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The non-native flora of Redberry Lake Biosphere Reserve, Canada

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Abstract: A checklist of alien plants of Redberry Lake Biosphere Reserve in the province of Saskatchewan, Canada is presented for the first time. By way of field surveys and herbarium research, 121 alien taxa (22.1% of the regional flora) were recorded. The most species rich families are *Poaceae* (24 taxa, 19.8%) and *Asteraceae* (22, 18.2%). Species richness is about evenly distributed across genera with *Rumex*, *Artemisia* and *Poa* (each contains 3 taxa or 2.5%) making up those with the greatest number of species. Concerning plant growth habits, the two dominant groups are forbs (94 taxa, 77.7%) and graminoids (23 taxa, 19%). Regarding habitat preferences, most alien plants occur in natural and seminatural habitats (48 taxa, 39.7%), ruderal places (43 taxa, 35.5%) and agricultural lands (30 taxa, 24.8%). In relation to the state of spread, invasive (63 taxa, 52%) and naturalised (48 taxa, 39.7%) species prevail. In terms of geographical origin, most alien plants are native to Eurasia–Africa (49 taxa, 40.5%) and Eurasia (34 taxa, 28.1%). The biosphere reserve is increasingly being invaded by alien plants whose introduction and distributions can be explained by intense agricultural pressure which resulted in extensive habitat alteration and proliferation of invasive species.

Keywords: alien plants, biodiversity, flora, invasiveness, invasion management, protected areas, Saskatchewan.

Introduction

One of the major consequences of global environmental change is the spread of alien species at an alarming pace during the past several decades. Invasive alien

species (IAS) pose severe threats to environment, ecosystem services and human well-being (Pejchar & Mooney 2009; Pyšek & Richardson 2010; Kueffer 2017). Impacts of IAS can be so severe that they are considered as one of the major drivers of biodiversity loss across the globe (Sala et al. 2000).

Apart from the general threat posed to native biodiversity, IAS affect protected areas – the cornerstones of biodiversity conservation. Most protected areas suffer from IAS impacts at the species and community levels, through the alteration of habitats, regime shifts and through diverse undesired effects on native species abundance, diversity, and richness (Pyšek et al. 2020). IAS are almost universally regarded as a major threat by managers of protected areas (Randall 2011; Foxcroft et al. 2017). Inventory of alien plant species, high-quality distribution data, and monitoring are needed to manage invasions and to prevent and contain IAS in protected areas (Oswalt et al. 2021). Unfortunately, most "standard" floras simply leave out all alien plant species or include only some alien taxa (Pyšek et al. 2004).

Biosphere reserves, initiated by Man and Biosphere (MAB) program of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1974, are a special kind of protected areas with mandate to harmonize conservation of biological and cultural diversity, and economic and social development, through partnerships between people and nature (UNESCO 2018). Redberry Lake Biosphere Reserve (RLBR), designated by UNESCO in 2000, is the only protected area of this kind in the province of Saskatchewan in southwest Canada (RLBR 2022).

Establishment of RLBR was accompanied by an increase in floristic surveys of its territory. The first list of vascular plant species of the biosphere reserve, which contains 281 taxa, was compiled by local naturalist M. Finley (Finley 2008). However, that list has not been published and it does not include alien plant species. During the past decade, the flora of RLBR has been systematically studied. It yielded in a few publications on sensitive, naturalised and rare plant species (Kricsfalusy & Ponomarenko 2013; Kricsfalusy 2016; Kricsfalusy & Kindrachuk 2018; Kricsfalusy 2021a, b, 2023).

The aim of this study is to present the first checklist of alien plant species recorded in the RLBR. Those surveys were not meant to produce a complete list of the non-native flora but rather provide its current inventory. This information will permit the evaluation of the biodiversity of the biosphere reserve as well as support management of invasive alien plants. The obtained data should also contribute to filling the knowledge gap on alien plant species in Saskatchewan.

Material and Methods

Study area

The province of Saskatchewan is situated in the heart of the Interior Plains of Canada, which are a northern extension of the Great Plains of North America (Acton et al. 1998). Saskatchewan has a vast total area of 651,900 km^2, which is larger than most of European countries. During the last century, vast areas of the province' most productive grasslands have been cleared and converted to cropland. As a result,

prairie is one of the most human-altered and fragmented landscape in Canada. The highest rates of grassland conversion in the Great Plains were found in the Aspen Parkland ecoregion within Saskatchewan and Alberta (WWF Plowprint Report 2017). Only 4% of the ecoregion is in conserved/protected areas. In its native state, this ecoregion is characterized by a mosaic of aspen groves and fescue grasslands.

Redberry Lake Biosphere Reserve is located about 60 km northwest of Saskatoon, Saskatchewan (Fig. 1). RLBR lies in the Aspen Parkland ecoregion, which is a transitional ecosystem from the boreal forest in the north to grasslands in the south. The biosphere reserve covers 112,200 hectares and its initially designated area coincides with the Redberry Lake watershed (RLBR 2022). The regional landscape is composed of rolling prairie dotted with seasonal ponds and marshes along with aspen/shrub groves. The core area is a saline lake with several islands. There are small patches of natural mixed prairie which are very rare in this highly grazed and cultivated part of the prairie.

The territory of RLBR consists of nearly level Hafford Plain and Whitewood Hills Upland; elevation varies from 370 to 842 m above sea level. Overall, current land cover reflects conversion of natural ecosystems to agriculture (Fig. 2). Major land use types are croplands (annual and perennial) and pastures, and to some extent forested areas in the northern part of the biosphere reserve. There are also smaller types of land use such as residential, recreation, transportation, and commercial.

The climate in the RLBR is cold and temperate. There is modest rainfall throughout the year. The mean annual rainfall is 463 mm, with the greatest precipitation in June. The variation in the precipitation during the year (between the driest and wettest months) is 67 mm. The mean annual temperature here averages 2.7 °C. The average monthly temperatures vary during the year (between the coldest and warmest months) by 32.2 °C. The mean annual temperature is 11°C, with a minimum average of -17.4 °C in January and a maximum average of 24.1 °C in July.

Fig. 1 Location of Redberry Lake Biosphere Reserve in the province of Saskatchewan, Canada. https://redberrylake.ca/designation-location/.

Field surveys

The field surveys of alien plants were conducted in the Redberry Lake Biosphere Reserve as a part of the floristic inventory of the biosphere reserve during 2011–2021. The presence and distribution of all alien plants observed was recorded, assessing their invasive status. Several alien plant records were contributed by students in the School of Environment and Sustainability at the University of Saskatchewan during environmental farm assessments in the region in 2014–2018.

All alien plants observed in the field were identified, and a few photos taken for each species. The problematic species were collected and then identified using the field guides, published works on the flora of Saskatchewan (Harms 2003) and herbarium specimens deposited at the W.P. Fraser Herbarium at the University of Saskatchewan (SASK 2021). Nomenclature for plant taxa follows the Database of Vascular Plants of Canada or VASCAN (Brouillet et al. 2010). Additional information on alien plants was obtain through the Saskatchewan Conservation Data Centre database (SKCDC 2014). Data relating to the geographical distribution and origin come from online databases (GBIF 2022; POWO 2022).

The invasion status of alien plants was classified according to Richardson et al. (2000) and Pyšek et al. (2004) to distinguish casual (alien plants that may occasionally reproduce outside cultivation without forming self-replacing populations), naturalized (alien plants that sustain self-replacing populations and reproduce without direct human intervention from seed or vegetative parts), and invasive

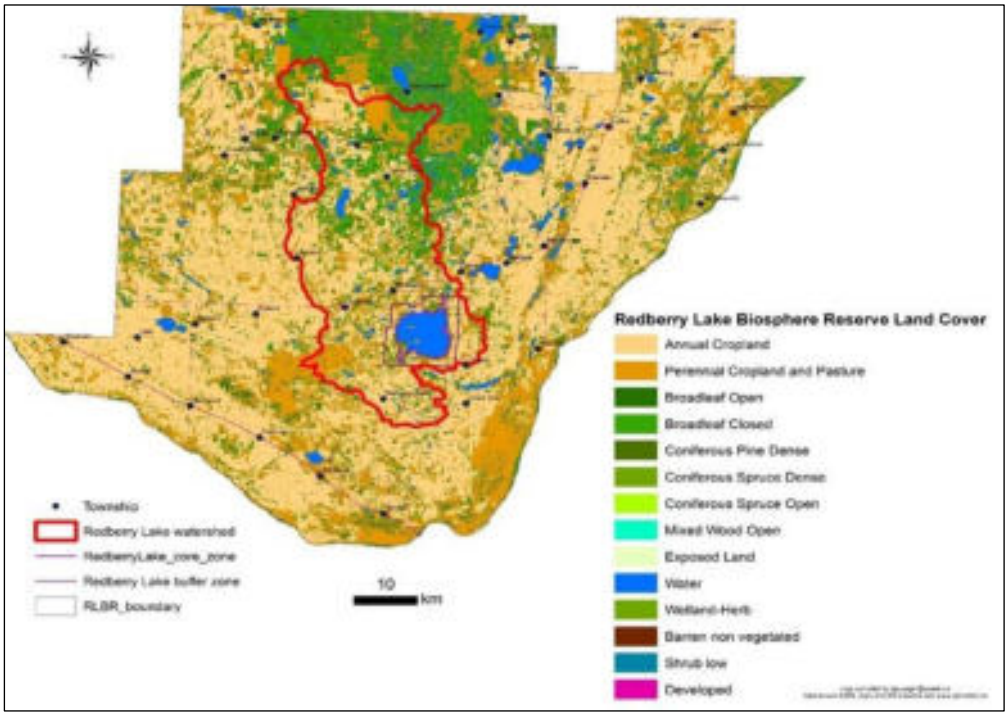

Fig. 2 Major land use types in the study area which reflect conversion of natural ecosystems to agriculture.

(a subset of naturalized plants with the potential to spread over a large area thanks to high reproductive efficiency and long-distance dispersion ability). Plants kept only in ornamental horticulture are not included in this study.

The following habitat groups were distinguished in the region: artificial surfaces (ruderal sites, including linear infrastructure), agricultural areas (regularly or recently cultivated agricultural habitats), natural and seminatural habitats. The latter were divided into grasslands, wetlands and woodlands. The distribution of alien plants among the different habitats was inferred from field observations on the frequency of occurrence. When a taxon is present in more than one habitat, the prevailing one is reported.

Results

Taxonomic diversity

Our study shows that non-native flora of Redberry Lake Biosphere Reserve comprises 121 taxa (species, subspecies, varieties and hybrids) in 27 families and 101 genera (Tab. 1, Tab. 2). When considering the whole vascular flora of the biosphere reserve which contains 547 taxa (Kricsfalusy 2022), alien plants represent 22.1% of all taxa.

Top families in terms of non-native species richness (Tab. 1) are *Poaceae* (24 taxa), *Asteraceae* (22 taxa), *Brassicaceae* (11), *Amaranthaceae* (10) and *Fabaceae* (10). Together they include 77 taxa which is more than half (63.6%) of all alien plants

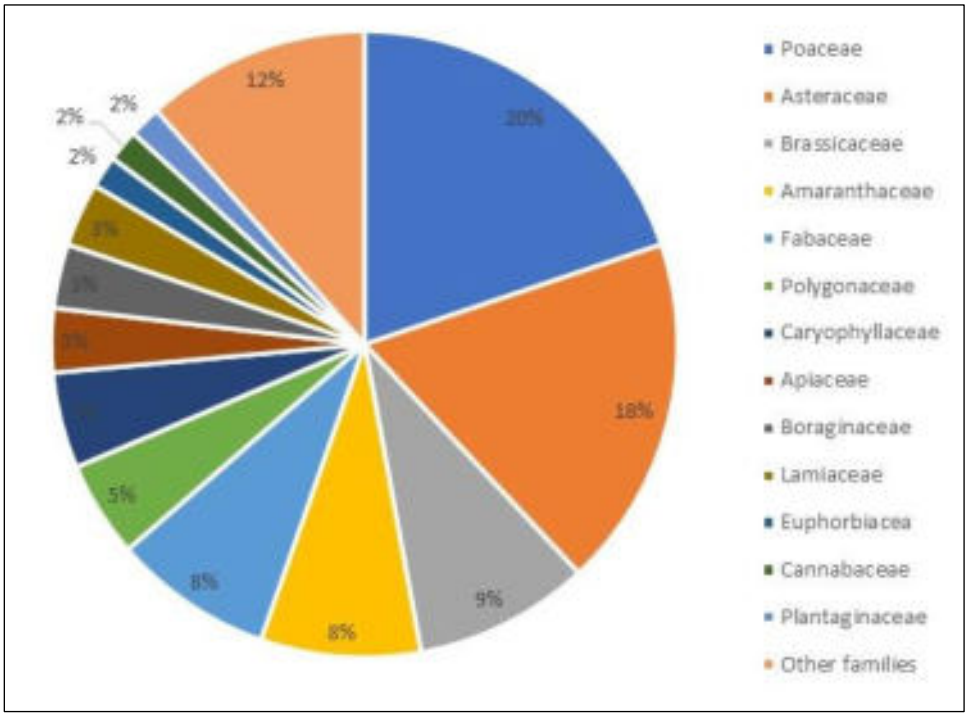

Fig. 3 The families represented in the non-native flora of Redberry Lake Biosphere Reserve.

Tab. 1 List of largest families and genera of the non-native flora of Redberry Lake Biosphere Reserve.

Family	Number of species	Number of genera	Genus	Number of species
Poaceae	24	19	*Rumex*	3
Asteraceae	22	18	*Artemisia*	3
Brassicaceae	11	10	*Poa*	3
Amaranthaceae	10	7	*Amaranthus*	2
Fabaceae	10	7	*Arctium*	2
Caryophyllaceae	6	5	*Atriplex*	2
Polygonaceae	6	4	*Bromus*	2
Apiaceae	4	4	*Cirsium*	2
Boraginaceae	4	4	*Kali*	2
Lamiaceae	4	4	*Lepidium*	2
Cannabaceae	2	2	*Medicago*	2
Plantaginaceae	2	2	*Melilotus*	2
Euphorbiacea	2	1	*Setaria*	2
Other families	14	14	*Silene*	2
Subtotal	**121**	**101**	*Trifolium*	2
			Triticum	2
			Other genera	86
			Subtotal	**121**

(Fig. 3). The next most encountered families with alien plants are *Polygonaceae* (6 taxa) and *Caryophyllaceae* (6). A few families contain 4 taxa (*Apiaceae*, *Boraginaceae* and *Lamiaceae*) or 2 taxa (*Cannabaceae*, *Euphorbiaceae* and *Plantaginaceae*) each. The rest 13 families are monotypic and include single taxon only.

Species richness is about evenly distributed across genera with *Rumex*, *Artemisia* and *Poa* (each contains 3 taxa or 2.5% of total) making up those with the greatest number of species (Tab. 1). These top genera are followed by *Amaranthus*, *Arctium*, *Atriplex*, *Bromus*, *Cirsium*, *Kali*, *Lepidium*, *Medicago*, *Melilotus*, *Setaria*, *Silene*, *Trifolium* and *Triticum* with 2 taxa each (Fig. 4). Together these 16 genera include 35 taxa which is almost one-third (28.9%) of all alien plants. The rest 86 genera each include 1 taxon only.

Concerning the number of genera per family, distribution patterns appear to be very similar to the described above for species diversity per family. The richest families by genera are *Poaceae* (19 genera) and *Asteraceae* (18). Together they include more than one third of all genera (37 or 36.6%) (Fig. 5). They are followed by *Brassicaceae* (10 genera), *Amaranthaceae* (7) and *Fabaceae* (7). A few families include 4-5 genera each – *Caryophyllaceae* (5 genera), *Polygonaceae* (4), *Apiaceae* (4), *Boraginaceae* (4) and *Lamiaceae* (4). The next 2 families (*Cannabaceae* and *Plantaginaceae*) contain 2 genera each, and the rest 14 families include 1 genus only.

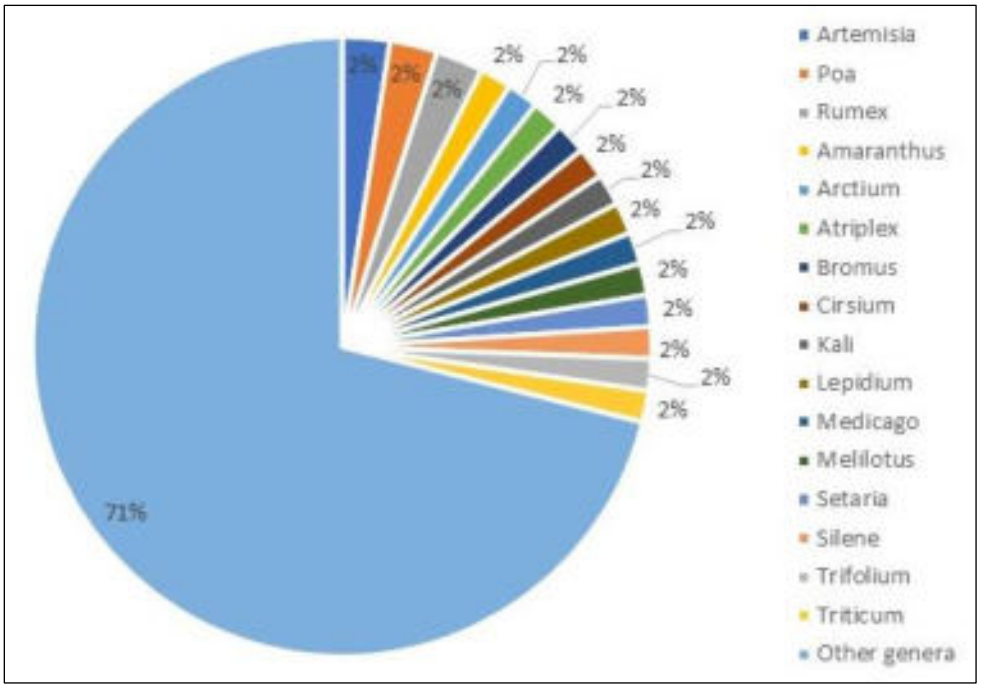

Fig. 4 The genera represented in the non-native flora of Redberry Lake Biosphere Reserve.

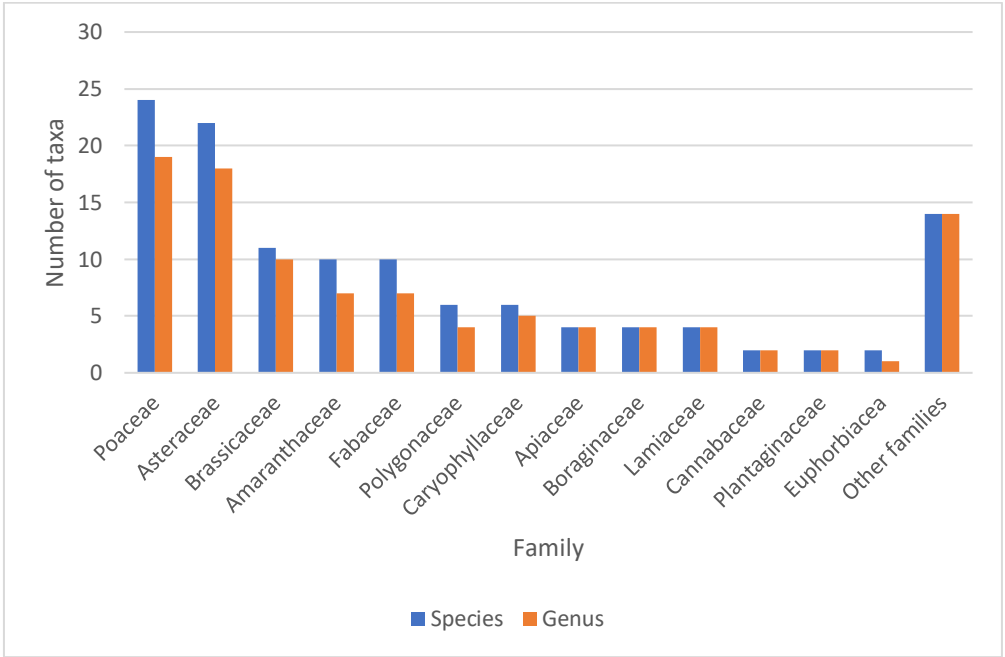

Fig. 5 Number of taxa most represented in the non-native flora of Redberry Lake Biosphere Reserve.

Tab. 2 Checklist of alien plant taxa recorded in the Redberry Lake Biosphere Reserve. The taxa arrangement is alphabetical by family, then by scientific name. Nomenclature for taxa follows the VASCAN database (Brouillet et al. 2010). WCA – The Weed Control Act (Government of Saskatchewan, 2010). Abbreviations: forb – f, vine – v, shrub – s, graminoid – g, tree – t; agricultural – agr, ruderal – rud, grassland – gras, wetland – wet, woodland – woo; naturalized – nat, invasive – inv, casual – cas; noxious – nox, nuisance – nui, prohibited – pro; Eurasia – EA, Asia – As, Europe – E, Africa – Af, North America – NA, Central America – CA, South America – SA, Australia – Au, Mediterranean – Med, Cosmopolite – Cos.

Taxon	Synonym	Growth habit	Habitat	Invasive status	WCA	Geographical origin
Amaranthaceae						
Amaranthus powellii S. Watson ssp. *powellii*		f	agr	nat		NA & CA
Amaranthus retroflexus L.		f	agr	inv		CA
Atriplex patula L.		f	agr	nat		EA, Af, NA
Atriplex prostrata Boucher ex DC.	*Atriplex patula* var. *hastata* (L.) Gray	f	agr	nat		EA, Af, NA
Axyris amaranthoides L.		f	agr	inv		EA
Bassia scoparia (L.) Voss	*Kochia scoparia* (L.) Schrad.	f	agr	inv	nox	As
Beta vulgaris L.		f	agr	cas		E
Chenopodium album L.		f	agr	nat		EA, Af, NA
Kali collinum (Pall.) Akhani & Roalson	*Salsola kali* L.	f	rud	inv	nui	EA
Kali tragus (L.) Scopoli	*Salsola tragus* L.	f	rud	nat		EA
Amaryllidaceae						
Allium schoenoprasum L. var. *schoenoprasum*		f	rud	nat		EA, NA
Apiaceae						
Carum carvi L.		f	rud	nat		EA
Conium maculatum L.		f	wet	inv	nox	EA, Af
Daucus carota L.		f	rud	nat		EA, Af
Pastinaca sativa L.		f	rud	inv	nox	EA
Asparagaceae						
Asparagus officinalis L.		f	rud	cas		EA
Asteraceae						
Arctium minus (Hill) Bernhardi		f	rud	inv	nox	EA, Af
Arctium tomentosum Mill.		f	rud	inv		EA
Artemisia absinthium L.		f	rud	inv	nox	EA, Af
Artemisia biennis Willd.		f	rud	nat		As, NA
Artemisia vulgaris L.		f	rud	inv		EA, Af
Carduus nutans L. ssp. *leiophyllus* (Petrovič) Stoj. & Stef.		f	agr	inv	nox	EA
Centaurea stoebe ssp. *australis* (Pančić ex A. Kern.) Greuter		f	rud	inv	pro	EA

Tab. 2 - cont.

Cichorium intybus L.		f	rud	inv		EA, Af
Cirsium arvense (L.) Scop.		f	agr	inv	nox	EA, Af
Cirsium vulgare (Savi) Tenore		f	agr	inv	nox	EA, Af
Crepis tectorum L.		f	rud	inv		EA
Gnaphalium uliginosum L.		f	rud	nat		EA, Af, NA
Lactuca serriola L.		f	gras	inv		EA, Af
Leucanthemum vulgare Lam.		f	gras	inv	nox	EA
Matricaria discoidea DC.		f	rud	nat		NA
Pilosella aurantiaca (L.) F.W. Schultz & Schultz Bip.	*Hieracium aurantiacum* L.	f	gras	nat		E
Senecio vulgaris L.		f	rud	nat		EA, Af
Sonchus arvensis L.		f	agr	inv	nox	EA
Taraxacum officinale F. H. Wigg.		f	rud	nat	nui	EA, Af
Tragopogon dubius Scop.		f	gras	inv	nui	EA, Af
Tripleurospermum inodorum (L.) Schultz-Bipontinus	*Matricaria perforata* Merat	f	rud	inv	nox	EA
Boraginaceae						
Anchusa arvensis (L.) M. Bieb.		f	rud	nat		EA, Af, NA
Cynoglossum officinale L.		f	agr	inv	pro	EA
Echium vulgare L.		f	rud	nat		EA
Lappula squarrosa (Retz.) Dumort.	*Lappula echinata* Gilbert ex Kuntze	f	rud	inv		EA
Brassicaceae						
Brassica rapa L.		f	agr	cas		E
Capsella bursa-pastoris (L.) Medik.		f	rud	inv		EA, Af
Descurainia sophia (L.) Webb ex Prantl		f	rud	nat		EA, Af
Erucastrum gallicum (Willd.) O.E. Schultz		f	rud	cas		E
Hesperis matronalis L.		f	rud	inv	nox	E
Lepidium appelianum Al-Shehbaz		f	agr	inv	nox	As
Lepidium rude L.		f	rud	inv		EA
Nasturtium officinale W.T. Aiton		f	wet	nat		EA, Af
Raphanus raphanistrum L. ssp. *raphanistrum*		f	rud	nat		EA, Af
Sinapis arvensis L.	*Brassica kaber* (DC.) Wheeler	f	rud	nat		EA, Af
Tanacetum vulgare L.		f	rud	nat	nox	EA
Thlaspi arvense L.		f	rud	nat		EA
Cannabaceae						
Cannabis sativa L.		f	agr	nat		As
Humulus lupulus L. var. *lupulus*		v	agr	cas		EA, Af
Caprifoliaceae						
Lonicera tatarica L.		s	woo	nat		EA
Caryophyllaceae						
Cerastium fontanum ssp. *vulgare* (Hartman) Greuter & Burdet	*Cerastium holosteoides* Fr.	f	rud	inv		EA, Af

Tab. 2 - cont.

Gypsophila paniculata L.		f	rud	inv	nox	EA
Silene latifolia Poir.	*Lychnis alba* Miler	f	gras	inv	nox	EA, Af
Silene vulgaris (Moench) Garcke		f	gras	inv	nox	EA, Af
Spergula arvensis L.		f	gras	nat		EA, Af
Stellaria media (L.) Vill. ssp. *media*		f	gras	nat		EA, Af
Convolvulaceae						
Convolvulus arvensis L.		f	agr	inv	nox	EA, Af
Euphorbiaceae						
Euphorbia cyparissias L.		f	rud	inv	nox	EA
Euphorbia virgata Waldst. & Kit.	*Euphorbia esula* var. *uralensis* (Fischer ex Link) Dorn	f	gras	inv	nox	EA
Fabaceae						
Astragalus cicer L.		f	gras	cas		EA
Caragana arborescens Lam.		s	rud	inv		As
Lotus corniculatus L.		f	gras	nat		EA, Af
Medicago lupulina L.		f	gras	inv		EA, Af
Medicago sativa L. ssp. *sativa*		f	gras	nat		Med, As
Melilotus albus Medik.		f	gras	inv		EA, Af
Melilotus officinalis (L.) Pall.		f	gras	inv		EA
Onobrychis viciifolia Scop.		f	gras	nat		E
Trifolium hybridum L.		f	gras	nat		Med, As
Trifolium pratense L.		f	gras	nat		EA, Af
Geraniaceae						
Erodium cicutarium (L.) L'Héritier ex Aiton ssp. *cicutarium*		f	gras	inv	nox	EA, Af
Iridacea						
Iris ×*germanica* L.		f	woo	nat		Med
Lamiaceae						
Galeopsis tetrahit L.		f	rud	cas		EA
Lamium amplexicaule L.		f	rud	nat		EA, Af
Leonurus cardiaca L. ssp. *cardiaca*		f	rud	inv		EA
Nepeta cataria L.		f	wet	nat		EA
Lythraceae						
Lythrum salicaria L.		f	wet	inv	nox	EA, Af, Au
Malvaceae						
Malva parviflora L.		f	rud	nat		EA, Af
Oxalidaceae						
Oxalis corniculata L.		f	rud	nat		CA & SA
Plantaginaceae						
Linaria vulgaris Mill.		f	gras	inv	nox	EA
Plantago major L.		f	rud	inv		EA, Af
Poaceae						
Agropyron cristatum (L.) Gaertn ssp. *pectinatum* (M. Bieb.) Tzvelev	*Elymus pectinatus* (M. Bieb.) M. Laínz	g	gras	inv		EA, Af

Tab. 2 - cont.

Agrostis stolonifera L.	*Agrostis stolonifera* var. *palustris* (Huds.) Farw.	g	gras	inv		EA, Af
Alopecurus pratensis L.		g	gras	inv		EA
Avena fatua L.		g	agr	nat		As
Bromus inermis Leyss.		g	gras	inv		EA
Bromus tectorum L.		g	gras	inv	nox	EA, Af
Dactylis glomerata L.	*Bromus glomeratus* (L.) Scopoli	g	gras	inv		EA, Af
Digitaria sanguinalis (L.) Scop.		g	gras	nat		EA, Af
Echinochloa crus-galli (L.) P. B.		f	gras	inv		EA, Af
Elymus repens (L.) Gould	*Agropyron repens* (L.) P. B., *Elytrigia repens* (L.) Nevski	g	gras	inv	nui	EA, Af
Festuca rubra L. ssp. *rubra*		g	gras	inv		EA, Af, NA
Hordeum vulgare L.		g	agr	cas		Med
Lolium perenne L.		g	gras	inv		EA, Af
Phalaris canariensis L.		g	gras	nat		Af
Phleum pratense L.		g	gras	nat		EA, Af
Phragmites australis (Cav.) Trin. ex Steud. ssp. *australis*	*Phragmites communis* Trinius	g	wet	inv		Cos
Poa compressa L.		g	gras	nat		EA, Af
Poa pratensis L. ssp. *pratensis*		g	gras	inv		EA, NA
Poa trivialis L.		g	gras	nat		EA, Af
Puccinellia distans (Jacq.) Parl.		g	wet	inv		EA
Setaria pumila (Poir.) Roem. & Schult. ssp. *pumila*	*Setaria glauca* var. *pumila* (Poiret) Ascherson & Graebner	g	gras	nat		EA, Af
Setaria viridis (L.) P Beauv.		g	agr	inv	pro	EA, Af, Au
Triticum durum Desfontaines		g	agr	cas		Med
Triticum turgidum L.		g	agr	cas		Med, As
Polygonaceae						
Fallopia convolvulus (L.) Á. Löve	*Polygonum convolvulus* L.	f	agr	inv		EA, Af
Persicaria maculosa Gray	*Polygonum persicaria* L.	f	agr	inv		EA, Af
Polygonum aviculare L. ssp. *aviculare*		f	agr	nat		EA, Af, NA
Rumex acetosa L.		f	agr	nat		EA, Af
Rumex pseudonatronatus (Borbas) Borbas ex Murb.	*Rumex fennicus* (Murb.) Murb.	f	agr	nat		EA
Rumex stenophyllus Ledeb.	*Rumex crispus* var. *dentatus* Schur	f	agr	inv		EA
Potamogetonaceae						
Potamogeton crispus L.		f	wet	nat		EA, Af
Ranunculaceae						
Ranunculus acris L.		f	rud	inv		EA
Typhaceae						
Typha angustifolia L.		f	wet	nat		EA, Af, NA
Ulmaceae						
Ulmus pumila L.		t	gras	inv		As
Urticaceae						
Urtica urens L.		f	rud	inv		EA, Af

Species status

In terms of plant growth habits, the non-native flora of Redberry Lake Biosphere Reserve consists mostly of forbs (94 taxa, 77.7%) and graminoids (23, 19%), but also includes 2 shrubs, 1 vine and 1 tree (Tab. 2). This reflects the influence of several environmental factors (temperature, rainfall, and soil conditions) of the grassland ecosystem on the alien plants growth and naturalization.

The results of the study show that alien plants grow mostly in natural and seminatural habitats (48 taxa, 39.7%), especially in grasslands (38 taxa, 31.4%), with wetlands (8, 0.07%) and woodlands (2, 0.02%) barely inhabited (Tab. 2). There is also significant representation for alien plants growing in ruderal places (43 taxa, 35.5%), including inhabited areas and linear infrastructure (roadside ditches, etc.). Agricultural surfaces such as croplands are also well represented (30 taxa, 24.8%) (Tab. 2).

In relation to weedy status (Tab. 2), 31 alien plants (25.6%) recorded in the biosphere reserve can be identified as noxious (24 taxa), nuisance (4) or prohibited (3) weeds, according to The Weed Control Act (Government of Saskatchewan 2010). Most alien plants are invasive (63 taxa, 52%), followed by naturalised (48, 39.7%) and casual (10, 8.3%) (Tab. 2). Overall, the ratio of alien (121 taxa) to native plants (547) in the flora of RLBR is approximately 1:4.5, which is higher than the average (1:6) for the flora of North America, estimated by Qian & Ricklefs (2006).

In terms of geographical origin (Tab. 2), most of the alien plants are native to Eurasia–Africa (49 taxa, 40.5%) or just to Eurasia (34, 28.1%). The next most important source regions are Eurasia–Africa–N. America (8 taxa, 6.6%); Asia (7, 5.8%); Europe (5, 4.1%) and Mediterranean (4, 3.3%), providing together 24 taxa (19.8%). Fewer species are native to the multiple regions: Mediterranean–Asia (3 taxa, 2.5%); Eurasia–N. America (2, 1.7%); Eurasia–Africa–Australia (2, 1.7%). Finally, each of these distribution areas – Africa, Asia–N. America, N. America, N.–C. America, C. America, C.–S. America and Cosmopolite – is represented by single taxon only.

Discussion

With steadily shrinking area of natural landscape in Saskatchewan due to large-scale industrial agriculture, alien plants become the great problem. When IAS becomes established, they may have serious environmental implications affecting both biotic and abiotic components of ecosystems, disturbing its structure and function, bringing in substantial costs to agriculture, forestry and human health and decreasing suitability of the soil for native plant species (Callaway & Ridenour 2004).These can become crucial, especially in protected areas, where risk on the rare native flora and fauna can increase and therefore, biodiversity loss and soil degradation maybe devastating.

Results obtained during this study demonstrate that the flora of Redberry Lake Biosphere Reserve is increasingly being invaded by alien plants whose introduction

Fig. 6 Proliferation of smooth brome (*Bromus inermis* Leyss.) into native fescue prairie in the Redberry Lake Biosphere Reserve.

Fig. 7 Grassland vegetation dominated by smooth brome (*Bromus inermis* Leyss.) in the buffer zone of Redberry Lake Biosphere Reserve.

and distributions are determined more by human activity than by environmental limitations. The taxonomic richness of the non-native flora observed for RLBR is driven by intense agricultural pressure in the region which resulted in extensive habitat alteration and proliferation of invasive alien plants. In total, alien plants represent 22.1% of all taxa recorded in the flora of the biosphere reserve which exceeds similar parameters for the adjacent regions. For example, percentage of alien species in the flora of Alberta equals 16% and average for the Great Plains is around 13.6% (Rejmánek & Randall 1999). It can be explained by substantial change of natural landscape of RLBR due to extensive agriculture (arable farming and livestock grazing), affecting the structure and composition of vegetation.

Alien plants invading the biosphere reserve can be traced to the earliest days of European settlement. Many of these alien plants have become introduced with seed crops, livestock feed, or brought here for use as forage crops or for planting shelterbelts, etc. The spread of alien plants continues currently, especially through roadsides and newly disturbed areas. It will probably increase in the future due to climate change, which may influence the patterns of invasion and the response of the native flora.

Taking into consideration the challenges mentioned above, the development of the ranking system to set control and management priorities for IAS in the RLBR is necessary. Such system should evaluate alien plants on their significance of impact (including location in sensitive habitats), ability to become naturalised and feasibility of control. There are a few effective systems for categorizing non-native plants according to their negative impacts on biodiversity in a large area such as a nation, state/province or ecological region (Hiebert 1997; Randall et al. 2008). Recently, the approach for prioritisation of IAS in Saskatchewan from the local to the provincial level to inform management decisions was suggested (Kricsfalusy & Zhang 2019). In general, the above-mentioned risk assessment frameworks allow for the collation of data that are useful to conservation agencies and organizations and can be modified to use in the biosphere reserve.

The results of this study indicate that differences in the levels of invasion across habitats should be taken into account when planning and implementing monitoring and management actions in the RLBR. In the decades before designation of the biosphere reserve, a large part of the natural landscape, which is now included in a buffer zone, become subject to severe transformations due to human activities such as grassland converting to farming. As a result, the floristic structure and composition of natural vegetation have been significantly changed, favouring the proliferation of different invasive plants into native habitat (Fig. 6, 7), particularly by smooth brome (*Bromus inermis* Leyss.). According to Palit & DeKeyser (2022), several studies found detrimental effects of smooth brome on the growth, survival, and extinction rate of the native grass species. In the prairies where it has invaded, there has often been a total elimination of native species and an overall homogenization of ecosystems.

To accomplish effective control of alien plants, it is necessary to monitor and survey IAS in order to document change in their status and results of any management methods. A high priority might be to attempt to prevent future invasions by instituting more effective programs to better keep out IAS. As well, rather than focusing on specific invasive alien plants that require control, it might be more effective to concentrate on certain habitats or rare species that are at greatest risk.

Conclusion

This is the first checklist of alien plant species for Redberry Lake Biosphere Reserve. The compiled list includes 121 taxa of vascular plants recorded during the last decade in the RLBR. This alien plant richness is attributable to intensive agricultural land use in the region. Even though the biosphere reserve is protecting typical ecosystems and flora of this region, it has been drastically changed by human development. Given an occurrence of high number of IAS, we suggest conducting their periodic monitoring for the analysis of population trends to implement effective control practices.

The status of RLBR as the only UNESCO biosphere reserve in Saskatchewan makes this study of particular importance, bettering our baseline understanding of its ecosystems. The data presented here underline the need of integrated management plan for a more conscious use of the territory. This approach should promote the use of traditional agriculture and cultivation techniques rather than industrial agriculture with intensive production of crops. All this to aim at an environmental restoration, while making landscape pleasant and unique in the eyes of the local people and of the visitors.

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