Thaiszia - J. Bot., Košice, 30 (1): 001-021, 2020
https://doi.org/10.33542/TJB2020-1-01

THAISZIA
JOURNAL OF BOTANY

Phytogeographical differentiation of the genus *Carex* (Cyperaceae) in Saskatchewan, Canada

Ivan M. Danylyk[1] & Vladimir V. Kricsfalusy[2]

[1] Institute of Ecology of the Carpathians, National Academy of Sciences of Ukraine, 4 Kozelnytska St, L'viv, 79026, Ukraine; idanylyk@ukr.net
[2] School of Environment and Sustainability, University of Saskatchewan, 117 Science Place, Saskatoon, Saskatchewan, Canada S7N5C8; vladimir.k@usask.ca

Danylyk I. M. & Kricsfalusy V. V. (2020): Phytogeographical differentiation of the genus *Carex* (Cyperaceae) in Saskatchewan, Canada. – Thaiszia – J. Bot. 30 (1): 001-021.

Abstract: This paper presents a phytogeographical analysis of the genus *Carex* (Cyperaceae) in Saskatchewan, Canada. *Carex* (sedges) is the largest genus of vascular plants in the provincial flora, which includes 105 species used in our analysis. Phytogeographical differentiation of the genus was determined based on zonal, climatic, altitudinal and regional position of the study species. First of all, 15 zonal range types were identified. It was found that the majority of the study species are located in moderately cold or cold natural zones and have rather large range sizes with a high degree of disjunction. After that, the study species were classified into four climatic range types, situated within the significant impact of the severe continental climate. Later, four altitudinal range types, with a slight predominance of the group of species associated with the plain and low-altitude areas, were recognised. Finally, based on the geographic distribution of *Carex* species they were classified into four regional range types. Overall, the range formation of the genus *Carex* in Saskatchewan took evolutionary a long time and was driven by latitudinal species migration in two directions – to the northern and to a lesser extent the southern boundary of the province. The genus *Carex* in Saskatchewan demonstrates much stronger biogeographical affinities to America, than to East Asia and Europe. There is a fairly high number of bipolar *Carex* species which are distributed in the province at high northern latitudes.

Keywords: taxonomic composition, geographical distribution, range types.

Introduction

The genus *Carex* L. (Cyperaceae Juss.) includes approximately 2000 species and is one of the largest genera of vascular plants in the world (Ball & Reznicek 2002). This genus is mostly represented in the Northern Hemisphere, from the temperate to arctic zone (Goetghebeur 1998; Egorova 1999; Govaerts et al. 2019). *Carex* (sedges), with 480 species, is one of the most diverse genera in the North American flora (Ball & Reznicek 2002). According to Brouillet et al. (2010+), there are 313 species of *Carex* in the flora of Canada, and consequently almost 10% of country's native vascular plants are sedges (Catling et al. 1990). There are 175 species of *Carex* listed for the Prairie Provinces (Alberta, Saskatchewan, and Manitoba) and 106 species for the territory of Saskatchewan (Brouillet et al. 2010+). This makes *Carex* the largest genus of vascular plants in this province.

The great species diversity of the genus *Carex* is manifested in a high differentiation of their geographical distribution. Combining similar species ranges into geographical elements (range types) and classifying them is an essential component of phytogeographical analysis of any flora or taxa above the species level, however it may include an ambiguous choice of principles and approaches. Distinct accounts of the phytogegraphy of the genus *Carex* can be a good example of such different approaches to identifying selection criteria for analysis of species distribution (Holub 1987; Ball 1990; Egorova 1999; Martín-Bravo & Escudero 2012; Spalink et al. 2016).

Creating a hierarchical system of phytogeographical elements is rather difficult task. In search of better explanations for diverse distribution patterns and classification of range types, more and more researchers have been applying the principles of botanical and geographical zoning of the world suggested by Meusel & Jäger (1992). This approach was recently successfully adapted in the Ecoflora of Ukraine (Didukh et al. 2000) and Exkursionsflora von Deutschland (Rothmaler 2002). Overall, this method enables to analyse range types of any size and accuracy, depending on the nature and purpose of the study, to describe zonal, climatic, altitudinal and regional position of species ranges. Using these criteria for phytogeographical analysis of the family Cyperaceae in Ukraine has recently demonstrated their effectiveness (Danylyk 2015).

Notwithstanding that *Carex* is the largest genus of vascular plants in Saskatchewan, its phytogeographical differentiation has not been analysed yet. Therefore, the goal of this study is to conduct a distribution analysis of *Carex* species occurring in Saskatchewan aiming at identifying their range types based on zonal, climatic, altitudinal and regional position. This will allow us to identify the distribution patterns of the study species from global to regional scale and might contribute to our understanding of different factors involved in the geographical differentiation of the genus *Carex* in Saskatchewan and North America.

In addition to contribution to knowledge and theory in phytogeography, this type of big data-informed analysis can provide practical applications in biodiversity exploration, identification of species of conservation concern, and prioritising of rare species for conservation planning (Kricsfalusy & Trevisan 2014).

Material and Methods

Study area

The biophysical environment of the province of Saskatchewan is characterised primarily based on information provided in the Encyclopedia of Saskatchewan (2005). The province has a total area of 651,036 km^2, and it is located in Canada's prairie region comprising of Alberta, Saskatchewan, and Manitoba (Fig. 1). Saskatchewan's western border runs concurrent with the 4th meridian or the 110° W longitude separating the province from Alberta. Saskatchewan's eastern border with the province of Manitoba is partially crooked and does not lie perfectly on the 102° W longitude. The Northwest Territories is north of the 60th parallel which forms the northern border of the province. The southern border with the U.S. states of Montana and North Dakota lies approximately on the 49th parallel. Saskatchewan has a temperate continental climate with hot to warm summers and cold winters, which means that the annual temperature range can be up to 65 °C. The historical monthly average for central Saskatchewan (Saskatoon, 482 m a.s.l., 52.1332° N, 106.6700° W) in January is -15 °C and in July is +19 °C. Saskatchewan is the sunniest Canadian province year-round (2206 hrs) and has the fourth-lowest total precipitation (428 mm).

Several biogeographic factors contribute to the richness and diversity of Saskatchewan's vegetation, which varies, depending on climate, soil and elevation. From north to south there is a variety of ecological zones (Fig. 1). The Taiga Shield ecozone stretches across a part of Canada's subarctic. It is dominated by the boreal coniferous forest. The Boreal Shield ecozone separates the warmer boreal plains in the south and from the colder taiga shield in the north. The southern boundary of boreal coniferous forest lies in the Boreal Plains ecozone. The latter borders the Prairie ecozone, a part of the Interior Plains of Canada, which is a northern extension of the Great Plains of North America (Acton et al. 1998).

Taxonomic approach

To review the taxonomic composition and nomenclature of the genus *Carex* in Saskatchewan, we analysed key literature sources and databases: *Carex* in Saskatchewan prepared by Hudson (1977) and its further revision Sedges (*Carex*) of Saskatchewan by Leighton (2012), Flora of North America (Ball & Reznicek 2002), Annotated Catalogue of Saskatchewan Vascular Plants (Harms 2006), the Database of Vascular Plants of Canada or VASCAN (Brouillet et al. 2010+), and World Checklist of Cyperaceae (Govaerts et al. 2019). The last mentioned one is a part of the database World Checklist of Selected Plant Families (WCSP). Herbarium specimens of questionable species of *Carex* were examined in the W.P. Fraser Herbarium of the University of Saskatchewan in Saskatoon (SASK 2019). After a critical review, 105 species of *Carex* were used for carrying out a phytogeographical analysis (Tab. 1). The species nomenclature follows the World Checklist of Cyperaceae (Govaerts et al. 2019).

Phytogeographical approach

Distribution ranges of *Carex* species occurring in Saskatchewan were identified based on a critical analysis of the literature sources and information from the databases listed in the previous subsection. The classification of species ranges was completed using the principles of botanical and geographical zoning of the word (Meusel & Jäger 1992), adapted for specific application by Rothmaler (2002). The modified scheme of geographical zoning of the word used in this study is shown in Fig. 2. Following these guidelines, natural zones reflect a vegetation cover according to its genesis and environmental conditions formed throughout the Earth's long history. Zonal range types are those that best reflect general patterns of species diversity and are less suitable to characterise specific distribution features. Climatic conditions have contributed to the formation of climatic range types with the particular degree of oceanic or continental relevance. Species with a wide ecological amplitude adapted to various climatic conditions do not have a clear range differentiation. Elevational range types include the species which occur at distinct altitude due to varying environmental conditions with often a disjunct distribution.

The range of any species is located in a specific geographic region or regions. Consequently, ranges can vary significantly depending on the size, from endemic (species existing only in one geographic region) to cosmopolitan (species occurring globally). All of the above-mentioned range types as more generalised units can be

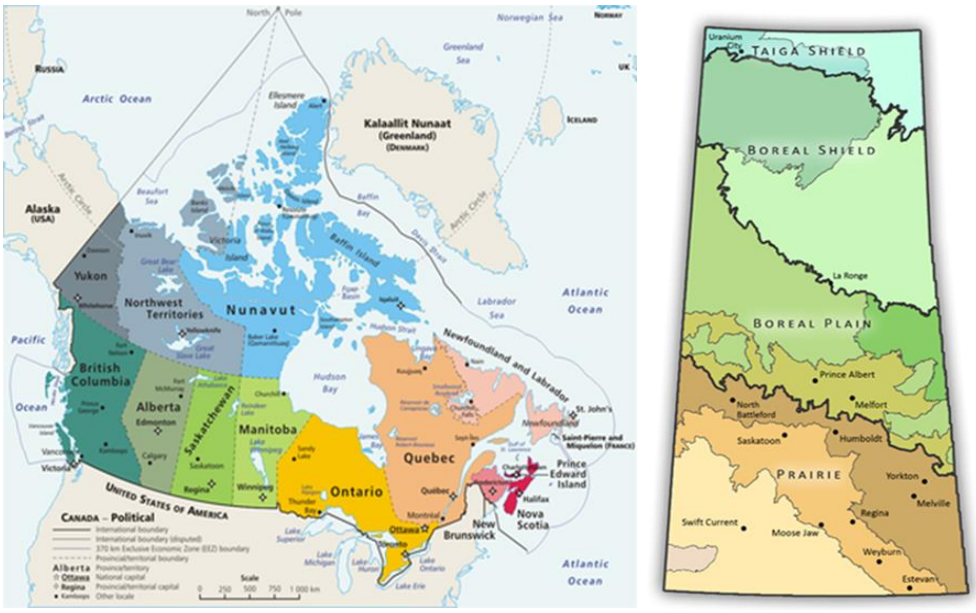

Fig. 1 Maps of Canada (a) and Saskatchewan (b) depicting four ecozones in the province. a: https://en.wikipedia.org/wiki/Geography_of_Canada#/media/File: Map_Canada_political-geo.png; b: http://www.biodiversity.sk.ca/eco.htm

further subdivided into range subtypes to create more specific or homogeneous units.

Phytogeographical elements of the genus *Carex* in Saskatchewan were determined in the following way: first, in a latitudinal (zonal) direction, then according to climatic (oceanic-continental) and elevational (altitude above sea level) gradients, and after that depending on the regional distribution. It should be noted that altitudinal distribution of the study species in Saskatchewan sometimes differ from the general patterns (Meusel & Jäger 1992; Rothmaler 2002) and therefore the identified altitudinal range types may not be necessarily representative for the true distribution of *Carex* species in the province.

Results and Discussion

Taxonomic notes

The first treatment of the genus *Carex* in Saskatchewan was completed by Hudson (1977), who listed 102 species. The recent revision of his work by Leighton (2012) includes 103 species. However, the number difference is not due to the simple addition of one species. In fact, three species have been removed from the flora

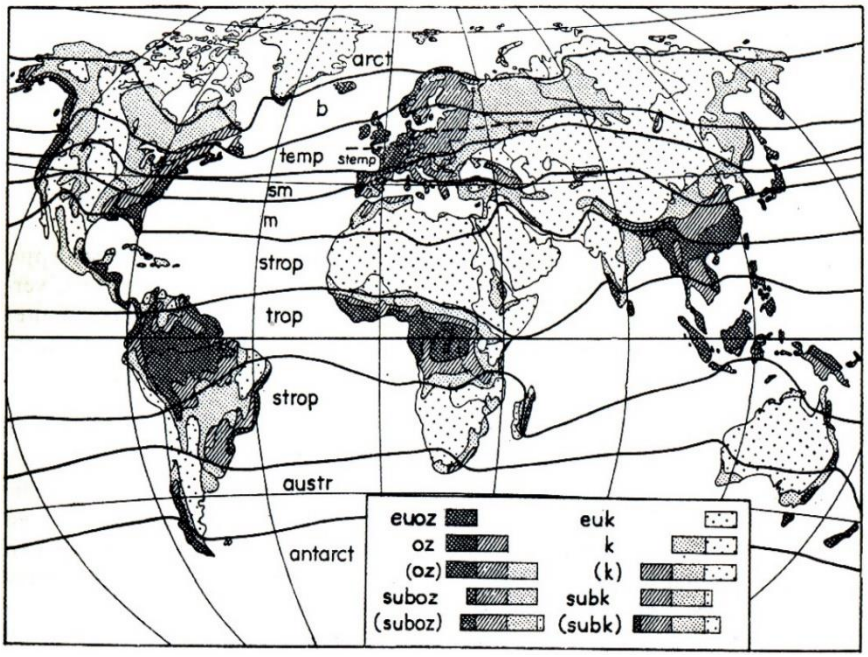

Fig. 2 The scheme of the word geographical zones (after Rothmaler 2002): arct – arctic, b – boreal, temp – temperate, stemp – subtemperate, sm – submediterranean, m – mediterranean, strop – subtropical, trop – tropical, austr – australian, antarct – antarctic, euoz – euoceanic, oz – oceanic, suboz – suboceanic, euk – eucontinental, k – continental, subk – subcontinental.

(*C. rufina*, *C. scoparia*, and *C. vesicaria*), two added (*C. mackenziei* and *C. projecta*), and one (*C. meadii*) merged into another species (*C. tetanica*). Besides, *C. rostrata* has been split in *C. rostrata* and *C. utriculata*, and material treated as *C. muricata* has been re-identified as *C. echinata* and *C. sterillis* (Leighton 2012). Based on a critical analysis of information in the available literature (Hudson 1977; Ball & Reznicek 2002; Harms 2006; Leighton 2012) and online databases (Brouillet et al. 2010+; Govaerts et al. 2019), we found some discrepancies in treatment of eight species of *Carex* in Saskatchewan. A more detailed examination of herbarium specimens in the W.P. Fraser Herbarium SASK showed that, in most cases, the species in question 1) exist in the province but were not reported in some sources, 2) are reported from the province, but no specimens were located, or 3) require a further collection effort and revision of their status. These discrepancies about the status of questionable species can be summarised as follows.

C. arcta – indicated by Hudson (1977), Ball & Reznicek (2002), Harms (2006), Leighton (2012) and Brouillet et al. (2010+), but not listed in Govaerts et al. (2019). There are multiple specimens in SASK, which confirm the species presence in Saskatchewan.

C. cryptolepis – not indicated by Ball & Reznicek (2002) and Govaerts et al. (2019), but listed as *C. flava* L. in Hudson (1977), Harms (2006), Leighton (2012), and Brouillet et al. (2010+). There are several specimens in SASK, which confirm the species occurrence in Saskatchewan.

C. echinodes – not indicated by Hudson (1977), Ball & Reznicek (2002), Harms (2006), Leighton (2012), and Govaerts et al. (2019), but listed in Brouillet et al. (2010+). There are no specimens in SASK to confirm its presence in Saskatchewan.

C. leptonervia – not indicated by Harms (2006), Ball & Reznicek (2002), Brouillet et al. (2010+), and Govaerts et al. (2019), but listed as *C. laxiflora* Lam. var. *blanda* (Dewey) Boott. in Hudson (1977) and indicated in Leighton (2012) as *C. laxiflora* var. *leptonervia* Fern. There a few specimens in SASK identified by J. Hudson as *C. laxiflora* var. *blanda* (Dewey) Boott (#47371, 17615) and *C. laxiflora* var. *varians* Bailey (#95685). So far *C. leptonervia* is known from only two locations at the eastern boundary of the province, and further studies are needed to confirm it occurrence in Saskatchewan.

C. pachystachya – not indicated by Hudson (1977) and Leighton (2012), but listed in Ball & Reznicek (2002), Harms (2006), Brouillet et al. (2010+), and Govaerts et al. (2019). The specimens in SASK do not allow us to make a conclusive decision about their taxonomic status. J. Hudson in his Errata, Revised Views and Additions to *Carex* of Saskatchewan (dated January 1987, May 1998) states that "I still remain unconvinced of the necessity of recognizing *C. pachystachya* in Saskatchewan". However, there is a specimen in SASK (#176189: *C. platylepis* Mack., coll. G.F. Ledingham, July 2, 1987, Cypress Hills), which was determined by J. Hudson as *C. pachystachya* in 1998 using the key in the Flora of North America manuscript for which he was a reviewer. Thus, more evidence is needed to confirm the presence of *C. pachystachya* in Saskatchewan.

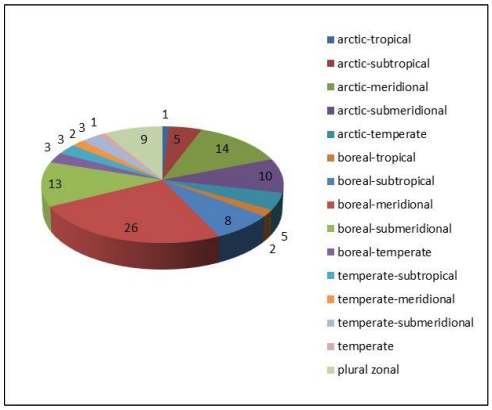

Fig. 3 Distribution of the *Carex* species of Saskatchewan according to the zonal range types.

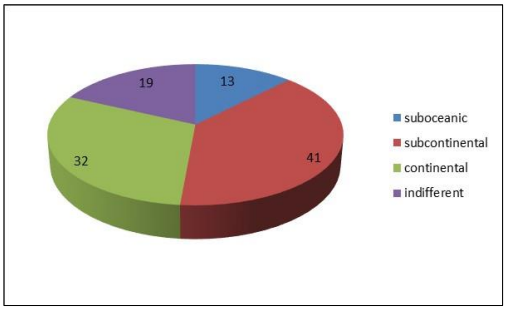

Fig. 4 Distribution of the *Carex* species of Saskatchewan according to the climatic range types.

C. pseudocyperus – indicated by Hudson (1977), Harms (2006), Ball & Reznicek (2002), Leighton (2012), and Brouillet et al. (2010+), but not listed in Govaerts et al. (2019). There are multiple specimens in SASK, which confirm the species occurrence in Saskatchewan.

C. saxatilis – indicated by Hudson, Ball & Reznicek (2002), Harms (2006), Leighton (2012), and Brouillet et al. (2010+), but not listed in Govaerts et al. (2019). There are several specimens in SASK, which confirm the species presence in Saskatchewan.

C. subspathacea – not indicated by Hudson (1977), Ball & Reznicek (2002), Leighton (2012), and listed as pending information in Harms (2006), but included in both databases (Brouillet et al. 2010+; Govaerts et al. 2019). There are no specimens in SASK to confirm the species occurrence in Saskatchewan.

Based on the research and analysis conducted, we separated the eight questionable species of *Carex* into two groups: 1) species absent in the province (*C. echinodes* and *C. subspathacea*), and 2) species present in the province (*C. arcta*, *C. cryptolepis*, *C. leptonervia*, *C. pachystachya*, *C. pseudocyperus*, and *C. saxatilis*), although *C. leptonervia* and *C. pachystachya* need more evidence and confirmation. The combined analysis of information obtained from different sources helped to minimise the biases associated with each of the data sets which in turn allowed us to clarify species composition in the study area. Therefore, ultimately 105 species were selected for carrying out phytogeographical analysis of the genus *Carex* in Saskatchewan (Tab. 1).

It has to be noted that 8 endemic taxa of the genus *Carex* indicated for Saskatchewan in VASCAN (Brouillet et al. 2010+) were not included in our treatment (*C. adusta* × *C. foenea*, *C. bebbii* × *C. cristatella*, *C. brevior* × *C. foenea*, *C. foenea* × *C. praticola*, *C. foenea* × *C. tenera* var. *tenera*, *C. foenea* × *C. xerantica*, *C. interior* × *C. sterilis*, and *C. saxatilis* × *C. utriculata*), because they are all hybrids and not reported in most other sources used in this study. Furthermore, according to Cayouette & Catling (1992), hybrids of the genus *Carex* involving circumpolar species may have

the same names in North America and Eurasia, when in fact, they are different, or they may have different names, when they are in fact the same.

Zonal range types

According to the position of the study *Carex* species in natural zones of the Earth, we have identified 15 range types (Tab. 1): arctic-tropical, arctic-subtropical, arctic-meridional, arctic-submeridional, arctic-temperate, boreal-tropical, boreal-subtropical, boreal-meridional, boreal-submeridional, boreal-temperate, temperate-subtropical, temperate-meridional, temperate-submeridional, temperate, and plural zonal. The species distribution based on zonal position of their ranges is shown in Fig. 3, which represents rather general patterns than peculiar features. The common attribute of almost all study species is that their ranges, except one (*C. hookeriana*), are found in two or more natural zones. It was established that ranges of most species (90 species - 85,7%) encompass three and more natural zones of the Northern Hemisphere. Consecutively, ranges of only a few species (9: 8,5%) are located in multiple natural zones of the Northern and Southern Hemisphere, and even less species (6: 5,7%) have ranges concentrated in two natural zones. Such a type of distribution attests to fairly wide ranges of the study species and almost the complete absence in Saskatchewan of *Carex* species with a narrow range.

The largest number of the study species (26: 24,8%) belong to the boreal-meridional range type (Tab. 1). This group includes the following *Carex* species: *C. arcta*, *C. atherodes*, *C. backii*, *C. bebbii*, *C. buxbaumii*, *C. crawei*, *C. crawfordii*, *C. granularis*, *C. gravida*, *C. hoodii*, *C. lacustris*, *C. microptera*, *C. obtusata*, *C. pachystachya*, *C. parryana*, *C. petasata*, *C. raynoldsii*, *C. retrorsa*, *C. rossii*, *C. sartwellii*, *C. siccata*, *C. sprengelii*, *C. stipata*, *C. tonsa*, *C. umbellata* and *C. xerantica*. All these species are distinguished by a large range size and a predominantly disjunct distribution.

Each of the following three groups include more than 10 *Carex* species (Tab. 1). To the arctic-meridional range type belong 14 (13,3%) species: *C. aquatilis, C. aurea*,

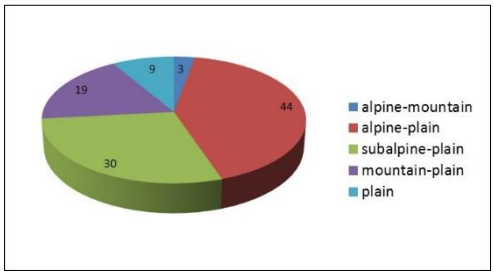

Fig. 5 Distribution of the *Carex* species of Saskatchewan according to the altitudinal range types.

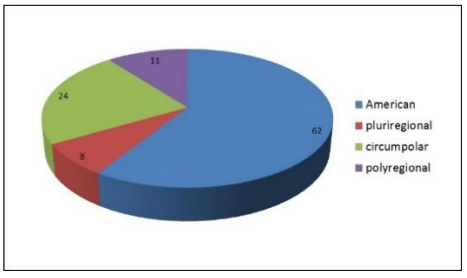

Fig. 6 Distribution of the *Carex* species of Saskatchewan according to the regional range types.

C. bigelowii, *C. capillaris*, *C. concinna*, *C. deflexa*, *C. disperma*, *C. garberi*, *C. lasiocarpa*, *C. media*, *C. nardina*, *C. scirpoidea*, *C. supina*, and *C. tenuiflora*. The arctic-submeridional range type consists of 10 (9,5%) species: *C. bicolor*, *C. brunnescens*, *C. chordorrhiza*, *C. foenea*, *C. loliacea*, *C. mackenziei*, *C. oligosperma*, *C. richardsonii*, *C. sterilis*, and *C. sychnocephala*. The boreal-submeridional range type includes 13 (12,4%) species: *C. alopecoidea*, *C. cryptolepis*, *C. deweyana*, *C. heleonastes*, *C. laeviconica*, *C. leptonervia*, *C. pauciflora*, *C. peckii*, *C. pedunculata*, *C. prairea*, *C. projecta*, *C. rostrata* and *C. tenera*. These three range types consist predominantly of arctic-boreal disjunct species (*C. aurea*, *C. bicolor*, *C. bigelowii*, *C. capillaris*, etc.) with the largest part of their ranges stretching over cold natural zones. These species are able to exist in moderately warm areas only due to clearly defined altitudinal zonation of mountain systems.

The plural zonal range type comprises 9 (8,6%) species of *Carex* (Tab. 1): *C. arctogena*, *C. canescens*, *C. diandra*, *C. echinata*, *C. magellanica*, *C. maritima*, *C. praegracilis*, *C. pseudocyperus* and *C. oederi*. The comparatively high species richness of this range type is not surprising, given its large range size due to the potential ability of *Carex* species to adapt to changing environmental conditions in different natural zones. These are mostly species that depend on wetlands, which contributed to their widespread distribution in all natural zones of the Earth due to smoothing effect of ecological factors in the water environment. The increase of *Carex* species ability to develop adaptations under the influence of climate change and human impact is an important condition of their range expantion, i.e. the spread of many species outside their original zones.

As we can see from the above-mentioned data, there are 72 *Carex* species (68,5%) in the first five zonal range types. The distribution analysis of species that belong to these range types shows that the majority of the study *Carex* species occur in moderately cold or cold natural zones, which is not surprising.

The succeeding boreal-subtropical range type is characterised by a comparatively high number of *Carex* species (8: 7,6%). These are (Tab. 1): *C. athrostachya*, *C. brevior*, *C. eburnea*, *C. filifolia*, *C. hystericina*, *C. inops*, *C. pellita* and *C. vulpinoidea*.

The next 9 range types include only 25 *Carex* species (23,8%), which overall represent specific zonal features (Tab. 1). In particular, the arctic-subtropical (*C. capitata*, *C. interior*, *C. leptalea*, *C. limosa* and *C. praticola*) and arctic-temperate (*C. glacialis*, *C. lenticularis*, *C. saxatilis*, *C. trisperma* and *C. vaginata*) range types both are represented by five *Carex* species (4,8%). The following range types include three *Carex* species (2,8%) each: the boreal-temperate (*C. adusta*, *C. assiniboinensis* and *C. houghtoniana*), temperate-subtropical (*C. meadii*, *C. douglasii* and *C. utriculata*) and temperate-submeridional (*C. cristatella*, *C. saximontana* and *C. tetanica*). The boreal-tropical (*C. duriuscula* and *C. michauxiana*) and temperate-meridional (*C. simulata* and *C. torreyi*) range types each consist of two *Carex* species (1,9%). Finally, the arctic-tropical (*C. livida*) and temperate (*C. hookeriana*) range types each include one *Carex* species (1,0%) only. It should be noted that *C. livida* is spread in

the largest number of natural zones (7), and *C. hookeriana* is found only in one natural zone.

Therefore, the analysis of the study *Carex* species, according to zonal position of their ranges, demonstrates a prevalence of species which belong to the boreal-meridional, arctic-meridional, boreal-submeridional, arctic-submeridional, and plural zonal range types. This indicates significant species differentiation, and refers as well to a large size of their ranges and a high degree of disjunction in the distribution of many species. A somewhat larger number of the study species have range types located in moderately cold or cold natural zones, while species with range types associated with moderately warm and warm zones are found rather in a smaller number. This also indicates the patterns of formation of the genus *Carex* in Saskatchewan by species migration along latitudinal gradient in two directions – to the northern, and to a lesser extent, the southern boundary of the province.

Climatic range types

Depending on the distribution of the study *Carex* species in climatic zones of the Earth, we recognised four range types (Tab. 1): suboceanic, subcontinental, continental, and indifferent. According to the data presented in Fig. 4, the majority of the study species (86: 81,9%) demonstrate a positive climatic dependence, i.e. their ranges are located in the regions with oceanic (the suboceanic range type comprises 13 species: 12,4%) or continental (the subcontinental and continental range types include 73 species: 69,5%) climate. A total of 19 *Carex* species (18,1%) are indifferent to climate, i.e. with their ranges found in regions with both oceanic and continental climate.

The subcontinental range type is represented by the largest group of *Carex* species (41: 39,0%) (Tab. 1): *C. alopecoidea*, *C. arcta*, *C. athrostachya*, *C. aurea, C. backii*, *C. bebbii*, *C. brevior*, *C. crawei*, *C. crawfordii*, *C. deflexa*, *C. deweyana*, *C. duriuscula*, *C. eburnea*, *C. filifolia*, *C. foenea*, *C. garberi*, *C. granularis*, *C. houghtoniana*, *C. hystericina*, *C. interior*, *C. lacustris*, *C. lenticularis*, *C. leptalea*, *C. meadii*, *C. microptera*, *C. oligosperma*, *C. peckii*, *C. pedunculata*, *C. pellita*, *C. prairea*, *C. projecta*, *C. richardsonii*, *C. sartwellii*, *C. scirpoidea*, *C. siccata*, *C. sprengelii*, *C. stipata*, *C. tenera*, *C. trisperma*, *C. umbellata* and *C. utriculata*. Species with this type of distribution are well adapted to a moderate continental climate, which allow them to spread in transitional (oceanic and continental) regions.

A total of 32 *Carex* species (30,5%) belong to the continental range type (Tab. 1): *C. adusta*, *C. arctogena*, *C. assiniboinensis, C. atherodes*, *C. capitata*, *C. chordorrhiza*, *C. concinna*, *C. diandra*, *C. douglasii*, *C. gravida*, *C. heleonastes*, *C. hoodia*, *C. hookeriana*, *C. inops*, *C. laeviconica*, *C. nardina*, *C. obtusata*, *C. pachystachya*, *C. parryana*, *C. petasata*, *C. praegracilis*, *C. praticola*, *C. raynoldsii*, *C. retrorsa*, *C. rossii*, *C. saximontana*, *C. simulate*, *C. supina*, *C. sychnocephala*, *C. torreyi*, *C. vaginata* and *C. xerantica*. Unlike species with the subcontinental range type,

Tab. 1 Phytogeographical distribution of the *Carex* species of Saskatchewan based on their zonal, climatic, altitudinal and regional position.

Species	Range type			
	[1]Zonal	[2]Climatic	[3]Altitudinal	[4]Regional
C. adusta Boott	b-temp	k	pl	Am
C. alopecoidea Tuck.	b-sm	subk	mon-pl	Am
C. aquatilis Wahlenb.	arct-m	ind	alp-pl	cir
C. arcta Boott	b-m	subk	salp-pl	Am
C. arctogena Harry Sm.	pl-zn	k	alp-pl	pol
C. assiniboinensis W. Boott	b-temp	k	pl	Am
C. atherodes Spreng.	b-m	k	alp-pl	cir
C. athrostachya Olney	b-strop	subk	alp-pl	Am
C. aurea Nutt.	arct-m	subk	alp-pl	Am
C. backii Boott	b-m	subk	salp-pl	Am
C. bebbii (L.H. Bailey) Olney ex Fernald	b-m	subk	salp-pl	Am
C. bicolor Bellardi ex All.	arct-sm	suboz	alp-pl	cir
C. bigelowii Torr. ex Schwein.	arct-m	suboz	alp-pl	cir
C. brevior (Dewey) Mack. ex Lunell	b-strop	subk	alp-pl	Am
C. brunnescens (Pers.) Poir.	arct-sm	ind	alp-pl	cir
C. buxbaumii Wahlenb.	b-m	suboz	alp-pl	cir
C. canescens L.	pl-zn	ind	salp-pl	pol
C. capillaris L.	arct-m	ind	alp-pl	cir
C. capitata Sol.	arct-strop	k	alp-pl	cir
C. chordorrhiza L.f.	arct-sm	k	salp-pl	cir
C. concinna R.Br.	arct-m	k	alp-pl	Am
C. crawei Dewey ex Torr.	b-m	subk	alp-pl	Am
C. crawfordii Fernald	b-m	subk	salp-pl	plur
C. cristatella Britton	temp-sm	suboz	pl	Am
C. cryptolepis Mack.	b-sm	suboz	pl	Am
C. deflexa Hornem.	arct-m	subk	alp-pl	Am
C. deweyana Schwein.	b-sm	subk	alp-pl	Am
C. diandra Schrank	pl-zn	k	alp-pl	pol
C. disperma Dewey	arct-m	ind	alp-pl	cir
C. douglasii Boott	temp-strop	k	alp-mon	Am
C. duriuscula C.A. Mey.	b-trop	subk	alp-pl	pol
C. eburnea Boott	b-strop	subk	salp-pl	Am
C. echinata Murray	pl-zn	suboz	salp-pl	pol

Tab. 1 - cont.

C. filifolia Nutt.	b-strop	subk	alp-pl	Am
C. foenea Willd.	arct-sm	subk	mon-pl	Am
C. garberi Fernald	arct-m	subk	salp-pl	Am
C. glacialis Mack.	arct-temp	ind	mon-pl	cir
C. granularis Muhl. ex Willd.	b-m	subk	mon-pl	Am
C. gravida L.H. Bailey	b-m	k	salp-pl	Am
C. heleonastes Ehrh. ex L.f.	b-sm	k	salp-pl	cir
C. hoodii Boott	b-m	k	alp-pl	Am
C. hookeriana Dewey	temp	k	pl	Am
C. houghtoniana Torr. ex Dewey	b-temp	subk	mon-pl	Am
C. hystericina Muhl. ex Willd.	b-strop	subk	salp-pl	Am
C. inops L.H. Bailey	b-strop	k	alp-pl	Am
C. interior L.H. Bailey	arct-strop	subk	alp-pl	Am
C. lacustris Willd.	b-m	subk	salp-pl	Am
C. laeviconica Dewey	b-sm	k	mon-pl	Am
C. lasiocarpa Ehrh.	arct-m	ind	salp-pl	cir
C. lenticularis Michx.	arct-temp	subk	alp-pl	Am
C. leptalea Wahlenb.	arct-strop	subk	alp-pl	Am
C. leptonervia (Fernald) Fernald	b-sm	suboz	pl	Am
C. limosa L.	arct-strop	ind	salp-pl	cir
C. livida (Wahlenb.) Willd.	arct-trop	ind	salp-pl	cir
C. loliacea L.	arct-sm	ind	mon-pl	cir
C. mackenziei V.I. Krecz.	arct-sm	ind	pl	cir
C. magellanica Lam.	pl-zn	ind	alp-pl	pol
C. maritima Gunnerus	pl-zn	ind	alp-pl	pol
C. meadii Dewey	temp-strop	subk	alp-pl	Am
C. media R.Br.	arct-m	ind	salp-pl	cir
C. michauxiana Boeckeler	b-trop	suboz	alp-pl	pol
C. microptera Mack.	b-m	subk	alp-pl	Am
C. nardina (Hornem.) Fr.	arct-m	k	salp-pl	Am
C. obtusata Lilj.	b-m	k	salp-pl	plur
C. oederi Retz.	pl-zn	ind	mon-pl	pol
C. oligosperma Michx.	arct-sm	subk	mon-pl	plur
C. pachystachya Cham. ex Steud.	b-m	k	alp-pl	plur
C. parryana Dewey	b-m	k	alp-pl	Am
C. pauciflora Lightf.	b-sm	suboz	salp-pl	cir
C. peckii Howe	b-sm	subk	salp-pl	Am

Tab. 1 - cont.

C. pedunculata Muhl. ex Willd.	b-sm	subk	mon-pl	Am
C. pellita Muhl. ex Willd.	b-strop	subk	alp-pl	Am
C. petasata Dewey	b-m	k	mon-pl	Am
C. praegracilis W. Boott	pl-zn	k	alp-pl	pol
C. prairea Dewey ex Alph.Wood	b-sm	subk	alp-pl	Am
C. praticola Rydb.	arct-strop	k	alp-pl	Am
C. projecta Mack.	b-sm	subk	pl	Am
C. pseudocyperus L.	pl-zn	ind	mon-pl	pol
C. raynoldsii Dewey	b-m	k	alp-mon	Am
C. retrorsa Schwein.	b-m	k	salp-pl	Am
C. richardsonii R.Br.	arct-sm	subk	salp-pl	Am
C. rossii Boott	b-m	k	alp-pl	Am
C. rostrata Stokes	b-sm	ind	salp-pl	cir
C. sartwellii Dewey	b-m	subk	salp-pl	Am
C. saxatilis L.	arct-temp	ind	alp-pl	cir
C. saximontana Mack.	temp-sm	k	alp-pl	Am
C. scirpoidea Michx.	arct-m	subk	alp-pl	cir
C. siccata Dewey	b-m	subk	alp-pl	Am
C. simulata Mack.	temp-m	k	alp-mon	Am
C. sprengelii Dewey ex Spreng.	b-m	subk	salp-pl	Am
C. sterilis Willd.	arct-sm	suboz	mon-pl	Am
C. stipata Muhl. ex Willd.	b-m	subk	salp-pl	plur
C. supina Willd. ex Wahlenb.	arct-m	k	mon-pl	plur
C. sychnocephala J. Carey	arct-sm	k	mon-pl	Am
C. tenera Dewey	b-sm	subk	mon-pl	Am
C. tenuiflora Wahlenb.	arct-m	ind	salp-pl	cir
C. tetanica Schkuhr	temp-sm	suboz	mon-pl	Am
C. tonsa (Fernald) E.P. Bicknell	b-m	suboz	mon-pl	Am
C. torreyi Tuck.	temp-m	k	alp-pl	Am
C. trisperma Dewey	arct-temp	subk	mon-pl	Am
C. umbellata Willd.	b-m	subk	pl	Am
C. utriculata Boott	temp-strop	subk	alp-pl	plur
C. vaginata Tausch	arct-temp	k	alp-pl	cir
C. vulpinoidea Michx.	b-strop	suboz	salp-pl	plur
C. xerantica L.H. Bailey	b-m	k	salp-pl	Am

Note: codes of world geographical zones adapted from Rothmaler (2002).

[1]**Zonal**: arct-trop – arctic-tropical, arct-strop – arctic-subtropical, arct-m – arctic-meridional, arct-sm – arctic-submeridional, arct-temp – arctic-temperate, b-trop – boreal-tropical, b-strop – boreal-subtropical, b-m – boreal-meridional, b-sm – boreal-submeridional, b-temp – boreal-temperate, temp-strop – temperate-subtropical, temp-m – temperate-meridional, temp-sm – temperate-submeridional, temp – temperate, pl-zn – plural zonal.
[2]**Climatic**: suboz – suboceanic, subk – subcontinental, k – continental, ind – indifferent.
[3]**Altitudinal**: alp-mon – alpine-mountain, alp-pl – alpine-plain, salp-pl – salpine-plain, mon-pl – mountain-plaine, pl – plaine.
[4]**Regional**: Am – American, plur – pluriregional, cir – circumpolar, pol – polyregional**.**

species with the continental distribution are well adapted to a more severe climate, because the main parts of their ranges are located in the continental regions of the Earth.

A significant part of *Carex* species (19: 18,1%) belongs to the indifferent range type (Tab. 1): *C. aquatilis*, *C. brunnescens*, *C. canescens*, *C. capillaris*, *C. disperma*, *C. glacialis*, *C. lasiocarpa*, *C. limosa*, *C. livida*, *C. loliacea*, *C. mackenziei*, *C. magellanica*, *C. maritima*, *C. media*, *C. oederi*, *C. pseudocyperus*, *C. rostrata*, *C. saxatilis* and *C. tenuiflora*. This trend is more typical for species with a circumpolar distribution. All these species are confined to hygrophilic habitats with constant moisture provision, which partly alleviates the impact of climate.

The suboceanic range type is represented by the lowest number of *Carex* species (13: 12,4%) (Tab. 1): *C. bicolor*, *C. bigelowii*, *C. buxbaumii*, *C. cristatella*, *C. cryptolepis*, *C. echinata*, *C. leptonervia*, *C. michauxiana*, *C. pauciflora*, *C. sterilis*, *C. tetanica*, *C. tonsa* and *C. vulpinoidea*. This can be explained by biophysical features and the geographical location of Saskatchewan, situated in the interior of the continent and far from the significant influence of humid oceanic air masses.

Thus, it was found that climatic range types of the study *Carex* species have a wide global distribution in regions with a continental climate. However, some species have ranges located in regions with the oceanic type of climate, and some are indifferent to climate conditions. Such attributes reflect the overall geographic location of Saskatchewan, which is situated within the range of the significant impact of a severe continental climate.

By comparison of climatic range types of the study *Carex* species with respect to natural zones (Tab. 2), it was found that three groups of the subcontinental species (boreal-meridional – 13, boreal-submeridional – 7, and boreal-subtropic – 6) along with one group of the continental species (boreal-meridional – 11) prevail. The indifferent species dominate in the arcto-meridional (6) and plural zonal (5) range types.

Altitudinal range types

Based on altitudinal distribution of the study *Carex* species, we distinguished five altitudinal range types (Tab. 1): alpine-mountain, alpine-plain, subalpine-plain, mountain-plain, and plain. The ranges of most species (102) are located, completely (9) or partially (93), in plain areas. However, as shown in Fig. 5, a substantial number

of species ranges (96), completely (3) or partially (93), display a mountain type of distribution. Such a pattern of distribution of *Carex* species into altitudinal ranges primarily reflects the biophysical features and geographic location of the province, as well as its evidence of species adaptation to the heterogeneity of the relief of Saskatchewan, where the plain areas prevail over mountainous.

Most of the study *Carex* species (44: 41,9%) were classified in the alpine-plain altitudinal range type (Tab. 1): *C. aquatilis*, *C. arctogena*, *C. atherodes*, *C. athrostachya*, *C. aurea*, *C. bicolor*, *C. bigelowii*, *C. brevior*, *C. brunnescens*, *C. buxbaumii*, *C. capillaris*, *C. capitata*, *C. concinna*, *C. crawei*, *C. deflexa*, *C. deweyana*, *C. diandra*, *C. disperma*, *C. duriuscula*, *C. filifolia*, *C. hoodia*, *C. inops*, *C. interior*, *C. lenticularis*, *C. leptalea*, *C. magellanica*, *C. maritima*, *C. meadii*, *C. michauxiana*, *C. microptera*, *C. pachystachya*, *C. parryana*, *C. pellita*, *C. praegracilis*, *C. prairea*, *C. praticola*, *C. rossii*, *C. saxatilis*, *C. saximontana*, *C. scirpoidea*, *C. siccata*, *C. torreyi*, *C. utriculata* and *C. vaginata*. Many species from this group have a disjunct type of distribution and on the territory of Saskatchewan they can be considered as relicts of the glacial period. Their ranges reach the highest altitude in the province (1392 m a.s.l.), while some of these species occur above 4000 m a.s.l. at lower latitude zones of the Earth. This indicates a high adaptability of these species to severe conditions of humid mountain climate in low latitude areas.

Quite a large number of *Carex* species (30: 28,6%) belong to the subalpine-plain range type (Tab. 1): *C. arcta*, *C. backii*, *C. bebbii*, *C. canescens*, *C. chordorrhiza*, *C. crawfordii*, *C. eburnean*, *C. echinata*, *C. garberi*, *C. gravida*, *C. heleonastes*, *C. hystericina*, *C. lacustris*, *C. lasiocarpa*, *C. limosa*, *C. livida*, *C. media*, *C. nardina*, *C. obtusata*, *C. pauciflora*, *C. peckii*, *C. retrorsa*, *C. richardsonii*, *C. rostrata*, *C. sartwellii*, *C. sprengelii*, *C. stipata*, *C. tenuiflora*, *C. vulpinoidea* and *C. xerantica*. Species from this group, like the species with the alpine-plain ranges, also widely distributed in highlands, but they are limited by an altitudinal gradient, which is restricted to the sub-alpine zone. The subalpine-plain species are located prevailingly in disjunctions or at their range boundaries which are defined by the complex influence of environment and, first of all, by an altitudinal gradient.

A large number of *Carex* species (19: 18,1%) belongs to the mountain-plain range type (Tab. 1): *C. alopecoidea*, *C. foenea*, *C. glacialis*, *C. granularis*, *C. houghtoniana*, *C. laeviconica*, *C. loliacea*, *C. oederi*, *C. oligosperma*, *C. pedunculata*, *C. petasata*, *C. pseudocyperus*, *C. sterilis*, *C. supina*, *C. sychnocephala*, *C. tenera*, *C. tetanica*, *C. tonsa* and *C. trisperma*. The distribution of species from this group is characterised by the lowest altitude, in particular in the temperate zone. These are the so-called mountain elements of the flora, which are widespread in the lower mountains and plain areas.

The plain range type is represented by 9 (8,6%) *Carex* species (Tab. 1): *C. adusta*, *C. assiniboinensis*, *C. cristatella*, *C. cryptolepis*, *C. hookeriana*, *C. leptonervia*, *C. mackenziei*, *C. projecta* and *C. umbellata*. The presence of these species in Saskatchewan is the evidence, on the one hand, of an ancient formation of *Carex*

Tab. 2 Distribution of the *Carex* species of Saskatchewan according to regional range types and subtypes.

Range type	Species n	%
American	62	59,0
pluriregional	8	7,6
Eurasian-American	6	5,7
European-American	2	1,9
circumpolar	24	22,9
polyregional	11	10,5
eupolyregional	5	4,8
bipolar	6	5,7
Total	**105**	**100**

species in plain areas, and on the other, of the migration processes that are being accelerated by climate change and human activities in more recent times. The ecological conditions of the Saskatchewan Plain have contributed to the establishment of *Carex* species with a various adaptation potential: from littoral coastal halophytes, to steppe xerophilous, to forest-steppe meso-, hygro-, and hydrophilic species. The presence of such a diverse group of species which, for the most part, have northern or southern boundaries here, indicates the possible (prevailing) trends in the paths of migrations of these species in the process of their genesis.

The alpine-mountain range type is formed by three (2,8%) *Carex* species (Tab. 1): *C. douglasii*, *C. raynoldsii* and *C. simulata*. This most closely reflects the mountain specificity of the genus *Carex* in Saskatchewan, although these species are provincially uncommon or even rare. These species are characterised by the purely mountain type of distribution which is confined mostly to uplands in the southern part of the province.

Consequently, the altitudinal differentiation of the genus *Carex* in Saskatchewan indicates a slight predominance of species associated with the plain and low-altitude areas. This is quite natural given the biophysical features and geographical location of the province with the dominance of plains and hills (95%), and a relatively small areas (5%) occupied by mountains. The mountain specificity of the genus *Carex* is reflected, to a larger extent, by the species of the alpine-mountain, and, to a lesser extent, the alpine-plain, subalpine-plain, and mountain-plain altitudinal range types.

Regional range types

According to the distribution of the study *Carex* species in specific geographic regions of the world, we classified them into four regional range types (Tab. 1, Fig. 6): American, pluriregional (Eurasian-American and European-American), circumpolar, and polyregional (eupolyregional and bipolar), with two subtypes in the

second and fourth group (Tab. 3). Distribution ranges of species belonging to the first three types encompass the Northern Hemisphere exclusively, while species from the fourth group have distribution ranges at least partially located in both hemispheres.

The biophysical environment and geographical location of Saskatchewan in the center of the North American continent determines to a large extent the affinities of *Carex* species to the American range type. To this group belong the majority of the study species of *Carex* (62: 59,0%) (Tab. 1): *C. adusta*, *C. alopecoidea*, *C. arcta*, *C. assiniboinensis*, *C. athrostachya*, *C. aurea*, *C. backii*, *C. bebbii*, *C. brevior*, *C. concinna*, *C. crawei*, *C. cristatella*, *C. cryptolepis*, *C. eburnea*, *C. deflexa*, *C. deweyana*, *C. douglasii*, *C. filifolia*, *C. foenea*, *C. garberi*, *C. granularis*, *C. gravida*, *C. hoodii*, *C. hookeriana*, *C. houghtoniana*, *C. hystericina*, *C. inops*, *C. interior*, *C. lacustris*, *C. laeviconica*, *C. lenticularis*, *C. leptalea*, *C. leptonervia*, *C. meadii*, *C. microptera*, *C. nardina*, *C. parryana*, *C. peckii*, *C. pedunculata*, *C. pellita*, *C. petasata*, *C. prairea*, *C. praticola*, *C. projecta*, *C. raynoldsii*, *C. retrorsa*, *C. richardsonii*, *C. rossii*, *C. sartwellii*, *C. saximontana*, *C. siccata*, *C. simulata*, *C. sprengelii*, *C. sterilis*, *C. sychnocephala*, *C. tenera*, *C. tetanica*, *C. tonsa*, *C. torreyi*, *C. trisperma*, *C. umbellata* and *C. xerantica*. They are characterised predominantly by a relatively small range size among the study *Carex* species. *C. hookeriana* is the species with the smallest range, occurring in the central part of North America only. Many species occur at the boundaries of their distribution, for example, a large portion of ranges of 6 species (*C. athrostachya*, *C. douglasii*, *C. filifolia*, *C. hoodii*, *C. raynoldsii* and *C. simulata*) is concentrated in the west part of North America. High mountain species of the American range type are characterised by an extremely disjunct distribution, i.e. they occur in the Arctic Region or in the North American Cordillera. A distinct distribution in this group is noted for *C. eburnea* and *C. trisperma* with their ranges stretching across North America and partially located at a top of the continent in Greenland. It's noteworthy to mention that North America is the home to the highest level of endemism in the genus *Carex* anywhere on the planet. We use term “endemic” in broad context here, i.e. species that exists only on North American continent. According to Ball & Reznicek (2002), there are 333 (69,4%) such type of endemics among 480 species of *Carex* that occur on the continent.

Only 8 (7,6%) *Carex* species belong to the pluriregional (Eurasian-American and European-American) range type (Tab. 1). Here, species of the Eurasian-American range subtype dominate (6: 5,7%): *C. obtusata*, *C. oligosperma*, *C. pachystachya*, *C. stipata*, *C. supina* and *C. utriculata*. To the European-American range subtype belong only two species (1,9%): *C. crawfordii* and *C. vulpinoidea*. Both species have the adventive status in Western and Central Europe (Egorova 1999; Koopman 2015). Given the fact that these species already become naturalised in Europe, we classified them under the pluriregional rather than the American range type.

Numerous *Carex* species (35: 33,3%) have a relatively wide distribution and belong to the circumpolar and polyregional range types (Tab. 1). Almost with continuous

Tab. 3 The range associations of the *Carex* species of Saskatchewan according to zonal and climatic types.

Zonal type	Species range Climatic type				
	suboceanic	sub-continental	continental	indifferent	Number of species
arctic-tropical	.	.	.	1	1
arctic-subtropical	.	2	2	1	5
arctic-meridional	1	4	3	6	14
arctic-submeridional	2	3	2	3	10
arctic-temperate	.	2	1	2	5
boreal-tropical	1	1	.	.	2
boreal-subtropical	1	6	1	.	8
boreal-meridional	2	13	11	.	26
boreal-submeridional	3	7	2	1	13
boreal-temperate	.	1	2	.	3
temperate-subtropical	.	2	1	.	3
temperate-meridional	.	.	2	.	2
temperate-submeridional	2	.	1	.	3
temperate	.	.	1	.	1
plural zonal	1	.	3	5	9
Total	**13**	**41**	**32**	**19**	**105**

ranges in the northern part of the Holarctic are species of the circumpolar (circumboreal) range type. To this group belong 24 (22,9%) species: *C. aquatilis*, *C. atherodes*, *C. bicolor*, *C. bigelowii*, *C. brunnescens*, *C. buxbaumii*, *C. capillaris*, *C. capitata*, *C. chordorrhiza*, *C. disperma*, *C. glacialis*, *C. heleonastes*, *C. lasiocarpa*, *C. limosa*, *C. livida*, *C. loliacea*, *C. mackenziei*, *C. media*, *C. pauciflora*, *C. rostrata*, *C. saxatilis*, *C. scirpoidea*, *C. tenuiflora* and *C. vaginata*. They are characterised by disjunctions in latitudinal and longitudinal directions.

The polyregional range type includes 11 (10,5%) *Carex* species (Tab. 1): *C. arctogena*, *C. canescens*, *C. diandra*, *C. duriuscula*, *C. echinata*, *C. magellanica*, *C. maritima*, *C. michauxiana*, *C. oederi*, *C. praegracilis* and *C. pseudocyperus*). A characteristic feature of all polyregional species is the location of their ranges in the Northern and Southern Hemisphere. In this regard, particular attention deserves 6 *Carex* species (*C. arctogena*, *C. canescens*, *C. diandra*, *C. echinata*, *C. magellanica* and *C. maritima*), which are distinguished by bipolar ranges (Egorova 1999). Overall, there are only 7 *Carex* species with a bipolar distribution in the flora of North America (Villaverde et al. 2017), which indicates a fairly high degree of bipolar species representativeness in Saskatchewan.

Significant differentiation of regional range types of the genus *Carex* in Saskatchewan testifies that the range formation took evolutionary a long time. It also attests to the closer, mostly American affinities, and allows us to trace migration routes along mountain systems in the American Cordillera and the Andes of South

America. At the same time East Asian and European connections are much less evident.

Conclusion

The results of distribution analysis of the genus *Carex* in Saskatchewan relieved a substantial phytogeographical differentiation of species ranges and allowed us to identify patterns of distribution of the study species in different natural zones, types of climate, altitudinal zones and regions across the province and continents of the Earth.

The analysis of the zonal range types of the study carices demonstrates their significant diversity with prevalence of species which belong to the boreal-meridional and arctic-meridional range types, and it also indicates a large size of species ranges and high degree of their disjunction. A somewhat larger number of the study species have their ranges located in moderately cold or cold natural zones, while species with ranges associated with moderately warm and warm zones are found rather in a smaller number. This also elucidates some patterns of formation of the genus *Carex* in Saskatchewan by species migration along latitudinal gradient in two directions – to the northern, and to a lesser extent, the southern boundary of the province.

The climatic range types show that the most study carices have a wide distribution in regions with a continental climate, however some species have their ranges located in regions with an oceanic type of climate. The analysis of the zonal range types of the study species that encompass different climatic regions indicates that they prevail in northern zones and regions with a severe continental climate.

The altitudinal differentiation of the genus *Carex* in Saskatchewan is manifested in a slight predominance of species associated with the plain and low-altitude areas which is determined by the biophysical features and geographical location of the province. The mountain specificity of the genus *Carex* is reflected, to a larger extent, by the presence of species of the alpine-mountain range type, and to a lesser extent, of species which belong to the alpine-plain, subalpine-plain, and mountain-plain altitudinal range types.

A significant differentiation of regional distribution of the study carices serves as an evidence that their range formation in the province took evolutionary a long time. It also attests to stronger American ties established through migration routes in the American Cordillera and the Andes of South America and demonstrates that biogeographical affinities to East Asia and Europe are somewhat weaker. Another noteworthy feature of the genus *Carex* in Saskatchewan is the fairly high presence of bipolar species which are distributed at high northern latitudes and high southern latitudes but nowhere in between. Ranges of most of the study species are comparatively large and endemic taxa are known among hybrid taxa only. Nonetheless, existence of hybrid taxa in Saskatchewan is an evidence of the active evolutionary processes caused by hybridisation which plays an important role in ecogeographic isolation and speciation in the genus *Carex*.

The suggested classification is the first attempt to develop a typology of range types of *Carex* species occurring in Saskatchewan based on the principles of botanical and geographical zoning of the word. The analysis of the distribution of *Carex* species was a difficult task as different classification approaches were used in primary data sources which were examined in this study. However, the proposed range types were comparable to the units recognised in literature. Therefore, this classification serves its ultimate goal by making possible the comparison of range types of *Carex* species occurring in Saskatchewan with existing data from other regions and continents.

Acknowledgement

We are grateful to A. Leighton for helpful comments on the taxonomy of *Carex* species in Saskatchewan. We thank D. Falconer for providing assistance with plant specimens at the W.P. Fraser Herbarium of the University of Saskatchewan (SASK). Comments of anonymous reviewers helped to improve the quality of our paper.

References

Acton D. F., Padbury G. A. & Stushnoff C. T. (1998): The Ecoregions of Saskatchewan. – Canadian Plains Research Center. University of Regina, Regina. 204 pp.

Ball P. (1990): Some aspects of the phytogeography of *Carex*. – Can. J. Bot. 68(7): 1462–1472. doi.org/10.1139/b90-185

Ball P. W. & Reznicek A. A. (Eds.) (2002): *Carex* L. – In: Flora of North America North of Mexico. Flora of North America Editorial Committee, vol. 23, p. 254–572. – Oxford University Press, New York & Oxford.

Brouillet L., Coursol F., Meades S. J., Favreau M., Anions M., Bélisle P. & Desmet P. (2010+): VASCAN, the Database of Vascular Plants of Canada. http://data.canadensys.net/vascan/ [accessed 5 May 2019].

Catling P. M., Reznicek A. & Crins W. J. (1990): Systematics and ecology of the genus *Carex*: Introduction. – Can. J. Bot. 68(7): 1405–1408. doi.org/10.1139/b90-179

Cayouette J. & Catling P. M. (1992): Hybridization in the genus *Carex* with special reference to North America. – The Bot. Rev. 58(4): 351–440.

Danylyk I. M. (2015): Geographical differentiation of the family Cyperaceae Juss. of the flora of Ukraine. – Sci. Principles Biodivers. Conserv. 6(13), (1): 63–86. [In Ukrainian].

Didukh Y. P., Plyuta P. H., Protopopova V. V. et al. (2000): Ecoflora of Ukraine. Vol. 1. – Phytosociocenter, Kyiv. 284 pp. [In Ukrainian].

Egorova T. V. (1999): The sedges (*Carex* L.) of Russia and adjacent states (within the limits of the former URSS). – St. Petersburg Chemical-Pharmaceutical Academy & Missouri Botanical Garden Press, St. Petersburg & St. Louis. 772 pp.

Goetghebeur P. (1998): Cyperaceae. – In: Kubitzki K. et al. (Eds.). The Families and Genera of Vascular Plants, vol. 4, p. 141–190. – Springer-Verlag, Berlin.

Govaerts R., Dransfield J., Zona S., Hodel D. R. & Henderson A. (2019): World Checklist of Cyperaceae. Facilitated by the Royal Botanic Gardens, Kew. http://wcsp.science.kew.org/ [accessed 5 May 2019].

Harms V. L. (2006): Annotated Catalogue of Saskatchewan Vascular Plants. – W. P. Fraser Herbarium, University of Saskatchewan, Saskatoon. 116 pp. http://www.biodiversity.sk.ca/Docs/AnnotatedCatalogueSKVascPlants2006.pdf

Holub J. (1987): Fytogeografická analýza Československých druhů rodu *Carex*. – Zpr. Čs. Bot. Společn. 22(6): 35–45. [In Czech].

Hudson J. H. (1977): *Carex* in Saskatchewan. – W. P. Fraser Herbarium, University of Saskatchewan. Bison Publishing House, Saskatoon. 173 pp + Appendix.

Koopman J. (2015): *Carex* Europaea. The Genus *Carex* L. (Cyperaceae) in Europe. Vol. 1. – Margraf Publishers, Weikersheim. 746 pp.

Kricsfalusy V. & Trevisan N. (2014): Prioritizing regionally rare plant species for conservation using herbarium data. – Biodivers. Conserv. 23 (1): 39–61. doi:10.1007/s10531-013-0583-4

Martín-Bravo S. & Escudero M. (2012): Biogeography of Flowering Plants: A Case Study in Mignonettes (Resedaceae) and Sedges (*Carex*, Cyperaceae). – In: Stevens L. (Ed.). Global Advances in Biogeography, p. 257–290. – InTechOpen.

Meusel H. & Jäger E. (1992): Vergreichende Chorologie der Zentraleuropäischen Flora. Vol. 3. – Fischer, Jena. 333 pp. (text) + 688 pp. (maps).

Leighton A. L. (2012): Flora of Saskatchewan. Sedges (*Carex*) of Saskatchewan. Fascicle 3. – Flora of Saskatchewan Association & Nature Saskatchewan, Regina. 280 pp.

Rothmaler W. (2002): Exkursionsflora von Deutschland. Gefäßpflanzen: Kritischer Band. Vol. 4. – Spektrum Akademischer Verlag, Heidelberg & Berlin. 948 pp.

SASK – The W. P. Fraser Herbarium at the University of Saskatchewan (2019): http://herbarium.usask.ca [accessed: 19 June 2019].

Spalink D., Drewb B. T., Pace M. C., Zaborsky J. G., Li P., Cameron K. M., Givnish T. J. & Sytsma K. J. (2016): Evolution of geographical place and niche space: Patterns of diversification in the North American sedge (Cyperaceae) flora. – Mol. Phylogenetics Evol. 95: 183–195. doi.org/10.1016/j.ympev.2015.09.028

The Encyclopedia of Saskatchewan (2005): Canadian Plains Research Center, University of Regina, Regina. 1071 pp.

Villaverde T., Escudero M., Martín-Bravo S., Jiménez-Mejías P., Sanmartín I., Vargas P. & Luceño M. (2017): Bipolar distributions in vascular plants: A review. – Am. J Bot. 104 (11): 1680–1694. doi: 10.3732/ajb.1700159m

Received: July 6th 2019
Revised: October 30th 2019
Accepted: November 30th 2019