DIVERSITY OF VASCULAR PLANT SPECIES IN THE MONTANE BOREAL FOREST OF WESTERN CANADA IN RESPONSE TO CLIMATIC CHANGES DURING THE LAST 25 KA, FIRE, AND LAND USE

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With 4 figures, 1 table and 1 appendix
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Summary: This paper examines the biodiversity of vascular plants in the vast boreal forest area of the southern Cordillera of western Canada. It was glaciated until 11 ka, and since then, vascular plants have had difficulties colonizing the deglaciated areas from the surrounding refugia. Problems include the topography, the comparatively inhospitable climate, limited source areas, natural wildfires, and fluctuations in climate. As a result, the forest consists of up to 494 species of vascular plants at any one site compared to 871 species at Mount Rainier, Washington State. For comparison, 2,993 taxa have been reported from British Columbia indicating the limited colonization that has occurred. European Man has added to these problems by increasing fire frequency and by extensive, repeated logging of large areas. A limited amount of intensive irrigated agriculture also occurs near southern rivers and lakes. The end result is a limited range of species, of which 30% are regarded as rare or endangered. The consumers of the resulting biomass are therefore also limited in their food supply.

Zusammenfassung: Die Auswirkungen von Klimawandel, Feuer und Landnutzung auf die Diversität der Gefäßpflanzenflora montaner borealer Wälder West-Kanadas in den letzten 25.000 Jahren. Dieser Artikel untersucht die Biodiversität von Gefäßpflanzen borealer Wälder der südlichen Kordillere im westlichen Kanada. Das Gebiet war bis vor 11.000 Jahren vergletschert und in der nachfolgenden Zeit hatten Gefäßpflanzen Schwierigkeiten bei der Wiedereinwanderung aus den umliegenden eiszeitlichen Refugien. Einwanderungshindernisse resultierten aus der Topographie, vergleichsweise ungünstigen klimatischen Verhältnissen, begrenzten Ursprungsarealen, natürlichen Feuern und Schwankungen des Klimas. Als Folge beträgt die Gesamtzahl der Gefäßpflanzen dieser Wälder lediglich 494 Arten; am Mount Rainier (Washington State) treten im Vergleich dazu 871 Arten auf. Der Vergleich mit der Gesamtzahl von 2.993 der beschriebenen Taxa in Britisch Columbia dokumentiert ebenfalls das eingeschränkte Ausmaß der Wiederbesiedlung. Europäische Siedler haben durch Erhöhung der Feuerfrequenz und wiederholten Holzeinschlag in ausgedehnten Gebieten ebenfalls zu einer Behinderung der Arteneinwanderung beigetragen. Darüber hinaus wird im Bereich der südlichen Seen und Flüsse in begrenztem Maße intensiver Ackerbau betrieben. Das Endresultat stellt ein eingeschränktes Artenspektrum dar; 30% der Arten sind zudem als selten oder gefährdet anzusehen. Die auf diese Biomasse angewiesenen Konsumenten sind daher in ihrem Futterangebot eingeschränkt.

Keywords: Plant diversity, montane boreal forest, revegetation after glaciation, refugia, fire, effects of forestry

1 Introduction

The boreal forest is the largest ecosystem in Canada, and occupies about 60% of the landscape in Alberta and British Columbia (Fig. 1). Of this, some 45% is found in the Cordillera, mainly south of the 56th parallel. It extends across 25° of longitude and 15° of latitude. In contrast, Germany occupies 6° of latitude and 7° of longitude, although it is one of the largest countries in Europe.

The area of the Cordillera with boreal forest shows a marked east-west climatic gradient, together with abrupt climatic divides (Fig. 1). It was also completely covered in ice during the Late Wisconsin glaciation, so that the present-day vegetation has had to migrate into the vast area during the last 11 ka. This paper explores the resulting biodiversity of the vascular plants, the natural causes of the pattern, and probable effects of climatic changes. Since the bulk of the human population in the mountains is located south of the 53rd parallel, this also provides the opportunity to explore the effects of different kinds of land use on this natural ecosystem. This paper summarizes our present knowledge of the resulting changes in biodiversity.

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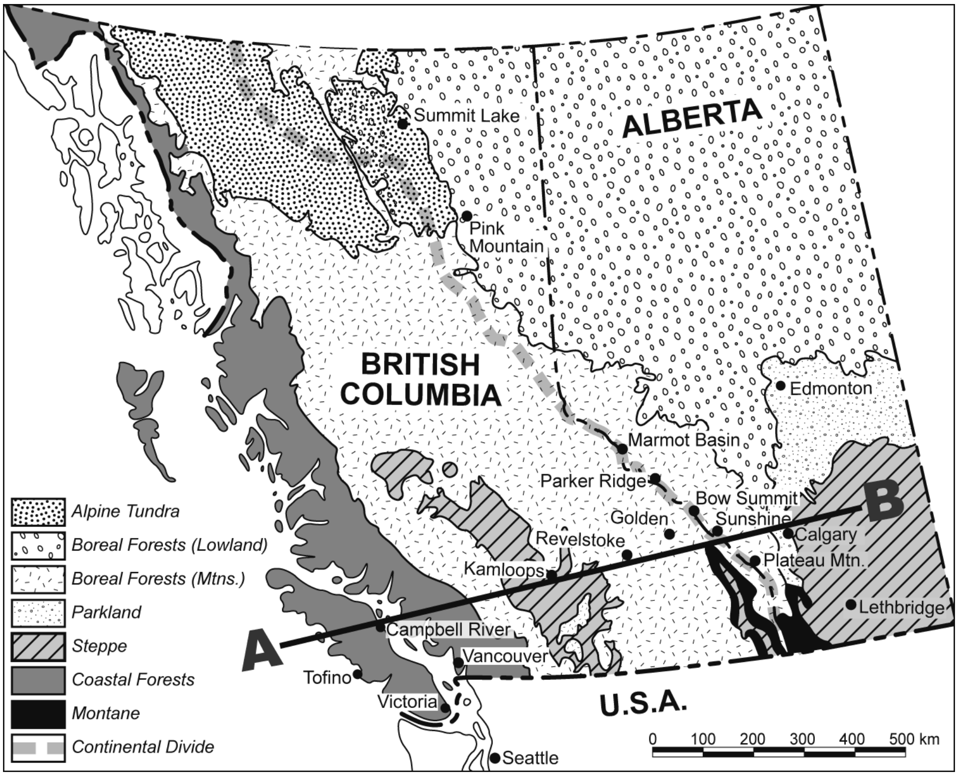

Fig. 1: Distribution of the boreal forest in the south of the 60th parallel in the Canadian Cordillera, and location of the study sites

2 Past work

The sheer size of the area and the limited access in much of northern British Columbia have caused severe problems for Biogeographers. The Biologists and Biogeographers based at the University of British Columbia in Vancouver have carried out numerous studies aimed at defining biogeoclimatic zones. This involved using 2 x 2m plots in limited areas and then tracing the distribution of those areas with special characteristics across the landscape using soil maps, climatic data and remote sensing techniques. Thus Hoefs et al. (1975) carried out a detailed study of the 32 plant associations on the south-east slopes of Sheep Mountain in the southwest Yukon Territory. These detailed studies gave excellent information on the plant associations found in the study area, but those associations do not provide a ready and clear source of information on species diversity or distribution in other areas where the plant associations are mapped. This system was devised by V. J. Krajina and has been refined by the B.C. Forest Service using additional field work to produce the currently used version (Pojar et al. 1987). It is this system that is used in atlases and as a broad summary of the biogeoclimatic zones, and the system has since been applied across the rest of Canada.

While these studies were going on, vascular plants were being collected and identified from across the Province, and a central data bank was developed at the Provincial Capital in Victoria. This has been developed, computerized and summarized in the latest 8-volume Flora of British Columbia under the leadership of G. W. Douglas (see for example, Douglas et al. 2002b). This indicates that British Columbia has one of the most diverse vascular floras in Canada with at least 2,993 taxa, but detailed examination of the distribution maps of individual species shows that many have a very limited area of occurrence. Douglas et al. (2002a) concluded that at least 30% of the species of vascular plants are rare or endangered. A similar conclusion had also been reached in a parallel study in Alberta (Kershaw et al. 2001).

In terms of the species diversity classification of Whittaker (1972), there are four biomes present (gamma diversity) of which we shall be dealing with only one, viz., the forest (Fig. 2). In the Cordillera, this can be subdivided into the coastal rain forest and the very extensive montane boreal forest of the interior. The latter can be subdivided into six main ecoregions (delta diversity), based on the dominant tree species, but as indicated in Appendix A, these exhibit tremendous variability in the species that are actually present (beta diversity). There is also an exceptionally low species diversity at any given place. It is the purpose of this paper to examine this species diversity in the montane boreal forest of the Canadian Cordillera and to try to determine the causes of its unusual characteristics.

3 Methodology

Over the past 35 years, the author and his students have been carrying out studies of permafrost distribution and the associated landforms in the Canadian Cordillera. In addition, detailed studies have been made of the effects of fire (Harris 1976) and snow avalanches (Winterbottom 1974; Chernoff 2001). As part of the work, detailed plant collecting and identification has been carried out in the key study areas. This involved collecting through-

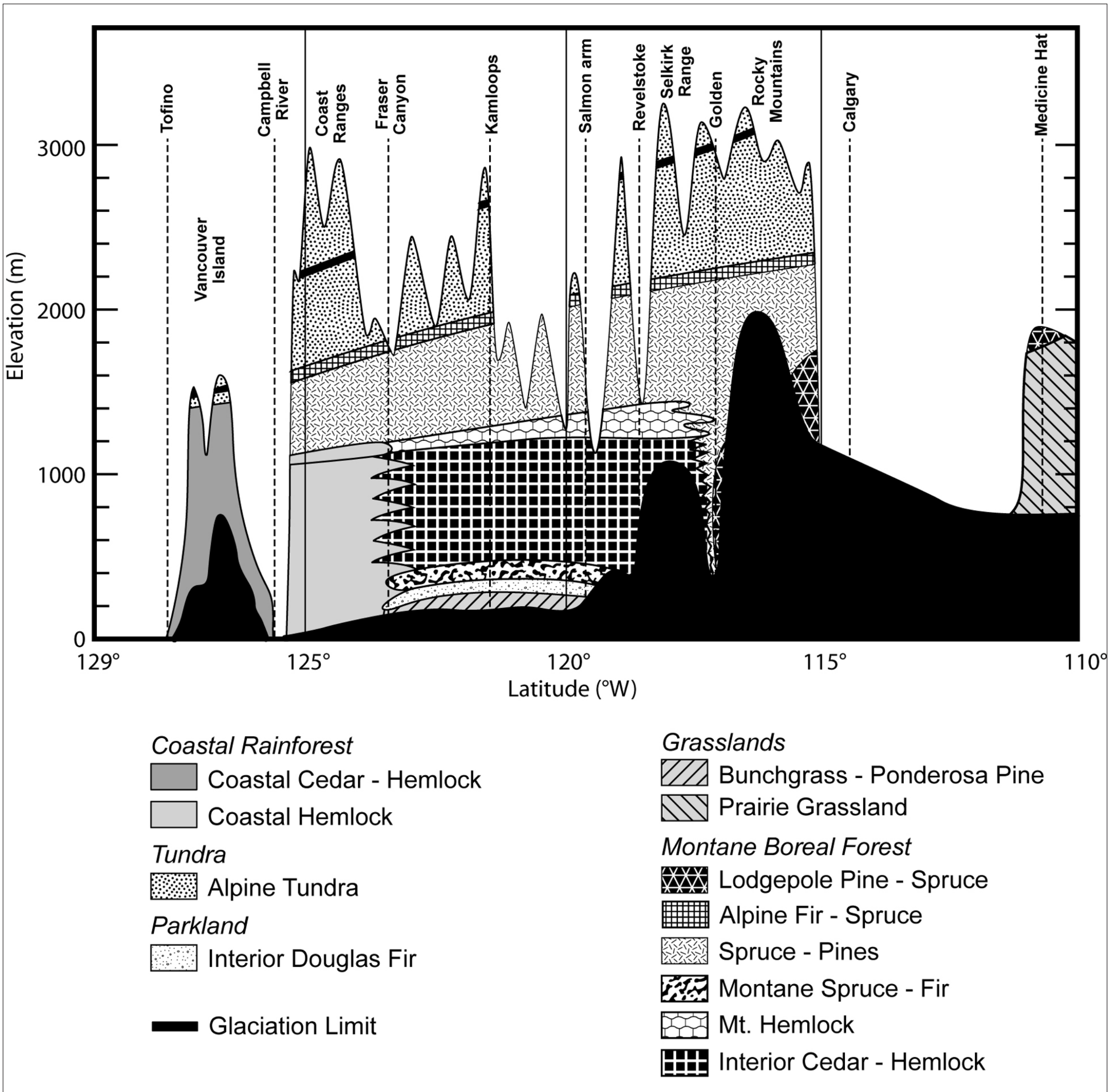

Fig. 2: The main vegetation zones along the transect across Southern British Columbia and Southern Alberta along line A-B in Figure 1

out the flowering season so that the succession of flowering plants at each site was adequately sampled. Sometimes 2 x 2 m plots were used, but it was found that collecting all the species present on the side of a mountain, noting their altitude and ecology, was more effective. In this way, detailed lists of plant distribution by biogeoclimatic zone could be produced for these sites. Other researchers at the University of Calgary have pursued the fire studies so that we now have a good idea of fire frequency and its effects (e.g., JOHNSON a. LARSEN 1991; JOHNSON a. MIYANISHI 1991), while others have tackled the problems facing the larger mammal populations as the southern part of the region becomes more intensively used by Humans (PAQUET 1993; ALEXANDER a. WATERS 2000).

Similar detailed studies of the species present at key locations have been carried out by other workers, mainly in the National Parks, e.g., Mount Revelstoke (ACHUFF et al. 1984; ACHUFF a. DUDYNSKY 1984) and Mount Rainier (BIEK 1999), and these are now sufficiently numerous that they can be used to provide a first look at the highly impoverished floras that are found across the slopes of the formerly glaciated mountains. These floras are in sharp contrast to the relatively rich floras of the Alps that show only limited species diversity across the area.

It is clear from this, that to properly understand the causes of the poor species diversity in the montane boreal forest, it is necessary to examine all the potential factors including the sources from which the vascular plants could have entered the vast formerly glaciated area in order to recolonise it. In the case of the Alps, the plants had to merely follow the retreating glaciers, but in the Cordillera, an area approaching four times the size of Germany had to be revegetated in a mere 11 ka from sources up to 1,600 km away and living under very different climatic conditions. Accordingly, the following discussion will be primarily descriptive rather than dealing with biodiversity statistics.

4 Present-day species distribution

Appendix A shows the species present in the montane boreal forest at nine locations, while the relevant climatic data for these sites will be found in table 1. The total numbers of taxa identified at these sites is 1,027, representing 34.3% of the flora of British Columbia. However it also includes some species primarily found on the eastern side of the Cordillera on the mountains in Alberta. Considering that the montane boreal forest is only one of four biomes present in British Columbia, the sites collectively have an appropriate number of taxa present.

When the data are examined more closely, the paucity of taxa at many of the sites becomes apparent. LESSICA (2002) found 1,132 species of vascular plants in Glacier National Park, Montana (latitude 48° 45' N), on the southern margin of the formerly glaciated zone. However, the numbers decrease dramatically when traced northwards. At wet sites within 250 km of the former ice margin, up to 494 species are found representing 48% of the total numbers of taxa at the nine sites (Glacier National Park, British Columbia and Sunshine Ski Resort in Banff National Park). Northwards, the numbers drop dramatically to a low of 109 species (10.6%) in north-central British Columbia. Further north, the numbers start to rise, culminating in 172 species at Kluane Lake on the margin of Beringia. Thus the beta diversity is very low compared with other parts of the world.

Only three species (White Spruce, *Picea glauca* (Moench.) Voss, Canadian Buffaloberry, *Shepherdia canadensis* (L.) Nuttall and Labrador Tea, *Ledum groenlandicum* Oeder) were found at all nine sites. However, 325 taxa (31.6% of the taxa in Appendix A) were only recorded at one of these sites. This percentage is very similar to the percentage of rare and endangered species in both Alberta and British Columbia (KERSHAW et al. 2001; DOUGLAS et al. 2002a). This emphasizes the extreme variability of species in addition to their limited numbers in many parts of the montane boreal forest.

The vertical distribution of species is known for the Alberta and Yukon sites, and also shows some anomalies. At Sunshine Ski Area in Banff National Park (Fig. 3) there is a marked reduction in species richness with altitude, as is found in studies in the Alps and Hindu Kush (BRECKLE 1981; AGAKHAJANZ a. BRECKLE 2002). However, at the other sites the number of species changes little with altitude, and this is also true for the boreal forest at Kluane Lake in the southwest Yukon Territory.

5 Evolution of this pattern

Under natural conditions, this species distribution would be the result of several interacting factors, viz., the difficulty of revegetation after deglaciation, climatic and topographic controls, and the effects of fire and snow avalanches. Superimposed on these are the activities of Man, the most important of which is the lumber industry.

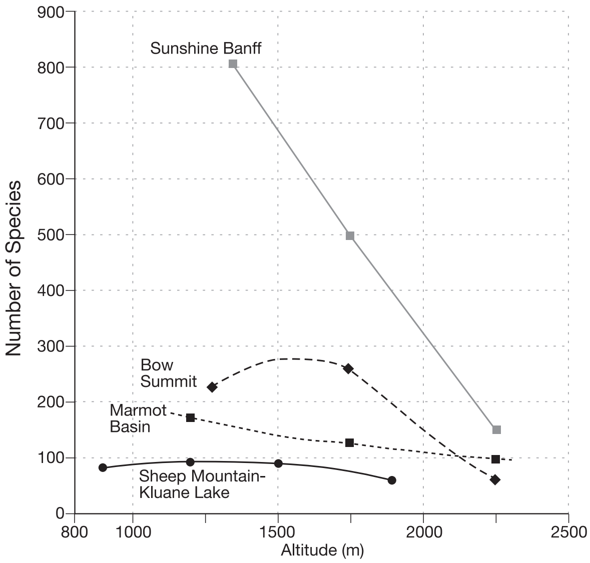

Fig. 3: Variation in numbers of species with altitude at four of the nine study sites in the boreal forest

5.1 Revegetation after deglaciation

Almost the entire area occupied by the boreal forest in the mountains (some 1,600 km in length and 800 km wide) was covered by the Late Wisconsin ice sheets (Prest et al. 1968; Prest 1969), so that the present-day boreal forest vegetation has had to spread into the area during the last 10–12 ka from either the unglaciated areas to the south, from Beringia (Harris 2004), or from local refugia such as the Queen Charlotte Islands (Calder a. Taylor 1968) and Plateau Mountain, south-west Alberta (Harris 1997). The belt of alpine tundra on the mountains that extend east-west across northern British Columbia limited the extent of large-scale colonization of the deglaciated slopes from the north (see Fig. 1) except during the climatic optimum, and is the reason for the increase in species diversity at Summit Lake compared with Pink Mountain (see Appendix A). The species diversity of the montane boreal forest in the southern Yukon Territory has even greater species diversity owing to its proximity to Beringia (Harris 2004).

There was revegetation of the eastern slopes of the Rocky Mountains from Plateau Mountain and Montana, with some species crossing through passes into eastern British Columbia from the boreal forest in the lowland to the east. The Queen Charlotte Islands provided one source for the vegetation along the western slopes of the Coastal Ranges, but the only places where they could cross into the interior plateau were where major rivers cut deep valleys through the mountains. An example of the results would be the distribution of Western Red Cedar (*Thuja plicata* Donn ex D. Don) that entered central British Columbia via the Prince Rupert-Kittimat and Fraser valleys (Hebda a. Mathewes 1984).

Limited revegetation took place from the refugium in the vicinity of Plateau Mountain, with some species migrating as far west as Revelstoke, e.g., *Erigeron aureus* Greene. Once again, the limited number of low passes through the mountains limited the effectiveness of this source, while the absence of calcareous bedrock west of Revelstoke would also have limited the westward migration of the calciphiles.

The main revegetation had to be achieved by species from the refugia to the south. Although there are large numbers of species in Oregon, Washington and Idaho, e.g., 1,150 species on Steens Mountain, Oregon (Mansfield 1999) and 871 species in Mount Rainier National Park (Biek 1999), the majority are adapted to hot, dry summers and cannot tolerate the moist but colder conditions found in areas of boreal forest. As a result, only those species that are particularly plastic in ecological requirements could migrate across the long distances needed to colonize the deglaciated areas. The colder temperatures to the north undoubtedly also play a role in the reduction of species abundance at higher latitudes (see Tab. 1). Whether any species are still migrating into and across the deglaciated area remains to be established.

In the Flora of North America, the interior montane zone from southern Yukon to New Mexico is mapped as one floral zone (Barbour a. Christensen 1993, 98, Fig. 5.1), however the climatic and vegetational history of the montane boreal forest in Canada is fundamentally different from the montane forests on the mountains to the south. During the Pleistocene, the climate to the south did not provide enough snow to produce substantial glaciers. As a result, vegetation survived in the area, even though the life zones would have migrated downwards in elevation and south with latitude as the climate became colder. New species were evolved on each major mountain block and species diversification was largely uninterupted. In the areas of widespread glaciation in the mountains of western Canada, the vegetation was completely removed and the area has had to be revegetated after the ice sheets had melted, just like the boreal forest of the adjacent plains to the east (Riley 2003).

Table 1: Climatic data for the nine study sites used in Appendix A (data from AES, no date), except where otherwise indicated

Site	Weather Station	Mean Annual Air Temperature (°C)	Mean Annual Precipitation (mm)	Elevation m
Kluane Lake	Kluane Lake	-2.7	223.9	766
Summit Late	Muncho Lake	-0.7	459.0	835
	Fort Nelson	-1.4	451.8	382
Pink Mountain	Pink Mountain	-0.5	533.4	1204
Marmot Basin	Jasper	2.8	409.3	1061
Parker Ridge	Columbia Icefields	-2.1	930.0	1981
Bow Summit	Bow Summit*	-2.9	–	2088
Sunshine	Banff	2.5	471.0	1397
	Lake Louise	-0.4	683.9	1524
	Ski Lodge+	-3.5	–	2407
Glacier N. Park	Rogers Pass	1.5	1606.0	1320
Mt. Revelstoke	Revelstoke	6.6	946.6	443

*Based on six years data; +Based on three years data

5.2 Climatic controls

Climate is a major limiting factor, and is closely related to topography (Fig. 4). The Coastal Ranges are warm and extremely wet due to the westerly moisture-bearing winds depositing copious amounts of moisture throughout the year on their western slopes. As the air moves eastwards, it descends onto the central plateau, and the precipitation drops dramatically, while the mean annual air temperature decreases. The mean annual precipitation at Tofino on the west coast of Vancouver Island is about double the highest values elsewhere, hence the temperate rain forest there. Precipitation is least on the deep valleys floors of the B.C. interior, which also have the highest numbers of degree-days above 10 ºC. This explains the steppe grasslands with scattered Ponderosa Pine trees (*Pinus ponderosa* P. Laws. ex C. Laws.) along its margins that have spread northwards from the dry areas of eastern Washington and Idaho. On the mountain slopes to the east is found the boreal forest characterized by less than 1,100 degree-days above 10 °C, variable precipitation of less than 1,000 mm/a except on the higher mountain ranges, and progressively lower mean annual temperatures to the east and north.

The western slopes of the Selkirk Range and Rocky Mountains have the highest precipitation, so the species composition of trees is enriched with the Pacific Yew (*Taxus brevifolia* Nuttall), Western Red Cedar, Rocky Mountain Douglas Fir (*Psuedotsuga menziesii* (Mirb.) Franco var. *glauca* (Beissn.) Franco), Western White Pine (*Pinus monticola* (Dougl.) ex D. Don), Western Larch (*Larix occidentalis* Nuttall), Mountain Hemlock (*Tsuga mertensiana* (Bong.) Carrière), and Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The eastern slopes of the Rocky Mountains are relatively dry, so the climax tree canopy consists mainly of Lodgepole Pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.), White Spruce, Engelmann Spruce (*Picea engelmannii* Parry ex Engelm.) and Alpine Fir (*Abies lasiocarpa* (Hook.) Nuttall). Additional species at tree line in the south include Alpine Larch (*Larix lyallii* Parl.) and Limber Pine (*Pinus flexilis* James). To the north, Black Spruce (*Picea mariana* (Mill.) BSP.) and Tamarack (*Larix laricina* (Du Roi) K. Koch.) are dominant in wet situations, the Tamarack occurring on the richer substrates.

The boreal forest has been traditionally divided into an upper subalpine (Hudsonian) zone characterized by coniferous forest, and the lower mixed forest (Canadian) zone in which deciduous trees are present. On the eastern slopes, the deciduous tree species consist mainly of Balsam Poplar (*Populus balsamifera* L.), Trembling Aspen (*Populus tremuloides* Michx.), and Black Cottonwood (*Populus trichocarpa* Torr. and A. Gray), but the Balsam Poplar is absent in British Columbia (Farrar 1995). Western White Birch (*Betula papyrifera* Marsh) and Water Birch (*Betula occidentalis* Hook.) are found throughout the area at low elevations.

The species diversity in the shrub and herb layers tends to be related to the diversity of the upper tree canopy. All species must be able to cope with an

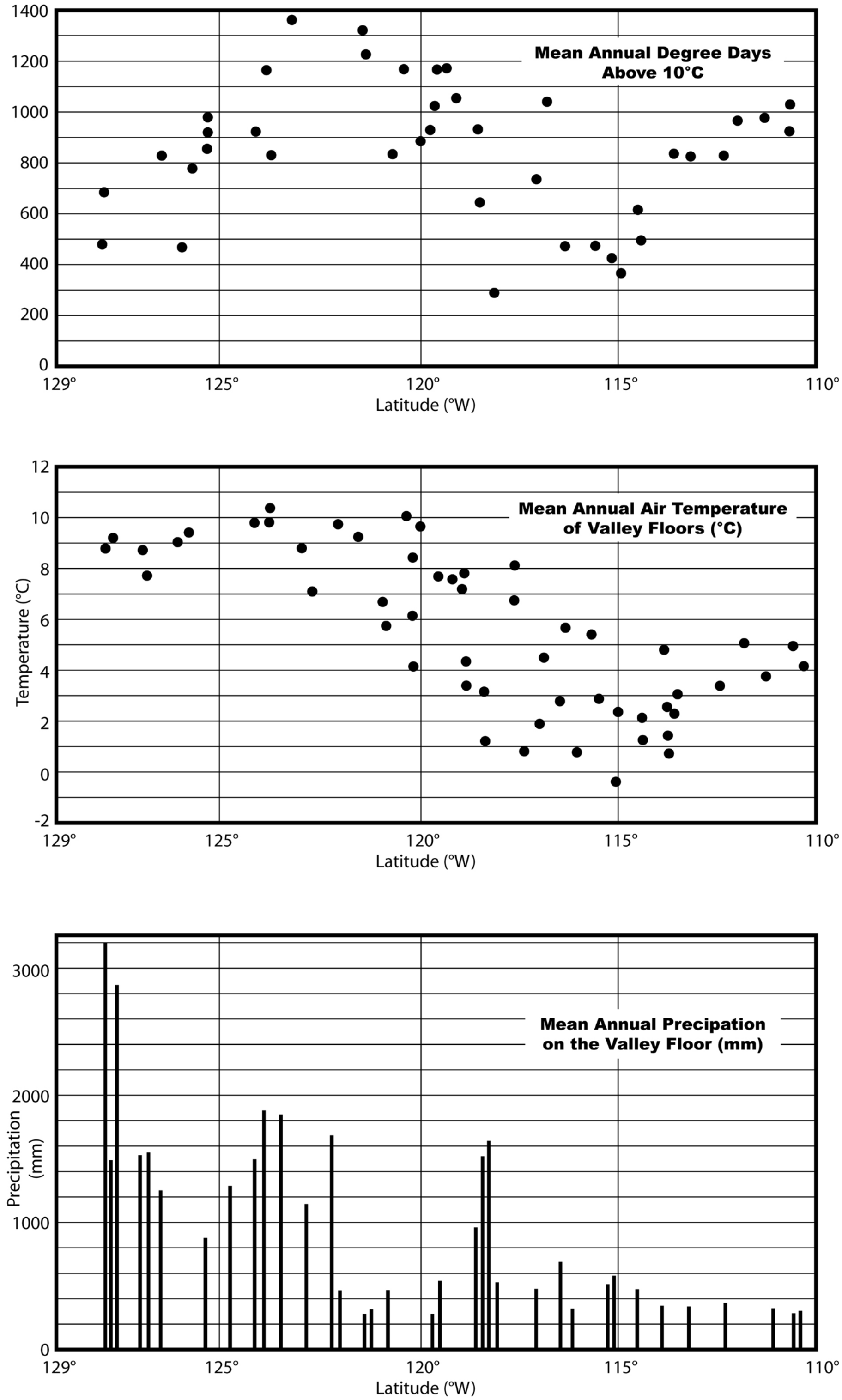

Fig. 4: Variation in the climate along transect A-B in Figure 1, based on the 30 year means published in AES (no date)

annual mean daily temperature variation of 60–80 °C in the south, and this increases northwards and eastwards (Harris 1989, Fig. 1). The maximum annual mean daily temperature range recorded so far is at the foot of the mountains east of Summit Lake, British Columbia (40 °C to -67 °C). The effects of the winter cold are partially offset by the deeper snow cover on the western slopes of the mountains, e.g., the Selkirk Range and at Sunshine Meadows, so that greater biodiversity is found there.

Moisture conditions are particularly important, and the early Holocene in central British Columbia was a time of drought (Alley 1976; Ryder et al. 1991). Harris (2003) suggested that the Hawk-Leaved Saxifrage (*Saxifraga hieraciifolia* Waldst. and Kit.*)*, normally found in the arctic tundra, migrated north from Washington State into central British Columbia at the lower boundary of the boreal forest where conditions were more suitable for its survival. Subsequently the determination of the specimen on which this was based has been changed to *Saxifraga integrifolia* Hooker, a very similar species. This raises the question as to whether they have evolved from a common ancestor by genetic drift.

The effects of increased moisture are also seen in table 1 and figure 3, where Sunshine ski area has much greater biodiversity than the other, drier Alberta stations. As such, it is acting as a refugium for the species that need more moisture than is currently received elsewhere on the eastern slopes of the Cordillera.

5.3 Effects of fire

Fire has always been a factor affecting the distribution of vegetation due to the frequent dry lightening strikes during late spring and early summer. Forest fires can be divided into two kinds, viz., crown fires and ground fires. The former scarcely affect the organic layer on the surface of the ground, whereas ground fires remove the upper organic soil horizons and also destroy the parts of the vegetation above ground. Thus a crown fire may kill the tree layer but spare the shrubs, herbs, and organic layer of the soil. Ground fires will kill any plants that do not have deeply buried rhizomes, corms, bulbs or underground stems, and will burn the soil organic horizons. Examples of typical plants that survive fires are several deep-rooted shrubs (*Menziesia ferruginea* J. E. Smith*; Shepherdia canadensis* (L.) Nuttall, lilies (*Fritillaria affinis* (Schultz) Sealy var. *affinis; Erythronium grandiflorum* Pursh.*)*, and some orchids (e.g., *Calypso bulbosa* (L.) Oakes). Fire also opens the cones of the Lodgepole Pine so that it is one of the first species to reappear after fire. Douglas Fir and Ponderosa Pine have a particularly thick bark, which protects the larger trees from ground fires.

Johnson and Miyanishi (1991) discussed the effect of fire on the population dynamics of the coniferous boreal forests. A forest fire greatly decreases the biodiversity of an area. In the case of the Vermilion Pass Fire in 1968, only 21 species of vascular plants had reappeared after the first seven years (Harris 1976). After 33 years, the Lodgepole Pine forest was tall enough to provide a suitable habitat for 69 vascular species, as well as 6 species of mosses and 6 lichens (Chernoff 2001). Dubé (1976) reported about 14 species of vascular plants in 55 year-old Lodgepole Pine stands, and 19 species in stands 120 years old when the stands of the Spruce-Fir secondary climax forest had replaced the pine forest. In stands over 235 years old, there were 20 species of vascular plants with considerably increased numbers of bryophytes. Many of the actual species present change with time as the stands age, but the actual number of species present does not change appreciably. Thus the effect of fire is to create a temporary gap in the distribution of many species characteristic of the climax forest, but provides a temporary, sunny microenvironment for other species in the sere. Thus there is a constant migration and colonization occurring within the montane boreal forest, and only those species that can readily carry out this recolonization will be commonly found in a given area. This is at least partly the reason for the patchy distribution of vascular plants in the Cordillera, and greatly complicates any migrations northwards that may be occurring.

Fire frequency is particularly important. Fires are almost unknown in the wet coastal rainforest as at Cathedral Grove, but almost all the montane boreal forest has been burned at some time during the Holocene. Fire frequency reaches an average of once every 90–120 years in the boreal forest on the eastern slopes of the Rocky Mountains (Masters 1990; Johnson a. Larsen 1991), so that examples of the mature stage of the secondary sere are relatively rare. It is a similar situation in the mixed forest of central British Columbia, in contrast to the wetter forests of the western slopes of the Selkirk Range near Revelstoke where 500 year-old Western Red Cedar trees are common in old growth stands, e.g., Giant Cedars, Mount Revelstoke National Park. Fire frequency reaches a peak in the parkland adjacent to the arid steppes, and in the boreal forest of the southeast of the Yukon Territory.

Well-known consequences of fire include increased soil erosion, runoff, and sediment yield, which affect the rivers downstream, causing increased flooding and erosion of stream banks. The amount of erosion depends on the techniques used in removing the timber. Left to nature, the trees gradually fall down while revegetation occurs. Under current forest practice, the burned timber is harvested for lumber leaving bare ground. Patch cutting results in increased sediment yield (Frederiksen 1970), but permits natural regeneration. Clear cutting results in less erosion, but unfortunately, rapid natural regeneration of the forest is almost impossible due to lack of seed sources. Moisture in the bare ground decreases, although there may be a greater snow accumulation in small openings in the forest. Bare soil is much more inhospitable as a seed bed for forest rejuvenation, and since Lodgepole Pine does not grow at tree line, fire results in a temporary lowering of the timberline (Kuchar 1975). Thus the trees in the upper 100 m of the montane boreal forest at Marmot Basin Ski Area, Jasper, are all under 100 years old.

The vascular plants in the boreal forest represent the primary producers for the entire ecosystem. If it is appreciably altered, then the consumers such as land snails and insects will tend to die off, reducing the food for the secondary consumers. Thus fire creates major problems for large parts of the ecosystem. Although land snails had colonized the ecosystem soon after the vascular plants moved into the region (Harris a. Pip 1973; Harris a. Hubricht 1982), there is evidence that some of the species of snails collected about a century ago are now extirpated (Forsyth 2004). This is undoubtedly primarily due to loss of habitat.

5.4 Snow avalanches

Snow avalanches are common on the over-steepened slopes of the interior mountains. Half the annual precipitation may fall as snow, e.g., Revelstoke receives about 10 metres of snow each winter. Snow avalanches cut open swaths down the mountain slopes, carrying with them everything in their path. This includes soil and seeds, which are deposited in the run-out zone. This results in exceptional species diversity in these zones at the base of the mountain slopes (Winterbottom 1974), resulting in a temporary increase in species diversity at lower elevations. This may be the cause of similar numbers of species at different elevations at some sites (Fig. 3). If there are no more avalanches on a particular slope, the forest will invade the open area, so that the only evidence of the former avalanche tracks are the mixed up soils and the even-age of the tree stands. In these stands, the only species to survive are those in the adjacent forest. There is photographic and tree-ring evidence for this process having been of widespread occurrence since 1900 A.D. due to a marked decrease in winter precipitation.

Snow avalanches modify the local microenvironment by altering the growing season and the available water in the run-out zone. Once again, the smaller openings in the forest may be the locus of increased snow accumulation. Measurements also show that the mean annual air temperature is about 1 °C lower in the clearing compared with the surrounding forest, and there is increased evaporation of moisture (Harris 1976).

5.5 Effects of Holocene climatic changes

The climate is always fluctuating, and there are changes occurring at different time scales. MacDonald (1987) discusses the postglacial development of the subalpine-boreal ecotone. Tree rings at sites where temperature is the limiting factor have increased from an average of 0.5 mm about 1800 A.D. to about 2.5 mm today (Allen 1982). Maximum tree ring width occurred in 1942–1943, and this is consistent with mean annual daily air temperature measurements, which indicate that the mean annual air temperature at tree line is decreasing slightly south of Calgary (Harris 1995). Evidence based on long-term climatic monitoring, coupled with mapping of the lower limits of the alpine vascular species on Plateau Mountain and on adjacent higher peaks in southwest Alberta indicate that there was a maximum increase in mean annual air temperature during the Altithermal period of 2 °C (Harris 2002).

Moisture is more important than temperature in the continental climate in southeast Alberta. The last Neoglacial ice advance was the most extensive in the last 11 ka, yet does not show in the tree rings at temperature sensitive sites. The current retreat of the glaciers is continuing in spite of the cooling air temperatures. It can therefore be inferred that the precipitation increased during the 19th century, and has now decreased substantially. This helps explain the evidence for much more extensive snow avalanches in the very recent past (Winterbottom 1974).

These changes are not necessarily unusual during the Holocene. Tree trunks coming out of the front of the glaciers and dating at 8–9 ka indicate that tree line has been at least 200 m higher in the Holocene (Luckman a. Kearney 1986), while the disjunct prairie vascular plants in the Peace River and southern Yukon indicate that it has been much warmer and drier than now earlier during both the Holocene, e.g., during the Hypsithermal event (Strong a. Hills 2003), or possibly during an earlier interglacial event (Harris 2007).

The western boundary of the montane boreal forest is controlled by topography and is relatively stable, in contrast to the dynamic eastern and southern borders. A decrease in precipitation or increase in temperature will decrease species diversity and cause the forest boundary to retreat away from the dry area. Increased precipitation would cause the boundary to expand outwards, forest fire frequency would be reduced, and species diversity would increase.

The controls on timberline are poorly known, but most timberlines exhibit an uneven upper front. The semi-circular patches of trees look suspiciously like areas of so-called krumholtz that have expanded and grown into a forest when conditions became suitable. The oldest tree in the forest 100 m below timberline at Marmot Basin, Jasper appears to be about 100 years old, suggesting a recent advance in elevation of the timberline. The forest is gradually infilling the open areas between the clumps of trees. Since isolated trees can be found up to 200 m above timberline at Sunshine, it appears as if the timberline is not fully in equilibrium with the present climate, but may be slowly advancing upwards when conditions are right. As noted previously, fire depresses the timberline temporarily, and the changes noted above may well be a slow response to depression of the timberline resulting from past fire events. Thus the elevation of the timberline in this region cannot be safely used as an indicator of past climate.

5.6 Land use

The most important factor affecting biodiversity since the arrival of the Europeans is the use of the forest. Many of the present-day settlements in the interior of British Columbia are dependent on the logging of the forests to provide cheap pulp and paper or wood for the construction industry. Much is exported, while some trees are cut for firewood. The limited number of tree species makes the montane boreal forest ideal for the timber industry. This is also aided by the fact that some of the trees are hardwood, e.g., the Douglas Fir and the Hemlocks, while the timber of the Western Red Cedar resists rot and is poisonous to most animals. Most of the southern half of the boreal forest has been cut over several times, and old growth forest is rapidly becoming a rarity. Using remote sensing techniques and field data, Franklin (2001) concluded that the present rate of use of the forest resources is unsustainable. When there is no more timber suitable for use, the mills close and many settlements become ghost towns.

The coniferous species are preferred by the timber industry, so where there is selective cutting, the deciduous trees tend to take over, unless there is replanting of seedlings. In the latter case, the seedlings will be of species that the owner of the forest lease regards as desirable and quick growing. They change the forest into a virtual plantation, which alters the microenvironment for the native species trying to move back into the area. Since the supply of old growth timber is almost exhausted in many areas, the second growth timber is exploited as soon as it reaches a useable size. Once again, the deciduous trees can move in, but the herbs are seriously depleted. By the time a third logging takes place, coniferous trees have almost disappeared. Thus in southern British Columbia, the distinction between the subalpine and mixed forest zones has become difficult to apply, and the logging greatly adds to the patchy distribution of even the most common species. The deciduous forest provides a more suitable environment for most ungulates, but unfortunately the rare Rocky Mountain Caribou (*Rangifera arcticus fortidens* Hollister) require the lichens found in old growth coniferous forests. Since the forest industry is vital to the local economy, the situation is likely to get worse until the mills are closed through lack of suitable timber. By then, the forest may have lost a considerable proportion of its original biodiversity. Whether this can be restored from the generally small Provincial Parks scattered through the Province remains to be seen, but a recent publication from Glacier National Park (B. C.) suggests that this is unlikely, and also will be too late to save the Caribou (Hall 1999).

Where there are settlements, fire frequency increases dramatically. Even the indigenous peoples cause some forest fires, though they tend to be more respectful of the environment. The years 2003 and 2004 proved to be very dry in most of the boreal forest, and in 2003 there were two really major fires east and north of Kamloops that wiped out whole settlements and burned most of Niskonlith Provincial Park. These Provincial Parks are usually in second growth forests, but represent a potential haven for biodiversity of the vascular plants. By the end of

June, 2004, over 800 fires had been started in British Columbia, of which 400 were still out of control at the beginning of August. Altogether about 177 km^2 of boreal forest were destroyed.

5.7 Additional factors

There are many other human factors, such as the mining industry, agriculture, recreation, housing, etc., as well as the effects of the plants on each other and on the substrate. The soils along the Rocky Mountains and the Selkirk Range tend to contain up to 30% calcium carbonate, which buffers them, preventing them from becoming too acid. However the soils further west are developed on non-calcareous rocks and are therefore more vulnerable to acidification. The high mean annual precipitation adds to the problem.

The widespread use of herbicides along roadsides together with pesticides around settlements, are also potential causes of decrease in species diversity in these areas. Invasions of pests such as the pine bark beetle destroy individual pine trees or large patches in the otherwise healthy forest, resulting in the trees falling down, and causing the forest to regenerate in the resulting open areas. The pine bark beetle is being particularly devastating in the Lodgepole Pine plantations established by the Forest industry. The deciduous trees may be attacked by tent caterpillars, which can consume most of the young leaves in a particular year. However, in this case the trees usually recover.

In southwest Alberta, the eastern slopes of the Rocky Mountains are also used for the grazing of cattle as summer pasture. The cattle tend to graze mainly at lower elevations, and may over-graze the shrubs and herbs in dry years. They also eat the young shoots of regenerating White Spruce trees. Once the timber has been removed for lumber, the resulting open areas become very important for feed for livestock at the expense of the forest. The ranchers may introduce new species of plants, e.g., legumes and grasses, so the ecosystems are changed. Trembling aspen is replacing balsam poplar in the open areas, probably partly due to its greater ability at suckering (Buckman a. Blankenship 1965), and partly due to the loss of the bison that used to roll in the aspen and destroy the suckers (Campbell et al. 1994). Ungulates benefit at the expense of the forest-dwelling animals, e.g., cougars (*Felix concolor missouriensis* Goldman), and porcupines (*Erethizon dorsatum nigrescens* Allen).

In the Ponderosa pine-grassland areas of the drier parts of the central plateau of southern British Columbia, ranching is also present, but the ranches are very extensive, and there is comparatively little damage done to the biodiversity. However, near settlements, hobby-farming, and small acreages are eating into the steppe. Where water is available from rivers or lakes, intensive fruit-growing and vineyards occur, resulting in the complete changing of the landscape, e.g., in the Okanagan Valley. More recently, intensive ginseng growing operations have appeared along the South Thompson River valley east of Kamloops, but these can only be used for a single crop before the land reverts to irrigated hay crops. However, these irrigated lands grow mainly introduced grasses.

Finally, major transportation routes such as roads and railways cross migration routes of the larger mammals, resulting in high mortality rates (Alexander a. Waters 2000). This is putting the grizzly bear (*Ursus arctos* Merriam) at risk of extirpation in Banff National Park, though the use of expensive animal underpasses and overpasses has improved the situation for many other species. Unfortunately, these did not save the wolves that were reintroduced into Banff National Park (Paquet 1993).

6 Conclusions

The species diversity at individual sites (beta diversity) in the vast montane boreal forest of the southern Cordillera is unexpectedly low compared with those of the ecosystems to the south. Only 3 species occur at all nine study sites out of the 1,037 taxa reported from them. Three hundred and twenty-five of these species (31%) were only recorded at one site. While 1,037 species represent a reasonable portion of the 2,993 taxa reported from all of British Columbia (Douglas et al. 2002b), the total number of species at a given site was found to be as little as 110 in east-central British Columbia. Thus the beta diversity is very low although the gamma and delta diversities are more normal. This is surprising considering the large numbers of species present in British Columbia.

Reasons for this limited colonization of the areas previously occupied by the Late Wisconsin glaciers include the problematic climate, the topography and limited access to potential source areas for new species. Fire has greatly complicated the process by wiping out many species from the burned areas, so that the process of re-invasion must begin again. Snow avalanches appear to temporarily increase species diversity, but climatic changes undoubtedly cause large changes to the eastern and southern boundaries and to the biodiversity within the forest. Increased precipitation would greatly improve species diversity, both by permitting species to occupy larger areas, and by reducing fire frequency. The latter is greatly increased by the activities of Man. Logging is the most devastating effect of the land use by the European settlers. Altogether, about 30% of the known species of vascular plants are classified as being rare or endangered. Thus the future of the biodiversity of the vascular plants in this montane boreal forest is very precarious, and this will largely determine the fate of the other organisms that depend on these primary producers for food and shelter. The expansion of irrigated agriculture on the drier steppe-forest boundary of southern British Columbia is further diminishing the areas of natural vegetation.

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Appendix A: Taxa collected at the nine study sites in the montane boreal forest in western Canada. The nomenclature is based on Cody (1996), Douglas et al. (2002b), Moss (1983), Farrar (1995) and Scoggan (1978), updated by the new Flora of North America North of Mexico (Flora of North America Editorial Committee 1993–2006). A complete species list is available at: http://www.giub.uni-bonn.de/erdkunde for free download.

Family	Number of collected species per family								
	Kluane Lake	Summit Lake	Pink Moun-tain	Marmot Basin	Parker Ridge	Bow Summit	Sun-shine-Banff	Mount Revel-stoke	Glacier N.Park.
Ophioglossaceae								1	4
Lycopodiaceae		3		4	1		4	6	5
Selaginelliaceae					1	1	3	2	2
Equisetaceae	1	2	4	5	3	2	7	3	6
Polypodiaceae	1				1		7	15	14
Taxaceae								1	1
Cupressaceae	2	2		2	2	2	3	3	2
Pinaceae	2	4	3	5	6	5	7	11	11
Typhaceae		1	1					1	1
Graminae	13	5	6	8	11	24	51	35	49
Cyperaceae	6	7	7	9	13	20	42	14	35
Juncaceae		6	5	5	5	6	11	11	16
Sparganiaceae								1	2
Araceae								1	1
Liliaceae	2	3			4	7	11	13	13
Orchidaceae	4	4	1	1	6	1	7	11	11
Salicaceae	15	4	4	5	15	15	17	7	18
Betulacaceae	2	5	3	1	2	2	4	5	4
Urticaceae					1	1	1	1	1
Santalaceae	1							2	2
Polygoniaceae	2	3	1	2	3	3	8	7	10
Chenopodiaceae	1						2		1
Portulacaceae	1					2	1	3	2
Caryophyllaceae	5	1	4	1	9	8	10	10	19
Ranunculaceae	7	8	5	8	7	9	24	13	14
Papaveraceae	1								
Berberidaceae								2	
Fumariaceae					1			1	1
Cruciferae	7			5	1	8	25	5	19
Droseraceae									1
Crassulaceae		1				2	2	1	1
Saxifragaceae	6	5	2	3	2	6	12	11	18
Parnassiaceae	2	2	1	1	2	3	4	2	2
Grossulariaceae						2	3	3	2
Rosaceae	9	6	9	8	5	18	27	26	28

Leguminosae	8	9	12	5	4	14	27	12	10
Geraniaceae			1			2	3		
Linaceae	1						1		
Empetraceae	1	1	1	1		1	1	1	1
Celastraceae								1	1
Balsaminaceae								1	1
Aceraceae							1	1	
Rhamnaceae								3	2
Hypericaceae								1	1
Violaceae				1		2	5	5	6
Elaeagnaceae	2	1	1	1	1	1	1	1	1
Onagraceae	2	3	1	3	1	5	7	8	10
Hippuridaceae							1	1	1
Araliaceae								2	2
Umbelliferae	1	1		1	1	1	8	5	5
Cornaceae			1	1	1	1	1	2	2
Pyrolaceae	3	5		2	1	5	6	6	7
Ericaceae	6	4	1	9	4	6	12	8	9
Vacciniaceae	1	2	1	3	1	4	5	5	6
Primulaceae	2				1	4	9	2	3
Gentianaceae	3	3	3	2	1	3	2		2
Menyanthaceae							1		1
Polemoniaceae	2	1	1			1	2		
Hydrophyllaceae							1		3
Boraginaceae	3	1	1			1	2	2	1
Labiatae						1		4	5
Scrophulariaceae	8	3	6	5	2	10	18	18	18
Lentibulariaceae						1	2		3
Plantaginaceae	1	1	1	1			1	2	2
Rubiaceae			1			1	3	2	2
Caprifoliaceae	2	1			1	2	6	9	7
Adoxaceae						1	1		
Valerianaceae	2			1		2	2	1	1
Campanulaceae			2			1	2	2	3
Compositae	36	13	19	21	11	41	73	57	65

Appendix A to ERDKUNDE article: Stuart A. Harris: Diversity of vascular plant species ...
Erdkunde Volume 62 Number 1 Pages 59-73, 2008
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Family	Species	Kluane Lake	Summit Lake	Pink Mountain	Marmot Basin	Parker Ridge	Bow Summit	Sunshine-Banff	Mount Revelstoke	Glacier N. Park.
Ophioglossaceae	*Botrichium lunaria* (L.) Sw.								X	X
	B. multifidum (Gmel.) Rupr.									X
	B. simplex E. Hitchcock									X
	B. virginianum (L.) Sw.									X
Lycopodiaceae	*Lycopodium alpinum* L.		X		X				X	X
	L. annotinum L.				X	X		X	X	X
	L. clavatum L. var. *monostachyon* Hooker & Grev.		X		X			X		
	L. complanatum L.		X					X	X	X
	L. obscurum L.								X	
	L. selago L.				X			X	X	X
	L. sitchense Rupr.								X	X
Selaginelliaceae	*Selaginella densa* Rydberg var. *scorpulorum* (Maxon) Tryon							X	X	X
	S. rupestris (L.) Spring						X	X		
	S. selaginoides (L.) Link					X		X	X	X
Equisetaceae	*Equisetum arvense* L.	X		X	X	X	X	X	X	X
	E. fluviatile L.							X	X	X
	E.hymenale L. ssp. *Affine* (Engelm.) Stone			X					X	
	E. palustre L.		X		X			X		X
	E. pratense Ehrh.		X	X	X			X		X
	E. scirpoides Michaux			X	X	X		X		
	E. sylvaticum L.							X		X
	E. variegatum Schleich.				X	X	X	X		X
Polypodiaceae	*Adiantium pedatum* L. ssp. *Aleuticum* (Rupr.) Calder & Taylor								X	X
	Aspidotis densa (Brack.) Lellinger								X	
	Asplenium trichomanes L.								X	X
	A. viride Huds.							X		X
	Athyrium alpestre (Hoppe) Rylands ssp. *Americanum* (Butters) Lellinger					X		X	X	X
	A. filix-femina (L.) Roth var. *cyclosorum* (Ledeb.) Moore								X	X
	Blechnum spicant (L.) Roth								X	
	Cryptogramma crispa (L.) R. Br. var. *acrostichoides* (R. Br.) C. B. Clarke								X	X
	C. stelleri (Gmel.) Prantl									X
	Cystopteris fragilis (L.) Bernh.	X						X	X	X
	Dryopteris assimilis							X	X	X
	D. filix-mas (L.) Schott								X	X
	Gymnocarpion dryopteris (L.) Newm. ssp. *Dryopteris*							X	X	X
	Phegopteris connectilis (Michaux) Watt								X	
	Polypodium hesperum Maxon								X	
	Polystichum andersonii Hopkins							X		
	P. lonchitis (L.) Roth									X
	Pteridium aquiliinum (L.) Kuhn var. *pubescens* Underw.								X	X
	Woodsia glabella R. Br.							X		
	W. scorpulina D. C. Eat.								X	X
Taxaceae	*Taxus brevifolia* Nuttall								X	X
Cupressaceae	*Juniperus communis* L. var. *nana*	X	X		X	X	X	X	X	X
	J. communis L. var. *saxatilis* Pall.							X		
	J. horizontalis Moench	X	X		X	X	X	X	X	
	Thuja plicata D. Don								X	X
Pinaceae	*Abies lasiocarpa* (Hook.) Nuttall var. *lasiocarpa*				X	X	X	X	X	X
	Larix laricina (Du Roi) K. Koch		X							
	L. lyallii Parl.							X		
	L. occidentalis Nuttall								X	X
	Picea engelmannii Parry ex Engelmann				X	X	X	X	X	X
	P. glauca (Moench.) Voss	X	X	X	X	X	X	X	X	X
	P. mariana (P. Mill.) B. S. P.	X	X	X	X	X	X			
	Pinus albicaulis Engelmann					X			X	X
	P. contorta Dougl. ex Loudon var. *latifolia Engelmann* ex S. Wats.		X	X	X	X	X	X	X	X
	P. flexilis James							X		
	P. monticola Dougl. Ex D. Don								X	X
	P. ponderosa Dougl. Ex P. C. Lawson								X	X
	Pseudotsuga menziesii (Mirb.) Franco var. *glauca* (Beissn.) Franco							X	X	X
	Tsuga heterophylla (Raf.) Sarg.								X	X
	Tsuga mertensiana (Bong.) Carr.								X	X
Typhaceae	*Typha latifolia* L.		X	X					X	X
Graminae	*Agroelymus mossii Lepage*									X
	Agropyron dasystachum (Hooker) Scribn. var. *riparium*				X			X		
	A. repens (L.) Beauv.							X		X
	Agrostis alba L. var. *alba*									X
	A. alba L. var. *stolonifera* L.								X	X
	A. mertensii Trin. var. *mertensii*	X							X	X
	A. pectiniforme R. & S.								X	X
	A. scabra Willd. var. *geminata* (Trin.) Swallen							X		
	A. scabra Willd. var. *scabra*			X				X	X	X
	A. stolonifera L.							X		
	A. tenuis									X

Appendix A to ERDKUNDE article: Stuart A. Harris: Diversity of vascular plant species ...
Erdkunde Volume 62 Number 1 Pages 59-73, 2008
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		A. thurberiana A. S. Hitchcock								X	X	
		Arctagrostis latifolia (R. Br.) Griseb.	X									
		Bromus carinatus Hooker & Arn.									X	
		B. ciliatus L.							X	X	X	
		B. inermis Leyss.			X				X		X	
		B. mollis L.							X			
		B. pumpellianus Scribn. var. *pumpellianus*	X						X			
		B. pumpellianus Scribn. var *tweedyi*	X									
		B. sitchensis								X		
		B. tectorum L.								X		
		B. vulgaris L.								X	X	
		Calamagrostis canadensis (Michaux) Beauv. ssp.										
		canadensis		X					X	X	X	
		C. canadensis (Michaux) Beauv. ssp. *langsdorffii*										
		(Link.) Hulten							X			
		C. canadensis (Michaux) Beauv. var. *robusta*							X			
		C. lapponica (wahlenb.) Hartm.						X				
		C. montanensis Scribn.							X			
		C. purpurascens R. Br. Var. *pupurascens*	X						X	X		
		C. rubescens Buckley							X	X		
		C. stricta (Timm.) Koeler ssp. *inexpansa* (Gray)										
		C. W. Greene				X					X	
		C. stricta (Timm.) Koeler ssp. *stricta*							X			
		Cinna latifolia (Trev.) Griseb.							X	X	X	
		Dactylis glomerata L.									X	
		Danthonia californica Boland							X			
		D. spicata (L.) Beauv.								X	X	
		Deschampsia atropurpurea						X		X	X	
		D. caespitosa (L.) Beauv.							X			
		Elymus alaskanus (Scribn. & Merr.) A. Love ssp.										
		borealis (Turcz.) Love & Love	X									
		E. calderi Barkworth	X									
		E. glauca Buckl. Var. *jepsonii*								X	X	
		E. innovatus Beal		X						X		
		E. trachycaulus (Link) Gould ex Shinners ssp.										
		subsecundus (Link) Gould								X	X	
		E. trachycaulus (Link) Gould ex Shinners										
		ssp. *trachycaulus*			X				X			
		E. trachycaulus (Link) Gould ex Shinners										
		ssp. *violacceus* (Hornem.) A. & D. Love	X	X	X				X			
		Festuca altaica Trin.	X	X	X				X			
		F. baffinensis Polunin					X	X	X			
		F. brachyphylla Schultes & Schultes	X				X	X				
		F. occidentalis Hooker								X		
		F. ovina L. var. *brevifolia*								X	X	
		F. rubra L.					X	X	X	X	X	
		F. saximontana Rydb. var. *saximontana*				X	X	X	X			
		F. scabrella Torrey						X	X			
		F. subulata Trin.									X	
		Glyceria elata (Nash) A. S. Hitchcock								X	X	
		G. grandis S. Wats.								X	X	
		G. pulchella (Nash) K. Schum.									X	
		G. striata (Lam.) Hitchc. var. *stricta* (Scribn.) Fern.					X	X	X	X		
		Hierochloe hirta (Schrank) Borbas ssp. *arctica* G. Weim.							X		X	
		Hordeum jubatum L.			X		X	X	X	X	X	
		Koeleria macrantha (Ledeb.) Schultes					X	X	X			
		Leymus innovatus (Beal) Pilger	X			X			X			
		Lolium perenne L.								X	X	
		Melica smithii (Porter) Vasey									X	
		M. subulata (Griseb.) Scribn.									X	
		Muhlenbergia glomerata (Willd.) Trin.							X		X	
		Phleum alpinum L.				X	X	X	X		X	
		P. pratense L.					X	X	X			
		Poa abbreviata R. Br. Ssp. *abbreviata*						X				
		P. abbreviata R. Br. Ssp. *pattersonii* (Vasey) A. Love										
		et al.						X	X		X	
		P. alpina L.	X			X	X	X	X		X	
		P. annua L.								X	X	
		P. arctica R. Br.							X	X	X	
		P. canbyi (Scribn.) Piper							X			
		P. compressa L.							X			
		P. cusickii Vasey							X	X	X	
		P. epilis Scribn.							X	X	X	
		P. fendleriana									X	
		P. glauca Vahl.						X	X		X	
		P. gracillima Vasey								X		
		P. interior Rydb.							X			
		P. leptocor				X		X	X		X	
		P. nemoralis L. var. *nemoralis*						X				
		P. nemoralis L. var. *interior*						X	X			
		P. nervosa (Hooker) Vasey								X		
		P. palustris L.						X	X	X	X	
		P. pratensis L. ssp. *pratensis*						X	X		X	
		P. pratensis L. ssp. *argutifolia*						X				
		P. sandbergii Vasey							X			
		P. stenantha Trin.									X	
		Schizachne purpurascens (Torrey) Swallen							X			
		Stipa columbiana Macoun							X		X	
		T. cernuum Trin. var. *cernuum*								X	X	
		T. montanum Vasey										
		T. spicatum (L.) Richt.	X	X		X	X	X	X	X	X	
		Vahlodea atropurpurea (wahlenb.) Fries						X				
Cyperaceae		*Carex albo-nigra* Mackenzie									X	
		C. aperta Boott in W. J. Hooker								X		
		C. aquatilis Wahlenberg		X	X	X	X	X	X		X	

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		C. atratiformis Britton ssp. *Raymondii* (Calder) Porsild							X			
		C. atrosquama Mackenzie				X	X	X	X			
		C. aurea Nuttall			X		X	X	X		X	
		C. brunnescens (Persoon) Poiret ex Lambert									X	
		C. canescens L.									X	
		C. capillaris L.						X	X			
		C. concinna R. Br.	X				X	X	X		X	
		C. concinnoides Mackenzie							X			
		C. deweyana Schweinitz					X	X			X	
		C. disperma Dewey							X		X	
		C. eleusinoides Turcz.									X	
		C. filifolia Nuttall	X						X			
		C. flava L.									X	
		C. foenea Willdenow									X	
		C. garberi Fernald						X	X			
		C. gynocrates Wormskjold							X	X	X	
		C. illota Bailey									X	
		C. incurviformis Mackenzie var. *incurviformis*							X			
		C. interior Bailey									X	
		C. lachenalli Schkuhr							X			
		C. lenticularis Michaux var. *lenticularis*								X	X	
		C. leptalea Wahlenberg							X		X	
		C. limosa L.							X		X	
		C. macloviana d'Urville var. *macloviana*						X	X			
		C. media R.Br.						X	X			
		C. membranacea Hooker			X							
		C. microglochin Wahlenberg ssp. *microglochin*							X		X	
		C. micropoda C. A. Meyer								X	X	
		C. microptera Mackenzie							X			
		C. nardina Fries var. nardina							X		X	
		C. nigricans C. A. Mey								X	X	
		C. obtusata Liljeblad	X						X			
		C. pachystachya Chamisso ex Steudel							X	X	X	
		C. petricosa Dewey var. *petricosa*					X	X				
		C. phaeocephala Piper				X	X	X	X	X	X	
		C. praeogracilis W. Boott							X			
		C. praticola Rydberg							X		X	
		C. preslii Steudel							X			
		C. raymondii Calder		X	X			X	X			
		C. raynoldsii Dewey					X					
		C. rossii Boott					X	X	X		X	
		C. rostrata Stokes							X		X	
		C. rupestris Allioni var. *rupestris*	X					X				
		C. saxatilis L.		X					X			
		C. scirpoidea Michaux var. *scirpoidea*	X			X		X	X	X	X	
		C. scorpulorum T. Holm var. *scorpulorum*					X	X	X			
		C. scorpulorum T. Holm var. *stenochlaena*							X			
		C. siccata Dewey					X	X	X			
		C. spectabilis Dewey				X				X		
		C. tenera Dewey									X	
		C. trisperma Dewey								X	X	
		C. vaginata Tausch				X			X			
		C. viridula Michaux		X					X			
		C. xerantica Bailey							X			
		Eleocharis quinqueflora (F. Hartm.) Schwartz		X								
		E. rostellata (Torrey) Torrey									X	
		Eriophorum angustifolium Honckeny var. *angustifolium*			X				X	X	X	
		E. branchyantherum Trautvetter & C. A. Meyer		X	X							
		E. chamissonis C. A. Meyer in Ledebour				X			X	X		
		E. gracile W. D. J. Koch ex Roth								X		
		E. scheuchzeri Hoppe				X		X	X			
		E. viridicarinatum (Engelmann) Fernald							X		X	
		Kobresia myosuroides (Villars) Fiori in Fiori	X				X	X				
		Schoenoplectus acutus (Muhlenberg ex Bigelow)										
		Love & Love									X	
		Scirpus microcarpus Presl. & Presl.		X	X					X	X	
		Trichophorum alpinum (L.) Persoon					X	X				
		T. cespitosum (L.) Shur				X			X		X	
Juncaceae		*Juncus acuminatus* Michaux								X	X	
		J. alpinoarticulatus Chaix in D. Villars		X						X	X	
		J. arcticus Willdenow var. *balticus* (Willdenow) Trautvetter			X	X	X	X	X		X	
		J. bolanderi Engelmann									X	
		J. bufonis L.		X								
		J. castaneus Smith		X	X	X	X	X	X			
		J. drummondii E. Meyer in C. F. von Ledebour				X	X	X	X	X	X	
		J. dudleyi Wiegand		X						X		
		J. ensifolius Wikstrom								X	X	
		J. ensifolius Wikstrom var. *montanus*							X		X	
		J. filiformis L.		X	X							
		J. mertensianus Bongard				X			X	X	X	
		J. nevadensis S. Wats.									X	
		J. parryi Engelmann								X	X	
		J. regelii Buchenau									X	
		J. stygius L. ssp. *americanus*			X							
		J. triglumis L. var. *albescens* Lange							X			
		J. vaseyi Engelmann			X							
		Luzula arcuata (Wahlenberg) Swartz ssp. *Unalaschkensis*										
		(Buchenau) Hulten							X	X	X	
		L. hitchcockii Hamet-Ahti								X	X	
		L. multiflora (Ehrhart) Lejeune						X	X			
		L. parviflora (Ehrhart) Desvaux		X		X	X	X	X	X	X	
		L. piperi (Coville) M. E. Jones									X	
		L. spicata (L.) de Candolle					X	X	X	X	X	
		L. wahlenburgii Ruprecht							X			

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Sparganiaceae	*Sparganium angustifolium* Michaux								X	X	
	S. minimum (Hartm.) Fries									X	
Araceae	*Lysichitum americanum*								X	X	
Liliaceae	*Allium cernuum* Roth var. *cernuum*					X	X	X			
	A. schoenoprasm L. var. *sibiricum* (L.) Hartm.							X			
	Camassia quamash (Pursh) Greene									X	
	Clintonia uniflora (Menzies ex J. A. & J. H. Schult.) Kunth								X	X	
	Erythronium grandiflorum Pursh						X	X	X	X	
	Lilium columbianum Hanson ex Baker								X		
	Lilium philadelphicum L. *var. andinum* (Nuttall) Ker-Gawl.							X	X		
	Lloydia serotina (L.) Reichenb.								X		
	Maianthemum canadense Desf.					X	X				
	M. racemosum (L.) Link ssp. *Amplexicaulis* (Nuttall)										
	Lafrankie								X	X	
	M. stellatum (L.) Link.	X						X	X	X	
	Prosartes hookeri Torr. Var. *oregana* (S. Wats.) Kartesz								X	X	
	P. trachycarpa S. Wats.							X	X	X	
	Stenanthium occidentale A. Gray					X	X	X			
	Streptopus amplexifolius (L.) DC.Var. *chalazatus* Fassett						X	X	X	X	
	S. lanceolatus (Ait.) Reveal var. *curvipes* (Vail) Reveal								X	X	
	S. streptopoides (Ledeb.) Frye & Rigg. ssp. *Brevipes*										
	(Baker) Calder & Taylor									X	
	Tofieldia coccinea Richards		X								
	T. pusilla (Michaux) Pursh		X				X	X			
	Veratrum viride W. Ait.							X	X	X	
	Zygadenus elegans Pursh ssp. *elegans*	X	X			X	X	X		X	
	Z. venenosus S. Wats.								X	X	
Orchidaceae	*Amerorchis rotundifolia (Banks ex Pursh) Hulten*							X			
	Calypso bulbosa (L.) Oakes in Z. Thompson							X			
	Coeloglossum viride (L.) Hartman		X			X		X	X		
	Corallorhiza maculata (Raf.) Raf.								X		
	C. mertensiana Bongard									X	
	C. striata Lindley								X	X	
	C. trifida Chatelaine	X				X	X	X	X	X	
	Cypridium passerinum Richards	X	X								
	Goodyera oblongifolia Rafinesque								X	X	
	G. repens (L.) R. Brown in Aiton & Aiton					X					
	Listeria caurina Piper									X	
	L. cordata (L.) R. Brown								X	X	
	Plantanthera dilatata (Pursh) Lindley ex L. C. Beck										
	var. *albiflora* (Chamisso) Ledebour									X	
	P. dilatata (Pursh) Lindley ex L. C. Beck var. *dilatata*				X	X		X	X	X	
	P. hyperborea (L.) Lindley		X	X				X	X	X	
	P. obtusata (Banks ex Pursh) Lindley	X	X			X					
	P. orbiculata (Pursh) Lindley								X		
	P. stricta Lindley								X	X	
	Spiranthes romanzoffiana Chamisso	X				X		X	X	X	
Salicaceae	*Populus balsamifera* L. ssp. *balsamifera*		X	X	X	X	X				
	P. balsamifera L. ssp. *trichocarpa* (T. & G.) Brayshaw								X	X	
	P. tremuloides Michaux		X	X	X	X	X	X	X	X	
	Salix alaxensis (Anderss.) Cov. var. *alaxensis*	X	X			X	X				
	S. arbusculoides Anderss.	X			X		X				
	S. arctica Pall. ssp. *arctica*	X				X	X			X	
	S. arctophila Cockerell									X	
	S. athabascensis Raup							X			
	S. barclayi Anderss.				X	X	X	X	X	X	
	S. barrattiana Hooker	X						X	X		
	S. bebbiana Sarg.	X		X	X	X	X	X			
	S. brachycarpa Nuttall ssp. *brachycarpa*	X				X	X	X		X	
	S. candida Flügge							X		X	
	S. commutata Bebb									X	
	S. drummondiana Barratt					X	X	X		X	
	S. glauca L. ssp. *acutifolia* (Hook.) Hulten	X									
	S. glauca L. var. *glauca*					X	X	X			
	S. glauca (L.) ssp. *glabrescens (* Anderss.) Hulten	X									
	S. glauca L. ssp. *richardsonii* (Hook.) Skvortsov	X									
	S. glauca L. var. *villosa*					X	X	X	X	X	
	S. lucida Muhl. ssp. lasiandra (Bentham) Argus									X	
	S. maccalliana Rowlee							X			
	S. melanopsis Nuttall									X	
	S. monticola Bebb					X	X				
	S. myrtilifolia Anderss. var. *myrtilifolia*	X				X	X	X			
	S. niphoclada x *S. setchelliana*	X									
	S. novae-angliae Anderss.	X									
	S. petiolaris J. E. Smith							X			
	S. planifolia Purs. Ssp. *planifolia*	X				X	X				
	S. polaris Wahlenb.	X									
	S. prolixa Anderss.									X	
	S. pseudomonticola Ball							X	X	X	
	S. reticulata L. ssp. *nivalis*					X		X		X	
	S. reticulata L. ssp. *reticulata*	X		X							
	S. scouleriana Barratt		X					X	X	X	
	S. sitchensis Sanson ex Bong.									X	
	S. vestita Pursh					X	X	X		X	
Betulacaceae	*Alnus crispa* (Drylander ex Ait.) Pursh ssp. *crispa*		X				X		X	X	
	Alnus crispa (Drylander ex Ait.) Pursh ssp. *sinuata*		X	X	X	X			X	X	
	A. incana (L.) Moench ssp. *tenuifolia*		X	X					X	X	
	Betula glandulosa Michaux	X	X	X				X			
	B. nana L. ssp. *exilis* (Suskatsch.) Hulten	X	X								
	B. occidentalis Hooker							X			
	B. papyrifera Marsh							X	X	X	

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	B. pumila L. var. *glandulifera* Regel					X	X	X			
	Corylus cornuta Marsh								X		
Urticaceae	*Urtica dioica* L. ssp. *gracilis* (Ait.) Selander					X	X	X	X	X	
Santalaceae	*Comandra umbellata* (L.) Nutt. ssp. *pallida* (A. D.C.)										
	Piehl								X	X	
	Geocaulon lividum (Richards) Fernald	X							X	X	
Polygoniaceae	*Eriogonum androsaceum* Bentham							X			
	E. flavum Nuttall										
	E. umbellatum Torrey var. *majus*							X			
	Fagopyrum esculentum Moench									X	
	Oxyria digyna (L.) Hill	X	X		X	X	X	X	X	X	
	Polygonium alaskanum Wight ex Hulten		X								
	P. amphibium L.									X	
	P. austinae Greene								X	X	
	P. aviculare L.							X			
	P. douglasii Greene								X	X	
	P. douglasii Greene var. *latifolium*										
	(Engelm.) Greene								X	X	
	P. engelmannii Greene								X	X	
	P. minimum S. Wats.								X		
	P. viviparum L.	X	X		X	X	X	X		X	
	Rumex acetosa L. ssp. *acetosa*							X			
	R. acetosa L. ssp. *alpestris* (Scop.) A. Love					X	X	X			
	R. acetosella L. ssp. *Acetosella*									X	
	R. maritimus L. ssp. *fueginus* (Phil.) Hulten							X			
	R. obtusifolius								X	X	
	R. occidentalis S. Wats.			X							
Chenopodiaceae	*Chenopodium album* L.							X		X	
	Eurotia lanata (Pursh.) Moq.)	X									
	Salsola kali var. kali							X			
Portulacaceae	*Claytonia lanceolata* Pursh						X	X	X	X	
	C. megarrhiza (A. Gray) Parry						X				
	Montia parviflora (Moc.) Greene								X	X	
	Montia sarmentosa (C. A. Mey.) Robins.	X							X		
Caryophyllaceae	*Arenaria capillaris* Poir. ssp. *americana* (Maguire) Davis							X	X	X	
	A. lateriflora L.									X	
	A. obtusiloba (Rydb.) Fernald								X	X	
	A. rubella (Wahl.) Sm.			X					X	X	
	Cerastium arvense L.							X			
	C. beeringianum Cham. & Schlecht.	X				X	X	X	X	X	
	C. vulgatum L.									X	
	Dianthus armeria L.								X	X	
	D. deltoides L.								X		
	Lychnis alba Mill.									X	
	L. apetala L.									X	
	L. drummondii (Hook.) Wats.									X	
	Minuartia austomontana Wolf & Packer							X			
	M. biflora (L.) Schinz. & Thell.					X	X		X	X	
	M. dawsonensis (Britt.) House					X	X				
	M. rossii (R. Br.) Graebn.	X									
	M. rubella (Wahlenb.) Graebn. ex Asch. & Graebn.				X	X	X	X			
	Moehringia lateriflora (L.) Fenzl							X			
	Sagina saginoides (L.) Karst									X	
	Silene acaulis L. ssp. *acaulis*	X						X	X	X	
	S. acaulis L. var. *subacaulescens* (F. N. Williams) Hulten					X					
	S. cserei Baumg.									X	
	S. noctiflora L.							X	X		
	S. parryi (S. Wats.) C. L. Hitchc.					X	X	X			
	S. scouleri Hook.									X	
	S. uralensis (Rupr.) Bocquet ssp. *uralensis*	X				X	X				
	Stellaria calycantha (Ledeb.) Bong.			X		X	X		X	X	
	S. crispa C. & S.									X	
	S. longifolia Muhl.		X	X							
	S. longipes Goldie ssp. *longipes*	X		X		X	X	X		X	
	Vaccaria hispanica (Miller) Rauschert									X	
Ranunculaceae	*Aconitum delphinifolium* DC. ssp. *delphinifolium*	X	X	X							
	Actaea rubra (Ait.) Willd. *var. rubra*				X			X	X	X	
	Anemone drummondii S. Wats. var. *lithophila* (Rydb.)										
	C. L. Hitchcock							X		X	
	A. multifida Poir. var. *multifida*	X	X			X	X	X	X	X	
	A. narcissifolia L. ssp. interior		X								
	A. occidentalis S. Wats.								X	X	
	A. parviflora Michaux	X	X		X	X	X	X		X	
	A. richardsonii Hooker	X									
	Aquilegia brevistyla Hooker		X								
	A. flavescens S. Wats.				X	X	X	X	X	X	
	A. formosa Fisch. ex DC.				X					X	
	Caltha leptosepala DC.						X	X		X	
	Clematis occidentalis (Hornem.) var. *grosseserrata*										
	(Rydb.) Taylor & MacBride							X	X		
	Delphinium bicolor Nuttall							X			
	D. glaucum S. Wats.		X	X	X	X	X	X			
	D. nuttallianum Pritz. ex Walp.							X		X	
	Pulsatilla ludoviciana (Nuttall) Heller	X						X			
	Pulsatilla occidentalis (S. Wats.) Freyn.					X		X			
	Ranunculus acris L.							X	X	X	
	R. aquatilis L. var. *capillaceous* (Thuill.) DC			X				X	X		
	R. cardiophyllus Hooker							X			
	R. eschscholtzii Schlecht.		X		X	X	X	X	X	X	

Appendix A to ERDKUNDE article: Stuart A. Harris: Diversity of vascular plant species ...
Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

	R. gmelinii DC. ssp. *gmelinii*			X				X	X	X	
	R. inamoenus Greene							X			
	R. macounii Britt.			X							
	R. pensylvanicus L.								X		
	R. petafidus Sm. ssp. *affinis* (R. Br.) Hulten	X									
	R. petafidus Sm. var. *leiocarpus*						X				
	R. petafidus Sm. Var. *petafidus*							X			
	R. pygmaeus Wahlenb.	X	X		X			X			
	R. unciatus D. Don								X	X	
	Thalictrium occidentale Gray							X	X		
	T. sparsifolium Turcz. ssp. *richardsonii* (Gray) Cody							X			
	T. venulosum Trel.						X	X			
	Trolius albiflorus (A. Gray) Rydb.				X	X	X	X	X	X	
Papaveraceae	*Papaver macounii* Greene ssp. *discolor* (Hulten)										
	Randell	X									
Berberidaceae	*Berberis aquilifolium* Pursh.								X		
	B. repens Lindl.								X		
Fumariaceae	*Corydalis aurea* Willd.					X			X	X	
Cruciferae	*Arabis divaricarpa* A. Nels.							X		X	
	A. drummondii Gray	X						X		X	
	A. hirsuta (L.) Scop. var. *hirsuta*							X		X	
	A. holboelii Hornem. var. *holboelii*							X			
	A. holboelii Hornem. var. *retrofracta* (Grah.) Rydb.								X	X	
	A. kamchatica (Fisch.) Ledeb.								X	X	
	A. lemmonii S. Wats. var. *lemmonii*						X			X	
	A. lyallii S. Wats.				X		X	X	X	X	
	Braya humulis (C. A. Mey) Robinson							X		X	
	Capsella bursa-pastoris (L.) Medic.									X	
	Cardamine bellidifolia L.									X	
	C. occidentalis (Wats.) Howell									X	
	Cardamine oligosperma Nuttall ssp. *kamtschatica*										
	(Regel) Cody								X	X	
	C. pennsylvanica Muhl.							X		X	
	C. purpurea Cham and Schlecht.	X									
	Descurania pinata (Walter) Britt. var. *pinata*							X			
	Drabe alpina L.	X									
	D. aurea M. Vahl					X	X	X		X	
	D. borealis DC.							X			
	D. cana Rydb.	X						X			
	D. crassifolia Grah.							X		X	
	D. fladnizensis Wulfen				X						
	D. incerta Payson				X		X	X		X	
	D. juvenilis							X			
	D. lonchocarpa Rydb.									X	
	D. longipes Raup	X									
	D. nemorosa L. var. *leiocarpa* Lindbl.							X			
	D. nivalis Liljebl.				X		X				
	D. oligosperma Hooker							X			
	D. palanderiana Kjellm.						X				
	D. paysonii MacBride						X	X			
	D. praealta Greene							X	X	X	
	D. stenoloba Ledeb.							X		X	
	Erucastrum gallicum (Willd.) Schulz							X			
	Erysimum cherianthoides L.	X									
	E. inconspicuum (S. Wats.) MacMill.							X			
	E. pallasii (Pursh) Fernald				X						
	Lepidium bourgeauanum Thell.							X			
	Parrya nudicaulis (L.) Regel	X									
	Physaria didymocarpa (Hook.) Gray							X			
	Rorippa palustris (L.) Besser							X			
	Smelkowskia calycina (Stephan) C. A. Mey						X				
	Thalaspi arvense L.							X			
Droseraceae	*Drosera anglica* Huds.									X	

Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

Crassulaceae	*Sedum lanceolatum* Torrey		X				X	X	X	X	
	S. stenopetalum Pursh										
	Rhodiola rosea L. ssp. *Integrifolia* Raf. Hara						X	X			
Saxifragaceae	*Chrysosplenium iowense* Rydb.							X			
	C. tetrandum (Lund) T. Fries							X			
	Heuchera cylindrica Dougl. Ex Hooker								X	X	
	H. glabra Willd. ex R. & S.								X	X	
	H. parvifolia Nuttall ex T. & G.								X		
	H. richardsonii R. Br.								X		
	Leptarrhena pyrolifolia (D. Don) R. Br.				X			X	X	X	
	Mitella breweri A. Gray								X	X	
	M. nuda L.								X		
	M. pentandra Hooker									X	
	M. trifida Graham									X	
	Saxifraga adscendens L.				X	X				X	
	S. aizoides L.		X				X	X		X	
	S. bronchialis L. var. *austomontana* (Wieg.) Piper						X	X		X	
	S. bronchialis L. ssp. *funstonii* (Small) Hulten	X	X								
	S. caespitosa L. ssp. *caespitosa*						X	X		X	
	S. cernua L.							X		X	
	S. ferruginea Graham								X	X	
	S. flagellaris Willd. ssp. *flagellaris*		X								
	S. flagellaris Willd. ssp. *setigera* (Pursh) Tolm.	X					X				
	S. heiraciifolia Waldst. and Kit.	X									
	S. lyallii Engler ssp. *hultenii* (Calder and Saville)										
	Calder and Taylor	X									
	S. lyallii Engler ssp. *lyallii*					X		X	X	X	
	S. nelsoniana D. Don ssp. *porsiliana* (Calder &										
	Saville) Hulten			X	X						
	S. occidentalis S. Wats.							X	X	X	
	S. oppositifolia L.	X	X				X	X			
	S. rhomboidea Greeene						X	X		X	
	S. rivularis L.							X		X	
	S. tricuspidata Rottb.	X	X	X							
	Tellima grandiflora (Pursh.) Dougl.									X	
	Tiarella unifoliata Hook.								X	X	
Parnassiaceae	*Parnassia fimbriata* Konig					X	X	X	X	X	
	P. kotzebuei Cham. & Schlecht.	X	X				X	X			
	P. palustris L. var. *neogaea*	X	X	X	X	X	X	X			
	P. parviflora DC.							X	X	X	
Grossulariaceae	*Ribes hirtellum* Michaux								X		
	R. lacustre (Pers.) Poir.						X	X	X	X	
	R. laxiflorum Pursh							X	X	X	
	R. oxycanthoides L.						X	X			
Rosaceae	*Amelanchier alnifolia* (Nuttall) Nuttall							X	X	X	
	A. utahensis								X		
	Chamaerhodos erecta (L.) Bunge ssp. *nuttallii*										
	(Pickering ex Rydb.) Hulten	X									
	Dryas alaskensis A. E. Porsild				X						
	D. drummondii Richards.		X				X	X		X	
	D. hookeriana Juz.				X			X	X	X	
	D. integrifolia M. Vahl var. *integrifolia*	X	X	X			X				
	D. octapetala L.			X		X		X			
	Fragaria virginiana Duchesne ssp. *glauca* (S. Wats.)										
	Staudt		X	X	X	X	X	X		X	
	F. vesca L.								X		
	Geum allepicum Jacq. ssp. *strictum* (Ait.) Clausen		X	X			X	X			
	G. macrophyllum Willd. ssp. *macrophyllum*							X	X	X	
	G. macrophyllum Willd. ssp. *perincisum* (Rydb.) Hulten										
	G. triflorum Pursh.							X			
	Holodiscus discolor (Pursh.) Maxim.								X		
	Leutkea pectinata (Pursh.) Ktze.				X				X	X	
	Potentilla arguta Pursh. ssp. *convallaria* (Rydb.) Keck							X			
	P. argentea L.								X		
	P. biflora Willd.	X									
	P. concinna Richards var. *concinna*							X			
	P. diversifolia Lehm.var. *diversifolia*			X	X	X	X		X	X	
	P. diversifolia Lehm. var. *glaucophylla*			X		X		X			
	P. diversifolia Lehm. var. *multisecta*							X			
	P. drummondii Lehm.								X	X	
	P. fruticosa L.		X	X	X	X	X	X	X	X	
	P. fruticosa L. ssp. *floribunda* (Pursh.) Elkington	X									
	P. gracilis Dougl. var. *brunescens*							X			
	P. gracilis Dougl. var. *gracilis*						X	X			
	P. gracilis Dougl. var.*pulcherrima*							X			
	P. hyparctica Malte	X								X	
	P. nivea L.						X				
	P. norvegica L.			X				X		X	
	P. ovina J. M. Macoun						X				
	P. palustris (L.) Scop.									X	
	P. pensylvanica L. var. *pensylvanica*	X						X			
	P. rubicaulis Lehmann	X									
	P. tridentata Ait.						X				
	P. uniflora Ledeb.	X						X		X	
	P. villosula Jurtz								X	X	
	Prunus pensylvanica L.			X				X	X		
	P. pensylvanica L. var. *saximontana* Rehd.								X	X	
	P. virginiana L. var. *virginiana*							X	X		
	Rosa acicularis Lindl.	X	X		X		X	X			
	R. gymnocarpa Nuttall									X	
	R. woodsii Lindl.						X		X		
	Rubus acaulis Michaux									X	

Appendix A to ERDKUNDE article: Stuart A. Harris: Diversity of vascular plant species ...
Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

	Rubus arcticus L. ssp. *gracilis*						X	X			
	R. discolor Weihe & Nees								X	X	
	R. idaeus L.								X	X	
	R. idaeus L. var. *strigosus* (Michaux) Maxim						X	X			
	R. parviflorus Nuttall							X	X	X	
	R. pedatus J. M. Sm.						X		X	X	
	R. pubescens Raf.									X	
	Sibbaldia procumbens L.						X	X	X	X	
	Sorbus scorpulina Greene				X		X		X	X	
	S. sitchensis Roemer								X	X	
	Spirea betulifolia Pall. ssp. *lucida* (Dougl. Ex Greene)										
	Taylor & MacBride						X	X	X	X	
	S. douglasii Hook.								X	X	
	S. splendens Baumann & K. Koch. ssp. *splendens*								X	X	
Leguminosae	*Astragalus aboriginum* Richards						X	X			
	A. adsurgens Pall. ssp. *robustior* (Hook.) Welsh										
	A. agrestis Dougl. Ex G. Don		X					X			
	A. alpinus L.	X	X	X	X	X	X	X			
	A. americanus (Hook.) M. E. Jones		X	X	X		X	X			
	A. canadensis L.										
	A. eucosmus Robins.			X			X	X			
	A. flexuosus Dougl. Ex Don.							X			
	A. miser Dougl. Ex Hook. var. *serotinus*										
	(Gray) Barneby							X			
	A. robinsii (Oakes) Gray var. *occidentalis*							X			
	A. striatus Nuttall						X	X			
	A. tenellus Pursh.								X		
	A. vexilliflexus Sheldon						X	X			
	A. williamsii Rydb.	X									
	Hedysarum alpinum L. ssp. *americanum* Michaux	X	X	X	X	X	X	X			
	H. boreale Nuttall var. *boreale*						X	X	X		
	H. boreale Nuttall var.*cinerescens*							X			
	H. boreale Nuttall ssp. *mackenzii* (Richards) Welsh	X			X	X	X	X			
	H. sulphurescens Rydb.							X			
	Lathyrus nevadensis Wats. var. *pilosellus* (Peck) Hitchc.			X							
	L. ochroleucus Hook.		X		X			X		X	
	Lupinus arcticus Wats ssp. *subalpinus* (Piper & Rob.)										
	Dunn								X	X	
	Lupinus arcticus Wats. ssp. *arcticus*	X	X	X							
	L. argenteus Pursh								X		
	L. polyphyllus Lindl. var. *burkei*								X		
	L. sericeus Pursh							X	X		
	Medicago lupulina L.								X		
	M. sativa L.								X	X	
	Meliotis alba Desr.								X	X	
	M. officinalis (L.) Lam.									X	
	Oxytropis cucsickii Greenm.						X	X			
	O. deflexa (Pall.) DC. var. *deflexa*			X				X			
	O. huddelsonii A. E. Porsild	X									
	O. monticola A. Gray							X			
	O. podocarpa A. Gray					X	X	X			
	O. scammaniana Hulten	X									
	O. sericea Nuttall ssp. *spicata* (Hook.) Cody			X			X	X			
	O. splendens Dougl.			X			X	X			
	O. viscida Nuttall	X		X				X			
	Thermopsis rhombifolia (Nutt.) Richards.							X			
	Trifolium aureum Poll.								X	X	
	Trifolium hybridum L.		X	X				X		X	
	T. pratense L.								X	X	
	T. repens L.		X							X	
	Vicia americana Muhl.		X	X			X	X			
	V. cracca L.								X	X	
Geraniaceae	*Geranium bicknellii* Britt.			X			X	X			
	G. richardsonii Fisch. & Trautv.						X	X			
	G. viscossimum Fisch. & Mey.							X			
Linaceae	*Linum lewisii Pursh*	X						X			
Empetraceae	*Empetrum nigrum* L. ssp. *hermaphroditum*	X	X	X	X		X	X	X	X	
Celastraceae	*Pachystima myrsinites* (Pursh) Raf.								X	X	
Balsaminaceae	*Impatiens noli-tangere* L.								X	X	
Aceraceae	*Acer glabrum* Torr.							X	X		
Rhamnaceae	*Ceanothus*								X	X	
	C. velutinus Dougl. Ex Hook.								X	X	
	Rhamnus purshiana DC.								X		
Hypericaceae	*Hypericum formosum* HBK. var. *scouleri* (Hook.) Coult.									X	
	H. perforatum L.								X		
Violaceae	*Viola adunca Sm. var. adunca*				X		X	X	X	X	
	V. canadensis L.							X	X	X	
	V. glabella Nuttall									X	
	V. nephrophylla Greene								X		
	V. nuttallii Pursh							X			
	V. orbiculata Geyer ex Hook.							X	X	X	
	V. palustris L.									X	
	V. renifolia A. Gray						X	X	X	X	
Elaeagnaceae	*Elaeagnus commutata* Bernh. ex Rydb.	X									
	Shepherdia canadensis (L.) Nuttall	X	X	X	X	X	X	X	X	X	

Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

Onagraceae	*Circaea alpina* L.								X	X	
	Epilobium alpinum L.								X	X	
	Epilobium anagallidifolium Lam.		X		X			X			
	E. angustifolium L.	X	X	X	X	X	X	X	X		
	E. ciliatum Raf. ssp. *ciliatum*						X	X	X		
	E. clavatun						X			X	
	E. glandulosum Lehm.							X	X	X	
	E. hornemannii Reichenb. ssp. *hornemannii*						X	X			
	E. lactiflorum Hausskn.							X	X	X	
	E. latifolium L.	X	X		X		X		X	X	
	E. lueteum Pursh							X		X	
	E. nutans Hornem.								X	X	
	E. palustre L.									X	
	E. watsonii Barbey var. *occidentale* (Trel.) Hitchc.									X	
Hippuridaceae	*Hippuris vulgaris* L.							X	X	X	
Araliaceae	*Aralia nudicaulis* L.								X	X	
	Oplopanax horridum (Sm.) Miq.								X	X	
Umbelliferae	*Angelica genuflexa* Nuttall								X		
	Cicuta douglasii (DC.) C. & R.							X	X	X	
	Heracleum lanatum Michaux	X	X		X	X		X	X	X	
	Ligusticum canbyi Coult. & Rose								X	X	
	Lomatium dissectum Nutt. var. *multifidum* (Nutt.) M. & C.							X			
	L. macrocarpum (Hook. & Arn.) Coult. & Rose							X			
	L. trinertanum (Pursh) Coult. & Rose var. *trinertanum*							X			
	Osmorhiza chilensis Hook. & Arn.							X			
	O. depauperata Philippi						X	X		X	
	O. purpurea (Coult. & Rose) Suksd.								X	X	
	Perideridea gairdneri (Hook. & Arn.) Mathais										
	ssp. *borealis* Chaung & Constance							X			
Cornaceae	*Cornus canadensis* L.			X	X	X	X	X	X	X	
	Cornus stolonifera Michaux								X	X	
Pyrolaceae	*Chimaphila umbellata (L.) Bart. var. occidentalis*										
	(Rydb.) Blake				X			X	X	X	
Pyrolaceae	*Moneses uniflora* (L.) A. Gray		X			X	X	X	X	X	
	Orthilia secunda (L.) House	X	X				X	X	X	X	
	Pyrola asarifolia Michaux ssp. *asarifolia*	X	X				X	X	X	X	
	P. asarifolia Michaux var. *purpurea*		X					X			
	P. chlorantha Sw.						X	X		X	
	P. grandiflora Radius	X	X				X				
	P. minor L.				X				X	X	
	P. picta J. E. Smith								X	X	
Ericaceae	*Arctostaphylos alpina* (L.) Spreng.	X									
	A. rubra (Rehd. & Wils.) Fernald	X			X	X	X	X			
	A. uva-ursi (L.) Spreng. ssp. adenotricha										
	(Fernald & MacBride) Calder & Taylor							X			
	A. uva-ursi (L.) Spreng. ssp. *uva-ursi*	X	X		X	X	X	X	X	X	
	Cassiope mertensiana (Bong.) D. Don								X	X	
	Cassiope tetragona (L.) D. Don ssp. *saximontana*										
	(Small) A. E. Porsild				X			X			
	C. tetragona (L.) D. Don ssp. *tetragona*	X	X							X	
	Gaultheria humifusa (Graham) Rydb.								X	X	
	G. cvatifolia Gray								X	X	
	Kalmia microphylla (Hook.) Keller				X			X	X	X	
	Ledum glandulosum Nuttall							X			
	L. groenlandicum Oeder	X	X	X	X	X	X	X	X	X	
	Menziesia ferruginea J. E. Smith var. *glabella*							X	X	X	
	Oxycoccus microcarpus Turcz.							X			
	Phyllodoce empetriformis (Sm.) D. Don				X			X			
	P. glanduliflora (Hook.) Cov.				X	X	X	X			
	P. intermedia (Hook.) Camp.				X						
	Rhododendron albiflorum Hook.				X		X	X	X	X	
	R. lapponicum (L.) Wahlenb.	X	X				X				
Vacciniaceae	*Vaccinium caespitosum* Michaux						X	X		X	
	V. membranaceum Dougl.						X	X	X	X	
	V. myrtilloides Michaux				X				X		
	V. myrtillus L.				X			X		X	
	V. ovalifolium J. E. Smith								X	X	
	V. scoparium Lieberg				X	X	X	X	X	X	
	V. uliginosum L.	X	X						X	X	
	V. vitis-idaea L. var. *minus (* Lodd.) Hulten		X	X			X	X			
Primulaceae	*Androsaceae chamaejasme* Host.					X	X	X			
	A. septentrionalis L. var. *diffusa*							X			
	A. septentrionalis L. var.*puberulenta*							X			
	A. septentrionalis L. var. *septentrionalis*						X	X		X	
	A. septentrionalis L. var. *subumbellata*							X			
	Dodecatheon conjugens Greene						X	X			
	D. frigidum C. & S.	X									
	D. pulchellum (Raf.) Merr. var. *pulchellum*						X	X			
	D. pulchellum (Raf.) Merr. var. *watsonii*							X			
	Lysimachia thyrsiflora L.								X		
	Primula incana M. E. Jones	X						X			
	P. mistassinica Michaux									X	
	Trientalis L. ssp. *arctica* (Fisch.) Hulten								X	X	
Gentianaceae	*Gentiana aquatica* L.						X				
	G. calycosa Griseb.										
	G. glauca Pallas		X		X					X	

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Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

	G. prostrata Haenke var. *prostrata*	X		X							
	Gentianella amarella (L.) Börner ssp. *acuta*				X		X	X			
	G. amarella (L.) Börner ssp. *amarella*		X	X							
	G. propinqua (Richards) Gillett	X	X	X		X	X	X		X	
	Lomatogonium rotatum (L.) Fries ssp. *tenuifolium*										
	(Griseb.) Fernald	X									
Menyanthaceae	*Menyanthes trifoliata* L.							X		X	
Polemoniaceae	*Collomia linearis* Nuttall							X			
	Polemonium acutiflorum Willd.	X	X	X			X				
	P. pulcherrimum Hook.	X						X			
Hydrophyllaceae	*P. hastata* Dougl.									X	
	P. sericea (Graham) Gray							X		X	
	Romanzoffia sitchensis Bong.									X	
Boraginaceae	*Hackelia floribunda* (Lehm.) A. E. Johnston							X			
	Lappula sqarrosa (Retz.) Dumort.	X									
	M. paniculata (Ait.) G. Don var. *paniculata*	X	X	X							
	Myosotis alpestris Schmidt ssp. asiatica Vestergr.	X					X	X	X		
	M. arvensis (L.) Hill									X	
	M. sylvatica Hoffm.								X		
Labiatae	*Galeopsis tetrahit* L.								X	X	
	Lycopus uniflorus Michaux									X	
	Melampyrum lineare Desr.									X	
	Mentha arvensis L.								X	X	
	Monardia fistulosa L. var. *menthifolia*										
	Prunella vulgaris L.								X	X	
	Stachys palustris L. var. *pilosa* (Nutt.) Epling						X		X		
Scrophulariaceae	*Besseya wyomingensis* (A. Nels.) Rydb.										
	Castilleja caudata (Pennell) Rebr.	X									
	C. elegans (Ostenf.) Malte										
	C. hispida Benth.							X	X	X	
	C. hypoborea Pennell	X									
	C. lutescens (Greenm.) Rydb.							X			
	C. miniata Dougl. ex Hook.		X		X	X	X	X	X	X	
	C. occidentalis Torr.				X	X	X	X	X	X	
	C. rhexifolia Rydb.							X	X	X	
	C. yukonis Pennell	X									
	Collinsia parviflora Dougl.							X		X	
	Digitalis purpurea L.								X	X	
	Euphrasia arctica Lange var. *disjuncta* Hulten			X							
	E. officinalis not L.									X	
	Linaria dalmatica (L.) Mill.							X			
	Mimulus guttatus DC.								X	X	
	M. lewisii Pursh								X	X	
	M. moschatus Dougl.								X	X	
	M. tilingii Regel								X	X	
	Orthocarpus luteus Nuttall							X			
	Pedicularis bracteosa Benth.				X		X	X	X	X	
	P. capitata Adams	X					X				
	P. groenlandica Retz.						X	X			
	P. labradorica Wirsing.	X	X	X	X						
	P. lanata Cham. & Schlect.						X				
	P. oederi Vahl.	X	X								
	P. racemosa Dougl. ex Benth.								X	X	
	P. sudetica Willd.	X		X							
	Penstemon albertinus Greene							X			
	P. confertus Dougl.						X	X			
	P. ellipticus Coult. & Fisher				X			X	X	X	
	P. fruticosus (Pursh) Greene ssp. *scouleri* (Lindl.)										
	Pennell & Keck								X	X	
	P. gormanii Greene	X									
	P. lyallii A. Gray							X			
	P. nitidus Dougl. ex Benth.							X			
	P. procerus Dougl. ex Grah.			X			X	X			
	P. serrulatus Menzies								X		
	Rhinanthus minor L.			X			X	X			
	Verbascum thapsus L.								X	X	
	Veronica americana Schwein.			X							
	V. officinalis L.								X		
	V. serpyllifolia L.								X	X	
	Veronica wormskoldii *Roem. & Schult.ssp.* wormskoldii						X	X	X	X	
Lentibulariaceae	*Pinguicula vulgaris* L.						X	X		X	
	Utricularia intermedia Hayne									X	
	U. minor L.									X	
	Utricularia vulgaris L.							X			
Plantaginaceae	*Plantago canescens* Adams	X									
	P. lanceolata L.								X	X	
	P. major L.		X	X	X			X	X	X	
Rubiaceae	*Galium boreale* L.			X			X	X			
	G. trifidum L.							X	X	X	
	G. triflorum L.							X	X	X	
Caprifoliaceae	*Linnaea borealis* L. ssp. *americana* (Forbes) Rehd.	X	X			X	X	X	X	X	
	Lonicera dioica L.								X		
	Lonicera involucrata (Richards) Banks ex Spreng.						X	X	X	X	
	L. utahensis S. Wats.								X	X	
	Sambucus cerulea Raf.								X		
	S. pubens Michaux							X			

Appendix A to ERDKUNDE article: Stuart A. Harris: Diversity of vascular plant species ...
Erdkunde Volume 62 Number 1 Pages 59-73, 2008
DOI: 10.3112/erdkunde.2008.01.05

	S. racemosa L. var. *melanocarpa* (Gray) McMinn							X	X	X	
	Symphoricarpos albus (L.) Blake							X	X	X	
	S. occidentalis Hook.								X	X	
	Viburnum edule (Michaux) Raf.	X						X	X	X	
Adoxaceae	*Adoxa moschatellina* L.						X	X			
Valerianaceae	*Valeriana capitata* Pall.	X									
	V. septentrionalis Rydb.						X	X			
	V. sitchensis Bong.	X			X		X	X	X	X	
Campanulaceae	*Campanula lasiocarpa* Cham.			X				X		X	
	C. rotundifolia L.			X					X	X	
	Campanula uniflora L.						X	X			
	Lobelia kalmii L.								X	X	
Compositae	*Achillea millefolium* L.	X	X	X	X		X	X	X	X	
	Adenocaulon bicolor Hooker								X	X	
	Agoseris aurantiaca (Hooker) Greene var. *aurantiaca*							X	X	X	
	A. glauca (Pursh.) Rafineque var. *glauca*						X	X			
	Anaphalis margaritacea (L.) Bentham & Hooker					X	X	X	X	X	
	Antennaria alpina (L.) Gaertner	X							X	X	
	A. anaphaloides Rydberg							X			
	A. corymbosa E. E. Nelson								X	X	
	A. lanata (Hooker) Greene				X	X	X	X	X	X	
	A. media Greene	X			X		X	X			
	A. microphylla Rydberg								X	X	
	A. monocephala de Candolle ssp. Monocephala	X		X							
	A. neglecta Greene							X			
	A. neodioica Greene ssp. *canadensis* (Greene) Bayer &										
	Stebbins							X			
	A. neodioica Greene ssp. *howellii* (Greene) Bayer			X				X			
	A. neodioica Greene ssp. *neodioica*							X	X		
	A. parviflora Nuttall	X						X	X		
	A. pulcherrima (Hooker) Greene ssp. *Pulcherrima*						X	X			
	A. racemosa Hooker				X			X			
	A. rosea Greene ssp. *Rosea*	X		X		X		X	X	X	
	A. rosea Greene ssp. *Confinis* (Greene) Bayer					X					
	A. umbrinella Rydberg			X			X	X	X		
	Arnica amplexicaulis Nuttall								X	X	
	A. angustifolia Vahl. in Hornem. ssp. *angustifolia*			X					X	X	
	A. angustifolia Vahl. in Hornem ssp. *tomentosa*										
	(J. M. Macoun) Douglas & Ruyle-Douglas	X					X	X			
	A. cordifolia Hook.			X			X	X		X	
	A. diversifolia Greene				X			X			
	A. fulgens Pursh							X			
	A. gracilis Rydb.						X	X			
	A. latifolia Bong.						X		X	X	
	A. lessingii Greene	X									
	A. lonchophylla Greene			X			X				
	A. longifolia D. C. Eat.									X	
	A. louisiana Farr									X	
	A. mollis Hook.								X	X	
	A. parryi Gray							X			
	A. rydbergii Greene						X	X		X	
	A. sororia Greene							X			
	Artemisia campestris L. ssp. *campestris*				X		X	X		X	
	A. campestris L. ssp. caudata (Michx.) H. & C.										
	A. dracunculus L.	X									
	A. frigida Willd.	X					X				
	A. furcata Bieb.	X									
	A. ludoviciana Nuttall var. *latiloba*							X			
	A. michauxiana Bess.					X	X	X	X	X	
	A. norvegica Fries ssp. *saxatilis* (Bess) H. & C.	X			X						
	A. rupestris L. ssp. *woodii* Nielson	X									
	A. tilesii Ledeb. ssp. *tilesii*	X		X							
	Aster alpinus L. ssp. *vierhapperi* Onno	X						X			
	Centaurea stoebe L. ssp. *micranthos* (S. G. Gmelin										
	ex Gugler) Hayek								X	X	
	Cichorum intybus L.								X	X	
	Cirsium arvense (L.) Scopoli								X	X	
	C. brevistylum Cronquist									X	
	C. flodmannii (Rydb.) Arthur							X			
	C. hookerianum Nuttall				X	X		X		X	
	C. vulgare (Savi) Tenore							X	X	X	
	Conyza canadensis (L.) Cronquist								X	X	
	Crepis nana Richardson in J. E. Franklin et al.										
	ssp. *nana*	X					X			X	
	C. tectorum L.			X						X	
	Erigeron acris L. ssp. *debilis*		X	X		X	X	X	X	X	
	E. acris L. ssp. *politus*		X					X	X	X	
	E. aureus Greene						X		X	X	
	E. caespitosus Nuttall	X									
	E. compositus Pursh var. *compositus*								X	X	
	E. compositus Pursh var. *glabratus*	X					X	X			
	E. glabellus Nuttall ssp. *glabellus*						X	X			
	E. glabellus Nuttall ssp. *pubescens* Hook.							X			
	E. grandiflorus Hook.	X		X			X				
	E. humulis Graham	X			X			X	X	X	
	E. lanatus Hook.				X						
	E. pallens Cronquist	X				X					
	E. peregrinus (Banks ex Pursh) Greene ssp.										
	callianthemus *var.* callianthemus			X	X		X	X	X	X	
	E. philadelphicus L.		X						X	X	
	E. radicatus Hook.						X				
	E. speciosus (Lindley) de Candolle				X	X		X			

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Erdkunde Volume 62 Number 1 Pages 59-73, 2008
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Eucephalus engelmannii (D. C. Eaton) Greene								X	X	
Eurybia conspicua (Lindlry) G. L. Neson							X	X		
E. sibirica (L.) G. L. Neson	X	X		X	X	X	X	X	X	
Gaillardia aristata Pursh							X			
Pseudognapthalium microcephalum (Nuttall) Anderberg								X		
Hieracium albiflorum Hooker								X	X	
H. aurantiacum L.								X		
H. floribundum x *H. lactucella*								X		
H. scouleri Hooker								X	X	
H. triste Willdenow ex Sprengel				X		X	X	X	X	
H. umbellatum L.						X	X	X		
Leucanthemum vulgare Lam.						X	X	X	X	
Matricaria discoidea de Candolle							X			
M. discoidea de Candolle in A. P. de Candolle								X	X	
Packera cana (Hook.) W. A. Weber & A Love						X	X			
P. cymbalaria (Pursh) A. Love & D. Love	X									
P. indecora (Greene) A. Love & D. Love				X			X			
P. ogotorukensis (Packer) A. Love & D. Love	X									
P. pauciflora (Pursh) A. Love & D. Love				X			X			
P. paupercaula (Michaux) A. Love & D. Love							X		X	
P. pseudoaurea (Rydb.) W. A. Weber & A. Love						X	X	X		
P. streptanthifolia (Greene) W. A. Weber & A. Love									X	
P. subnuda (De Candolle) Trock & T. M. Barkley						X	X			
Petasites frigidus (L.) Fries ssp. *frigidus*	X		X	X			X	X		
P. frigidus (L.) Fries ssp. palmatus		X	X	X			X			
P. frigidus (L.) Fries var. *sagittatus*		X						X	X	
P. frigidus (L.) Fries var. *x vitifolius*						X	X		X	
Rudbeckia hirta L.								X	X	
Saussurea angustifolia (L.) de Candolle var.										
yukonensis A. E. Porsild	X									
S. nuda Ledebour							X		X	
Senecio fremonti Torrey & A. Gray							X		X	
S. hydrophiloides Rydb.							X			
S. integerrimus Nuttall var. *exaltatus* Nutt.) Cronq.						X				
S. integerrimus Nuttall var. *integerrimus*								X	X	
S. lugens Richardson in J. E. Franklin et al.	X	X	X			X	X	X		
S. triangularis Hook.				X	X	X	X	X	X	
Solidago canadensis L.		X						X	X	
S. multiradiata Airon var. *multiradiata*	X	X	X	X		X	X	X	X	
S. simplex Kunth in A. von Humboldt ssp.*simplex*	X	X	X			X				
S. spathulata de Candolle in A. P. de Candolle						X	X			
Sonchus arvensis L.							X		X	
S. asper (L.) Hill									X	
S. oleraceus L.								X		
Symphytrichum ascendens (Lindley) G. L. Neson									X	
S. boreale (Torrey & A. Gray) Love & Love								X	X	
S. campestre (Nuttall) G. L. Neson							X	X	X	
S. ciliolatum Love & Love		X	X			X	X	X		
S. foliaceum (Lindley ex de Candolle) G. L. Neson										
var. *apricum* (A. Gray) G. L. Neson							X	X	X	
S. laeve (L.) G. L. Neson var. *geyeri* (A. Gray) G. L. Neson		X					X			
S. laeve (L.) G. L. Neson var. *laeve*						X				
S. lanceolatum (Willdenow) G. L. Neson var. *hesperium*										
(A. Gray) G. L. Neson									X	
S. puniceum (L.) Love & Love							X			
S. subspicatum (Nees) G. L. Neson							X			
S. yukonense (Cronquist) G. L. Neson	X									
Taraxacum ceratophorum (Ledebour) de Candolle	X								X	
T. erythrospermum Andrzejowski ex Besser									X	
T> officinale F. H. Wiggers				X		X	X			
T. scorpulorum (A. Gray) Rydberg	X							X	X	
Tonestus lyallii (A. Gray) A. Nelson							X	X	X	
Tephroseris frigida (Richardson) Holub	X									
T. kjellmanii (A.E.Porsild) Holub	X									
T. tundricola (Tolmatchev) Holub	X									
Townsendia hookeri Beaman	X									
T. parryi D. C. Eaton							X			
Trapopogon dubius Scopoli							X			
T. pratensis L.									X	