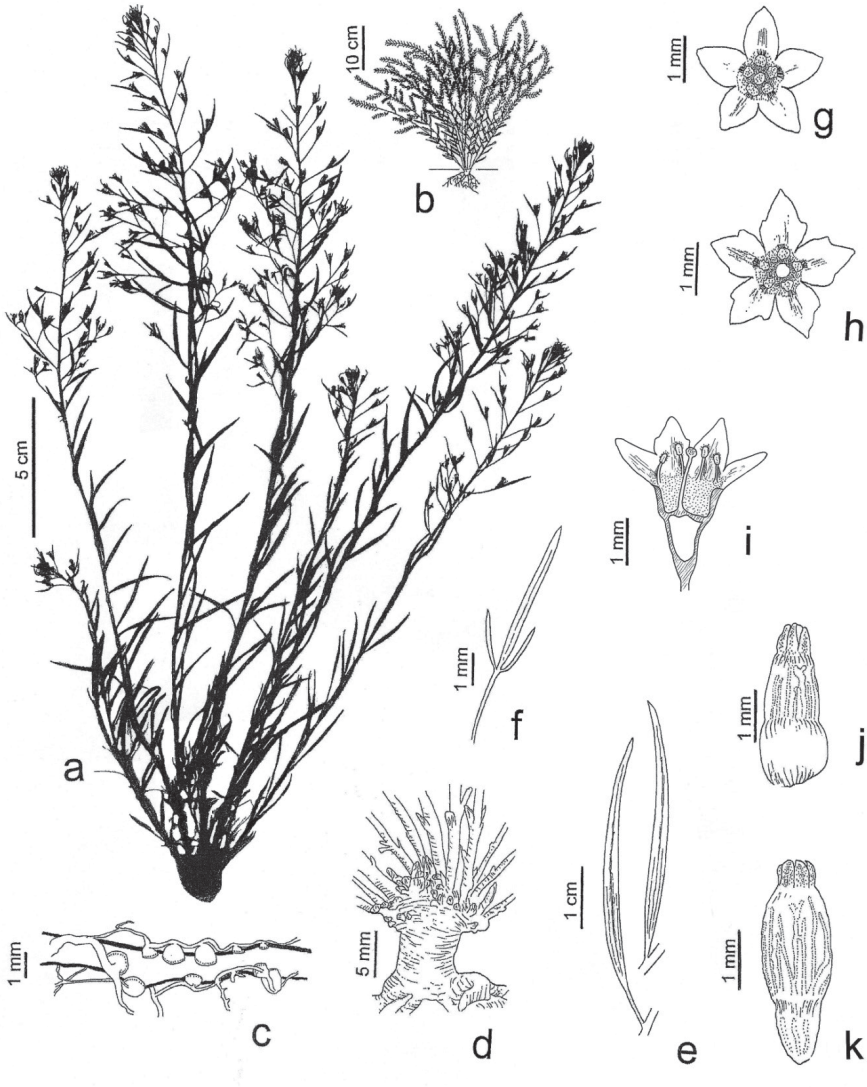

FIGURE 1. Field Thesium (*Thesium ramosum* Hayne). a. whole plant (STMU 4846: Ian D. Macdonald 140705a1), b. growth habit, c. haustoria attached to host root, d. caudex with aerial branches and buds, e. aerial branch leaves, f. bract and bracteoles, g. typical flower with smooth margins on corolla lobes, note anthers with supporting post-staminal hairs, h. flower with toothed margins on corolla lobes, i. longitudinal section of flower showing hypanthium, pistil, and anther arrangement, j. young fruit with fleshy elaiosome, k. mature fruit with firm elaiosome. Illustration by I.D. Macdonald from specimen microscope photos.

serrulate, clear margins and a finely scabrid surface with a single midvein. Two veinless bracteoles on either side of the bract's base are about (1/5) 1/3–1/2 (3/5) of its length.

The **flowers** in the Alberta sites begin to develop by late May with notable numbers by mid-June, and may continue to develop through to early October. Generally only 1–3 flowers are open at the apex of each inflorescence branch at any one time. The corollas are perfect, 4–5 mm in diameter, with a single whorl of 5 (4),1–1.3 mm long, petal-like **corolla lobes**, which Der and Nickrent (2008: 107) interpreted as a perianth where "the calyx is reduced and fused to the wall of the inferior ovary", with the sepals present only as small glands (Nickrent 2016a). The corolla lobes are triangular, only occasionally with a single tooth

along each margin, and bright white with a green base adaxially and a single broad green midvein abaxially. The ovary is inferior with a single clear, pale white, erect style and a finely textured, capitate stigma that at anthesis is exserted barely above the anthers. The capitate anthers and pollen are yellow and the filaments are pale white. The five stamens originate from the green hypanthium ring at the base of the green corolla lobes and initially lie along one-half to two-thirds of the corolla lobe's length. Multiple threads (**post-staminal hairs**) attach the stamen's filaments to the corolla lobe, and as the flowers open over several hours in the mid-morning, these hairs extend to push the filaments to a vertical position so that the anthers are then held surrounding, but away from, the stigma. The flowers close by late afternoon or early evening by the swelling of the abaxial broad green midvein that pushes the corolla lobes to close around the stamens causing the corolla tips to refold back over the anthers to cover them. The flowers do not reopen again. Hence, the open corolla is available for pollination for about nine hours, and the refolded corolla lobe tips appear to prevent the anthers from touching the stigma. The refolded corolla lobes wither to a length of 0.7–0.9 mm and persist on the apex of the mature fruit. No information as to whether the plants are cross- or self-pollinated is available for our population.

The **fruit** is a nutlet-like pseudodrupe that is medium green, linear, cylindric-ovate, with an overall length of 4.1–4.4 mm, and presents three sections. At the base is the persistent pedicel that becomes the lipid-rich **elaiosome**, which is 1.0–1.3 (1.8) mm long and about half the main fruit body length. It is ivory-white and fleshy when young, but due to drying, becomes amber, firm, and longitudinally wrinkled when mature. Above this is the 2.0–2.8 mm long and 1.4–1.6 (1.8) mm wide, inferior ovary. Its surface is fluted with 12 to 16 longitudinal, parallel, finely textured veins with occasional cross veinlets. It contains a single white, oval seed that essentially fills the fruit body. At the top are the persisting, withered corolla lobes. The fruits mature over 6–10 days, start to abscise by late June or early July, and are continually produced over the growing season, often well into early October. Typical plants average over 30 aerial stems, and by late September, each inflorescence axis will have 30–50 fruits, and an additional 30–40 along the branchlets. As a result, potentially over 2250 fruits per plant may be produced.

Seedlings from the previous year's fruits develop by mid-June, and those that survive the summer's droughts can grow to about 15 cm long by the autumn. The more vigorous of these seedlings will produce flowers and fruits and have growth buds at their bases on their developing caudices at the end of the growing season. Unlike the 'tumbleweeds' of the prairies, *T. ramosum* does not separate from the ground and roll with the wind at the end of the season; rather, its dead aerial stems remain attached to the caudex, or occasionally break off, and allow their inflorescences to simply fall with minimal dispersion of any persisting fruits.

Comparison to *Comandra* and *Geocaulon*

Two related species, formerly in Santalaceae but both placed in Comandraceae (Nickrent *et al.* 2010) in *Flora of North America* (Nickrent 2016b), share similar floral characteristics in having the five-merous corollas, post-staminal hairs and fruits that are pseudodrupes, but differ in several important and readily recognizable ways. The first species is Bastard Toadflax (*Comandra umbellata* (L.) Nuttall) with three subspecies in Canada: Eastern Bastard Toadflax (*Comandra umbellata* (L.) Nuttall subsp. *umbellata*) that occurs across Canada and the eastern half of the USA, Pale Bastard Toadflax (*Comandra umbellata* subsp. *pallida* (A. de Candolle) Piehl) that occurs across the western half of the continent, and California Bastard Toadflax (*Comandra umbellata* subsp. *californica* (Eastwood ex Rydberg) Piehl) that is restricted to Vancouver Island, British Columbia. This species has dull white, narrow petals with pinnately branching abaxial midveins that neither swell nor significantly fold the petals inward after pollination, and has a fruit that is a brown, spherical, hard pseudodrupe. The subspecies differ in glaucescence, leaf thickness, and leaf blade lateral vein presentation (Flora of North America Committee 1993+; Nickrent 2016b).

The second species, Northern Comandra (*Geocaulon lividum* (Richardson) Fernald), occurs across Canada and the northern tier of states. Its petals are green and become maroon with maturity; they have reticulate abaxial veins that greatly swell and become rugose after pollination. The drying petals fold upwards and are persistent, but unlike *T. ramosum*, their tips do not enclose the stamens. Its anthers and post-staminal hairs are very short, and its fruit is a red, ovoid, fleshy pseudodrupe. However, neither species has the indeterminate growth nor the profuse branching of *T. ramosum* and neither is invasive. *Comandra umbellata* subsp. *pallida* has the synonym *Thesium umbellatum* L. [Sp. Pl. 208. 1753] (Fosberg 1940).

Occurrence in Alberta, Elsewhere in North America, and Eurasia

In Canada, *T. ramosum* currently is known from only eight locations within and near Calgary, Alberta, in the province's Grassland Natural Region, Foot-

hills Fescue Natural Subregion (Alberta Sustainable Resource Development 2006). The most extensive population occurs along the 17.8 km length of Fish Creek Provincial Park (centrum 50.9259°N, 114.0572°W, elevation range 993–1112 m; Figure 2). Since its discovery, it has been reported from seven additional locations in Calgary and one area outside the city (see below for location descriptions).

While several of the Field Thesium sites along the Fish Creek and Bow River floodplains were inundated by the major Calgary flood of early June 2013, the plants had not yet set fruit, and it is unlikely that propagules were distributed downstream along the Bow River after this event. However, only recently it has been reported from three locations along the river south of the park (K.L. Hull pers. comm. 1 December 2021). It has not yet been reported from elsewhere in Alberta (ACIMS 2018), or the adjacent provinces: British Columbia (Douglas *et al.* 2000; BCCDC 2021); Saskatchewan (Harms 2006; SCDC 2021); Manitoba (Burchill 2016; Manitoba Environment and Biodiversity 2021), or elsewhere in Canada (Brouillet *et al.* 2010+).

Elsewhere in North America, the first collection was in 1943 from northeastern North Dakota in Towner County (Stevens 1944) from roadside and pasture sites, and was originally identified as Flaxleaf (*Thesium linophyllon* L.) by O.A. Stevens and W. Wieland (Stevens 1944). Their 1943 specimen is now at the Missouri Botanical Garden (MO 971578; van Bruggen 1986), along with a more recent 1974 specimen (MO 971576). As well, Musselman and Haynes (1996) reported *T. arvense* from Eddy County (North Dakota) based on a collection by C. Slaughter, now at the herbarium of Old Dominion University, Norfolk, Virginia (ODU *sine numero*), and included a photo illustration of a specimen with the species' characteristic corolla and cylindric-ovate fruit shape. No additional county locations in North Dakota have been reported (A.S. Shipunov pers. comm. 19 March 2022).

The species was first recorded as *T. arvense* from southwestern Montana in Madison County in 1992 by P. Lesica; his collections are now at the University of Montana (MONTU 118539). It has since been reported in that state from seven counties of the Rocky Mountains and western foothills at elevations between 1676 and 2286 m in a variety of habitats, including dry roadside rights-of-way, meadows, native and improved grasslands, riparian zone, native slope, moist grassland, and river-side hummocks in calcareous meadows (Lesica 2012; Mincemoyer 2013; Consortium of Pacific Northwest Herbaria 2016a). Indeed, just in the western portion of Teton County it is now known to be well-established in over 15 locations, including along river courses and in native grasslands (M. Korte pers. comm. 28 August 2017).

In southeastern Idaho the species, originally identified as *T. arvense*, was collected in 1993 by E.F.

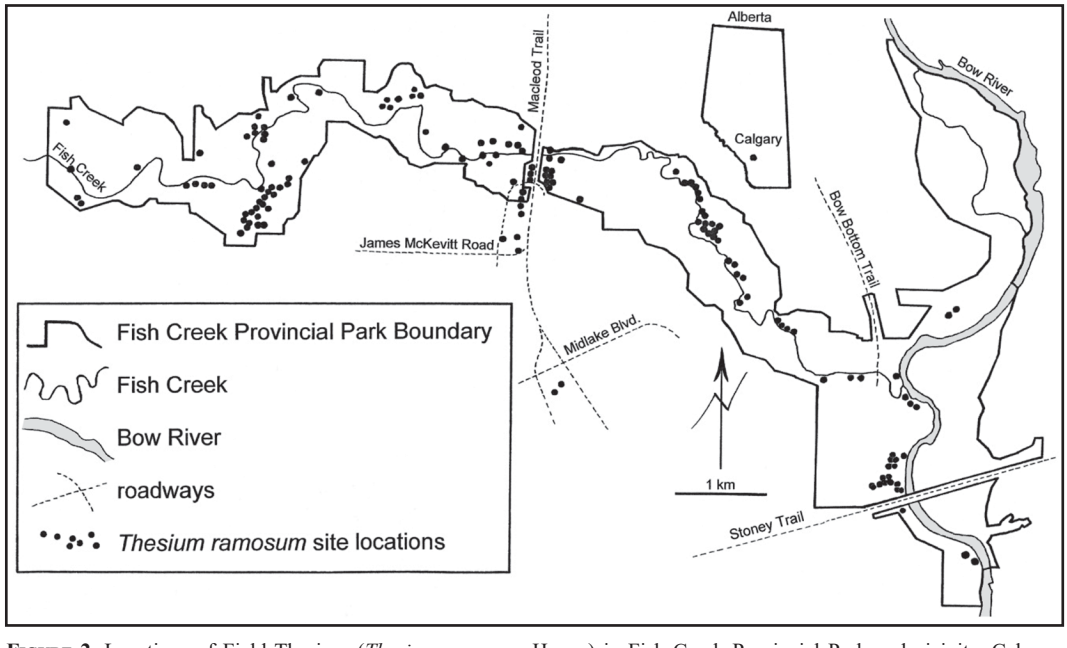

FIGURE 2. Locations of Field Thesium (*Thesium ramosum* Hayne) in Fish Creek Provincial Park and vicinity, Calgary, Alberta (to 2018).

Evert (University of Wyoming [RM] 907040) from a montane riparian meadow at an elevation of 1807 m in Teton County (BONAP 2015; Consortium of Pacific Northwest Herbaria 2016b).

There are no records from elsewhere in the United States (BONAP 2015; Nickrent 2016a), although Haynes and Musselman (1994) indicated that the genus *Thesium* had been introduced into the United States on several occasions and was reported as a minor weed in the Great Plains several decades ago, but had since been extirpated. There is only one species of *Thesium* currently known to occur in North America: *T. ramosum*. The confusion of the species with *T. linophyllon* in the original North Dakota and Montana specimen identifications probably derived from the lack of available reference floras and descriptions. *Thesium linophyllon* differs from *T. ramosum* in having rhizomes, a dichasium inflorescence, and comparatively short bracts (Gudžinskas and Žalnervičius 2017). All of the North American occurrences have been mapped in the United States Department of Agriculture weed risk assessment (PPQ 2019) and in the United States on a county level, by the Biota of North America Program (BONAP 2015).

Hendrych (1961) indicated that, of all the species of the genus *Thesium*, *T. ramosum* had the largest distribution in Eurasia. Its native distribution in southern Europe, as cited by Plants of the World (2022) and Ukranian Biodiversity Information Network (2018), extends from Italy to the Czech Republic to southwestern Russia to Ukraine to Greece; its western Asian distribution extends from Turkey to Iraq to Iran, and its central Asian distribution extends east of the Caspian Sea from Afghanistan to Turkmenistan to Kazakhstan to the Tan-Shan Mountains of western China. It also is introduced in northern European and the southeastern Baltic countries (PPQ 2019), but has not been reported from the western European and northern Baltic countries.

Invasive Potential

Around the world, the genus *Thesium* includes many species that are regarded as being invasive and weedy in agricultural situations. The Global Compendium of Weeds (Thomas 2011), which listed over 28 000 species from around the world that have been cited as having potential for being weedy, included 11 references for species of *Thesium*, *T. ramosum* (sub *T. arvense*) being listed as a 'casual alien', naturalized, or an agricultural weed in various European countries. Randall (2017) also listed invasive plant species from around the world, including five references for *T. arvense*, and at least two other species in the genus that are toxic. Other sources that cited various species of *Thesium* as being invasive include Clement and Foster (1994) for Great Britain, Haynes and Musselman (1994) for the Middle East, and Randall (2012) for Australia. Of the at least 18 species of *Thesium* occurring in Europe (Hendrych 1980), Dostálek and Münzbergová (2010) indicated that some were well-known agricultural weeds, while some species, including *T. arvense*, were considered to be endangered in some parts of Europe. For example, in the Czech Republic, they indicated that *T. linophyllon* was quite common and was capable of using a wide range of angiosperms as hosts, listing the genera *Themeda* (red grass), *Poa* (bluegrass), *Galium* (bedstraw), *Hordeum* (barley), *Allium* (onion), and *Vitis* (grape). They also found of three species studied that, while *T. linophyllon* showed some degree of host preference, two other species, *Thesium ebracteatum* Hayne and *Thesium bavarum* Schrank, showed none; however, all three had an extremely wide host range. In Jordan, Qasem (2006) indicated that *Thesium chinese* Turczanionow was a problematic species that posed high concern to farmers and was a potential threat to agriculture and forestry. In Japan, Suetsugu *et al.* (2008) reported that *T. chinese* had 22 species from 11 families as hosts, including members of their preferred hosts in the Poaceae, as well as species in the Caryophyllaceae, Rosaceae, Cyperaceae, Oxalidaceae, Violaceae, and Rubiaceae.

In North America, The Animal and Plant Health Inspection Service (PPQ 2019) produced a weed risk assessment report that dealt with the potential for *T. ramosum* to become a problem species in the USA. Their analysis considered four major topics: Establishment and Spread Potential, possibly by contamination in seed, grain, hay, etc., or in soil from foot or vehicle traffic or construction; Impact Potential on natural and agricultural environments; Geographic Potential, based on several climatic, edaphic, and habitat criteria; and Entry Potential that considered its possible spread to other jurisdictions. Despite the authors' cautions about very high uncertainty and insufficient documentation, they concluded that *T. ramosum*, with its ability to parasitize a wide variety of species, has a "High Risk invasive potential" to become weedy or invasive in the extensive range of geographic, climatic, and diverse habitat conditions which occur through much of the USA. Indeed, their Figure 2 encompasses virtually all of the lower 48 states and extends into the lower third of all Canada's provinces, including in Alberta, a corridor that reaches up to its northern boundary.

In Montana, Musselman and Haynes (1996) reported that *Thesium* plants formed haustoria on a diversity of hosts (* indicates non-native species): Timber Milk-vetch (*Astragalus miser* Douglas), *Smooth Brome (*Bromus inermis* Leysser), horsetail (*Equise-*

tum spp.), Prairie Junegrass (*Koeleria macrantha* (Ledebour) Schultes), *Kentucky Bluegrass (*Poa pratensis* L.), Sandberg's Bluegrass (*Poa secunda* J. Presl), Prickly Rose (*Rosa acicularis* Lindley), willow (*Salix* sp.), snowberry (*Symphoricarpos* sp.), Mountain Golden Banner (*Thermopsis montana* Nuttall), *Yellow Goatsbeard (*Tragopogon dubius* Scopoli), and *Red Clover (*Trifolium pratense* L.). Musselman and Haynes (1996) also noted that for Montana, it was remarkable that so few introductions of *Thesium* had occurred, considering how widespread the genus was, and how many comparable habitats were present. However, M. Korte (pers. comm. 28 August 2017) reported that *T. ramosum* is invading, not only disturbed habitats, but also native fescue grasslands, and given its spread in Teton County, it probably actually is far more widespread now than presently known in Montana.

In Alberta, *T. ramosum* presently is localized, the most widespread population being within the boundaries and immediate vicinity of the valley of Fish Creek Provincial Park (Figure 2), with small populations currently known from seven other locations within and near the city of Calgary (see below). Within the park, it has spread from a single location in 2001 to many locations along 11 km within the park by 2005, with subpopulations of only several plants to hundreds. At one location in the park (Marshall Springs), where a slope was cleared of vegetation for the construction of a storm pond and planted in rehabilitation species, *T. ramosum* initially was recorded the following year as having only an incidental occurrence, but within two years the population had exploded to over 650 vigorous plants in a 25 m × 60 m area. At another site in the park (Glennfield) that had compacted soil from former disturbance, there were 518 plants in a 5 m × 20 m area.

A survey of 102, 0.5 m radius circular plots in the park that were centred around plants of *T. ramosum* recorded 153 species. Those which occurred in more than 20% of the plots were the following (* indicates non-native species): **B. inermis* (76.5%), **P. pratensis* (64.7%), Western Snowberry (*Symphoricarpos occidentalis* Hooker; 56.9%), *Canada Thistle (*Cirsium arvense* L. (Scopoli); 50.0%), *Common Dandelion (*Taraxacum officinale* F.H. Wiggers; 35.3%), Northern Bedstraw (*Galium boreale* L.; 34.3%), *Black Medick (*Medicago lupulina* L.; 34.3%), Smooth Aster (*Symphyotrichum laeve* (L.) Á. Löve & D. Löve; 28.4%), Wood's Rose (*Rosa woodsii* Lindley; 22.5%), American Vetch (*Vicia americana* Muhlenberg ex Willdenow; 20.6%), and *Leafy Spurge (*Euphorbia virgata* Waldstein & Kitabel; 20.6%). The remaining 142 additional associated species with less than 20% frequency included three tree species, 16 shrub species, 15 native grassland grasses, 75 native grassland forbs, three wetland species, 16 local crop species, and 14 other non-native species. The habitats for these sites included successional open sites with recent or past disturbance, open low thickets, aspen grove margins, and pathway verges. The success of this species probably is due to its high production of seeds and the ability of its haustoria to tap the roots of a variety of associated host plants.

Conclusion

By the definition of Randall (2017), *T. ramosum* in Alberta at this time would be a "sleeper weed", i.e., a species that has been identified as being present and posing a future threat. In the United States, while the weed risk assessment for *T. ramosum* (PPQ 2019) has designated it as having High Risk of becoming weedy or invasive across the nation, it has not been proposed for federal listing (PPQ 2019). None of the three states where it is reported have active control measures in place (G.D. Adams pers. comm. 10 January 2018). Nevertheless, all *Thesium* species are parasitic and are regulated by the United States Department of Agriculture (USDA 2018). In Canada, the species is not listed as a regulated invasive plant species (Government of Canada 2021a,b). Also, in Alberta, *T. ramosum* has not been designated by the government (Alberta Queen's Printer 2017; Wheatland County 2017), although the Alberta Invasive Species Council (2014) has identified this species as an invasive weed for legislative consideration by the Alberta government and has recommended that it be listed as a Prohibited Noxious Weed (McClay 2012).

Selected Voucher Specimens

Specimens of *T. ramosum* from Fish Creek Provincial Park and elsewhere in Calgary have been deposited at the following herbaria (acronyms follow Thiers 2017+): University of Alberta (ALTA), Canadian Museum of Nature (CAN), Canadian Food Inspection Agency/Genotyping/Botany (CFIA-BOT), Agriculture and Agri-Food Canada (DAO), Minot State University (MISU), University of Montana (MONTU), Royal Alberta Museum (PMAE), Queen's University, Kingston (QK), St. Mary's University, Calgary (STMU), University of Calgary (UAC), University of Regina (USAS), Royal British Columbia Museum (V), and University of Manitoba (WIN). These species are listed chronologically by collection date, and present location, latitude/longitude, habitat, collection date, collector and number, and housing herbarium and accession number.

CANADA, ALBERTA: Calgary, Fish Creek Provincial Park: Marshall Springs: *ca* 50.923°N, 114.109°W, meadow, 1 July 2003, *G.J. Yaki* s.n. (UAC 81466); Glennfield, east of Macleod Trail, south of Fish Creek; along paved pathway, 50.9288°N, 114.0688°W, Fish

Creek valley basin, successional meadow of *Symphoricarpos occidentalis, Rosa woodsii / Bromus inermis, Euphorbia esula* (now *E. virgata*), *Poa pratensis, Cirsium arvense, Galium boreale, Tragopogon dubius, Taraxacum officinale*, 20 July 2009, *I.D Macdonald 090720a1* (ALTA 123602); Glennfield: north of entrance, 50.9289°N, 114.0685°W, Fish Creek valley basin, fringe and opening of floodplain mesic mid-aged deciduous forest of *Populus balsamifera*, with *Bromus inermis, Symphoricarpos occidentalis, Poa pratensis, Monarda fistulosa, Cirsium arvense, Agrostis stolonifera, Equisetum arvense, Zigadenus elegans* (now *Anticlea elegans*), *Anemone canadensis* (now *Anemonastrum canadensis*), *Trifolium hybridum, Hesperostipa curtiseta*, 30 Oct. 2009, *I.D. Macdonald 091030a1* (UAC 84126); south of Bebo Grove: 50.9266°N, 114.1163°W, along pathway through successional opening in aspen forest cover, associated with *Symphoricarpos occidentalis, Bromus inermis, Poa pratensis, Plantago major, Taraxacum officinale, Solidago gigantea, Cirsium arvense*, 12 Sept. 2013, *I.D. Macdonald 130912a7* and 130912a6iii (CAN 606617 and V 239272); Marshall Springs: engineered wetlands, 50.9230°N, 114.1113°W, Fish Creek valley basin south side slope, associated with *Elymus repens, Festuca trachyphylla, Cirsium arvense, Medicago lupulina, Melilotus officinalis*, 20 Sept. 2013, *I.D. Macdonald 130920a5* (USAS *sine numero*); Marshall Springs: western portion of park south of Fish Creek, engineered wetland, 50.9236°N, 114.1091°W, Fish Creek valley basin, south side of upper slope, population of 660 plants in 25 × 60 m area, in large submesic meadow of *Elymus repens, Festuca trachyphylla, Melilotus officinalis, Medicago lupulina, Cirsium arvense, Sonchus uliginosus* (now *Sonchus arvensis* L. subsp. *uliginosus* (M. Bieberstein) Nyman), *Thesium arvense* (now *T. ramosum*), *Euphorbia esula* (now *E. virgata*), *Trifolium hybridum*—Note: 43 branches, longest 51 cm, actively budding at branch bases, 28 Sept. 2013, *I.D. Macdonald 130928a1* (WIN 76458 and STMU 3495); Marshall Springs: engineered wetland pond berm south of Fish Creek, 50.9238°N, 114.1094°W, Fish Creek valley basin south side slope terrace, associated with successional meadow of *Elymus repens, Cirsium arvense, Medicago lupulina, Thesium arvense* (now *T. ramosum*), *Melilotus officinalis*, 11 Oct. 2013, *I.D. Macdonald* 131011a1 (MONTU 159781); Marshall Springs: engineered wetland pond berm south of Fish Creek, 50.9238°N, 114.1094°W, Fish Creek valley basin south side slope terrace, associated with successional meadow of *Elymus repens, Bromus inermis, Cirsium arvense, Medicago lupulina, Thesium arvense* (now *T. ramosum*), *Melilotus officinalis*, July 7, 2014, *I.D. Macdonald 140707a1* (MISU 0-29002); Parkside: 50.922230°N, 114.043340°W, Fish Creek valley basin, above floodplain, associated with successional meadow of *Poa pratensis, Elymus repens, Cirsium arvense, Medicago lupulina, Bromus inermis, Galium boreale, Melilotus officinalis*, 14 July 2014, *I.D. Macdonald 140714a1* (CFIA-BOT 6033 and 6034); Shawnessy: southwest corner of Macleod Trail and Shawnessy Boulevard SW intersection, 50.9118°N, 114.0682°W, urban disturbed refuse site in unkempt rough meadow, with *Symphoricarpos occidentalis, Poa pratensis, Euphorbia esula* (now *E. virgata*), 25 July 2013, *I.D. Macdonald 130725a1* (STMU 3967); Greengate Nursery: between company eastern fence and west side roadbed slope of Macleod Trail SW, south of Fish Creek Provincial Park boundary, 50.9272°N, 114.0711°W, highway roadbed berm, west-facing, successional meadow of *Bromus inermis, Poa pratense, Melilotus officinalis, Medicago lupulina, Medicago sativa, Festuca trachyphylla, Thesium arvense* (now *T. ramosum*), *Elymus repens, Euphorbia esula (*now *E. virgata*), 28 July 2013, *I.D. Macdonald 130728a3–5* (PMAE B13.2.2., QK 18310997 and SASK *sine numero*); Bowmont Park: south of Silver Springs Road NW, 51.0975°N, 114.1797°W, Bow River valley basin, crest and slope of the northern valley promontory, associated with native grassland species *Hesperostipa comata, Calamovilfa longifolia* (now *Sporobolus rigidus* (Buckley) P.M. Peterson var. *rigidus*), *Bouteloua gracilis, Muhlenbergia cuspidata, Carex filifolia, Symphoricarpos occidentalis, Rosa acicularis, Symphyotrichum ericoides, Symphyotrichum laeve, Solidago missouriensis, Artemisia frigida, Maianthemum stellatum, Linum lewisii, Linum rigidum, Heterotheca villosa*, 29 Sept. 2016, *I.D. Macdonald & Jenna Cross 160929a1* (UAC 93189); Beaverdam Flats Park: central portion of park, northwest corner of Ogden Community, 50.9971°N, 114.0246°W, Bow River Valley Basin floodplain, sandy opening in Balsam Poplar (*Populus balsamifera* L.) grove, associated with *Amelanchier alnifolia, Tanacetum vulgare, Rosa woodsii, Betula occidentalis, Juncus alpinus* var. *balticus, Melilotus alba, Bromus inermis, Medicago sativa,* elev. 1026 m, 9 August 2018, *I.D. Macdonald & Gustave J. Yaki 180809a1* (STMU 5800).

Additional Reported Calgary and Vicinity Locations with respect to Fish Creek Provincial Park

Ann and Sandy Cross Conservation Area: about 8 km to its southwest, but outside the boundary of the city, 51.8763°N, 114.2344°W; elev. 1262 m, 2006 (*fide* G.J. Yaki pers. comm. August 2010); McHugh Bluff Park in Sunnyside, 14 km to its north, 50.0614°N, 114.0748°W, elev. 1077 m, 2019 (K.L. Hull pers. comm. 12 July 2019); Arbour Lake: in northwestern Calgary, 23 km to its north northwest, 51.1309°N, 114.2174°W, elev. 1244 m, 2019 (B.M. Smith pers. comm. 20 August

2019); also, three sites along the Bow River south of the Park within the city with no available locations (K.L. Hull pers. comm. 1 December 2021).

Author Contributions

Investigation: I.D.M. and S.V.; Writing – Original Draft: I.D.M. and S.V.; Writing – Review & Editing: I.D.M. and S.V.; Visualization: I.D.M.

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