



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

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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 with heavy grazing impacts 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 ap-

proach based on dominant species (e.g. EVSTIFEV & 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 RETZER (2004) and WESCHE & RETZER (2005) used enclosure 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 STAALDUINEN 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-

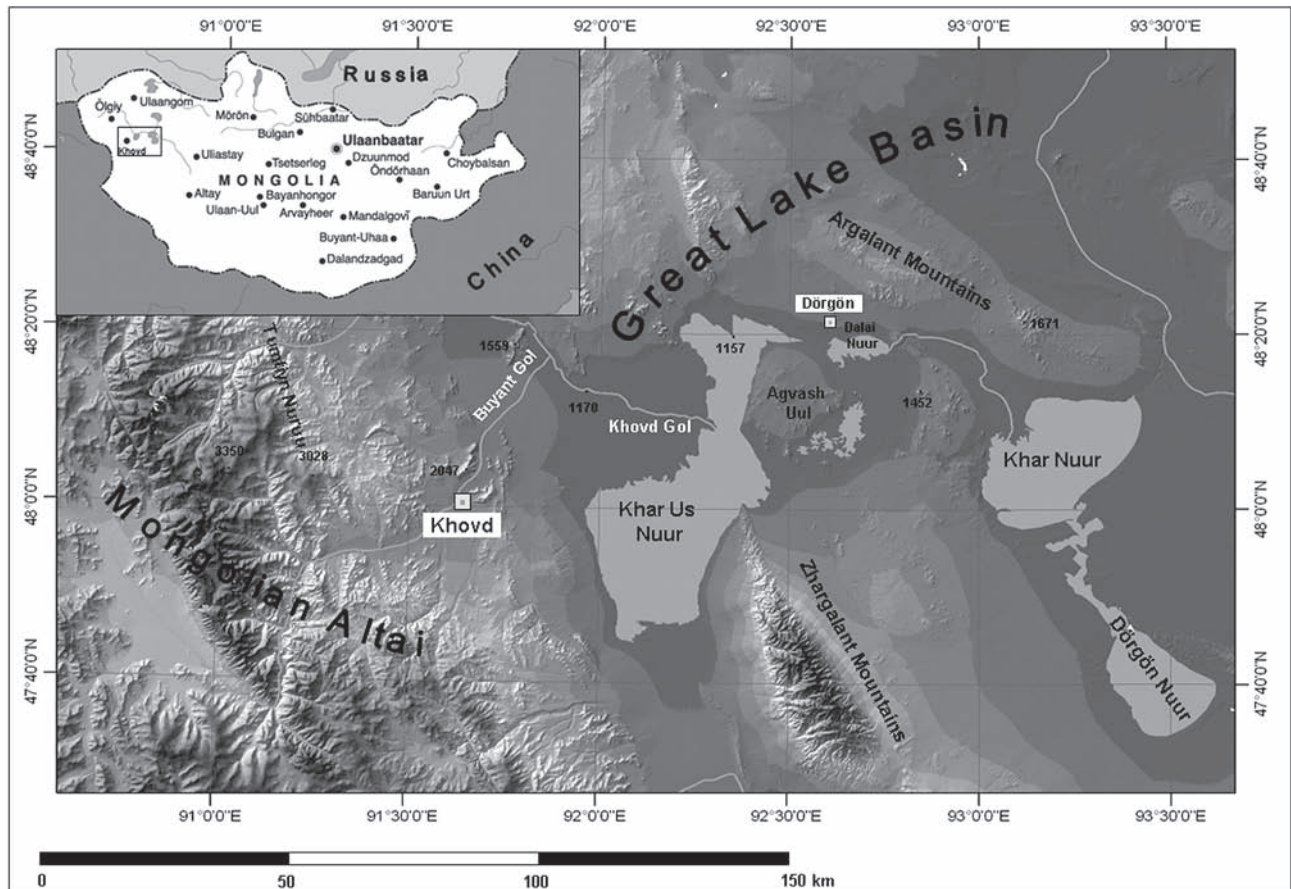


Fig. 1. Geographical location of the study area: 48°00'N, 91°05'E and 48°23'N, 93°10'E (Sources: KRETSCHMER 2004, modified).

tion, 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 (BARTHEL 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).

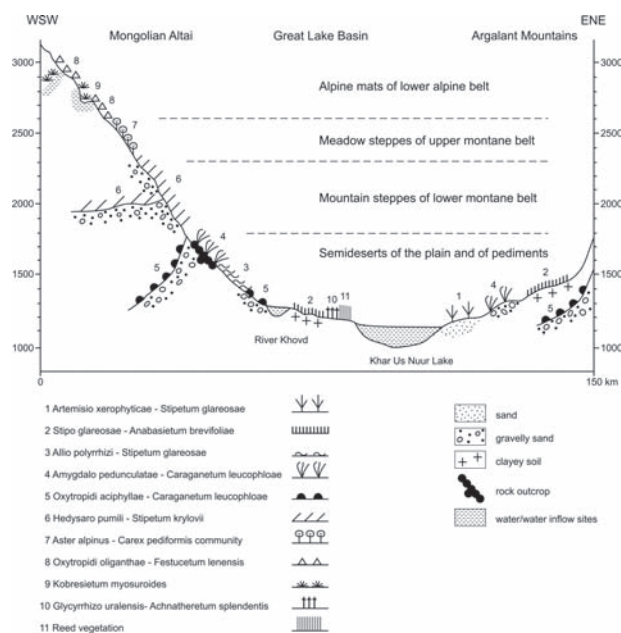


Fig. 2. Vegetation profile of the study area showing the change of vegetation belts along the elevation gradient (Graph: P. Wiese).

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 WILMANN (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 vegetations 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, BARTHEL 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 leucophloea* and *Krascheninnikovia ceratoides* 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

Artemisio 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 Agvash 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-Caraganeetum leucophloae 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-Caraganeetum leucophloae is characterised by shrubs such as *Caragana leucophloea*, *Krascheninnikovia ceratoides* and *Atraphaxis frutescens* and belongs to the Caraganian leucophloae.

Gobi-Altai from the Great Lake Basin and the Dzungenian 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 Stipetea 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



Fig. 3. Stand of the Artemisio xerophyticae-Stipetum glareosae with *Artemisia xerophytica* (left) and *Stipa glareosa* (right in the front) (Photo: M. Schnittler 2003).

Stipo glareosae-Anabasietum brevifoliae
Hilbig (1987) 1990
(Table 1: 2, 3)

The association is one of the most common semidesert communities distributed north and south of the

reaumurietosum songaricae Hilbig 2009) occurs on sites of higher salinity, distinguished by the name-giving species.

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.

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--|-----|-----|-----|----|----|-----|-----|
| Mean species number per relevé | 10 | 10 | 10 | 10 | 23 | 19 | 17 |
| Number of relevés | 23 | 69 | 10 | 5 | 2 | 20 | 40 |
| Diagnostic species of Stipetea glareosae-gobicae & Allion polyrrhizi | | | | | | | |
| <i>Anabasis brevifolia</i> | III | V | V | . | 1 | IV | . |
| <i>Stipa glareosa</i> | V | IV | III | V | 2 | V | V |
| <i>Allium mongolicum</i> | I | V | V | . | 2 | V | + |
| <i>Gypsophila desertorum</i> | . | II | I | V | 1 | II | V |
| <i>Arnebia guttata</i> | . | I | + | . | . | + | . |
| <i>Artemisia caespitosa</i> | II | II | + | . | . | . | . |
| <i>Astragalus monophyllus</i> | I | I | + | . | . | + | . |
| <i>Dontostemon senilis</i> | . | I | . | . | 1 | V | r |
| <i>Lagochilus ilicifolius</i> | . | I | . | . | 1 | IV | . |
| <i>Asterothamnus heteropappoides</i> | . | II | + | V | 1 | r | II |
| <i>Asterothamnus poliifolius</i> | . | . | . | . | . | IV | . |
| <i>Neopallasia pectinata</i> | . | III | II | . | 2 | I | + |
| <i>Allium polyrrhizum</i> | . | + | . | . | . | . | . |
| <i>Plantago minuta</i> | . | + | + | . | 1 | II | . |
| <i>Convolvulus ammani</i> | . | . | . | V | . | . | III |
| <i>Iris tenuifolia</i> | . | . | . | IV | . | . | II |
| <i>Potentilla astragalifolia</i> | . | . | . | . | . | . | III |
| <i>Scutellaria grandiflora</i> | . | . | . | . | . | . | II |
| <i>Youngia tenuicaulis</i> | . | r | + | . | 1 | III | . |
| <i>Cleistogenes songorica</i> | . | r | . | . | . | II | . |
| <i>Scorzonera pseudodivariata</i> | . | r | . | . | 2 | III | . |
| <i>Panzerina lanata</i> | . | . | . | . | 1 | r | . |
| <i>Elytrigia nevskii</i> | . | . | . | . | . | II | r |
| Differential species of Artemisia frigida subass. of Allio polyrrhizi - Stipetum glareosae and Oxytropidi aciphyllae- | | | | | | | |
| Caraganetum leucophloae | | | | | | | |
| Diagnostic species of Stipion krylovii | | | | | | | |
| <i>Stipa krylovii</i> | . | . | . | . | . | . | V |
| <i>Cleistogenes squarrosa</i> | . | . | + | V | . | . | V |
| <i>Allium anisopodium</i> | . | . | . | IV | . | . | V |
| <i>Ptilotrichum canescens</i> | . | . | . | . | . | . | II |
| <i>Pulsatilla bungeana</i> | . | . | . | I | . | . | II |
| <i>Kochia prostrata</i> | . | . | . | V | . | . | r |
| <i>Artemisia frigida</i> | . | . | . | I | . | . | V |
| <i>Poa attenuata</i> | . | . | . | . | . | . | + |
| <i>Bupleurum bicaule</i> | . | . | . | . | . | . | r |
| Diagnostic species of Cleistogenetea squarrosae | | | | | | | |
| <i>Agropyron cristatum</i> | . | . | . | II | . | . | V |
| <i>Koeleria cristata</i> | . | . | . | . | . | . | II |
| <i>Dontostemon integrifolius</i> | . | . | . | . | . | . | IV |
| <i>Dracocephalum fruticosum</i> | . | . | . | . | . | . | II |
| Differential species of Artemisio xerophyticae-Stipetum glareosae | | | | | | | |
| <i>Artemisia xerophytica</i> | V | . | . | . | . | r | . |
| Differential species of Reaumuria songorica subass. of Stipo glareosae-Anabasiatum brevifoliae | | | | | | | |
| <i>Reaumuria songarica</i> | . | . | V | . | . | r | . |
| Diagnostic species of Caraganion leucophloae | | | | | | | |
| <i>Prunus pedunculata</i> | . | . | . | . | 2 | . | . |
| <i>Caragana leucophloea</i> | . | r | . | . | 2 | V | V |
| <i>Krascheninnikovia ceratoides</i> | . | . | . | . | 2 | V | I |
| <i>Ajania fruticulosa</i> | . | r | . | . | 2 | I | II |
| <i>Convolvulus gortschakovii</i> | . | . | . | . | 1 | II | . |
| <i>Atraphaxis pungens</i> | . | . | . | . | . | . | I |
| <i>Caragana bungei</i> | . | . | . | . | . | . | + |

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|-----|----|-----|----|---|-----|-----|
| Summer annuals | | | | | | | |
| <i>Aristida heymanii</i> | V | V | V | . | . | III | . |
| <i>Eragrostis minor</i> | IV | V | III | . | 1 | II | II |
| <i>Enneapogon borealis</i> | IV | IV | V | . | . | III | . |
| <i>Lappula intermedia et granulata</i> | II | V | V | . | 1 | III | I |
| <i>Micropeplis arachnoidea</i> | II | II | II | . | 2 | II | . |
| <i>Kochia melanoptera</i> | . | I | + | . | . | r | . |
| <i>Euphorbia humifusa</i> | . | II | I | . | . | II | . |
| <i>Tribulus terrestris</i> | III | r | . | . | 1 | II | . |
| <i>Senecio dubitabilis</i> | . | . | . | . | 1 | II | r |
| <i>Senecio subdentatus</i> | . | II | I | . | . | r | . |
| <i>Erodium tibetanum</i> | II | I | . | . | . | . | . |
| Summer annual disturbance indicators | | | | | | | |
| <i>Salsola collina et tragus</i> | III | I | + | IV | 2 | IV | V |
| <i>Chenopodium album agg.</i> | . | I | I | . | . | IV | V |
| <i>Chenopodium foliosum</i> | . | I | + | . | . | I | . |
| <i>Chenopodium aristatum</i> | I | + | + | . | . | + | V |
| <i>Chenopodium acuminatum</i> | . | r | . | . | . | . | II |
| <i>Chenopodium hybridum</i> | . | . | . | . | 1 | + | . |
| <i>Bassia dasyphylla</i> | IV | I | + | . | 2 | V | II |
| <i>Corispermum mongolicum</i> | I | . | . | . | . | . | + |
| <i>Setaria viridis</i> | . | . | . | . | . | II | I |
| <i>Axyris prostrata</i> | . | + | + | . | . | . | . |
| <i>Agriophyllum pungens</i> | IV | + | . | . | . | . | . |
| Further species | | | | | | | |
| <i>Orostachys thyrsiflora</i> | . | I | . | . | . | r | . |
| <i>Echinops gmelinii</i> | I | . | . | . | . | . | . |
| <i>Onosma setosa</i> | . | . | . | . | . | I | . |
| <i>Astragalus cf. grubovii</i> | + | r | . | . | . | r | . |
| <i>Artemisia macrocephala</i> | . | . | . | . | 2 | r | III |
| <i>Euphorbia mongolica</i> | . | r | . | . | 2 | II | . |
| <i>Ephedra cf. sinica</i> | . | r | . | . | . | + | I |
| <i>Androsace maxima</i> | . | . | . | . | . | r | I |
| <i>Craniospermum mongolicum</i> | . | . | . | . | 1 | I | + |
| <i>Stellaria amblyosephala</i> | . | . | . | . | 1 | + | + |
| <i>Scorzonera ikonnikovii</i> | . | r | . | . | . | I | . |
| <i>Artemisia cf. schischkinii</i> | I | . | . | . | . | . | . |
| <i>Chenopodium vulvaria</i> | . | r | + | . | . | . | . |
| <i>Schizonepeta annua</i> | . | r | . | . | . | r | . |
| <i>Zygophyllum pterocarpum</i> | . | . | . | . | 1 | r | . |

Further in column 1: *Astragalus cf. kurtshumensis* r, *Saussurea pricei* r

4: *Oxytropis cf. micrantha* I

5: *Carex duriuscula* III

6: *Atriplex sibirica* III, *Lepidium densiflorum* III, *Lepidium ruderales* II, *Silene spec.* +

7: *Astragalus cf. brevifolius* +, *Astragalus cf. kurtshumensis* I, *Astragalus cf. laguroides* r, *Astragalus vallestis* r, *Carex duriuscula* III, *Clausia aprica* r, *Ephedra przewalskii* r, *Eritrichium thymifolium* r, *Gueldenstaedtia monophylla* I, *Halogeton glomeratus* r, *Lappula cf. stricta* r, *Nitraria sibirica* r, *Silene spec.* +, *Stellaria dichotoma* I, *Vicia costata* r, *Vincetoxicum sibiricum* +

Column:

1 - *Artemisia xerophyticae*-*Stipetum glareosae*

2 - *Stipo glareosae*-*Anabasiatum brevifoliae* typicum

3 - *Stipo glareosae*-*Anabasiatum brevifoliae* *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*

Allio polyrrhizi-Stipetum glareosae (1987) 1990
(Table 1: 4)

So far, this association has only been documented for the Gobi Altai (HILBIG 1995, WESCHE et al. 2005, HILBIG & TUNGALAG 2006). It is floristically closely related to the *Stipo glareosae-Anabasiatum brevifoliae*. In the study area, we observed the typical association in the transition from the Great Lake Basin to the Mongolian Altai west of the lake Khar Us Nuur. In the present paper, we provide only records of the *Artemisia frigida* subassociation (*Allio polyrrhizi-Stipetum glareosae artemisietosum frigidae* 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-Anabasiatum 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 & SCHAMSRAN 1977) and is missing in the presented relevés.

The differential species of the *Artemisia frigida* subassociation such as *Agropyron cristatum*, *Allium anisopodium*, *Cleistogenes squarrosa* 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.

Shrub semidesert communities – Caraganon leucophloea Hilbig 2000

Amygdalo pedunculatae-Caraganetum leucophloea Hilbig (1987) 1990
(Table 1: 5)

The association, designated by shrubs and semi-shrubs, 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 Argalant Mts. and the lakes Khar Us Nuur and Khar Nuur. It is furthermore found in the transition of shrub-semideserts to mountain steppes on the eastern downward slope of the Mongolian Altai on rocky sites with Haplic Calcisol (KRETSCHMER & ZEMMRICH 2009). It covers rock outcrops and gravelly sites of high habitat heterogeneity resulting in a high species number (Table 1: 5).

The shrub layer, covering 20%, is dominated by *Caragana leucophloea* and *Prunus pedunculata* (*Amygdalus pedunculata*). *Krascheninnikovia ceratoides*, *Ajania fruticulosa* and *Convolvulus gortschakovii* additionally participate in the shrub assembly. *Atrap-*

basis pungens and *Caragana bungei* are often observed in stands of the study area (KRETSCHMER & ZEMMRICH 2009), but are absent in the presented relevés. Low-growing semidesert species especially *Allium mongolicum*, *Anabasis brevifolia* and *Stipa glareosa* are also present. The herb layer covers 5 to 15%.

Table 3. Nomenclatural typus relevés of the *Oxytropidi aciphyllae-Caraganetum leucophloea* typicum subass. nov. hoc loco (Column 1; after Hilbig 1990) and of the *Oxytropidi aciphyllae-Caraganetum leucophloea 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%.

| Column | 1 | 2 |
|---------------------------|-----------|------|
| Relevé no. | 155a/74 * | 2-03 |
| Shrub cover in % | 30 | 5 |
| Herb cover in % | 20 | 15 |
| Species number per relevé | 14 | 19 |

Diagnostic species of *Stipetea glareosae-gobicae* &

Allion polyrrhizi

| | | |
|--------------------------------------|---|---|
| <i>Stipa glareosa</i> | 2 | + |
| <i>Gypsophila desertorum</i> | + | + |
| <i>Asterothamnus heteropappoides</i> | . | + |
| <i>Convolvulus ammani</i> | + | + |

Differential species of *Artemisia frigida* subass. of

Oxytropidi aciphyllae-Caraganetum leucophloea

Diagnostic species of *Stipion krylovii*

| | | |
|-------------------------------|---|----|
| <i>Stipa krylovii</i> | . | 2a |
| <i>Allium anisopodium</i> | . | + |
| <i>Ptilotrichum canescens</i> | . | + |
| <i>Pulsatilla bungeana</i> | . | + |
| <i>Artemisia frigida</i> | . | + |
| <i>Oxytropis aciphylla</i> | 1 | . |

Diagnostic species of *Cleistogenetea squarrosae*

| | | |
|----------------------------------|---|---|
| <i>Agropyron cristatum</i> | + | + |
| <i>Dontostemon integrifolius</i> | + | . |
| <i>Dracocephalum fruticosum</i> | . | + |

Diagnostic species of *Caraganion leucophloea*

| | | |
|-------------------------------------|---|----|
| <i>Caragana leucophloea</i> | 3 | 2m |
| <i>Krascheninnikovia ceratoides</i> | + | r |
| <i>Gueldenstaedtia monophylla</i> | 1 | + |
| <i>Caragana bungei</i> | . | r |

Summer annual disturbance indicators

| | | |
|----------------------------------|---|---|
| <i>Salsola collina et tragus</i> | . | + |
| <i>Corispermum mongolicum</i> | . | + |

Further species

| | | |
|-------------------------------|---|---|
| <i>Ephedra spec.</i> | 1 | . |
| <i>Chamaerhodos erecta</i> | 1 | . |
| <i>Heteropappus spec.</i> | + | . |
| <i>Dracocephalum foetidum</i> | + | . |
| <i>Carex duriuscula</i> | . | + |
| <i>Stellaria dichotoma</i> | . | + |

Oxytropidi aciphyllae-Caraganetum leucophloae Hilbig (1987) 1990

(Table 1: 6, 7)

This association, firstly 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 leucophloae. Dominating shrubs are *Krascheninnikovia ceratoides* and *Caragana leucophloea*, 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 leucophloae 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 leucophloae 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*



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

krylovii compared to the typical subassociation (Table 1: 6, 7). Furthermore, it extends above the typical subassociation between 1450 m and 1650 m asl.

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 Khangay (YUNATOV 1950).

Above semidesert vegetation follows the mountain steppe belt between 1800 m and 2200 m asl with a vegetation cover between 20% and 55% (Fig. 2). 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 on 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 (POLYNOV 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 schelliani, 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.

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|-----|-----|-----|-----|----|-----|-----|-----|----|
| Mean species number per relevé | 11 | 15 | 24 | 22 | 23 | 17 | 20 | 18 | 14 |
| Number of relevés | 10 | 25 | 50 | 6 | 3 | 27 | 28 | 12 | 4 |
| Diagnostic species of Cleistogenetea squarrosae | | | | | | | | | |
| <i>Poa attenuata</i> | . | IV | V | IV | 3 | IV | III | . | . |
| <i>Koeleria cristata</i> | III | V | V | V | 3 | r | . | II | . |
| <i>Agropyron cristatum</i> | V | V | IV | . | . | . | . | . | . |
| <i>Carex duriuscula</i> | II | IV | I | II | . | . | . | . | . |
| <i>Artemisia dolosa</i> | . | V | V | V | 3 | . | . | . | . |
| <i>Bupleurum bicaule</i> | II | V | V | IV | 3 | . | . | . | . |
| <i>Potentilla multifida</i> | . | I | + | III | . | V | IV | V | 4 |
| <i>Potentilla bifurca</i> | . | r | + | II | . | . | . | . | . |
| <i>Oxytropis cf. potaninii</i> | . | . | . | V | . | . | . | . | . |
| <i>Phlomidoides tuberosa</i> | . | II | V | . | 2 | . | . | . | . |
| <i>Dontostemon integrifolius</i> | I | V | V | . | . | . | . | . | . |
| Diagnostic species of Stipion krylovii | | | | | | | | | |
| <i>Stipa krylovii</i> | IV | V | V | . | . | . | . | . | . |
| <i>Artemisia frigida</i> | V | II | III | . | 1 | II | r | . | . |
| <i>Allium anisopodium</i> | I | III | III | . | . | . | . | . | . |
| <i>Ptilotrichum canescens</i> | + | IV | IV | . | . | . | . | . | . |
| <i>Leymus chinensis</i> | . | . | III | . | . | . | . | . | . |
| <i>Scorzonera ikonnikovii</i> | II | II | III | . | . | . | . | . | . |
| <i>Astragalus cf. brevifolius</i> | . | IV | III | . | . | . | . | . | . |
| <i>Allium tenuissimum</i> | . | I | II | V | . | . | r | . | . |
| <i>Pulsatilla bungeana</i> | I | II | V | II | . | . | . | . | . |
| <i>Iris potaninii</i> | . | II | III | . | . | . | . | . | . |
| <i>Oxytropis cf. micrantha</i> | + | II | IV | . | . | . | . | . | . |
| <i>Allium eduardii</i> | . | I | II | . | . | . | . | . | . |
| Differential species of Stipa glareosa form of Hedysaro pumili-Stipetum krylovii | | | | | | | | | |
| <i>Cleistogenes squarrosa</i> | V | . | r | . | . | . | . | . | . |
| <i>Stipa glareosa</i> | V | . | . | . | . | . | . | . | . |
| <i>Asterothamnus heteropappoides</i> | III | . | . | . | . | . | . | . | . |
| <i>Youngia tenuicaulis</i> | II | . | I | . | . | . | . | . | . |
| Differential species of Stellaria petraea subass. of Hedysaro pumili-Stipetum krylovii | | | | | | | | | |
| <i>Amblynotus rupestris</i> | . | + | V | I | 3 | . | . | . | . |
| <i>Arenaria capillaris</i> | . | r | V | . | . | . | . | . | . |
| <i>Rhinactinidia eremophila</i> | . | . | IV | . | . | . | . | . | . |
| <i>Chamaerhodos altaica</i> | . | . | II | . | 1 | . | . | . | . |
| <i>Oxytropis tragacanthoides</i> | . | . | III | I | 3 | . | . | . | . |
| <i>Orostachys spinosa</i> | . | . | II | I | . | + | r | . | . |
| <i>Thalictrum foetidum</i> | . | . | I | III | 2 | . | . | . | . |
| <i>Ferulopsis hystrix</i> | . | r | II | II | . | . | . | . | . |
| <i>Stellaria dichotoma</i> | . | . | I | . | . | . | . | . | . |
| <i>Smelowskia alba</i> | . | . | + | . | . | . | . | . | . |
| <i>Youngia tenuifolia</i> | . | . | + | I | 2 | . | . | . | . |
| <i>Clausia aprica</i> | + | I | I | II | . | . | . | . | . |
| <i>Dracocephalum fruticulosum</i> | . | r | + | . | . | . | . | . | . |
| <i>Sibbaldianthe adpressa</i> | . | + | + | . | . | r | . | . | . |
| <i>Ephedra cf. sinica</i> | + | . | I | . | . | . | . | . | . |
| Diagnostic species of Helictotrichion schelliani | | | | | | | | | |
| <i>Festuca lenensis</i> | . | V | V | V | 3 | V | V | III | 4 |
| <i>Carex pediformis</i> | . | . | . | II | 3 | . | . | . | . |
| <i>Aster alpinus</i> | . | . | . | V | 3 | . | . | . | . |
| <i>Dianthus versicolor</i> | . | . | r | V | 3 | . | . | . | . |
| <i>Potentilla sericea</i> | . | . | r | V | 3 | . | . | . | . |
| <i>Aconogonon alpinum</i> | . | . | + | V | 3 | . | . | . | . |
| <i>Festuca sibirica</i> | . | . | . | V | . | . | . | . | . |
| <i>Gentiana decumbens</i> | . | . | . | IV | 3 | . | . | . | . |
| <i>Silene repens</i> | . | . | . | V | . | . | . | . | . |
| <i>Lychnis sibirica</i> | . | . | . | II | . | . | . | . | . |
| <i>Senecio integrifolius</i> | . | . | . | II | . | . | . | II | . |
| <i>Galium verum</i> | . | . | . | II | . | . | . | . | . |
| <i>Silene chamarhensis</i> | . | r | . | I | 3 | . | . | . | . |
| <i>Hedysarum ferganense</i> | . | . | I | . | . | I | I | . | . |
| Species with main distribution in the alpine belt | | | | | | | | | |
| Diagnostic species of Oxytropidi oliganthae-Festucetum lenensis | | | | | | | | | |
| <i>Androsace chamaejasme</i> | . | . | . | . | . | V | V | III | . |
| <i>Oxytropis oligantha</i> | . | . | r | . | . | III | V | IV | . |
| <i>Eritrichium pauciflorum</i> | . | . | . | II | . | II | V | II | . |
| <i>Draba eriopoda</i> | . | . | . | . | . | II | I | . | . |
| <i>Papaver pseudocanescens</i> | . | . | . | . | . | I | I | II | . |
| <i>Stellaria brachypetala</i> | . | . | . | . | . | V | IV | IV | 2 |
| <i>Arenaria meyeri</i> | . | . | . | V | 3 | III | V | IV | . |
| <i>Pachyneurum grandiflorum</i> | . | . | r | II | . | IV | V | III | . |
| <i>Artemisia phaeolepis</i> | . | . | . | II | . | IV | II | II | . |
| <i>Draba fladnizensis</i> | . | . | . | . | . | IV | I | I | . |
| <i>Melandrium apetalum</i> | . | . | . | . | . | IV | III | + | . |
| <i>Saxifraga sibirica</i> | . | . | . | . | . | II | III | + | . |
| <i>Artemisia pycnorhiza</i> | . | . | . | . | . | V | IV | . | . |
| <i>Elytrigia geniculata</i> | . | . | . | . | . | V | IV | I | . |
| <i>Alopecurus turczaninovi</i> | . | . | . | . | . | I | II | . | . |
| <i>Allium amphibolum</i> | . | . | . | . | 1 | II | r | . | . |
| <i>Plantago komarovii</i> | . | . | . | . | . | V | IV | + | . |

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 ex-

tending 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 *Rhodiotalia 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 melanantha* 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.

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Relevé no. | 610-05 | 611-05 | 605-05 | 606-05 | 612-05 | 117-03 | 614-05 | 600-05 | 601-05 | 602-05 |
| Total vegetation cover in % | 4 | 3 | 2 | 5 | 10 | 10 | 15 | 4 | 3 | 5 |
| Species number per relevé | 3 | 3 | 4 | 4 | 4 | 6 | 6 | 8 | 8 | 8 |
| Diagnostic species of <i>Stipetea glareosae-gobicae</i> & <i>Allion polyrrhizi</i> | | | | | | | | | | |
| <i>Anabasis brevifolia</i> | . | . | . | . | . | + | . | . | . | . |
| <i>Stipa glareosa</i> | 1 | 1 | 1 | 1 | 2a | 1 | 1 | 1 | + | + |
| <i>Echinops gmelinii</i> | . | . | + | r | . | . | . | . | . | . |
| Summer annuals | | | | | | | | | | |
| <i>Aristida heymannii</i> | + | + | + | + | 2m | 2m | 2a | + | + | + |
| <i>Eragrostis minor</i> | + | . | . | . | . | . | + | + | + | + |
| <i>Enneapogon borealis</i> | . | + | . | . | . | . | . | + | + | + |
| <i>Lappula intermedia et granulata</i> | . | . | . | . | . | + | . | . | . | . |
| <i>Micropeplis arachnoidea</i> | . | . | . | . | . | . | . | + | + | + |
| <i>Tribulus terrestris</i> | . | . | . | . | . | . | + | r | + | + |
| Summer annual disturbance indicators | | | | | | | | | | |
| <i>Bassia dasyphylla</i> | . | . | + | + | + | + | + | + | + | + |
| <i>Corispermum mongolicum</i> | . | . | . | . | + | . | + | + | + | + |
| <i>Agriophyllum pungens</i> | . | . | . | . | . | + | . | . | . | . |

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 veg-

etation 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 7. Relevés of the *Stipo glareosae*-*Anabasietum brevifoliae* within a distance of 100 m from animal corrals.

| Column | 1 | 2 | 3 | 4 |
|---|--------|--------|--------|--------|
| Relevé no. | 187-03 | 184-03 | 188-03 | 185-03 |
| Total vegetation cover in % | 40 | 40 | 40 | 40 |
| Species number per relevé | 17 | 18 | 14 | 16 |
| Diagnostic species of <i>Stipetea glareosae-gobicae</i> & <i>Allion polyrrhizi</i> | | | | |
| <i>Anabasis brevifolia</i> | 2m | 2a | 2m | 2m |
| <i>Stipa glareosa</i> | r | . | . | . |
| <i>Allium mongolicum</i> | 2m | 2m | r | 2m |
| <i>Gypsophila desertorum</i> | + | r | . | . |
| <i>Astragalus monophyllus</i> | r | . | r | . |
| <i>Neopallasia pectinata</i> | + | + | + | r |
| <i>Plantago minuta</i> | . | + | . | r |
| <i>Echinops gmelinii</i> | . | . | . | . |
| Summer annuals | | | | |
| <i>Aristida heymannii</i> | + | + | . | + |
| <i>Eragrostis minor</i> | 2m | 2a | 2m | 2m |
| <i>Enneapogon borealis</i> | 2m | 2a | 2m | 2m |
| <i>Lappula intermedia et granulata</i> | + | + | r | r |
| <i>Kochia melanoptera</i> | 2a | 2a | 2b | 2a |
| <i>Tribulus terrestris</i> | . | + | . | . |
| <i>Senecio subdentatus</i> | + | + | + | + |
| Summer annual disturbance indicators | | | | |
| <i>Salsola collina et tragus</i> | + | + | 2m | 2m |
| <i>Chenopodium album agg.</i> | 2m | + | 2a | 2a |
| <i>Chenopodium aristatum</i> | . | + | . | + |
| <i>Chenopodium acuminatum</i> | r | + | + | . |
| <i>Bassia dasyphylla</i> | r | + | r | r |
| <i>Axyris prostrata</i> | 2m | + | 2m | 2a |
| Further species | | | | |
| <i>Chenopodium vulvaria</i> | . | . | . | r |

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*-*Anabasi-etum brevifoliae* within a distance of up to 100 m from animal corrals annual disturbance indicators such as *Bassia dasyphylla*, *Chenopodium album*, *Salsola collina et tragus*, *Axyris prostrata* and the summer annuals *Senecio subdentatus* and *Kochia melanoptera* (GRUBOV 2001) more frequently occurred (cf. Table 7 with Table 1: 2). Disturbance indicators here represent typical species of open semidesert vegetation, which usually occur in habitats of natural disturbances 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 remained almost unaffected except for the highly palatable, diagnostic *Stipa glareosa* which was found only in single patches. (cf. Table 1: 2 with Table 7). However, 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 occurrence of annuals depends on summer rain (LAVRENKO & KARAMYSCHEVA 1993). As annuals have no diagnostic 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* community (Table 8) represents stands dominated by annual species of the Chenopodiaceae family. It grows on slightly saline sites of the *Glycyrrhizo uralensis*-*Achnatheretum splendentis* indicating the transition from semidesert to groundwater dependent 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 otherwise dry environment, are used as camp locations for herders and animal corrals. They are area-wide heavily 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 relevé material by HILBIG & SCHAMSRAN 1977, HILBIG 1995, STRAUSS 2004).

Grazing impact on plant communities of mountainous vegetation

Unlike semidesert vegetation, mountainous vegetation displayed obvious changes under grazing impact reflected in distinct grazing-mediated plant communities (Table 9–12). Taxa of grazing-mediated com-

munities mainly represent survivors of the original associations plus disturbance indicators (e.g. *Salsola*, *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 palatability (e.g. *Oxytropis myriophylla*). Except for the survivors, they all show an enhanced competitive power under grazing pressure and trampling. In the present paper they are summarised as grazing indicators (Table 9–12). The severity of grazing impact differs among the communities due to the differing accessibility 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 krylovii* typicum, indicates an almost complete species 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 conditions and the occurrence of *Leymus chinensis* and *Phlomooides tuberosa* indicate the close relationship of this community to the *Hedysaro pumili*-*Stipetum krylovii* *stellarietosum petraeae* (ZEMMRICH 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 observations).

While in the lower montane belt grazing-mediated stands indicate higher vegetation cover than the original vegetation, in the upper montane belt grazing-mediated vegetation demonstrates lower covers. Moreover, with rising elevation the response of vegetation to grazing and trampling is detectable across longer distances (see below). The *Agropyron cristatum* community is found in the upper montane belt on plain sites closely adjacent to the *Aster alpinus*-*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 impoverishment 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 ad-

ditional 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.

- C Stipetea glareosae-gobicae Hilbig 2000
 - O Allietalia polyrrhizi Hilbig 2000
 - L Allion polyrrhizi Hilbig 2000
 - A Artemisio xerophyticae-Stipetum glareosae ass. nov. hoc loco (Table 1: 1, Table 2)
 - A Stipo glareosae-Anabasiatum brevifoliae Hilbig (1987) 1990
 - typicum Hilbig 2009 (Table 1: 2)
 - reaumurietosum songaricae Hilbig 2009 (Table 1: 3)
 - A Allio polyrrhizi-Stipetum glareosae Hilbig (1987) 1990
 - artemisietosum frigidae Hilbig 2009 (Table 1: 4)
 - O Zygophyllo xanthoxyli-Brachanthe-metalia gobici (Mirkin in Kašapov et al. 1987) Mirkin et al. 1988
 - L Caraganion leucophloae Hilbig 2000
 - A Amygdalo pedunculatae-Caragane-tum leucophloae Hilbig (1987) 1990 (Table 1: 5)
 - A Oxytropidi aciphyllae-Caragane-tum leucophloae Hilbig (1987) 1990
 - typicum subass. nov. hoc loco (Table 1: 6, Table 3: 1)

Table 8. Grazing-mediated *Chenopodium album*-*Salsola collina* community on sites of the Glycyrrhizo uralensis-Achnatheretum splendidis.

| Column | 1 | 2 | 3 | 4 | 5 |
|--|--------|--------|--------|--------|--------|
| Relevé no. | 312-03 | 311-03 | 313-03 | 314-03 | 315-03 |
| Total vegetation cover in % | 70 | 50 | 40 | 50 | 15 |
| Species number per relevé | 4 | 6 | 5 | 6 | 5 |
| Summer annual disturbance indicators | | | | | |
| <i>Salsola collina et tragus</i> | 2m | 2m | 2m | 2m | r |
| <i>Chenopodium album</i> agg. | 3 | 3 | 3 | 3 | 2m |
| <i>Chenopodium aristatum</i> | . | + | r | r | . |
| <i>Chenopodium acuminatum</i> | 2a | 2a | 2a | 2m | + |
| <i>Chenopodium vulvaria</i> | . | . | r | 2a | 2a |
| <i>Setaria viridis</i> | . | . | . | + | r |
| Diagnostic species of Achnatherion splendidis | | | | | |
| <i>Achnatherum splendens</i> | r | r | . | . | . |
| Diagnostic species of Caraganion leucophloae | | | | | |
| <i>Krascheninnikovia ceratoides</i> | . | 2a | . | . | . |

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.

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Relevé no. | 396-03 | 394-03 | 395-03 | 397-03 | 498-03 | 499-03 | 399-03 | 398-03 | 497-03 | 496-03 | 383-03 | 491-03 | 492-03 | 380-03 | 494-03 | 644-03 | 645-03 | 646-03 | 382-03 | 490-03 | 381-03 | 379-03 |
| Total vegetation cover in % | 70 | 60 | 50 | 60 | 55 | 40 | 25 | 30 | 60 | 85 | 70 | 80 | 75 | 40 | 70 | 55 | 70 | 80 | 35 | 85 | 50 | 30 |
| Species number per relevé | 22 | 18 | 19 | 13 | 9 | 12 | 13 | 7 | 5 | 2 | 1 | 6 | 7 | 2 | 3 | 4 | 2 | 3 | 2 | 2 | 2 | 2 |
| Diagnostic species of Cleistogenetea squarrosae | | | | | | | | | | | | | | | | | | | | | | |
| <i>Poa attenuata</i> | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Koeleria cristata</i> | + | + | . | . | + | 2a | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Agropyron cristatum</i> | 1 | 2a | 2a | + | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Carex duriuscula</i> | 2b | . | . | 2m | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Artemisia dolosa</i> | + | + | 1 | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Bupleurum bicaule</i> | . | . | r | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Phlomis tuberosa</i> | 1 | . | 1 | + | . | 1 | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Dontostemon integrifolius</i> | + | 1 | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Diagnostic species of Stipion krylovii | | | | | | | | | | | | | | | | | | | | | | |
| <i>Stipa krylovii</i> | 1 | 1 | 1 | + | r | . | + | . | . | . | . | . | . | r | . | . | . | . | . | . | . | . |
| <i>Artemisia frigida</i> | 1 | + | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Ptilotrichum canescens</i> | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Scorzonera ikonnikovii</i> | + | . | 2m | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Astragalus cf. brevifolius</i> | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Allium tenuissimum</i> | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Iris potaninii</i> | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Oxytropis cf. micrantha</i> | . | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Differential species of Stellaria petraea subass. of Hedysaro pumili-Stipetum krylovii | | | | | | | | | | | | | | | | | | | | | | |
| <i>Stellaria dichotoma</i> | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Grazing indicators | | | | | | | | | | | | | | | | | | | | | | |
| <i>Leymus chinensis</i> | 1 | 2a | 2a | 1 | 2a | 1 | 1 | . | 1 | + | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Leymus secalinus</i> | . | . | . | . | . | . | . | . | . | . | 2a | 1 | 3 | 2a | 3 | 2b | 2a | 2b | 2a | 2a | 1 | + |
| <i>Chenopodium album agg.</i> | + | + | 1 | 1 | 3 | + | 2a | 1 | 3 | 5 | . | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 5 | 4 | 3 |
| <i>Axyris prostrata</i> | 2a | 1 | 1 | 2b | 2m | 2m | 2m | 2b | 2m | . | . | 2a | 2a | . | . | 2m | . | . | . | . | . | . |
| <i>Salsola collina et tragus</i> | + | 1 | 1 | + | . | + | + | . | + | . | . | + | + | . | + | . | . | . | . | . | . | . |
| <i>Artemisia macrocephala</i> | + | 2m | + | + | . | . | + | 2a | . | . | . | . | . | . | . | r | . | . | . | . | . | . |
| <i>Chenopodium acuminatum</i> | 1 | 1 | 1 | + | + | + | + | + | . | . | . | . | . | . | . | . | . | r | . | . | . | . |
| <i>Chenopodium vulvaria</i> | 1 | 1 | 1 | + | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Senecio dubitabilis</i> | + | + | + | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Chenopodium aristatum</i> | r | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Further species | | | | | | | | | | | | | | | | | | | | | | |
| <i>Elytrigia nevskii</i> | 1 | 2a | 2a | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Artemisia rutifolia</i> | r | . | . | . | 1 | 3 | + | r | 2a | . | . | . | + | . | . | . | . | . | . | . | . | . |
| <i>Heteropappus hispidus</i> | . | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| <i>Urtica cannabina</i> | . | . | . | . | r | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |

artemisietosum frigidae subass. nov.
hoc loco (Table 1: 7, Table 3: 2)

C Cleistogenetea squarrosae Mirkin et al. ex
Korotkov et al. 1991

Syn. Agropyretea cristati Hilbig et Kololjuk
2000

O Stipetalia krylovii Kononov, Gogoleva et
Mironova 1985

L Stipion krylovii Kononov, Gogoleva et
Mironova 1985

A Hedysaro pumili-Stipetum krylovii
Hilbig (1987) 1990 corr. 1995

Stipa glareosa form (Table 4: 1)

typicum Hilbig 2009 (Table 4: 2)

stellarietosum petraeae Hilbig 2009
(Table 4: 3)

Agropyron cristatum community (Table 10)

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.

| Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Relevé no. | 58-03 | 56-03 | 60-03 | 26-03 | 57-03 | 52-03 | 59-03 | 53-03 | 27-03 | 55-03 | 51-03 | 54-03 |
| Total vegetation cover in % | 10 | 20 | 15 | 25 | 20 | 20 | 10 | 20 | 30 | 15 | 15 | 15 |
| Species number per relevé | 19 | 14 | 18 | 15 | 13 | 13 | 12 | 10 | 8 | 11 | 10 | 6 |
| Diagnostic species of Cleistogenetea squarrosae | | | | | | | | | | | | |
| <i>Poa attenuata</i> | . | . | . | + | . | . | . | . | . | r | . | . |
| <i>Koeleria cristata</i> | + | 2a | + | + | 2m | 2a | 2m | 2a | + | + | 2a | . |
| <i>Agropyron cristatum</i> ** | + | 2a | . | r | + | + | 2m | + | + | . | 1 | . |
| <i>Carex duriuscula</i> */** | + | + | + | . | + | . | + | . | . | . | . | 2a |
| <i>Artemisia dolosa</i> | + | + | + | 1 | 2m | 1 | + | + | + | + | + | . |
| <i>Potentilla bifurca</i> ** | + | + | + | + | + | + | + | + | + | + | + | . |
| <i>Bupleurum bicaule</i> | + | . | . | r | . | . | . | . | . | . | . | . |
| <i>Potentilla multifida</i> | . | . | . | . | . | . | . | + | . | . | . | 2m |
| <i>Phlomis tuberosa</i> | . | . | . | . | . | . | . | . | + | r | . | . |
| Diagnostic species of Stipion krylovii | | | | | | | | | | | | |
| <i>Stipa krylovii</i> | + | + | . | . | + | . | . | . | . | . | . | . |
| <i>Artemisia frigida</i> * | . | . | + | . | . | . | + | . | . | . | . | . |
| <i>Scorzonera ikonnikovii</i> | . | . | . | . | . | . | . | . | . | 2m | . | . |
| <i>Astragalus cf. brevifolius</i> | . | . | . | . | . | r | . | r | . | + | . | . |
| <i>Allium tenuissimum</i> | . | . | + | . | . | . | . | . | . | . | . | . |
| <i>Oxytropis cf. micrantha</i> | . | + | . | . | . | . | + | . | . | . | . | . |
| Differential species of Stellaria petraea subass. of Hedysaro pumili-Stipetum krylovii | | | | | | | | | | | | |
| <i>Amblynotus rupestris</i> | r | + | + | + | + | r | + | . | . | . | . | . |
| <i>Chamaerhodos altaica</i> * | r | . | + | . | 1 | . | . | . | . | . | . | . |
| <i>Oxytropis tragacanthoides</i> | . | . | + | . | . | . | . | . | . | . | . | . |
| <i>Smelowskia alba</i> | . | . | r | + | . | . | . | . | . | . | . | . |
| <i>Clausia aprica</i> | + | . | . | + | . | + | . | . | . | . | r | . |
| Diagnostic species of Helictotrichion schelliani | | | | | | | | | | | | |
| <i>Festuca lenensis</i> | + | + | 2m | 1 | 2m | . | 2m | . | . | . | . | . |
| <i>Potentilla sericea</i> | + | + | + | + | + | + | + | + | + | . | . | + |
| <i>Festuca sibirica</i> | . | . | . | + | . | . | . | . | + | . | . | . |
| <i>Hedysarum ferganense</i> | r | + | + | . | . | . | . | . | . | . | . | . |
| Species with main distribution in the alpine belt | | | | | | | | | | | | |
| Diagnostic species of Oxytropidi oliganthaefestucetum lenensis | | | | | | | | | | | | |
| <i>Stellaria brachypetala</i> | r | . | . | . | . | . | . | . | . | . | . | + |
| <i>Arenaria meyeri</i> | 1 | 1 | + | . | r | . | 1 | . | . | 1 | . | . |
| <i>Elytrigia geniculata</i> | . | . | + | . | . | . | . | . | . | . | . | . |
| <i>Plantago komarovii</i> | r | + | . | . | r | r | + | . | . | . | . | . |
| Differential species of Stellaria pulvinata subass. of Oxytropidi oliganthaefestucetum lenensis | | | | | | | | | | | | |
| <i>Saussurea leucophylla</i> | r | . | . | . | . | . | . | . | . | . | . | . |
| Diagnostic species of Kobresion myosuroidis | | | | | | | | | | | | |
| <i>Carex rupestris</i> | . | . | . | . | . | + | . | + | . | + | + | r |
| Summer annual disturbance indicators | | | | | | | | | | | | |
| <i>Axyris hybrida</i> * | . | . | . | . | . | + | . | + | . | + | 2m | . |
| <i>Chenopodium glaucum</i> * | . | . | . | r | . | . | . | . | + | . | . | . |
| Further species | | | | | | | | | | | | |
| <i>Astragalus cf. versicolor</i> | . | . | . | + | . | . | . | . | . | . | . | . |
| <i>Astragalus cf. dilutus</i> | r | . | . | . | . | . | . | . | . | . | . | . |
| <i>Oxytropis cf. pauciflora</i> | . | . | . | . | . | . | . | 1 | . | . | . | . |
| <i>Elymus aegilopoides</i> | . | . | + | . | . | . | . | . | . | . | . | . |
| <i>Oxytropis myriophylla</i> * | . | . | + | + | . | + | . | . | 1 | . | . | . |
| <i>Dontostemon senilis</i> * | . | . | . | . | . | . | . | . | . | + | + | . |
| <i>Ephedra monosperma</i> | . | 2m | . | . | r | . | . | . | . | . | . | . |

Further in column 1: *Leymus secalinus* +
 3: *Elytrigia nevskii* 2m
 6: *Oxytropis cf. gracillima* +
 11: *Hymenolobus procumbens* r, *Taraxacum eriopodum* r
 12: *Poa tianschanica* +

- 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)
- C Carici rupestris-Kobresietea bellardii
 Ohba 1974
 O Kobresietalia myosuroidis Mirkin et al.
 (1983) 1986
 L Kobresion myosuroidis Mirkin et al. ex
 Hilbig 2000
 A Oxytropidi oliganthae-Festucetum
 lenensis ass. nov. hoc loco

- typicum subass. nov. hoc loco
 (Table 4: 6, Table 5: 1–11)
 stellarietosum pulvinatae subass. nov.
 hoc loco (Table 4: 7, Table 5: 12–22)
Axyris prostrata-*Festuca lenensis* community
 (Table 11)
 A Kobresietum myosuroidis Mirkin et
 al. ex Hilbig 2000
 typical form (Table 4: 8)
Kobresia smirnovii form (Table 4: 9)
Koeleria cristata community (Table 12)

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 oliganthae-Festucetum lenensis. Grazing indicators are labelled with one and xerophytisation indicators with two asterisks.

| Column | 1 | 2 | 3 | 4 | 5 |
|---|--------|--------|--------|--------|--------|
| Relevé no. | 233-03 | 231-03 | 232-03 | 229-03 | 230-03 |
| Total vegetation cover in % | 15 | 15 | 10 | 15 | 15 |
| Species number per relevé | 13 | 13 | 13 | 11 | 11 |
| Diagnostic species of Cleistogenetea squarrosae | | | | | |
| <i>Poa attenuata</i> | + | + | + | + | + |
| <i>Bupleurum bicaule</i> ** | + | . | . | + | . |
| <i>Potentilla multifida</i> | 1 | + | + | 1 | 1 |
| <i>Dontostemon integrifolius</i> ** | 1 | + | + | + | + |
| Diagnostic species of Stipion krylovii | | | | | |
| <i>Artemisia frigida</i> * | . | 1 | . | . | . |
| Differential species of Stellaria petraea subass. of Hedysaro pumili-Stipetum krylovii | | | | | |
| <i>Sibbaldianthe adpressa</i> ** | + | 1 | 1 | + | . |
| Diagnostic species of Helictotrichion schelliani | | | | | |
| <i>Festuca lenensis</i> | + | + | 1 | + | + |
| Species with main distribution in the alpine belt | | | | | |
| Diagnostic species of Oxytropidi oliganthae-Festucetum lenensis | | | | | |
| <i>Oxytropis oligantha</i> | . | . | . | r | . |
| <i>Stellaria brachypetala</i> | . | . | . | . | 2a |
| <i>Pachyneurum grandiflorum</i> | . | . | + | . | . |
| <i>Melandrium apetalum</i> | . | . | . | . | + |
| <i>Artemisia pycnorhiza</i> | 1 | 1 | 1 | 1 | 1 |
| <i>Elytrigia geniculata</i> | . | . | + | . | . |
| <i>Alopecurus turczaninovii</i> | + | + | + | 2m | + |
| <i>Allium amphibolum</i> | + | + | + | . | . |
| <i>Plantago komarovii</i> | + | + | + | + | + |
| Diagnostic species of Kobresion myosuroidis | | | | | |
| <i>Carex rupestris</i> | . | + | + | . | + |
| <i>Ranunculus pedatifidus</i> | r | . | . | . | . |
| Summer annual disturbance indicators | | | | | |
| <i>Axyris prostrata</i> ** | 2a | 2a | 1 | 1 | + |
| Further species | | | | | |
| <i>Stellaria amblyosephala</i> ** | r | . | . | . | . |
| <i>Draba nemorosa</i> | . | r | . | . | . |

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.

| Column | 1 | 2 | 3 | 4 |
|--|-------|-------|-------|-------|
| Relevé no. | 45-02 | 44-02 | 37-02 | 36-02 |
| Total vegetation cover in % | 90 | 85 | 95 | 95 |
| Species number per relevé | 22 | 17 | 18 | 8 |
| Diagnostic species of Cleistogenetea squarrosae | | | | |
| <i>Koeleria cristata</i> ** | + | + | 2m | + |
| <i>Carex duriuscula</i> ** | . | . | 2m | 4 |
| <i>Potentilla multifida</i> | + | + | + | + |
| Diagnostic species of Helictotrichion schelliani | | | | |
| <i>Festuca lenensis</i> | 2b | 2a | 3 | . |
| <i>Senecio integrifolius</i> ** | + | + | 1 | . |
| Species with main distribution in the alpine belt | | | | |
| Diagnostic species of Oxytropidi oliganthae-Festucetum lenensis | | | | |
| <i>Androsace chamaejasme</i> | + | 2m | 2m | . |
| <i>Oxytropis oligantha</i> | 2b | 3 | r | . |
| <i>Eritrichium pauciflorum</i> | 2b | 2b | . | . |
| <i>Stellaria brachypetala</i> | + | + | + | + |
| <i>Arenaria meyeri</i> | 2m | + | . | . |
| <i>Pachyneurum grandiflorum</i> | + | 2m | + | . |
| <i>Artemisia phaeolepis</i> | . | . | + | . |
| <i>Melandrium apetalum</i> | . | . | + | . |
| <i>Plantago komarovii</i> | + | + | + | . |
| Differential species of Stellaria pulvinata subass. | | | | |
| <i>Stellaria pulvinata</i> | 2a | 2a | . | . |
| <i>Smelowskia mongolica</i> | + | r | . | . |
| Diagnostic species of Kobresion myosuroidis | | | | |
| <i>Kobresia myosuroides</i> | + | . | . | . |
| <i>Thalictrum alpinum</i> | + | r | . | . |
| <i>Carex rupestris</i> | 2m | 1 | + | . |
| <i>Ranunculus pedatifidus</i> | + | . | + | + |
| <i>Poa alpina</i> | . | + | . | . |
| <i>Poa altaica</i> | + | + | + | . |
| Species of alpine wet sites | | | | |
| <i>Primula farinosa</i> | . | . | . | r |
| Further species | | | | |
| <i>Artemisia argyrophylla</i> ** | r | . | . | . |
| <i>Oxytropis cf. pauciflora</i> | + | . | 1 | . |
| <i>Artemisia blepharolepis</i> | . | . | 2m | + |
| <i>Taraxacum spec.</i> | . | . | . | + |

Further in column 1: *Spodiopogon sibiricus* r
 2: *Poa tianschanica* +, *Trisetum litwinowii* r

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 her-

bivory-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-

agement 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, STUMPP et al. 2005) demonstrated negligible grazing impacts on semideserts 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 air mass above (MURZAEV 1954). The vegetation of the alpine belt serves as summer pasture, grazed from mid-June until the end of August. Alpine vegetation, representing a comparatively high productivity along the altitudinal gradient (mean above standing biomass per sqm: semidesert – 34 g / harvested in September, mountain steppe – 46 g / September, alpine mats – 55 g / July; unpublished data), is grazed during the growing period of plants representing a time, in which vegetation is more susceptible to grazing than before or after the growing period. Since the grazing period of alpine vegetation coincides with the lactation and reproduction period of livestock, animals require the highest nutritive en-

ergy resulting in the highest biomass uptake during the year (GLATZLE 1990). The productive 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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