Plant communities along an elevation gradient under special consideration of grazing in Western Mongolia

by Anne ZEMMRICH, Greifswald, Germany, Werner HILBIG, Petershausen, Germany, and Damdinsürengiyn OYUUNCHIMEG, Khovd, Mongolia

with 4 figures and 12 tables

Abstract. Plant communities of semidesert, mountain steppe and alpine vegetation are described in terms of distribution and edaphic conditions along an elevation gradient from the Great Lake Basin to the Central Mongolian Altai in Western Mongolia. References to the Russian classification terminology of corresponding vegetation belts are included. Two new associations and further subassociations are also introduced. The impact of grazing on the presented communities is analysed in a comparable approach along the elevation gradient of decreasing aridity. While no obvious grazing response was detectable in the semidesert vegetation, mountainous vegetation revealed grazing-mediated communities characterised by survivors of the original associations and grazing indicators, by grazing-induced xerophytisation of the vegetation cover and an increasing spatial extent of grazing impact with rising elevations. Evolutionary history reflecting the adaptation of arid and semi-arid ecosystems to grazing and the effective adaptation of management practices to the phenology patterns of vegetation are proposed as important factors of limited grazing impact on arid semidesert vegetation of the study area.

Keywords: alpine vegetation, mountain steppe, non-equilibrium theory, pastoralism, Russian classification terminology, semidesert, xerophytisation.

Introduction

Western Mongolia exemplifies a gradual transition from landscapes of the Great Lake Basin to those of the Mongolian Altai. Wetland vegetation occurs at lakeshores, semideserts in the plains followed by mountain steppes and alpine vegetation at higher altitudes. Within a range of just 150 km multiple plant communities of different vegetation belts can be observed.

Since the process of transformation towards market economy and democracy ensued in 1992, fundamental changes in mobile pastoralism and pastoral land use patterns in Mongolia have taken place. The number of herders and livestock increased significantly due to the disbandment of cooperatives and the privatization of their livestock which was supported by climatically favourable conditions of high rainfall at that time. The subsequent cancellation of grazing rules has resulted in reduced mobility among pastoralists and regional unsustainable grazing patterns especially around settled areas. These developments pose a threat to regional vegetation as a major natural resource (JANZEN & BAZARGUR 2003, JANZEN 2005). Furthermore, the isolation of Western Mongolia, that has so far beneficially protected the region, is now being jeopardised by the construction of the “Millennium road” which will link Western and Central Mongolia.

The vegetation of Western Mongolia has been extensively described in the traditional Russian approach based on dominant species (e.g. Evstifeev & Rachkovskaya 1991, Buyan-Orshikh 1992, Volkova 1994, Oyuunchimeg 1998, Beket 2003). However, access to these publications is difficult due to language barriers and little is known about the Russian terminology for the classification of Central Asian vegetation. Phytosociological investigations, focusing on the Uvs Nuur Basin and the adjacent Kharkhiraa mountain complex, were conducted by Hilbig et al. (1984, 1989, 1999), Hilbig & Koroljuk (2000) and Sommer & Treter (1999). In two early papers, Hilbig & Schamsran (1977, 1981) provided reports on wetland, floodplain and semidesert vegetation of the Khovd-gol area in the southern part of the Great Lake Basin. A recent description of the wetland vegetation of Khar Us Nuur was provided by Strauss (2004). However, phytosociological descriptions especially of the central parts of the Mongolian Altai are still missing.

The impact of grazing on vegetation that resulted from recent developments in Mongolia has been examined in several studies: Fernandez-Gimenez & Allen-Diaz (1999, 2001), Stumpp et al. (2005) and Sasaki et al. (2008) examined variables of vegetation structure and soil along grazing gradients on the basis of statistical analyses in Central and Southern Mongolia. In a comparative study Retszer (2004) and Weische & Retzer (2005) used exclosure experiments for testing the influence of grazing and precipitation in high and low rainfall years. The impact of different grazing regimes on plant functional groups, pro-
ductivity and on plant nutrients in a mountain forest steppe was analysed by Tserendash & Erdenebaatar (1993) and van Stalduinen et al. (2007). These studies revealed limited changes of vegetation in arid and semi-arid grasslands under grazing impact while in steppe and mountain steppe grazing pressure represented a driving factor of species composition.

The limited grazing responses of semi-arid rangelands are generally explained by its non-equilibrium dynamics predicting that highly variable rainfall is of more importance for productivity and species composition as exemplified by Wesche & Retzer (2008). Thus abiotic environmental factors exert a greater influence on the dynamics of plant communities than herbivore grazing. In contrast, under conditions of more homogenous rainfall, vegetation and livestock are in equilibrium, a stable carrying capacity of the ecosystem is supported and grazing pressure rather than abiotic environmental conditions have an impact on vegetation dynamics (Vetter 2005). So far, previous research largely focused on temporal vegetation dynamics. A comparative analysis of grazing-mediated vegetation change on the basis of existing phytosociological classification is still missing.

The present study constitutes an overview of typical plant communities found in the elevation belts ranging from semideserts in the Great Lake Basin to alpine vegetation in the central part of the Mongolian Altai. The newly described associations are intended to complete Hilbig’s classification of Mongolia’s vegetation (Hilbig 1990, 1995, 2000). Furthermore, this study provides a short outline of the Russian classification terminology of corresponding vegetation belts. Finally, it analyses the grazing impact on presented plant communities based on the phytosociological classification in a comparative approach along the elevation gradient of decreasing aridity. It will test whether potential grazing impact is explicitly to derive on the basis of floristically, clearly defined associations especially in arid semideserts. Moreover, it identifies typical patterns of floristic changes under grazing in the presented vegetation belts.

**Study area**

**Geography and climate**

Situated in the northern part of the Western Mongolian province of Khovd, the study area covers landscapes in the southern part of the Khyargas Nuur Basin, one of the three drainless basins which form the Great Lake Basin, and parts of the adjacent Mongolian Altai. A set of larger and smaller lakes in the eastern part of the study area shapes a network of interconnected freshwater lakes with wetland vegeta-

Fig. 1. Geographical location of the study area: 48°00’N, 91°05’E and 48°23’N, 93°10’E (Sources: Kretschmer 2004, modified).
Plant communities along an elevation gradient, surrounded by softly undulating pediments of adjacent mountain ranges such as e.g. Argalant and Zhargalant Mts. (Fig. 1). The extended pediment area of prevailing sandy and gravelly soils, covered by semideserts, is shaped by salt pans, small hills and dry river valleys sporadically bearing water. In a short distance of 20 to 50 km from the western shore of the lake Khar Us Nuur to the west, the pediment area merges into a steeply inclined mountain foreland and further into mountain ranges of the Mongolian Altai covered by mountain steppes and alpine vegetation (Fig. 2). The mountainous area consists of separate ridges in latitudinal arrangement divided by intermountain depressions or connected by passes. The surface is covered by erosion debris predominantly consisting of granite and slate rock (MURZAEV 1954).

The Great Lake Basin and adjacent areas are located in a sheltered position surrounded by the Tannu Ola Mts. farther north, the Khangay Mts. in the east, the Gobi Altai in the south and ranges of the Mongolian Altai in the west creating an extremely continental and dry climate. Major daily and annual temperature fluctuations are typical (long-term annual amplitude of mean monthly temperature 41 K). The stable Siberian anticyclone causes long, cold and dry winters with mean January temperatures of –22 °C. Frost-free periods are only found in the plains between June and August. Winter precipitation is low, failing to create an isolating snow cover and providing access to vegetation for livestock. In winter extensive temperature inversions, involving warm airmass in the lower montane belt superimposed above cold airmass in the plains, lead to relatively warm conditions on the winter pastures at approx. 2000 m asl. In spring westerly winds carry warm and humid airmass, which rarely crosses the mountain barriers of the Mongolian Altai. Summers are short and warm with mean July temperatures of 19 °C. About 70–90% of annual precipitation occurs in summer, even though quantities may vary considerably over the years (see data in methods below). Since low total precipitation is accompanied by high evaporation rates, summer is generally characterised by arid conditions and summer drought in the plains. Spring and autumn are very short (BARTHÉL 1983, 1990, GUNIN et al. 1999, ZEMMRICH 2008).

The elevation gradient of the study area reveals a gradient of decreasing aridity shifting from arid conditions in the semidesert via semi-arid conditions in the montane belt to humid conditions in the alpine belt. This gradient is accompanied by a decreasing length of the vegetation period with mean daily temperatures above 10 °C varying from 83 days per year in the lowland, to 41 days in the montane belt, and 29 days in the alpine belt (climate data provided by the Climate Station Khovd 1983–2004).

**Material and methods**

392 Vegetation relevés were collected between 2002 and 2005 along the elevation gradient from the Argalant Mts. to the Tumtiyn Nuruu mountain range between 1150 m and 3050 m asl (Fig. 1). In the first and the third year of the study, 2002 and 2004, the sites received below average precipitation. The second year, 2003, was an extremely moist year (rainfall of 2002, 2003 & 2004: 77, 223 & 102 mm vs. mean annual precipitation of 128 mm according to Climate Station Khovd 1983–2004). Sampling sites were chosen with respect to homogeneity and representation. The size of vegetation relevés varied from 4 to 100 sqm, depending on plant density, homogeneity of vegetation cover and the size of homogenous spatial units. In each relevé, all vascular plant species were recorded according to the cover-abundance-scale of BRAUN-BLANQUET (1964) modified by WILMANNS (1998). Plants species were identified according to GRUBOV (2001) and validated in the ‘Mongolian Collection’ of the Institute of Geobotany and Botanical Garden, Martin Luther University Halle-Wittenberg, Germany (HAL). Identification of critical species was supported by specialists. To provide the recent state in the nomenclature of Mongolia’s vascular plants, we follow GUBANOV (1996).

Since Mongolia’s vegetation has been grazed since millennia and comprises an evolutionary history of grazing (MURPHEY 1989, PUREV 1991), the analysis of grazing impact needs a clearly justified explanation of grazing-caused vegetation. We use the category ‘grazing-mediated community’ for plant communities formed under a grazing pressure that (i) clearly...
exceeds the natural grazing intensity by wildlife and hence, (ii) indicates a clear-cut floristic change of diagnostically relevant perennial species compared to the original vegetation. As grazing intensity is hard to quantify on nomadic pasture land of Mongolia with free-roaming livestock, grazing impact was recorded along grazing gradients, extending from an animal corral or a water source to more distant areas. In the animal corrals, situated next to herder camps, sheep and goats are fenced for protection against wolves and cold and move daily from the herder camps to the pasture ground. Water sources concentrate numerous herds within a small area repeatedly, everyday. Thus, the transects from the corrals and water sources to the pastures far away represent long-term gradients of decreasing grazing intensity (FERNANDEZ-GIMENEZ & ALLEN-DIAZ 2001, STUMPP et al. 2005). Grazing transects in a length between 1300 and 3400 m were chosen within otherwise homogenous environmental conditions. We refrained from deriving independent associations of grazing-mediated vegetation as grazing may cause quite heterogeneous changes of species composition depending on grazing intensity.

Vegetation classification follows the sorted table approach of BRAUN-BLANQUET (1964). In the synoptic tables (Table 1, 4), species constancies are given in constancy classes (DIERSCHKE 1994). In case of less than 5 relevés, the absolute number of species occurrences is specified. To visualize floristic modifications and changes of grazing impact and for the purpose of further comparison, the species order of single vegetation relevés follows the synoptic tables containing the corresponding original associations (cf. e.g. Table 1, 2, 6). Some newly presented communities are described as associations or subassociations according to the International Code of Phytosociological Nomenclature (WEBER et al. 2000). The presented communities are arranged into a syntaxonomic overview at the end of the description.

The geographical position and altitude of all sample plots and animal corrals were recorded with a handheld GPS device; the distances to the next adjacent animal corrals were determined by a GIS system. For the purposes of comparison, soil types are provided in the internationally accepted terms (FAO 1998). Sampling and evaluation of soil samples are discussed by ZEMMRICH (2006); more detailed information on soil genesis and soil properties are to be found in ZEMMRICH (2008). Data on the palatability of plant species were taken from YUNATOV (1954) and JIGJIDSUREN & JOHNSON (2003).

Results

Introduction to semidesert vegetation

Semidesert vegetation in Mongolia is distributed from the Great Lake Basin across the foothills of the Mongolian Altai southwards to the Valley of Lakes, south of the Gobi Altay, in the Dzungarian Gobi and further to the southeast in the Transaltay Gobi and the Alashan Gobi. Within the study area, it occurs between 1150 m and 1800 m asl. According to the Russian terminology, semidesert is generally denominated as desert steppe (pustynnaya step) and divided into the northern desert steppe and the desert steppe sensu stricto (ZEMMRICH 2005). The northern desert steppe is situated north of desert steppe sensu stricto, whereas the latter forms the southern border of the Eurasian steppe zone with the Central Asian desert zone (YUNATOV 1974). Within the study area, the latitudinal order of vegetation zones is primarily modified by elevation and the related climatic gradients and does not clearly follow the common north-south pattern. Thus, in the SW edge of the Great Lake Basin in the transient area to the Mongolian Altai northern desert steppe is situated above the NE adjacent desert steppe belt.

The sparse vegetation cover of 10–30% is dominated either by dwarf semi-shrubs, bunch grasses and onion geophytes, or by shrubs. It facilitates erosion processes such as wind deflation with removal of the top soil layer in consequence of strong winds, appearing as hurricanes, thunderstorms, or gusts in spring (THIEL 1958, BARTHHEL 1990). Hence, annuals provide a typical feature especially of semidesert vegetation sensu stricto indicating disturbances such as wind erosion and intensive grazing. In high-rainfall years vegetation cover is enhanced up to 40–70% by the increasing dominance of annuals occurring late in the summer (LAVRENKO & KARAMYSHEVA 1993). Due to the unreliability of their occurrence, they have a low diagnostic value for the classification of vegetation.

YUNATOV (1950) and HILBIG (1995) distinguish shrub semideserts and low-growing Stipa-Allium semideserts. In the study area, the former are mainly characterised by shrubs such as Caragana leucopbloea and Krascheninnikovia ceratooides and occupy rocky sites and slopes where water recharge is enhanced. The latter occur on plain sites mainly representing run-off habitats. In both types, the transition from semidesert to steppe is indicated by subassociations introduced in the following paragraphs.

Low growing semidesert communities – Allion polyrrhizi Hilbig 2000

Artemisia xerophyticae-Stipetum glareosae ass. nov. hoc loco
(Table 1: 1; Table 2: holotypus relevé 177–03, Table 2: 7)

Stands of the association were found on sandy plains near the lake shore of Khar Us Nuur and Agyvash Uul peninsula at a lowest elevation of 1150 m asl in the study area on sandy Haplic Calcisol (Fig. 2, 3). The soil and the altitudinal location provide climatically and edaphically notably dry conditions accompanied by low microhabitat heterogeneity.
As differential species of the rarely occurring association, the psammophilous semi-shrub *Artemisia xerophytica* joins typical representatives of the Allion polyrrhizi such as *Allium mongolicum*, *Anabasis brevifolia* and *Stipa glareosa*. In high-rainfall years, annuals occur numerously and enhance the vegetation cover from 5–15% to 25–35%. Among them *Aristida heymannii*, *Eragrostis minor* and *Enneapogon borealis* are especially dominant. Hilbig (1995) described a closely related Artemisio xerophyticae-Caraganetum leucophloeae within the Khovd province found on slopes with shallow soils on rock outcrops. While the Artemisio xerophyticae-Stipetum glareosae harbours only low semi-shrubs and belongs to the Allion polyrrhizi, the Artemisio xerophyticae-Caraganetum leucophloeae is characterised by shrubs such as *Caragana leucophloea*, *Krascheninnikovia ceratoides* and *Atraphaxis frutescens* and belongs to the Caraganion leucophloeae.

The association is one of the most common semidesert communities distributed north and south of the Gobi-Altai from the Great Lake Basin and the Dzungarian Gobi to the East Gobi (Hilbig 1995, Wesche et al. 2005, Hilbig & Tungalag 2006). It occurs on pediments of gently sloping foreland between 1200 m and 1450 m asl on clayey Haplic Calcisol of high water retention capacity. It is characterised by the name-giving species: the dwarf semi-shrub *Anabasis brevifolia*, the feather grass *Stipa glareosa* and furthermore by the onion species *Allium mongolicum* and *Allium polyrrhizum*. In the Great Lake Basin and in the study area, *Allium polyrrhizum* is rare (see Table 1: 2) as already shown by Hilbig & Schamsran (1977). In the presented stands further diagnostic species of the Stipetae glareosae-gobicae join the association with only low frequency. The high rainfall of the sample year 2003 explains the high proportion of annuals.

Beside the typical subassociation (*Stipo glareosae-Anabasietum brevifoliae typicum* Hilbig 2009) the *Reaumuria songarica* subassociation (*Stipo glareosae-Anabasietum brevifoliae reaumurietosum songaricae* Hilbig 2009) occurs on sites of higher salinity, distinguished by the name-giving species.

Fig. 3. Stand of the Artemisio xerophyticae-Stipetum glareosae with *Artemisia xerophytica* (left) and *Stipa glareosa* (right in the front) (Photo: M. Schnittler 2003).
Table 1. Synoptic table of semidesert communities in the southern part of the Great Lake Basin and in the lower parts of adjacent mountain ranges of the Mongolian Altai.

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<thead>
<tr>
<th>Column</th>
<th>1</th>
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<th>4</th>
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<tr>
<td>Mean species number per relevé</td>
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<td>10</td>
<td>10</td>
<td>10</td>
<td>23</td>
<td>19</td>
<td>17</td>
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<tr>
<td>Number of relevés</td>
<td>23</td>
<td>69</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>20</td>
<td>40</td>
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</table>

**Diagnostic species of Stipetalia glareosae-gobicae & Allion polyrrhizae**

- *Anabasis brevifolia* - I, V, V
- *Stipa glareosa* - V, IV, III, V, 2, V, V
- *Allium mongolicum* - I, V, V, 2, V, +
- *Gypsophila desertorum* - ., II, I, V, 1, II, V
- *Arnebia guttata* - ., I, +, 1, V, r
- *Astragalus monophyllus* - I, I,+, ., ., +
- *Dontostemon senilis* - ., I, ., ., 1, V, r
- *Lagochilus ilicifolius* - ., I, ., 1, IV, .
- *Asterothamnus heteropappoides* - ., II, +, V, 1, r, II
- *Neopallasia pectinata* - ., III, II, ., 2, I, +
- *Plantago minuta* - ., +, ., 1, II, .
- *Convolvulus ammani* - ., ., ., V, ., III
- *Iris tenuifolia* - ., ., IV, ., ., II
- *Potentilla australis* - ., ., ., ., ., ., III
- *Scutellaria grandiflora* - ., ., ., ., ., ., II
- *Youngia tenuicaulis* - ., r, +, ., 1, III, .
- *Cleistogenes songorica* - ., r, ., ., ., II
- *Scorzonera pseudodivaricata* - ., r, ., ., 2, III, .
- *Panzerina lanata* - ., ., ., 1, r, .
- *Eltyria nevski* - ., ., ., r, .

**Diagnostic species of Artemisia frigida** subass. of Allio polyrrhiz - Stipetum glareosae and Oxytropidi aciphyllae-

**Caraganetum leucophloeae**

- *Stipa krylovii* - V
- *Cleistogenes squarrosa* - ., ., +, V, ., ., V
- *Allium anisopodium* - ., ., IV, ., ., V
- *Phlctrichum canescens* - ., ., ., ., ., II
- *Pulsatilla bungeana* - ., ., I, ., ., II
- *Kochia prostrata* - ., ., ., V, ., r
- *Artemisia frigida* - ., ., I, ., ., V
- *Poa attenuata* - ., ., ., ., +
- *Bupleurum bicaule* - ., ., ., r

**Diagnostic species of Cleistogenetea squarrosae**

- *Agropyron cristatum* - ., ., ., II, ., ., V
- *Koeleria cristata* - ., ., ., ., ., ., II
- *Dontostemon integrifolius* - ., ., ., ., IV, .
- *Dracocephalum fruticosum* - ., ., ., ., ., II

**Differential species of Artemisia frigida** subass. of Allio polyrrhiz - Stipetum glareosae and Oxytropidi aciphyllae-

**Reaumuria songarica**

- *Artemisia frigida* - V

**Differential species of Reaumuria soongorica** subass. of Stipo glareosae-Anabasietum brevifolii

**Reaumuria songarica**

- *Prunus pedunculata* - ., ., ., ., 2, .
- *Caragana leucophloea* - ., r, ., 2, V, V
- *Krascheninnikovia ceratoides* - ., ., ., 2, V, I
- *Ajania fruticosus* - ., r, ., 2, I, II
- *Convolvulus gortschakovi* - ., ., ., 1, II, .
- *Atraphaxis pungens* - ., ., ., ., ., I
- *Caragana bungei* - ., ., ., ., ., +
Plant communities along an elevation gradient

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<td>Aristida heymannii</td>
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<td>V</td>
<td>V</td>
<td>.</td>
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<td>IV</td>
<td>V</td>
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<td>V</td>
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<td>Euphorbia humifusa</td>
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<td>Tribulus terrestris</td>
<td>III</td>
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<td>Salsola collina et tragus</td>
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<td>Chenopodium album agg.</td>
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<td>Chenopodium hybridum</td>
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<td>Bassia dasyphylla</td>
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<td>Corispermum mongolicum</td>
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<td>Setaria viridis</td>
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<td>Agrophyllum pungens</td>
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<th>Further species</th>
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<td>Orostachys thyrsiflora</td>
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<td>Echinops gmelini</td>
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<td>Astragalus cf. grubovii</td>
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<td>Artemisia macrocephala</td>
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<td>Euphorbia mongolica</td>
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<td>Ephedra cf. sinica</td>
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<td>Androsace maxima</td>
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<td>Craniospermum mongolicum</td>
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<td>Stellaria amblyosephala</td>
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<td>Scorzoneria ikonnikovii</td>
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<td>Artemisia cf. schischkinii</td>
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<td>Chenopodium vulvana</td>
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<td>Schizonepeta annua</td>
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<td>Zygophyllum pterocarpum</td>
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Further in column 1: Astragalus cf. kurtschumensis r, Saussurea pricei r
4: Oxytropis cf. micrantha I
5: Carex duriuscula III
7: Astragalus cf. brevifolius +, Astragalus cf. kurtschumensis I, Astragalus cf. laguroides r, Astragalus vallestris r, Carex duriuscula III, Clausia aprica r, Ephedra przewalskii r, Ertrichium thymifolium r, Gueldenstaedtia monophylla I, Halogoniet glomeratus r, Lappula cf. stricta r, Nitraria sibirica r, Silene spec. +, Stellaria dichotoma I, Vicia costata r, Vincetoxicum sibiricum +

Column:
1 - Artemisio xerophyticae-Stipetum glareosae
2 - Stipo glareosae-Anabasietum brevifolii typicum
3 - Stipo glareosae-Anabasietum brevifolii reaumurietosum songaricae
4 - Allio polyrrhizi - Stipetum glareosae artemisietosum frigidae
5 - Amygdalo pedunculatae-Caraganetum leucophloeae
6 - Oxytropidi aciphyllae Caraganetum leucophloeae typicum
7 - Oxytropidi aciphyllae-Caraganetum leucophloeae artemisietosum frigidae
| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|--------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Relevé no. | 183-609-03 | 179-181-03 | 172-173-174-175-176-177-178-454-464-122-123-124-182-458-455-131-133-129-128-03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 | 03 |
| Total vegetation cover in % | 35 15 30 20 25 30 30 35 10 10 35 20 30 15 10 10 25 10 15 5 15 10 10 |
| Species number per relevé | 9 11 15 12 11 11 14 14 14 9 9 9 8 8 9 6 11 7 8 5 6 6 7 |

### Diagnostic species of Stipetea glareosae-gobicae & Allion polyrrhizi

| Species | 2a | 2a | 2b | 2a | 2b | 2b | 2b | 2a | 2m | 2a | 2b | 2a | 2m | 2a | 2a | 1 2a | 2m |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Anabasis brevifolia | r | + | + | + | + | + | 1 | 1 | + | . | . | . | . | . | . | . | . | . |
| Stipa glareosa | 2a | 1 | 2a | 2m | 2m | 1 | 2m | + | 1 | 1 | 3 | 2m | 1 | 1 | 1 | 2a | 2m | 1 | 2a | 1 | 1 | 2a | 2m |
| Allium mongolicum | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Artemisia caespitosa | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Astragalus monophyllus | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |

### Differential species of Artemisio xerophyticae-Stipetum glareosae

| Species | 2m | 1 | 2m | 1 | 2m | 1 | 2a | 2a | 1 2a | 2a | 2m | 1 | 1 | 2a | 1 | 2a | 1 | 2a | 2m |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Artemisia xerophytica | 2m | 1 | 2a | 2b | 2a | 2b | 2b | 2b | 2a | 2m | + | + | + | + | + | + | + | + | + | + | + | + |
| Eragrostis minor | + | + | + | + | + | + | + | 2m | . | . | . | + | + | + | + | + | + | + | + | + |
| Enneapogon borealis | + | + | + | + | 2m | + | + | 2m | . | . | . | + | + | + | . | + | 2m | + | . | . | . | . |
| Lappula intermedia et granulata | . | . | + | + | + | + | + | + | r | . | + | + | + | + | + | + | + | + | + | + | + | + |
| Micropeplis arachnoidea | . | . | + | r | 2a | 2m | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Tribulus terrestris | + | + | + | + | + | 2a | . | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Erodium tibetanum | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |

### Summer annual disturbance indicators

| Species | 2m | 1 | 2m | 1 | 2m | 1 | 2a | 2a | 1 2a | 2a | 2m | 1 | 1 | 2a | 1 | 2a | 1 | 2a | 2m |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Salsola collina et tragus | + | + | r | . | + | + | + | 2m | + | + | . | + | + | + | + | + | + | + | + | + | + | + | + |
| Chenopodium aristatum | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Bassia dasyphylla | + | + | + | 2m | + | + | 1 | + | + | + | + | + | + | + | r | + | + | + | + | + | + | + | + |
| Corispermum mongolicum | + | + | + | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Agriophyllum pungens | + | + | + | 2m | . | + | + | . | + | + | + | + | + | + | r | 1 | . | + | + | + | + | + | + |

### Further species

| Species | 2m | 1 | 2m | 1 | 2m | 1 | 2a | 2a | 1 2a | 2a | 2m | 1 | 1 | 2a | 1 | 2a | 1 | 2a | 2m |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Echinops gmelinii | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| Astragalus cf. grubovii | + | + | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Artemisia cf. schischkinii | + | + | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Astragalus cf. kurtschumensis | + | + | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Saussurea pricei | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
**Shrub semidesert communities – Caragana leucophloeae Hilbig 2000**

_Amygdalo pedunculatae-Caraganetum leucophloeae Hilbig (1987) 1990_  
(Table 1: 5)

The association, designated by shrubs and semishrubs, is recorded by only two relevés. Hilbig (1995) described it for the Khovd-gol region of the Great Lake Basin and the Valley of Lakes and WESCHE et al. (2005) for the outskirts of the Gobi Altai. In the study area, it covers the large area between the lower part of the Argalan Mts. and the lakes Khor Us Nuur and Khor Nuur. It is furthermore found in the transition from the Great Lake Basin to the Mongolian Altai west of Khovd and the lakes Khor Us Nuur. In the present paper, we provide only records of the _Artemisia frigida_ subassociation ( _Allio polyrrhizi-Stipetum glareosae_ Hilbig 2009) from the foreland of the Mongolian Altai west of Khovd city between 1400 m and 1500 m asl in which the name-giving species is only rare. Compared to the _Stipo glareosae-Anabasietum brevifoliae_, the sites of higher elevations represent climatically less dry conditions and comprise sandy Haplic Calcisol and Eutric Arenosol allowing water percolation. The name-giving species _Allium polyrrhizum_ in contrast to _Allium anisopodium_ occurs only rarely in the study area (HILBIG & SCHAMRSAN 1977) and is missing in the presented relevés.

The differential species of the _Artemisia frigida_ subassociation such as _Agropyron cristatum, Allium anisopodium, Cleistogenes squarrosae_ and _Kochia prostrata_ are typical species of the steppe vegetation. This subassociation indicates the transition to the mountain steppe belt and occurs above the typical subassociation. The low number of annuals reflects the low rainfall of the sample year in 2002.

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### Table 3. Nomenclatural typus relevés of the Oxytropidi aciphyllae-Caraganetum leucophloeae typicum sub-ass. nov. hoc loco (Column 1; after Hilbig 1990) and of the Oxytropidi aciphyllae-Caraganetum leucophloeae artemisietosum frigidae subass. nov. hoc loco (Column 2). Note, that in the asterisk labelled relevé the original scale of Braun-Blanquet (1964) is used. 2-03: province Khovd, district Khovd, 1594 m asl, 48.1033 N, 91.4915 E (WGS 84), 16 sqm, 10.07.2003, total cover 20%.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
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<tr>
<td>Relevé no.</td>
<td>155a/74</td>
<td>2-03</td>
</tr>
<tr>
<td>Shrub cover in %</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Herb cover in %</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Species number per relevé</td>
<td>14</td>
<td>19</td>
</tr>
</tbody>
</table>

**Diagnostic species of Stipetea glareosae-gobicae & Allion polyrrhizi**

- _Stipa glareosa_
- _Gypsophila desertorum_ +
- _Asterothamnus heteropappoides_ . +
- _Convolvulus ammanni_ +

**Diagnostic species of Cleistogenetum squarrosae**

- _Agropyron cristatum_ +
- _Dontostemon integrifolius_ + .
- _Dracocephalum fruticosum_ .

**Diagnostic species of Caraganion leucophloeae**

- _Caragana leucophloeae_ 3 2m
- _Krascheninnikovia ceratoidea_ + . r
- _Guldenstaedtia monophylla_ 1 +
- _Caragana bungei_ . r

**Summer annual disturbance indicators**

- _Salsola collina et tragus_ .
- _Corispermum monotricum_ .

**Further species**

- _Ephedra spec._ 1 .
- _Chamaerhodos erecta_ 1 .
- _Heteropappus spec._ + .
- _Dracocephalum foetidum_ + .
- _Carex duriauscula_ .
- _Stellaria dichotoma_ .
The Oxytropidi aciphyllae-Caraganetum leucophloeae association, first documented by Hilbig & Schamsran (1977) for the Khovd region, is common in the study area and inhabits dry valleys of middle and upper pediments of mountain forelands (Fig. 4). Those valleys, irregularly flooded by water, temporarily provide an enhanced ground water and enabling the establishment of shrubs. Furthermore, these habitat conditions cause temporary disturbances by scree erosion which supports annual disturbance indicators. Moreover, in the transition to the Mongolian Altai the association is distributed in areas with steep slope inclination. Due to these habitat features, the community grows on gravelly Petric Gypsisol and sandy Haplic Calcisol. The resulting high microhabitat diversity causes the high number of species.

Among diagnostic species of the association, *Oxytropis aciphylla* is missing in the stands we recorded. However, remaining species allocate the stands to the Oxytropidi aciphyllae-Caraganetum leucophloeae. Dominating shrubs are *Krascheninnikovia ceratoides* and *Caragana leucophloeae*, covering 15–30%. Both shrubs benefit from groundwater by means of their long branchless taproot (Baytulin 1993) and erosion, reducing the interspecific competition (Lavrenko 1957). In the herb layer, covering 10–40%, low-growing semidesert species of the Stipetea glareosae-gobicae are abundantly present in the typical subassociation. It is distributed across an elevation range from 1200 m to 1700 m asl. The high number of annuals was caused, among other factors, by the high rainfall of the sampling year 2003. Furthermore, it represents the floristic response to erosive disturbances (Table 1: 6).

In addition to the Oxytropidi aciphyllae-Caraganetum leucophloeae typicum subass. nov. hoc loco, which is represented by the nomenclatorial typus of the association published in Hilbig 1990 (holotypus 155a/74, Table 3: 1), we describe an *Artemisia frigida* subassociation, Oxytropidi aciphyllae-Caraganetum leucophloeae artemisietosum frigidae subass. nov. hoc loco (holotypus relevé 2–03, Table 3: 2). Similar to the *Artemisia frigida*, subassociation of the Allio polyrrhizi-Stipetum glareosae, denotes the transition to the mountain steppe belt: In its stands, most of the characteristic semidesert species of Stipetea glareosae-gobicae provide a lower constancy and are partly replaced by steppe species of Stipion

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**Fig. 4.** Stand of the Oxytropidi aciphyllae-Caraganetum leucophloeae in a dry river valley within the Great Lake Basin with the Mongolian Altai in the left background (Photo: M. Kretschmer 2003).


**Introduction to mountainous vegetation**

Due to the extremely continental climate, the study area is situated in the semidesert zone reaching their maximum northern extent in the northern part of the Great Lake Basin, in the Uvs Nuur Basin (Karamysheva et al. 1986, Hilbig et al. 1999). Hence, the vegetation belts in the Mongolian Altai are located at much higher elevations than corresponding belts in the Great Lake Basin, in the Uvs Nuur Basin (Karamysheva et al. 1986, Hilbig et al. 1999). It is dominated by perennial bunch grasses. Summer annuals are only abundant in moist years. While mountain slopes farther to the north differ with Larix sibirica forests on north-facing slopes and meadow steppes on south-facing slopes (Hilbig 1995), mountain steppes of the study area do not show obvious exposure-related differences, neither regarding the occurrence of different vegetation types nor plant communities, and forests are completely absent. In the transition to the upper montane belt between 2300 m and 2400 m asl, *Stipa krylovii* is replaced by Festuca lenensis and the proportion of grasses compared to herbs decreases. Hence, the meadow steppes, extending between 2300 m and 2600 m asl (Fig. 2), are determined by sedges and perennial grasses in combination with herbs. Vegetation cover attains 50–80% of the soil surface.

The alpine belt comprises alpine grass mats at the slopes of the lower alpine belt above 2600 m asl and alpine sedge mats in the wet bottom of alpine valleys. The vegetation of alpine grass mats covers between 30% and 80% depending on the density of boulders common in the alpine belt. Dominant species include sedges, medium-tall grasses and cushion plants. Sedges have a high share in vegetation cover but due to the dry conditions the high proportion of perennial grasses persists. It determines the steppe character up to the alpine belt (Polyanov cited in Yunatov 1950, Buyan-Orshikh 1992) prompting Russian and Mongolian botanists to denominate that vegetation type as cryophyte steppe (Volkova 1994). In close contact to the alpine grass mats, sedge mats are distributed at valley bottoms and further habitats of water surplus. They indicate a dense vegetation cover. Less dense cover values of vegetation between 65 and 80% must be attributed to boulders and rocks loosely distributed. Species of the genera Carex and Kobresia are dominant.

The high alpine belt between 3100 m and 3600 m asl is covered by cushion vegetation. Above 3700 m asl vegetation growth is almost completely limited in the nival belt (Volkova 1994, Hilbig 1995). The study area includes the lower alpine belt up to 3050 m asl.

**Montane belt**

Hedysaro pumili-Stipetum krylovii Hilbig (1987) 1990 corr. 1995 (Table 4: 1–3)

The montane belt of southern Mongolian mountains is covered by *Stipa* mountain steppes and meadow steppes except for rare relict birch forests surviving on few north-facing slopes (Hilbig 1995, Cermak et al. 2005). In the study area, mountain steppes cover plain mountain valleys, terraces and gentle slopes on sandy, gravelly Kastanozem between 1900 m and 2400 m asl. This association was described by Hilbig (1995) from the southern mountain regions of Mongolia (Gobi-Altai, southern part of the Mongolian Altai and Khangay); material from the Gobi-Altai was also collected by Wesche et al. (2005). The species composition is dominated by *Stipa krylovii* and further steppe grasses such as *Agropyron cristatum*, *Koeleria cristata*, *Poa attenuata* and *Festuca lenensis*. Also sagebrush species such as *Artemisia frigida*, *A. dolosa* and onion species such as *Allium anisopodium*, *A. eduardii* and *A. tenuissimum* belong to the diagnostic species of the association. The stands cover 15 to 40%. In our relevés the diagnostically important species *Astragalus brevifolius* and *Hedysarum ferganense* (*H. pumilum*) are only partly found. However, we consider their inclusion into the *Hedysaro pumili-Stipetum krylovii* as the best decision until further studies can offer more extensive material for a conclusive review.

In the study area we distinguish three subunits:

The typical subassociation on plain sites with high proportions of fine soil fractions, the *Stellaria petraea* subassociation at inclined slopes of gravelly soils and a *Stipa glareosa* form at lower elevations below 1900 m asl. Even if the name-giving *Stellaria petraea* was not found in the study area, the contribution of further petrophilous differential species in the *Stellaria petraea* subassociation such as *Amblynotus rupestris*, *Arenaria capillaris* and *Rhinactinidia eremophila* is high (Grubov 2001, see Table 4: 3). In border areas to the semidesert vegetation differential species of the *Stipetea glareosae-gobicae* appear while species of higher elevated belts such as *Artemisia dolosa*, *Festuca lenensis* and *Poa attenuata* (Grubov 2001) are absent in the *Stipa glareosa* form. However, a conclusive syntaxonomic classification needs an overall revision of the mountain steppe vegetation.

Aster alpinus-Carex pediformis community (Table 4: 4, 5)

Herb rich meadow steppes of the *Helictotrichion schellianii*, as distributed in the lower montane belt in the North of Mongolia including the northern part of the Mongolian Altai (Hilbig 1995, Tuvshintogtokh 2005), are also, however rarely, met in the Gobi
### Table 4. Synoptic table of mountainous communities of the Mongolian Altai.

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<thead>
<tr>
<th>Column</th>
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<td>Number of relevés</td>
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<td>3</td>
<td>27</td>
<td>28</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

#### Diagnostic species of Cleistogenetea squarrosae

- *Poa attenuata*
  - IV
- *Koeleria cristata*
  - V
- *Agropyron cristatum*
  - IV
- *Carex duriuscula*
  - IV
- *Artemisia dolosa*
  - V
- *Bupleurum bicaule*
  - V
- *Potentilla multifida*
  - I
- *Potentilla bifurca*
  - r
- *Oxypotis cf. potanini*
  - II
- *Phlomoides tuberosa*
  - II
- *Dentostemon integrifolius*
  - I

#### Diagnostic species of Stipion krylovii

- *Stipa krylovii*
  - IV
- *Artemisia frigida*
  - II
- *Allium anisopodium*
  - I
- *Pilothrix canescens*
  - +
- *Leymus chinensis*
  - III
- *Scirpocoryne ikonnikovi*
  - II
- *Potentilla alba*
  - I
- *Oxytropis cf. ramosa*
  - +
- *Potentilla bungeana*
  - I
- *Oxytropis cf. micronata*
  - +
- *Allium edwardsii*
  - I

#### Differential species of Stipa glareosae form of Hedysaro pumili-Stipetum krylovii

- *Cleistogenes squarrosa*
  - V
- *Stipa glareosa*
  - V
- *Asterothamnus heteropappus*
  - I
- *Youngia tenella*
  - I

#### Differential species of Stellaria petraeae subass. of Hedysaro pumili-Stipetum krylovii

- *Amblynotus rupistris*
  - +
- * Arenaria capillaris*
  - r
- *Rhynchospora eremophila*
  - V
- *Chaenorehodos altaica*
  - II
- *Oxypotis tragacanthoides*
  - III
- *Orostachys spinosa*
  - +
- *Thalictrum foetidum*
  - II
- *Ferulopsis hystrix*
  - r
- *Stellaria dichotoma*
  - I
- *Smelowska alba*
  - +
- *Potentilla tenuifolia*
  - +
- *Clasusia aprica*
  - +
- *Draccephalum fructulosum*
  - r
- *Sibbaldianthe adpressa*
  - +
- *Ephedra cf. sinica*
  - +

#### Diagnostic species of Helictotrichion schellianii

- *Festuca lenensis*
  - V
- *Carex pediformis*
  - II
- *Aster alpinus*
  - V
- *Dianthus versicolor*
  - r
- *Potentilla sericea*
  - r
- *Aconogonon alpinum*
  - V
- *Silene repens*
  - V
- *Lychnis sibirica*
  - I
- *Senecio integrifolius*
  - II
- *Silene chamarrhensis*
  - III
- *Hedysarum ferganense*
  - I

#### Species with main distribution in the alpine belt

#### Diagnostic species of Oxytropidi oliganthae-Festucetum lenensis

- *Androsace chamaejasme*
  - V
- *Oxypotis oligantha*
  - r
- *Eritrichium pauciflorum*
  - V
- *Draba eriopoda*
  - r
- *Papaver pseudocanescens*
  - r
- *Stellaria brachypetala*
  - V
- *Arenaria meyeri*
  - V
- *Pachynerium grandiflorum*
  - V
- *Artemisia pycnorhiza*
  - l
- *EIytrigia geniculata*
  - V
- *Akepescus tunczinovii*
  - II
- *Allium amphibulum*
  - II
- *Plantago komarovi*
  - V
Plant communities along an elevation gradient

Unlike the typical meadow steppes of rich species composition in mountain massifs of Northern Mongolia they comprise species-poor stands characterised by typical meadow steppe species that have their southern boundary of distribution there.

In our study area those meadow steppes with typical species of the Helictotrichion schellianum extend to the upper montane belt between 2350 m and 2550 m asl and are recorded on Haplic Chernozems and Haplic Kastonzems. However, Helictotrichion schellianum was not found. As in the associations de-
scribed above, medium-tall Poaceae and Cyperaceae such as *Festuca lenensis*, *Koeleria cristata*, *Poa attenuata* and *Carex pediformis* constitute the base stock of the stands while annuals are almost completely missing. Typical herbs with the main distribution in meadow steppes are *Aster alpinus*, *Dianthus versicolor*, *Potentilla sericea*, *Aconogonon alpinum*, *Gentiana decumbens*, *Senecio integrifolius* and *Galium verum*. We assign the meadow steppe of our study area as a rankless *Aster alpinus-Carex pediformis* community with stands of a typical and of an *Amblynotus rupestrensis* subcommunity. The latter covers edaphically dri-
er, gravelly sites indicated by *Amblynotus rupestris*, *Chamaerhodos altaica* and *Oxytropis tragacanthoides* (Grubov 2001) as the differential species.

Alpine belt

*Oxytropidi oliganthae-Festucetum lenensis* ass. nov. hoc loco (Table 4: 6, 7; Table 5)

This grass-dominated association is distributed on well drained slopes and mountain-saddles of the lower alpine belt above 2600 m asl on humus rich Histic and Mollic Cryosol. It is characterised by a dense vegetation cover with medium-tall grasses such as *Festuca lenensis* and *Poa attenuata*, sedges such as *Carex rupestris* and cushion plants such as *Androsace chamaejasme*, *Arenaria meyeri* and *Oxytropis oligantha*. The dense vegetation actually covers only 70–85% due to commonly distributed boulders and boulder fragments. Further diagnostically important species of the alpine belt are represented by *Bistorta vivipara*, *Melandrium apetalum*, *Pachyneurum grandiflorum*, *Plantago komarovii*, *Ranunculus pedatifidus*, *Saxifraga sibirica* and *Stellaria brachypetala*. *Kobresia myosuroides* is present in a part of the relevés but with only low cover values.

We distinguish the *Oxytropidi oliganthae-Festucetum lenensis typicum* subass. nov. hoc loco (holotypus relevé 281–03, Table 5: 10) and the *Oxytropidi oliganthae-Festucetum lenensis stellarietosum pulvinatae* subass. nov. hoc loco (holotypus relevé 285–03, Table 5: 20). The latter is distinguished by the higher abundance of cushion plants and appears above 2700 m asl extending to higher altitudes than the typical subassociation. Differential species are *Saussurea leucophylla*, *Smelowskia mongolica* and the Altai endemic *Stellaria pulvinata*. They were already quoted by Hilbig (2000) for a rankless *Stellaria pulvinata* community of the Mongolian Altai above 3000 m asl. Those high elevations, commonly covered by distinct cushion communities on polygonal Cryosol soils, were not encountered in the study area. The association has a close relation to the communities of the *Rhodoletalia quadrifidae* regarding species composition and soil types. However, the relatively high proportion of grasses and elements of the *Kobresia* mats speaks for its placement in the *Kobresion myosuroidis*.

*Kobresietum myosuroidis* Mirkin et al. ex Hilbig 2000 (Table 4: 8, 9)

The *Kobresia* mats, generally known from various high mountains of Mongolia and from the lower alpine belt of the Khubsugul region (Hilbig 1995), are recorded in the study area on moist sites on Gelic Gleysol. While the lower alpine belt in the northern mountains of Mongolia is situated between 2000 m and 2300 m asl, in the study area and the farther southern mountains it raises to 2600 m and 2900 m asl (Yunatov 1950). The sites receive water surplus from adjacent mountain slopes during thawing periods in summer forming soils of high fine soil fractions. The predominantly closed vegetation cover is dominated by *Kobresia myosuroides*, *Carex melanthera* and *C. rupestris*. Besides the species of the *Kobresion myosuroidis*, further diagnostically important spe-

### Table 6. Relevés of the Artemisio xerophyticae-Stipetum glareosae impoverished by grazing.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
<tr>
<td>Relevé no.</td>
<td>610-</td>
<td>611-</td>
<td>605-</td>
<td>606-</td>
<td>612-</td>
<td>117-</td>
<td>614-</td>
<td>600-</td>
<td>601-</td>
<td>602-</td>
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<tr>
<td>Total vegetation cover in %</td>
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<td>3</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Species number per relevé</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

**Diagnostic species of Stipetea glareosae-gobicae & Allion polyrrhizi**

*Anabasis brevifolia*  
*Stipa glareosa* 1 1 1 1 2a 1 1 1 + +  
*Echinops gmelinii*  
**Summer annuals**

*Aristida heymannii* + + + + 2m 2m 2a + + +  
*Eragrostis minor* + . . . . . + + + +  
*Enneapogon borealis* . + . . . + + + +  
*Lappula intermedia et granulata* . . . . + + + +  
*Micropeplis arachnoidea* . . . . . + + +  
*Tribulus terrestris* . . . . . . + r + +  

**Summer annual disturbance indicators**

*Bassia dasyphylla* . . + + + + + + + +  
*Corispermum mongolicum* . . . + + + + + +  
*Agriophyllum pungens* . . . . + + + +  

...
cies of high frequency include *Arenaria meyeri*, *Oxytropis oligantha* and *Stellaria brachypetala*. Meadow steppes elements of the upper montane belt are only represented by *Festuca lenensis*.

In stands with a higher water supply *Kobresia smirnovii* and *Festuca kryloviana* additionally occur while species, common in the alpine belt, mainly disappear. *Kobresia smirnovii* indicates still moister sites than other species of *Kobresia* do (Volkova 1994). Furthermore, species of alpine wet sites such as *Ranunculus pseudohirculus* and *Saxifraga hirculus*, only occasionally occurring in *Kobresia* mats, are more frequent here. We can thus distinguish a typical and a *Kobresia smirnovii* form of the association. In case of more substantial relevé material, the *Kobresia smirnovii* stands might be assigned as a subassociation of the *Kobresietum myosuroidis*.

### Grazing impact on plant communities of semidesert vegetation

Grazing impact on semidesert communities was not very pronounced. While in the animal corrals the vegetation cover was completely destroyed, outside the corrals we could not find separate grazing-mediated plant communities except in the transition area from semidesert to groundwater affected vegetation (see *Chenopodium album* community below, Table 8). Minor grazing-related floristic changes were detectable however. Table 6 presents stands of the *Artemisia xerophyticae-Stipetum glareosae* under grazing influence, indicating an apparent species loss as a result of the low frequency of the majority of diagnostic species (cf. Table 2 with Table 6). Like the original association, the stands were dominated by *Stipa glareosa* with reduced cover values. Further diagnostic species such as *Artemisia xerophytica*, *A. caespitosa* and *Allium mongolicum*, palatable to sheep and goats during autumn and winter, completely disappear. The diagnostic species of the original association *Anabasis brevifolia*, less palatable due to a distinctive taste, was only rarely found. However, the low species number of the grazed stands was furthermore caused by the low rainfall of the sampling year 2005 in contrast to the moist sampling year of the pristine stands in 2003. The stands occurred only locally in a close vicinity of up to 50 m distance from

<table>
<thead>
<tr>
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<th>4</th>
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<td>188-03</td>
<td>185-03</td>
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<td>Species number per relevé</td>
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<td>18</td>
<td>14</td>
<td>16</td>
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</tbody>
</table>

### Diagnostic species of Stipetea glareosae-gobicae & Allion polyrrhizi

<table>
<thead>
<tr>
<th>Species</th>
<th>Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anabasis brevifolia</em></td>
<td>2m 2m</td>
</tr>
<tr>
<td><em>Stipa glareosa</em></td>
<td>r</td>
</tr>
<tr>
<td><em>Allium mongolicum</em></td>
<td>2m 2m r</td>
</tr>
<tr>
<td><em>Gypsophila desertorum</em></td>
<td>+ r</td>
</tr>
<tr>
<td><em>Astragalus monophyllus</em></td>
<td></td>
</tr>
<tr>
<td><em>Neopallasia pectinata</em></td>
<td>+ + + r</td>
</tr>
<tr>
<td><em>Plantago minuta</em></td>
<td>. + . r</td>
</tr>
<tr>
<td><em>Echinops gmelinii</em></td>
<td></td>
</tr>
</tbody>
</table>

### Summer annuals

<table>
<thead>
<tr>
<th>Species</th>
<th>Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aristida heymannii</em></td>
<td>+ + . .</td>
</tr>
<tr>
<td><em>Eragrostis minor</em></td>
<td>2m 2m</td>
</tr>
<tr>
<td><em>Enneapogon borealis</em></td>
<td>2m 2m</td>
</tr>
<tr>
<td><em>Lappula intermedia et granulata</em></td>
<td>+ + r</td>
</tr>
<tr>
<td><em>Kochia melanoptera</em></td>
<td>2a 2a 2b 2a</td>
</tr>
<tr>
<td><em>Tribulus terrestris</em></td>
<td></td>
</tr>
<tr>
<td><em>Senecio subdentatus</em></td>
<td>+ + . .</td>
</tr>
</tbody>
</table>

### Summer annual disturbance indicators

<table>
<thead>
<tr>
<th>Species</th>
<th>Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salsola collina et tragus</em></td>
<td>+ + 2m 2m</td>
</tr>
<tr>
<td><em>Chenopodium album agg.</em></td>
<td>2m + 2a 2a</td>
</tr>
<tr>
<td><em>Chenopodium aristatum</em></td>
<td>. + . .</td>
</tr>
<tr>
<td><em>Chenopodium acuminatum</em></td>
<td>r + + .</td>
</tr>
<tr>
<td><em>Bassia dasyphylla</em></td>
<td>r + r r</td>
</tr>
<tr>
<td><em>Axyris prostrata</em></td>
<td>2m + 2m 2a</td>
</tr>
</tbody>
</table>

### Further species

<table>
<thead>
<tr>
<th>Species</th>
<th>Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Chenopodium vulvaria</em></td>
<td>. . r</td>
</tr>
</tbody>
</table>
herder camps and water sources, which may explain even the loss of the less palatable species due to trampling.

In stands of the *Stipo glareosae-Ababas-
etum brevifoliae* within a distance of up to 100 m from animal corrals annual disturbance indicators such as *Bassia dasyphylla*, *Chenopodium album*, *Sal-
sola collina et tragus*, *Axyris prostrata* and the summer annuals *Senecio subdentatus* and *Kochia melanoloptera* (GRUBOV 2001) more frequently occurred (cf. Table 7 with Table 1: 2). Disturbance indicators here rep-
resent typical species of open semidesert vegetation, which usually occur in habitats of natural distur-
ances such as dry valleys periodically bearing water (Mong. sayr, Arab. wadi, Afrikaans rivier) or wind exposed sites. Under grazing impact they show an enhanced frequency explaining the enhanced species richness and vegetation cover (10 vs. 16 mean species number of relevés, 14% vs. 40% mean total cover of relevés). Dominant perennial semidesert species re-
mained almost unaffected except for the highly palat-
able, diagnostic *Stipa glareosa* which was found only in single patches. (cf. Table 1: 2 with Table 7). How-
ever, there was no proof of the reliable recurrence of the annuals under grazing influence since data were recorded in an extremely moist year and the occur-
rence of annuals depends on summer rain (LAVRENKO & KARAMYSHEVA 1993). As annuals have no diagnos-
tic values for syntaxonomy and these stands were recorded by single relevés, we regard these changes rather as a relatively weak response to grazing of a naturally variable semidesert community.

The *Chenopodium album-Salsola collina* com-
unity (Table 8) represents stands dominated by annual species of the Chenopodiaceae family. It grows on slightly saline sites of the *Glycyrrhizo uralen-
sis-Achnatheretum splendentis* indicating the transition from semidesert to groundwater depend-
ent vegetation. The *Glycyrrhizo uralensis-
Achnatheretum splendentis* is thus an element of the semidesert zone but represents a particular groundwater affected plant community of only local occurrence. These sites, providing water in an other-
wise dry environment, are used as camp locations for herders and animal corrals. They are area-wide heav-
ily grazed and trampled, therefore, we cannot present comparable less grazing-affected reference relevés. In addition, *Achnatherum splendens* vegetation may vary considerably depending on species composition of adjacent semidesert communities (cf. further rele-

**Grazing impact on plant communities of mountainous vegetation**

Unlike semidesert vegetation, mountainous vegeta-
tion displayed obvious changes under grazing impact reflected in distinct grazing-mediated plant commu-
nities (Table 9–12). Taxa of grazing-mediated com-
munities mainly represent survivors of the original associations plus disturbance indicators (e.g. *Salsolea*, *Bassia*), grazing-tolerant rhizomatous species (e.g. *Leymus, Carex duriuscula*), specialists of nutrient-
rich sites such as *Chenopodium album* and *Axyris prostrata* (FOULDS 1993) and species of low palatabil-
ity (e.g. *Oxytropis myriophylla*). Except for the sur-
vivors, they all show an enhanced competitive power under grazing pressure and trampling. In the pres-
ent paper they are summarised as grazing indicators (Table 9–12). The severity of grazing impact differs among the communities due to the differing access-
ibility to livestock (e.g. Table 9 and following).

In the lower montane belt, grazing impact leads to vegetation free sites of animal corrals on the one hand, but on the other hand, to high vegetation cover of annual weeds nearby as shown in Table 9. The *Leymus secalinus* community, growing in close vicinity, up to 30 m distance from animal corrals on sites of the *Hedysaro pumili-Stipetum kry-
lovii typicum*, indicates an almost complete spe-
cies turnover (cf. Table 9: 11–22 with Table 4: 2). It is dominated by *Chenopodium album*, benefiting from high N-concentration in soil (FOULDS 1993), and by the rhizomatous grazing-tolerant *Leymus secalinus*.

The *Leymus chinensis* community is found up to 50 m distant from corrals of winter camps at gravelly slopes (Table 9). It maintains a few more common species of mountain steppe compared to the *Leymus secalinus* community on plain sites due to the more difficult livestock access. However, it is dominated by short-living annuals such as *Chenopodium album*, *Axyris prostrata* and the grazing indicator *Leymus chinensis* (VAN STAALDUINEN 2005). The edaphic condi-
tions and the occurrence of *Leymus chinensis* and *Phlomoides tuberosa* indicate the close relationship of this community to the *Hedysaro pumili-Stiper-
tum krylovii stellarietosum petraeae* (ZEM-
MICH 2006). Both grazing-mediated communities present a mean vegetation cover of over 50%, caused by the high coverage of annual Chenopodiaceae and both *Leymus* species, versus the original associations with mean covers between 20% and 25%. Obviously visible grazing impact in the lower montane belt was recorded up to 100 m from animal corrals (own ob-
servations).

While in the lower montane belt grazing-mediat-
ed stands indicate higher vegetation cover than the original vegetation, in the upper montane belt graz-
ing-mediated vegetation demonstrates lower covers. Moreover, with rising elevation the response of veg-
etation to grazing and trampling is detectable across longer distances (see below). The *Agropyron crista-
tum* community is found in the upper montane belt on plain sites closely adjacent to the *Aster alpini-
Carex pediformis* community within a distance up to 200 m from herder camps (cf. Table 10 with Table 4: 4, 5). This community indicates a species impoverish-
ment and a lower vegetation cover compared to the original *Aster alpinus-Carex pediformis* community (mean vegetation cover per relevé 20% vs. 60% and
45%). Species composition includes species of the lower elevated montane belt such as *Agropyron cristatum* immigrating or comprising an increased frequency such as *Potentilla bifurca* and *Carex duriuscula*. Furthermore, very palatable and typical species of the *Aster alpinus-Carex pediformis* community such as *Poa attenuata*, *Festuca lenensis* and *Bupleurum bicaule* reveal a declining frequency. Obviously visible grazing impact in the upper montane belt was recorded up to 600 m from corrals of herder camps.

In the lower alpine belt, the *Axyris prostrata-Festuca lenensis* community was found directly adjacent to animal corrals on sites of the *Oxytropidi oliganthae-Festucetum lenensis* (Table 11). Common species of the latter association such as *Oxytropis oligantha*, *Stellaria brachypetala* and *Arenaria meyeri* disappeared or occurred at lower frequency. The mean vegetation cover dropped from 60% to 10–15%. Repeatedly, species of the lower montane belt such as *Dontostemon integrifolius*, *Sibbaldianthe adpressa* and *Axyris prostrata* occurred as grazing indicators with higher frequency than in the original *Oxytropidi oliganthae-Festucetum lenensis* (cf. Table 4: 1–3 with Table 5, 11). Grazing impact on slopes of the lower alpine belt was visibly recorded up to 100 m from animal corrals.

Grazing impact on *Kobresia* mats resulted in the grazing-mediated *Koeleria cristata* community on sites of the *Kobresietum myosuroidis*, which were recorded between 50 m and 800 m distant from animal corrals. Here, the diagnostic species of the *Kobresietum myosuroidis* such as *Bistorta vivipara* and *Carex melanantha* were missing (cf. Table 4: 8 with Table 12). Again species of the lower montane belts additionally occurred or were more abundant as grazing indicators, *Koeleria cristata*, *Carex duriuscula* and *Senecio integrifolius* (cf. Table 4: 1–4, 8 with Table 12). The proportion of annual disturbance indicators is only slightly increased. The additional annuals and species of lower elevations may compensate for the species loss. Thus, grazing-mediated modifications refer mainly to species composition while species number and vegetation cover are less affected (mean species number per relevé 16 vs. 18, mean total vegetation cover 91% vs. 96%).

In the following a syntaxonomic overview of the presented plant communities and their position in the phytosociological system of Mongolia’s vegetation according to Hilbig (2000, modified) and Hilbig (2009, modified) for subassociations is given. Classification levels are indicated as follows: C – Class, O – Order, L – Alliance, A – Association.

### Table 8. Grazing-mediated *Chenopodium album-Salsola collina* community on sites of the *Glycyrrhiza uralensis-Achnatheretum splendentis*.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevé no.</td>
<td>312-03 311-03 313-03 314-03 315-03</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>70</td>
<td>50</td>
<td>40</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Species number per relevé</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

**Summer annual disturbance indicators**

<table>
<thead>
<tr>
<th>Species</th>
<th>2m</th>
<th>2m</th>
<th>2m</th>
<th>2m</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salsola collina et tragus</em></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2m</td>
</tr>
<tr>
<td><em>Chenopodium album agg.</em></td>
<td>.</td>
<td>+</td>
<td>r</td>
<td>r</td>
<td>.</td>
</tr>
<tr>
<td><em>Chenopodium aristatum</em></td>
<td>2a</td>
<td>2a</td>
<td>2a</td>
<td>2m</td>
<td>+</td>
</tr>
<tr>
<td><em>Chenopodium acuminatum</em></td>
<td>.</td>
<td>.</td>
<td>r</td>
<td>2a</td>
<td>2a</td>
</tr>
<tr>
<td><em>Setaria viridis</em></td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>+</td>
<td>r</td>
</tr>
</tbody>
</table>

**Diagnostic species of Achnatherion splendentis**

<table>
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<tr>
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<th>.</th>
<th>.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achnatherum splendens</em></td>
<td>r</td>
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</table>

**Diagnostic species of Caraganion leucophloeae**

<table>
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<th>.</th>
<th>.</th>
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</tr>
</thead>
<tbody>
<tr>
<td><em>Krascheninnikovia ceratoidea</em></td>
<td>.</td>
<td>2a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
</tbody>
</table>
Table 9. Grazing-mediated *Leymus chinensis* community (Columns 1–10) near sites of the *Hedysaro pumili-Stipetum krylovii* stellarietosum petraeae and *Leymus secalinus* community (Columns 11–22) on sites of the *Hedysaro pumili-Stipetum krylovii* typicum. To highlight floristic differences among both communities, grazing indicators are compiled in an independent species group.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>Total vegetation cover in %</td>
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<td>60</td>
<td>50</td>
<td>60</td>
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<td>70</td>
<td>80</td>
<td>35</td>
<td>85</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Species number per relevé</td>
<td>22</td>
<td>18</td>
<td>19</td>
<td>13</td>
<td>9</td>
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<td>2</td>
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</tbody>
</table>

**Diagnostic species of Cleistogenetea squarrosae**

- Poa attenuata
- Koeleria cristata
- Agropyron cristatum
- Carex duriuscula
- Artemisia dolosa
- Bupleurum bicaule
- Phlomoides tuberosa
- Dontostemon integrifolius

**Diagnostic species of Stipion krylovii**

- Stipa krylovii
- Artemisia frigida
- Ptilotrichum canescens
- Scorzonera ikonnikovii
- Astragalus cf. brevifolius
- Allium tenuissimum
- Iris potaninii
- Oxytropis cf. microntha

**Diagnostic species of Stellaria petraeae subass. of Hedysaro pumili-Stipetum krylovii**

- Stellaria dichotoma

**Grazing indicators**

- Leymus chinensis
- Leymus secalinus
- Chenopodium album agg.
- Axyris prostrata
- Salsola collina et tragus
- Artemisia macrocephala
- Chenopodium acuminatum
- Chenopodium vulvaria
- Senecio dubitabilis
- Chenopodium aristatum

**Further species**

- Elytrigia nevskii
- Artemisia ruftolila
- Heteropappus hispidus
- Urtica cannabina

---

**Table 9. Grazing-mediated *Leymus chinensis* community (Columns 1–10) near sites of the *Hedysaro pumili-Stipetum krylovii* stellarietosum petraeae and *Leymus secalinus* community (Columns 11–22) on sites of the *Hedysaro pumili-Stipetum krylovii* typicum. To highlight floristic differences among both communities, grazing indicators are compiled in an independent species group.**

<table>
<thead>
<tr>
<th>Column</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<th>18</th>
<th>19</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total vegetation cover in %</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>60</td>
<td>55</td>
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<td>25</td>
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<td>55</td>
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<td>80</td>
<td>35</td>
<td>85</td>
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<tr>
<td>Species number per relevé</td>
<td>22</td>
<td>18</td>
<td>19</td>
<td>13</td>
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**Diagnostic species of Cleistogenetea squarrosae**

- Poa attenuata
- Koeleria cristata
- Agropyron cristatum
- Carex duriuscula
- Artemisia dolosa
- Bupleurum bicaule
- Phlomoides tuberosa
- Dontostemon integrifolius

**Diagnostic species of Stipion krylovii**

- Stipa krylovii
- Artemisia frigida
- Ptilotrichum canescens
- Scorzonera ikonnikovii
- Astragalus cf. brevifolius
- Allium tenuissimum
- Iris potaninii
- Oxytropis cf. microntha

**Diagnostic species of Stellaria petraeae subass. of Hedysaro pumili-Stipetum krylovii**

- Stellaria dichotoma

**Grazing indicators**

- Leymus chinensis
- Leymus secalinus
- Chenopodium album agg.
- Axyris prostrata
- Salsola collina et tragus
- Artemisia macrocephala
- Chenopodium acuminatum
- Chenopodium vulvaria
- Senecio dubitabilis
- Chenopodium aristatum

**Further species**

- Elytrigia nevskii
- Artemisia ruftolila
- Heteropappus hispidus
- Urtica cannabina

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...
Table 10. Grazing-mediated *Agropyron cristatum* community in close proximity to the *Aster alpinus-Carex pediformis* community. Grazing indicators are labelled with one and xerophytisation indicators with two asterisks.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<td>60-</td>
<td>26-</td>
<td>57-</td>
<td>52-</td>
<td>59-</td>
<td>53-</td>
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<td>51-</td>
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<td>03</td>
<td>03</td>
<td>03</td>
<td>03</td>
<td>03</td>
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<td>15</td>
<td>13</td>
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<td>12</td>
<td>10</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

**Diagnostic species of Cleistogenetaceae squarrosae**

*Poa attenuata*

*Koeleria cristata*  + 2a  +  +  2m  2a  2m  2a  +  +  2a  .

*Agropyron cristatum**  + 2a  .  r  +  +  2m  +  +  1  .

*Carex duriuscula**/*  +  +  +  .  +  .  +  .  +  .  +  2a

*Artemisia dolosa*  +  +  +  2m  1  +  +  +  +  +  .

*Potentilla bifurca*/*  +  +  +  +  +  +  +  +  +  +  .

*Bupleurum bicaule*  +  .  r  +  .  .  .  .  .  .

*Potentilla multifida*  +  .  .  .  .  .  +  .  .  .  2m

*Phlomoides tuberosa*  +  .  .  .  +  .  r  .  .  .

**Diagnostic species of Stipion krylovii**

*Stipa krylovii*  +  +  .  +  .  .  .  .  .  .  .  .

*Artemisia frigida*  .  +  .  +  .  .  .  .  .  .  .  .

*Scorzonera ikonnikovii*  .  .  .  .  .  .  .  .  2m  .

*Astragalus cf. brevifolius*  +  .  .  .  .  .  .  .  .  .  .  .

*Allium tenuissimum*  .  .  +  .  .  .  .  .  .  .  .  .

*Oxytropis cf. micrantha*  .  +  .  .  .  .  .  .  .  .  .  .

**Diagnostic species of Stellario petraea subass. of Hedysaro pumilii-Stipetum krylovii**

*Amblynotus rupestris*  r  +  +  +  +  r  +  .  .  .  .  .

*Chamaerhodos altaica*  r  .  +  .  .  .  .  .  .  .  .  .

*Oxytropis tragacanthoides*  .  +  .  .  .  .  .  .  .  .  .  .

*Smelowskia alba*  .  r  .  .  .  .  .  .  .  .  .  .

*Clausia aprica*  +  .  .  .  +  .  +  .  .  .  .  .

**Diagnostic species of Helicotrichion schelliani**

*Festuca lenensis*  +  +  2m  1  2m  .  2m  .  .  .  .  .

*Potentilla sericea*  +  +  +  +  +  +  +  +  .  .  .  .

*Festuca sibirica*  .  .  +  .  .  .  .  .  .  .  .  .

*Hedysarum ferganense*  r  +  +  .  .  .  .  .  .  .  .  .

**Species with main distribution in the alpine belt**

**Diagnostic species of Oxytropidi oligantheae-Festucetum lenensis**

*Stellaria brachypetala*  r  .  .  .  .  .  .  .  .  .  .  +

*Arenaria meyeri*  1  1  +  .  r  1  .  .  .  .  .

*Elytrigia geniculata*  .  +  .  .  .  .  .  .  .  .  .  .

*Plantago komarovii*  r  +  .  .  r  .  r  +  .  .  .  .

**Differential species of Stellaria pulvinata subass. of Oxytropidi oligantheae-Festucetum lenensis**

*Saussurea leucophylla*  r  .  .  .  .  .  .  .  .  .  .  .

**Diagnostic species of Kobresion myosuroidis**

*Carex rupestris*  .  .  .  .  +  +  +  +  +  +  r

**Summer annual disturbance indicators**

*Axyris hybrida*/*  .  .  .  .  +  +  +  2m  .  .  .  .  .

*Chenopodium glaucum*/*  .  .  .  .  +  +  +  2m  .  .  .  .  .

**Further species**

*Astragalus cf. versicolor*  .  .  +  .  .  .  .  .  .  .  .  .

*Astragalus cf. dilutus*  r  .  .  .  +  .  .  .  .  .  .  .

*Oxytropis cf. pauciflora*  .  .  +  .  .  .  .  .  .  .  .  .

*Elymus aegilopoides*  .  .  +  .  .  .  .  .  .  .  .  .

*Oxytropis myriophylla*  .  .  +  +  +  +  .  .  1  .  .  .

*Dontostemon senilis*/*  .  .  .  .  .  .  .  .  .  .  .  .

*Ephedra monosperma*  .  2m  .  r  .  .  .  .  .  .  .  .

Further in column 1: *Leymus secalinus* +
3: *Elytrigia nevskii* 2m
6: *Oxytropis cf. gracillicima* +
11: *Hymenolobus procumbens* r, *Taraxacum eriopodium* r
12: *Poa tianschanica* +
Plant communities along an elevation gradient

Leymus chinensis community (Table 9: 1–10)
Leymus secalinus community (Table 9: 11–22)
O Helictotrichetalia schelliani Hilbig 2000
L Helictotrichion schelliani Hilbig 2000
Aster alpinus–Carex pediformis community
    typical subcommunity (Table 4: 4)
Amblynotus rupestris subcommunity
    (Table 4: 5)

O Helictotrichetalia schelliani Hilbig 2000
Aster alpinus–Carex pediformis community
    typical subcommunity (Table 4: 4)
Amblynotus rupestris subcommunity
    (Table 4: 5)

O Helictotrichetalia schelliani Hilbig 2000
Aster alpinus–Carex pediformis community
    typical subcommunity (Table 4: 4)
Amblynotus rupestris subcommunity
    (Table 4: 5)

Discussion

Our results revealed that on the basis of plant associations no clear-cut grazing impact on semidesert vegetation can be inferred. Within the mountainous

Table 11. Grazing-mediated Axyris prostrata-Festuca lenensis community on sites of the Oxytropidi oligantha-Festucetum lenensis. Grazing indicators are labelled with one and xerophytisation indicators with two asterisks.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
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<td>232-03</td>
<td>229-03</td>
<td>230-03</td>
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<tr>
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<td>13</td>
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**Diagnostic species of Cleistogenetea squarrosae**
- Poa attenuata
- Bupleurum bicaule**
- Potentilla multifida
- Donostemon integrifolius**

**Diagnostic species of Stipion krylovii**
- Artemisia frigida*

**Diagnostic species of Helictotrichion schelliani**
- Festuca lenensis

**Diagnostic species with main distribution in the alpine belt**
- Oxytropis oligantha
- Stellaria brachypetala
- Pachyneurum grandiflorum
- Melandrium apetalum
- Artemisia pycnorhiza
- Elytrigia geniculata
- Alopecurus turczaninovii
- Allium amphibulum
- Plantago komarovii

**Diagnostic species of Kobresion myosuroidis**
- Carex rupestris
- Ranunculus pedatifidus

**Summer annual disturbance indicators**
- Axyris prostrata** 2a
- Stellaria amblyosephala**
- Draba nemorosa
vegetation, grazing-mediated vegetation patterns change alongside the elevation belts. The most striking pattern reflects that from the upper montane belt on upwards grazing impacts result in the occurrence of species from lower elevation belts. These species indicate drier environmental conditions than it might be expected by climate; an effect of a grazing-induced ‘xerophytisation’ (Gorshkova & Grineva 1977, Vostokova et al. 1995, Gunin et al. 2002, Christensen et al. 2004). We regard it as an effect of herbivory-driven changes of community structure and associated changes of soil and habitat microclimate (Zimov et al. 1995). Thus, our results are consistent with recent literature on increasing grazing responses of vegetation of decreasing aridity (Vetter 2005). However, beside the most widely applied explanation of the predominant role of rainfall variability included in the non-equilibrium theory (NET) (Ellis & Swift 1988, Vetter 2005), we furthermore want to point out to the specific adaptation of grazing man-

### Table 12. Grazing-mediated Koeleria cristata community on sites of the Kobresietum myosuroidis. Grazing indicators are labelled with one and xerophytisation indicators with two asterisks.

<table>
<thead>
<tr>
<th>Column</th>
<th>1</th>
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<td>Species number per relevé</td>
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<td>8</td>
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</tbody>
</table>

#### Diagnostic species of Cleistogenetea squarrosae
- Koeleria cristata** + + 2m +
- Carex duruscula** . . 2m 4
- Potentilla multifida + + + +

#### Diagnostic species of Helictotrichion schelliani
- Festuca lenensis 2b 2a 3 .
- Senecio integrisolius** + + 1 .

### Species with main distribution in the alpine belt

#### Diagnostic species of Oxytropidi oliganthae-Festucetum lenensis
- Androsace chamaejasme + 2m 2m .
- Oxytropis oligantha 2b 3 r .
- Entrichium pauciflorum 2b 2b . .
- Stellaria brachypetala + + + +
- Arenaria meyeri 2m + . .
- Pachyneurum grandiflorum + 2m + .
- Artemisia phaeolepis . . + .
- Melandrium apetalum . . + .
- Plantago komarovii + + + .

#### Differential species of Stellaria pulvinata subass.
- Stellaria pulvinata 2a 2a . .
- Smelowskia mongolica + r . .

#### Diagnostic species of Kobresion myosuroidis
- Kobresia myosuroides + . . .
- Thalictrum alpinum + r . .
- Carex rupestris 2m 1 + .
- Ranunculus pedatidus + . + +
- Poa alpina . + . .
- Poa altaica + + + .

#### Species of alpine wet sites
- Primula farinosa . . . r

#### Further species
- Artemisia argyrophylla** r . . .
- Oxytropis cf. pauciflora + . 1 .
- Artemisia blepharolepis . . 2m +
- Taraxacum spec. . . . +

Further in column 1: Spodiopogon sibiricus r
2: Poa tianschanica +, Trisetum lithwinowii r
Plant communities along an elevation gradient

Margaret practices to the phenology of vegetation: In the study area semideserts serve as spring pastures between the end of January and the beginning of June, as autumn pastures between the end of August and mid-November and locally as winter pastures between mid-November and the end of February (Oktyabri 2005). In the winter and spring season, if plant growth is limited by temperatures, herders live more scattered with lower livestock density than in summer and autumn. The latter periods, climatically favourable to plant growth, represent labour-intensive times and more families join into household communities (Janzen & Bazargur 1999). Furthermore, semideserts represent water-limited ecosystems dominated by plant specialists being capable of surviving climatically extreme conditions (Whitford 2002). Thus, the species pool is limited in case of further enhanced environmental stress such as grazing although belowground competition is especially important in low-productive habitats (Casper & Jackson 1997). Moreover, the grazing seasons in spring, autumn and winter before and after the growing period ensure an almost undisturbed regeneration of the plant cover. This is supported by the fact that 70–90% of living phytomass in semideserts are hidden belowground reflecting the evolutionary history of grazing in arid and semi-arid ecosystems (Titlyanova et al. 1999).

This and further studies without time series analyses (Fernandez-Gimenez & Allen-Diaz 2001, Stumpf et al. 2005) demonstrated negligible grazing impacts on semidesert vegetation, although NET focuses on the role of interannual variability of precipitation. We expect additional factors, currently not included in the NET, to account for the limited grazing impacts in semideserts (Zemmrich et al. accepted). Thus, the effective adaptation of grazing patterns to vegetation phenology and the historical conditions of ecosystem genesis including grazing by large herbivores may, beside NET, additionally explain why no distinct grazing impacts on semidesert communities could be detected.

The vegetation in the montane belt between 1900 m and 2200 m asl serves as winter pasture grazed from November until the end of February (Oktyabri 2005), reflecting the pronounced winter temperature inversions with cold air accumulations in basins and valleys and warmer airmass above (Murzaev 1954). The vegetation of the alpine belt might be better capable in compensating for grazing pressures during the growing period of vegetation in summer than the low-productive semidesert vegetation. Low-productive semideserts and mountain steppes are grazed before or after the reproduction cycle of plants in spring, autumn or winter while high-productive alpine vegetation during the summer growing period in which plants are more susceptible to grazing. These grazing patterns are adapted to seasonal changes in productivity and phenology patterns of vegetation. They are furthermore supported by decreasing densities of herders and livestock from labour-intensive summer pastures in the alpine belt to winter and spring pastures in mountain steppes and semideserts, in which plant growth is limited by low winter temperatures.

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Plant communities along an elevation gradient


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Addresses of the authors:

Anne Zemmrich*, Institute of Botany and Landscape Ecology, University Greifswald, 17487 Greifswald, Germany
Weiner Hilbig, Münchner Str. 8, 85238 Petershausen, Germany

* Corresponding author, e-mail: zemmrich@uni-greifswald.de.