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Plant diversity along altitudinal gradients in the Central Alps (South Tyrol, Italy) and in the Central Greater Caucasus (Kazbegi region, Georgia)

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Abstract

Plant species diversity and species ranges were investigated in two siliceous mountain regions: the Central Alps (Nature Park Texelgruppe, South Tyrol, Italy) and Central Greater Caucasus (Cross Pass area, Kazbegi region, Georgia). Altitudinal gradients from the treeline ecotone to the upper alpine/subnival and nival zone, respectively, are compared. The research was carried out within the projects GLORIA-Europe (**Gl**obal **O**bservation **R**esearch **I**nitiative in **A**lpine Environments) and GLORIA-worldwide. The idea of the GLORIA projects is to describe the actual diversity (= task of the first recording), and to observe diversity changes and migrations of low-altitude species to higher altitudes (= task of the monitoring every 5–10 years).

The objective of this paper is to analyse (1) altitudinal gradients from the treeline to the nival zone in the Central Caucasus and in the Central Alps, (2) floristic similarities between the two mountain regions, (3) signs of migrating montane species to higher altitudes in both regions. In each mountain region four summits were selected and 3 x 3 m square clusters were established at the 5 m contour line below the highest summit point in each of the four main compass directions. In the four corner plots (4 x 1 m²) of the square cluster plots frequency analyses were performed and vegetation cover was estimated. Additionally, species sampling was made from the highest summit point down to the 10 m contour line of each summit. The species were classified according to their distribution (endemic vs. non-endemic species) and their altitudinal range (colline-montane-treeline-alpine-subnival-nival species).

The total species number of the GLORIA summits in the Central Caucasus was 116, in the Central Alps 140. Differences between the two mountain regions were detected regarding species diversity per summit, number of endemic species and altitudinal ranges of the species. In the Central Alps, a high number of montane species was present at the treeline ecotone in contrast to the Central Caucasus, where species of lower altitudes did hardly occur at the investigated summits.

Zusammenfassung: Artenvielfalt entlang von Höhengradienten in den Zentralalpen (Südtirol, Italien) und im Zentralkaukasus (Kasbek Region, Georgien)

Jeweils vier Gipfel der Zentralalpen (Naturpark Texelgruppe, Südtirol, Italien) wurden mit vier Gipfeln des Zentralkaukasus (Kreuzberg-Pass, Georgien) hinsichtlich Artenvielfalt und Höhenverbreitung der Arten verglichen. Die Untersuchung wurde im Rahmen der Projekte GLORIA-Europe (**Gl**obal **O**bservation **R**esearch **I**nitiative in **A**lpine Environments) und GLORIA-worldwide durchgeführt. Im Mittelpunkt der GLORIA-Projekte steht die Beschreibung der aktuellen Diversität (= Ziel der ersten Aufnahme), die Beobachtung der Diversitätsänderung und der Migration von Arten als Folge der Klimaänderung (= Ziel des Monitorings alle 5–10 Jahre).

Ziel der vorliegenden Studie war es, 1.) die Höhengradienten von der Waldgrenze zur nivalen Stufe im Zentralkaukasus und in den Zentralalpen zu vergleichen, 2.) floristische Ähnlichkeiten aufzuzeigen, 3.) erste Anzeichen einer Migration von montanen Arten in höhere Lagen aufzuzeigen. In jeder der beiden Gebirgsregionen wurden vier Berggipfel ausgewählt. 5 Höhenmeter unterhalb jeden Gipfels wurden in jeder Haupthimmelsrichtung 3 x 3 m-Aufnahmecluster eingerichtet. In den 4 x 1m² Eckflächen dieser Cluster erfolgten Frequenzanalysen und Deckungsschätzungen. Außerdem wurde die Artenanzahl vom höchsten Punkt jeden Gipfels bis 10 Höhenmeter unterhalb aufgenommen. Die Arten wurden anschließend nach ihrer Verbreitungshäufigkeit (Endemiten vs. Nicht-Endemiten) und nach ihrer Höhenverbreitung klassifiziert.

Die Gesamtartenzahl der GLORIA-Gipfel belief sich im Zentralkaukasus auf 116, in den Zentralalpen auf 140 Arten. Unterschiede zeigten sich vor allem hinsichtlich der Artenvielfalt pro Gipfel, der Anzahl

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an endemischen Arten und der Höhenverbreitung der Arten. In den Zentralalpen war ein relativ hoher Anteil an Arten mit montaner Verbreitung bereits im Bereich der niedrigen Gipfel zu finden, während im Zentralkaukasus keine Arten aus tieferen Lagen auftraten.

Keywords: endemism, floristic similarity, frequency, GLORIA, species ranges, permanent plots.

1. Introduction

Alpine environments are very rich in plant diversity (BARTHLOTT et al. 1996, THEURILLAT & GUISAN 2002, KÖRNER 2003, BURGA et al. 2004) and they represent one of the most sensitive ecosystems to global warming (GUISAN & THEURILLAT 2001). If current predictions of global warming scenarios (temperature increases of 1.1 to 6.4 K till 2099, IPCC 2007) are correct, we should expect significant changes in plant diversity in mountain ecosystems (SALA et al. 2000, BAKKENES et al. 2002, DULLINGER et al. 2004, STANISCI et al. 2005, PAROLO & ROSSI 2008). Zones above treeline are expected to be more sensitive to climate change than lower altitudes (KÖRNER 1992, 1999). Empirical studies in the Alps (GOTTFRIED et al. 1994, GRABHERR et al. 1994, 2001, WALTHER et al. 2005 a,b, PAULI et al. 2007, ERSCHBAMER et al. 2009, HOLZINGER et al. 2008, VITTOZ et al. 2008) provided already evidence that many plants have extended their altitudinal range as a result of recent climate warming. Observations carried out since 1962 in the Kazbegi High-Mountain Research Station (KHARADZE 1966, NAKHUTSRISHVILI 1971, 1974, 1975, 1998, KETSKHOVELI et al. 1975, IVANISHVILI 1998, NAKHUTSRISHVILI et al. 2005) as well as in the northwest Caucasus (ONIPCHENKO 2004), have also revealed important changes in species composition and vitality of alpine plant species due to climate warming and increased aridity in the region. Subalpine meadows in the Kazbegi region became drier during the last decades and penetration of plant species characteristic for steppes such as *Stipa* spp. and *Festuca* spp. have been observed (NAKHUTSRISHVILI 2000, 2003). In order to follow the changes, to provide scenarios for future vegetation development, and to propose effective protection measures it is highly recommended to monitor plant diversity along the altitudinal gradients in mountain ecosystems (SIEG 2007).

The EU-funded project GLORIA-Europe (**Gl**obal **O**bservation **R**esearch **I**nitiative in **A**lpine Environments) and the project GLORIA-worldwide (Fig. 1) established a monitoring network in high mountain regions by means of permanent plots on summits from the treeline ecotone to the subnival/nival zone. The main idea of the monitoring project is to investigate species richness (= actual diversity) in a first monitoring and to observe changes in diversity and plant migrations after 5–10 years when monitoring will be repeated. One of the strengths of the GLORIA-network is its focus on the alpine zone, i.e. the zone above treeline. Comparisons between different mountain regions are possible due to standardized recording.

The main aim of this paper is to analyse species diversity along altitudinal gradients in the Central Caucasus and in the Central Alps, to highlight similarities and to explain possible divergences. Both mountain regions are characterized by siliceous bedrock. They were classified as nemoral mountain systems having comparable altitudinal belts (OZENDA 2002). Although both the regions experienced different geological and vegetation histories, they host at least partly the same biogeographic groups, i.e. elements from the Arctic-, the Mediterranean-, and the Central Asian chorological groups (REISIGL 1983, NAKHUTSRICHVILI & OZENDA 1998). Both mountain regions have been populated since ancient times and the alpine grasslands have been used for thousands of years (CERNUSCA & NAKHUTSRISHVILI 1983, VORREN et al. 1993, BORTENSCHLAGER 1993, 2000, 2001, NAKHUTSRISHVILI et al. 2005). Nowadays, these factors have a different impact in the two regions. While in the Caucasus over-grazing or grazing cessation prevails, this applies only partly to the Alps where intense tourism may be regarded as one of the major diversity threats. Nevertheless, it was possible to find more or less undisturbed or moderately grazed summits in the Cross Pass area of the Greater Caucasus (Georgia) and in the Nature Park Texelgruppe (South Tyrol, Italy).

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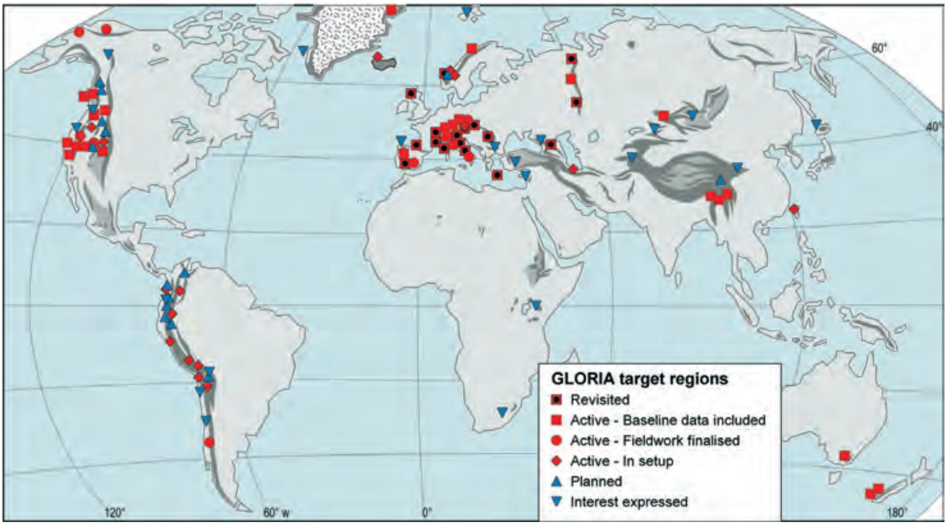

Fig. 1: Overwiev of GLORIA target regions (www. gloria.ac.at).

Abb. 1: Übersicht der GLORIA-Zielgebiete (www. gloria.ac.at).

The following questions were addressed: (1) are there similar diversity gradients from the treeline ecotone to the nival zone in the Central Caucasus and in the Central Alps? (2) are there floristic similarities between the two mountain regions? (3) are there signs of migrating montane species ('lowland' species) to higher altitudinal belts in both regions? (4) are there signals indicating threats for endemic species?

2. Study sites

According to the GLORIA protocol (PAULI et al. 2001, 2004) in each mountain region four summits were chosen along the vertical vegetation zones: summit 1 at the treeline ecotone (i.e. area between the timber line and the treeline with predominately dwarf/alpine vegetation, not dominated by trees or tall shrubs); summit 2 at the lower alpine zone (i.e. transition between treeline ecotone and alpine grassland) in the Central Caucasus and at the alpine zone (i.e. alpine grassland) in the Central Alps, respectively; summit 3 at the upper alpine zone (i.e. transition between alpine grassland and subnival vegetation) in the Central Caucasus and the upper alpine/subnival zone in the Central Alps, respectively; summit 4 at the upper alpine/subnival zone in the Central Caucasus and at the nival zone (i.e. close to the limits of vascular plant life) in the Central Alps. Informations on the selected summits in the two study sites are reported in Table 1. At present, the summits exhibit no substantial anthropogenic impacts with exception of summit 3 in the Central Caucasus which is occasionally visited by cattle. However, all summits in the Central Caucasus represent deforested areas since the Late Holocene (JANELIDZE & MAGRGALITADZE 1977) when forests disappeared probably due to worsening of the climatic conditions and human impact.

The Caucasian summits are located at the Cross Pass in the eastern part of the Central Greater Caucasus, Georgia. The summits are on the main watershed range and on its S and N outgrowths. Historical-geographically this is the Khevi region. Administratively it belongs to the Mtskheta-Mtianeti region (Kazbegi region subdivision). The summits are located in the vicinities of the alpine ski resort Gudauri. The topography is formed by Jurassic rocks, Paleozoic and even older grey granites, younger lava, and moraines, washed out in some places as a result of erosion activity of the river Tergi. Mountain massifs of the Kazbegi volcanic area are overlain by Quaternary glacial or river deposits and rock falls as well as major accumulations of calcareous tuffs and travertine. Glacial deposits occur in many

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places. Deposits of the Jurassic period, in particular Leas, are most widespread in the region. The rocks are composed of slates and quartzite. Sandy loams and diabasic veins are also found. The relief of the Kazbegi region is formed by ascending, bare, sharp ridges, isolated peaks, very steep rocky slopes, narrow gorges and caves of erosion-tectonic origin (KHARADZE 1966, NAKHUTSRISHVILI 1998, NAKHUTSRISHVILI et al. 2005).

The plant communities and dominant plants along the altitudinal gradient in the Kazbegi region (Table 2) are defined according to NAKHUTSRISHVILI (2003). According to the long-term observations of the meteorological station located close to the Cross Pass (2395 m), the mean annual air temperature is 0.3°C. The absolute maximum is 27°C; the mean temperature in July-August hardly reaches 10°C; the mean temperature in January-February amounts to –14°C. The number of days without frost is 118. The soil temperatures at the summits from 2001–2005 are shown in Table 1. Snow persists in the Cross Pass area for 7–8 months with 150–200 cm depth; in depressions snow remains throughout the year. The duration of the growing season is about 120–130 days (NAKHUTSRISHVILI 2003, NAKHUTSRISHVILI et al. 2005). The mean annual precipitation is about 1250 mm (mean monthly precipitation in May-August: 215.5 mm). Mist is frequent in the Cross Pass area (about 140–150 misty days per year). Strong western winds prevail.

The central Alpine summits (Table 1) are located in the western part of the Eastern Alps and belong to the Nature Park Texelgruppe in South Tyrol, Italy. TEX 1 and 2 can be reached through the Passeier- and Falser Valley, TEX 3 and 4 through the Schnals Valley. The whole Nature Park is moderately grazed by sheep. Geologically, the research area is built up by gneiss, schists and phyllites (inner alpine crystallic rocks) of the Oetztal-Stubai complex (FRANK et al. 1987, HOINKES & THÖNI 1993) and more rarely by amphibolites. There are no precipitation and air temperature measurements at the summits. The mean annual precipitations at lower altitudes are 668 mm (at Vorderkaser, Schnals Valley, 1705 m a.s.l., a locality close to TEX 3 and 4) and 1035 mm (at Platt, Passeier Valley, 1147 m a.s.l., a locality close to TEX 1 and 2; data from HYDROGRAPHISCHES AMT, AUTONOME PROVINZ BOZEN, 1990). The mean annual air temperatures are 4.6°C at 1676 m a.s.l. (Vorderkaser, Schnals Valley) and 8.0°C at 1147 m a.s.l. (Platt, Passeier Valley, FLIRI 1975). Mean annual air temperatures at Rauhjoch (2926 m, Pfelders, Passeier Valley) amounted to –3.7°C (unpubl. data 2000–2004, HYDROGRAPHISCHES AMT, AUTONOME PROVINZ BOZEN). The mean monthly soil temperatures for the period 2003–2005 are shown in Table 1. The altitudinal gradient of the vegetation in the Nature Park is shown in Table 2 (according to RAFFL 1982, MALLAUN et al. unpubl.).

Table 1: Description of the selected summits for the GLORIA project in the Central Caucasus, Kazbegi region, Georgia (CAU) and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy (TEX), mean annual temperatures in 10 cm soil depth measured in the 3 x 3m square clusters at the 5m contour line below each summit (CAU: 2001–2005, TEX: 2003–2005) and altitudinal belt of the respective summit.

Tabelle 1: Beschreibung der ausgewählten Gipfel für das GLORIA-Projekt im Zentralkaukasus, Kasbek Region, Georgien (CAU) und in den Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX), Jahresmitteltemperaturen in 10 cm Bodentiefe innerhalb der 3 x 3 m Quadrate, 5 Höhenmeter unterhalb des höchsten Gipfelpunktes (CAU: 2001–2005, TEX: 2003–2005) und Höhenstufen des entsprechenden Gipfels.

Summit	Altitude m a.s.l.	Coordinates	mean annual soil temperature (°C)	altitudinal belt
CAU 1	2240	N 44°29'35'', E 42°32'33''	5,58	treeline ecotone
CAU 2	2477	N 44°27'33'', E 42°29'57''	5,61	lower alpine
CAU 3	2815	N 44°30'04'', E 42°29'44''	4,94	upper alpine
CAU 4	3024	N 44°30'36'', E 42°29'49''	4,32	upper alpine/subnival
TEX 1	2180	N 46°44'34'', E 11°09'51''	4,58	treeline ecotone
TEX 2	2619	N 46°44'28'', E 11°06'38''	2,37	alpine
TEX 3	3074	N 46°43'03'', E 10°57'54''	-0,62	upper alpine/subnival
TEX 4	3287	N 46°44'45'', E 10°53'19''	-2,59	nival

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Table 2: Plant communities and dominant species along the altitudinal gradient from the upper montane to the nival belt in the Central Caucasus, Kazbegi region, Georgia, and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy.

Tabelle 2: Pflanzengemeinschaften und dominante Arten entlang der Höhengradienten von der oberen montanen bis zur nivalen Stufe im Zentralkaukasus, Kasbek Region, Georgien und in den Zentralalpen, Naturpark Texelgruppe, Sudtirol, Italien

Altitudinal belt	**Plant communities or dominant species in the Central Caucasus, Kazbegi region, Georgia**
upper montane (1500 - 1850m)	*Fagus orientalis* forest; *Juniperus oblonga* community
subalpine-lower alpine (1850 - 2500 m)	*Betula litwinowii* and *Pinus kochiana* forest; *Rhododendron caucasicum* shrubbery; *Festuca ovina*, *F. varia, Hordeum violaceum, Bromopsis variegata* grasslands; *Astragalus denudatus* tragacanth scrub
alpine (2500 - 3000 m)	*Rhododendron caucasicum* shrubbery; *Nardus stricta, Kobresia capilliformis, Carex tristis* grasslands; *Dryas caucasica* dwarf-shrub heath
subnival (3000 - 3700 m)	patches of *Delphinium caucasicum, Lamium tomentosum, Scrophularia minima, Saxifraga mollis, S. moschata, Colpodium versicolor, Minuartia inamoena, Tripleurospermum subnivale*
nival (> 3700 m)	patches of *Cerastium kazbek, Alopecurus dasyanthus*

Altitudinal belt	**Plant communities or dominant species in the Central Alps, Nature Park Texelgruppe, Italy**
upper montane (1500 - 1850 m)	*Larix decidua-Picea abies* forests; *Alnus viridis* shrubbery
subalpine (1850 - 2300 m)	*Larix decidua-Pinus cembra* forests; *Alnus viridis* shrubbery; dwarf-shrub heath with *Rhododendron ferrugineum*, *Vaccinium* spp., *Juniperus communis* ssp. *alpina, Arctostaphylos uva-ursi, Loiseleuria procumbens, Empetrum hermaphroditum*; *Nardus stricta, Carex sempervirens, Festuca* spp. grasslands;
alpine (2300 - 2800 m)	*Carex curvula* grasslands; snowbeds with *Salix herbacea, Luzula alpinopilosa, Polytrichum sexangulare*; *Carex sempervirens-Juncus trifidus* grasslands, *Kobresia myosuroides* grasslands
subnival (2800 - 3100 m)	fragments of *Carex curvula* grassland; patches of *Androsace alpina, Ranunculus glacialis, Saxifraga bryoides, Cerastium uniflorum*
nival (> 3100 m)	patches of *Androsace alpina, Ranunculus glacialis*

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Fig. 2: Mt. Kazbegi (5033 m a.s.l.) in the Central Caucasus. The lower summits are widely deforested since the Late Holocene.

Abb. 2: Kasbek (5033 m Meereshöhe) im Zentralkaukasus. Die niederen Gipfel sind bereits seit dem späten Holozän weitgehend entwaldet.

Fig. 3: CAU 4 (3024 m a.s.l.), the highest GLORIA summit in the Central Caucasus, Kazbegi region, with the 3 x 3 m square cluster during the monitoring.

Abb. 3: Der höchste GLORIA-Gipfel im Zentralkaukasus, Kasbek Region (CAU 4: 3024 m Meereshöhe), mit dem 3 x 3 m-Aufnahmecluster während des Monitorings.

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Fig. 4: TEX 3 (3074 m a.s.l.) in the Central Alps, Nature Park Texelgruppe, with the 3 x 3 m square cluster during the monitoring.

Abb. 4: Der zweithöchste GLORIA-Gipfel in den Zentralalpen, Naturpark Texelgruppe (TEX 3: 3074 m Meereshöhe), mit dem 3 x 3 m-Aufnahmecluster während des Monitorings.

Fig. 5: TEX 1 (2180 m a.s.l.) in the Central Alps, Nature Park Texelgruppe.

Abb. 5: Der niedrigste GLORIA-Gipfel in den Zentralalpen, Naturpark Texelgruppe (TEX 1: 2180 m Meereshöhe).

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3. Methods

The summits in the Central Caucasus were monitored in 2001, those in the Central Alps in 2003. The sampling design developed by the GLORIA-EU project (PAULI et al. 2001, 2004) was used in all study sites on each summit. 3 x 3 m square clusters were marked in all four main compass directions at the 5 m contour line below each highest summit point. The four corner plots (1 x 1 m permanent plots) of each square cluster were sampled using a frequency frame divided in 100 subplots (16 plots of 1 m^2 and 1600 subplots of 1 dm^2 per plot per summit). The presence of species was recorded in each subplot. The vegetation cover and the occurrence of solid rocks, scree and bare ground were recorded in percentage in each 1 m^2 permanent plot. In the central plot of the 3 x 3 m square cluster data loggers were buried in 10 cm soil depth. Between the highest summit point and the 10 m contour line the species number was recorded in the summit area sections (PAULI et al. 2001, 2004) using a semi-quantitative cover estimation.

Altitudinal ranges of the species in the Central Caucasus were defined according to SAKHOKIA & KHUTSISHVILI (1975), in the Central Alps according to FISCHER et al. (2005). Six ranges were distinguished: **(colline)-montane-treeline**, (co)-mo-tl = species from lower altitudes growing up to the treeline (= subalpine zone) but 'normally' not occurring in the alpine zone; **montane-treeline-alpine**, mo-tl-al = species with a wide altitudinal range from the montane to the alpine zone; **treeline-alpine-nival**, tl-al-ni = species occurring from the treeline (= subalpine zone) to the subnival/nival zone; **alpine**, al = species typically of the alpine zone; **alpine-nival**, al-ni = species of the alpine, subnival, and **nival** zone; nival, ni = species exclusively growing in the nival zone. **Endemic species** were defined for the whole Alps according to AESCHIMANN et al. (2004) and for the whole Caucasus according to SAKHOKIA & KHUTSISHVILI (1975). Nomenclature of taxa follows FLORA EUROPAEA (Royal Botanic Garden, Edinburgh, http://rbg-web2.rbge.org.uk/FE/fe.html). Lichens were sampled, though not reported in this paper; mosses were not considered during the first recording of the GLORIA plots.

Statistical analyses were carried out with the programme SPSS 13.0 (similarities, analyses of variance) and STATISTICA 6.0 (correlations of species number and cover). Comparisons between the species numbers of the summits were performed using the similarity index of Jaccard (JI: 1 = highest similarity; 0 = lowest similarity). Univariate ANOVAs were performed to test differences between the summits and effects of exposition on species number.

4. Results

4.1. Species diversity at the summits from the highest point to the 10 m contour line

The overall diversity expressed as total vascular species number of all four GLORIA-summits was 116 in the Central Causasus and 140 in the Central Alps. In the Central Alps the altitudinal gradient was more pronounced compared to the Central Caucasus (Fig. 6) with highest species numbers at the treeline ecotone (104 species) and a steep decline towards the alpine zone (62 species). In the Central Caucasus the treeline ecotone and the lower alpine summit had nearly the same number of species (71 and 74 species, respectively). For the upper alpine/subnival ecotone the differences between the two mountain systems were low (Fig. 6). In the Central Alps a steep decline was observed from this ecotone to the nival zone where only 9 species resulted.

The Caucasus is well-known for the high amount of endemic species: Fig. 7 shows the highest percentage at the treeline ecotone (24 species) and at the alpine/subnival ecotone (18 species). In the Alps 7 endemic species were recorded on the treeline ecotone and 4–5 on each of the higher summits. No endemic species was found on the highest summit (Fig. 7).

Some striking differences were detected regarding the altitudinal ranges of the species. In the Central Alps a bulk of (co)-mo-tl species reached the lowest summit TEX 1 whereas in the Caucasus this species group was completely missing (Fig. 8). A total of 39 'lowland' species were present here and still 4 of them occurred in the alpine zone (TEX 2, Fig. 8), within those a young plant of *Sorbus aucuparia*, i.e. a woody species occurring normally up to the treeline. In the Central Alps, the wide ranging species group (mo-tl-al) occurred from the treeline to the subnival ecotone while in the Central Caucasus this group was hardly present (Fig. 8): only two species of this group (*Salix kazbekensis, Trifolium ambiguum*) reached the lowest summit CAU 1, at CAU 2 only one (*Trifolium ambiguum*) occurred. The GLORIA-summits of the Central Alps have no species restricted to the nival zone while in the Caucasus several species are confined to the subnival-nival zone (Fig. 8).

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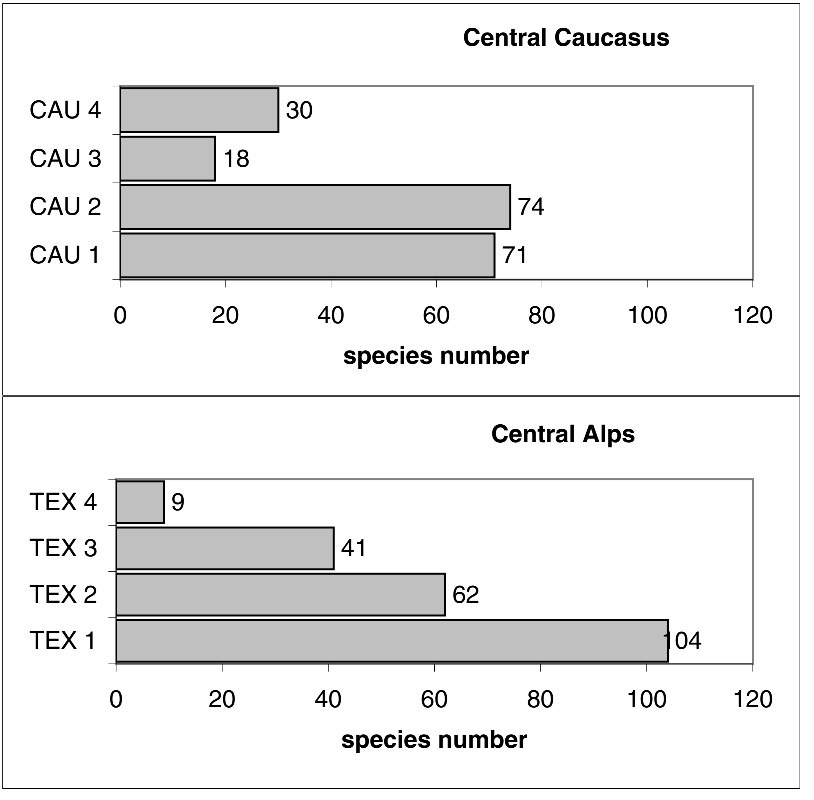

Fig. 6: Total number of species per summit in the Central Caucasus, Kazbegi region, Georgia (CAU) and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy.

Abb. 6: Gesamtanzahl der Arten pro Gipfel im Zentralkaukasus, Kasbek Region, Georgien (CAU) und in den Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX).

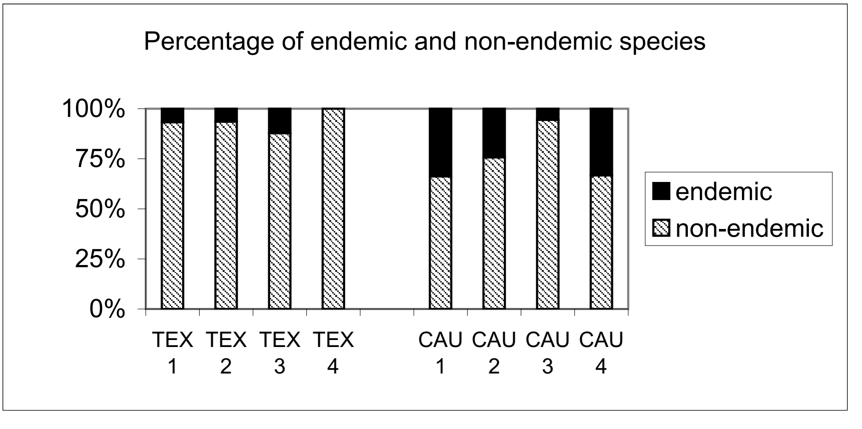

Fig. 7: Percentage of endemic and non-endemic species at the summits in the Central Caucasus, Kazbegi region, Georgia (CAU) and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy (TEX).

Abb. 7: Prozentueller Anteil an endemischen und nicht-endemischen Arten auf den Gipfeln des Zentralkaukasus, Kasbek Region, Georgien (CAU) und der Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX).

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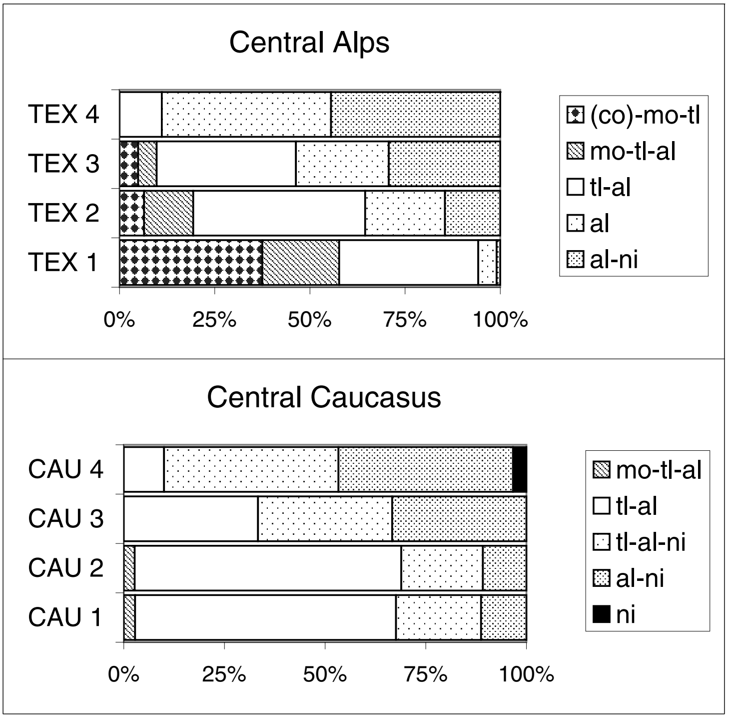

Fig. 8: Altitudinal ranges of the species in the Central Caucasus, Kazbegi region, Georgia (CAU) and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy (TEX). Abbreviations: (co)-mo-tl = (colline)-montane-treeline; mo-tl-al = montane-treeline-alpine; tl-al = treeline-alpine; tl-al-ni = treeline-alpine-nival; al = alpine; al-ni = alpine-nival; ni = nival.

Abb. 8: Höhenverbreitung der Arten im Zentralkaukasus, Kasbek Region, Georgien (CAU) und in den Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX). Abkürzungen: (co)-mo-tl = (kollin)-montan-Waldgrenze; mo-tl-al = montan-Waldgrenze-alpin; tl-al = Waldgrenze-alpin; tl-al-ni = Waldgrenze-alpin-nival; al = alpin; al-ni = alpin-nival; ni = nival.

Floristic comparisons of the two mountain systems (Table 5 at the end) exhibited a relatively low intraregional similarity in the Central Caucasus (Jaccard index JI: 0.16–0.39, Table 3) and in the Central Alps (JI: 0.02-0.42, Table 3). The interregional similarity was extremely low (JI: 0.01 to 0.05, Table 3). The lowest summits of both the mountain systems shared 15 species: *Agrostis capillaris* (= *A. tenuis*), *Anthoxanthum alpinum*, *Deschampsia flexuosa*, *Euphrasia minima*, *Hieracium pilosella*, *Leontodon hispidus*, *Luzula multiflora*, *L. spicata*, *Nardus stricta*, *Phleum alpinum*, *Poa alpina*, *Polygonum viviparum*, *Saxifraga exarata*, *Vaccinium myrtillus*, *V. vitis-idaea*. The summits in the alpine zone shared only four species: *Anthoxanthum alpinum*, *Euphrasia minima*, *Luzula spicata*, *Poa alpina*. The two uppermost summits had no species in common.

4.2. Species richness in the 1 m² permanent plots at the 5 m contour line below the highest summit point

Mean species richness per permanent plot is shown in Table 4. In the Central Alps, a significantly higher species number per plot ($P < 0.0001$) was found with a maximum of 28 species in one E-exposed plot of the lowest summit (2180 m a.s.l.) compared to 23 species in one N-exposed plot of the 2477 m summit in the Central Caucasus. Species number per permanent plot was correlated to exposition in the Central Alps ($P < 0.0001$) with highest numbers for E or S exposition (Fig. 9). No correlation between species richness and exposition

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Table 3: Floristic similarity expressed as Jaccard Index between the summits of the Central Caucasus, Kazbegi region, Georgia (CAU) and those of the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy (TEX). 1 = highest similarity, 0 = lowest similarity. Bold numbers show the highest similarities.

Tabelle 3: Floristische Ähnlichkeit (Jaccard Index) zwischen den Gipfeln des Zentralkaukasus, Kasbek Region, Georgien (CAU) und jenen der Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX). 1 = höchste Ähnlichkeit, 0 = geringste Ähnlichkeit. Fette Zahlen stehen für höchste Ähnlichkeit.

	CAU 1	CAU 2	CAU 3	CAU 4	TEX 1	TEX 2	TEX 3
CAU 2	**0,39**						
CAU 3	0,16	**0,21**					
CAU 4	**0,25**	**0,20**	**0,20**				
TEX 1	0,05	0,05	0,04	0,02			
TEX 2	0,02	0,04	0,03	0,05	**0,29**		
TEX 3	0,01	0,02	0,00	0,03	0,11	**0,42**	
TEX 4	0,01	0,01	0,00	0,05	0,02	0,11	**0,20**

Table 4: Mean number of species per 1m² permanent plot at the 5 m contour line below each summit (number of plots per summit in brackets), standard deviations (St.dev.), minima (Min) and maxima (Max). CAU = summits of Central Caucasus, Kazbegi region, Georgia; TEX = summits of the Central Alps, Nature Park Texelgruppe, South Tyrol, N-Italy.

Tabelle 4: Mittlere Artenanzahl pro 1m² in den Dauerflächen 5 Höhenmeter unterhalb des höchsten Gipfelpunktes (Anzahl der Dauerflächen pro Gipfel in Klammern), Standardabweichung (St.dev.), Minima (Min) und Maxima (Max) im Zentralkaukasus (CAU) und in den Zentralalpen (TEX).

Summits	Species no.	St.dev.	Min	Max
CAU 1	12.5 (16)	3,03	6	18
CAU 2	17.63 (16)	3,14	12	23
CAU 3	9.19 (16)	1,22	7	11
CAU 4	5.25 (16)	2,54	2	11
TEX 1	20.93 (16)	4,53	13	28
TEX 2	13.08 (13)	2,87	9	18
TEX 3	14.54 (10)	3,05	8	18
TEX 4	2.63 (11)	1,11	1	5

was detected in the Central Caucasus ($P = 0.273$). Here and there a significant positive correlation between species number and vegetation cover was detected (Central Alps $R^2 = 0.59$, $P<0.0001$); Central Caucasus $R^2 = 0.47$, $P<0.0001$).

5. Discussion

Generally, species richness decreases stepwise along the elevation belts (OZENDA 1988, GRABHERR et al. 1995, ODLAND & BIRKS 1999, HOLTEN 2003, OZENDA & BOREL 2003, THEURILLAT et al. 2003, STANISCI et al. 2005) with few species reaching up to the nival zone (REISIGL & PITSCHMANN 1958, GRABHERR et al. 1995). The results from the Central Alps are in line with this statement. However, this was not the case in the Central Caucasus. Here, the treeline ecotone exhibited lower species numbers than the lower alpine summit. The reasons for this phenomenon may be the changes in the Late Holocene (JANELIDZE & MARGALITADZE 1977) and/or the peculiarities of the relief (NAKHUTSRISHVILI 1998, 1999).

In the study presented here only 116 vascular plant species were recorded for the Central Caucasus. This is lower than the total vascular plant diversity of the GLORIA target regions South Alps (198 species, ERSCHBAMER et al. 2003), NE-Alps (174 species, PAULI et al. unpubl.), and Central Alps (140), respectively. The lower number of species in the Central Caucasus might be explained by two hypotheses: (1) the selected summits might not represent the highest potential diversity, (2) the vegetation history may differ from summit to summit.

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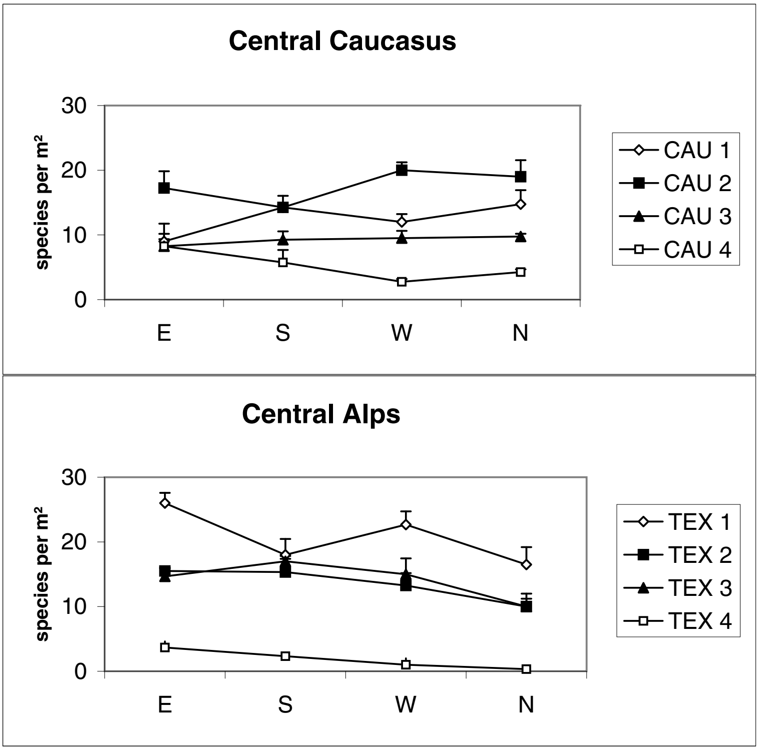

Fig. 9: Mean species number and standard deviations per main compass direction in the 1 m² permanent plots at the 5 m contour line below the highest summit point in the Central Caucasus, Kazbegi region, Georgia and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy.

Abb. 9: Mittlere Artenzahl und Standardabweichung je nach Haupthimmelsrichtung in den 1m² Dauerflächen 5 Höhenmeter unterhalb des höchsten Gipfelpunktes im Zentralkaukasus, Kasbek Region, Georgien (CAU) und in den Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX).

The complex orographic structure of Georgia and its geographical position account for the geographical and ecological isolation of certain plant species, which has resulted in a high ratio of local endemism, particularly endemics of the Greater Caucasus (KHARADZE 1948). In the Kazbegi region, 203 of total 761 high mountain flowering plant species are endemic. Estimations among different altitudinal belts in the Kazbegi region revealed highest endemism in the subnival belt (NAKHUTSRISHVILI 1998, 2000, 2003). In our study the highest number of endemic species is found at the treeline and in the subnival ecotone. In the Alps, most of Tertiary flora got extinct during the glacial period and a comparatively low number of relicts survived. 70 endemic species occur along the whole arch of the Alps and only 10 species are endemic in the Central Alps (PAWLOWSKI 1970 in OZENDA & BOREL 2003). Alpine grasslands of the order *Caricetalia curvulae* are particularly poor in endemic species (PAWLOWSKI 1969). The fact of missing endemic species at the highest studied summit in the Central Alps resulted certainly by chance because for instance the alpine endemic *Androsace alpina* is regularly occurring up to the nival zone at the adjacent summits. Endemic species are assumed to be highly threatened by climate change (GRABHERR et al. 1994, 1995, GOTTFRIED et al. 1994, GRABHERR et al. 2000, DIRNBÖCK et al. 2003) especially those with a disjunct distribution pattern (THEURILLAT 1995). The central alpine endemic species are widely distributed whereas in the Kazbegi region gradual extinction of endemic species raises particular alarm. Climate warming may enforce the threat in the Caucasus.

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Floristic similarity between the Alps and the Caucasus summits was rather low. Considerable dissimilarities have already been shown between southern and mid-latitude European high mountains (NAGY et al. 2003). The flora in the Alps developed till the end of the Tertiary period with elements from four main phytogeographical regions: the Arctic, Central Asia (Himalaya, Altai), the Mediterranean mountains and Africa (REISIGL 1983, REISIGL & KELLER 1987). The flora of the Caucasus consists of autochthonous Tertiary/Quaternary species (FEDOROV 1952 and KHARADZE 1960 in NAKHUTSRISHVILI 2003), arctic-alpine species (NAKHUTSRISHVILI & OZENDA 1998) mixed with boreal and Anterior Asian elements (GROSSHEIM 1936). The 15 species occurring in the Caucasus and in the Alps are mainly Eurosibiric and Arctic-Alpine elements, followed by European-Asiatic and S-European elements. For several genera vicariant species pairs can be mentioned such as *Antennaria carpatica/caucasica, Carex sempervirens/tristis, Kobresia myosuroides/capilliformis, Minuartia recurva/oreina, Poa laxa/caucasica, Primula glutinosa/algida, Rhododendron ferrugineum/caucasicum, Sedum alpestre/oppositifolium, Sibbaldia procumbens/semiglabra, Thymus polytrichus/nummularius.*

One striking difference between both the study regions was the relatively high amount of (colline)-montane-treeline species found at the treeline ecotone and in the alpine zone of the Central Alps. In the Caucasus hardly any species from lower altitudes were recorded. This may not be typical for the whole Caucasus but it is a peculiar feature for the Kazbegi region. In general, forested areas are scarcely present here, the forests having been cleared since hundreds of years, and the remnants occurring in great distance from the investigated summits (i.e. Dariali gorge with fragments of *Fagus orientalis* forests). In the Central Alps, species with mainly montane distribution reaching the lower summits are tall forbs, montane grassland species, dwarf shrubs and in one case – at TEX 2 – a tree species. Considering a continuous warming, they are likely going to extend their distribution area. Thus, these species may be regarded as indicators of climate change and this hypothesis has to be checked in the next recording periods. The predicted expansion of the lower altitude species at the central alpine summits can probably be regarded as "filling" rather than as "moving" process (GRABHERR et al. 1995), i.e. those species spread from their outpost position to the surrounding. The speed of this process may depend on the higher competitive ability of the 'lowland' against the alpine species.

Another interesting contrast between the two mountain regions was shown by a specific nival species group present in the Caucasus but not in the Alps. Here, a considerable amount of species from the alpine belt reach the nival zone (REISIGL & PITSCHMANN 1958; GRABHERR et al. 1995) representing mainly the Alpine or Arctic-Alpine chorological groups, containing only few endemic species (OZENDA 2002). In contrast, the nival flora of the Caucasus derives from the SW-Asian chorological group with a high percentage of endemic species (NAKHUTSRISHVILI 1998, NAKHUTSRISHVILI & GAGNIDZE 1999) and no relations to the nival flora of the Alps (OZENDA 2002).

In contrast to the Alps, many species in the Central Caucasus have a wide altitudinal range from the treeline to the subnival zone. One reason may be the long-lasting grazing impact in the Caucasus high altitudes (JANELIDZE & MAGRGALITADZE 1977). It is expected that plant dispersal was connected with movement of domestic stock herds in the mountains. Anthropogenic disturbances of the high mountain vegetation had already begun in prehistoric times leading to strong changes in the vegetation cover and it is rather difficult to restore the picture of pre-anthropogenic natural conditions. Moreover, it is not often born in mind that in the past wild grazers rather than domestic animals had a strong influence on vegetation determining grassland composition from the treeline to its highest distribution area. The fauna of ancient times was much richer and more diversified, while the number of animals was immeasurably bigger than nowadays (NAKHUTSRISHVILI et al. 2005). Thus, wild and domestic animals could have intensified the unification of the flora at higher altitudes in the Caucasian summit areas from the treeline to the subnival ecotone.

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Table 5: Species on the four summits in the Central Caucasus, Kazbegi region, Georgia (CAU) and in the Central Alps, Nature Park Texelgruppe, South Tyrol, Italy (TEX).

Tabelle 5: Arten auf den vier Gipfeln des Zentralkaukasus, Kasbek Region, Georgien (CAU) und in den Zentralalpen, Naturpark Texelgruppe, Südtirol, Italien (TEX).

Species	CAU				TEX			
	1	2	3	4	1	2	3	4
Species occuring in both regions								
Luzula spicata	+	+	.	+	+	+	+	+
Poa alpina	+	+	+	+	+	+	.	.
Anthoxanthum alpinum	+	+	+	.	+	+	.	.
Euphrasia minima	.	+	.	.	+	+	+	.
Saxifraga exarata	.	.	.	+	.	+	+	+
Vaccinium myrtillus	+	.	.	.	+	.	.	.
Vaccinium vitis-idaea	+	.	.	.	+	.	.	.
Phleum alpinum	.	+	+	.	+	.	.	.
Nardus stricta	.	+	+	.	+	.	.	.
Luzula multiflora	.	+	+	.	+	.	.	.
Leontodon hispidus	+	+	.	.	+	.	.	.
Agrostis tenuis	+	+	.	.	+	.	.	.
Deschampsia flexuosa	+	.	.	.	+	.	.	.
Hieracium pilosella	+	.	.	.	+	.	.	.
Cerastium cerastoides	.	.	.	+	.	+	.	.
Polygonum viviparum	.	+	.	.	.	+	.	.
Species in the Central Caucasus								
Festuca ovina	+	+	+	+	.	.	.	.
Festuca supina	+	+	+	+	.	.	.	.
Potentilla crantzii	+	+	+	+	.	.	.	.
Taraxacum stevenii	+	+	+	+	.	.	.	.
Carum caucasicum	+	+	+	+	.	.	.	.
Carex tristis	+	+	+	+	.	.	.	.
Agrostis planifolia	+	+	+	.	.	.	.	.
Alchemilla sericata	+	+	+	.	.	.	.	.
Tripleurospermum caucasicus	+	+	+	.	.	.	.	.
Alchemilla caucasica	+	+	.	+	.	.	.	.
Alchemilla retinervis	+	+	.	+	.	.	.	.
Alchemilla rigida	+	+	.	+	.	.	.	.
Campanula collina	+	+	.	+	.	.	.	.
Festuca varia	+	+	.	+	.	.	.	.
Primula algida	+	+	.	+	.	.	.	.
Thymus nummularius	+	+	.	+	.	.	.	.
Veronica gentianoides	+	+	.	+	.	.	.	.
Antennaria caucasica	+	.	+	+	.	.	.	.
Betonica macrantha	+	+	.	.	.	.	.	.
Bromopsis variegata	+	+	.	.	.	.	.	.
Carex medwedewii	+	+	.	.	.	.	.	.
Carum alpinum	+	+	.	.	.	.	.	.
Centaurea cheiranthifolia	+	+	.	.	.	.	.	.
Cerastium purpurascens	+	+	.	.	.	.	.	.
Inula orientalis	+	+	.	.	.	.	.	.
Kobresia capilliformis	+	+	.	.	.	.	.	.
Leontodon caucasicus	+	+	.	.	.	.	.	.
Leontodon danubialis	+	+	.	.	.	.	.	.
Luzula pseudosudetica	+	+	.	.	.	.	.	.
Ranunculus oreophilus	+	+	.	.	.	.	.	.
Sedum oppositifolium	+	+	.	.	.	.	.	.
Sedum spurium	+	+	.	.	.	.	.	.
Silene ruprechtii	+	+	.	.	.	.	.	.
Taraxacum confusum	+	+	.	.	.	.	.	.
Tragopogon filifolius	+	+	.	.	.	.	.	.
Trifolium ambiguum	+	+	.	.	.	.	.	.
Trifolium trichocephalum	+	+	.	.	.	.	.	.
Anthemis iberica	+	.	.	+	.	.	.	.
Minuartia inamoena	+	.	.	+	.	.	.	.
Minuartia oreina	+	.	.	+	.	.	.	.
Plantago caucasica	.	+	+	.	.	.	.	.
Sibbaldia semiglabra	.	+	+	.	.	.	.	.
Alchemilla chlorosericea	.	+	.	+	.	.	.	.
Alchemilla tephroserica	+	.	.	.	.	.	.	.
Anthyllis caucasica	+	.	.	.	.	.	.	.
Campanula bellidifolia	+	.	.	.	.	.	.	.
Campanula hohenackeri	+	.	.	.	.	.	.	.
Carex meinshauseniana	+	.	.	.	.	.	.	.
Carum carvi	+	.	.	.	.	.	.	.
Cicerbita racemosa	+	.	.	.	.	.	.	.
Dryas caucasica	+	.	.	.	.	.	.	.
Empetrum nigrum	+	.	.	.	.	.	.	.
Euphrasia hirtella	+	.	.	.	.	.	.	.
Galium cruciata	+	.	.	.	.	.	.	.
Gentiana aquatica	+	.	.	.	.	.	.	.
Helictotrichon asiaticum	+	.	.	.	.	.	.	.
Hieracium pannoniciforme	+	.	.	.	.	.	.	.
Macrotomia echioides	+	.	.	.	.	.	.	.
Minuartia circassica	+	.	.	.	.	.	.	.
Minuartia imbricata	+	.	.	.	.	.	.	.
Rhododendron caucasicum	+	.	.	.	.	.	.	.
Salix kazbekensis	+	.	.	.	.	.	.	.
Thymus collinus	+	.	.	.	.	.	.	.
Vicia alpestris	+	.	.	.	.	.	.	.
Vicia grossheimii	+	.	.	.	.	.	.	.
Campanula biebersteiniana	.	+	.	.	.	.	.	.
Cephalaria gigantea	.	+	.	.	.	.	.	.
Cerastium arvense	.	+	.	.	.	.	.	.
Cruciata glabra	.	+	.	.	.	.	.	.
Cynoglossum officinalis	.	+	.	.	.	.	.	.
Draba hispida	.	+	.	.	.	.	.	.
Fritillaria lutea	.	+	.	.	.	.	.	.
Gentiana angulosa	.	+	.	.	.	.	.	.
Geranium ibericum	.	+	.	.	.	.	.	.
Linum hypericifolium	.	+	.	.	.	.	.	.
Myosotis arvensis	.	+	.	.	.	.	.	.
Oxytropis cyanea	.	+	.	.	.	.	.	.
Poa longifolia	.	+	.	.	.	.	.	.
Polygonum carneum	.	+	.	.	.	.	.	.
Primula amoena	.	+	.	.	.	.	.	.
Pyrethrum carneum	.	+	.	.	.	.	.	.
Ranunculus lojkae	.	+	.	.	.	.	.	.
Rhinanthus minor	.	+	.	.	.	.	.	.
Rumex acetosa	.	+	.	.	.	.	.	.
Rumex acetosella	.	+	.	.	.	.	.	.
Rumex alpinus	.	+	.	.	.	.	.	.
Scabiosa caucasica	.	+	.	.	.	.	.	.
Swertia iberica	.	+	.	.	.	.	.	.
Tragopogon reticulatus	.	+	.	.	.	.	.	.
Trollius ranunculinus	.	+	.	.	.	.	.	.
Matricaria caucasica	.	.	+	.	.	.	.	.
Cerastium multiflorum	.	.	.	+	.	.	.	.
Dentaria microphylla	.	.	.	+	.	.	.	.
Draba supranivalis	.	.	.	+	.	.	.	.
Jurinella subacaulis	.	.	.	+	.	.	.	.
Poa caucasica	.	.	.	+	.	.	.	.
Saxifraga moschata	.	.	.	+	.	.	.	.
Veronica telephiifolia	.	.	.	+	.	.	.	.

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Species in the Central Alps								
Leucanthemopsis alpina	.	.	.	.	+	+	+	+
Agrostis alpina	.	.	.	.	+	+	+	.
Agrostis rupestris	.	.	.	.	+	+	+	.
Cardamine resedifolia	.	.	.	.	+	+	+	.
Carex curvula	.	.	.	.	+	+	+	.
Festuca halleri	.	.	.	.	+	+	+	.
Huperzia selago	.	.	.	.	+	+	+	.
Oreochloa disticha	.	.	.	.	+	+	+	.
Phyteuma hemisphaericum	.	.	.	.	+	+	+	.
Primula hirsuta	.	.	.	.	+	+	+	.
Sedum alpestre	.	.	.	.	+	+	+	.
Cerastium uniflorum	.	.	.	.	.	+	+	+
Poa laxa	.	.	.	.	.	+	+	+
Ranunculus glacialis	.	.	.	.	.	+	+	+
Saxifraga bryoides	.	.	.	.	.	+	+	+
Agrostis agrostiflora	.	.	.	.	+	+	.	.
Avenula versicolor	.	.	.	.	+	+	.	.
Campanula scheuchzeri	.	.	.	.	+	+	.	.
Carex sempervirens	.	.	.	.	+	+	.	.
Cerastium fontanum	.	.	.	.	+	+	.	.
Deschampsia cespitosa	.	.	.	.	+	+	.	.
Gentiana acaulis	.	.	.	.	+	+	.	.
Geum montanum	.	.	.	.	+	+	.	.
Hieracium alpinum	.	.	.	.	+	+	.	.
Homogyne alpina	.	.	.	.	+	+	.	.
Juncus trifidus	.	.	.	.	+	+	.	.
Leontodon helveticus	.	.	.	.	+	+	.	.
Ligusticum mutellina	.	.	.	.	+	+	.	.
Loiseleuria procumbens	.	.	.	.	+	+	.	.
Luzula alpinopilosa	.	.	.	.	+	+	.	.
Potentilla aurea	.	.	.	.	+	+	.	.
Pulsatilla vernalis	.	.	.	.	+	+	.	.
Soldanella pusilla	.	.	.	.	+	+	.	.
Solidago virgaurea	.	.	.	.	+	+	.	.
Vaccinium uliginosum	.	.	.	.	+	+	.	.
Veronica bellidioides	.	.	.	.	+	+	.	.
Viola biflora	.	.	.	.	+	+	.	.
Rhododendron ferrugineum	.	.	.	.	+	.	+	.
Doronicum clusii	.	.	.	.	.	+	+	.
Erigeron uniflorus	.	.	.	.	.	+	+	.
Gentiana bavarica	.	.	.	.	.	+	+	.
Kobresia myosuroides	.	.	.	.	.	+	+	.
Minuartia sedoides	.	.	.	.	.	+	+	.
Minuartia recurva	.	.	.	.	.	+	+	.
Omalotheca supina	.	.	.	.	.	+	+	.
Primula glutinosa	.	.	.	.	.	+	+	.
Salix herbacea	.	.	.	.	.	+	+	.
Senecio incanus carniolicus	.	.	.	.	.	+	+	.
Silene acaulis exscapa	.	.	.	.	.	+	+	.
Veronica alpina	.	.	.	.	.	+	+	.
Draba fladnizensis	.	.	.	.	.	.	+	+
Achillea millefolium	.	.	.	.	+	.	.	.
Ajuga pyramidalis	.	.	.	.	+	.	.	.
Alchemilla alpina	.	.	.	.	+	.	.	.
Antennaria dioica	.	.	.	.	+	.	.	.
Arnica montana	.	.	.	.	+	.	.	.
Bellardiochloa violacea	.	.	.	.	+	.	.	.
Calamagrostis villosa	.	.	.	.	+	.	.	.
Calluna vulgaris	.	.	.	.	+	.	.	.
Campanula barbata	.	.	.	.	+	.	.	.
Cirsium spinosissimum	.	.	.	.	+	.	.	.
Coeloglossum viride	.	.	.	.	+	.	.	.
Crocus albiflorus	.	.	.	.	+	.	.	.
Crytogramma crispa	.	.	.	.	+	.	.	.
Diphasiastrum alpinum	.	.	.	.	+	.	.	.
Drypopteris dilatata	.	.	.	.	+	.	.	.
Empetrum hermaphroditum	.	.	.	.	+	.	.	.
Euphrasia rostkoviana	.	.	.	.	+	.	.	.
Festuca nigrescens	.	.	.	.	+	.	.	.
Gentiana punctata	.	.	.	.	+	.	.	.
Gentianella anisodonta	.	.	.	.	+	.	.	.
Geranium sylvaticum	.	.	.	.	+	.	.	.
Gymnocarpium robertianum	.	.	.	.	+	.	.	.
Hieracium glaciale	.	.	.	.	+	.	.	.
Hieracium intybaceum	.	.	.	.	+	.	.	.
Hieracium lactucella	.	.	.	.	+	.	.	.
Hieracium murorum	.	.	.	.	+	.	.	.
Hypochoeris uniflora	.	.	.	.	+	.	.	.
Juniperus communis alpina	.	.	.	.	+	.	.	.
Larix decidua	.	.	.	.	+	.	.	.
Laserpitium halleri	.	.	.	.	+	.	.	.
Lotus alpinus	.	.	.	.	+	.	.	.
Luzula lutea	.	.	.	.	+	.	.	.
Luzula luzuloides	.	.	.	.	+	.	.	.
Lycopodium clavatum	.	.	.	.	+	.	.	.
Molinia caerulea	.	.	.	.	+	.	.	.
Myosotis alpestris	.	.	.	.	+	.	.	.
Pedicularis tuberosa	.	.	.	.	+	.	.	.
Phegopteris connectilis	.	.	.	.	+	.	.	.
Phyteuma betonicifolium	.	.	.	.	+	.	.	.
Pinguicula vulgaris	.	.	.	.	+	.	.	.
Potentilla erecta	.	.	.	.	+	.	.	.
Pulsatilla alpina apiifolia	.	.	.	.	+	.	.	.
Rhinanthus aristatus	.	.	.	.	+	.	.	.
Rosa pendulina	.	.	.	.	+	.	.	.
Saxifraga aspera	.	.	.	.	+	.	.	.
Selaginella selaginoides	.	.	.	.	+	.	.	.
Sempervivum montanum	.	.	.	.	+	.	.	.
Silene rupestris	.	.	.	.	+	.	.	.
Silene vulgaris	.	.	.	.	+	.	.	.
Thesium alpinum	.	.	.	.	+	.	.	.
Thymus praecox polytrichus	.	.	.	.	+	.	.	.
Trifolium alpinum	.	.	.	.	+	.	.	.
Urtica dioica	.	.	.	.	+	.	.	.
Veronica chamaedrys	.	.	.	.	+	.	.	.
Veronica fruticans	.	.	.	.	+	.	.	.
Veronica officinalis	.	.	.	.	+	.	.	.
Viola sp.	.	.	.	.	+	.	.	.
Achillea moschata	.	.	.	.	.	+	.	.
Antennaria carpatica	.	.	.	.	.	+	.	.
Arenaria biflora	.	.	.	.	.	+	.	.
Pedicularis kerneri	.	.	.	.	.	+	.	.
Sibbaldia procumbens	.	.	.	.	.	+	.	.
Sorbus aucuparia	.	.	.	.	.	+	.	.
Androsace alpina	.	.	.	.	.	.	+	.
Cardamine alpina	.	.	.	.	.	.	+	.
Draba dubia	.	.	.	.	.	.	+	.
Gentiana brachyphylla	.	.	.	.	.	.	+	.
Koeleria hirsuta	.	.	.	.	.	.	+	.
Linaria alpina	.	.	.	.	.	.	+	.
Lloydia serotina	.	.	.	.	.	.	+	.
Potentilla frigida	.	.	.	.	.	.	+	.
Saxifraga oppositifolia	.	.	.	.	.	.	.	+

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