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# Plant communities of the Gobi Gurvan Sayhan National Park (South Gobi Aymak, Mongolia)

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## ABSTRACT

WESCHE, K., S. MIEHE & G. MIEHE (2005). Plant communities of the Gobi Gurvan Sayhan National Park (South Gobi Aymak, Mongolia). *Candollea* 60: 149-205. In English, English and French abstracts.

This paper presents the first detailed description of plant communities in the south-eastern Gobi Altay, covering the terrain of the Gobi Gurvan Sayhan National Park and adjacent areas. Phytosociological classification of 549 relevés yielded 4 community groups with 39 communities. The distribution of communities is largely controlled by water availability, which is generally higher in the mountains. The upper slopes are covered by scrub with *Juniperus sabina* and by various types of mountain steppes with *Stipa krylovii*, while *S. gobica* desert-steppes dominate the upper piedmont areas. With decreasing humidity, *Stipa glareosa*-*Allium polyanthum* desert steppes occur and merge with semi-desertic, very open dwarf-shrublands towards the inter-montane basins and salt pans. *Anabasis brevifolia*, *Salsola passerina*, *Zygophyllum xanthoxylon*, and *Haloxylon ammodendron* are the most characteristic woody constituents of these semi-deserts. Extra-zonal vegetation types of minor spatial extent concentrate in water-surplus habitats in both extremes of the humidity range: *Betula microphylla* forests, *Helictotrichon schellianum* meadow steppes, and *Kobresia myosuroides* mats are restricted to the moistest slopes in the mountains; they contrast with *Nitraria* scrub, takyr communities, salt meadows, and *Phragmites* reeds in saline habitats of the inter-montane basins. The steppes have been grazed by both, wild and domestic herbivores for millennia, so all occurring plant species are well adapted to the grazing pressure. No regional grazing indicators could be identified, and grazing appears to be sustainable on the current level. However, rare occurrences of trees (*Populus laurifolia* gallery forest in the mountains, *Populus diversifolia* woodlands, and *Ulmus pumila* stands in the piedmont zones) indicate a certain potential for tree growth at favourable sites in the study area. Further studies are needed to assess whether trees could become more abundant if grazing is strictly controlled.

## RÉSUMÉ

WESCHE, K., S. MIEHE & G. MIEHE (2005). Les communautés végétales du Parc National de Gobi Gurvan Sayan (South Gobi Aymak, Mongolie). *Candollea* 60: 149-205. En anglais, résumés en anglais et français.

Cet article présente la première description détaillée des communautés végétales dans le sud-est du Gobi Altay, couvrant le terrains du Parc National de Gobi Gurvan Sayan et des régions adjacentes. La classification phytosociologique de 549 relevés a donné 4 groupements végétaux comprenant 39 communautés. La distribution des communautés dépend surtout de la disponibilité d'eau qui, en général, est plus abondante dans les montagnes. Les pentes supérieures sont couvertes de différents types de steppes montagnardes avec *Stipa krylovii*, tandis que les parties plus hautes des régions de piedmont sont dominées par des steppes désertiques avec *S. gobica*. Avec l'humidité décroissante

apparaissent des steppes désertiques avec *Stipa glareosa*, et *Allium polyrrhizum*; en allant vers les bassins intermontagnards et les bassins salés, ces steppes désertiques se mêlent à des terrains semi-désertiques clairsemés de broussailles naines dont *Anabasis brevifolia*, *Salsola passerina*, *Zygophyllum xanthoxylon* et *Haloxylon ammodendron* sont les constituants ligneux les plus caractéristiques. Il y a des types de végétation extra-zonaux peu étendus qui sont concentrés dans les habitats caractérisés par un surplus d'eau édaphique, dans les deux extrêmes d'humidité climatique présentant des forêts de *Betula microphylla*, des broussailles de *Juniperus sabina* et des pelouses de *Kobresia myosuroides*, limités aux pentes très humides des montagnes, et, en contraste, des broussailles de *Nitraria sibirica*, des communautés takyr, des prés-salés et des communautés de *Phragmites communis* dans les habitats salés des bassins inter-montagnards. Les steppe ont été pâturées par des herbivores sauvages aussi bien que domestiques pendant des millénaires, et toutes les espèces de plantes sont donc bien adaptées à la pâture. Il n'a pas été possible d'identifier les espèces indicatrices de pâtures régionales. La pâture apparaît être supportable en l'état actuel. De plus, la présence d'arbres, même si elle est rare (des forêts-galleries de *Populus laurifolia* dans les montagnes, des bois de *Populus diversifolia*, et des populations d'*Ulmus pumila* dans les zones de piedmont) témoigne dans la zone étudiée de sites favorables à la croissance d'arbres. Il est nécessaire de continuer les recherches pour juger si les arbres pourraient devenir plus abondants sous conditions d'une pâture strictement contrôlée.

**KEY-WORDS:** Mongolia – Semi-deserts – Grazing impact – Phytosociology – Steppes – Vegetation

## 1. Introduction

The Gobi Gurvan Sayhan National Park in southern Mongolia is the second largest protected area in Mongolia and one of the largest national parks in the world (BEDUNAH & SCHMIDT, 2000). It covers some 27 000 km<sup>2</sup>, with some 400 km E-W extension and around 80 km width in N-S direction (Fig. 1). The park was designated in the 1990s to protect a variety of landforms and habitats. It was named after the three easternmost outposts of the Gobi Altay range, which form green islands in the semi-desert and are therefore called the “Three Beauties of the Gobi” (Mongolian: “Gobi Gurvan Sayhan”). They emerge from surrounding semi-deserts with sand fields, takyrs (salt pans), and extensive pediments typical of a central Asian landscape.

The area is known for its wildlife, which includes several endangered large mammals (READING & al., 1999) and endemic arthropods (BAYARTOGTOKH & al., 2002); several plant species are endemic to the Gobi Altay (UNDRAKH & al., 2003: 135). The flora of Mongolia is reasonably well known (summary in GUBANOV, 1996; GRUBOV, 2000), and general inventories of the vegetation are also available (e.g. LAVRENKO & KARAMYSHEVA, 1993; HILBIG, 1995; KARAMYSHEVA & KHRAMTSOV, 1995; review in HILBIG, 1982, 1988). Detailed information on the Gobi Gurvan Sayhan region (henceforth GGS NP) is, however, limited and only part of the area was visited by vegetation scientists in the last decades (JUNATOV, 1974; HELMECKE & SCHAMSAN, 1979a; HILBIG, 1990a). The region is close to the interstate boundary, but the vegetation on the Chinese side is hardly studied except for a recent publication on the vegetation of the Chinese part of the northern Gobi (KÜRSCHNER, 2004). Desert steppes, i.e. semi-desert grasslands, and deserts in north-western Mongolia have been studied in more detail (HILBIG & al., 1988; HILBIG, 2003), but are different from southern Mongolia because more species with western Asian affinities occur (HILBIG & KOROLJUK, 2000). Detailed vegetation maps have been produced for the north-western part of the country (BURKART & al., 2000), but maps for southern Mongolia are only available on a coarse scale (LAVRENKO, 1979; GUNIN & VOSTOKOVA, 1995).

Thus, the aim of the present study is twofold. We present a reasonably detailed account on a region, which has not been intensively studied before, and test and amend the available classification scheme for the vegetation of Mongolia (HILBIG, 2000c). This information is also meant to provide baseline data for the management of the GGS NP. In describing the vegetation patterns, we chose a phytosociological method, in order to allow reference to the most comprehensive classification system for the vegetation of Mongolia (HILBIG, 1995; HILBIG, 2000c).

## 2. Study area

### 2.1 Geology, landforms and soil

The landforms of the study area are dominated by inter-montane basins, pediments, and rocky mountain massifs. Sand dunes and salt marshes cover 6% in basins at altitudes between 1300 and 1500 m; pediments cover 63% of the area up to 2300 m, while steep rocks and scree slopes reach up to 2850 m, and account for the remaining 31%. The rocky massifs are mainly built of Palaeozoic gabbros, sandstones, slate, and tonalit; basalts of cretaceous age occur in small spots (ANONYMUS, 1990). Blocks and their Jurassic or Cretaceous cover were uplifted during the Tertiary along WNW-ESE running faults (CHAIN & KORONOVSKIJ, 1995), but earthquakes are still common. Rocky outcrops have been exposed to heavy frost weathering since the Quaternary and are widely covered with screes. Quaternary sediments cover more than three quarters of the area; pediments developed in several generations, and are currently dissected by broad valleys with episodic run-off (Mongolian: "sayrs"). Ancient beach ridges and cliff-like shorelines delimit the pediments against the former lake basins, as they do in the lake regions of Northwest Mongolia (WALTHER, 1998).

Thus, the younger landscape history is characterised by two major erosive processes, namely, episodic linear erosion during heavy rainfall in summer, and permanent wind deflation on the pediments. The surfaces of the deflation pavements change comparatively slowly as indicated by coatings of desert varnish on all stones, but material is still blown out and accumulates around shrubs, in flat basins, or forms active sand dunes, which are often surrounded by oases.

Though not described previously for the GGS NP, glacial remains were found in the form of old morainic substrates buried during pedimentation on the southern slope of Nemegt Uul (2220 m, Fig. 1), and on the northern slopes of the Baruun Sayhan near the valley mouth of Gegeetiy Am (1850 m). Younger deposits shaped like terminal moraines have been found in the southern declivity of the Nemegt Uul and Sevrey Uul in 2200 m altitude.

The mountain slopes carry shallow kastanosems, parachernosems, and leptosols, while the dominant soil types in the upper pediment areas are burosems and kastanosems. Edaphically special situations include sandy areas with weakly developed arenosols and temporarily moist depressions where solonchak and solonetz soils are found.

### 2.2 Climate

The climate is semi-arid and highly continental, and the growing season is limited by little precipitation in spring and by frost between September and May (Fig. 2). All climatic stations of the National Meteorological Service are situated in the semi-deserts of the inter-montane basins. Mean temperatures in July are just above 20°C, whereas for January means depend on the relief. Sevrey in 1750 m, situated in a flat watershed between two massifs, encounters -13°C only, whereas Bayandalay (1570 m) in the centre of an inter-montane basin has -18°C.

The mean annual precipitation of the basins and on the pediments is well below 150 mm and decreases westwards from 131 mm/a (Dalandzadgad) to 84 mm/a (Sevrey), indicating that the East Asian Monsoon (coming from south-east) accounts for part of the summer precipitation (HELMCKE & SCHAMSRAN, 1979a; BARTHEL & al., 1983). Rainfall in the mountain massifs is considerably higher; rain gauge measurements along a transect between 1800 m and 2850 m in the Dund Sayhan in summer of 2001 revealed an increase from 10 mm (drought conditions, see below) at the foot of the mountain massif to well above 50 mm at the summit region (RETZER, 2004). Snowfall in winter is unpredictable and insignificant in terms of water volume, but locally nomads avoid locations where snow is known to accumulate. Snow-mould damage of junipers in valley grounds also indicates the at least periodical presence of a snow cover.

Precipitation totals vary tremendously from year to year. Although it is generally held that central Asia dries out slowly, the available data do not reflect such a trend in the last decades (Fig. 3).

This finding is supported by recent dendroclimatological studies that suggest unchanged or even increasing annual precipitation for Mongolia in the 20<sup>th</sup> century (JACOBY & al., 2000). The strongest winds occur in April and May (up to 100 km/h; RETZER, 2004). Westerly directions prevail; these are relatively dry as is indicated by the low cover of vegetation on slopes exposed to western winds in comparison to leeward sites.

### 2.3 The regional floristic context

The Gobi desert is part of the central Asian desert region that borders the northern steppe regions. The steppe flora belongs to the Mongolian sub-region of the Central Siberia-Dauria-Mongolian region, as opposed to the desert flora of the Gobi province, which is part of the Central-Asiatic region (MALYSHEV, 2000). Both provinces / sub-regions are, however, sometimes included in the Central-Asiatic region (MEUSEL & al., 1992a, 1992b). The species set clearly reveals affinities to the eastern parts of Asia, and several species reach their western limits in Mongolia (*Stellaria dichotoma*, *Panzeria lanata*, *Convolvulus ammannii*, HILBIG & al., 1999). In contrast, western Eurasian elements (e.g. *Nanophyton erinaceum*, *Ceratocarpus arenarius*) are still found in the Uvs Nuur basin and in the Dzungarian Gobi in western Mongolia (JÄGER & al., 1985). In the GGS NP, three floristic areas intersect, namely, the Gobi Altay area with a relatively rich flora influenced by the mountains (some 700 species), whereas towards the far south the dry Alashan Gobi and West Gobi areas are much poorer in species (250 and 350 species respectively, MALYSHEV, 2000).

The drier semi-desert areas are characterised by woody perennials, with Chenopodiaceae having the largest diversity. Other characteristic species include *Reaumuria soongorica* (Tamaricaceae) and *Caragana leucophloea* (Fabaceae). Pennate feather grasses of the section *Barbatae* (mainly *Stipa glareosa* and *S. gobica*) and several onions (*Allium mongolicum*, *A. polorrhizum*) are the typical herbaceous species. The corresponding taxa in the steppe vegetation of the mountain ranges are *Stipa* sect. *Leiostipa* (*S. krylovii* in the southern part of Mongolia, HILBIG & al., 1999) and *Agropyron cristatum*. A higher diversity of herbs (*Astragalus* div. spec., *Oxytropis* div. spec.) is characteristic here. *Artemisia frigida* is the most common dwarf-shrub in the mountain steppes. The Altay mountains offered migration routes for species from the northern parts of the country, and consequently, isolated outposts of moist steppe vegetation occur in some parts of the Gurvan Sayhan ranges. These are among the plant communities with the highest species richness in the area. Large phanerophytes are only found in extrazonally moist, mostly montane habitats, the prime example are stands of *Betula microphylla*, which are widespread elsewhere in northern and central Mongolian forests (GRUBOV, 2001).

### 2.4 Administration and land use

The National Park is located in southern Mongolia in the South Gobi Aymak west of the Aymak centre Dalandzadgad, and touches 5 "Sums" (in the size comparable to an English county), namely Bayandalay, Hurmen, Sevrey, Bulgan and Gurvantes. We concentrated on the park itself but covered the adjacent territories wherever possible (Fig. 1).

Given that precipitation is unreliable and low, land use has always been and still is based on nomadic pastoralism. Nomadism has as a long history in Mongolia (FERNANDEZ-GIMENEZ, 1999) and at present grazing affects almost the entire park area (STUMPP & al., in press). Thus the remaining plants and communities should be grazing-tolerant to some extent; whether there is a potential for growth of more sensitive species will be discussed in the last chapter after the results.

### 3. Methods

#### 3.1 Data collection

The present classification is based on a total of 549 relevés, which were collected during two field campaigns in 1996 and 2001. Relevé sampling followed a modified Braun-Blanquet approach. We used quadrates 10 x 10 m in size, and recorded all vascular plant species. Since commonly applied cover abundance scales (Braun Blanquet scale, Londo scale; cf. LONDO, 1976) were not detailed enough for the sparse vegetation in the GGS NP, we estimated the absolute cover percentage. Classification, however, relied mainly on presence/absence of a species. Cover served as supplementary information for the general description of stands or in the classification of rankless communities, e.g. dominance stands.

We sampled plots only once, because the growth season is short in the region such that almost all plants develop simultaneously during the two summer months. An extraordinary drought hit the South Gobi Aymak in 2001. As a consequence, annuals were much rarer than in 1996, so data analysis had to concentrate on perennial species (see e.g. Table 3). Their presence shows little inter-annual differences as demonstrated by a repeated sampling study in neighbouring Bayankhongor Aymak (FERNANDEZ-GIMENEZ & ALLEN-DIAZ, 1999). Selection of sample sites was deliberate, but was partly aided by visual inspection of printouts from LANDSAT 7 scenes, which were subjected to an unsupervised classification prior to fieldwork. Samples were georeferenced with ordinary hand-held GPS. The survey character of the work restricted the range of supplementary data to the most easily assessed parameters (Table 1). In selected plots, a mixed sample of the topsoil (-5 cm, taken from at least three sites within the plot) was analysed for pH and conductivity (20 dry fine soil, 50 ml deionised water, AG BODENKUNDE, 1994).

#### 3.2 Plant identification

A (relatively) comprehensive flora became recently available in English (GRUBOV, 2001); this and the available volumes of the Plants of Central Asia (GRUBOV, 2000) were used for preliminary identifications in the field. For reasons of consistency, scientific names of plants follow GRUBOV (2001), although species names are not always those currently accepted (e.g. in *Populus*, *Salicornia*, *Carex*). At least two herbarium specimens were prepared for all species; individuals of unidentified species or those belonging to difficult groups (e.g. *Fabaceae*) were always collected. Identifications were checked in the Herbarium of the Institute of Geobotany and Botanical Garden, University of Halle (HAL). Some critical groups were cross-checked by specialists (s. acknowledgements). Vouchers were deposited at the national park administration in Dalandzadag and in the Herbarium in Halle.

#### 3.3 Classification of vegetation types

There are two principal lines of thought on vegetation classification in Eurasia. Russian vegetation scientists used to classify plant communities according to the abundance of dominant species (synthesis by WALTER, 1974), while the phytosociological or Braun-Blanquet approach designates communities largely on the presence of character species (BRAUN-BLANQUET, 1964; MUELLER-DOMBOIS & ELLENBERG, 1974). In the present study, we also used phytosociological methodology, since the most recent comprehensive classification of the Mongolian vegetation is based on the Braun-Blanquet approach (HILBIG, 1990a; 1995; 2000c). Moreover, Braun-Blanquet tables are probably more easily understood by the general reader than dominance-based classifications (HILBIG, 1990b). Recent publications by Russian authors adopted a similar methodology (e.g. KARAMYSHEVA & KHRAMTSOV, 1995).

We compiled all data in one table (549 samples and 349 species), which was sorted according to the presence of diagnostic species (BRAUN-BLANQUET, 1964; MUELLER-DOMBOIS & ELLENBERG, 1974). For consistency, labelling of communities followed HILBIG (2000c and reference

therein) wherever possible. Thus, names are given as phytosociological associations, in some cases where the status of communities is not clear we used the rankless term community. In some cases, we describe communities that have no own character species except for those of a higher syntaxon. We refrained from naming them according to the “deductive method” (KOPECKY & HEJNY, 1978), because this has been widely criticised on theoretical and practical grounds (DENGLER, 2003). Thus we retained e.g. Hilbig’s *Stipo glareosae-Anabasietum brevifoliae*, which has no character species other than those of the alliance *Allion polyyrhizi* (HILBIG, 2000c). We think that this is better regarded as a central association of the higher syntaxon, an approach recently defended by DENGLER (2003). The same refers to some communities described in the following text which could probably also be classified as central syntaxa once the overall position is clear.

HILBIG (1990a, 1995) describes subassociations, whenever associations are composed of subunits that lack separate character species but have distinct ecological preferences and an otherwise characteristic species composition. According to the code of phytosociological nomenclature (WEBER & al., 2001), these should be indicated by suffixes based on the scientific name of a diagnostic species. HILBIG (1995) adopts another scheme (“*Hedysaro inundati-Stipetum krylovii – Stellaria petraea* subassociation” rather than the correct “*Hedysaro inundati-Stipetum krylovii stellarietosum*”). We followed Hilbig’s proposal here to allow reference to the available literature. We used the term subcommunity whenever a community covered ecologically distinct subunits without having separate character species.

For presentation, data were split into four main community groups. Accordingly, four constancy tables were compiled, which indicate the frequency of a given species in that community. Frequencies are shown as absolute number of occurrences in case a community was represented by less than 5 relevés, for 5 and more relevés so called “constancy classes” were calculated after DIERSCHKE (1994) (cf. Table 2). Prefixes indicate diagnostic properties of the species. “C” means that the species is a character species which is largely exclusive to that unit. Character species listed in HILBIG (2000c) receive letters “AC” if they are typical for an association, and “LC” (typical for an alliance) or “CC” (typical for a class) if they are characteristic for higher syntaxonomical units. “rC” indicates regional character species that are restricted to the given community in our study area but might occur in other communities elsewhere. Species without a prefix are only diagnostic in the present context and can be found in other communities as well (differential species). Non-diagnostic companions were listed if they had more than two occurrences in the given table, those with two or one occurrence were listed at the bottom of the tables. Full phytosociological tables with the complete data are available from the authors on request and were also placed on the website of the first author (<http://www.biologie.uni-halle.de/bot/wesche.html>). Supplementary data gathered during the survey were summarised as Box and Whisker Plots (Fig. 4). A list of the communities and their syntaxonomical relationships is provided in the appendix.

#### 4. Description of plant communities

##### 4.1 Extrazonal vegetation of the upper mountain slopes (Table 2)

Within the GGS NP precipitation is higher in the mountains than in the lowlands and higher in the east than in the west. Thus, the northern slopes of the eastern mountain ranges in the park support vegetation types typical of moister northern and western Mongolia. Their spatial extent in the Gobi Gurvan Sayhan region is negligible, but nevertheless their importance for the park’s biodiversity is immense, simply because most of the typical species are restricted to these habitats in the area.

###### 4.1.1 *Betula microphylla* community (Table 2, no. 11)

This is the only forest type in the national park which is not confined to river beds and oases. Birch forests occur in northern exposures in the easternmost mountain range, the Zuun Sayhan. The forests are restricted to the upper parts of steep slopes, and receive surplus water trickling down

from the adjacent rock walls. The underlying soils are rich in organic matter and have a neutral pH (Fig. 4). Grazing is apparent at the fringe of the stands but the interior is nearly impenetrable and not grazed. We found no evidence of logging, but the local herders regularly collect fruits.

Among others, the dominant species *Betula microphylla* and *Salix bebbiana* are the character species (Table 2). Trees are single- to multi-stemmed and reach up to 7 meters in height. Young growth of *Salix* and *Betula* is found inside and outside the forest but a possible advance of the forest is hindered by livestock grazing at the fringes (Fig. 5). However, many of the saplings found in the forest interior originate from clonal growth by means of layering, so the importance of sexual regeneration could not be assessed. The undergrowth is dominated by several shrub species and is relatively dense; the herbaceous vegetation is sparse.

There are no other *Betula* forests in the national park, and the nearest known birch forests occur in the Ikh Bogd (HILBIG, 1990a; CERMAK & al., 2005) 350 km distant. The phytosociological position of the *Betula microphylla* forests in Mongolia is uncertain as a consequence of their rareness in the country. Thus we use the rankless name until more material becomes available to assess whether this community deserves association status.

#### 4.1.2 *Populus laurifolia* community (Table 2, no. 12)

A single small patch of *Populus laurifolia* forest grows in a steep valley in the north-eastern Zuun Sayhan. The forest is restricted to the bed of a semi-permanent river and stands are heavily disturbed due to occasional flooding. This is a water surplus site functioning as a “seed trap”; the characteristic poplars are accompanied by various plants common on the surrounding slopes and annuals common of river beds. Trees are mostly single-stemmed and up to 6 m high; several size classes are present although seedlings are rare. The site conditions are apparently not favourable as poplars’ leaves were partly wilted and heavily infected by parasites in 2001. The stand is grazed, but logging is insignificant due to the sacred state of trees in the Gobi. Stands with *P. laurifolia* occur abundantly in the northern parts of Mongolia, where they are much richer in species. We regard our stand as an impoverished community within the *Populion laurifoliae*, which is otherwise widespread in northern and central Mongolia (HILBIG & al., 1999; HILBIG, 2000c).

#### 4.1.3 *Kobresia* mats of the upper slopes – *Kobresietum myosuroidis* Mirkin & al. ex Hilbig 2000 (Table 2, no. 13)

Mats dominated by *Cyperaceae* are typical for the alpine belt of central Asian mountains, but their distribution is very restricted in the Gobi Altay. Small patches occur in the moist easternmost ranges in the GGS NP, where they grow in flat depressions in northern exposures. All stands are heavily grazed, mostly by Yaks, but *Kobresia* mats are generally resistant to grazing and the limiting factor in the national park is definitely moisture. Water surplus in terms of ground water or snow is crucial and this explains why stands are often just a few square metres in size. The surface is structured by small humps that indicate freeze-thaw activity.

*Kobresia* mats have the highest richness of species among the plant communities in the national park, with samples ranging between 19 and 38 vascular plant species. Character species are the dominant *K. bellardii*, *Polygonum viviparum* and several regional character species. The exact phytosociological position is not easily assessed since stands differ in their species set but the available number of samples is too low to designate subcommunities. Moreover, most dominant companions in the study area as well as in the Ikh Bogd (HILBIG, 1990a) are equally common in meadow steppes, which are floristically related to the *Kobresia* mats. Samples of these two communities are mere outposts and are relatively poorly developed, so KARAMYSHEVA & KHRAMTSOV (1995) united them in one larger unit, the “*Festuca lenensis-Festuca kryloviana-Poa attenuata* communities with *Kobresia myosuroides*” acknowledging the floristic similarity of *Kobresia* mats and meadow steppes in the region.

#### 4.1.4 Meadow steppes – *Androsaco ovczinnikovii-Helictotrichetum schelliani* Hilbig 1987 (1990)

##### (Table 2, no. 14)

Most meadow steppes are replacement communities of forest vegetation in northern and central Mongolia (SOMMER, 1998; SOMMER & TRETER, 1999). Not surprisingly, they are very rare in the Gobi Gurvan Sayhan region, and were only found bordering the birch forests, and on a sheltered ravine slope nearby. The belt of meadow steppe vegetation is less than 5 m in width, and the presence of an occasional birch sapling hinted at the successional character of the meadow steppes. These meadow steppes are poorly developed, and share many species with the *Kobresia* mats and with moist mountain steppes described below. This is clearly seen in Table 2, where *Kobresia* mats and meadow steppes share diagnostic species which belong to different alliances (*Kobresion* and *Helictotrichion*). However, stands are physiognomically different from *Kobresia* mats; the characteristic features are: the dominance of medium-sized *Poaceae* rather than low *Cyperaceae*, the presence of *Festuca* species such as *F. lenensis* rather than *K. myosuroides*, and the occurrence of several differential herbaceous species such as *Androsace dasypylla*, which replaces *A. ovcinnikovii* described from similar stands in the Mongolian Altay by HILBIG (1995, 2000c).

#### 4.2 Mountain steppes and related communities (Table 3)

Table 3 covers scrub communities of open scree-slopes and grass-dominated mountain steppes, both groups forming small-scale mosaics in the south-eastern Gobi Altay. Dry mountain steppes are the principal vegetation type of all mountain ranges of the GGS NP. They cover a wide range of habitats from moist mountain slopes neighbouring meadow steppes to weakly inclined pastures on the upper pediments. Not surprisingly, they are differentiated in several subassociations. They lack most of the species typical of the communities described above, and a set of diagnostic species distinguishes them clearly from desert steppes of the lower slopes (*Stipa krylovii*, *Artemisia frigida*). Yet, mountain steppes in the Gobi Altay are much more open than similar stands in northern and central Mongolia, and many species typical of open and partly moving substrate can be found (e.g. *Arenaria meyeri*, *Orostachys spinosa*). Thus, mountain steppes belong to the alliance *Stipion krylovii*, but the presence of species shared with the *Thymion gobici* (Table 3) is a characteristic feature.

The typical species of the mountain steppes on the nearby Ikh Bogd (*Carex pediformis*, *Arenaria capillaris*, *Iris potaninii*, *Hedysarum pumilum*, HILBIG, 2000c) are relatively rare in the GGS NP, a possible local character species is *Oxytropis pumila*. Several other diagnostic species known from sites in the central Gobi Altay are also rare, but we nonetheless adopt the classification by HILBIG (1990a, 1995), who describes several subassociations within the single, rather wide association *Hedysaro pumili-Stipetum krylovii* Hilbig 1987 (1990).

#### 4.2.1 Mountain steppes on moist slopes – *Hedysaro pumili-Stipetum krylovii* Hilbig (1987) 1990: *Festuca valesiaca* variant of the *Stellaria petraea* subassociation Hilbig 1990 (Table 3, no. 211)

Species of the *Thymion gobici* characterise steep slopes with partly open substrate and some soil movement. Stands lack exclusive character species, so they were grouped in a subassociation here, which comprises two variants in our area. A number of species typical of open substrates (*Allium eduardii*, *Arenaria [Eromogone] meyeri*) occur in both communities (no. 211 & 212), which constitute the *Stellaria petraea* subassociation of the *Hedysaro-Stipetum* (HILBIG, 1990a: Table 17). *Stellaria petraea* is relatively rare in the GGS NP, where it is replaced by *S. dichotoma*. The latter indicates similar conditions as *S. petraea* and is a characteristic element of dry mountain steppes in eastern central Asia (HILBIG, 2000a).

Northern exposures in eastern ranges of the park (Baruun Sayhan to Zuun Sayhan, Fig. 1) are covered by relatively dense steppes with a distinct set of species. Stands often grow adjacent to *Kobresia* mats and meadow steppes, and species of these intrude the mountains steppes (Table 3, no. 211). Nevertheless, stands in the GGS NP correspond well with Hilbig's classification, and have several, partly regional character species, among them the dominant *Festuca valesiaca*, *Artemisia*

*pycnorhiza* and *Amblynotus rupestris*. This group and a set of species shared with the Androsaco-Helictotrichetum clearly separate this variant from other mountain steppe communities in the area. Similar steppes with *F. valesiaca* and *A. rupestris* occur in the surroundings of the Uvs Nuur basin (“rock steppes”, HILBIG & al., 1999; HILBIG, 2000a, 2003) and can also be regarded as a subassociation of true grass steppes (*Arctogeranum gramineum* subassociation of the *Cymbario-Stipetum krylovii*, HILBIG, 1995). It might be possible to raise the community to the level of a subassociation as it has at least regional differential species, but we maintain the original classification and regard them as a variant closely related to the next community.

Thus *F. valesiaca* steppes are transitory and are the moistest mountain steppes in the Gobi Gurvan Sayhan region. They reach well above 50% cover and the second highest number of species (mean species richness = 24) after the related *Kobresia* mats and meadow steppes. The character species of mountain steppes (e.g. *Agropyron cristatum*, *Stipa krylovii*) are relatively rare, which points to the alpine rather than montane character of the stands. The lower limit is reached at 2200 m in the Zuun Sayhan, while it climbs to above 2500 m in the Nemegt Uul. Debris movement is a characteristic feature of all sites, and scree and rocks typically cover between 20 and 60% of the sample plots. Where moisture becomes more limited, stands get more open and form the following community.

#### **4.2.2 Mountain steppes – *Hedysaro pumili-Stipetum krylovii* Hilbig (1987) 1990: *Phlojodicarpus sibiricus* variant of the *Stellaria petraea* subassociation Hilbig 1990 (Table 3, no. 212)**

This is the vegetation of the scree slopes in the drier mountain ranges such as Nemegt and Sevrey Uul (Fig. 1), but it occurs on shallow sites eastwards up to the Dund Sayhan. Vegetation rarely reaches 50% cover; most of the surface is covered by scree. Species typical of meadow steppes are absent, and species of mountain steppes (i.e. the *Stipa krylovii* group) are more important than in the *F. valesiaca* variant indicating the transition to mountain steppes of the lower slopes. *Phlojodicarpus sibiricus* is a regional character species together with *Allium eduardii*. The presence of *Arenaria meyeri* (closely related to *A. capillaris* listed by HILBIG, 2000c) and *Stellaria dichotoma* indicates that stands form another variant of the same subassociation as described before.

#### **4.2.3 Mountain steppes on upper pediments – *Hedysaro pumili-Stipetum krylovii* Hilbig (1987) 1990: *Astragalus inopinatus* subassociation Hilbig 1990 (Table 3, no. 213)**

Pediments reach altitudes up to 2300 m in the GGS NP, and still carry mountain steppes on their upper parts. Inclinations are, however, much less than on the scree slopes and petrophilous species give way to bunch grasses and other plants of stable substrates. *Arenaria meyeri* and its allies are rare, while species of grass steppes are always present. The regional character species are the small perennials *Sibbaldianthe adpressa* and *Astragalus laguroides*, (the latter was often sterile or even missing in the dry conditions of 2001). *Astragalus inopinatus*, which is common in mountain steppes of the Ikh Bogd (HILBIG, 1990a) is rare in the GGS NP. *Stipa krylovii* and *Artemisia frigida* designate the stands as mountain steppes, although species of desert steppes also occur, of which *Allium polyyrrhizum* and *S. gobica* are the most common ones. They indicate the transition to semi-desert vegetation of the lower pediments (Table 4). Stands of this subassociation are among the best and most heavily grazed pastures in the park as indicated by the presence of *Carex stenophylla* (= *C. duriuscula* & *C. stenophylloides*, DICKORÉ, 1995), which is favoured under heavy grazing, and gains even more importance in the next unit.

#### **4.2.4 Heavily grazed mountain steppes – *Carex stenophylla* (= *C. duriuscula*) subassociation Hilbig (1987) 1990 (Table 3, no. 214)**

The name-giving sedge forms rhizomes and is thus tolerant to heavy grazing. Bunch grasses such as *Stipa krylovii* and *Agropyron cristatum* are also tolerant, but stands become more open under trampling. Species belonging to the *S. krylovii* group are present but weakly competitive, and short-lived species often invade the stands (e.g. HILBIG, 2000a). These include *Chenopodium*

*acuminatum*, *Craniospermum mongolicum* and *Androsace maxima*, resulting in an overall increased species richness in comparison to the previous subassociation. These species are also found where the surface is disturbed by soil movement along ravines and gullies that dissect the upper pediments everywhere in the park. Moreover, burrowing small mammals (mainly *Ochotona pallasi*) were abundant in most relevés creating equally disturbed habitats (Fig. 6A, B). Similar, partly ruderal conditions on small mammal burrows are also described from other steppes of the country (PETERSON, 1994; HILBIG & al., 1999; SAMJAA & al., 2000). Thus, effects of animal impact and soil erosion are rather similar in terms of species composition unless trampling becomes very severe at herder's winter places and around gers (Mongolian for "yurt"). Here many of the hemicryptophytes typical of mountain steppes are rare, and higher nutrient levels allow the establishment of pioneer species with ruderal characteristics. These degradation stages can, however, be regarded as separate associations.

#### 4.2.5 Ruderal vegetation – *Chenopodio prostrati-Lepidietum densiflori* Hilbig (1987) 1990 (Table 3, no. 221)

*Lepidium prostratum* is a character species for heavily disturbed sites with increased nutrient availability. Various *Chenopodium* species accompany it (*C. album* s.l., *C. vulvaria*, *C. hybridum*), which were, however, poorly developed in the dry conditions of 2001. Thus we were unable to differentiate them further and recorded them as *C. "album"* in most cases. Among the perennial species, mainly *Allium polyrrhizum* tolerates the strong disturbances. Natural sites include beds of sayrs (semi-permanent rivers) and disturbed soils on small mammal burrows. Notably, levels of nitrogen and phosphorus are higher on the burrows (WESCHE & al., 2003) and resemble intensively used sites. Near wells and winter places, nutrient levels are also higher (STUMPP & al., in press), and soils are open due to grazing impact. If moisture is sufficient, gers are often surrounded by a belt of luxuriously growing dark green *A. polyrrhizum* that indicates the "fertilized" conditions here. This explains why the *Chenopodio-Lepidietum* increased under human impact and occurs now in ruderal sites all over the country (HILBIG, 1995).

#### 4.2.6 *Achnatherum inebrians* community (Table 3, no. 222)

Within Mongolia, *Achnatherum inebrians* is restricted to montane slopes in the Gobi. Below 2000 m, it is replaced by the widespread related species *A. splendens*, but on the upper pediments *A. inebrians* is the dominant species. Stands are found at level yet disturbed sites (such as small mammal burrows; Fig. 6A, B), but more often in situations with water surplus around wells or in river beds. Both *Achnatherum* species are salt-tolerant, and *A. splendens* occurs at really saline sites (cf. Table 5). *Achnatherum inebrians* has a low value as fodder and is even regarded poisonous, and can be found at a wide range of not necessarily saline sites provided that some groundwater is available. Both *Achnatherum* species grow in steppes wherever these conditions are met and share several species with the various steppe communities. Thus, the respective communities could be regarded as yet another subassociation of mountain steppes (as indicated by HILBIG, 2000c: 83). *Achnatherum inebrians* is a differential species, but occurs also in juniper scrub (Table 2). Whether it can serve as a character species of a possible new association or merely differentiates a subassociation, might become clear when more material is available. Stands in the GGS NP most closely resemble the *Caragano microphyllae-Achnatheretum splendentis* (HILBIG, 2000c), but the character species *Caragana microphylla* does not occur in the region and *A. splendens* is largely replaced by *A. inebrians*.

#### 4.2.7 *Juniperus sabina* community (Table 3, no. 231 & 232)

Shrub-dominated communities with somewhat uncertain syntaxonomic position can be found in all mountains of the eastern Gobi Altay, and juniper scrub is the most abundant and most conspicuous woody vegetation there. Most sites represent steep slopes (Fig. 7A, B), often characterised by moving scree subject to freeze-thaw activity. The soil is often additionally disturbed by burrows of small mammals (*Ochotona pallasi*). Juniper scrub prefers southern exposures in the

moist Zuun Sayhan, where the northern exposures are covered by dense alpine mats and mountain steppes which hinder substrate movement. These mats disappear in the drier, western ranges of the park, where *Juniperus sabina* becomes more and more restricted to northern exposures (Fig. 8). Here, both main exposures offer open substrates, but only the northern one is sufficiently moist to allow the growth of junipers. Levels of human impact are low, although small quantities of juniper wood are used for religious purposes. Seeds were abundantly produced at all sites, but seedlings were not found. We suspect that reseeding is generally hampered by dry climatic conditions, so clonal growth is the dominant mode of regeneration (WESCHE & al., in press).

The character species is the prostrate *J. sabina*, and stands probably belong to the *Juniperion sabinae* (the similar *J. pseudosabina* does not occur in the park). However, their exact syntaxonomical position is somewhat unclear as *J. sabina* occurs all over Eurasia westwards to the Alps, where it is confined to coniferous forests and open mats on dry slopes in calcareous mountain ranges (OBERDORFER, 1990; ROTHMALER & al., 2002). The juniper builds safe sites for a number of accompanying species. A regional character species in the GGS NP is *Poa stepposa* (incl. *P. botryoides*). Given that juniper scrub occurs from the moist to the driest mountains in the park it is not surprising that two subcommunities can be distinguished, which have no character species but a nevertheless typical species set. The *Lonicera microphylla* subcommunity (Table 3, no. 231) grows on moister sites and is restricted to the eastern ranges of the park, where it typically occupies valley bottoms and small ravines. It is rich in accompanying shrubs and the most vigorous stands show affinities to scrub-types of the *Spiraeion aquilegifoliae* (HILBIG, 2000c), which are currently only described from the steppe zone of Mongolia (HILBIG, 1995, and Table 9 therein).

Where sites are generally drier, the typical *Juniperus sabina* subcommunity (Table 3, no. 232) is found. It occupies steep slopes in the moist eastern ranges of the park and becomes the only juniper community in the western ranges. The lower altitudinal limit decreases with increasing humidity being at 2600 m in the dry Nemegt Uul, at 2300 m in the Arts Bogd and below 2200 m in the three eastern ranges of the park. Stands are negatively characterised by the absence of larger shrub species and sometimes host species belonging to desert steppes of the pediments (e.g. *Caragana leucophloea*).

#### 4.2.8 *Artemisia santolinifolia* community (Table 3, no. 24)

*Artemisia santolinifolia* is the most common dwarf-shrub in the montane parts of the study region and grows in all sites with some soil disturbance. It colonises gullies and ravines, grows in all communities described above on disturbed soils, and invades even old vehicle tracks (Fig. 9). The most extensive stands occur on south-facing scree slopes in the moist western parts of the GGS NP, where they occupy partly the same sites as *Juniperus sabina*. Unlike the juniper, stands show reseeding and might invade and possibly replace the juniper stands in the long run. However, *A. santolinifolia* also forms species-poor dominance stands on scree slopes, which lack any character species. The differential feature is the dominance of *A. santolinifolia* itself, and the presence of species such as *A. dracunculus*, *Iris potanini*, and *Orobanche coeruleascens*. Though geographically widespread, *Artemisia santolinifolia* can be seen as a character species of the alliance *Juniperion pseudosabinae* (HILBIG, 2000c), in which case the *Artemisia santolinifolia* community would be a species-poor central community of that alliance. Dominance stands of *Artemisia santolinifolia* are described from the Ikh Bogd (HILBIG, 1990a: Table 30) and are a typical feature of the vegetation of the GGS NP. Thus we kept them in a separate albeit rankless unit.

#### 4.2.9 *Artemisia rutifolia* community (Table 3, no. 25)

Shrubs occur in montane situations all over the park wherever the substrate is coarse and/or disturbed, so bunch grasses with their shallow roots (BORISOVA & POPOVA, 1985) are relatively rare. *Artemisia santolinifolia* is the dominant species of the upper slopes and pediments above some 2200 m; below, plants of desert steppes become more important. In true desert steppes, *Stipa krylovii*

is replaced by *S. gobica* and *S. glareosa*, while *Caragana leucophloea* is the dominant shrub species in desert steppes of the GGS NP. The *Artemisia rutifolia* community (HILBIG, 1990a: Table 8) occupies an intermediate position between mountain and desert steppes, which is reflected by its intermediate floristic composition. The differential features within the context of montane vegetation types are the abundance of *C. leucophloea* and the joint occurrence of species belonging to the *Agropyretea cristati* (grass and mountain steppes) together with those belonging to the *Stipetea glareosae-gobicae* (i.e. desert steppes). True character species were not found; *A. rutifolia* occurs regularly at sites occupied by this community but it has low abundance and is therefore missing in most samples. *Caragana leucophloea* occurs instead of *C. pygmaea* (cf. HILBIG, 1990a: Table 8); which is rare in the GGS NP.

The intermediate position of this unit renders a definite placement in the phytosociological system difficult. Species of the mountain steppes suggest a placement in the *Stipion krylovii* or in the *Spireion aquilegfoliae* (montane scrub) as proposed by HILBIG (2000c), although stands share no character species with the latter except for *C. leucophloea*. On the other hand, *C. leucophloea* is a character species of the *Caraganion leucophloae* (cf. Table 4), which together with the *Stipa gobica* group indicates semi-desertic conditions. Thus we retain the name *A. rutifolia* community but propose to include it in the *Caraganion* described below.

#### 4.3 Semi-desert and desert vegetation of the piedmont regions and inter-montane basins (Table 4)

The larger part of the study area are piedmont regions that cover an altitudinal range between 1500 to 2300 m. This corresponds to a wide range of hygric conditions; which support mountain steppes on the uppermost pediments but can only sustain desert vegetation at the lowermost elevations. The intermediate communities have a continuous albeit open vegetation cover and are thus semi-desert vegetation types, which are traditionally termed desert steppes in central Asia. The characteristic species are several dwarf-shrubs (*Ajania achilleoides*, *Ptilotrichum canescens*), geophytes (*Allium polyrrhizum*, *A. mongolicum*), and notably the feather grasses *Stipa gobica* and *S. glareosa* (Table 4). *Caragana leucophloea* is the most common larger shrub species followed by *Eurotia ceratoides*. All communities of Table 4 belong to the large class *Stipetea glareosae-gobicae* (HILBIG, 2000c).

Desert steppes are a heterogeneous group that includes rather dense, grass-dominated vegetation types, but also open shrublands with few grasses and low pasture value. In the GGS NP, stands between 1900 and 2300 m are usually dominated by grasses, and are characterised by a set of species that are largely restricted to that altitudinal range (*Caragana leucophloea*, *Ephedra sinica*, *Stipa gobica*). These communities (Table 4, no. 331 to 332) mediate between the desert steppes and the mountain steppes of the upper slopes (Table 3).

The remaining part of Table 4 (no. 41 to 49) comprises a heterogeneous assemblage of the most drought-tolerant communities in the GGS NP. These include dry desert steppes related to the previous units as well as open shrublands in semi-deserts, which cover vast areas in the western and northern parts of the park. Nonetheless, all but the most extreme stands share a set of common species. Most important are *Stipa glareosa* and *Anabasis brevifolia*, while others occur also in moister vegetation types described above (e.g. *Dontostemon senilis*, *Ajania fruticulosa*).

The upper limit of communities belonging to this group lies around 1900-2000 m in the eastern part of the park but rises towards the drier ranges in the west. There, relevés with *Anabasis brevifolia* were found up to the uppermost pediment regions in 2200 m, whereas they are mostly restricted to sites well below 2000 m (Fig. 10).

##### 4.3.1 *Caragana* scrub – *Artemisio xerophyticae-Caraganetum leucophloae* Hilbig (1987) 1990 (Table 4, no. 31)

*Caragana* shrubs attain up to 1.5 m in height, but stands are usually heavily grazed and in this case plants are below 0.3 m. They cover extensive areas on the upper pediments wherever soils

are disturbed or too shallow to support dense grass vegetation. *Caragana leucophloea* is a character species of this and the next community. The first community is distinguished by the character species *Artemisia caespitosa*. It replaces *A. xerophytica* described by HILBIG (2000c) for the Uvs Nuur basin; the latter is more common in drier vegetation types in the GGS NP (Table 3). A further difference is the presence of *Ephedra sinica* and *Allium polyrrhizum*, which are absent from HILBIG (1990a: Table 25). Thus, if more material becomes available it might be possible to devise a new association. Stands grow mainly in the footzone of the western mountain ranges in the study area, where conditions are relatively dry.

#### 4.3.2 *Caragana* scrub – *Amygdalo pedunculatae-Caraganetum leucophloae* Hilbig (1987) 1990 (Table 4, no. 32)

This is the more widespread *Caragana* community, which covers extensive areas in the moister eastern mountain ranges wherever coarse or shallow substrates are available. Almonds are often mixed with *C. leucophloea*, most notably in beds of semi-permanent rivers. The character species *Amygdalus pedunculata* and *Caryopteris mongholica* are, however, rare as are species listed by HILBIG (1990a) for other *Caragana* communities (e.g. *Oxytropis aciphylla*). Thus, in the GGS NP the unit is negatively defined by the absence of *Artemisia caespitosa* and *Ephedra sinica*. The community is nonetheless floristically and physiognomically distinct, and most closely resembles other stands with *Amygdalus pedunculata* described by HILBIG (1990a).

#### 4.3.3 *Stipa gobica* community: typical subcommunity (Table 4, no. 331)

The two feather grasses *S. gobica* & *S. glareosa* cannot be distinguished without caryopses and most authors lump them together in their accounts of desert steppes (e.g. HELMECKE & SCHAMSAN, 1979a). However, the caryopses are very distinct, so we tried to record the exact species wherever possible. Contrary to expectations, both species separated quite well in the phytosociological table (cf. Table 4) and showed distinct habitat preferences. *Stipa gobica* has its centre of abundance in the *Caraganion leucophloae*, i.e. in moister desert steppes of the upper pediments (see altitude diagram in Fig. 10, community no. 33), whereas *S. glareosa* is rare above 2000 m (Fig. 10, no. 41). The latter is more widespread in drier conditions and is even found in desert communities such as Saxaul stands (Table 4, no. 471 & 472), where *S. gobica* never occurs. Thus we differentiated a distinct community based on the presence of the character species *S. gobica*.

For the time being we assign a rankless community (Table 4, no. 331), which is related to the *Allio polyrrhizi-Stipetum glareosae* (HILBIG, 2000c), and shares several species with the *Artemisia frigida* subassociation previously described for that unit (HILBIG, 1990b: Table 27). The difference is made up by the presence of *S. gobica* rather than *S. glareosa*, by the frequent occurrence of *Ajania achilleoides*, and by the absence of *Allium mongolicum*, which is a character species of the *Allio-Stipetum glareosae*. It is more tolerant to osmotic stress than *A. polyrrhizum*. HELMECKE & SCHAMSAN (1979a) describe a *Stipa-Allium* community in the GGS region, and have apparently found *S. gobica* more often than *S. glareosa*. They distinguish a “high-mountain variant” of the *Stipa-Allium* steppes, which is identical with our *Stipa gobica* community (including the presence of *Ephedra sinica* and *Artemisia frigida*). Moreover, own observations in the Great Gobi B National Park in western Mongolia (Von Wehrden & Wesche, *pers. comm.*) suggest similarly distinct habitat preferences of *S. gobica* there, so if more material becomes available it might be possible to devise a separate association. This would presumably lack character species others than those of higher syntaxonomical rank and could then serve as a central association of the *Allion polyrrhizi*. Our data would even allow a placing of the *Stipa gobica* community in the *Caraganion leucophloae*, but clarification of this issue depends on the availability of detailed records, which distinguish between *S. glareosa* and *S. gobica*.

The typical subcommunity of the *Stipa gobica* community covers the larger part of the upper pediments in the eastern ranges of the park at elevations between 1600 m and 2100 m. It is a grassland, transient in structure and position between the *Astragalus inopinatus* mountain steppes

of the upper slopes, and the *Stipa glareosa*-*Allium polyrrhizum* steppes of the lower pediments. *Carex stenophylla* occurs in the majority of samples, and indicates the generally high levels of grazing. These are strikingly demonstrated if livestock is excluded and litter is allowed to accumulate (Fig. 11). In resemblance to *Caragana* scrub, species composition changes in the drier western half of the park and *Ephedra sinica* becomes an important companion in a distinct subcommunity.

#### 4.3.4 *Ephedra sinica* subcommunity of the *Stipa gobica* community (Table 4, no. 332)

Desert steppes with *Ephedra sinica* are the dominant vegetation of the upper pediments and the lower parts of the inter-montane valleys in the western part of the GGS NP. Relevés are characterised by a similar species set as the previous community, but *Ajania fruticulosa* is more common than in other plant communities in the area. Species richness is lower than in the typical subcommunity of the *Stipa gobica* community, mainly because annual species (*Setaria viridis*, *Panzeria lanata*) are completely missing.

#### 4.3.5 *Allio polyrrhizi-Stipetum glareosae* Hilbig (1987) 1990 (Table 4, no. 41)

These desert steppes replace the *Stipa gobica* community with increasing aridity, i.e. at lower elevations and/or in the western part of the study area. They mediate between grass-dominated steppes of moderately dry situations and semi-desert vegetation with a low cover of grasses. Several species are shared with the *S. gobica* steppes (Table 4, no. 331). *Stipa glareosa* is a differential species as are *Oxytropis aciphylla* and *Convolvulus ammanii*, while *Gypsophila desertorum* serves as a regional character species. *Carex stenophylla* hints at the grazing impact.

The physiognomic structure of the *Stipa glareosa* steppes is simple; the field layer reaches 10-20 cm in height (including flower stems), while shrubs rarely grow taller than 20 cm. Some relevés showed signs of degradation, most notably in the surroundings of the Aymak centre Dalandzadgad. Here shrubs are almost entirely missing, and weeds such as *Tribulus terrestris* indicate the anthropo-zoogenic soil disturbance. The *Allio polyrrhizi-Stipetum glareosae* has its centre of distribution in the eastern half of park, and is replaced by desert steppes with *Anabasis brevifolia* in the western part of the park. The latter are confined to altitudes below 1400 m in the eastern GGS NP.

HELMECKE & SCHAMSAN (1979a) distinguish four variants of their *Stipa-Allium* community in the GGS NP, of which the typical variant corresponds to the present association. The high-mountain variant corresponds to the *Stipa gobica* community described above. *Allium mongolicum* can be used to distinguish a drier variant, but the transition towards the drier sites is gradual. Stands of the *Anabasis brevifolia* variant of HELMECKE & SCHAMSAN (1979a) are possibly better included with the following vegetation unit.

#### 4.3.6 *Stipo glareosae-Anabasietum brevifoliae* Hilbig (1987) 1990: *Convolvulus ammanii* subassociation (Table 4, no. 421)

*Anabasis brevifolia* is a dwarf-shrub with reduced leaves and is relatively tolerant to drought. It is one of the most widespread species in the desert steppes of southern Mongolia. Stands grade into true desert communities, which are dominated by dwarf-shrubs (mainly *Chenopodiaceae*) rather than grasses. Yet, most samples with *A. brevifolia* have a grass layer (*S. glareosa*, *Cleistogenes songorica*) and are desert steppes. There are, however, no exclusive character species of this unit (HILBIG, 2000c), as the naming species are shared with other communities. The differential feature is the joint presence of *Stipa glareosa* and *Anabasis brevifolia*; which serve as character species of higher syntanomical units. Thus, the unit can be seen as a central association of the *Allion polyrrhizi*. As usually only one central association per alliance is allowed (DENGLER, 2003) this might lead to conflict with the placement of the *Stipa gobica* community described above. However, this issue can only be decided with more material becoming

available. Moreover, at least in the GGS NP *Astragalus vallestris* serves as a regional character species, further diagnostic species include *Allium mongolicum*, and occasional annuals such as *Eragrostis minor* or *Donostostemon senilis*.

The subassociation, which is named after the less drought-tolerant *Convolvulus ammannii* (HELMECKE & SCHAMSRAN, 1979a) is very widespread in the eastern and northern parts of the study area, and covers all sites with neither extremely saline nor extremely dry conditions. The plant cover is still relatively dense in comparison to other semi-desert communities, and consequently most stands are heavily grazed. *Tribulus terrestris* grows in sites with heavy impact by trampling.

#### **4.3.7 *Stipo glareosae-Anabasietum brevifoliae* Hilbig (1987) 1990: *Reaumuria soongorica* subassociation (Table 4, no. 422)**

Precipitation decreases towards the south-western lowlands of the park (Fig. 2) and conditions become too harsh for a number of species typical of the previous subassociation. Overall species richness drops, but the drought- and salt-tolerant species *Reaumuria soongorica* and *Salsola passerina* are found and differentiate a special subassociation. They tolerate a wide range of osmotic stress levels (HELMECKE & SCHAMSRAN, 1979b). Both form also communities around saline depressions, and in the most arid regions of the park, where species of the *Allium polyrrhizum* group are largely lacking. They are the character species of another alliance (*Reaumurio soongoricae-Salsolion passerinae*, see Table 4), rendering syntaxonomical placement of stands summarised in column 422 of Table 4 difficult. For simplicity, we follow HILBIG (2000c) proposal and keep them tentatively in a subassociation of the *Stipo glareosae-Anabasietum brevifoliae*.

#### **4.3.8 *Salsolo passerinae-Reaumurietum soongoricae* Kasapov & al. ex Hilbig 2000 (Table 4, no. 43)**

Flat depressions are common in the lower piedmont areas of the park. There are no weather stations in this region, but mean annual precipitation is probably well below 100 mm. Soil water movement is thus generally upwards and minerals accumulate near the surface, so osmotic stress adds to the general climatic dryness of the sites (Fig. 10). Moisture is almost permanently limited and herbaceous species are largely replaced by succulent dwarf-shrubs (Fig. 12). *Anabasis brevifolia* is still regularly present but grasses and herbs of the *Allion polyrrhizi* become rare. *Reaumuria soongorica* and *Salsola passerina* are most abundant in such sites and form a species-poor community. They are the character species of an alliance (*Reaumurio soongoricae-Salsolion passerinae*, HILBIG, 2000c), but *S. arbuscula* can serve as a (regional) character species of the *Salsolo-Reaumurietum* in the GGS NP. As grasses and *Allium* species are rare, such stands are often regarded as true deserts (HILBIG, 1995).

Most of the soil surface is covered by deflation pavements, fine soil material is sparse but the shrubs themselves work as traps and have commonly fine tailings of aerial-borne sand. Migrating camels visit the stands and are the principal domestic livestock species found. Even more common are gazelles (*Gazella subgutturosa*, *Procapra gutturosa*), and Wild Ass (*Equus hemionus*) also occur here.

#### **4.3.9 *Potaninio mongolicae-Sympegmetum regelii* Kasapov & al. ex Hilbig 2000 (Table 4, no. 44)**

This association is characterised by the sub-endemic Rosaceae *Potaninia mongolica*, which is, within Mongolia, confined to desert vegetation of the Gobi Altay region. It avoids saline sites in the study area, but all other site conditions are similar to those of the previous association. *Potaninia mongolica* is not succulent and does not develop any leaves under drought conditions. It differs fundamentally from succulent semi-desert shrubs which were among the most vigorously growing plants in the drought of 2001. Recovery after drought is slow in *P. mongolica*, and even in 2003 only part of the old branches managed to develop new leaves. The character species *P. mongolica* is often accompanied by *Sympegma regelii*, but the latter is more common in south-western Mongolia and neighbouring China (KÜRSCHNER, 2004), and is only found in the western parts of the GGS NP.

#### 4.3.10 *Artemisia sphaerocephala* community (Table 4, no. 45)

In the eastern parts of the park, beds of semi-permanent rivers above 1800 m are covered by the *Amygdalo-Caraganetum* (Table 4, no. 32). Sayrs in the western parts or at lower altitudes are covered by open shrublands, which are dominated by the character species *Artemisia sphaerocephala*. This shrub attains up to 1 m in height, is drought-tolerant, and displayed bright green leaves even in 2001. A herbaceous field layer is weakly developed due to substrate movement in flooding events, but several species have chances for establishment on the open gravel. Among them are species of desert steppes (*Allion polyyrrhizi* in Table 4), while *Astrothamnus centralasiaticus* is a regional character species. It occurs in semi-desert scrub, often together with *Zygophyllum xanthoxylon* and *Eurotia ceratoides* (alliance *Zygophyllo xanthoxyli-Brachanthemion gobici*). HILBIG (2000c) describes the *Caragano bungei-Brachanthemetum gobici* from the northern parts of our study area (near Bulgan, Fig. 1), with *Artemisia xanthochroa* as a character species. This is a very similar species and seemingly has the same ecology as *A. sphaerocephala* (GRUBOV, 2001). However, of the two other character species listed by HILBIG (2000c), *Brachanthemum gobicum* was only found north of the Gurvan Sayhan in our study, while *Caragana bungei* grows on sandy sites in the GGS NP (see below, Table 4, no. 48). Thus our *Artemisia sphaerocephala* community on river beds is probably a distinct entity, which will remain as a rankless community until more material becomes available. It belongs, however, to the *Zygophyllo-Brachanthemion* as does the following association.

#### 4.3.11 *Eurotio ceratoidis-Zygophylletum xanthoxyli* Hilbig (1987) 1990 (Table 4, no. 46)

The shrub *Zygophyllum xanthoxylon* is a shrub of depressions and riverbeds. It forms very open stands, with the individuals being usually between 0.5 and 1 m tall. The “field” layer is formed by the suffruticose *Anabasis brevifolia* and species of the previous unit, but *Artemisia sphaerocephala* is absent. The vegetation is relatively luxurious in comparison to the surroundings and therefore always grazed. The character species is *Zygophyllum xanthoxylon*, while *Eurotia ceratoides* is a diagnostic species within the context of the alliance *Zygophyllo-Brachanthemion*. *Amygdalus mongolica* is a regional character species of the *Eurotio ceratoidis-Zygophylletum xanthoxyli* (HILBIG, 2000c), and forms similar stands in sayrs of the Chinese Alashan Gobi (*Amygdalus mongolica* community of KÜRSCHNER, 2004). It possibly differentiates a distinct subassociation, which would then be transitory to the *Caraganion leucophloae*, stands of which grow in moister sayrs. This is supported by the occasional occurrence of *Caragana leucophloea* and *Amygdalus pedunculata* (Table 4, no. 32). Stands with *Amygdalus mongolica* replace the more species-rich *Amygdalo-Caraganetum* where river beds dissect semi-desert surroundings. The almonds benefit from a high groundwater table in the sayrs, and are strong enough to withstand the occasional flooding events, although they often have a “brushed” appearance. They are also rarely found on rocky sites, so *Eurotia ceratoides* and *Zygophyllum xanthoxylon* remain as the only diagnostic species of this association. In any case, the available material is not sufficient to designate a subassociation within the GGS NP.

#### 4.3.12 *Calligono mongolici-Haloxyletum ammodendronis* Hilbig (1987) 1990: *Reaumuria soongorica* sub-association (Table 4, no. 471)

The Saxaul, *Haloxyylon ammodendron*, is one of the most conspicuous species of the Gobi. It is an aphyllous shrub or tree with green, somewhat succulent shoots that can form single-stemmed trees to 5 m in height and up to 0.5 m in stem diameter. Dense Saxaul woodlands are rare in the study area, and more commonly Saxaul forms open scrub (Fig. 13). Saxaul occupies the habitats with the lowest precipitation in the study area. Grazing levels are generally low because of the lack of drinking water. The Bactrian camel is the only livestock species that feeds regularly on the shrubs. However, where stands grow on sandy soils allowing water to percolate to lower soil horizons, wells were often dug, and here we observed grazing by goats.

The principal character species of the association is *H. ammodendron*. *Calligonum mongolicum* is relatively rare in the GGS NP; scattered individuals are found on sandy soils in the westernmost parts. Saxaul can grow on a wide variety of substrates, and therefore two subassociations are distinct based on the set of accompanying species. The *Reaumuria soongorica* subassociation of the *Calligono-Haloxyletum* (termed 'Ausbildung' by HILBIG, 2000c) is characterised by the presence of the salt-tolerant shrubs *R. soongorica*, *Salsola passerina* and *S. arbuscula*. Characteristic habitats are flat depressions and basins in the western part of the park where shrubs with their extensive root system might have access to ground water. Moreover, denser stands create their own microclimate and moderate the harsh climatic conditions (HELMECKE & SCHAMSRAN, 1979a). Soils are usually loamy to clayey, and soil conductivity indicates often saline conditions (Fig. 10). Grazing levels are low in these remote areas, but nevertheless seedlings were not encountered in our study. HELMECKE & SCHAMSRAN (1979a) attribute the lack of regeneration to presumably high levels of grazing, but drought certainly is also important, since Saxaul would not flower in years of extreme drought. However, *H. ammodendron* is extensively collected as fuel wood, probably the main reason why true forests are rare and mostly small shrubby individuals were found.

The small annual *Micropeplis arachnoides* is a regional character species of this subassociation, and is sometimes accompanied by other annuals such as *Artemisia scoparia* and *Bassia dasiphylla*. Moisture is at least temporarily available in the basins, so the mean species richness is higher than in the second subassociation.

#### 4.3.13 *Calligono mongolici-Haloxyletum ammodendronis* Hilbig (1987) 1990: *Nitraria sphaerocarpa* subassociation (Table 4, no. 472)

At the lowest altitudes in the park, only few species accompany the Saxaul at the dry and often sandy sites. The dominant features are the aridity of the habitats, which is a consequence of the generally low altitudes (900 to 1450 m), and the fact that the relevés were sampled in the driest westernmost part of the park. Soils are well-drained, so moisture levels are never high. The soil matrix is coarse (5 to 60% stones) and the surface is sealed by a deflation pavement. The differential species *Nitraria sphaerocarpa* (HILBIG, 2000c) is rare in the GGS NP but becomes more common westwards in the Transalay Gobi. It is widely distributed in *Haloxyylon* stands of the Chinese Alashan Gobi, where it also forms a separate association within the *Zygophyllo-Brachanthemion* but without *Haloxyylon ammodendron* (*Nitrario sphaerocarpae-Artemisietum tschernievianae*, KÜRSCHNER, 2004). Its character species *Artemisia tschernieviana* is, however, not found in Mongolia (GUBANOV, 1996). In the Alashan Gobi, the corresponding unit to the *Haloxyletum ammodendronis* is the *Haloxyylon ammodendron-Nitraria tangutorum* community of KÜRSCHNER (2004).

*Lycium ruthenicum* is a regional character species in the GGS NP. Stands show the lowest mean species richness of all communities in the GGS NP, which is in accordance with descriptions given by HELMECKE & SCHAMSRAN (1979a) for the same region.

#### 4.3.14 *Caragano bungei-Brachanthemetum gobici* Kasapov & al. 1988 (Table 4, no. 48)

Sand dunes are a common substrate in the inter-montane depressions in the GGS NP. Depending on the local wind conditions, sands can be rather flat and stable or can form steep dunes as in Hongoriyn Els (Fig. 14). The latter are virtually free of any vegetation, but the older, flattened sand deposits are covered by distinct plant communities. The shrubs *Caragana bungei* and *C. korshinskii* are characteristic there; *Brachanthemum gobicum* occurs on the sands north of the study area were no relevés were sampled. However, the general composition resembles the typus sample given in HILBIG (2000c), so we tentatively regard our stands as a local variety. RACHSKOVSKJA (1993) describe stands with *Psammochloa villosa* and *Caragana korshinskii* from south-eastern Mongolia. The latter species is distributed in the poorly studied regions of southern Mongolia and

neighbouring China. Thus, with more material becoming available it may be possible to designate a new association with *C. korshinskii* as a character species. At present, the small number of relevés renders any decision on this point impossible. The *Caragano-Brachanthemetum* grows around the large sand fields northeast of Hongoriyn Els.

#### 4.3.15 *Psammochloa villosa* community (Table 4, no. 49)

Unconsolidated flat sands are colonised by the large grass *Psammochloa villosa*. Its shoots are flexuous and withstand the permanent movement of the sand. The other accompanying species also have strong shoots (*Artemisia xerophytica*, *Iris tenuifolia*) or are annuals. *Agriophyllum pungens* is a regional character species, while *P. villosa* is a character species of similar sites all over the country (HILBIG & al., 1999; HILBIG & KOROLJUK, 2000). However, on northern Mongolian dunes the set of species differs (*Leymus racemosus*, *Hedysarum fruticosum*), and the phytosociological position of the *P. villosa* community is uncertain. HILBIG (2000c) places it in the new class *Brometea korotkyi*, but none of its character species occurs in the samples from the GGS NP. *Artemisia sphaerocephala* is present in more than half of the samples, and the occurrence of species such as *Stipa glareosa*, *Allium polyrrhizum*, and *Caragana bungei* suggests also a relationship to communities from the *Stipetea gobicae-glareosae*. Unfortunately, the available material for the three communities with *Artemisia sphaerocephala*, *Caragana bungei* and *Psammochloa villosa* is not sufficient to arrive at a definite statement on their syntaxonomical position.

### 4.4 Communities of saline habitats (Table 5)

Wells are found in the entire GGS NP and indicate that groundwater is within some few metres of the surface in the larger part of the park. Natural surface water occurs at several sites in the park; above 2000 m most commonly in deep valleys but also occasionally on the uppermost pediments. In the desert, oases are found around large dune fields such as Hongoriyn Els (Fig. 14), where rain percolates through the loose sand and accumulates on the underlying pediment surfaces. Water supply is permanent here, whereas flat clayey depressions (takys) are only temporarily flooded. Potential evaporation is high at all these sites, therefore soil water movement is mostly upwards resulting in saline conditions (Table 5).

Given that the geomorphological settings are so widely different, it is not surprising that several salt-tolerant plant communities can be distinguished in the park. However, sites are always small, so the number of relevés is also limited. For the same reason we did not draw boxplots of the environmental parameters as in Fig. 4 & 10, but included the values in the constancy table (Table 5).

#### 4.4.1 *Glycyrrhizo-Achnatheretum splendens* Hilbig (1987) 1990 (Table 5, no. 51)

*Nitraria sibirica* (Zygophyllaceae) builds very characteristic vegetation types. They are usually found around saline depressions, where each *Nitraria* shrub forms a small micro-dune growing up to 1.5 m in height and 3 m in diameter, which rises from the otherwise flat soil surface. These micro-dunes are formed by sand trapped by the *Nitraria*, which grows as the hummocks rise. Roots reach down to the underlying fine soils and benefit from the seasonally available moisture there (HELMECKE & SCHAMSRA, 1979a; KUTSCHERA & al., 1997). Two communities are distinguished according to the level of grazing, the duration of the wet period, and the soil pH value (Table 5, no. 51 & 52). Both are characterised by the presence of *N. sibirica*. Stands near settlements are often heavily grazed, and several grazing indicators differentiate a distinct community. *Achnatherum splendens* and *Peganum nigellastrum* are differential species, while *Atriplex sibirica* is a regional character species (cf. HILBIG & al., 1999). Conditions are partly ruderal including disturbance by trampling, and few salt-tolerant species tolerate this. Species richness is therefore low, and the principal feature is the dominance of *N. sibirica*.

The phytosociological relationships are not certain since *N. sibirica* occurs in two separate groups of associations, namely the *Achnatheretea splendentis* and the *Stipetea glaerosae-gobicae* (HILBIG, 2000c). Community 51 lacks character species of the latter, so we regard it as an impoverished version of the *Glycyrrhizo-Achnatheretum splendentis* (within the *Achnatheretea splendentis*), which lacks further character species due to human impact. The unit borders saline pans towards semi-desert vegetation with *Reaumuria soongorica* (Table 4) or towards ruderal communities of settlements. The matrix of the underlying soil is constituted by fine material as everywhere in the basins. The conductivity of the fine soil ranged between 1500 and 5500 µS, but one sample had an extremely high value of 32 000 µS. The groundwater table rises seasonally up to near the surface, and the differential species are intolerant of prolonged flooding. Where this occurs, another association is found.

#### 4.4.2 *Nitrario sibiricae-Kalidietum gracilis* Hilbig 2000 (Table 5, no. 52)

*Kalidium gracile* colonises similarly saline sites as *N. sibirica*, but has a smaller altitudinal range (1250-1450 m). Sites have a high groundwater table during the larger part of the year. Stands have two distinct “shrub” layers, the tall *Nitraria* dunes and the *K. gracile* layer that is at most 0.4 m high. The latter is a true halophyte and able to maintain constant osmotic pressure in its tissues under a wide range of edaphic and microclimatic conditions (HELMECKE & SCHAMSRAN, 1979b). The two name-giving species are character species, the presence of *Salsola passerina* and *Reaumuria soongorica* indicates the relationship to desert steppes in zonal habitats (Table 5). Grazing weeds such as *Peganum nigellastrum* are absent, and stands are indeed negligibly grazed. *Kalidium* itself is not browsed at all, and the spiny twigs of *N. sibirica* are not attractive either. Where pans have an even higher salinity, i.e. mostly in their centre where salts accumulate, conditions become too harsh for *N. sibirica* and communities are entirely dominated by *Chenopodiaceae*.

#### 4.4.3 *Salsolo passerinae-Kalidietum foliati* Kasapov & al. ex Hilbig 2000 (Table 5, no. 53)

*Kalidium foliatum* joins *K. gracile* on moist and extremely saline sites. Soil conductivity values are among the highest found in the park (800-6800 µS), and the community is restricted to the lowermost depressions in its western parts. *Kalidium foliatum* and *K. cuspidatum* are character species. Stands are physiognomically different from the previous association with a single layer dominated by suffruticose *Chenopodiaceae*.

#### 4.4.4 *Salicornia europaea* community (Table 5, no. 54)

Takyrs (Mongolian “Toyrim”) are habitats characterised by clayey soils and temporary flooding (WALTER & BRECKLE, 1994). They occur in the moistest parts of salt pans and at the shorelines of semi-permanent water bodies, where conditions change tremendously throughout the year. Few species tolerate these conditions, including succulent *Chenopodiaceae* and specialised annuals. The principal species is *Salicornia europaea* s.l. (the central Asian species most probably belong to the taxon *S. perennans*, FREITAG & al., 2001). The *Salicornia europaea* community was sampled at Tohomiyn Nuur, the only large lake in the region at 1400 m (located in the intermontane basin west of Bayandalay, Fig. 1). The lake is shallow and disappears in drought years, as in 2001. Site conditions are governed by the water regime. Suitable sites for *S. europaea* are not available in all years and soils dry out rapidly once the water has retreated. Thus moisture levels are initially high, as is the salinity. Although animals are abundantly present at the lake, livestock avoids grazing in the unit. The character species is the succulent *S. europaea*, the perennial *Kalidium gracile* is occasionally present. *Salicornia europaea* starts growth immediately after the water has retreated, it grows quickly and dies back within less than three months of development. HILBIG (2000c) designated a rankless *Salicornia europaea* community within the *Thero-Suaedion*. The following association appears to tolerate even more extreme conditions.

#### 4.4.5 *Crypsietum aculeatae* (Bojko 1932) Wenzl 1934 (Table 5, no. 55)

Sites closer to the water are colonised by *Crypsis aculeata*, a prostrate annual grass. It is a character species of stands that border the habitat described above towards the retreating water body. The site conditions are similar to those of the *S. europaea* community, but moisture levels are higher, opportunities for growth occur more rarely, and the growth period is shorter. We observed *C. aculeata* in the middle of June but 6 weeks later it had already died. It forms a second field layer among the *S. europaea* plants, which reach their optimal density here. Perennial species are absent and even fewer species than in the previous unit can grow. Size of stands is always limited, but the community is typical for similar habitats at large lakes from the Orog Nuur to the Uvs Nuur (HILBIG & al., 1999). In the Chinese Alashan Gobi, *Crypsis aculeata* is accompanied by *Halerpestes cymbalaria* and forms a separate association (*Halerpesto cymbalariae-Crypsietum aculeatae*, KÜRSCHNER, 2004). The first species is not found in Mongolia, but stands show clear affinities to saline meadows and their replacement communities at the end of this chapter.

#### 4.4.6 *Suaedo corniculatae-Achnatheretum splendens* Mirkin & al. ex Golub 1994 (Table 5, no. 56)

The third takyr community is characterised by *Suaeda corniculata*; *Elymus paboanus* and *E. chinensis* are differential species. *Achnatherum splendens* covers a wide range of altitudes but is found on saline sites between 1300 and 1500 m. The association colonises the fringes of shallow ponds, where grasses become dominant at some distance to the shoreline. Sites are not flooded but the groundwater table is near the surface at least part of the year. The drainage is poor, so soil conductivity and pH are extremely high. The soil matrix consists of clay and silt. Livestock, which is always kept on the neighbouring salt meadows, avoids the dominant species unless there is no other fodder available.

#### 4.4.7 *Blysmetum rufi* Du Rietz 1925 (Table 5, no. 57)

Saline meadows are found at sites with a permanently high groundwater table but without extensive flooding. They occur in all altitudes between 1300 and 2250 m, with wetness and salinity as the unifying factors. Fresh water is delivered during the larger part of the growing season so drought stress is negligible. Consequently, a closed sward vegetation can develop (cover 98-100%). These are the most productive stands in the national park, and thus the high grazing levels are not surprising. All saline meadows of Mongolia are characterised by a common set of species (*Halerpestion salsuginosae*, Table 5, no. 57), which do not occur in the neighbouring mountain steppes and semi-desert communities. Within the GGS NP the species set is rather similar over a wide altitudinal range. Character species of the association include *Blysmus rufus*, *Cnidium salinum* and *Poa tibetica*. The material is not sufficient to distinguish a second association of less saline situations (*Halerpesto-Hordetum brevisubulati*, HILBIG, 2000c), but meadows with *Hordeum brevisubulatum* occur at few sites within the moist mountain ranges (Dund & Zuun Sayhan), where they never cover more than a few square metres.

#### 4.4.8 *Iris lactea* community (Table 5, no. 58)

*Iris lactea* occurs around saline meadows, where the groundwater table is not permanently near the surface and grazing impact is strong. Repeated drying out of the sites explains the high conductivity values and soils are often covered by salt efflorescences. *Iris lactea* is not grazed and is a grazing weed; stands grow about 0.3 to 0.5 m in height and the field layer covers between 50 and 60%. *Iris lactea* is the character species, but stands share some species with the salt meadows (e.g. *Puccinellia hauptiana*). Thus they are closely related and can be regarded as a degradation stage of saline meadows (HILBIG, 2000c).

#### 4.4.9 *Phragmitetum communis* (Gams 1927) Schmale 1939 (Table 5, no. 59)

*Phragmites communis* also invades salt meadows, but is nonetheless intensively grazed, and dwarfed individuals growing less than 5 cm in height are often found. True, mono-dominant reed

beds are extremely rare in the park, and the only proper samples were taken in the remote desert oases Hermen Tsav and Zulganai Gol. Only the latter is grazed by cattle and goats, which roam around the permanent pool.

#### 4.5 *Extrazonal woodlands*

The lower pediment areas receive less than 120 mm of precipitation per year and are thus clearly semi-deserts. Nevertheless, trees were encountered in several places in the park at altitudes below 2000 m. These were single individuals in most cases, therefore we feel unable to establish any separate plant communities. The presence of trees in the arid parts of the park is, however, so remarkable, that we will finish our account with some brief notes on the two principal species.

“*Populus diversifolia* woodlands” constitute dense stands and even forests in the oases in the western semi-deserts of the park. The poplar is identical with the more widely known *P. euphratica*, but we use the name currently established in the literature on Mongolian flora and vegetation (GUBANOV, 1996). We have only one sample (see below table) originating from an elevation of 950 m, some 2 m above the bed of the semi-permanent brook in Hermen Tsav (cover in percent).

<i>Populus diversifolia</i>	50	<i>Lycium ruthenicum</i>	3
<i>Haloxylon ammodendron</i>	8	<i>Tamarix ramosissima</i>	10
<i>Reaumouria soongorica</i>	2	<i>Limonium erythrorhizum</i>	0.5

There are no character species except *P. diversifolia* itself, so we leave the community rankless. Given that *P. diversifolia* is exceedingly widespread in Eurasia occurring westwards into the Mediterranean and even Spain (FAY & al., 1999), the community can be tentatively grouped in the *Populetae euphratica* Zohary 1962 (KÜRSCHNER, 2004). *Populus diversifolia* occurs in oases all over central Asia and forms extensive stands where moisture is sufficient. At suitable sites, trees grow to well above 8 m and have a stem diameter of close to 0.5 m, but we did not find any young seedlings. Often, saplings and root suckers form a shrub layer.

Fragments of this community are found as single trees at erosion gullies south to southwest of the Nemegt Uul. This is a dry area with clearly less than 100 mm annual precipitation. Poplars grow at the upper rim of a gully about 3 m above the bottom. The linear erosion suggests the occasional presence of water, but the groundwater table is definitely low, as was indicated by the *Reaumuria soongorica* semi-desert vegetation in the surroundings. When grazing is excluded, root suckers of *P. diversifolia* grow up to 1.5 m, but seedlings were not observed.

The other common large shrub to small tree in semi-desert areas of the park is *Tamarix ramosissima*. It forms impenetrable stands on sand dunes and occasionally in sayrs. Stands are mono-specific, and are sometimes regarded as a separate *Tamarix ramosissima* community (KÜRSCHNER, 2004).

*Ulmus pumila* forms typical woodlands in water surplus sites like river beds in the central and northern parts of Mongolia, where they presumably represent fragments of the former natural forest vegetation (HILBIG, 1995). The elms are relatively drought-tolerant and were planted in suitable places in the semi-deserts around Bulgan Sum and east of Gurvantes (Fig. 1), which receive around 100 to 120 mm precipitation. After establishment, planted trees survive without additional watering, but flowers or seedlings are not observed. Scattered *U. pumila* trees occur elsewhere in the park. They are extremely rare and are mostly found in steep gullies and rock crevices at the foothills of the mountain ranges. Occasionally, solitary trees grow on the upper pediments, far from every apparent water surplus (Fig. 15). The surrounding vegetation was grazed *Stipa glareosa-Anabasis brevifolia* desert steppe. We do not know if seedlings are absent because of the high grazing impact, nor if they would be able to establish under the current climatic conditions. These are only fragments of communities belonging to the *Ulmion pumilae* (HILBIG, 2000c), which are much better developed in northern and central Mongolia.

## 5. Discussion

### 5.1 Human impact on the vegetation in the Gobi Gurvan Sayhan National Park

Apart from moisture availability, grazing and trampling certainly are the most important environmental factors in our study area. Nomadic pastoralism has a long history in Mongolia and in the Gobi (FERNANDEZ-GIMENEZ, 1999), and has affected the vegetation over centuries and possibly even millennia. We encountered livestock at almost all sites in the park, the only exception were the most remote desert areas, where wells are not available. Thus, almost the entire study region is grazed, and this corresponds with data from transect studies in the mountain steppes of the GGS NP (STUMPP & al., in press). Other authors share the same opinion (BEDUNAH & SCHMIDT, 2000), while the “Ecosystems of Mongolia” (GUNIN & VOSTOKOVA, 1995) misleadingly classify the human impact as “absent or weak” in the mountains, and “weak or moderate” in the desert steppes.

Grazing impact is among the most strongly debated issues in the ecology of Mongolian desert steppes, with some authors reporting widespread degradation (BATKHISHIG & LEHMKUHL, 2003; OPP & HILBIG, 2003), while others describe pulse-driven rangeland dynamics with low degradation risk (FERNANDEZ-GIMENEZ & ALLEN-DIAZ, 1999). Given that the issue is so controversial, we will close with some short comments on the consequences of human impact in our study area. These will include a discussion on possible grazing effects in the various communities, the role of woody perennials in steppes, and a comment on the sustainability of grazing in the area.

### 5.2 Influence of grazing on the major vegetation types

The available data suggest that almost the entire region is under anthropo-zoogenic impact, so all vegetation types are grazing-tolerant to a certain degree. If grazing initiated a replacement of plant communities, then the “natural” vegetation has gone long ago, and at present it would be difficult even to imagine what it could have been. Thus there is no real reference for an assessment of grazing impact and inferences must remain speculative.

The mountains host the moistest and most productive plant communities apart from the saline meadows, and all mountain sites are permanently grazed by horses and, in the eastern part of the park, by Yaks. The distribution of shrubs and forests is largely determined by the edaphic conditions, but the pattern is modified by the ubiquitous livestock. *Helictotrichon* meadow steppes are known to represent replacement communities of forests elsewhere in Mongolia (HILBIG, 1987; SOMMER & TRETER, 1999) and the presence of birch saplings indicates that the respective sites are a potential habitat for trees in the GGS NP. However, birch forests are restricted to extreme water-surplus sites there and would not be able to colonise extensive areas even without grazing. *Lonicera microphylla* shrubs are found in most ranges of the park, but the most vigorous plants grow often amidst *Juniperus sabina* patches, which offer protection from grazing (Fig. 7A, B). Juniper itself is not grazed, but needs open substrate as does *Artemisia santolinifolia*. These two common woody species in the mountain ranges benefit at least partially from the anthropo-zoogenic impact.

In the mountain steppes, a general trend is the replacement of moisture-demanding plant species by those of drier sites with increasing grazing pressure. Steeply inclined *Arenaria meyeri* steppes are invaded by *Agropyron cristatum*, *Carex stenophylla*, and *Artemisia frigida* from the lower slopes. In mountain steppes with *Sibbaldianthe adpressa* and *Astragalus laguroides*, grazing (and nutrient influx around resting places) leads to an increase in *Agropyron cristatum*, *Allium polyanthum*, and *Carex stenophylla*; some dwarf-shrubs like *Artemisia frigida* and *Heteropappus altaicus* seem to benefit as well. At relatively moist sites *Achnatherum inebrians* spreads under heavy grazing. However, such extreme sites are restricted to the immediate surroundings of gers and winter places. Overall, the pattern of vegetation types remains largely controlled by the natural conditions, which are merely modified by grazing.

*Caragana leucophloea*- and *Stipa gobica* communities host few true grazing weeds, and the majority of plants are palatable. The principal exceptions are *Iris bungei*, *Achnatherum inebrians* and *A. splendens*, which indicate heavy grazing and, at least in the case of the latter species, relatively moist sites. Elsewhere, herbaceous species show little differentiation according to human impact. Again, only the direct surroundings (radius <100 m) of gers and wells are obviously transformed. Here, intensive grazing and high trampling impact results in an increase of ruderal weeds (*Chenopodiaceae*, *Lepidium densiflorum*). *Allium polyanthum* dominates whereas the cover of other steppe species is reduced. However, the spatial extent of these degradation stages is negligible.

*Caragana leucophloea* is collected for fuel wood and grows higher in exclosures maintained by the Bulgan research institute (Fig. 11, JUNATOV, 1974). We therefore tested whether gradients in shrub density could be found in utilisation belts around wells and winter places, but were unable to find statistically sound proof of the idea of strong anthropo-zoogenic impact on shrub distribution (STUMPP & al., in press). Edaphic conditions (presence of coarse substrate) were the main controlling factors instead.

Desert and semi-desert vegetation of the park is very heterogeneous, and we did not find any general grazing indicators. The dominant species of the semi-desert plant communities, i.e., *Stipa glareosa*, *Cleistogenes songorica*, and *Allium polyanthum*, are all tolerant of heavy grazing. Annual species like *Artemisia scoparia*, *Eragrostis minor*, and *Bassia dasypylla* benefit from soil disturbance, but they are much more common in the extensive sayrs than in grazed zonal steppes. The *Zygophyllaceae* *Peganum nigellastrum* is a true indicator of human activity, but is restricted to sites with the most heavy soil disturbance plus nutrient input around settlements and wells.

*Anabasis brevifolia* tolerates grazing, but disappears under heavy trampling. The presence of the evergreen dwarf-shrubs is crucial, as they offer some fodder in the winter time and during drought periods, when herbaceous species might not be available. They are, however, still exceedingly widespread in the GGS NP. Even the dry *Reaumuria soongorica*-*Salsola passerina* semi-deserts are grazed, and livestock feed on the dwarf-shrubs. Yet, the example of *Potaninia mongolica*, which had no leaves in the drought of 2001 and needed years for recovery afterwards, illustrates the governing importance of the climatic conditions. If there are any degradation phenomena, then they are masked by the decisive factor of water availability.

Saxaul deserts offer fresh green biomass even in drought years such as 2001. It is not surprising that most stands are browsed by Bactrian camels. Where goats are kept near Saxaul stands they feed on the shoots as well. Nonetheless, Saxaul trees and shrubs in all cases had many green shoots, so biomass production probably exceeds consumption. The rareness of seedlings certainly is reason for concern, but seed production is again climatically controlled. While the impact of grazing is thus not easily assessed, fuel wood collection certainly is a problem with respect to the low reproduction in the region.

Most of the salt-tolerant communities are rare in the park. Livestock avoid feeding on succulent dwarf-shrubs and annuals of saline sites, and stands remained largely untouched as they do not even offer fuel-wood. *Nitraria sibirica* forms the most common community on saline soils, but it is hardly grazed even near settlements and appears to be weakly affected by human impact. In contrast, saline meadows are heavily grazed. They offer rich pastures even in extreme years, and all species present are necessarily grazing-tolerant. We did not find any ungrazed meadow, because they are so attractive that camels would migrate even to the most remote sites. On the other hand, even in small fenced places such as in Hongoriyn Gol, we found only species that also occur in the grazed salt meadows.

### 5.3 On the importance of woody perennials in steppe-ecosystems

Steppes are not pure grasslands but usually have a more or less well developed shrub cover. However, unlike in other grassland regions of the world, overgrazing does not lead to increased shrub cover in central Asia. Woody perennials might decrease locally under heavy human impact,

but generally, shrub density does not increase along gradients of decreasing grazing intensity in the GGS NP (STUMPP & al., in press). In grass steppes of central Mongolia *Caragana microphylla* is an important woody component. Research on the impact of *Microtus brandti* (PETERSON, 1994; SAMJAA & al., 2000) showed that woody perennials are part of the successional cycle on winter burrows of Brandt's vole. The authors conclude that without the impact of livestock, there would be large thickets of *Caragana microphylla* (SAMJAA & al., 2000: 356). As these do not occur, it can be concluded that the effect of browsing keeps the grass steppes in the status of a graminoid-dominated ecosystem. However, desert steppes of southern Mongolia are clearly zonal (as opposed to some grass steppes and most meadow steppes) and even in the absence of grazing shrubs would not entirely replace the bunch grasses in the GGS NP.

In northern and central Mongolia, heavy grazing induced a replacement of forests by meadow steppes (SOMMER & TRETER, 1999; HILBIG, 2000b) and *Ulmus pumila* forests of the southern slopes were most strongly affected (HILBIG, 1987). Thus, the presence of scattered *Ulmus pumila* and *Populus diversifolia* trees in the GGS NP raises the question, whether there is a potential for more extensive forest in the semi-deserts of southern Mongolia. Most trees are bound to water-surplus sites, but a few grow outside of visibly favourable habitats (Fig. 15). Poplars are restricted to oases and sayrs, but elms are found on the proper pediments and could potentially be much more widespread in the GGS NP. It is conceivable that the present trees are relic individuals of a more humid climate, but dendrochronological analyses (Opgenoorth, *pers. comm.*) reveal that neither poplars nor elm trees in the GGS NP are older than around one hundred years. Both species form root suckers, which are preferentially grazed, and seedlings would certainly suffer from high grazing impact. For reseeding, these poplars appear to require flooded terrain (BRUELHEIDE & al., 2003), while elms germinated on the upper pediments in the GGS NP when experimentally seeded under natural conditions (Wesche, *pers. comm.*). However, neither *P. diversifolia* nor *U. pumila* produce seeds under the present climatic conditions, so there are hardly any chances for a notable increase in the number of trees in the region. Yet, established individuals might persist for extensive periods by means of clonal resprouting as has been shown for oases in the Taklamakan (BRUELHEIDE & al., 2003). Whether or not trees would play a major role in the area will have to be reconsidered in the course of future monitoring and experiments on grazing exclosures.

#### 5.4 On the sustainability of land use in the GGS NP

The sustainability of human utilisation of the vegetation in the GGS NP is not easily assessed by vegetation data alone. Soil degradation and decreasing livestock productivity are parameters at least as important as the vegetation structure, but their quantification is beyond the scope of this study. So we will restrict ourselves to a few comments.

The nomadic grazing system practised over centuries in the Gobi necessarily was sustainable to some extent, otherwise it would have collapsed long ago. Nomads are able to adapt to inter-annual climatic changes, as was impressively demonstrated by the large-scale migration of nomads and livestock from the drought-affected South Gobi to other Aymaks in 2001 (RETZER, 2004). The basic trends of the last decade are a return to the semi-nomadic way of living and an increase in livestock, especially in goats, which is paralleled in the Gobi by a decrease of camel stocks (JANZEN & BAZARGUR, 1999; MÜLLER, 1999; BASTIAN, 2000). We believe that the "new Nomadism" is positive from a nature conservationist's point of view, since it avoids heavy degradation of specific areas in unfavourable years. Yet, the increase in livestock numbers certainly poses some threats, most notably the recent increase in goat numbers while the well adapted camels become progressively rarer. Goats feed on woody plants and might affect shrub cover in the long run, leading to shortages in fuel wood supply. However, at present this is not yet a problem.

As to the carrying capacity, we believe that this is a question of scale. Semi-arid environments are probably pulse-driven (ELLIS & SWIFT, 1988; ILLIUS & O'CONNOR, 1999; OBA & al., 2000). This became apparent in the drought 2001, and livestock casualties clearly demonstrated that the

long-term carrying capacity of the Gobi Gurvan Sayhan area definitely had been exceeded in that year. However, many animals survived in neighbouring Aymaks, so on a regional scale (i.e. southern Mongolia) the carrying capacity is at most marginally exceeded. That is precisely the strength of the nomadic life-form, but makes any studies on the carrying capacity extremely difficult since studies are usually local, whereas the processes and the reactions on them are regional.

One of the basic questions in nature conservation is the preservation of biodiversity. Again this is a matter of scale. Vegetation is transformed by grazing, but  $\alpha$ -diversity as such might even increase. Intriguing examples are the meadow steppes around the birch forests, which are species-rich replacement communities of species-poor birch forests; or the higher species numbers around winter gers in comparison to the surrounding grass steppe. The  $\beta$ -diversity has probably decreased because the significant environmental factor of grazing is omnipresent and has levelled out part of the regional variation due to edaphic factors. Abiotic site conditions are, however, still important and they are responsible for a nonetheless high heterogeneity of vegetation types, and thus for the  $\gamma$ -diversity. A multitude of microsites offer habitats for more than 600 vascular plant species growing in the park. Less than ten of these are endemic or sub-endemic, and some of the latter belong to taxonomically difficult groups (*Caragana gobica*, *Papaver saichanense*). Most of the taxonomically well-known sub-endemic species of the Gobi Altay (*Galitzkya macrocarpa*, *Potentilla ikonnikovii*, *Valeriana saichanensis* and *Saussurea saichanensis*) are restricted to rocky outcrops and high-altitude swards, where they are relatively widespread and not endangered by livestock grazing. *Rheum uninerve* is probably the only endemic that occurs on the colline sites (GRUBOV, 2001) and would presumably be endangered by grazing. There are very few records at all for Mongolia and we were not able to find a single plant. Thus we are unable to comment on its status, but overall, the immediate threats for biodiversity posed by human activity appear to be relatively small.

Although we find ourselves unable to state whether livestock numbers already exceed the ecological carrying capacity, we nevertheless think that numbers are high and near their upper limit. An increase in the number of wells might facilitate a more flexible use of the available resources but might also promote even higher livestock numbers. Moreover, grazing would extend to areas, where there is little or no livestock at present, and where there are the refuges for wild herbivores (e.g. the basin north of Nemegt Uul). In any case, grazing levels in general will remain high in all sites of the region, because we seriously doubt that it is feasible to exclude livestock from certain parts of the park.

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**Table 1.** – Numerical “header data” data for the relevés.

Parameter	Method
GPS Position	decimal degrees
Elevation	altimeter, GPS
Aspect	degrees
Inclination	degrees
Stoniness	% soil particles >2mm
Organic substance	% estimated
Carbonate	estimated with HCl addition
Grazing influence	ordinal scale with 4 divisions
Cover of vegetation strata (trees, shrubs, field etc.)	visual estimate in %
Lab: soil pH in water	in pH units, values for 1 and 24 hrs. of soaking
Lab: soil conductivity in water	µS, values for 1 and 24 hrs. of soaking

**Table 2.** – Constancy table of extrazonal communities of moist mountain slopes in the Gobi Gurvan Sayhan National Park.

Diagnostic species are indicated: CC = Class-level character species; LC = Alliance-level character species; AC = Association-level character Species, rC = regional character species. For more than 5 relevés in a given community, frequency is given as constancy classes ("r" = present in <5 % of all relevés of that community; "+" = 5 - 10%; "I" = 10 - 20%; "II" = 20 - 40%; "III" = 40 - 60%; "IV" = 60 - 80%; "V" = 80 - 100 %, DIERSCHKE, 1994).

Community no.	11	12	13	14
<b>No. of relevés</b>	4	1	5	4
<b>Mean species richness</b>	18	20	31	32
<i>BETULA MICROPHYLLA</i> COMMUNITY				
AC <i>Betula microphylla</i>	4	.	I	.
AC <i>Salix bebbiana</i>	4	.	I	.
rC <i>Lonicera altaica</i>	3	.	.	.
rC <i>Ribes rubrum</i>	4	.	.	.
LC <i>Spiraea media</i>	4	.	.	.
rc <i>Rosa acicularis</i>	3	.	.	.
rC <i>Cystopteris fragilis</i>	4	.	.	.
rC <i>Carex obtusata</i>	3	.	.	.
rC <i>Atragene sibirica</i>	4	.	I	.
LC <i>Campanula turczaninovii</i>	3	.	I	1
rC <i>Saxifraga sibirica</i>	3	.	.	1
MONTANE SHRUBLANDS				
<i>Spiraea flexuosa</i>	.	1	.	.
<i>Grossularia acicularis</i>	.	1	.	.
rC <i>Lonicera microphylla</i>	1	1	.	.
INTROGRESSIVES OF THE <i>JUNIPERUS SABINA</i> COMMUNITY				
AC <i>Juniperus sabina</i>	3	1	.	.
<i>Lophanthus chinensis</i>	.	1	.	.
AC? <i>Poa stepposa</i> (incl. <i>P. botryoides</i> )	.	1	I	.
<i>Thalictrum foetidum</i>	1	1	I	3
<i>Silene repens</i>	4	.	I	3
POPULUS LAURIFOLIA COMMUNITY				
LC <i>Populus laurifolia</i>	.	1	.	.
<i>Nepeta sibirica</i>	.	1	.	.
<i>Aquilegia viridiflora</i>	.	1	.	.
<i>Urtica cannabina</i>	.	1	.	.
KOBRESIETUM MYOSUROIDIS Mirkin & al. 1988				
rC <i>Lagotis integrifolia</i>	1	.	III	.
rC <i>Gentiana decumbens</i>	.	.	IV	.
rC <i>Saussurea arctecapitulata</i>	.	.	III	.
rc <i>Potentilla crebridens</i>	.	.	III	.
rC <i>Gentiana azurea</i>	.	.	IV	1
AC <i>Artemisia phaeolepis</i>	.	.	III	4

Community no.	11	12	13	14
No. of relevés	4	1	5	4
Mean species richness	18	20	31	32
KOBRESION MYOSUROIDIS Mirkin & al. 1983				
LC <i>Polygonum viviparum</i>	.	.	IV	.
LC <i>Kobresia bellardii</i>	.	.	V	1
LC <i>Oxytropis strobilacea/oligantha</i>	.	.	II	3
<i>Gentiana barbata</i>	.	.	IV	3
AC <i>Ranunculus pedatifidus</i>	.	.	.	2
HELIOTRICHION SCHELLIANI Hilbig 2000				
LC <i>Aster alpinus</i>	.	.	II	3
LC <i>Carex pediformis</i>	1	.	IV	4
LC <i>Galium verum</i>	1	.	III	4
LC <i>Festuca lenensis</i>	.	.	II	2
LC <i>Helictotrichon schellianum</i>	.	.	IV	4
LC <i>Leontopodium ochroleucum</i>	.	.	II	2
ANDROSACO OVCZINNIKOVII-HELIOTRICHETUM SCHELLIANI Hilbig 1987 (1990)				
<i>Cerastium arvense</i>	1	.	III	3
AC <i>Lomatogonium carinthiacum</i>	.	.	II	1
AC? <i>Androsace dasypylla</i>	.	.	II	3
rC <i>Potentilla chionea</i>	.	.	.	3
rC <i>Festuca kurtschumica</i>	.	.	.	2
CC <i>Veronica incana</i>	.	.	.	2
SPECIES OF THE STIPION KRYLOVII				
<i>Carex stenophylla</i>	.	.	I	.
rC <i>Allium eduardii</i>	.	.	.	1
CC <i>Agropyron cristatum</i>	.	.	I	2
LC <i>Stipa krylovii</i>	.	.	.	1
rC <i>Artemisia pycnorhiza</i>	.	.	I	1
rC <i>Festuca valesiaca</i>	.	.	II	1
rC <i>Amblynotus rupestris</i>	.	.	I	1
rC <i>Koeleria altaica</i>	.	.	II	4
CC <i>Bupleurum bicaule</i>	.	.	I	2
Lc <i>Sibbaldianthe adpressa</i>	.	.	.	1
<i>Oxytropis pumila</i>	.	.	I	2
SPECIES OF THE THYMION GOBICI				
LC <i>Arenaria meyeri</i>	.	.	I	.
LC <i>Potentilla sericea</i>	.	1	I	3
LC <i>Silene jenisseensis</i>	.	.	II	2
LC <i>Orostachys spinosa</i>	.	.	I	2

Community no.	11	12	13	14
No. of relevés	4	1	5	4
Mean species richness	18	20	31	32
OTHER COMPANIONS				
<i>Androsace septentrionalis</i>	1	.	I	.
<i>Moehringia lateriflora</i>	2	.	I	.
<i>Cotoneaster mongolica</i>	2	.	.	.
<i>Potentilla desertorum</i>	1	1	.	.
<i>Pedicularis flava</i>	.	.	I	1
<i>Stellaria amblyosepala</i>	.	.	II	1
<i>Linaria acutiloba</i>	.	.	.	.
<i>Astragalus multicaulis</i>	.	.	I	2
<i>Allium amphibolum</i>	.	.	.	2
<i>Poa pratensis</i>	.	.	III	1
<i>Polygonum alpinum</i>	.	.	III	2
<i>Potentilla multifida</i>	.	.	II	2
<i>Saxifraga cernua</i>	.	.	III	1
<i>Papaver saichanense</i>	.	.	II	2
<i>Draba lanceolata</i>	.	.	II	1
<i>Festuca</i> sp. nov.	.	.	III	.

## ADDITIONALLY

**11:** *Adoxa moschatellina*, *Viola* cf. *arenaria*, *Rubia cordiflora*, *Carex amgunensis*

**12:** *Lappula intermedia*, *Chenopodium* «*album*», *Clematis tangutica*, *Astragalus frigidus*

**13:** *Eritrichium pauciflorum*, *Thlaspi cochleariforme*, *Kobresia simpliciuscula*, *Peucedanum* sp., *Elymus schrenkianus*, *Potentilla nivea*, *Lloydia serotina*, *Bromus inermis*, *Astragalus frigidus*, *Elymus chinensis*, *Carex orbicularis*, *Papaver croceum*, *Hordeum brevisubulatum*, *Gentiana acuta*, *Adoxa moschatellina*

**14:** *Androsace maxima*, *Rheum undulatum*, *Carex orbicularis*, *Papaver croceum*, *Hordeum brevisubulatum*, *Gentiana acuta*, *Scorzonera ikonnikovii*, *Vicia semenovii*, *Clausia aprica*, *Carex enervis*

**Table 3.** – Mountain steppes, montane scrub and related communities (for explanation of constancy classes see Table 2).

Community no.	211	212	213	214	221	222	231	232	24	25
<b>No. of relevés</b>	23	31	55	8	12	30	11	12	7	27
<b>Mean species richness</b>	24	16	15	17	11	13	13	14	18	16
<i>AGROPYRETEA CRISTATI</i> Hilbig et Koroljuk 2000										
CC <i>Agropyron cristatum</i>	V	V	V	V	IV	IV	IV	IV	V	IV
CC <i>Bupleurum pusillum</i>	II	II	II	I	.	+	.	.	I	II
CC <i>Heteropappus altaicus</i>	I	II	II	V	III	II	.	.	III	III
CC <i>Poa attenuata</i>	V	II	I	IV	.	II	.	.	III	II
CC <i>Dontostemon integrifolius</i>	+	.	+	.	+	r	.	.	.	.
CC <i>Bupleurum bicaule</i>	III	II	II	.	.	.	.	+	III	+
CC <i>Potentilla bifurca</i>	r	.	r	.	.	r	.	.	.	.
<i>THYMION GOBI</i> (Mirkin & al.) Kasapov & al. 1987										
LC <i>Arenaria meyeri</i>	V	IV	II	I	+	+	II	.	III	II
LC <i>Amblynotus rupestris</i>	V	+	r	.	.	.	+	.	.	.
LC <i>Orostachys spinosa</i>	III	+	+	I	.	+	+	.	I	r
LC <i>Thymus gobicus</i>	.	I	.	.	+	.	.	.	I	r
LC <i>Youngia tenuifolia</i>	r	I	.	.	.	r	.	.	II	r
LC <i>Silene jenisseensis</i>	III	+	.	.	.	.	+	.	I	I
<i>STIPION KRYLOVII</i> Kononov, Gogoleva et Mironova 1985										
LC <i>Stipa krylovii</i>	III	IV	IV	IV	III	III	I	II	III	II
LC <i>Artemisia frigida</i>	V	V	V	II	III	III	.	.	III	IV
LC <i>Kochia prostrata</i>	.	I	II	I	.	+	.	.	.	II
LC <i>Allium anisopodium</i>	.	.	r	.	.	+	I	II	.	.
LC <i>Elymus chinensis</i>	.	r	r	.	.	+	.	r	I	+
<i>Panzeria lanata</i>	.	.	.	II	.	I	.	.	.	I
<i>HEDYSARO PUMILI-STIPETUM KRYLOVII</i> Hilbig (1987) 1990										
AC <i>Iris potaninii</i>	I	I	r	.	.	r	.	.	III	I
AC? <i>Oxytropis pumila</i>	IV	II	III	I	III	+	.	.	II	+
<i>FESTUCA VALESIACA</i> VARIANT OF THE <i>STELLARIA PETRAEA</i> SUBASSOCIATION Hilbig 1990										
rC <i>Festuca valesiaca</i>	V	+	r	.	.	.	.	.	.	.
rC <i>Artemisia pycnorhiza</i>	IV	II	+	.	.	r	I	+	I	+
rC <i>Limonium flexuosum</i>	IV	r	.	.	.	r	.	.	II	.
<i>Thalictrum foetidum</i>	III	I	.	.	.	r	IV	III	II	.
TYPICAL VARIANT OF THE <i>STELLARIA PETRAEA</i> SUBASSOCIATION Hilbig 1990										
rC <i>Phlojodicarpus sibiricus</i>	r	II	r	.	.	.	I	+	.	r
rC <i>Allium eduardii</i>	III	IV	r	.	.	.	+	+	I	II
rC <i>Crepis crocea</i>	II	I	.	.	.	.	r	r	II	.
rC <i>Peucedanum hystrix</i>	III	+	r	.	.	.	.	.	I	.
ASTRAGALUS INOPINATUS SUBASS. Hilbig 1990 WITH <i>SIBBALDIANTHE ADPRESSA</i>										
LC <i>Sibbaldianthe adpressa</i>	.	+	III	.	.	+	.	I	I	I
LC <i>Astragalus laguroides</i>	II	I	III	I	III	I	.	.	.	I



Community no.	211	212	213	214	221	222	231	232	24	25
<b>No. of relevés</b>	23	31	55	8	12	30	11	12	7	27
<b>Mean species richness</b>	24	16	15	17	11	13	13	14	18	16
rC <i>Koeleria altaica</i>	IV	r	r	.	.	.	+	.	II	.
rC <i>Potentilla sericea</i>	IV	II	+	III	.	r	+	+	III	r
AC <i>Polygonum angustifolium</i>	I	.	.	.	.	.	.	.	.	.
LC <i>Carex pediformis</i>	.	.	.	.	.	.	+	.	.	.
SPECIES OF THE CARAGANION LEUCOPHLOEAE Hilbig 2000										
LC <i>Caragana leucophloea</i>	.	II	II	.	.	I	.	III	I	IV
LC <i>Eurotia ceratoides</i>	+	II	I	II	III	I	.	r	I	III
LC <i>Ephedra sinica</i>	I	II	r	I	.	r	+	I	I	II
OTHER SPECIES OF THE STIPETEA GLAREOSAE-GOBICAE Hilbig 2000										
CC <i>Stipa gobica</i>	r	III	III	.	.	I	r	r	.	IV
CC <i>Ptilotrichum canescens</i>	III	IV	V	III	III	II	+	II	IV	IV
LC <i>Allium polyanthum</i>	r	II	IV	I	IV	IV	.	.	.	III
CC <i>Cleistogenes songorica</i>	.	r	II	I	+	I	.	.	.	II
CC <i>Ajania achilleoides</i>	.	I	+	II	+	+	.	.	.	II
CC <i>Convolvulus ammannii</i>	.	+	III	.	+	I	.	.	.	I
CC <i>Lagochilus ilicifolius</i>	.	I	II	.	.	r	.	.	I	II
AC <i>Caryopteris mongholica</i>	.	r	.	.	.	+	.	r	.	II
LC <i>Limonium tenellum</i>	.	r	.	.	.	r	.	.	.	r
AC <i>Oxytropis aciphylla</i>	.	.	+	.	.	.	.	.	.	.
LC <i>Gypsophila desertorum</i>	.	.	II	.	.	.	.	.	.	+
LC <i>Astrothamnus centrali-asiaticus</i>	.	.	.	.	+	+	.	.	.	.
CC <i>Stipa glareosa</i>	.	.	.	.	+	+	.	.	.	.
LC <i>Artemisia pectinata</i>	.	.	.	.	+	+	.	.	.	I
LC <i>Amygdalus pedunculata</i>	.	.	.	.	.	+	.	.	.	.
rC <i>Amygdalus mongolica</i>	.	.	.	.	.	.	.	.	.	.
LC <i>Atraphaxis pungens</i>	.	.	.	.	.	.	.	.	.	.
OTHER COMPANIONS										
<i>Artemisia dracunculus</i>	r	+	r	I	+	I	I	I	I	I
<i>Allium prostratum</i>	III	I	+	I	+	.	.	.	.	I
<i>Astragalus multicaulis</i>	III	+	+	III	.	+	.	I	II	+
<i>Pedicularis flava</i>	III	II	I	I	.	.	II	I	III	I
<i>Astragalus brachybotrys/</i> <i>miniatus</i>	I	I	I	I	.	.	.	.	.	.
<i>Scorzonera ikonnikovii</i>	I	II	II	.	+	+	.	r	I	+
<i>Saussurea pricei</i>	II	II	+	.	.	r	.	.	I	r
<i>Carex enervis</i>	II	+	I	.	III	II	.	r	II	.
<i>Clausia aprica</i>	I	+	r	.	.	.	.	r	III	+
<i>Dracocephalum fruticosum</i>	r	I	r	.	+	r	.	II	I	r
<i>Ajania fruticulosa</i>	r	II	II	.	.	r	.	.	I	II
<i>Oxytropis bungei</i>	r	+	r	.	.	.	.	.	I	r
<i>Potentilla agrimonoides</i>	r	r	r	.	.	.	+	II	.	.

Community no.	211	212	213	214	221	222	231	232	24	25
No. of relevés	23	31	55	8	12	30	11	12	7	27
Mean species richness	24	16	15	17	11	13	13	14	18	16
<i>Astragalus mongolicus</i>	+	r	.		+	.	.	.		.
<i>Saussurea saichanensis</i>	II	r	.	.	.	.	.	.		.
<i>Pedicularis abrotanifolia</i>	II	+	.	.	.	.	.	.	.	r
<i>Androsace septentrionalis</i>	II	+	.	.	.	.	+	.		.
<i>Thlaspi cochleariforme</i>	II	r	.	.	.	.	.	.	.	.
<i>Rheum undulatum</i>		r	.	.	.	r	.	.	III	.
<i>Goniolimon speciosum</i>		+	.	.	.	.	.	.	.	.
<i>Oxytropis tragacanthoides</i>	+		.	.	.	.	.	.		r
<i>Hedysarum gmelinii</i>	r	r	.	.	.	.	.	.	.	r
<i>Ephedra przewalskii</i>	r	+	.	.	.	.	.	.	.	.
<i>Polygonum alpinum</i>	II	.	.	.	.	.	.	.		.
<i>Rhodiola rosea</i>	II	.	.	.	.	.	.	.	.	.
<i>Leontopodium ochroleucum</i>	II	.	.	.	.	.	.	.	.	.
<i>Papaver saichanense</i>	II	.	.	.	.	.	.	.	.	.
<i>Papaver croceum</i>		.	.	.	.	.	.	.	.	.
<i>Smelovskia alba</i>		.	.	.	.	.	.	.	.	.
<i>Serratula cf. marginata</i>		.	.	.	.	.	.	.	.	.
<i>Stellaria amblyosepala</i>		.	.	.	.	.	+	.	.	.
<i>Oxytropis chionophylla</i>		.	.	.	.	.	.	.	.	.
<i>Taraxacum leucanthum</i>	r	.	.	.	.	+	.	.		.
<i>Gentiana decumbens</i>	+	.	.	.	.	.	.	.	.	.
<i>Artemisia palustris</i>	r	.	.	II	.	.	.	.	.	.
<i>Lagotis integrifolia</i>	r	.	.	.	.	.	.	.	.	.
<i>Axyris prostrata</i>	+	.		II	.	r	.	.		.
<i>Dontostemon senilis</i>	r	.	+	.	.	r	.	.	.	+
<i>Linaria acutiloba</i>	r	.	.	.	.	.		+	.	.
<i>Lappula intermedia</i>	.	r	.	II	+	r	.	r		+
<i>Astragalus spec.</i>	.	r	r	.	.	r	.	.	.	.
<i>Haplophyllum davuricum</i>	.		r	.	.	+	.	r	.	
<i>Orostochys fimbriata</i>	.	+	+	.	.	.	.	.	.	
<i>Elymus paboanus</i>	.	r	.		.	+	.	.	.	.
<i>Euphorbia mongolica</i>	.	r	.	.	+	+	.	.		+
<i>Artemisia gobica</i>	.	r	.	.	.	+	r	r		.
<i>Ptilotrichum tenuifolium</i>	.	r	.	.	.	.	.	.	.	+
<i>Potentilla multifida</i>	.	r	.	.	.	+	.	.	.	.
<i>Nepeta sibirica</i>	.	r	.	.	.	.	.	.	.	.
<i>Youngia tenuicaulis</i>	.		.	.	.	.	.	.		.
<i>Astragalus saichanensis</i>	.		.	.	.	.	.	.	.	.
<i>Stipa breviflora</i>	.	+	.	.	.	.	.	.		.
<i>Krylovia eremophila</i>	.	+	.	.	.	.	.	.	.	r
<i>Iris bungei</i>	.	.	+	II		+	.	.	II	.

Community no.	211	212	213	214	221	222	231	232	24	25
No. of relevés	23	31	55	8	12	30	11	12	7	27
Mean species richness	24	16	15	17	11	13	13	14	18	16
<i>Scorzonera capito</i>	.	.	r	.	.	.	.	.	.	+
<i>Astragalus grubovii</i>	.	.	r	.	.	.	.	.	.	r
<i>Astragalus vallestris</i>	.	.	II	.	+	+	.	.	.	r
<i>Artemisia macrocephala</i>	.	.	+	.	+	II	.	.	.	l
<i>Allium</i> sp.	.	.	+	.	.	.	.	.	.	.
<i>Descurainia sophia</i>	.	.	.	II	.	+	.	.	.	.
<i>Hackelia thymifolia</i>	.	.	.	II	.	.	.	.	.	+
<i>Chenopodium hybridum</i>	.	.	.	l	II	.	.	.	.	r
<i>Orobanche coerulescens</i>	.	.	.	l	.	.	.	.	l	r
<i>Dracocephalum foetidum</i>	.	.	.	.	.	+	.	.	.	+
<i>Schizonepeta annua</i>	.	.	.	.	.	r	.	.	.	+
<i>Urtica cannabina</i>	.	.	.	.	.	r	+	+	.	.
<i>Cotoneaster mongolica</i>	.	.	.	.	.	.	+	.	.	.
<i>Potentilla desertorum</i>	.	.	.	.	.	.	+	.	.	.
<i>Melandrium brachypetalum</i>	.	.	.	.	.	.	+	l	.	r
<i>Allium amphibolum</i>	.	.	.	.	.	.	.	l	r	.
<i>Poa pratensis</i>	.	.	.	.	.	.	.	+	.	.

## ADDITIONALLY

211: *Allium tenuissimum*, *Arenaria* cf. *formosa*, *Artemisia commutata*, *Chenopodium aristatum*, *Eritrichium pauciflorum*, *Iris tenuifolia*, *Kobresia simpliciuscula*, *Linaria acutiloba*, *Oxytropis* sp., *Papaver rubro-aureum*, *Pulsatilla bungeana*, *Taraxacum* cf. *cuspidatum*, *Tougarinovia mongholica*, *Vicia multicaulis*, *Vicia semenovii*, *Festuca brevisubulatum*

212: *Allium tenuissimum*, *Caragana bungei*, *Chamaerhodos sabulosa*, *Comarum salesovianum*, *Festuca rubra*, *Galitzkyia macrocarpa*, *Poaceae*, *Potentilla ojorensis*, *Ephedra equisetina*

213: *Artemisia scoparia*, *Chenopodium* sp., *Cymbalaria dahurica*, *Elymus gmelinii*, *Peucedanum vaginatum*

214: *Brassicaceae*, *Scutellaria grandiflora*

221: *Artemisia xerophytica*

222: *Scutellaria grandiflora*, *Peucedanum vaginatum*, *Oxytropis* sp., *Arabidopsis mollissima*, *Artemisia caespitosa*, *Artemisia sericea*, *Astragalus frigidus*, *Chiazzospermum lactiflorum*, *Crepis flexuosa*, *Glaux maritima*, *Incarvillea potaninii*, *Iris lactea*, *Plantago depressa*, *Psathyrostachys juncea*, *Ptilagrostis pelliotii*, *Puccinellia hauptiana/tenuifolia*, *Reaumuria soongorica*, *Scorzonera pseudodivaricata*, *Scrophularia incisa*, *Taraxacum* sp., *Thermopsis lanceolata*, *Artemisia gmelinii*, *Elymus amgunensis*, *Hordeum brevisubulatum*, *Stellaria brachypetalum*, *Vincetoxicum sibiricum*

231: *Artemisia caespitosa*, *Elymus gmelinii*, *Clematis tangutica*

232: *Allium tenuissimum*, *Artemisia caespitosa*, *Elymus gmelinii*, *Vicia semenovii*

241: *Carex korshinskyi*, *Astragalus frigidus*, *Scorzonera pseudodivaricata*, *Vicia multicaulis*, *Allium altaicum*, *Allium amphibolum*, *Arnebia fimbriata*, *Axyris hybrida*, *Schizonepeta multifida*, *Thesium refractum*

242: *Artemisia scoparia*, *Chenopodium aristatum*, *Allium mongolicum*, *Anabasis brevifolia*, *Arabis* sp., *Artemisia intricata*, *Enneapogon borealis*, *Eragrostis minor*, *Erysimum marshallianum*, *Jurinea mongolica*, *Melandrium brachypetalum*, *Scorzonera divaricata*, *Setaria viridis*

**Table 4.** – Semi-desert and desert vegetation of the piedmont regions and inter-montane basins (for explanation of constancy classes see Table 2).

Community no.	31	32	331	332	41	421	422	43	44	45	46	471	472	48	49
No. of relevés	13	58	23	14	36	29	29	21	8	11	22	14	9	2	4
Mean species richness	17	15	12	10	15	15	9	8	10	14	12	10	6	13	8
STIPA GOBICA COMMUNITY															
CC ?/hC <i>Stipa gobica</i>	III	IV	V	V	r	r	r	r	r	r	r	+	+	+	+
rC <i>Iris bungei</i>	·	==	—	—	==	==	==	+	·	·	·	·	·	·	·
<i>Ajania fruticulosa</i>	II	II	II	IV	II	+	III	II	II	II	II	III	II	II	·
ALLIO POLYRRHIZI-STIPETUM GLAREOSAE Hilbig (1987) 1990															
CC <i>Stipa glareosa</i>	II	II	+	—	V	V	V	V	V	V	V	V	V	V	II
LC <i>Gypsophila desertorum</i>	·	—	r	—	III	—	r	—	—	—	—	—	—	—	·
CC <i>Convolvulus ammannii</i>	—	—	II	II	IV	II	II	—	—	—	—	+	+	—	—
<i>Oxytropis aciphylla</i>	—	+	+	—	III	III	II	—	—	II	II	+	+	—	2
<i>Carex stenophylla</i>	—	II	III	—	III	r	—	—	—	—	r	II	—	—	—
STIPO GLAREOSAE-ANABASSETUM BREVIFOLIAE Hilbig (1987) 1990: TYPICAL SUBASSOCIATION															
LC <i>Anabasis brevifolia</i>	·	r	—	—	r	IV	V	V	V	V	+	IV	IV	IV	—
rC <i>Astragalus vallestris</i>	II	+	—	+	II	II	II	—	—	—	—	—	—	—	—
rC <i>Eragrostis minor</i>	—	+	r	—	II	II	II	—	—	—	—	—	—	—	—
<i>Bassia dasypylla</i>	—	II	r	—	II	II	—	r	—	—	+	—	—	—	—
REAUMURIO SOONGORICAE-SALSOLIUM PASSERINAE (Kasapov et al. 1988) Mirkin et al. 1988															
LC <i>Reaumuria soongorica</i>	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
LC <i>Salsola passerina</i>	—	—	—	—	r	III	IV	—	—	—	—	—	—	—	—
SALSOLO PASSERINAE-REAUMURIETUM SOONGORICAE Kasapov et al. ex Hilbig 2000															
rC <i>Salsola arbuscula</i>	—	r	r	—	—	—	—	—	—	—	—	—	—	—	—
POTANINIO MONGOLICAE-SYMPERMETUM REGELII Kasapov et al. 1988															
AC <i>Potaninia mongolica</i>	II	r	r	+	—	—	—	—	r	V	—	—	—	—	—
AC <i>Sympetrum regelii</i>	—	—	—	—	—	—	—	—	r	—	—	r	—	—	—
ZYGOPHYLLO XANTHOXYLI-BRACHANTHEMION GOBIC/ (Mirkin in Kasapov et al. 1988) Mirkin et al. 1988															
LC <i>Zygophyllum xanthoxylon</i>	II	r	—	—	—	—	—	—	r	r	r	—	+	V	II

Community no.	31	32	331	332	41	421	422	43	44	45	46	471	472	48	49
No. of relevés	13	58	23	14	36	29	21	8	11	22	14	9	2	4	
<b>Mean species richness</b>															
ARTEMISIA SPHAEROCEPHALA COMMUNITY	17	15	12	10	15	15	9	8	10	14	12	10	6	13	8
AC? <i>Artemisia sphaerocephala</i>		r	·	·	·	·	+	·	·	V	·	+		·	3
LC <i>Asterothamnus centrali-asiaticus</i>		·	r	+	+	+	r	·	·		·	·	·	·	·
<b>EUROTIO CERATOIDS-ZYGOPHYLLETUM XANTHOXYLI Hilbig (1987) 1990</b>															
AC? <i>Amygdalus mongholica</i>	+	+	·	·	·	·	·	·	·	r	·	·		·	1
<b>CALLIGONO MONGOLICI-HALOXYLETUM AMMODENDRONIS Hilbig (1987) 1990</b>															
AC <i>Haloxylon ammodendron</i>	·	·	·	·	·	·	·	·	·	+	r	V	V	·	·
<b>REAUMURIA SUBASSOCIATION OF THE CALLIGONO-HALOXYLETUM</b>															
rC <i>Micropeplis arachnoidea</i>	·	·	·	·	·		·	r	·	+	r	IV	·	·	·
AC <i>Artemisia scoparia</i>	·	·	·	·	·	·		r			·	IV	·	·	·
<b>NITRARIA SPHAEROCARPA SUBASSOCIATION OF THE CALLIGONO-HALOXYLETUM</b>															
rC <i>Lycium ruthenicum</i>	·	·	·	·	·	·	·	·	·	+	·	·	IV	·	·
AC <i>Nitraria sphaerocarpa</i>	·	·	·	·	·	·	·	·	·	r	r	·	·	·	·
<b>CARAGANO BUNGEI-BRACHANTHEMETUM GOBICI Kasapov et al. 1988</b>															
AC <i>Caragana bungei</i>	·	·	·	·	·	·	·	·	·	·	+	·	·	1	·
Caragana korshinskii	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1
<b>PSAMMOCHLOA VILLOSA COMMUNITY</b>															
AC <i>Psammochloa villosa</i>	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4
rC <i>Agriophyllum pungens</i>	·	·	·	·	·	·	·	·	·	·	·	+	·	·	2
<i>Iris tenuifolia</i>	·	·	·	·	·	·	r	r	·	·	·	·	·	1	1
<b>SPECIES OF THE ACHNATHERUM NEBRANS COMMUNITY</b>															
AC? <i>Achnatherum inebrians</i>	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·
<i>Achnatherum splendens</i>		+		+	+	·	·	·	·	+	·	·	·	·	·
<b>SPECIES OF THE AGROPYRETEA CRISTATI</b>															
LC <i>Kochia prostrata</i>	+					·	·	·	·	r	·	·	·	·	·
AC? <i>Astragalus laguroides</i>	·					·	r	r	·	·	·	r	·	·	1
CC <i>Heteropappus altaicus</i>	IV									r	·	+	·	·	·





Community no.	31	32	331	332	41	421	422	43	44	45	46	471	472	48	49
No. of relevés	13	58	23	14	36	29	29	21	8	11	22	14	9	2	4
Mean species richness	17	15	12	10	15	15	9	8	10	14	12	10	6	13	8
<i>Kochia</i> cf. <i>krylovii</i>	.	.	.	.			.	r	.	.	.		.	.	.
<i>Tribulus terrestris</i>	.	.	.	.			.	.	.	—	.	+	.	1	.
<i>Aristida heymanii</i>	.	.	.	.	—	—	r	r	.	—	.	.	.	.	.
<i>Peganum nigellastrum</i>	.	.	.	.	—	—	—	—	—	—	—	.	.	.	1
<i>Chenopodium prostratum</i>	.	.	.	.	—	+	r	.	.	—	—		.	.	.
<i>Tougarinovia mongholica</i>	.	.	.	.	—	+	r	.	.	—	—	+	.	.	.
<i>Dontostemon crassifolius</i>	.	.	.	.	—	+	—	—	—	—	—	+	.	.	.
<i>Convolvulus gortschakovii</i>	.	.	.	.	—	—	r	r	—	—	—	—	—	—	1
<i>Zygophyllum rosowii</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	—
<i>Crepis flexuosa</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	.
<i>Limonium erythrorhizum</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	1
<i>Kalidium gracile</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	.
<i>Dontostemon elegans</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	.
<i>Echinops gmelinii</i>	.	.	.	.	—	—	—	—	—	—	—	—	—	—	1

## ADDITIONALLY

31: *Chamaerhodos sabulosa*, *Incarvillea potaninii*, *Euphorbia mongolica*, *Artemisia anethifolia*, *Carex enervis*, *Dracocephalum fruticosum*32: *Euphorbia mongolica*, *Dracocephalum fruticosum*, *Elymus chinensis*, *Galitzkya macrocarpa*, *Orostachys fimbriata*331: *Artemisia anethifolia*332: *Orostachys fimbriata*, *Carex enervis*41: *Artemisia anethifolia*, *Ferula bungeana*, cf. *Corispermum*421: *Ferula bungeana*, *Lappula intermedia*, *Plantago minuta*, *Convolvulus arvensis*, *Astragalus multicaulis*422: *Chesneya mongolica*43: cf. *Sonchus dentatus*, *Populus diversifolia*44: *Salsola abrotanoides*, cf. *Sonchus dentatus*45: *Lappula intermedia*, *Plantago minuta*, *Jurinea mongolica*46: *Salsola abrotanoides*, cf. *Sonchus dentatus*, *Lappula intermedia*471: *Artemisia anethifolia*472: *Chesneya mongolica*48: *Jurinea mongolica*

**Table 5.** – Vegetation on saline sites (environmental data as medians if n>1, for explanation of constancy classes see Table 2).

Community no.	51	52	53	54	55	56	57	58	59
<b>No. of relevés</b>	3	5	3	1	1	1	7	2	1
<b>Mean species richness</b>	7	7	3	7	5	13	11	9	5
<b>altitude</b>	1360	1416	1179	1418	1418	1418	1513	1118	1252.5
<b>pH</b>	7.0	8.2	8.3	8.3	8.9	8.2	8.1	9.8	9.5
<b>conductivity (mikroSiemens)</b>	3795	1964	3220	6300	5120	9050	2580	19300	3507.5
<b>carbonate (%)</b>	10	9.5	10	10	9	10	10	10	8.5
<b>GLYCYYRHIZO-ACHNATHERETUM SPLENDENTIS</b> Hilbig (1987) 1990									
AC <i>Nitraria sibirica</i>	3	IV	.	1	.	.	.	.	.
<i>Peganum nigellastrum</i>	3	.	.	.	.	.	.	.	.
rC <i>Atriplex sibirica</i>	2	.	.	.	.	.	.	.	.
<b>STIPETEA GLAREOSAE-GOBICAE</b> Hilbig 2000									
AC <i>Anabasis brevifolia</i>	1	II	.	.	.	.	.	.	.
AC <i>Lycium ruthenicum</i>	1	I	.	.	.	.	.	.	.
AC <i>Micropeplis arachnoidea</i>	1	I	.	.	.	.	1	.	.
<b>REAUMURIO SOONGORICAE-SALSOLION PASSERINAE</b> (Kasapov et al. 1988) Mirkin et al. 1988									
LC <i>Reaumuria soongorica</i>	.	III	2	.	.	.	.	.	.
LC <i>Salsola passerina</i>	.	III	2	.	.	.	.	.	.
<b>NITRARIO SIBIRICAE-KALIDIETUM GRACILIS</b> Hilbig 2000									
AC <i>Kalidium gracile</i>	.	V	3	1	.	.	.	.	.
<i>Tamarix ramosissimum</i>	.	I	.	.	.	.	.	.	1
<b>SALSOLO PASSERINAE-KALIDIETUM FOLIATAE</b> Kasapov et al. ex Hilbig 2000									
AC <i>Kalidium foliatum</i>	.	.	2	.	.	.	.	1	.
rC <i>Kalidium cuspidatum</i>	.	.	1	1	.	.	.	.	.
<b>SALICORNIA EUROPAEA COMMUNITY</b>									
AC <i>Salicornia europaea</i>	.	.	.	1	1	.	.	.	.
<b>CRYPSIETUM ACULEATAE</b> (Bojko 1932) Wenzl 1934									
AC <i>Crypsis aculeata</i>	.	.	.	.	1	.	.	.	.
<b>ACHNATHERION SPLENDENTIS</b> Mirkin et al. ex Hilbig 2000									
LC <i>Achnatherum splendens</i>	3	I	.	.	.	1	.	.	.
<b>SUAEDO CORNICULATAE-ACHNATHERETUM SPLENDENTIS</b> Mirkin et al. ex Golub 1994									
AC <i>Suaeda corniculata</i>	.	.	.	.	1	1	.	2	.
<i>Elymus paboanus</i>	.	I	.	.	.	1	.	.	.
<i>Elymus chinensis</i>	1	.	.	.	.	1	.	.	.
<b>HALERPESTION SALSUGINOSAE</b> Mirkin et al. ex Golub 1994									
LC <i>Halerpestes salsuginosa</i>	.	.	.	.	.	1	V	.	.
CC <i>Juncus gerardii</i>	.	.	.	.	.	.	IV	.	.
LC <i>Carex enervis</i>	.	.	.	.	.	.	III	.	.
LC <i>Triglochin palustre</i>	.	.	.	.	.	.	II	.	.
CC <i>Potentilla anserina</i>	.	.	.	.	.	1	III	.	.
LC <i>Triglochin maritima</i>	.	.	.	.	.	1	III	1	.

CC	<i>Glaux maritima</i>	.	.	.	.	.	V	1	.
OC	<i>Puccinellia hauptiana/tenuifolia</i>	.	.	.	1	1	IV	2	.
	<i>Taraxacum leucanthum</i>	.	.	.	.	1	IV	1	.
<b>BLYSMETUM RUFU</b> Du Rietz 1985									
AC	<i>Blysmus rufus</i>	.	.	.	.	.	III	.	.
	<i>Taraxacum cf. cuspidatum</i>	.	.	.	.	.	II	1	.
	<i>Cnidium salinum</i>	.	.	.	.	.	III	.	.
	<i>Poa tibetica</i>	.	.	.	.	.	III	.	.
	<i>Halerpestes sarmentosa</i>	.	.	.	.	.	II	.	.
	<i>Eleocharis uniglumis</i>	.	.	.	.	.	II	.	.
	<i>Carex orbicularis</i>	.	.	.	.	1	I	.	.
<b>IRIS LACTEA COMMUNITY</b>									
AC?	<i>Iris lactea</i>	.	.	.	1	.	I	1	.
	<i>Carex stenophylla</i>	.	I	.	.	1	II	1	.
	<i>Saussurea dahurica</i>	1	.	.	1	.	I	1	.
	<i>Carex reptabunda</i>	.	.	.	.	.	II	.	.
<b>PHRAGMITETUM COMMUNIS</b> (Gams 1927) Schmale 1939									
	<i>Phragmites communis</i>	.	I	.	1	.	III	2	1

Appendix – Summary of associations and communities described in the text, and their phytosociological relations (after HILBIG, 2000c; C = class; O = order, L = alliance; A = association; communities and associations in bold letters).

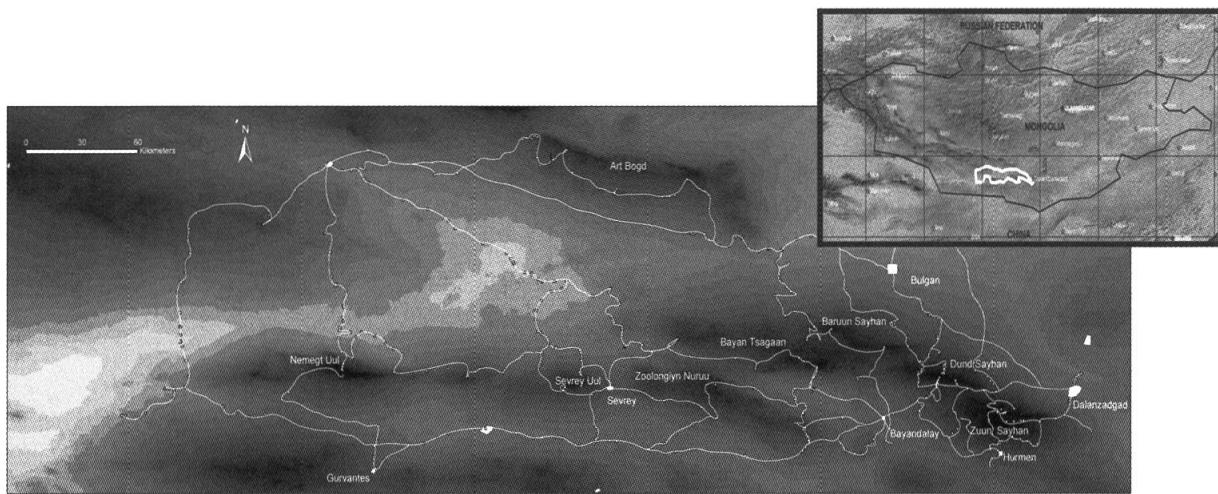


Fig. 1. – Map of the study region, with the major mountain ranges and sum centres. The grey lines follow the itineraries of the survey teams; small dots indicate the positions of relevés. The insert gives the position of the Gobi Gurvan Sayhan region within Mongolia.

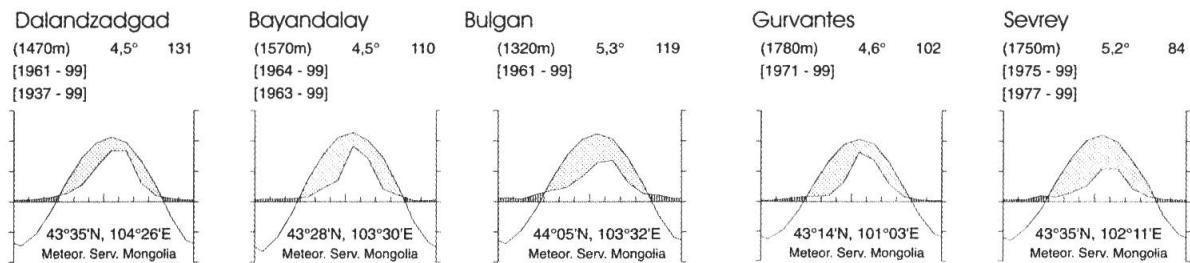


Fig. 2. – Walter-Lieth diagrams for the sum centres in the Gobi Gurvan Sayhan region (source: Dept. of Meteorology, draft C. Enderle, Marburg).

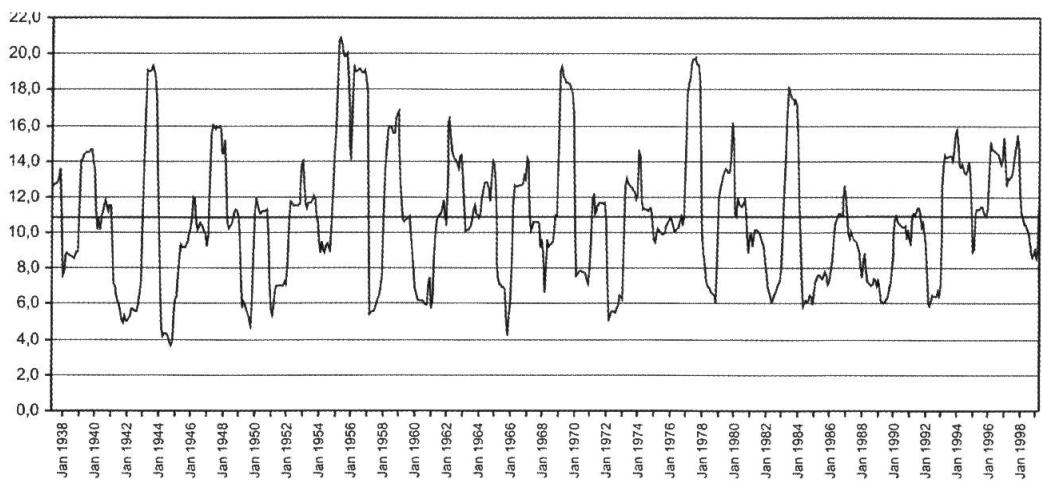


Fig. 3. – Trends in the precipitation totals during the 20th century at Dalandzadgad (12 months running average, horizontal line indicates long-term mean, draft J. Bergius).

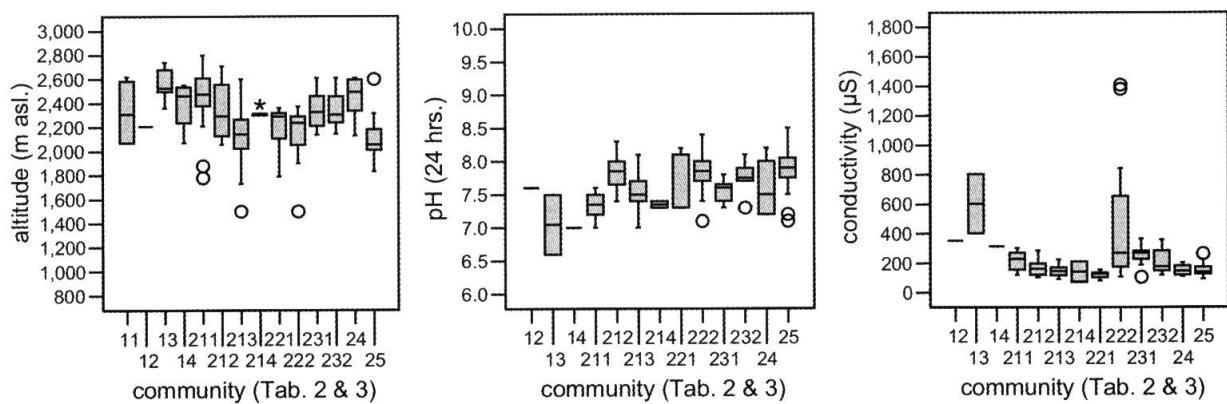


Fig. 4. – Box and Whisker Plots for important environmental variables of mountain vegetation. Samples are grouped according to the plant communities described in the text (community numbers as on Tables 2 & 3). The altitudinal data are based on the entire set of relevés, those for the other variables were calculated for the samples of 2001 only (boxes indicate the position of the median, the interquartile range and the overall range, outliers as dots).



Fig. 5. – The lower boundary of the birch forests east of Yolyn Am. The meadow steppes in the front are grazed, and birch saplings are kept short by livestock (K. Wesche, July 2001).

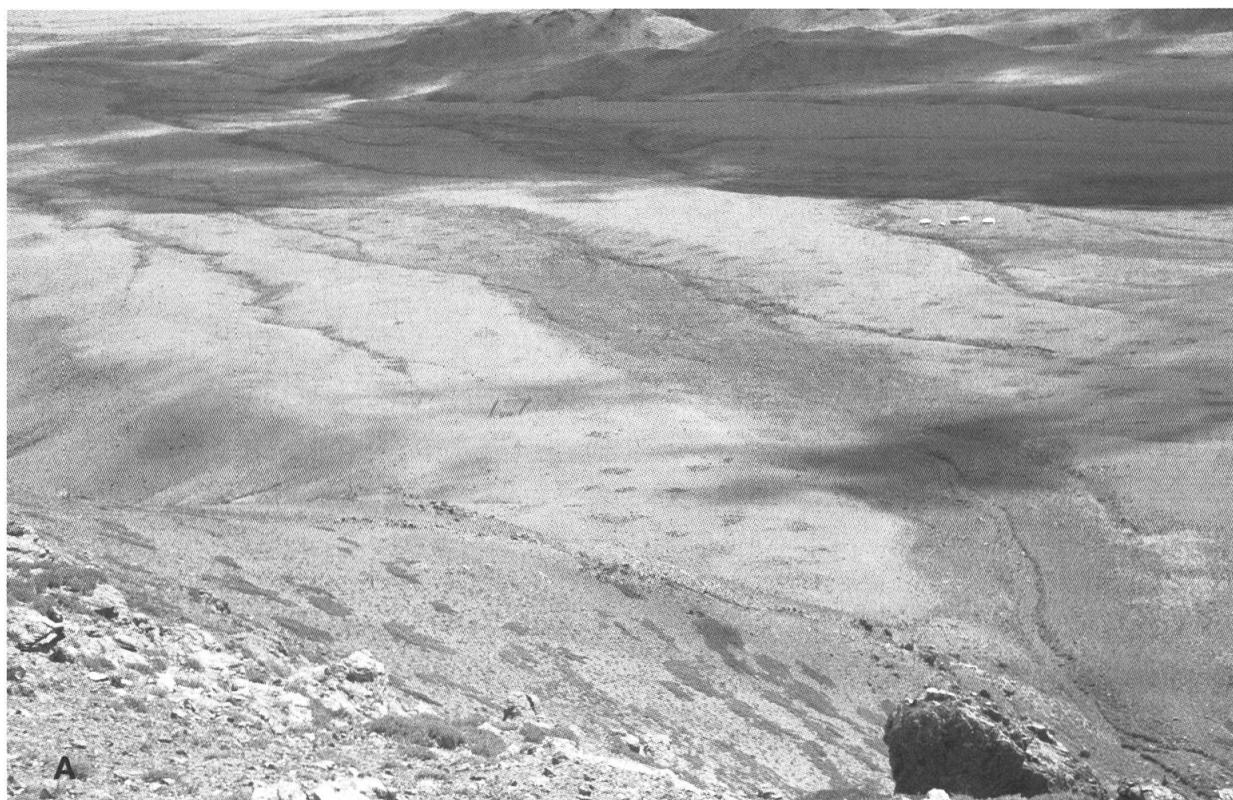


Fig. 6. – A. Upper pediment south of Dund Sayhan (*Astragalus inopinatus* mountain steppe) with circular patches of dense vegetation growing on pika (*Ochotona pallasi*) burrows. Dark *Caragana leucophloea* scrub is restricted to drainage lines at that altitude (K. Wesche, June 2001). B. Close up of an *Ochotona* burrow with *Artemisia santolinifolia* and *Achnatherum inebrians* (K. Wesche, July 2002).

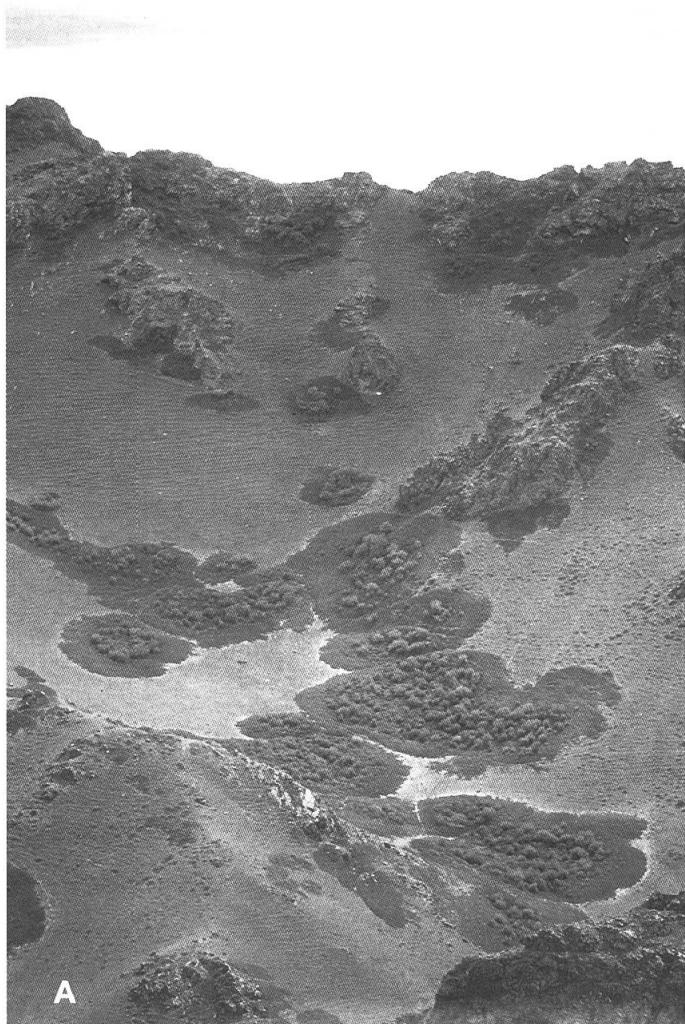


Fig. 7. – **A.** *Juniperus sabina-Lonicera microphylla* scrub surrounded by moist mountain steppes in north-facing water-surplus locations (Baruun Sayhan, near Gegeetyn Am, 2380 m, G. Miehe, Aug. 1996). **B.** Close-up of Fig. 6A. The emergent *Lonicera microphylla* shrubs attain heights of 3 m (Baruun Sayhan, near Gegeetyn Am, 2380 m, G. Miehe, Aug. 1996).





Fig. 8. – While Juniper is mainly common on south-facing slopes in the moister mountain ranges, in the drier mountains it is strongly restricted to moisture surplus sites in northern exposures, as here in the Arts Bogd (K. Wesche, July 2001).



Fig. 9. – *Artemisia santolinifolia* colonises old vehicle tracks in the upper piedmont areas (southern Dund Sayhan, K. Wesche, Aug. 2001).

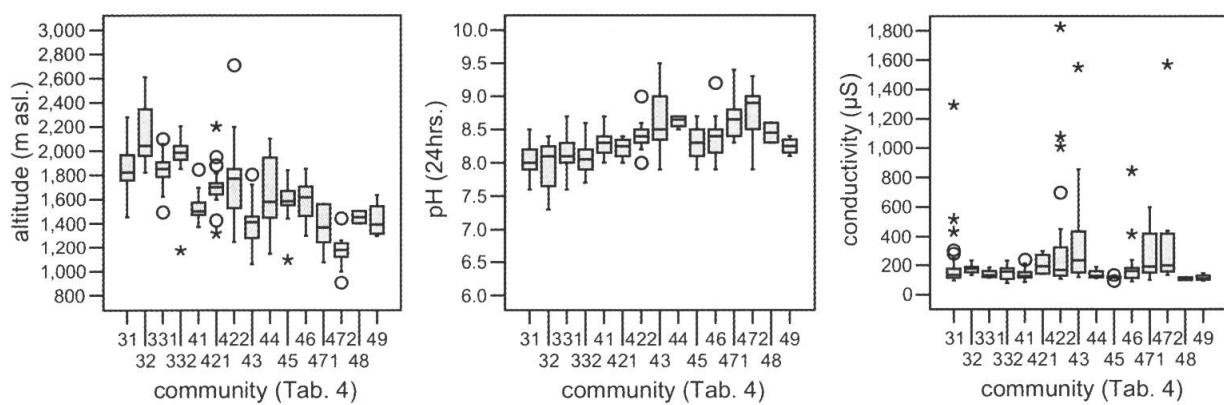


Fig. 10. – Box and Whisker Plots for important environmental variables of desert steppes and other semi-desert communities (community numbers according to Table 4).



Fig. 11. – Exclosure plot of the steppe research Institute Bulgan at the north-eastern part of the Baruun Sayhan. The mountain steppe is strikingly denser inside the exclosure but this is mainly a consequence of the accumulation of dead biomass. Green biomass was almost equally sparse outside and inside the fence in 2000 and 2001 (K. Wesche, June 2001).

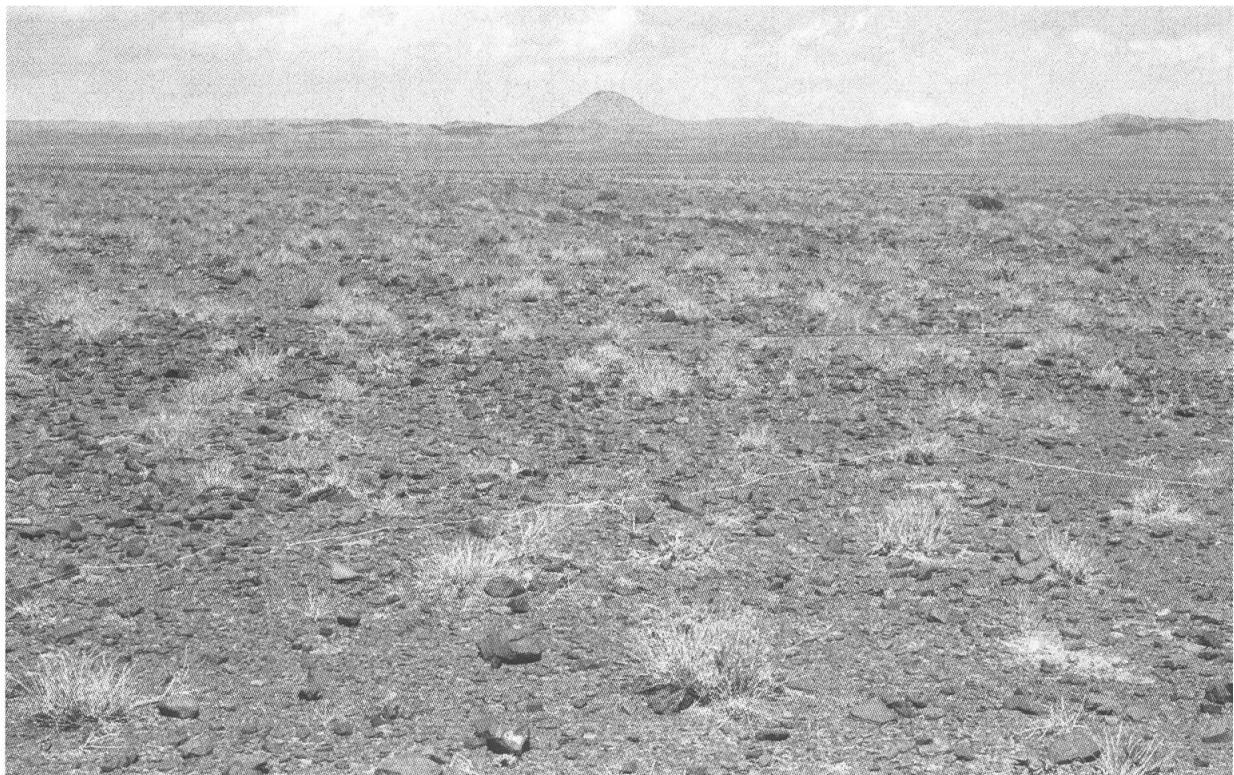


Fig. 12. – *Reaumuria soongorica*-*Salsola passerina* deserts in the dry western parts of the park south of Zulganai Gol (K. Wesche, Aug. 2001).

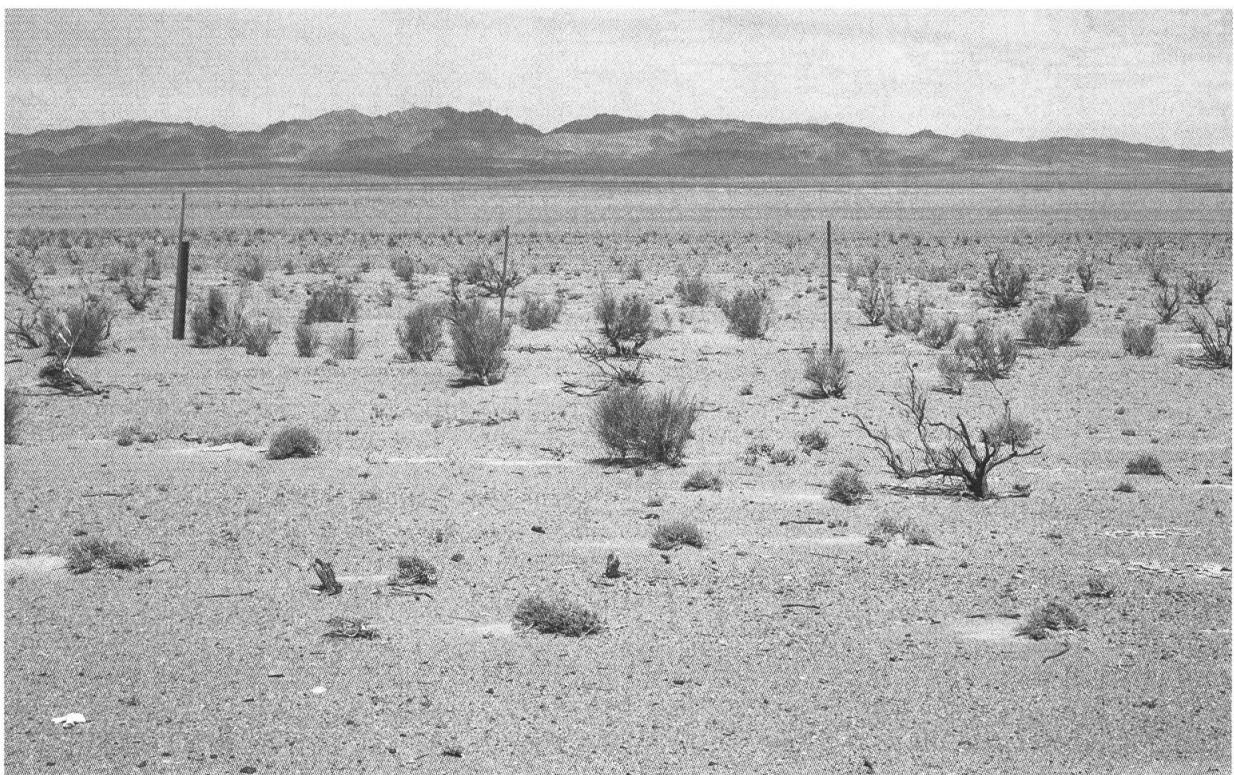


Fig. 13. – *Haloxylon ammodendron* scrub south of Nemegt Uul. This is a moderately open stand typical of the Gobi Gurvan Sayhan National Park. The vegetation in the enclosure in the background does not show any differences from the surroundings and neither the density of adult plants nor of saplings is higher inside the fence (K. Wesche, Aug. 2001).



Fig 14. – Rain water percolates easily through loose sand, thus large dune areas contribute to the formation of groundwater. At Hongoriyn Gol, the groundwater reaches the surface immediately adjacent to the dune, where dense salt meadows occur (K. Wesche, July 2001).

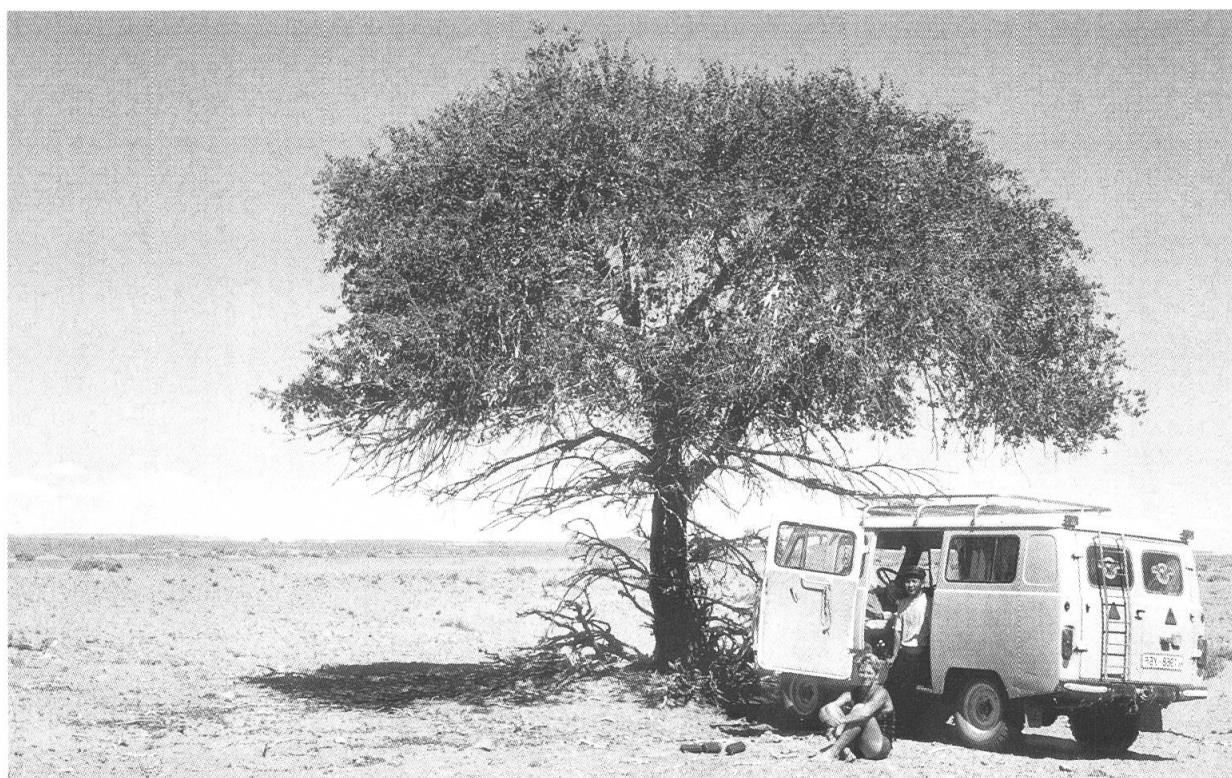


Fig. 15. – Solitary *Ulmus pumila* tree on a pediment covered by the *Stipo glareosae-Anabasietum brevifoliae* south of the Zoolongiyn Nuruu. The tree grew vigorously, and a small root sucker or sapling was found some 4 meters from the trunk. There were no other visible sign of regeneration (V. Clausnitzer, Aug. 2001).

## Appendix

Summary of associations and communities described in the text, and their phytosociological relations (after HILBIG, 2000c; C = class; O = order, L = alliance; A = association; communities and associations in bold letters).

C *Phragmitetea communis* R. Tx. et Prsg. 1942

O *Phragmitetalia communis* (W. Koch 1926) R. Tx. et Prsg. 1942

L *Phragmition communis* W. Koch 1926

A ***Phragmitetum communis*** (Gams 1927) Schmale 1939

C *Thero-Salicornietea* Pignatti 1953 em. R. Tx. in R. Tx et Oberd. 1958

O *Thero-Suaedetalia* Br.-Bl. et De Bolos 1957 em. Beeftink 1962

L *Thero-Suaedion* Br.-Bl. (1931) 1933 em. R. Tx. 1950

***Salicornia europaea* community**

C *Crypsietea aculeatae* Vicherek 1973

O *Crypsietalia aculeatae* Vicherek 1973

L *Cypero-Spergularion salinae* Slavnic 1948

A ***Crypsietum aculeatae*** (Bojko 1932) Wenzl 1934

C *Achnatheretea splendensis* (Mirkin in Kasapov & al. 1987) Mirkin & al. 1988

O *Achnatheretalia splendensis* (Mirkin in Kasapov & al. 1987) Mirkin & al. 1988

L *Achnatherion splendensis* Mirkin & al. ex Hilbig 2000

A ***Glycyrrhizo-Achnatheretum splendensis*** Hilbig (1987) 1990

A ***Suaedo corniculatae-Achnatheretum splendensis*** Mirkin in Mirkin & al. ex Golub 1994

***Achnatherum inebrians* community**

***Iris lactea* community** (position unclear, degradation stages of the following class)

C *Asteretea tripolium* Westh. et Beeftink 1965

O *Halerpestetalia salsuginosae* Mirkin & al. ex Golub 1994

L *Halerpestion salsuginosae* Mirkin & al. ex Golub 1994

A ***Blysmetum rufi*** Du Rietz 1985

C *Agropyretea cristati* Hilbig et Koroljuk 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

***Stellaria petraea* subassociation** Hilbig 1990

***Festuca valesiaca* variant**

**Typical variant**

***Astragalus inopinatus* subassociation** Hilbig 1990

***Carex duriuscula* subassociation** Hilbig 1990

O *Helictotrichetalia schelliani* Hilbig 2000

L *Helictotrichion schelliani* Hilbig 2000

A *Androsaco ovzennikovii-Helictotrichetum schelliani* Hilbig 1987 (1990)

C *Stipetea glareosae-gobicae* Hilbig 2000

O *Allietalia polyrrhizi* Hilbig 2000

L *Allion polyrrhizi* Hilbig 2000

***Stipa gobica* community**

***Typical* subcommunity**

***Ephedra sinica* subcommunity**

A *Allio polyrrhizi-Stipetum glareosae* Hilbig (1987) 1990

A *Stipo glareosae-Anabasietum brevifoliae* Hilbig (1987) 1990

***Convolvulus ammanii* subassociation**

***Reaumuria soongorica* subassociation**

***Psammochloa villosa* community** (position unclear, transitional to *Brometea korotkyi* Hilbig et Koroljuk 2000)

O *Reaumurio soongoricae-Saldoletalia passerinae* (Mirkin in Kasapov & al. 1988) Mirkin & al. 1988 em. Hilbig 2000

L *Reaumurio soongoricae-Salsolion passerinae* (Kasapov & al. 1988) Mirkin & al. 1988 em. Hilbig 2000

A *Salsolo passerinae-Reaumurietum soongoricae* Kasapov & al. ex Hilbig 2000

A *Potaninio mongolicae-Sympetrum regelii* Kasapov & al. ex Hilbig 2000

A *Salsolo passerinae-Kalidietum foliati* Kasapov & al. ex Hilbig 2000

A *Nitrario sibiricae-Kalidietum gracilis* Hilbig 2000

O *Zygophyllo xanthoxyli-Brachanthemetalia gobici* (Mirkin in Kasapov & al. 1988) Mirkin & al. 1988

L *Zygophyllo xanthoxyli-Brachanthemion gobici* (Mirkin in Kasapov & al. 1988) Mirkin & al. 1988

A *Eurotio ceratoidis-Zygophylletum xanthoxyli* Hilbig (1987) 1990

***Artemisia sphaerocephala* community**

A *Caragano bungei-Brachanthemetum gobici* Kasapov & al. 1988

A *Calligono mongolici-Haloxyletum ammodendronis* Hilbig (1987) 1990

***Reaumuria soongorica* subassociation**

***Nitraria sphaerocarpa* subassociation**

L *Caraganion leucophloeae* Hilbig 2000

A *Amygdalo pedunculatae-Caraganetum leucophloeae* Hilbig (1987) 1990

A *Artemisio xerophyticae-Caraganetum leucophloeae* Hilbig (1987) 1990

***Artemisia rutifolia* community** (in Hilbig 2000 to *Spiraeion aquilegifoliae* Hilbig 2000)

C ? *Populetea euphratica* Zohary 1962

***Populus diversifolia* community** (position unclear)

C *Carici rupestris-Kobresietea bellardii* Ohba 1974

O *Kobresietalia myosuroidis* Mirkin & al. (1983) 1986

L *Kobresion myosuroidis* Mirkin & al. 1983 em. Hilbig 2000

A ***Kobresietum myosuroidis*** Mirkin & al. 1988 ex Hilbig 2000

C *Juniperetea pseudosabinae* Mirkin & al. 1986

O *Juniperetalia pseudosabinae* Mirkin & al. 1986

L *Juniperion pseudosabinae* Mirkin & al. 1986

***Juniperus sabina* community**

***Lonicera microphylla* subcommunity**

**Typical subcommunity**

***Artemisia santolinifolia* community** (position unclear)

C *Sisymbrietea officinalis* Gutte et Hilbig 1975

O *Sisymbrietalia officinalis* J. Tx. in Lohm. & al. 1962

L *Sisymbrium officinalis* R.Tx., Lohm. et Prsg. in R. Tx. 1950 em. Hejný 1979

***Chenopodio prostrati-Lepidietum densiflori*** Hilbig (1987) 1990

C *Populetea laurifolio-suaeveolentis* Hilbig 2000

O *Populetalnia laurifolio-suaeveolentis* Mirkin & al. em. Hilbig 2000

L *Populion laurifoliae* Mirkin & al. ex Hilbig 2000

***Populus laurifolia* community**

C ?

***Betula microphylla* community** (position unclear)

