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Plant communities of the southern Mongolian Gobi

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with 27 figures and 8 tables.

Abstract. The present study provides an updated inventory and classification of the plant communities of the Gobi region in southern Mongolia based on a set of 1418 sample plots. The vast Gobi landscape is characterised by a dry climate with mean annual precipitation in the semi-deserts of between 50 and 150 mm, while the highest mountain peaks may receive up to 200 mm/a. The wetter montane regions are composed of extrazonal communities including woodlands and comparatively dense mountain steppes. The surrounding lowlands are characterised by sparse and more diffuse vegetation comprising dry grass steppes and, more commonly, shrub formations. Water surplus sites host various salt-adapted vegetation types which contrast sharply with the surrounding semi-deserts in terms of their high vegetation cover and species richness. In total, 28 associations / communities plus 18 sub-associations / sub-communities or variants are listed. Nine of these are newly described, and the syntaxonomical status of several other units known from literature has been clarified. The distribution of the plant communities is exemplified by six vegetation profiles.

Keywords: Gobi desert, grazing, phytosociology, steppe, vegetation classification.

1. Introduction

Central Asia hosts some of the largest steppe and semi-desert areas in the world (White et al. 2000) and detailed knowledge on their ecological conditions is of high interest in terms of basic research but also for applied aspects including land use and conservation. Some 55 % of the Mongolian territory can be considered as drylands, with average annual precipitation levels below 200 mm. Most of these are found in the southern Mongolian Gobi, which contains five large protected areas (see Fig. 1). Two of the protected areas were established several decades ago, while the other three were designated in the 1990's (Reading et al. 2006). Altogether they cover an area of approximately 100 000 km² – with the total managed area being even larger due to the presence of extensive buffer zones – placing these reserves among the largest in the world (World Conservation Union and UNEP-World Conservation Monitoring Centre 2004). This indicates the high conservation value of the relatively intact southern Mongolian steppes, which still host several large rare mammal species (Zevegmid & Dawaa 1973), but which are also of high importance regarding the protection of several plant species (e.g. Wesche et al. 2005a).

Unfortunately, most of the available knowledge on the vegetation is of a summarised character and is on

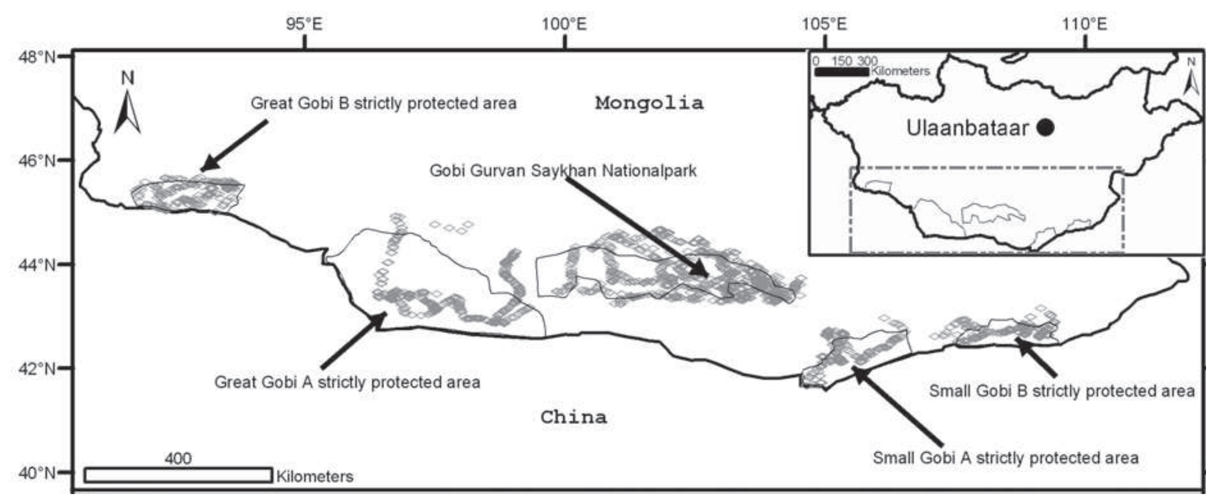

Fig. 1. Locations of the working regions and relevé sampling sites (open diamonds) within the southern Mongolian Republic.

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a broad spatial scale (Anonymous 1990, Gunin & Vostokova 1995, Vostokova & Gunin 2005), while only a few accounts give details on particular regions (Rachkovskaya & Volkova 1977, Helmecke & Schamsran 1979, Jäger et al. 1985, von Wehrden 2005, von Wehrden et al. 2006b, 2006c). Early descriptions were mainly provided by Russian and Mongolian scientists and followed a dominance-based classification approach; much of the results are summarised in Walter (1974). Hilbig (1990, 1995) employed the Braun-Blanquet approach and compiled an overview of the plant communities of the Mongolian Republic which culminated in a syntaxonomical synopsis (Hilbig 2000). These and the following studies from northern Mongolia (Hilbig et al. 1999, 2004, Hilbig & Koroljuk 2000, Hilbig 2003a, 2003b) form the most comprehensive description of the Mongolian vegetation available as yet. However, the number of available records on southern Mongolia for the general synopsis was relatively limited until fairly recently, when Hilbig & Tungalag (2006) published a phytosociological survey for the eastern part of our working area. We also conducted regional surveys (Wesche et al. 2005b, von Wehrden et al. 2006b, 2006c).

It became apparent that the southern Mongolian environments are differentiated from their surrounding regions by their generally sparse vegetation and the high importance of low shrubs (Hilbig 1995). The eastern Gobi forms a transitional zone between these semi-deserts and the grass steppes of central and north-eastern Mongolia. The high thrust of the Altay range complicates the pattern as it hosts mountain steppes with denser vegetation cover. Southwards, changes are rather gradual, and descriptions from northern Chinese regions suggest a generally high similarity, especially in the drier north-west (Kürschner 2004). However, no concise overview for the dry steppes and (semi-)deserts, which cover more than 400000 km² in southern Mongolia alone, has been compiled. Here, we present a first synoptic account of the plant communities of southern Mongolia drawing on the dramatic increase in data available. With respect to the sheer size of territory, we restricted ourselves to the protected areas, which were expected to offer sufficiently representative samples of the typical vegetation.

2. Study area

2.1. Geology and landforms

As a result of the ongoing Indian-Asian collision, the Gobi regions have become deformed due to a strike-slip faulting pattern (Tapponnier & Molnar 1979); the orogeny is characterised by a unique combination of structural and basin elements (Cunningham 2005). The rocks are predominantly metamorphic derived from older sediments, but other rock types such as granite intrusions also occur (Cressey 1960, Rippington et al. 2006). The southern and south-eastern parts of the Altay mountain range traverse the working area; their chains largely follow an east-west direction (Tapponnier & Molnar 1979). Thus, most of the protected areas are characterised by the pronounced relief which is typical for the Gobi (Cressey 1960); only the easternmost Small Gobi Strictly Protected Areas lie completely below 2000 metres asl. The spatial extent of the montane environments is still comparably limited; and most of the regions consist of plains, lowlands, platforms and hills.

The current surfaces were mainly shaped by wind- and water-mediated processes in the Quaternary (Lehmkuhl 2000). Physical erosion prevails with constant weathering of all mountain substrates with freeze and thaw cycles eroding rocks and stones. Torrential rainfalls transport the material down-slope forming vast pediments and fans. Strong winds resulted in almost all pediment surfaces being deflated – with the exception of dry riverbeds where substrates which are episodically turned over –, and stone pavements seal huge parts of the landscape. This differs in general to the depressions which are mostly characterised by fine soil material. Catchment areas are large, thus water may accumulate, even under the endorheic discharge regime, resulting in the formation of periodic swamps and lakes. At lower elevations sand accumulates, yet extensive high dunes are rare and only found at one location (= Khongorijn Gol in the Gobi Gurvan Saykhan National Park).

The dominant soil types on the upper pediment areas are Burosems and Kastanosems. The mountain slopes carry shallower Kastanosems, Parachernosems, and Leptosols. Sandy spots are edaphically unique situations and contain weakly developed Arenosols; at temporarily moist depressions, Solonchaks and Solonetz soils are found.

2.2. Climate

The southern Mongolian Gobi is part of the Central Asian dryland region (Lehmkuhl 1997) and forms the easternmost part of the Old World's desert belt (Cressey 1960). The climate is semi-arid and highly continental with a very short growing season due to the long, cold winters (Weischet & Endlicher 2000). Levels of annual precipitation are roughly 200 mm/a at the wettest sites in the eastern Gobi Altay (Hijmans et al. 2005), while other parts receive much lower mean precipitation with values ranging from 100 mm/a to as low as ~33 mm/a at the driest sites in southern Mongolia (see Fig. 2). At lower elevations the temperature, and consequently evaporation, increases; this pattern reverses during the winter when cold air accumulates widely in the depressions rendering the mountainous regions relatively warmer (Weischet & Endlicher 2000). These vertical gradients collapse during springtime, when strong storms roar through the Gobi region; the frequency of storm-events has increased over the last few decades (Natsagdorj et al. 2003).

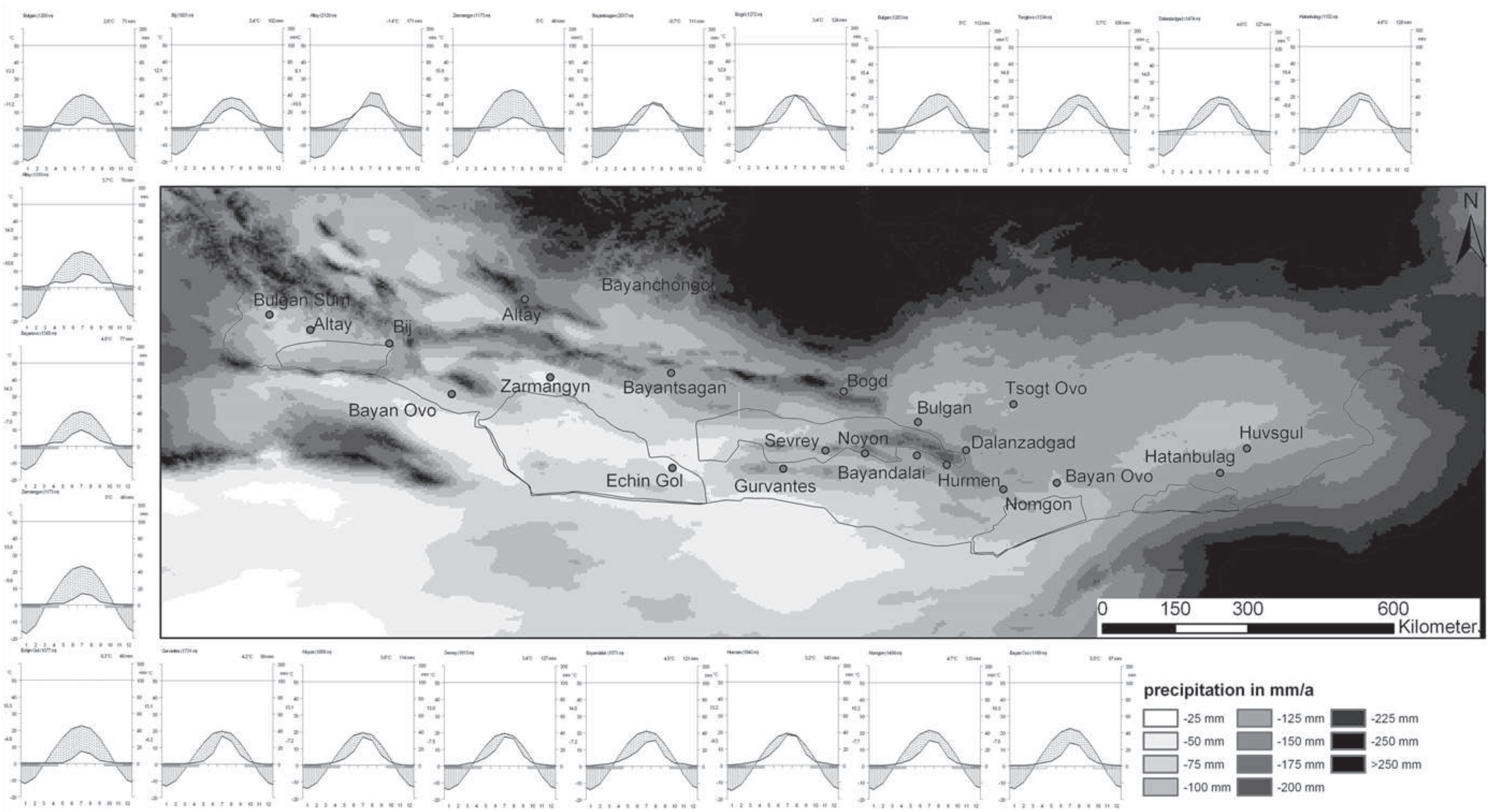

Fig. 2. Climatic overview of the working area. Climate data was obtained from Hijmans et al., 2005, design of climate diagrams according to Walter & Lieth (e.g. Walter 1974).

The climatic influence in the southern Mongolian Gobi originates from two directions. The eastern part of the working area is partly influenced by monsoonal disruptions that penetrate into the Mongolian Gobi through eastern Mongolia (Wesche et al. 2005b, Herzschuh 2006), while most parts of south-west Mongolia benefit from the influence of western disturbances (von Wehrden et al. 2006c) that cross the Turranic highlands or the adjacent northern lowlands. The depression of the Dzungarian Gobi thereby receives most precipitation from the west, linking this region with the Aralo-Caspian area. Therefore, winter precipitation is higher in the western Mongolian Gobi in comparison to the east (Hijmans et al. 2005). The main macro-climatic influence in Central Asia during the winter is the Siberian anticyclone, which pushes continental cold air masses into the Gobi and creates a north-south temperature zonation (Weischet & Endlicher 2000). The persistence of snow cover is generally low; most snow evaporates quickly, although snow depths tend to be somewhat higher in the western part of the region (Morinaga et al. 2003). The southern central region of Mongolia, the Transaltay Gobi, does not receive much precipitation from the east or from the west, and is thus extremely dry (Fig. 2). Towards the east, rainfall increases gradually. The border between the eastern and the western climate regions is not clear-cut, due to varying topography, but lies somewhere between 96 °E and 100 °E (Jäger 2005).

Rainfall at any given site is determined by an altitudinal gradient; mountain sites receive more than twice as much precipitation as the surrounding lowlands (Retzer 2004, von Wehrden & Wesche 2007a, 2007b).

During the Holocene, vegetation belts experienced pronounced shifts as evidenced from the available pollen records and the analysis of biogeographical patterns (Herzschuh et al. 2004, Jäger 2005, Miehe et al. 2007). Available palynological studies are far from conclusive, but it is certain that not only temperatures, but also the magnitude of the East Asian monsoon varied during the Holocene (Jiang et al. 2006). Today, climate change is affecting Central Asia, resulting in higher temperatures with stable to slightly increasing precipitation rates (Christensen et al. 2007, Shi et al. 2007, Wei et al. 2005). It is not yet clear whether the anticipated increase in evaporation will render sites physiologically drier (Lioubimtseva et al. 2005, Li et al. 2006), potentially leading to reduced productivity and C-sequestration (Christensen et al. 2003, 2004).

2.3. The floristic context

The Gobi province is part of the Central Asian desert region (Meusel et al. 1965). This can be divided into a western and an eastern sub-region / province, reflecting the two different climatic regimes mentioned above. Typical Central Asian elements, which dominate the vegetation, unite both regions (e.g. *Haloxylon ammodendron, Anabasis brevifolia, Reaumuria songarica, Sympegma regelii*). In the western sub-province, elements of the Aralo-Caspian flora characterise the Dzungarian Gobi (Meusel et al. 1965, Jäger et al. 1985), e.g. *Nanophyton erinaceum, Anabasis aphylla, Halimodendron halodendron, Kaschgaria komarovii*. The eastern sub-province contains a few differentiating elements, e.g. *Ammopiptanthus mongolicus, Brachanthemum gobicum* and *Salsola passerina*, although the latter also occurs at the western Tien Shan (Grubov 2000). The intermediate parts, i.e. the Transaltay Gobi, are relatively poor in species, which is in line with the low levels of precipitation there (von Wehrden & Wesche 2007b).

The generally poor flora of the lowlands contrasts with the richer mountain chains. Most of the plants found there are also common in northern Mongolia (Gubanov 1996); endemics are present, but are few in number (Grubov 1989, Wesche et al. 2005a). Though being of a small extent, mountain regions contain the highest plant biodiversity of the southern Mongolian Gobi (von Wehrden & Wesche 2007b), and many relicts (e.g. *Betula microphylla, Paeonia anomala, Kobresia myosuroides*) hint at formerly different climatic conditions during the Holocene (Miehe et al. 2007).

2.4. Principal physiognomic features of the vegetation

In general, terminology for formations has been inconsistent in existing literature (Zemmrich 2005), so we include a short introduction in this report.

The driest depressions are devoid of vegetation – or show only contracted vegetation along drainage lines – and can be classified as deserts in the strictest sense (von Wehrden et al. 2006a). The vegetation of the southern Mongolian Gobi is widely dominated by semi-desert formations which contain shrubs as their dominating and characterizing components (Hilbig 1995). Often, semi-desert vegetation with an appreciable cover of grasses is termed desert steppe, while denser grass steppes are restricted to montane sites, such as the Gobi-Altay (Wesche et al. 2005b) and the border mountains of the Dzungarian Gobi (von Wehrden 2005, von Wehrden et al. 2006c). These correspond to grass steppes in Central Mongolia, but are termed mountain steppes in the context of the Gobi (Hilbig 1995).

2.5. Human land use and other grazing influences

The Gobi represents an old grazing ecosystem (Fernandez-Gimenez 1999). Due to the numerous wild herbivores grazing has been common over evolutionary time-scales, but the introduction of domestic livestock has presumably altered both grazing intensity and frequency. Several mammal species are

Table 1. Supplementary data available for interpretation of plant community composition for any given sample plot.

Parameter	Method
Geographical position	GPS (in decimal degrees)
Elevation	altimeter, GPS (m asl.)
Aspect	Compass (degrees)
Inclination	clinometer (degrees)
Cover of vegetation strata (tree, shrub, herb layer)	visually estimated (percentage scale)
Climate: mean annual temperature	Data from Hijmans et al. 2005, in °C
Climate: mean annual precipitation	Data from Hijmans et al. 2005, in mm

still recognised by the nomads as grazing competitors including Khulans, gazelles, Marco Polo sheep, ibex and even pikas (Retzer 2004, Retzer et al. 2006).

For centuries the pastoral economy was regionally organised by an administrative system (Fernandez-Gimenez 2006), but during the last century the rise and fall of socialism triggered tremendous changes. Collectivisation was undertaken in order to stabilise and diversify the economy. Technical progress intensified changes even more, mainly due to well-digging and better veterinarian services. The rise of democracy led to a free-market economy that enforced the privatisation of herds. In the last two decades numbers of animals increased somewhat (Fernandez-Gimenez 2006) and –more importantly– the herd composition shifted towards a higher proportion of goats (National Statistical Office of Mongolia 2001 2003), mainly with a view to increasing cashmere production. However, recent droughts at the start of the new millennium led to dramatic losses and livestock numbers dropped to pre-1990`s levels (Reading et al. 2006).

Since all animals except camels need daily drinking water, wells, springs and their surroundings are intensely grazed. In the drier regions, overall numbers of livestock are regularly curtailed by drought, and so called *non-equilibrium* conditions restrict overgrazing to human settlements and land around water sources (Bedunah & Schmidt 2004, Wesche & Retzer 2005). Moreover, the working area shows an obvious and well defined altitudinal zonation of forage availability (Retzer et al. 2006), since higher and thus moister sites support more productive vegetation (von Wehrden & Wesche 2007b). Depending on the macro-climate, some mountains may nonetheless be dry and support only a few herders, if any.

Many of these oases have undergone tremendous changes due to land use (Gunin et al. 1999); however some remote sites have remained largely untouched (Pankova & Golovanov 2005). In contrast, oases on the Chinese territory are often severely modified (Bruelheide 2003), and the vegetation is degraded (Kürschner 2004).

Collection of firewood modifies the ecosystem as well. Prominent species used as fuel are *Haloxylon ammodendron, Caragana leucophloea* and *Juniperus sabina*. This poses threats due to the species' slow regeneration rates and the often clonal persistence pattern (Wesche et al. 2005c). In the last years, mining for mineral deposits has considerably increased and affects large regions (Thacker 2004).

3. Material and methods

3.1. Data collection

Our classification is based on 1418 sample plots collected during the vegetation periods of 1996, 2001, 2003, 2004 and 2005 (see Fig. 1). Sampling followed a standardised protocol (modified following Mucina et al. 2000): Sample plots were 10x10 m² in size, which proved suitable after assessing the minimum area of typical vegetation types (Miehe 1998). All higher plants were recorded on a percentage cover scale, which seemed feasible with respect to the overall low cover. Each site was georeferenced using a handheld Garmin GPS. Table 1 provides an overview of the additional environmental parameters that were collected along with each relevé.

Sample sites were deliberately chosen with the help of Landsat ETM data acquired from the global Landcover facility (http://glcf.umiacs.umd.edu). Red-Green-Blue transformations and unsupervised classifications (Campbell 1996) were computed and taken as printouts on the field trips. Thereby, samples were selected to represent all major vegetation types; extra- and azonal sites such as higher mountains and larger oases were always sampled. Topographical maps supplemented sample site selection; these maps were derived from SRTM and Gtopo30 datasets, which were also obtained through the global Landcover facility.

3.2. Plant identification

Mongolian higher plants are reasonably well described in a standard flora, which has recently become available in English (Grubov 2001). New monographic treatments are available for some taxa (e.g. *Allium*, see Friesen 1995) and updated information is published in the "Plants of Central Asia" (Grubov 2000ff). Data on plant distribution within Mongolia was revised a decade ago (Gubanov 1996), though our survey yielded a number of additional records (Jäger et al., manuscript). All species were later cross-checked in the Herbarium in Halle/Germany; difficult groups were additionally checked by specialists (see acknowledgements).

3.3. Classification of vegetation types

Two approaches to vegetation classification are commonly employed in Eurasia. The first descriptions of the Central Asian vegetation were based on the dominance approach (Alexandrova 1973, see an overview in Walter 1974). Some of the regional accounts relevant to our study regions also followed that method (Rachkovskaya 1993, Karamysheva & Khramtsov 1995).

We opted for the Braun-Blanquet approach, since dominance structure may vary strongly in this non-equilibrium ecosystem while presence/absence relationships are much more stable; we therefore widely refrained from discussing vegetation cover values. The complete set of 1418 sample plots was compiled in Juice (Tichý 2002) based on four regional sets, which were created using Tabwin (http://www.landeco.uni-oldenburg.de/21346.html). Some closely related species needed to be grouped together (e.g. *Zygophyllum xanthoxylon* & *Z. kaschgaricum*; *Convolvulus gortschakovii* and *C. fruticosus*); the final table was transformed into presence/absence scaling to facilitate handling of the data.

Whenever possible, we followed Hilbig (2000) in naming of syntaxonomical units. His approach differs partly from current standards (Weber et al. 2000), particularly in naming of sub-associations (e.g. "*Reaumuria* sub-association" instead of "reaumourietosum"). We refrained from following Hilbig's original proposal; instead we labelled all new sub-associations in accordance to Weber et al. (2000). Units with unclear syntaxonomical status were referred to as communities; subsequently, these were divided into sub-communities if differential species were detectable. Our study regions stretched over a distance of 1500 km in an east-west direction; therefore we had to take regional characteristics of certain syntaxonomical units into account, and thus also devised regional character species. We refer to the respective units as regional sub-associations or regional sub-communities. Variants are provided as hierarchically lower units, which are of local value only.

An initial classification of the entire sample plot set suggested dividing the data into six constancy tables. Here, we provide only condensed constancy tables, showing standard constancy classes (20 % intervals); where there were less than 5 sample plots in a given unit, frequency was given in Arabian numbers. Raw data are available from the corresponding author on request. Cover values of individual sample plots are published in regional publications (e.g. von Wehrden et al. 2006a, 2006c, von Wehrden & Wesche 2007a, Wesche et al. 2005b).

3.4. Supplementary variables

From an open source climate extrapolation model (Hijmans et al. 2005) we extracted the average precipitation and the July maximum temperature as a proxy for conditions during the growing season. The altitudinal information provided in the schematic vegetation profiles (Fig. 22–27) was extracted from SRTM (shuttle radar topographical mission) -tiles. Raw data was obtained from the Global Landcover facility (http://www.landcover.orghttp://glcf.umiacs.umd.edu). Box & Whisker plots were drawn of the two climate parameters and the species richness per 100 m² plot (e.g. Fig. 3). All graphs were drawn using R software package (R Development Core Team 2007, version 2.6); all GIS analyses were performed using Arc-Map (version 8.2).

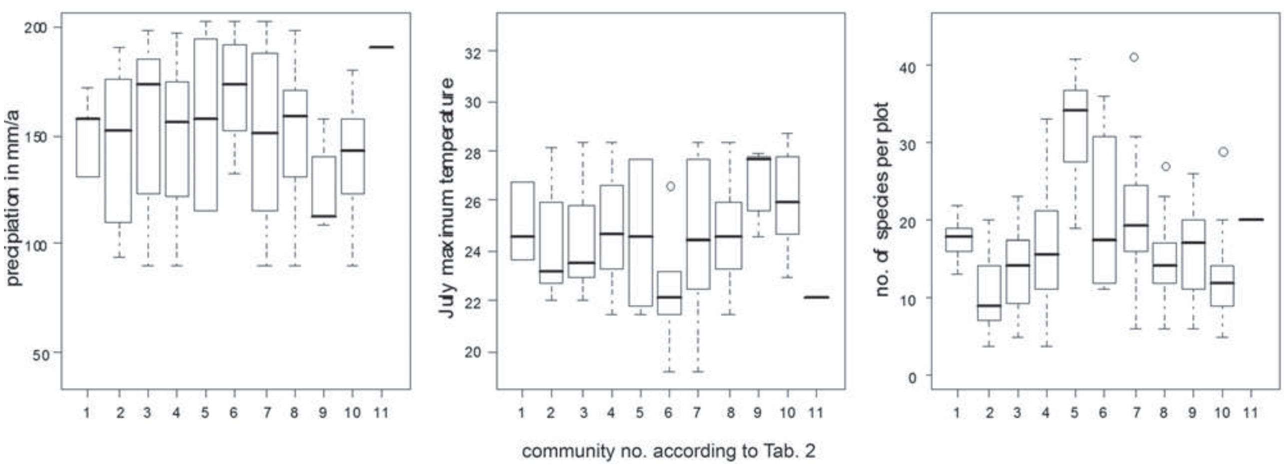

Fig. 3. Boxplots summarising the background information for the montane vegetation. From left to right: precipitation in mm/a, July maximum temperature in °C (both based on the model by Hijmans et al. 2005), and the number of species per plot (100 m²). The x-axis is labelled with the community numbers according to the text (Table 2).

Table 2. Montane steppes, juniper communities and other montane units. Where more than 5 sample plots were available for a given community, frequency is given in constancy classes ("r" = present in <5 % of all sample plots of that community; "+" = 5–10 %; "I" = 11–20 %; "II" = 21–40 %; "III" = 41 – 60 %; "IV" = 61–80 %; "V" = 81–100 %); units with less than 5 sample plots sampled are given as absolute Arabian numbers.

Unit	1	2	3	4	5	6	7	8	9	10	11
no. of relevés	5	16	11	51	7	10	28	70	25	84	1
BETULA MICROPHYLLA COMMUNITY (1)											
Betula microphylla	V	.	.	.	.	.	.	.	.	.	.
Salix bebbiana	IV	.	.	.	I	.	.	.	.	.	.
Cystopteris fragilis	IV	.	.	.	.	.	.	.	.	.	.
Ribes rubrum	IV	.	.	.	.	.	.	.	.	.	.
Spiraea media	IV	+	+	.	.	.	.	.	.	.	.
Rosa acicularis	III	.	.	.	.	.	.	.	.	.	.
Saxifraga sibirica	III	.	.	.	I	.	+	r	.	.	.
Lonicera altaica	III	.	.	.	.	.	.	.	.	.	.
Carex obtusata	III	.	.	.	.	.	.	.	.	.	.
Campanula turczaniniovii	III	.	.	.	I	I	.	.	.	.	.
Carex amgunensis	II	.	.	.	.	.	.	.	.	.	.
Moehringia lateriflora	II	.	.	.	I	.	.	.	.	.	.
Viola dissecta	II	.	.	.	.	I	.	.	.	.	.
Cotoneaster mongolica	II	+	.	.	.	.	.	.	.	.	.
Rubia cordifolia	II	.	.	.	.	.	.	.	.	.	.
Silene repens	IV	III	+	r	III	I	.	.	.	r	.
JUNIPERUS SABINA COMMUNITY (2 & 3)											
Lonicera microphylla	I	IV	.	+	.	.	.	.	.	.	1
Juniperus sabina	III	V	V	.	.	.	.	.	.	.	1
Thalictrum foetidum	I	III	III	I	II	III	II	.	.	r	1
Poa stepposa (& P. botryoides)	.	II	III	r	I	.	r	r	.	r	1
Lophanthus chinensis	.	III	III	I	.	I	r	r	.	r	1
ARTEMISIA SANTOLINIFOLIA COMMUNITY (4)											
Artemisia santolinifolia	.	III	V	V	.	.	I	r	IV	.	.
Heteropappus altaicus	.	II	II	IV	.	.	II	II	II	II	.
KOBRESIETUM MYOSUROIDIS (5)											
Kobresia myosuroides	I	.	.	.	IV	.	.	.	.	.	.
Kobresia simpliciuscula	.	.	.	.	III	.	.	.	.	.	.
Gentiana decumbens	I	.	.	.	III	.	r	.	.	.	.
Gentiana azurea	I	.	.	.	III	.	.	.	.	.	.
Ceratocarpus arenarius	II	.	.	.	III	I	.	.	.	.	.
Polygonum viviparum	I	.	.	.	III	.	.	.	.	.	.
Thlaspi cochleariforme	.	.	.	.	III	.	I	.	.	.	.
Stellaria amblyosepala	.	.	.	r	III	.	+	.	.	.	.
Eritrichium pauciflorum	.	.	.	.	III	.	.	.	.	.	.
Oxytropis strobilacea/oligantha	.	.	.	r	III	II	.	r	.	r	.
Lomatogonium carinthiacum	.	.	.	.	III	.	.	.	.	.	.
Saussurea arctecapitulata	I	.	.	.	II	.	.	.	.	.	.
ANDROSACO -HELICTOTRICHETUM SCHELLIANI (6)											
Carex pediformis	II			.	IV	II	.	.	.	.	
Gentianopsis barbata	I			.	IV	II	.	.	.	.	
Helictotrichon schellianum	.			.	V	II	.	.	.	.	
Galium verum	I			r	IV	III	.	.	.	.	
Leontopodium ochroleucum	.			.	III	III	I	.	.	.	
Polygonum alpinum	.			r	III	III	I	.	.	.	
Artemisia phaeolepis	I			.	IV	III	+	.	.	.	
Potentilla multifida	.			r	III	I	r	.	.	.	
Festuca lenensis	.			.	III	II	.	.	.	.	
Saxifraga cernua	.			.	III	I	.	.	.	.	
Aster alpinus	.	.	.	.	III	III	II	r	.	.	.
Rheum undulatum	.	+	.	+	.	III	r	.	.	.	.
Festuca kryloviana	.	.	.	.	.	III	.	.	.	.	.
FESTUCA VALESIACA SUB-ASSOCIATION (7)											
Poa attenuata	II	I	II	II	V	III	IV	I	II	.	.
Koeleria altaica	.	I	.	r	IV	III	III	r	.	r	.
Pedicularis flava	.	I	I	I	II	IV	III	I	+	r	.
Orostachys spinosa	.	+	.	r	I	IV	III	I	.	+	.
Festuca valesiaca	I	I	.	.	IV	II	V	.	.	.	.
Amblynotus rupestris	.	+	.	.	III	II	IV	I	.	.	.
Artemisia pycnorhiza	.	+	+	I	II	II	III	I	.	.	.
Limonium flexuosum	.	.	.	+	II	I	III	.	.	.	.
Ranunculus pedatifidus	.	.	.	.	III	II	r	.	.	.	.
Allium prostratum	.	+	.	r	I	I	II	I	.	r	.
CLEISTOGENETEA SQUARROSAE AND HEDYSARO - STIPETUM (7-10)											
Stipa krylovii	.	I	II	III	.	II	III	IV	IV	+	.
Artemisia frigida	.	II	III	III	I	III	V	V	III	III	.
Agropyron cristatum	.	III	V	V	III	V	V	V	V	IV	.
Arenaria meyeri	.	I	.	II	II	II	V	III	II	+	.
Oxytropis pumila	.	.	.	II	II	II	IV	II	III	+	.
Astragalus multicaulis	.	+	I	I	III	I	III	+	I	r	.
Bupleurum bicaule	.	+	+	I	III	I	III	II	I	.	.
Carex enervis	.	+	+	I	II	.	II	I	II	r	.
Potentilla sericea s.l.	.	I	+	II	III	III	III	I	r	.	.1
Silene jenisseensis	.	.	.	I	III	III	II	r	.	.	.
Sibbaldianthe adpressa	.	.	I	I	I	II	r	II	II	I	.

Unit	1	2	3	4	5	6	7	8	9	10	11
no. of relevés	5	16	11	51	7	10	28	70	25	84	1
Stellaria dichotoma	.	I	III	II	I	I	I	r	r	r	.
Kochia prostrata	.	.	.	+	.	I	r	II	r	II	.
CHENOPODIO PROSTRATI-LEPIDIETUM DENSIFLORI (9)											
Achnatherum inebrians	.	+	II	I	.	.	.	r	II	+	.
Achnatherum splendens	.	+	.	+	.	.	.	+	IV	+	.
Artemisia macrocephala	.	.	.	r	.	.	.	.	III	r	.
Chenopodium acuminatum	.	.	.	I	.	.	r	r	IV	r	.
Chenopodium "album"	.	+	.	II	.	.	r	+	V	r	1
Lepidium densiflorum	.	.	.	I	.	.	.	r	V	r	.
Chenopodium hybridum	.	+	+	.	.	.	.	.	II	.	.
Allium vodopjanovae	.	+	.	II	.	.	II	II	IV	+	.
Carex stenophylla	.	+	I	II	I	II	I	II	IV	I	.
STIPETEA GLAREOSAE (ad 10)											
Ptilotrichum canescens	.	I	II	III	.	II	II	V	IV	III	.
Ajania fruticulosa	.	+	.	I	.	I	+	II	I	III	.
Ajania achilleoides	.	.	.	I	.	.	.	II	+	II	.
Caragana leucophloea	.	+	II	II	.	I	.	II	II	III	.
Allium polyrrhizum	.	.	.	II	.	I	r	III	V	III	.
Astragalus laguroides	.	.	.	I	.	I	I	II	III	II	.
Cleistogenes songorica	.	.	.	II	.	.	.	+	III	III	.
Stipa gobica	.	+	+	II	.	II	I	III	+	IV	.
Convolvulus ammanii	.	.	.	.	.	.	.	II	II	III	.
Eurotia ceratoides	.	+	I	II	.	.	+	II	I	III	.
Ephedra sinica	.	+	I	I	.	I	I	I	.	II	.
Lagochilus ilicifolius	.	.	.	r	.	.	.	II	+	II	.
POPULUS LAURIFOLIA COMMUNITY (11)											
Populus laurifolia	.	.	.	.	.	.	.	.	.	.	1
Nepeta sibirica	.	+	.	r	.	.	.	.	.	.	1
Aquilegia viridiflora	.	.	.	.	.	.	.	.	.	.	1
COMPANIONS											
Rhodiola rosea	.	.	.	.	II	I	II	.	.	.	.
Lonicera hispida	.	I	.	.	.	.	.	.	.	.	
Spiraea flexuosa	.	+	.	r	.	.	.	.	.	.	1
Bupleurum pusillum	.	.	.	I	.	II	II	III	r	.	.
Allium eduardii	.	.	+	I	.	III	III	II	.	+	.
Phlojodicarpus sibiricus	.	I	+	r	.	.	I	I	.	r	.
Iris bungei	.	.	.	I	.	.	.	I	I	I	.
Androsace dasyphylla	.	.	.	r	III	II	II	I	.	.	.
Androsace maxima	.	.	.	+	.	II	.	.	r	.	.
Androsace septentrionalis	I	+	.	r	I	II	I	r	.	.	.
Artemisia dracunculus	.	+	I	II	.	I	r	+	.	+	.
Poa pratensis	I	+	.	.	III	.	.	.	.	.	.
Polygonum angustifolium	.	.	.	.	II	I	r	.	.	.	.
Potentilla agrimonioides	.	+	II	.	.	.	+	r	.	.	.
Papaver saichanense	.	.	.	.	III	I	I	.	.	.	.
Peucedanum hystrix	.	.	.	r	III	I	III	r	.	.	.
Saussurea pricei	.	.	.	+	.	II	II	I	.	r	.
Saussurea saichanensis	.	+	+	.	I	II	I	r	.	r	.
Scorzonera ikonnikovii	.	.	+	I	.	I	II	II	I	+	.
Clausia aprica	.	+	+	+	.	I	II	r	+	.	.
Linaria acutiloba	.	I	+	.	.	.	r	.	.	.	.
Festuca rubra	.	.	.	r	I	.	.	.	.	r	.
Potentilla bifurca	.	.	+	r	.	.	r	r	.	.	.
Potentilla sp.	.	.	.	.	.	II	r	.	.	.	.
Smelovskia alba	.	.	.	.	I	I	+	.	.	.	.
Taraxacum cf. cuspidatum	.	.	+	.	I	.	r	.	.	.	.
Thymus gobicus	.	.	+	+	.	.	+	r	.	.	.
Vicia costata	.	+	I	I	.	.	.	.	r	r	.
Vicia semenovii	.	.	+	.	I	I	.	.	.	.	.
Amygdalus mongholica	.	.	.	+	.	.	.	r	.	r	.
Amygdalus pedunculata	.	.	+	+	.	.	.	r	.	+	.
Stipa glareosa	.	.	.	+	.	.	.	r	.	II	.
Ephedra przewalskii	.	.	.	r	.	I	I	.	.	.	.
Asterothamnus centrali-asiaticus	.	.	.	+	.	.	.	r	.	I	.
Oxytropis aciphylla	.	.	.	.	.	.	.	r	I	+	.
Scorzonera pseudodivaricata	.	.	.	+	.	II	.	.	.	+	.
Taraxacum leucanthum	.	.	.	r	.	.	r	.	.	.	.
Allium altaicum	.	.	+	r	.	.	.	.	.	r	.
Allium amphibolum	.	.	I	r	I	I	.	.	.	.	.
Allium anisopodium	.	I	II	r	.	.	.	r	.	.	.
Allium sp.	.	.	.	r	.	.	.	r	.	.	.
Allium tenuisissimum	.	.	I	r	.	I	r	.	.	r	.
Artemisia caespitosa	.	+	+	I	I	.	.	r	.	I	.
Artemisia commutata	.	.	.	.	I	I	.	.	.	r	.
Artemisia gmelinii	.	.	+	r	.	.	.	r	.	r	.
Artemisia gobica	.	+	+	r	.	.	.	r	.	r	.

Unit no. of relevés	1 5	2 16	3 11	4 51	5 7	6 10	7 28	8 70	9 25	10 84	11 1
Artemisia pectinata	.	.	.	I	.	.	.	r	+	II	.
Artemisia rutifolia	.	+	.	I	.	.	.	r	.	r	.
Artemisia sphaerocephala	.	.	.	.	.	I	.	.	.	r	.
Astragalus brachybotrys/miniatus	.	.	.	+	.	II	I	I	+	+	.
Astragalus brevifolius/junatovii	.	.	.	I	I	.	+	II	.	r	.
Astragalus frigidus	I	+	.	r	.	.	.	.	.	.	1
Astragalus grubovii	.	.	.	.	.	.	.	r	.	r	.
Astragalus mongholicus	.	+	.	+	.	.	+	.	r	.	.
Astragalus vallestris	.	.	.	r	.	.	.	I	II	+	.
Atraphaxis pungens	.	.	.	r	.	.	.	r	.	r	.
Axyris prostrata	.	.	.	I	.	.	+	r	II	.	.
Caragana spec.	.	.	.	.	.	.	.	.	.	I	.
Caragana bungei	.	.	.	.	.	.	.	r	.	r	.
Caryopteris mongholica	.	.	I	I	.	.	.	r	.	I	.
Craniospermum mongolicum	.	+	I	+	.	.	I	+	r	+	.
Crepis crocea	.	I	+	r	I	.	II	r	.	.	.
Dontostemon integrifolius	.	.	.	+	.	.	I	r	.	.	.
Dontostemon senilis	.	.	.	+	.	.	r	r	r	II	.
Draba lanceolata	.	.	.	.	II	I	.	.	.	.	.
Dracocephalum foetidum	.	.	.	r	.	I	.	.	r	r	.
Dracocephalum fruticulosum	.	+	II	+	.	I	+	+	.	r	.
Elymus chinensis	.	+	+	+	I	.	.	+	.	r	.
Elymus gmelinii	.	.	+	r	.	.	.	.	+	.	.
Ephedra intermedia	.	.	.	.	.	II	.	.	.	r	.
Galitzkya macrocarpa	.	+	.	.	.	.	.	r	.	r	.
Goniolimon speciosum	.	.	.	.	.	I	I	r	.	r	.
Grossularia acicularis	.	I	.	r	.	.	.	.	.	.	1
Gypsophila desertorum	.	.	.	+	.	.	.	I	.	+	.
Hackelia thymifolia	.	.	.	+	.	I	.	.	r	.	.
Haplophyllum dahuricum	.	.	I	r	.	.	.	I	.	+	.
Hedysarum gmelinii	.	.	.	.	.	.	r	r	.	r	.
Hordeum brevisubulatum	I	.	.	r	I	.	.	.	.	.	.
Iris potaninii	.	+	+	I	.	.	I	+	.	r	.
Koeleria macrantha	.	+	.	+	.	I	+	r	r	.	.
Lagotis integrifolia	II	.	.	.	II	I	.	.	.	.	.
Lappula intermedia	.	+	+	+	.	.	r	.	+	r	1
Limonium tenellum	.	.	.	.	.	I	.	r	.	+	.
Melandrium brachypetalum	.	+	I	r	.	.	.	.	.	.	.
Orostachys fimbriata	.	.	+	r	.	.	.	+	r	r	.
Oxytropis bungei	.	.	.	r	.	.	r	r	.	+	.
Oxytropis chionophyla	.	.	.	.	II	.	+	.	.	.	.
Oxytropis tragacanthoides	.	+	.	r	.	I	II	+	.	.	.
Panzeria lanata	.	.	.	II	.	.	.	r	.	+	.
Papaver croceum	.	.	.	.	II	II	r	.	.	.	.
Pedicularis abrotanifolia	.	.	.	.	I	.	II	r	.	.	.
Ptilotrichum tenuifolium	.	.	.	r	.	.	r	r	.	.	.
Salsola jacquemontii & collina	.	.	.	II	.	.	r	+	II	I	.
Scorzonera divaricata	.	.	+	.	.	I	r	r	.	+	.
Scutelaria grandiflora	.	.	.	r	.	.	.	.	r	r	.
Stipa breviflora	.	.	.	+	.	.	.	r	.	r	.
Youngia tenuifolia	.	+	.	I	.	I	r	r	.	r	.
Youngia tenuicaulis	.	.	+	+	.	.	r	+	r	.	.
Potentilla chionea	.	.	.	.	I	II	.	.	.	.	.
Potentilla crebridens	I	.	.	.	II	.	.	.	.	.	.
Carex orbicularis	I	.	.	.	I	.	.	.	.	.	.
Gentianella acuta	.	.	.	.	I	I	.	.	.	.	.
Aconitum barbatum	.	.	.	.	I	.	.	.	.	.	.

Unit no. of relevés	1 5	2 16	3 11	4 51	5 7	6 10	7 28	8 70	9 25	10 84	11 1
Adoxa moschatellina	I	.	.	.	I	.	.	.	.	.	.
Arabis rupicola	.	.	.	.	.	II	.	.	.	.	.
Cerastium bungeanum	.	.	.	.	.	I	.	.	.	.	.
Descurainia sophia	.	.	.	r	.	.	.	.	I	.	.
Potentilla sp.	I	.	.	.	I	.	.	.	.	.	.
Artemisia xanthochroa	.	I	.	.	.	.	.	.	.	r	.
Ephedra equisetina	.	.	.	r	.	I	.	.	.	.	.
Plantago depressa	.	.	.	r	I	.	.	.	.	.	.
Potentilla desertorum	I	I	.	.	.	.	.	.	.	.	1

ad 1: Arabidopsis mollissima, Cotoneaster melanocarpa, Carex karoi, Euphrasia tatarica, Oxytropis deflexa, Primula serrata, Salix taraikensis
ad 2: Bistorta vivipara, Bromus pumpellianus, Bromus inermis, Delphinium cheilanthum, Elymus schrenkianus, Euphorbia hirta, Galium boreale, Gentiana pseudoaquatica, Lloydia serotina, Potentilla anserina, Potentilla nivea, Puccinellia hauptiana, Pyrola minor, Stellaria graminea, Taraxacum sp.
ad 3: Festuca kurtschumica, Festuca brevisubulatum, Gentiana riparia, Polygonum argyrocoleon Pulsatilla bungeana, Rheum nanum, Rumex thyrsiflorus, Serratula centauroides, Taraxacum dealbatum, Veronica incana
ad 4: Artemisia palustris, Astragalus monophyllus, Dracocephalum origanoides, Gypsophila dshungarica, Iris tenuifolia, Melandrium viscosum, Papaver rubro-auriantiacum, Potentilla ojorensis, Serratula marginata, Tougarinovia mongholica, Vicia multicaulis
ad 5: Artemisia freyniana, Carex korshinskyi, Clematis tangutica, Cotoneaster uniflora, Euphorbia potaninii, Melica virgata, Rosa spinosissima, Urtica cannabina
ad 6: Arabis sp.
ad 7: Arabis sp., Arnebia fimbriata, Artemisia intricata, Artemisia palustris, Artemisia xerophytica, Artemisia sericea, Axyris hybrida, Bassia dasyphylla, Chamaerhodos sabulosa, Chenopodium aristatum, Chenodium sp., Chiazospermum lactiflorum, Clematis tangutica, Corispermum mongolicum, Crepis flexuosa, Cymbaria dahurica, Elymus angunensis, Elymus paboanus, Euphorbia mongolica, Erysimum marshallianum, Incarvillea potaninii, Orobanche coerulescens, Peucedanum vaginatum, Physochlaina physaloides, Potentilla evistata, Potentilla ikonnikovii, Potentilla ojorensis, Ptilagrostis pelliotii, Schizonepeta annua, Schizonepeta multifida, Scrophularia incisa, Scorzonera capito, Sedum aizoon, Setaria viridis, Stellaria brachypetala, Thermopsis lanceolata, Thesium refractum, Urtica cannabina, Vicia multicaulis, Vincetoxicum sibiricum
ad 8: Anabasis brevifolia, Astragalus saichanensis, Axyris hybrida, Comarum salesovianum, Elymus paboanus, Krylovia eremophila
ad 9: Artemisia scoparia, Orobanche coerulescens
ad 10: Agropyron fragile, Allium mongolicum, Anabasis brevifolia, Arnebia fimbriata, Artemisia anethifolia, Artemisia scoparia, Asparagus gobicus, Astragalus monophyllus, Astragalus rudolvii, Artemisia xerophytica, Bassia dasyphylla, Chenopodium aristatum, Chenopodium foliosum, Convolvulus arvensis, Cymbaria dahurica, Echinops gmelinii, Elymus angunensis, Enneapogon borealis, Erodium tibetanum, Eragrostis minor, Euphorbia mongolica, Jurinea mongolica, Kochia krylovii, Lappula stricta, Micropeplis arachnoidea, Nitraria sibirica, Oxytropis squamulosa, Peganum nigellastrum, Peucedanum vaginatum, Potaninia mongolica, Ptilagrostis pelliotii Reaumuria soongorica, Salsola arbuscula, Salsola laricifolia, Salsola passerina, Schizonepeta annua, Scorzonera capito, Scrophularia incisa, Senecio subdentatus, Setaria viridis, Tougarinovia mongholica, Vincetoxicum sibiricum, Zygophyllum neglectum, Zygophyllum xanthoxylon
ad 11: Clematis tangutica, Urtica cannabina

4. Description of the plant communities

4.1. Montane communities: Hedysaro-Stipetum and related units, extrazonal stands (Table 2)

The highest and most humid mountain sites may receive up to 200 mm/a precipitation (von Wehrden & Wesche 2007b) and, although they have limited spatial extend, comprise a high plant biodiversity (Jäger 2005). Any comparable zonal occurrences for many of these isolated species lie hundreds of kilometres away (Miehe et al. 2007). In the Gobi-Altay, lowland areas separating mountains are some 60 km wide (Jäger 2005), but mountains of the Dzungarian Gobi and Transaltay Gobi are even more widely isolated by the Dzungarian depression.

Betula microphylla community (Table 2, no. 1)

Diagnostic species: *Betula microphylla*, *Salix bebbiana*, *Cystopteris fragilis*, *Ribes rubrum*, *Spiraea media*
The northern slopes of the easternmost Gobi Altay (Zuun Saykhan, eastern Gobi Gurvan Saykhan NP) host relic forests built by *B. microphylla* (Cermak et al. 2004, Opgenoorth et al. 2005). Low radiation, permafrost relics and suitable precipitation create a habitat that supports the only dense forest stands with a closed canopy layer found within our working area (apart from oases). Stands grow as high as seven metres and accommodate an unusually high number of rare plant species (median 18 species/100 m²; see also Jäger 2005).

The nearest comparable stands are described from the Ikh Bogd some 250 km away (Hilbig et al. 1988). Although the southern Mongolian birch forests are clearly distinct from the surrounding vegetation, they are not easily placed in the syntaxonomical sys-

Fig. 4. Juniper stands at the peaks of the southern Dzungarian Gobi; in the foreground *Lonicera hispida* is growing within the Juniper patch, where it is presumably protected from grazing. In the background more Juniper stands can be seen.

tem (Hilbig 2000) because diagnostic species from a range of syntaxa grow together here.

Juniperus sabina community (Table 2, no. 2 & no. 3)
Diagnostic species: *Lonicera microphylla, Juniperus sabina, Thalictrum foetidum, Poa stepposa (*and *P. botryoides)*
This shrub community is common in the mountain habitats above some 1800 metres NN in the Gobi-Altay, where it replaces grass-dominated vegetation (see below) on steep south-facing slopes with high substrate movement. Distribution maps of *J. sabina* (Meusel et al. 1965, Adams & Schwarzbach 2006) indicate that sites represent the easternmost outposts in the species' range that is otherwise widespread in middle and western Eurasian mountains. Stands in the Gobi Gurvan Saykhan appear to be remnants of former more beneficial climatic conditions, which is reflected in their extremely poor reproduction (Wesche et al. 2005c).

In the Dzungarian Gobi stands are confined to the highest mountain sites (von Wehrden et al. 2006c) where they often grow on gentle slopes with no clear preferences in terms of exposure (Fig. 4). Sample plots reach high cover values and are accompanied by several disturbance indicators such as *Artemisia santolinifolia, Thalictrum foetidum* and *Poa stepposa* along with widespread species of southern Mongolian mountains (e.g. *Agropyron cristatum, Stipa krylovii* and *Artemisia frigida*).

The syntaxonomical status of this juniper scrub is unclear even in the well-studied European mountains (Exner & Willner 2004). Stands in the southern Mongolian mountains have no exclusive character species, although *Juniperus sabina* and *Poa stepposa* are most abundant here. This community can nevertheless be tentatively placed in the Juniperion pseudosabinae. Montane shrubs such as *Lonicera microphylla* differentiate a sub-community on more humid mountain sites (Table 2, no. 2). In south-western Mongolia, *Lonicera hispida* and *Rosa spinosissima* supplement the species set. The typical sub-community on more open substrates is differentiated by *Artemisia santolinifolia*. Further details on the juniper stands are provided by Wesche & Ronnenberg (2005b), Wesche et al. (2005b) and von Wehrden et al. (2006 c).

Artemisia santolinifolia community (Table 2, no. 4)
Diagnostic species: *Artemisia santolinifolia*
Artemisia santolinifolia is widespread in disturbed sites all over Central Asia south to the Himalayas (Miehe et al. 2002). In southern Mongolia, this small shrub is common on stony or disturbed lower montane sites occurring on small mammal burrows, eroding slopes, dry river beds and former Ger (Mongolian for yurt) sites (Hilbig 1995, Wesche & Ronnenberg 2004).

The presence of *Poa attenuata, Stipa krylovii* and *Agropyron cristatum* clearly testifies the montane context, but in central and northern Mongolia the community becomes more abundant, even in the

Fig. 5. Stands of the Kobresietum and the *Festuca* sub-association on the northern slopes of the Gobi Gurvan Saykhan, Yaks can be seen in the background (author HvW in the foreground).

lowlands. The community lacks exclusive character species and a proper syntaxonomical assessment depends on deeper understanding of Middle and Central Asian shrub communities. From a Mongolian perspective, *A. santolinifolia* can be seen as a character species of the *Juniperion pseudosabinae*, which is thus represented by the *J. sabina* community and the *A. santolinifolia* community in dry southern Mongolia. In contrast, Ermakov et al. (2006) described the new Artemisio santolinifoliae-Berberidetea sibirica from southern Siberia. Species overlap with the samples from southern Mongolia is however limited and the relation to Mirkin et al.'s Juniperetea pseudosabinae is unresolved at the moment.

Samples from the *Artemisia rutifolia* community recorded by Wesche et al. (2005b) from the Gobi Gurvan Saykhan are included here. They have an intermediate position between montane vegetation and desert steppes and have no distinct character species except for *A. rutifolia*, which is however rare in southern Mongolia outside the Gobi Gurvan Saykhan.

Kobresietum myosuroidis (Table 2, no. 5)

Diagnostic species: *Kobresia myosuroides, Kobresia simpliciuscula, Gentiana decumbens, Gentiana azurea, Ceratocarpus arenarius, Polygonum viviparum, Thlaspi cochleariforme, Stellaria amblyosepala, Eritrichium pauciflorum, Oxytropis strobilacea/oligantha, Lomatogonium carinthiacum, Saussurea arctecapitulata*

Kobresia myosuroides evolved in Central Asia (Meusel et al. 1965) and is widespread in alpine regions throughout Mongolia (Hilbig 1995). In our working area it is restricted to the moistest north-facing slopes of the Gobi Gurvan Saykhan above some 2300 metres NN. Stands are largely isolated with proximate neighbours being in the Ikh-Bogd (Hilbig 1990). The stands are heavily grazed; mainly by Yaks (see Fig. 5). Suitable micro-sites are small and species from the surrounding vegetation are common introgressives in the stands (e.g. *Poa attenuata, Koeleria altaica, Festuca valesiaca*). This is reflected in the constancy table, but *Kobresia* meadows are nonetheless clearly characterised by their distinct site conditions and the presence of species, that are clearly restricted to high mountains of Central Asia (see diagnostic species). Although species richness is among the highest in our study region (see Fig. 3); stands must be regarded impoverished when compared to Kobresietum samples from the Khangay and the Mongolian Altay. Nonetheless samples from the Gobi Gurvan Saykhan can be included in the Kobresietum described by Hilbig (2000); they resemble sample plots from shallow soils in the Ikh Bogd (Hilbig 1990).

Ten plots lack *Kobresia* and their species composition resembles meadow steppes of central Mongolia. Most samples came from a narrow belt (<10 m wide) surrounding the above-mentioned birch forests. The presence of *Rheum undulatum* and *Polygonum alpinum* hints at intense soil movement, and not surprisingly, sample plots reflect a mixture of various floristic elements. They may be regarded as an impoverished variant of true meadow steppes (Androsaco ovzcinnikovii-Helictotrichetum schelliani, Table 2, no. 6, see WESCHE et al. 2005b). In addition to a large number of species shared with samples from the Kobresietum, *Aster alpinus*, *Rheum undulatum* and *Festuca kryloviana* are potential diagnostic species in our region.

Hedysaro pumili-Stipetum krylovii, *Festuca valesiaca* sub-community (Table 2, no. 7)
Diagnostic species: *Festuca valesiaca, Amblynotus rupestris, Artemisia pycnorhiza* in addition to the association's character species (see below)

The steep upper slopes of the Gobi Altay and the Dzungarian Mountains are covered by relatively dense rock steppes of *F. valesiaca* and related *Festuca* species with partly unresolved taxonomy. Being restricted to upper-montane to alpine habitats, the sub-community receives high precipitation (see Fig. 3), which supports both a high biodiversity as well as cover values around 50 %. Stands grow on rocky soils with intense physical erosion, leading to disturbance and a heterogenous species set.

Several species are shared with the described *Kobresia* mats, but most species are much less moisture-demanding and represent widespread montane elements. We followed HILBIG's (2000) proposal and incorporated all mountain steppes of the dry Mongolian mountain ranges into a relatively broadly defined Hedysaro pumili-Stipetum krylovii. This is based on the presence of several characteristic species from the Stipion krylovii (*Stipa krylovii*, *Artemisia frigida*) with *Oxytropis pumila* as a possible new association character species. *Amblynotus rupestris* and *Arenaria meyeri* indicate affinities to the rock-dwelling communities of the Thymion gobici; and indeed *F. valesiaca* stands grow on shallow soil and have a transitory character. There are no exclusive character species, but with respect to the abundance of these rock steppes (HILBIG et al. 1999, HILBIG 2003a), in dry mountainous regions of southern and western Mongolia we tentively desigante their syntaxonomical status to sub-community level. Apart from *F. valesiaca* (included as *F. lenensis* in Hilbig's works), differential species include *Amblynotus rupestris*, *Artemisia pycnorhiza*, *Potentilla sericea,* and *Poa attenuata*. The rock steppes of the Dzungarian mountains contain several taxa that are not found in the Gobi Altay (see VON WEHRDEN et al. 2006c), but which nonetheless belong to the same sub-community.

Fig. 6. Southern slopes of the Gobi Gurvan Saykhan, grown with Hedysaro pumili-Stipetum krylovii steppes. The vegetation cover is much lower compared to the northern slopes. Some juniper patches are visible in the top right hand section of the image.

Hedysaro pumili-Stipetum krylovii – typicum (Table 2, no. 8)
Diagnostic species: *Stipa krylovii, Artemisia frigida, Agropyron cristatum, Arenaria meyeri, Astragalus multicaulis, Bupleurum bicaule, Oxytropis pumila*
The lower mountain steppes of the Gobi-Gurvan Saykhan receive less precipitation, show higher mean July maximum temperatures (Fig. 3), and provide habitat conditions that overlap with those of the *Artemisia santolinifolia* community described above. Stands lack the luxurious yet heterogeneous set of accompanying species which characterises the sub-association with *Festuca valesiaca* described above. *Festuca* spp., *Koeleria* spp., *Kobresia* spp. and other alpine elements are rare and total cover values are lower than in *Festuca* spp. stands (see Fig. 6).

Mountain steppes share a basic set of species such as *Agropyron cristatum, Stipa krylovii, Artemisia frigida* and *Arenaria meyeri* with grass steppes of central Mongolia, and belong also to the Cleistogenetea squarrosae (synonymous to Hilbig's Agropyretea cristati, Ermakov et al. 2006). The main difference is an overall lower number of species and a variation in the set of character species. The latter differ depending on the environmental conditions. *Carex duriuscula/stenophylla* is diagnostic for mountain steppes with high-grazing disturbance (Wesche et al. 2005b), but it characterises a mere variant or facies rather than an independent sub-association. The typical sub-association as described here includes the remaining samples of the former *Stellaria petraea* sub-association (proposed by Hilbig 1990 but not listed in Hilbig 2000) that are not included in the sub-community with *Festuca valesiaca*; and those stands of the former *Astragalus inopinatus* sub-association (Hilbig 1990) that do not belong to the Hedysaro-Stipetum stipetosum gobicae described below. *Astragalus inopinatus* is not widespread in southern Mongolian mountain steppes, so we include part of these stands in the typical sub-association.

Chenopodio prostrati-Lepidietum densiflori and other replacement communities of the Hedysaro-Stipetum (Table 2, no. 9)
Diagnostic species: *Achnatherum inebrians, Achnatherum splendens, Artemisia macrocephala, Chenopodium acuminatum, Chenopodium "album", Lepidium densiflorum*

Around old wintering sites, at springs and wells and at other overgrazed sites the mountain steppes are replaced by ruderalised communities. Due to higher nutrient levels in the soils and potential water surplus the overall plant cover values are often higher than in the surrounding areas, especially in the wider proximity of Ger-places and wells (Stumpp et al. 2005). Short-lived Chenopodiaceae (*Chenopodium acuminatum, Chenopodium album, Chenopodium hybridum, Axyris prostrata*) as well as *Lepidium densiflorum* are typical indicators of heavy soil disturbance; *Achnatherum splendens* and *A. inebrians* as well as *Artemisia santolinifolia* also form stands on somewhat less disturbed sites. Stands of annuals are usually classified as the Chenopodio prostrati-Lepidietum densiflori, but syntaxonomy of ruderal communities is still unclear and the number of available samples is still low. We thus refrained from disentangling the relationships between annual- and perennial-dominated replacement communities here.

Hedysaro pumili-Stipetum krylovii, stipetosum gobicac sub-ass. (=*Astragalus inopinatus* sub-association) (Table 2, no. 10)
Diagnostic species: Stipa gobica, *Eurotia ceratoides* in addition to the diagnostic species of the association

The upper pediments reach montane altitudes and several species mark the transition zone between the mountain steppes and the lower semi-deserts. They constitute a distinct sub-association which is found on the upper and intermediate pediments of the Gobi Gurvan Saykhan (von Wehrden et al. 2006b). *Stipa krylovii, Artemisia frigida* and *Agropyron cristatum* are less abundant than in typical mountain steppes, and *Stipa gobica* and *Caragana leucophloea* become more abundant on the upper pediments; however at least one of the typical montane elements is always present, suggesting a placement into the "high mountain variant" proposed by Helmecke & Schamsran (1979).

Stands resemble sample plots from the *Astragalus inopinatus* sub-association described by Hilbig (1990, 1995) for other sites in Mongolia. In the south-eastern most part of the Small Gobi strictly protected area similar stands with *Stipa gobica* and *Artemisia frigida* were found; these show a lower species richness but are nonetheless included here.

Populus laurifolia community (Table 2, no. 11)
Diagnostic species: *Populus laurifolia*
A single patch of *Populus laurifolia* forest was sampled in the eastern Gobi Gurvan Saykhan. The species forms floodplain vegetation in northern Mongolia, and at the Gobi Gurvan Saykhan site trees were also growing in a deep valley ensuring a high water surplus. The stand was accompanied by typical species of the surrounding vegetation; therefore it was also included in Table 2, although the species set is heterogeneous and the syntaxonomical status is unclear (Hilbig 2000).

4.2. Desert steppes of pediments and moister semi-deserts: Allio polyrrhizi-Stipetum glareosae (Table 3)

Allio polyrrhizi-Stipetum glareosae, stipetosum gobicae sub-ass. nov. hoc loco (Table 3, no. 1)
Diagnostic species: *Stipa gobica* in addition to the diagnostic species of the association: *Eurotia ceratoides, Ajania fruticulosa, Allium mongolicum, Stipa glareosa*
Nomenclature typus is relevé 1 in Table 4.

Table 3. Constancy table for the Allio polyrrhizi-Stipetum glareosae (no.1–2), the Caraganion (no. 2–7) and the *Psammochloa villosa*-community (no. 8) of the southern Mongolian Gobi (for explanation of constancy classes see Table 2).

Unit	1	2	3	4	5	6	7	8
no. of relevés	16	61	56	32	16	46	35	5
ALLIO-STIPETUM AND ITS SUB-ASSOCIATIONS (1-2)								
Stipa gobica	V	.	II	III	.	II	r	.
Stipa glareosa	+	V	IV	III	V	V	V	II
STIPETEA GLAREOSAE – ALLION POLYRRHIZI (ad 1-2, 3-4)								
Gypsophila desertorum	+	I	r	II	.	.	.	.
Allium polyrrhizum	V	II	III	IV	.	II	III	.
Dontostemon senilis	II	II	II	II	+	III	II	.
Ajania achilleoides	III	I	II	IV	.	I	III	.
Cleistogenes songorica	IV	III	II	V	.	II	III	.
Allium mongolicum	I	II	II	II	V	II	II	II
Eurotia ceratoides	III	III	IV	III	I	III	I	.
Ajania fruticulosa	III	III	III	II	I	IV	+	.
CARAGANION LEUCOPHLOEAE (3-7)								
Oxytropis aciphylla	.	II	II	II	III	I	I	.
Caragana leucophloea	.	.	V	V	V	V	V	II
Artemisia pectinata	+	I	II	III	.	I	I	.
Iris bungei	I	+	.	V	.	r	.	.
Convolvulus ammanii	I	II	+	IV	+	+	II	.
Carex stenophylla	I	I	+	III	.	r	.	.
Corispermum mongolicum	.	.	r	.	V	r	.	.
Lappula stricta	.	+	+	.	V	I	r	.
Agropyron michnoi	.	.	.	.	III	r	.	.
Iris tenuifolia	.	.	.	.	IV	r	.	I
Ephedra przewalskii	+	I	I	.	IV	II	.	.
Artemisia sublessingiana	I	I	I	I	V	I	r	.
SYMPEGMO-CARAGANETUM & TRANSITIONS (6-7)								
Sympegma regelii	+	I	II	.	.	II	II	.
Zygophyllum neglectum	.	+	r	.	+	II	.	.
Anabasis brevifolia	.	r	.	.	.	V	V	.
Zygophyllum xanthoxylon	.	I	II	.	.	II	II	.
Reaumuria songarica	+	I	I	.	.	.	IV	.
Salsola passerina	.	r	r	.	.	.	IV	.
PSAMMOCHLOA COMMUNITY (8)								
Caragana korshinskii	.	.	.	.	.	.	.	II
Psammochloa villosa	.	.	.	.	.	.	.	V
Agriophyllum pungens	.	.	.	.	.	.	.	II
COMPANIONS								
Ptilotrichum canescens	I	I	I	III	+	I	+	II
Bassia dasyphylla	.	+	I	III	III	II	.	.
Heteropappus altaicus	II	I	I	II	+	+	+	.
Scorzonera pseudodivaricata	I	I	II	II	+	II	+	II
Convolvulus gortschakovii	.	I	+	.	I	I	+	.
Salsola arbuscula	+	I	r	.	+	I	II	.
Asterothamnus centrali-asiaticus	+	I	I	I	.	I	I	.
Lagochilus ilicifolius	+	I	I	II	.	+	II	.
Artemisia scoparia	+	I	I	r	.	+	I	.
Artemisia phaeolepis	+	I	+	r	II	+	.	.
Atraphaxis frutescens	.	r	I	.	I	r	.	II
Cousinia affinis	.	.	r	.	II	r	.	.
Kochia prostrata	II	+	+	II	.	r	.	.
Panzeria lanata	.	r	+	I	II	r	.	.
Ptilagrostis pelliotii	+	r	I	+	.	II	II	.
Rheum nanum	+	+	+	II	.	.	r	.
Salsola jacquemontii & collina	I	I	II	III	.	+	r	III
Salsola paulsenii	.	+	I	.	IV	I	.	.
Artemisia santolinifolia	.	.	r	+	.	r	.	.
Stipa krylovii	.	.	.	I	.	.	.	.
Agropyron cristatum	.	.	.	II	.	.	.	.
Achnatherum splendens	.	r	+	I	.	r	+	.
Chenopodium acuminatum	.	.	r	I	.	.	.	.
Chenopodium "album"	.	.	r	I	.	+	.	.
Lepidium densiflorum	.	.	r	r	.	r	r	.
Chenopodium hybridum	.	.	.	.	.	+	.	.
Allium vodopjanovae	+	r	r	I	.	r	.	.
Artemisia dracunculus	.	.	I	+	.	.	.	.
Sibbaldianthe adpressa	.	.	r	+	.	.	.	.
Astragalus laguroides	II	r	r	II	.	.	.	.
Scorzonera ikonnikovii	+	.	.	+	.	.	.	.
Amygdalus mongholica	.	.	r	.	.	I	.	I
Amygdalus pedunculata	.	.	r	+	.	r	+	.
Ephedra sinica	II	+	+	I	.	r	r	.
Nanophyton erinaceum	.	r	r	.	.	.	.	.
Micropeplis arachnoidea	.	+	r	.	.	+	r	II
Allium anisopodium	.	.	.	+	.	.	.	.
Allium tenuisissimum	.	r	.	r	.	I	.	.
Aristida heymannii	+	+	r	+	.	.	.	.
Arnebia fimbriata	.	r	+	.	+	+	r	.
Artemisia caespitosa	.	.	+	.	.	+	.	.
Artemisia xanthochroa	.	r	.	.	II	r	.	II

Unit	1	2	3	4	5	6	7	8
no. of relevés	16	61	56	32	16	46	35	5
Artemisia xerophytica	.	+	r	+	.	+	.	II
Asparagus gobicus	.	+	+	+	.	+	II	.
Astragalus brevifolius/junatovii	.	+	r	r	.	.	.	III
Astragalus grubovii	.	+	r	II	.	.	.	.
Astragalus monophyllus	.	+	+	I	I	+	.	.
Astragalus vallestris	I	r	+	II	.	r	.	.
Atraphaxis pungens	.	.	r	+	.	+	r	.
Cancrinia discoidea	+	.	.	.	+	r	.	.
Caragana sp.	.	r	r	.	.	.	+	.
Caryopteris mongholica	.	r	+	I	.	+	r	.
Ceratocarpus arenarius	.	+	r	.	I	r	.	.
Clematis fruticosa	.	r	r	.	.	.	r	.
Craniospermum mongolicum	+	r	r	r	.	r	.	.
Crepis flexuosa	.	.	r	r	.	r	.	.
Dontostemon crassifolius	.	I	r	r	I	+	.	.
Dracocephalum foetidum	.	r	r	+	.	.	.	.
Echinops gmelinii	.	r	r	.	.	.	I	II
Elymus angunensis		.	.	.	I	.	.	.
Elymus chinensis	.	.	r	r	.	r	.	.
Enneapogon borealis	+	+	r	+	.	r	.	.
Eragrostis minor	+	+	r	II	.	.	.	.
Erodium stephanianum	.	+	.	+	.	.	.	.
Erodium tibetanum	.	+	r	+	.	r	r	.
Euphorbia humifusa	+	r	r	I	+	.	.	.
Galitzkya macrocarpa	+	.	.	.	.	r	r	.
Goniolimon speciosum	.	r	r	.	.	+	.	.
Haplophyllum dahuricum	+	+	+	I	.	r	.	.
Iris potaninii	I	.	.	.	.	.	.	.
Kochia krylovii	.	+	r	I	.	.	.	.
Kochia melanoptera	.	r	r	.	.	r	.	.
Limonium tenellum	I	r	r	+	.	r	II	.
Orostachys spinosa	.	.	+	.	.	+	r	.
Peganum nigellastrum	+	I	I	.	.	r	+	.
Potaninia mongolica	.	r	r	.	.	r	.	.
Salsola laricifolia	.	r	r	.	.	r	II	.
Salsola pestifera	.	r	.	.	+	.	r	.
Schizonepeta annua	.	.	r	r	.	+	.	.
Scorzonera capito	.	r	r	+	.	r	.	.
Scorzonera divaricata	.	+	r	r	.	r	+	.
Setaria viridis	I	.	+	II	.	.	r	.
Stipa breviflora	+	r	+	.	.	r	.	.
Tribulus terrestris	+	+	.	+	.	.	.	.
Zygophyllum rosovii	.	r	r	.	.	+	r	.
Vincetoxicum sibiricum	.	.	.	I	.	.	.	I
Youngia tenuicaulis	.	.	r	r	.	.	r	.
Zygophyllum pterocarpum	.	r	r	.	.	r	.	.
Allium prostratum	.	.	.	.	.	r	I	.

ad 1: Astragalus brachybotrys/miniatus, Carex enervis, Elymus sibiricus, Saussurea catharinae, Stipa orientalis
ad 2: Alyssum obovatum, Anabasis aphylla, Anabasis elatior, Artemisia anethifolia, Artemisia implicata, Artemisia intricata, Artemisia pycnorhiza, Artemisia sp., Astragalus brachybotrys/miniatus, Calligonum mongolicum, Caragana bungei, Chenopodium prostratum, Cistanche salsa, Dontostemon elegans, Halogeton glomeratus, Iris lactea, Jurinea mongolica, Limonium bicolor, Limonium chrysocomum, Orostachys fimbriata, Orostachys spinosa, Peganum harmala, Stipa orientalis, Tougarinovia mongholica, Zygophyllum potaninii
ad 3: Achnatherum inebrians, Allium eduardii, Arnebia guttata, Artemisia macrocephala, Bupleurum pusillum, Ephedra glauca, Incarvillea potaninii, Chamaerhodos sabulosa, Jurinea mongolica, Kaschgaria komarovii, Limonium aureum, Limonium flexuosum, Lophanthus chinensis, Melandrium brachypetalum, Nitraria sibirica, Nitraria sphaerocarpa, Oxytropis pumila, Plantago minuta, Psathyrostachys juncea, Stellaria dichotoma, Thymus gobicus, Vicia costata
ad 4: Achnatherum inebrians, Artemisia macrocephala, Axyris prostrata, Bupleurum bicaule, Chenopodium prostratum, Euphorbia mongolica, Lappula intermedia, Leptopyrum fumarioides, Oxytropis bungei, Oxytropis pumila, Plantago minuta, Saussurea pricei, Vicia costata, Vicia semenovii
ad 5: Astragalus ammodytes, Calligonum junceum, Kalidium foliatum
ad 6: Allium eduardii, Artemisia frigida, Atragene sibirica, Atriplex sibirica, Chenopodium foliosum, Dontostemon elegans, Dracocephalum bungeanum, Ephedra intermedia, Geranium collinum, Kaschgaria komarovii, Lepidium lacerum, Panicum miliaceum, Ptilotrichum tenuifolium,Orobanche cumana, Senecio dubitabilis, cf. Sonchus dentatus, Stellaria dichotoma, Zygophyllum gobicum
ad 7: Arenaria meyeri, Bupleurum pusillum, Chloris virgata, Ephedra equisetina, Orostachys spinosa, Ulmus pumila shrub, Youngia tenuifolia
ad 8: Artemisia frigida, Artemisia sphaerocephala, Nitraria sibirica

Table 4. Comprehensive table sumarising all type relevés.

type relevé number	1	2	3	4	5	6	7	8	9	10	11	12
Ajania achilleoides	1											
Allium polyrrhizum	1	1	1	1								
Ajania fruticulosa	1	1	1	1		1				1		
Eurotia ceratoides		1	1	1		1	1					
Stipa glareosa		1	1		1	1	1					
Allium mongolicum	1			1	1	+	1					
Caragana leucophloea			1	1	1							
Artemisia sphaerocephala			+	+								
Stipa gobica	1			1		1						
Cleistogenes songorica		+		1								
Anabasis brevifolia						1	r					
Artemisia sublessingiana					1		1					
Ephedra przewalskii						1	1		+	1	1	
Astragalus brachybotrys	+											
Ephedra sinica	1											
Heteropappus altaicus	1											
Iris potaninii	+											
Ptilotrichum canescens	r			+								
Peganum nigellastrum			+									
Dontostemon senilis			r			r						
Achnatherum splendens				1								
Artemisia xerophytica				+								
Convolvulus ammanii				1								
Iris bungei				1								
Oxytropis aciphylla				+	1							
Agropyron michnoi					1							
Convolvulus gortschakovii					1							
Corispermum mongolicum					1							
Iris tenuifolia					1							
Lappula stricta					+	r						
Panzeria lanata					+							
Zygophyllum neglectum						1	1					
Cancrinia discoidea						1						
Kochia melanoptera						1						
Micropeplis arachnoidea						1		1			+	
Ptilagrostis pelliotii						1						
Salsola paulsenii						1						
Sympegma regelii						1				1		
Goniolimon speciosum						+						
Halogeton glomeratus							1					
Nanophyton erinaceum							1					
Bassia dasyphylla							+	+				
Ceratocarpus arenarius							r					
Artemisia scoparia										1		
Dontostemon crassifolius										1		
Iljinia regelii								1				
Limonium aureum										1		
Nitraria roborovskii											1	
Zygophyllum xanthoxylon									+	1		
Reaumuria songarica											1	1
Nitraria sphaerocarpa												1
Salsola passerina												1

ad column 1: Typus relevé for the Allio polyrrhizi-Stipetum glareosae stipetosum gobicae sub-ass. nov. hoc loco (plot no. KW-HVW-2001- 337). Total shrub cover was around 9 %, field cover some 6 %. The relevé was sampled on the pediments of the Gobi Gurvan Saykhan National Park (at 1650 metres; 43° 22' north, 100° 33' east) the soil-surface was deflated but the matrix contained silt and fine sand.
ad column 2: Typus relevé for the Allio polyrrhizi-Stipetum glareosae eurotietosum sub-ass. nov. (plot no. KW-HVW-2001-299). Total shrub cover was around 2 %, field cover some 10 %. The relevé was recorded on the higher pediments of the Gobi Gurvan Saykhan range (1750 metres; 43° 18' north, 103° 55' east); the soil was deflated and sealed by a stone pavement.
ad column 3: Typus relevé for the Oxytropidi aciphyllae-Caraganetum leucophloeae typicum sub. ass. nov. (plot no. HVW-2004-281); the plot was sampled on rather sandy deflated pediments. Shrub cover was around 3 %, field cover some 6 %. The plot was situated on vast pediments south of the Altay main range, north of the Great Gobi A strictly protected area (1650 metres; geographical position: 44° 14' north, 99° 02' east).
ad column 4: Typus relevé for the Oxytropidi aciphyllae-Caraganetum leucophloeae iridetosum bungei sub. ass. nov. (plot no. KW-HVW-2001-75); Shrub cover was around 7 %, whilst the field layer covered some 25 %. The plot represents a ravine aspect on the lower pediments of the Gobi Gurvan Saykhan range (1650 metres; 43° 18' north, 104° 24' east).
ad column 5: Typus relevé for the Oxytropidi aciphyllae-Caraganetum leucophloeae iridetosum tenuifoliae sub. ass. nov. (plot no. HVW-2003-177); the plot was sampled on a micro-dune, which had a deflated stone net in between the sandy spots; altitude was 1650 metres (45° 31'

ad column 6: Typus relevé for the Stipo glareosae-Anabasietum brevifoliae stipetosum gobicae sub-ass. nov. (plot no. HVW-2003-123). Shrub cover was around 10 %, the field layer covered some 7 %. The plot was sampled on a relatively steep (25° slope) stony hill in the Great Gobi B strictly protected area (1395 metres; 45° 22' north, 92° 24' east).
ad column 7: Typus relevé of the Artemisio sublessingianae-Nanophytetum erinacei ass. nov. (plot no. HVW-2003-016). Shrub cover was around 9 %, the field layer covered some 2 %; the relevé was sampled on a deflated pediment in the north-eastern Great Gobi B strictly protected area (1487 metres; 45° 32' north, 92° 48' east).
ad column 8: Typus relevé of the Iljinietum regelii ass. nov., typicum sub-ass. nov. (plot no. HVW-2004-67). Shrub cover was around 5 %, the field layer covered some 1 %; the relevé was sampled in a ravine of the lower pediment (1141 metres; 43° 27' north, 96° 53' east) within the Great Gobi A strictly protected area.
ad column 9: Typus relevé of the Ephedro przewalski-Zygophylletum xanthoxyli ass. nov., typicum (plot no. HVW-2004-18). Shrub cover was around 4; the relevé was sampled in a stony ravine in between smaller hills (1550 metres; 43° 09' north, 96° 54' east) within the Great Gobi A strictly protected area.
ad column 10: Typus relevé of the Ephedro przewalski-Zygophylletum xanthoxyli ass. nov., sympegmetosum regelii (plot no. HVW-2004-157). Shrub cover was around 6 %, the field layer covered some 1 %; the relevé was sampled in a ravine of the lower pediment (1600 metres; 42° 57' north, 98° 14' east) within the Great Gobi A strictly protected area.
ad column 11: Typus relevé of the Ephedro przewalski-Zygophylletum xanthoxyli nitrarietosum roborovskii sub-ass. nov. (plot no. HVW-2004-230). Shrub cover was around 7 %, field cover around 1 %; the relevé was sampled in a stony ravine of the lower pediment (992 metres; 43° 39' north, 98° 59' east) within the Great Gobi A strictly protected area.
ad column 12: Typus relevé of the Ephedro przewalski-Zygophylletum xanthoxyli nitrarietosum sphaerocarpae sub-ass. nov. (plot no. HVW-2004-76). Shrub cover was around 5 %; the relevé was sampled in a stony ravine of the lower pediment (842 metres; 41° 45' north, 104° 38' east) within the Small Gobi A strictly protected area.

Dry grasslands of the pediment regions are characterised by the Allio-Stipetum (Hilbig 2000), which is distinguished from other desert steppes by the rareness of perennial Chenopodiaceae, which are typical for Mongolian semi-deserts (*Anabasis brevifolia, Haloxylon ammodendron, Sympegma regelii, Salsola passerina*). *Stipa gobica* characterises the stony habitat of the upper pediments, and stands were previously designated as a "high mountain variant" (Helmecke & Schamsran 1979). This is somewhat misleading as characteristic montane species such as *Agropyron cristatum* and *Stipa krylovii* are absent. Still, our data confirm that *S. gobica* clearly favours relatively moister climates (Fig. 7) and/or rocky sites in the context of the Stipetea glareosae-gobicae, and serves as a good differential species within the Allio polyrrhizi-Stipetum glareosae. We thus designate a new sub-association here.

Montane desert steppes of this sub-association are restricted to the forelands of the Gobi-Gurvan Saykhan range (von Wehrden et al. 2006b). In most other regions the transitional zone between mountain and desert steppe is more abrupt due to the drier climate, hence comparable stands are absent. *Stipa gobica* replaces *S. glareosa* as a typical more drought-tolerant desert steppe grass, while *Ephedra sinica* is abundant; the latter often indicates degradation (Ivanov et al. 2004). Growing on disturbed sites, the previously described *Ephedra sinica* sub-community (Wesche et al. 2005) shows an inhomogeneous data set and has been included in the stipetosum gobicae here.

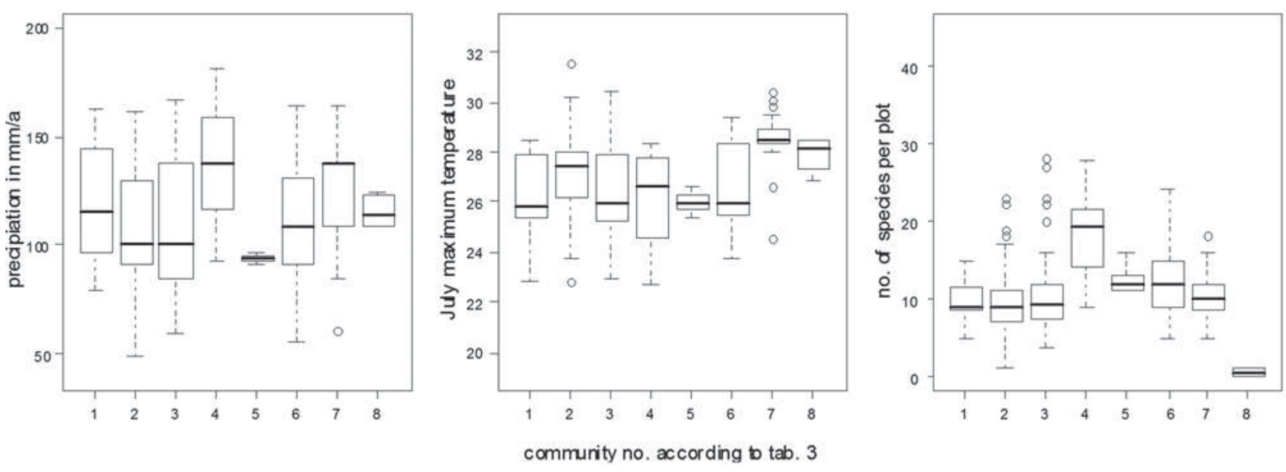

Fig. 7. Boxplots summarising the background information for the Allio-Stipetum and the Caraganion; the y-labels follow Fig. 3, the x-labels Table 3.

Allio polyrrhizi-Stipetum glareosae, eurotietosum ceratoidis sub-ass. nov. hoc loco (Table 3, no. 2)
Diagnostic species: *Eurotia ceratoides, Ajania fruticulosa*
Nomenclature typus is relevé 2 in Table 4.
In the Dzungarian Gobi, stands of *Eurotia ceratoides* and *Ajania fruticulosa* were usually found on higher pediments; in the much drier Transaltay Gobi (= Great Gobi A strictly protected area) they occurred on montane sites where they reached up to the summit regions. In the Gobi Gurvan Saykhan and further east, stands were mainly encountered in dry riverbeds, which receive average precipitation levels comparable to the mountain sites in the Transaltay Gobi (von Wehrden & Wesche 2007a, 2007b). The two shrub-species *E. ceratoides* and *A. fruticulosa* are thus common in dry stony riverbeds or other sites with episodically downpouring water.

Stands are found on drier sites than those of the previous unit (see Fig. 7, no. 2); and contrary to the sub-association with *S. gobica*, stands were sampled in all working areas. The high abundance of *Stipa glareosa* indicates the general context of the semi-deserts.

The entire Allio-Stipetum is poorly defined with respect to a lack of exclusive character species. Its position in the Allion polyrrhizi (Hilbig 2000) is, however, obvious; and it can be regarded as the basal association of that alliance.

4.3. Scrub of moderately dry semi-deserts: Caraganion leucophloeae (Table 3, no. 3–7)

Caragana leucophloea is a spiny Fabaceae that forms characteristic scrub communities in southern Mongolia (Hilbig 1995, 2000). Stands grow on semi-desert sites and species such as *Stipa glareosa* and *Allium mongolicum* indicate the moderately dry conditions. Another typical companion is *Cleistogenes songorica*, and most of the typical species of the two previous units are equally common. *Caragana leucophloea* may also occur in mountain steppes of the Gobi-Altay, where it occasionally accompanies *Stipa gobica* and *S. krylovii* on stony substrates. These stands belong to the Cleistogenetea squarrosae (Hedysaro-Stipetum stipetosum gobicae, see Table 2). All stands without the characteristic montane elements mentioned above are however included into the Stipetea glareosae, where Hilbig (2000) assigned them to the Zygophyllo xanthoxyli-Brachanthemetalia gobici. With respect to the high presence of shared species such as *Allium polyrrhizum, Dontostemon senilis* and *Artemisia pectinata,* we suggest placing this alliance into the order Allietalia polyrrhizi. On the alliance level, differences between the Allion and the Caraganion are also somewhat weak because, apart from *C. leucophloea*, only *Oxytropis aciphylla* shows any preference toward the Caraganion, but it is rare overall (Table 3). Whether alliances should really be distinguished in future depends on a Central-Asian wide assessment. Affinity of the respective units is also supported by the environmental context, which indicates comparable precipitation values within these units (e.g. von Wehrden et al. 2006c); the overall number of species (see also Fig. 7) and the high cover values of Caraganion stands support this assumption.

Oxytropidi aciphyllae-Caraganetum leucophloeae (Table 3, no. 3)
Diagnostic species: *Caragana leucophloea, Oxytropis aciphylla*
Nomenclature typus is relevé 3 in Table 4.
These stands are the most common vegetation of the pediments in southern and south-western Mongolian parts of the eastern Gobi (von Wehrden et al. 2006b). In the drier Transaltay Gobi and the Dzungarian Gobi, stands are mainly restricted to hills or mountains slopes (von Wehrden et al. 2006a). Both name-giving species form a characteristic association, which along with *Ajania achilleoides* and *A. fruticulosa* builds shrub-dominated stands. After rainfall the vegetation is often enriched by emerging annuals (*Salsola collina, Artemisia pectinata, Artemisia scoparia)*; perennial onions are also abundant (*Allium polyrrhizum, Allium mongolicum*). This unit has already been described by Hilbig (2000), but we support our syntaxonomic proposal to place this association into the Allietalia polyrrhizi, and therefore give a type relevé.

Oxytropidi aciphyllae-Caraganetum leucophloeae, iridetosum bungei sub-ass. nov. hoc loco (Table 3, no. 4)
Diagnostic species: *Iris bungei, Convolvulus ammanii* in addition to the diagnostic species of the association
Nomenclature typus is relevé 4 in Table 4.
On the pediments of the Gobi-Altay, sandy sites often have unsettled surfaces which lack the usual cover of stone pavements. The soil conditions are defined by this aeolian influence; plants adapted to the frequent wind benefit however from the often higher groundwater of these sites. *Iris bungei* differentiates these stands from the typical sub-association; small nebkhas are formed around the specimens. *Convolvulus ammanii* is another common companion. Stands do not grow as high as in the typical sub-association, but the number of species per plot is higher, which is probably related to the slightly higher moisture availability (see Fig. 7, no. 4). The high abundance of *Cleistogenes songorica* indicates the eastern biogeographic affinities of this sub-association (Zemmrich 2005), which reaches its westernmost distribution limit in the forelands of the Mongolian Altay, just north of the eastern Transaltay Gobi. Stands of the Artemisio xerophyticae-Caraganetum leucophloeae were described for the Valley of Lakes (Hilbig 2000) just north of our working area; where

this unit may be more abundant. However in our working area it is rare.

Oxytropidi aciphyllae-Caraganetum leucophloeae, iridetosum tenuifoliae sub-ass. nov. hoc loco (Table 3, no. 5)
Diagnostic species: *Iris tenuifolia, Agropyron michnoi*, *Corispermum mongolicum, Lappula stricta* in addition to the diagnostic species of the association
Nomenclature typus is relevé 5 in Table 4.
In the Dzungarian Gobi, a more westerly distributed sub-association replaces the previous unit (von Wehrden et al. 2006c). Stands are mainly found among the northern hills of the Dzungarian basin where they are restricted to sandy sites. The sand layers are usually less than half a metre thick, but this is sufficient enough to prevent many species occurring on the surrounding stony hills from growing (e.g. *Stipa gobica, Orostachys spinosa, Goniolimon speciosum, Anabasis brevifolia, Halogeton glomeratus* etc.). Stands are relatively species-poor (see Fig. 7, no. 5).

Sympegmo regelii-Caraganetum leucophloeae and related transition stands (Table 3, no. 6)
Diagnostic species: *Sympegma regelii, Zygophyllum neglectum*, *Anabasis brevifolia*
On lower pediments shrubby Chenopodiaceae join *Caragana leucophloea* and transitory stands are quite widespread. The Central Asian element *Anabasis brevifolia* indicates deflated soils with a sealed surface; *Sympegma regelii* underlines the relatively dry situation. These stands represent a link between the drier semi-deserts of the Stipo-Anabasietum described below and the moister stands of the Caraganion.

Some of the sample plots can be included into the Sympegmo regelii-Caraganetum leucophloeae described from the Transaltay region (von Wehrden et al. 2006a). The western Central Asian element *S. regelii* becomes rare east of the Transaltay Gobi, so similar stands there lack this shrubby Chenopodiaceae. Their syntaxonomical placement is difficult, which is also shown by Table 25, co. 4 in Hilbig (1990) where similar *Caragana* stands were placed in a different alliance (Zygophyllo xanthoxyli-Brachanthemion gobici). By our judgement, the general species set supports placement in the Caraganion, where we also place this and associated transitory samples.

Oxytropidi aciphyllae-Caraganetum leucophloeae, *Reaumuria songarica* sub-community (Table 3, no. 7)
Diagnostic species: *Reaumuria songarica, Salsola passerina* in addition to the diagnostic species of the association
Wherever sites become more saline in the southern Mongolian semi-deserts, the shrubs *Reaumuria songarica* and *Salsola passerina* join the species from the zonal communities. They typically characterise distinct sub-units in Mongolian semi-deserts and the *C. leucophloea* scrub is no exception (see Table 3, no. 7). Stands are mostly restricted to the lower pediments of the Gobi Gurvan Saykhan and the hills and pediments of the eastern Gobi (including the higher Alashan Gobi), which explains the higher precipitation and July temperature levels of the these stands in comparison to the other Caraganion communities (see Fig. 7, no. 7). The overall species set is intermediate between the Caraganion and the Stipo-Anabasietum described below, with most of the accompanying species being more typical for the moister stands of the Caraganion. More data is needed to clarify the syntaxonomical placement of the unit (see also Table 25 and 27 in Hilbig 1990). We therefore currently refrain from designating a new sub-association; no typus relevé is provided.

Psammochloa villosa community (Table 3, no. 8)
Diagnostic species: *Psammochloa villosa, Caragana korshinskii, Agriophyllum pungens*
Unconsolidated sand dunes are colonised by the Central Asian endemic grass *P. villosa*. It is a clear character species, but syntaxonomical position of this community remains unclear, due to the low number of sample plots. Samples from southern Mongolia differ from those of northern Mongolia (Hilbig & Koroljuk 2000), and sample plots often comprise a heterogeneous set of species which share a tolerance of moving substrates. Affinities to the Allietalia polyrrhizi are obvious, but with respect to the abundance of *Caragana* species (*C. leucophloea*, *C. bungei*, *C. korshinskii*, details in Wesche et al. 2005a, Rachkovskaja 1993) we tentatively place the community in the Caraganion rather than in the Allion (cf. Hilbig 2000).

4.4. Dry desert steppes: Stipo glareosae-Anabasietum brevifoliae and associated communities (Table 5, no. 1–4)

Hilbig (1995) mentions the low-growing shrub *Anabasis brevifolia* as one of the most widely distributed species of the Central Asian vegetation. With its small growth form it is typical for deflated pavements with a sealed, and therefore stable, surface; it avoids coarse sandy soils. It is the diagnostic species of the Stipo-Anabasietum, which is extremely widespread and includes several sub-associations. A low growing shrub layer (<50 cm) is common to all of them; otherwise the vegetation cover is lower than in other semi-desert communities. Stands were described from all regions of the southern Mongolian Gobi (Helmecke & Schamsran 1979, Jäger et al. 1985, Wesche et al. 2005b, Hilbig & Tungalag 2006, von Wehrden et al. 2006a, von Wehrden et al. 2006c) and adjacent regions in Inner Mongolia (Hou 1983). Kürschner (2004) recorded sample plots for Inner Mongolia but placed them in the Potaninio mongolicae-Sympegmetum regelii, which seems inconsistent in view of the total lack of *Potaninia mongolica*.

Stipo glareosae-Anabasietum brevifoliae, stipetosum gobicae sub-ass. nov. hoc loco (Table 5, no. 1)
Diagnostic species: *Stipa gobica* in addition to diagnostic species of the association
Nomenclature typus is relevé 6 in Table 4.
In the Dzungarian Gobi the Allion is rare and in hill regions it is replaced by the Stipo-Anabasietum. Steep slopes with ongoing physical erosion and undeveloped soils often host *Stipa gobica*, which differentiates a sub-association of the Allio-Stipetum as described above. In the Dzungarian Gobi *S. gobica* also differentiates a new locally common sub-association (see von Wehrden et al. 2006c). A higher abundance of both *Eurotia ceratoides* and *Ajania fruticulosa*, along with high species richness (see Fig. 8,

Table 5. Constancy table of the Anabasietum (no. 1–4), the *Convolvulus gortschakovii*-communities (no. 5–6) and the Artemisio sublessingianae-Nanophytetum erinacei (no. 7) of the southern Mongolian Gobi (for explanation of constancy classes see Table 2).

Unit	1	2	3	4	5	6	7
no of relevés.	13	152	56	77	13	10	22
ALLION POLYRRHIZI (ad 1)							
Stipa gobica	V	.	.	r			
Allium mongolicum	III	II	II	r	IV	.	IV
Allium polyrrhizum	II	II	II	II	I	.	.
Ajania fruticulosa	IV	II	II	+	II	.	IV
Dontostemon senilis	IV	II	II	+	.	.	II
Eurotia ceratoides	III	II	II	+	II	I	III
STIPO GLAREOSAE-ANABASIETUM BREVIFFOLIAE (1-4)							
Stipa glareosa	III	IV	V	IV	IV	IV	IV
Anabasis brevifolia	V	V	V	V	.	.	III
Convolvulus ammanii	+	+	r	+	.	I	II
Reaumuria songarica	.	.	V	V	II	.	I
Salsola passerina	.	I	.	V			
CONVOLVUS GORTSCHAKOVII COMMUNITY (5-6)							
Convolvulus gortschakovii	.	I	I	I	V	V	II
Lappula stricta	II	+	I	.	III	.	II
Salsola paulsenii	I	r	.	.	III	.	I
Bassia dasyphylla	.	+	.	r	III	.	+
Oxytropis aciphylla	.	I	+	I	+	IV	.
ARTEMISIO-NANOPHYTETUM ERINACEI (7)							
Nanophyton erinaceum	.	.	.	.	.	.	V
Artemisia sublessingiana	.	.	.	.	IV	.	V
COMPANIONS							
Ptilotrichum canescens	+	I	II	r	I	.	.
Ajania achilleoides	I	II	I	I	.	I	.
Sympegma regelii	I	II	II	II	I	.	.
Ephedra przewalskii	II	II	II	.	IV	II	III
Zygophyllum xanthoxylon	I	I	II	I	I	III	.
Zygophyllum neglectum	II	+	II	.	II	.	II
Cleistogenes songorica	II	II	I	II	+	.	.
Orostachys spinosa	I	r	I	.	.	.	.
Ptilagrostis pelliotii	II	II	I	I	.	.	.
Salsola arbuscula	I	+	I	+	II	II	I
Iris bungei	I	r	r	.	.	.	.
Arnebia fimbriata	I	+	r	.	.	.	.
Artemisia pycnorhiza	r	.	.	.	.	.	.
Bupleurum bicaule	r	.	r	.	.	.	.
Agropyron cristatum	+	.	r	r	.	.	.
Artemisia frigida	+	.	r	r	.	.	.
Achnatherum splendens	.	r	r	r	+	.	+
Chenopodium hybridum	+	.	.	.	.	.	.
Allium vodopjanovae	+	.	+	r	.	.	.
Ephedra sinica	+	r	r	.	.	.	.
Asterothamnus centrali-asiaticus	.	I	r	I	.	.	.
Heteropappus altaicus	+	+	r	r	.	.	.
Lagochilus ilicifolius	+	+	II	+	.	.	.
Scorzonera pseudodivaricata	+	+	+	r	II	.	.
Micropeplis arachnoidea	+	+	I	r	+	.	.
Nitraria sibirica	.	r	r	I	.	.	.
Nitraria sphaerocarpa	+	r	.	.	.	.	.
Aristida heymannii	+	r	.	.	.	.	.
Arnebia guttata	.	r	r	.	.	.	.
Artemisia caespitosa	.	r	I	r	.	.	.
Artemisia sublessingiana	+	I	II	.	.	.	.
Artemisia pectinata	+	r	r	+	.	.	.
Artemisia scoparia	.	+	I	+	.	.	.
Artemisia sphaerocephala	.	r	r	r	.	.	.
Asparagus gobicus	.	r	+	r	.	.	.
Astragalus monophyllus	.	+	I	.	I	.	II
Astragalus multicaulis	+	r	.	.	.	.	.
Astragalus vallestris	.	+	+	r	.	.	.
Cancrinia discoidea	II	+	I	.	.	.	.
Cleistogenes squarrosa	.	r	r	.	.	.	.
Crepis flexuosa	+	r	r	.	.	.	.
Dontostemon crassifolius	.	r	+	.	+	.	+
Echinops gmelinii	.	r	+	+	.	.	.
Enneapogon borealis	.	.	.	.	.	II	.
Ephedra intermedia	+	r	.	.	.	.	.
Erodium tibetanum	I	+	+	r	.	.	.
Goniolimon speciosum	+	r	r	.	II	.	I
Gypsophila dshungarica	+	r	.	.	.	.	.
Halogeton glomeratus	.	r	+	.	I	.	II
Haplophyllum dahuricum	I	r	r	.	.	.	.
Kaschgaria komarovii	I	r	.	.	.	.	.
Convolvulus ammanii	+	+	r	+	.	I	II
Panzeria lanata	+	r	r	.	.	.	.
Peganum nigellastrum	.	+	+	+	I	II	.
Potaninia mongolica	+	r	I	r	.	.	.
Rheum nanum	.	I	r	r	.	.	.
Salsola jacquemontii & collina	+	+	.	.	.	.	.
Salsola laricifolia	.	+	+	I	.	.	.
Salsola pestifera	.	r	r	r	.	.	.
Schizonepeta annua	.	r	.	r	.	.	.
Scorzonera capito	+	r	r	r	.	.	.
Scorzonera divaricata	.	r	r	r	.	.	.
Setaria viridis	+	r	.	.	.	.	.
Tougarinovia mongholica	.	r	r	.	.	.	.
Zygophyllum gobicum	.	r	r	.	.	.	.
Zygophyllum potaninii	.	+	r	.	.	.	.
Zygophyllum rosovii	.	+	I	r	.	.	.
Carex stenophylla	.	r	r	.	.	.	.
Iris tenuifolia	.	r	.	r	.	.	.
Amygdalus pedunculata	.	r	r	.	.	.	.
Artemisia xanthochroa	.	r	r	.	+	.	.
Artemisia xerophytica	.	r	r	.	+	.	.
Astragalus beitagensis	.	r	+	.	.	.	.
Astragalus brevifolius/junatovii	.	r	r	.	.	.	.
Astragalus grubovii	.	r	.	r	.	.	.
Dracocephalum foetidum	.	r	r	.	.	.	.
Krylovia eremophila	.	r	r	.	.	.	.
Lappula intermedia	.	r	r	.	.	.	.
Limonium aureum	.	r	r	.	.	.	.

ad 1: Elymus paboanus, Sibbadianthe adpressa
ad 2: Achnatherum inebrians, Amygdalus mongolica, Artemisia macrocephala, Astragalus sp., Astragalus brachybotrys/miniatus, Astragalus laguroides, Ceratocarpus arenarius, Chenopodium acuminatum, Chenopodium "album", Climacoptera affinis, Convolvulus arvensis, Corispermum mongolicum, Elymus chinensis, Ephedra glauca, Eragrostis minor, Erodium stephanianum, Euphorbia humifusa, Ferula bungeana, Gypsophila desertorum, Kochia cf. krylovii, Kochia iranica, Lepidium densiflorum, Oxytropis stenophylla, Plantago minuta, Potentilla ikonikovii, Saussurea dahurica, Saussurea pricei, Senecio dubitabilis, Stellaria amblyosepala, Stipa sp., Stipa orientalis, Tribulus terrestris, Zygophyllum pterocarpum
ad 3: Dontostemon elegans, Enneapogon borealis, Linum pallescens, Lycium ruthenicum, Salsola abrotanoides, Stellaria dichotoma
ad 4: Allium eduardii, Allium prostratum, Arenaria meyeri, Artemisia intricata, Atraphaxis frutescens, Caragana spec, Chesneya mongolica, Craniospermum mongolicum, Ephedra equisitina, Kalidium cuspidatum, Kalidium gracile, Limonium erythrorhizum
ad 5: Agropyron michnoi, Arnebia fimbriata, Arnebia guttata, Artemisia dracunculus, Asparagus gobicus, Asterothamnus centrali-asiaticus, Astragalus grubovii, Atraphaxis pungens, Atriplex sibirica, Calligonum junceum, Ceratocarpus arenarius, Chamaerhodos sabulosa, Chenopodium acuminatum, Chenopodium "album", Elymus chinensis, Panzeria lanata, Plantago minuta, Potentilla dealbata, Tribulus terrestris
ad 7: Astragalus baytagensis, Astragalus stenophyllus, Atraphaxis frutescens, Caragana leucophloea, Ceratocarpus arenarius, Cleistogenes squarrosa, Elymus angustus, Haloxylon ammodendron, Lappula intermedia, Orostachys spinosa, Peganum harmala, Rheum nanum, Salsola pestifera, Stellaria amblyosepala, Zygophyllum pterocarpum, Zygophyllum rosovii

no. 1; see also Fig. 9), indicates the distinct character of these stands and demonstrates the affinities to the Stipo-Allietum.

Stipo glareosae-Anabasietum brevifoliae, typicum (= *Convolvulus ammanii,* Hilbig 1990) (Table 5, no. 2)
Diagnostic species: *Stipa glareosa, Anabasis brevifoliae, Convolvulus ammanii*
The typical sub-association occurs on drier pediments and is perhaps the most widely distributed community in southern Mongolia. *Convolvulus ammanii* was proposed as a name-giving species but it is far from frequent in this sub-association (see also tables in Hilbig 1990, 1995) but we stated the established terminology for reasons of priority. *Allium mongolicum* and *A. polyrrhizum* are typical companions (Grubov 2000); the latter is however absent in the Dzungarian Gobi (Friesen 1995, von Wehrden et al. 2006c). In comparison to the previous sub-association, *Stipa gobica* is not present and is replaced by *S. glareosa*. Most of the abundant species are Central Asian elements. *Cleistogenes songorica* defines stands from the Gobi-Altay and further east, since it is a typical ele-

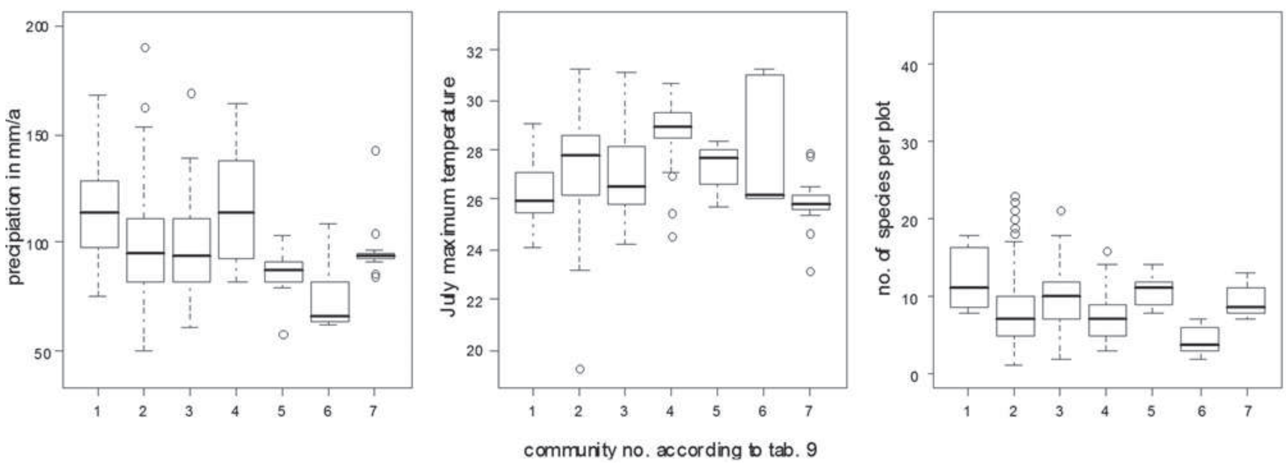

Fig. 8. Boxplots summarising the background information for the Anabasietum and associated communities; the y-labels follow Fig. 3, the x-labels Table 5.

Fig. 9. The reintroduced natural grazers *Equus przewalskii*, which were presumably extinct in the wild and are nowadays roaming the semi-deserts again. The vegetation in the picture is a comparably luxurious variant of the Stipo-Anabasietum in the Dzungarian Gobi.

ment of the "eastern" semi-desert (Zemmrich 2005). *Sympegma regelii* indicates drier sites of southern Mongolia and. This shrubby Chenopodiaceae is confined to the drier semi-deserts of the southern Mongolian Gobi. It therefore has only regional value for syntaxonomy, but it differentiates the southern Mongolian semi-deserts from the vegetation of central and northern Mongolia (von Wehrden et al. 2006a). It also demonstrates linkages westwards to the forelands of the Tien Shan and the outer surroundings of the Taklamakan (Grubov 2000).

Stipo glareosae-Anabasietum brevifoliae, *Reaumuria songarica* sub-association (Table 5, no. 3)
Diagnostic species: *Reaumuria songarica* in addition to diagnostic species of the association

Wherever salt contents in the soil are high, the low shrubby Tamaricaceae *Reaumuria songarica* becomes common. It can be seen as the most prominent indicator of (sub-) saline conditions in the region; and its leaves often show salt efflorescences. The median number of species is higher compared to the typical sub-association of the Stipo-Anabasietum, indicating a certain salt tolerance of the larger part of species in the region. The sub-association is commonly found on lower pediments (see Fig. 10). The differences from the following unit are rather slight, allowing for its inclusion into the *R. songarica* sub-association.

Stipo glareosae-Anabasietum brevifoliae, *Salsola passerina* variant of the *R. songarica* sub-association (Table 5, no. 4)
Diagnostic species: *Reaumuria songarica, Salsola passerina* in addition to diagnostic species of the association
In the lowlands of southern-central Mongolia, higher July temperatures and precipitation levels lead to increased effective evapotranspiration and more water is seasonally transported from lower soil horizons. *Salsola passerina* is commonly found on such spots, where it designates a variant of the *R. songarica* sub-association described before. The *Salsola passerina* variant is common at the lowest pediments and around salt pans, often bordering the extrazonal vegetation. There, it frequently mediates towards stands of the Salsolo passerinae-Reaumurietum soongoricae. Within the southern Mongolian Gobi stands are prominently found in the Alashan Gobi, where they were also recorded by Hilbig & Tungalag (2006). Kürschner (2004) characterised *S. passerina* as the most salt-tolerant species of the zonal semi-deserts of the northern Gobi and this is also indicated by personal measurements (Wesche et al. 2005b). The median number of species is comparable to the typical sub-association of the Stipo-Anabasietum described above.

4.5. *Convolvulus gortschakovii*-communities (Table 5, no. 5 & 6)

Diagnostic species: *Convolvulus gortschakovii*
The spiny shrub *C. gortschakovii* forms conspicuous vegetation types which are mainly found on sandy sites, though occasionally stony sites may be colonised as well (von Wehrden et al. 2006c, Wesche

Fig. 10. A drier variant of the Stipo-Anabasietum (*Reaumuria songarica* sub-association). These stands are typically found at the lower pediments, in this example in the southern Dzungarian Gobi.

et al. 2005b). Distribution, composition and environment of the stands all imply that two separable units occur in the southern Mongolian Gobi. The syntaxonomical status of both communities can not be clarified based on the available data. Both units should be included in the Caraganion, yet more data is needed in order to designate two distinct vicariating sub-associations. For the time being we have thus defined two geographical sub-communities.

Lappula stricta sub-community (Table 5, no. 5)
Diagnostic species: *Convolvulus gortschakovii, Lappula stricta*
This sub-community grows on micro-dunes and hills with some sand cover and is mainly found in the Dzungarian Gobi (von Wehrden et al. 2006c) and on the forelands of the Altay north of the Transaltay Gobi (von Wehrden et al. 2006a). The number of species per plot is comparably high, which may be due to the heterogeneous habitat and the higher precipitation gains compared to the next unit (Fig. 8, no. 5 & 6). Differential species are *Lappula stricta* and *Allium mongolicum* and to some extend the annual *Salsola paulsenii*, which may be absent in drought years (see Table 5, no. 5).

Convolvulus gortschakovii-community – *Oxytropis aciphylla* sub-community (Table 5, no. 6)
Diagnostic species: *Convolvulus gortschakovii, Oxytropis aciphylla*
In the eastern Gobi and the Alashan Gobi *Convolvulus gortschakovii* grows on sand, but also on the lower deflated pediments, where sample plots contain less than half the species (see Table 5, no. 6 & Fig. 8, no. 6) as the previous unit; in the basin of the Galbyn Gobi some stands were built by *C. gortschakovii* alone, and thus represent the lowest biodiversity of the zonal vegetation within the Alashan Gobi. *Oxytropis aciphylla* is a common companion.

4.6. Artemisio sublessingianae-Nanophytetum erinacei ass. nov. hoc loco (Table 5, no. 7)

Diagnostic species: *Nanophyton erinaceum, Artemisia sublessingiana*
Nomenclature typus is relevé 7 in Table 4.
Nanophyton erinaceum is a cushion plant and is thus a rather untypical Chenopodiaceae. The species is an Aralo-Caspian element (Meusel et al. 1965, Grubov 2000) and it reaches its easternmost distribution limit in Mongolia, where it is mostly restricted to the Uvs Nuur region and the Dzungarian depression (Hanelt 1970). Its low growth form restricts *Nanophyton erinaceum* from occurring on deflated sites to those that show no soil movement (see Fig. 11). In the Dzungarian Gobi the association forms a belt on the northern pediments surrounding the basin (Jäger et al. 1985). The proposal by Hilbig (2000) to include the *Nanophyton* stands from the Dzungarian Gobi into the Reaumurio soongaricae-Salsolion passerinae (see below) cannot be supported with our data. Stands in Hilbig (1990) were sampled near Bulgan (Khovd) just north of our study region; there, a

Fig. 11. Artemisio sublessingianae-Nanophytetum erinacei on the southern forelands of the Altay, where it is mainly restricted to the Dzungarian Gobi.

more pronounced salt content in the soil probably results in the presence of the association suggested by Hilbig (1990, 2000). However, our samples clearly show affinities to the Allion polyrrhizi, although *A. polyrrhizum* is largely replaced by *A. mongolicum* in the Dzungarian Gobi (von Wehrden et al. 2006c).

4.7. Calligono mongolici-Haloxyletum ammodendronis and Iljinietum regelii (Table 6)

The Saxaul, *Haloxylon ammodendron*, is the most eye-catching species of the southern Mongolian Gobi (Walter 1974). While *Anabasis brevifolia* widely dominates the middle and upper pediments and depends on a stable surface, *H. ammodendron* tolerates different grain sizes in the soils; even high shifting sand dunes are colonised by this species (see Fig. 12). Although it can become a tree, specimens in southern Mongolia rarely exceed two metres, and often form corkscrew-shaped shrubs. Helmecke & Schamsram (1979) describe the influence of grazing on the species' growth-form, which may also be modified by groundwater availability. Individuals often show a large fraction of dead wood, giving them a grazed appearance, and indeed both camels and goats were observed browsing Saxaul.

Hilbig (2000) named the Central Asian Saxaul association Calligono-Haloxyletum. A limited number of sample plots were available to validate this description, and our own records suggest that the name-giving *Calligonum mongolicum* is much rarer than anticipated. Moreover, the taxon has more recently been split into a number of separate species (Grabovskaya-Borodina 2004). We nonetheless maintain the original name to avoid confusion. The syntaxonomical status suggested by Hilbig (2000), i.e. placement in the Zygophyllo-Brachanthemetalia, is only weakly supported by our own data, since most species of the order and alliance are not abundant. The low number of co-abundant species (see Table 6, no. 1–3) renders a syntaxonomic placement of the stands somewhat difficult. Because

Table 6. Constancy table of the Calligono mongolici-Haloxyletum ammodendronis (no. 1–3) and the Iljinietum regelii (no. 4, for explanation of constancy classes see Table 2).

Unit	1	2	3	4
no. of relevés	15	68	88	32
CALLIGONO-HALOXYLETUM (1-3)				
Haloxylon ammodendron	V	V	V	r
REAUMURIA SONGARICA SUB-ASSOCIATION				
Reaumuria songarica	.	.	V	I
Nitraria sphaerocarpa	.	I	I	.
Micropeplis arachnoidea	.	I	III	I
ILJNIETUM REGELII (4)				
Iljinia regelii	.	.	.	V
COMPANIONS				
Anabasis brevifolia	.	I	I	I
Stipa glareosa	.	I	I	r
Allium mongolicum	.	+	I	.
Ephedra przewalskii	.	I	II	I
Zygophyllum xanthoxylon	.	I	I	+
Salsola arbuscula	.	+	II	.
Sympegma regelii	.	I	I	I
Calligonum mongolicum	.	+	r	I
Bassia dasyphylla	.	I	I	+
Eurotia ceratoides	.	+	II	r
Artemisia scoparia	.	II	r	I
Cancrinia discoidea	.	r	I	I
Artemisia macrocephala	.	r	r	.
Carex stenophylla	.	+	r	.
Ptilotrichum canescens	.	+	r	.
Lappula stricta	.	.	II	.
Artemisia xanthochroa	.	r	.	r
Ajania fruticulosa	.	r	I	r
Caragana leucophloea	.	r	+	r
Ephedra sinica	.	r	r	.
Salsola passerina	.	+	+	.
Convolvulus gortschakovii	.	r	I	.
Allium polyrrhizum	.	+	r	.
Scorzonera pseudodivaricata	.	r	+	.
Zygophyllum neglectum	.	.	I	.
Lycium ruthenicum	.	r	+	.
Nitraria sibirica	.	+	+	.
Arnebia fimbriata	.	+	r	r
Arnebia guttata	.	r	r	+
Artemisia gobica	.	r	I	.
Artemisia sphaerocephala	.	+	r	r
Astragalus brachybotrys/miniatus	.	r	r	.
Astragalus monophyllus	.	r	r	.
Dontostemon senilis	.	r	.	r
Erodium tibetanum	.	r	+	.
Halogeton glomeratus	.	.	I	.
Kochia cf. krylovii	.	r	+	.
Peganum nigellastrum	.	.	r	r
Potaninia mongolica	.	+	r	.
Ptilagrostis pelliotii	.	r	r	.
Rheum nanum	.	r	r	r
Salsola collina	.	+	r	r
Salsola paulsenii	.	r	I	.
Tribulus terrestris	.	r	r	r
Zygophyllum gobicum	.	r	.	r
Zygophyllum potaninii	.	+	r	r
Zygophyllum pterocarpum	.	r	r	+
Zygophyllum rosovii	.	r	I	.

ad 1: Anabasis elatior, Astragalus grubovii , Astragalus laguroides, Alyssum obovoatum, Artemisia implicata , Artemisia anethifolia, Artemisia xerophytica, Asparagus gobicus, Astragalus brevifolius/junatovii, Chenopodium prostratum, Craniospermum mongolicum, Dontostemon elegans, Echinops gmelinii, Enneapogon borealis, Glycyrrhiza uralensis, Kalidium gracile, Limonium erythrorhizum, Oxytropis aciphylla, Phragmites communis, Salsola laricifolia, Salsola pestifera, Sophora alopecuroides, Stipa gobica
ad 2: Allium vodopjanovae, Ajania achilleoides, Anabasis aphylla, Anabasis elatior, Anabasis truncata, Artemisia caespitosa, Artemisia pectinata, Asterothamnus centrali-asiaticus, Astragalus baitagensis, Astragalus grubovii, Astragalus vallestris, Atraphaxis frutescens, Atraphaxis pungens, Calligonum junceum, Caryopteris mongholica, Ceratocarpus arenarius, Chamaerhodos sabulosa, Chenopodium prostratum, Chesneya mongholica, Cleistogenes songorica, Clematis fruticosa, Convolvulus ammanii, Corispermum mongolicum, Dontostemon crassifolius, Goniolimon speciosum, Halerpestes salsuginosa, Halimodendron halodendron, Heteropappus altaicus, Kalidium cuspidatum, Kalidium foliatum, Kochia iranica, Kochia melanoptera, Kochia prostrata, Lagochilus ilicifolius, Lepidium densiflorum, Limonium suffruticosum, Orostachys spinosa, Oxytropis aciphylla, Phragmites communis, Scorzonera divaricata, Setaria viridis, Stipa breviflora, Suaeda corniculata

of the priority system and in favour of conformity of classification we decided to leave the association in the order of the Zygophyllo xanthoxyli-Brachanthemetalia gobici.

Calligono mongolici-Haloxyletum ammodendronis, mono-dominant stands (Table 6, no. 1)
Diagnostic species: *Haloxylon ammodendron*

This association is exclusively built by the Saxaul, and it lacks any accompanying species. Most stands were found in the driest parts of the region (e.g. the southern Alashan Gobi and the lower Transaltay Gobi, see Fig. 13, no. 1). The soil parameters are variable, yet sandy sites or even small dunes are the most frequent habitat. Almost all stands were sampled at a great distance from the nearest human settlements and their livestock. Any influence from grazing can therefore only be attributed to wildlife, and harshness of the climate is the most likely reason for explaining the paucity of those stands.

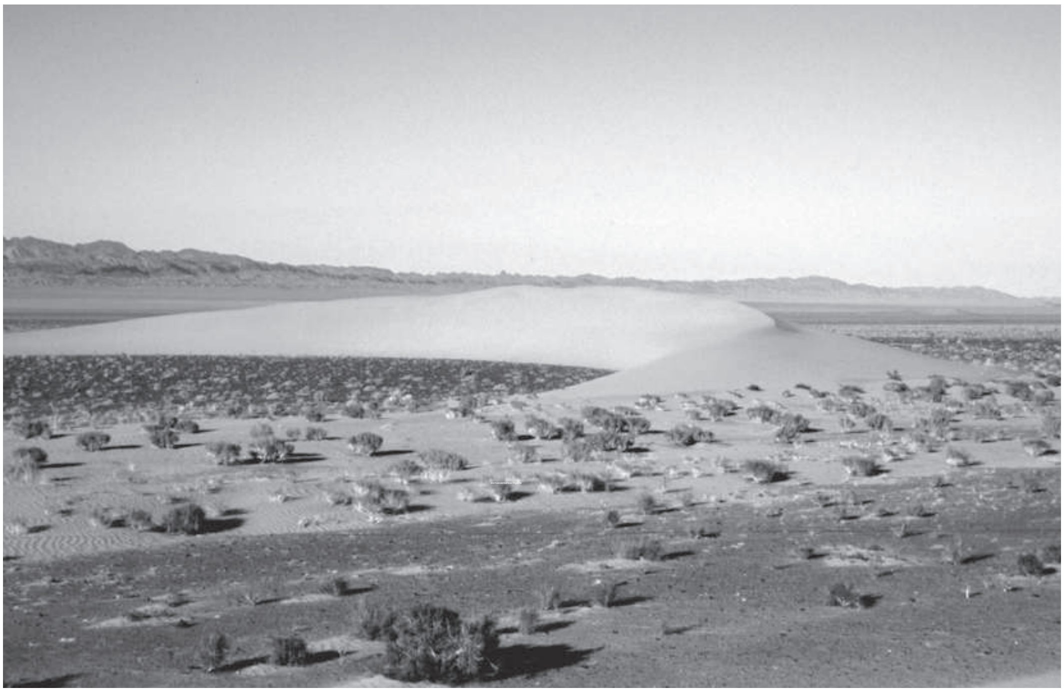

Fig. 12. Sand dune surrounded by *Haloxylon ammodendron* stands. Note the height of the shrubs on the sandy spot in the centre of the picture.

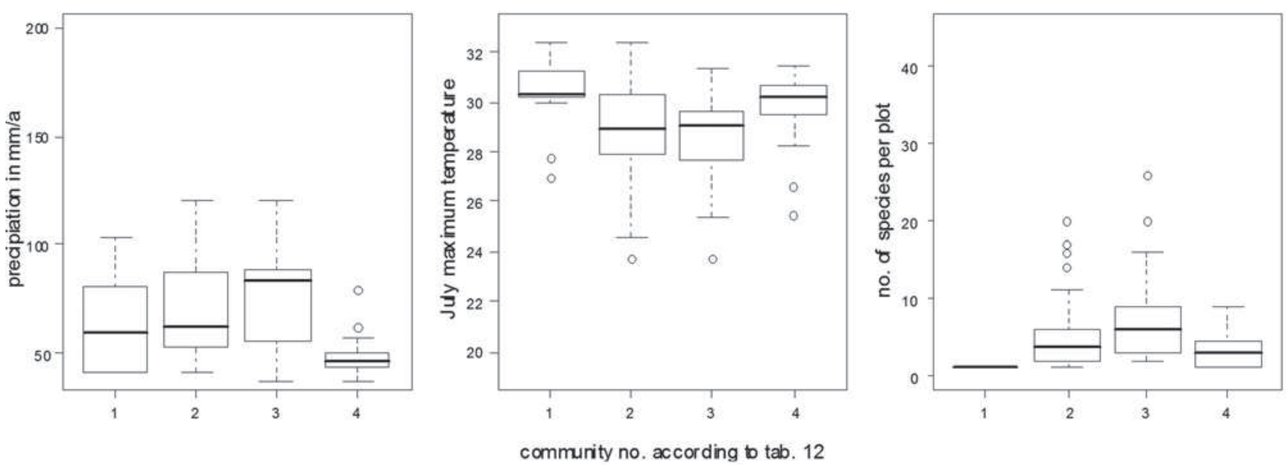

Fig. 13. Boxplots summarising the background information for the Haloxyletum and the Iljinetum; the y-labels follow Fig. 3, the x-labels Table 6.

Calligono mongolici-Haloxyletum ammodendronis typicum (Table 6, no. 2)
Diagnostic species: *Haloxylon ammodendron*
In the Transaltay Gobi the typical sub-association is often accompanied by *Sympegma regelii* (von Wehrden et al. 2006a). A slightly higher salt content in the soils is indicated by the presence of *Nitraria sphaerocarpa*, which mainly occurs in the drier Alashan Gobi and the Transaltay Gobi (von Wehrden et al. 2006a). In rainy years, Saxaul stands also host annuals which are more typical of the drier semi-deserts such as *Bassia dasyphylla* and *Micropeplis arachnoidea*. In addition, the sub-association contains a high and variable number of accompanying species, which often indicates transitional stages; e.g. *Anabasis brevifolia* may join Saxaul on pediment sites.

Calligono mongolici-Haloxyletum ammodendronis, *Reaumuria songorica* sub-association (Table 6, no. 3)
Diagnostic species: *Reaumuria songorica* in addition to the diagnostic species of the association
Reaumuria songarica differentiates a distinct sub-association on saline sites as it does in other communities described above. *Ephedra przewalskii* occurs in Saxaul stands from the western Gobi Altay to the Dzungarian Gobi (von Wehrden et al. 2006b, von Wehrden et al. 2006c), indicating rare but strong episodic rainfalls which result in surface flow and soil movement. Stands of the Calligono-Haloxyletum reaumurietosum thus receive slightly more moisture than the typical sub-association (see Fig. 13, no. 3), which is also indicated by the presence of *Eurotia ceratoides* and *Lappula stricta* as well as the overall higher species richness. Some of the typical species are restricted to the Dzungarian Gobi, such as *Cancrinia discoidea* and *Halogeton glomeratus*. Similar stands from Inner Mongolia are described by Kürschner (2004), and Hilbig (2000). The *Nitraria sphaerocarpa* sub-association described from the Transaltay Gobi (von Wehrden et al. 2006a) may be included here if one considers a Gobi-wide perspective; but more data is needed to confirm the status of the as yet only regionally described sub-association.

Iljinietum regelii ass. nov. hoc loco (Table 6, no. 4)
Diagnostic species: *Iljinia regelii*
Nomenclature typus is relevé 8 in Table 4.
This low woody Chenopodiaceae is probably the most drought-adapted perennial plant occurring in Mongolia (see precipitation values in Fig. 13, no. 4), if not in the whole Central Asian zone. Within Mongolia it is mainly found in the Transaltay Gobi and in the neighbouring regions of northern China. It is restricted to the driest sites (including the western Gobi-Altay, the lower Dzungarian Gobi and the lowland basins of the Alashan Gobi) where the community is most widespread on the lowest pediments and depressions (von Wehrden et al. 2006a). Total cover of the stands is extremely low, mostly less than 1 %, demonstrating that these are true deserts with contracted vegetation and often only one plant individual per 100 m²-plot. After episodic rainfalls annuals such as *Micropeplis arachnoidea* may nonetheless become abundant.

Where mean annual rainfall drops below a mere 40 mm/a, and is presumably absent for years, even *Iljinia regelii* becomes restricted to small catchment sites and drainage lines. The strong evaporation is indicated by massive gypsum layers below the topsoil, and on one sample site *I. regelii* grew on almost pure gypsum. On somewhat wetter sites cover may increase and stands show affinities to semi-desert associations, namely the Stipo-Anabasietum and the Calligono-Haloxyletum. We have designated a new association, which belongs to the alliance Reaumurio soongoricae-Salsolion passerinae.

4.8. Dry scrub vegetation: Ephedro-Zygophylletum, Salsolo-Reaumourietum, Nitrario-Kalidetum and associated communities (Table 7)

Dry riverbeds or *sayrs* in the southern Mongolian Gobi are often defined by their heterogenous species set, rendering syntaxonomical assessments difficult. Only a few species characterise these habitats throughout the entire region, among them *Eurotia ceratoides, Zygophyllum xanthoxylon, Amygdalus* spp., *Salsola arbuscula and Asterothamnus centrali-asiaticus*. All of these may also occur within the surrounding zonal vegetation. Locally, sites have become saline, and scrubs of moderately saline sites are thus treated together with the *sayr* vegetation.

Ephedro przewalskii-Zygophylletum xanthoxyli ass. nov. hoc loco typicum (Table 7, no 1)
Diagnostic species: *Ephedra przewalskii, Zygophyllum xanthoxylon*
Nomenclature typus is relevé 9 in Table 4.
The association occurs in the Alashan Gobi and rarely in the drier parts of the Gobi Altay as well. Most sample plots were sampled on the pediments of the Atas Bogd and the Tsagaan Bogd, which are the two highest mountain ranges in the Transaltay Gobi. Both name-giving species are typical for dry riverbeds that experience strong substrate movement during episodic rainfalls. The presence of *Reaumuria songarica* hints at a higher salt content (von Wehrden et al. 2006a). Stands have so far been described as a rankless community (Hilbig 2000), but as our extended data set implies that the presence of *E. przewalskii* is sufficiently characteristic, we describe a new association within the Zygophyllo xanthoxyli-Brachanthemion gobici. These stands include the Eurotio ceratoides-Zygophylletum xanthoxyli from Hilbig (2000), because *Eurotia ceratoides* has a wide ecological range in the southern Mongolian Gobi and cannot serve as an association character species. In contrast, the distribution of *Ephedra przewalskii* is

Table 7. Constancy table of the scrub vegetation of erosion gullies and saline sites of the southern Mongolian Gobi (for explanation of constancy classes see Table 2).

Unit	1	2	3	4	5	6	7	8	9	10
no. of relevés	17	25	6	9	23	35	17	12	13	6
EPHEDRO-ZYGOPHYLLETUM (1-3)										
Ephedra przewalskii	IV	IV	IV	.	.	.	+	.	.	.
Zygophyllum xanthoxylon	III	III	I	IV	+	I	+	.	.	+
SYMPEGMETOSUM REGELII (2)										
Sympegma regeli	+	V	.	+	II	II	+	I	.	.
NITRARIETOSUM ROBOROVSKII (3)										
Nitraria roborovskii	.	.	V	.	.		.	.		.
CARAGANA TIBETICA-AMMOPIPTANTHUS MONGOLICUS COMM. (4)										
Ammopiptanthus mongolicus	.	.	.	IV	.	.	.	.	.	.
Caragana tibetica	.	.	.	III	.	.	.	.	.	.
SALSOLO-REAUMURIETUM (5-7)										
Reaumuria soongorica	III	II	IV	II	V	V	V	V	.	I
Salsola passerina	.	.	.	II	V	V	.	V	+	.
Nitraria sphaerocarpa	I	.	.	III	.	V	III	+	.	.
NITRARIO-KALIDIETUM (8-10)										
Nitraria sibirica	+	.	.	I	+	+	II	III	V	IV
Kalidium gracile	.	.	.	.	.	.	II	V	+	III
Peganum nigellastrum	.	I	.	II	r	I	I	I	III	I
Kalidium foliatum	.	.	.	.	.	.	I	+	.	I
Phragmites communis	.	.	.	.	.	.	.	.	.	V
Achnatherum splendens	.	.	.	+	+	.	+	+	II	III
COMPANIONS										.
Achnatherum inebrians	+	.	.	.	.	.	.	.	.	.
Bassia dasyphylla	.	+	.	.	r	.	r	.	.	+
Micropeplis arachnoidea	.	r	.	+	r	+	.	.	+	I
Elymus chinensis	+	.	.	.	.	.	r	.	+	I
Stipa glareosa	+	II	.	II	I	II	+	.	+	.
Anabasis brevifolia	.	.	.	I	.	II	+	+	.	.
Allium polyrrhizum	.	r	.	.	r	.	r	.	.	.
Oxytropis aciphylla	.	r	.	+	+	.	.	.	+	.
Ajania fruticulosa	.	III	.	.	.	.	.	.	.	+
Asterothamnus centrali-asiaticus	+	I	.	.	r	+	.	+	+	+
Allium mongolicum	.	r	.	.	.	.	.	.	.	.
Ajania achilleoides	.	.	.	r	+	+	r	.	.	.
Convolvulus gortschakovii	.	.	.	.	.	II	.	.	.	.
Calligonum mongolicum	I	I	.	+	.	.	r	.	.	.
Cleistogenes songorica	+	r	.	+	I	+	.	+	+	.
Dontostemon crassifolius	.	II	.	.	.	.	.	.	.	.
Allium prostratum	.	.	.	.	+	.	.	.	.	.
Scorzonera pseudodivaricata	.	I	.	.	.	.	.	.	+	+
Lycium ruthenicum	.	.	.	.	+	.	.	.	+	.
Arnebia guttata	.	I	.	.	.	.	.	.	.	.
Astragalus brevifolius/junatovii	.	.	.	+	.	.	.	.	.	.
Agriophyllum pungens	.	.	.	I	.	.	.	.	.	.
Caragana leucophloea	.	.	.	I	.	.	.	.	.	.
Artemisia implicata	.	r	.	.	.	.	+	.	.	.
Artemisia pectinata	+	.	.	.	.	.	.	+	+	.
Artemisia scoparia	.	I	.	.	r	.	.	.	.	.
Artemisia xanthochroa	+	.	.	I	.	.	r	.	+	.
Atraphaxis pungens	+	r	.	.	.	.	.	.	.	I
Atriplex sibirica	+	.	.	.	.	.	.	.	I	.
Enneapogon borealis	+	.	.	.	.	+	.	.	+	.
Limonium aureum	.	r	.	.	.	.	+	.	.	.
Ptilagrostis pelliotii	.	+	.	.	.	I	.	.	.	.
Salsola laricifolia	.	r	.	I	.	+	.	.	.	.
Salsola jacquemontii & collina				+						+
Setaria viridis	.	r	.	.	.	.	.	.	+	.
Polygonum aviculare	.	.	.	.	.	.	.	.	I	.

ad 1: Artemisia macrocephala, Chenopodium hybridum, Kochia melanoptera, Allyssum desertorum, Heteropappus altaicus, Zygophyllum rosovii, Salsola paulsenii, Zygophyllum gobicum, Chenopodium "album"
ad 3: Artemisia dracunculus, Ephedra glauca, Stipa gobica, Zygophyllum potaninii, Zygophyllum pterocarpum
ad 4: Artemisia xerophytica, Atraphaxis frutescens, Echinops gmelinii, Eurotia ceratoides, Ptilotrichum canescens, Scorzonera divaricata, Setaria viridis
ad 5: Artemisia gobica, Artemisia sp., Artemisia sphaerocephala, Convolvulus arvensis, Cynomorium songaricum, Iris lactea, Lactuca tatarica, Scorzonera divaricata
ad 6: Amygdalus pedunculata, Arnebia fimbriata, Asparagus gobicus, Caragana leucophloea, Haloxylon ammodendron, Lagochilus ilicifolius, Lepidium densiflorum, Orobanche coerulescens, Salsola pestifera
ad 7: Artemisia caespitosa, Dontostemon senilis, Iris bungei
ad 8: Echinops gmelinii
ad 9: Convolvulus ammanii, Iris tenuifolia, Kalidium cuspidatum, Limonium tenellum
ad 10: Artemisia sp., Asparagus gobicus, Calligonum mongolicum, Carex sp., Elymus angustifolius, Elymus secalinus, Elymus sibiricus, Halimodendron halodendron, Iris bungei, Iris tenuifolia, Kalidium cuspidatum, Lactuca tatarica, Lepidium densiflorum, Orobanche coerulescens, Puccinellia hauptiana, Saussurea davurica, Suaeda corniculata, Scorzonera sp., Taraxacum cuspidatum

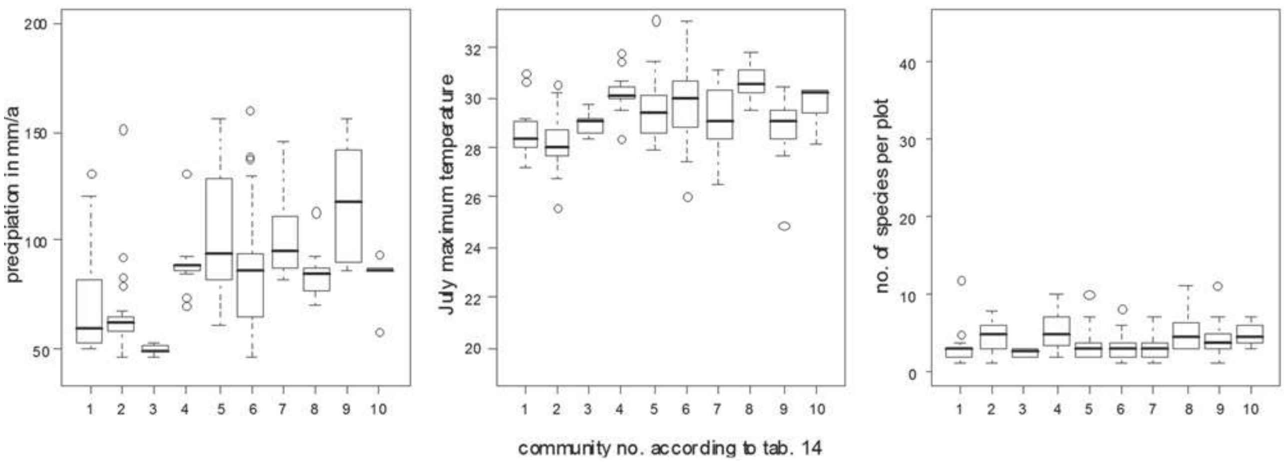

Fig. 14. Boxplots summarising the background information for scrub vegetation on erosion gullies and saline sites; the y-labels follow Fig. 3, the x-labels Table 7.

comparably well defined and restricted to drier semi-desert ravines and pediments.

Ephedro przewalskii-Zygophylletum xanthoxyli, sympegmetosum regelii sub-ass. nov. hoc loco (Table 7, no. 2)
Diagnostic species: *Sympegma regelii* in addition to the diagnostic species of the association
Nomenclature typus is relevé 10 in Table 4.
Stands of this regional sub-association receive only limited rain (see Fig. 14, no. 2), and the dryness is also underlined by the abundance of *Sympegma regelii* (see also von Wehrden et al. 2006a). The shrub-layer grows up to one metre in height, yet the vegetation covers generally less than 10 % with median cover being much lower (3 %, see von Wehrden & Wesche 2007).

Overall, the Ephedro-Zygophylletum takes an intermediate position (von Wehrden et al. 2006a); stands link-up between the semi-deserts of higher elevations with higher species richness and the drier semi-deserts, which are mainly dominated by *Haloxylon*. In contrast to earlier proposals, we have now come to the conclusion that the presence of *Amygdalus mongolica* and *A. pedunculata* is of limited syntaxonomical value. Several associations were described such as the Amygdalo pedunculatae-Caraganetum leucophloeae and partly the Eurotio ceratoidis-Zygophylletum xanthoxyli (see Wesche et al. 2005, Hilbig 2000 and Hilbig & Tungalag 2006). Both species are indeed common along dry riverbeds, especially in the Bordzongijn Gobi (Hilbig & Tungalag 2006); but sample plots with Almonds in our dataset apparently belonged to the Caraganion, the Stipo-Anabasietum and the Ephedro przewalskii-Zygophylletum xanthoxyli. Further notes on the transitory character of these stands are provided by Kürschner (2004) for the Chinese Alashan Gobi.

Ephedro przewalskii-Zygophylletum xanthoxyli, nitrarietosum roborovskii sub-ass. nov. hoc loco (Table 7, no. 3)
Diagnostic species: *Nitraria roborovskii* in addition to the diagnostic species of the association
Nomenclature typus is relevé 11 in Table 4.
On the lower pediments of the Transaltay mountain ranges, *Nitraria roborovskii* occurs and differentiates a sub-association of the *Ephedro-Zygophylletum*. The salinity is more pronounced, as indicated by the presence of *Reaumuria songarica*; and the precipitation is overall lower compared to the previous units (see Fig. 14, no. 3). Only six sample plots were sampled, which do however compare well to data given by Rachkovskaya & Volkova (1977).

Caragana tibetica-Ammopiptanthus mongolicus community (Table 7, no. 4)
Diagnostic species: *Ammopiptanthus mongolicus, Caragana tibetica*
Caragana tibetica is a conspicuous and comparatively large (up to 2 m and more) spiny shrub; *Ammopiptanthus mongolicus* achieves the same size. Both species are characteristic for, and mainly restricted to, the Alashan Gobi (Ge et al. 2005, Wang 2005), where they are typically growing in dry ravines and riverbeds but may also be found, on occasion, in sandy semi-deserts. The relatively high levels of salt in the soil are indicated by introgressives from the surrounding vegetation such as *Nitraria sphaerocarpa, Nitraria sibirica, Salsola passerina* and *Reaumuria songarica*. Stands of *Amygdalus mongolicus* in the Inner Mongolian part of the Alashan Gobi were previously defined as a distinct community (Kürschner 2004), but the low number of available sample plots makes a definitive assessment difficult.

Salsolo passerinae-Reaumurietum songaricae (Table 7, no. 5)

Diagnostic species: *Reaumuria soongorica, Salsola passerina*
This association represents some of the driest aspects of the vegetation of the Gobi-Altay (Hilbig 2000, Wesche et al. 2005b, von Wehrden et al. 2006b), where it is often found around flat depressions. At lower elevations, especially in the Galbyn Gobi region in south-eastern Mongolia, the presence of *Sympegma regelii* underlines the arid Central Asian distribution of this association.

With increasing salinity, habitat conditions become intolerable for semi-desert species such as *Anabasis brevifolia*, *Caragana leucophloea* and *Stipa glareosa*. Typical salt adapted species define the vegetation on these sites, and *Reaumuria songarica* and *Salsola passerina* have been described as character species of a distinct association. At least temporal dryness of sites is indicated by salt efflorescences on the soil surfaces, testifying to the ascending soil water movement. The vegetation cover may increase towards oases and other sites with a higher water surplus. The point distribution map of *Salsola passerina* provided by Grubov (2000) indicates that it occurs also in Middle Asia; in the Dzungarian Gobi the species is however absent.

Salsolo passerinae-Reaumurietum songaricae, nitrarietosum sphaerocarpae sub-ass. nov. hoc loco (Table 7, no. 6)
Diagnostic species: *Nitraria sphaerocarpa* in addition to the diagnostic species of the association
Nomenclature typus is relevé 12 in Table 4.
In the Eastern Gobi and the Alashan Gobi the stands of the previous unit occur on saline sites, where they hardly grow higher than 0.5 metre. However, in the lower Bordzongijn Gobi salinisation appears to be a strong determining factor (see the comparably high July temperature in Fig. 14, no. 6). These stands are often accompanied by *Nitraria sphaerocarpa*, which we placed in a new sub-association (see Fig. 15); which includes stands of Hilbig's (2000) former *Reaumuria songarica-Nitraria sphaerocarpa* community. Some accompanying species such as *Anabasis brevifolia, Stipa glareosa* and *Convolvulus gortschakovii* are introgressive species from neighbouring vegetation units.

Salsolo passerinae-Reaumurietum songaricae, nitrarietosum sphaerocarpae – western regional variant (Table 7, no. 7)
Diagnostic species: *Reaumuria soongorica, Nitraria sphaerocarpa*

Fig. 15. Dry stand of the Salsolo passerinae-Reaumurietum soongaricae nitrarietosum close to the Chinese-Mongolian border in the Bordzongijn Gobi.

This unit is distributed throughout the drier parts of the Transaltay (Hilbig 2000, von Wehrden et al. 2006a) and Alashan Gobi (Kürschner 2004), and partly includes the *Reaumuria songarica-Nitraria sphaerocarpa* community (von Wehrden et al. 2006a). The vegetation cover varies with precipitation, but never reaches more than 10% (not considering annuals, which vary strongly in abundance with the given year's precipitation). The unit replaces the previous one in the lowlands of the Transaltay depression, where it was recorded by von Wehrden et al. (2006a), and reaches its eastern distribution limit in the driest south-western Bordzongijn Gobi. We include this unit in the Salsolo passerinae-Reaumurietum soongoricae although *Salsola passerina* is absent. This has a chorological background, since *S. passerina* does not occur in the western Mongolian Gobi where the respective sample plots were taken. Due to the presence of *Nitraria sphaerocarpa* and the other typical species the stands were nevertheless fit into the Salsolo-Reaumurietum songaricae nitrarietosum sphaerocarpae. The occasional presence of *Nitraria sibirica* and *Kalidium gracile* indicates transitions to the following unit.

Nitrario sibiricae-Kalidietum gracilis (Table 7, no. 8)
Diagnostic species: *Nitraria sibirica, Kalidium gracile*
This association is common in saline depressions in all study areas, and has repeatedly been described before (Helmecke & Schamsran 1979, Hilbig 1995). The vegetation cover differs depending on the varying levels of salt and water accumulation (Fig. 16). Shrubs dominate in terms of cover and species composition; *Peganum nigellastrum* is the only reasonably abundant herbaceous species, presumably indicating disturbance. On extremely saline sites within the lowermost depressions a few stands were found that contained both *Kalidium gracile* and *Kalidium foliatum*. These have been tentatively included into this association, but assignment to a different unit (Salsolo passerinae-Kalidietum foliati, Hilbig 2000) may prove justified if more data becomes available.

Nitraria sibirica community (Table 7, no. 9)
Diagnostic species: *Nitraria sibirica*
This community is found throughout the entire southern Mongolian Gobi. *Nitraria sibirica* forms characteristic large nebkhas around saline sites in depressions and lowlands, where it often grows as high as three metres (Fig. 17). These nebkhas depend on aeolian sand input for growth, but *Nitraria sibirica* also needs access to groundwater; salinity levels are thus often high (Wesche et al. 2005b). Disturbance indicators such as *Achnatherum splendens* and *Peganum nigellastrum* are the most abundant companions. Several of the described character species are rare, (e.g. *Cynomorium songaricum*, *Salsola passerina*, see also Hilbig 2000), and we are presently not certain whether earlier proposals (Salsolo passerinae-Nitrarietum sibiricae, Hilbig 2000) will prove valid.

Fig. 16. Typical salt-adapted shrub vegetation (Nitrario sibiricae-Kalidietum gracilis) in a salt pan in the Gobi Gurvan Saykhan. On the left a small A*chnatherum* bunch can be seen.

Nitrario sibiricae-Kalidietum gracilis, *Phragmites communis* variant (Table 7, no. 10)
Diagnostic species: *Nitraria sibirica, Kalidium gracilis, Phragmites communis*
Several large reed beds were found in the working area; although most were small, some form impressive stands covering more than a square kilometre. These stands are often dominated by *P. communis*, which grows as high as three metres (see Fig. 18). Mono-dominant stands of *Phragmites communis* (= Phragmitetum communis) rarely occur in the Gobi (Wesche et al 2005b, von Wehrden et al.

Fig. 17. *Nitraria sibirica* community bordering the dune belt of Khongorijn Gol in the Gobi Gurvan Saykhan; the *Nitraria*-hummocks are up to one meter in height at this locality.

Fig. 18. *Phragmites* belt in the Transaltay Gobi. The dark stands on the left are *Populus diversifolia* trees.

2006a) and are not provided in this table; positions can be obtained from the corresponding author on request. On the edge of these reed-beds, transitional stages towards *Nitraria*-stands were recorded, within which *P. communis* grows only a few centimetres in height due to the high salinity, which indicates a variant of the Nitrario-Kalidietum.

Ephemeral vegetation of true deserts
The climatically most extreme sites, mostly in the Transaltay Gobi below some 1500 metres NN, are completely devoid of permanent vegetation. Locally, dried individuals of *Micropeplis arachnoidea* testified to the temporary development of annuals following heavy rains. Such stands can hardly be regarded as a plant community, and if anything, form a rankless unit (see also von Wehrden et al. 2006a).

4.9. Vegetation of saline water-surplus sites: *Ulmus pumila* community, Populetum euphraticae, Blysmetum rufi and associated vegetation types

At water accumulation sites, typical azonal formations are found which benefit from the water surplus, but which also have to be salt-tolerant due to the high evaporation in the Gobi desert (Fig. 19). Stands are physiognomically quite distinct from the zonal vegetation, and dense meadows and even high trees grow at the innermost parts of oases. Some sites contain introgressive species of the zonal vegetation, while others comprise completely azonal vegetation. Such water-surplus sites are found under various conditions:

- Depressions are the most typical habitat of salt-tolerant vegetation in the Mongolian Gobi. The endorheic discharge regime results in salt pans or oases being formed in almost all the larger basins.
- The rivers running down from the Altay´s main thrust into the Dzungarian Depression and the Transaltay Gobi represent particular regional features. Since the Altay peaks at some 4000 metres asl., catchments are large and the outgoing rivers reach as far as the lowest depressions of the Dzungarian Gobi. Most of the water flows as groundwater seepage; but the forelands of the Altay support several river oases.
- Geological horizons with a sandy matrix may serve as aquifers and transport groundwater over large distances. Where they reach the surface, extensive oases can form, often in the forelands of larger mountain systems where the water originates. Such oases are found north of the Gobi Altay as well as in the Bordzongijn Gobi (Gunin et al. 1999).
- Extensive sand dunes trap rainfall; the water percolates rapidly downwards into the sandy substrat where it is protected from evaporation. Once the fine-texture pediment surface is reached, water moves laterally and accumulates on the edge of the sand field. There, oases are found; the most prominent examples being the huge oases on the northern border of the high dunes of Khongorijn Gol (see Fig. 17).
- On a smaller scale, intramontane basins or small catchments may form tiny water-surplus habitats often only few dozen metres squared in extent. These are common, even in the driest parts of southern Mongolia.

Ulmus pumila community (Table 8, no. 1)
Diagnostic species: *Ulmus pumila*
The Siberian Elm is an east-Asiatic element (Hilbig & Knapp 1983) and elm trees are relatively common in the dry south-eastern Mongolia. The westernmost distribution limit in our working area is reached in the southern Gobi-Altay; they may also occur as far westwards as the Tien Shan in northern China. A few stands were found in the Gobi-Altay, often comprising only single individuals. Toward the east, with the more pronounced influence of the monsoon (see Fig. 2) the number of elm trees increases; in the Small Gobi B strictly protected area thousands of

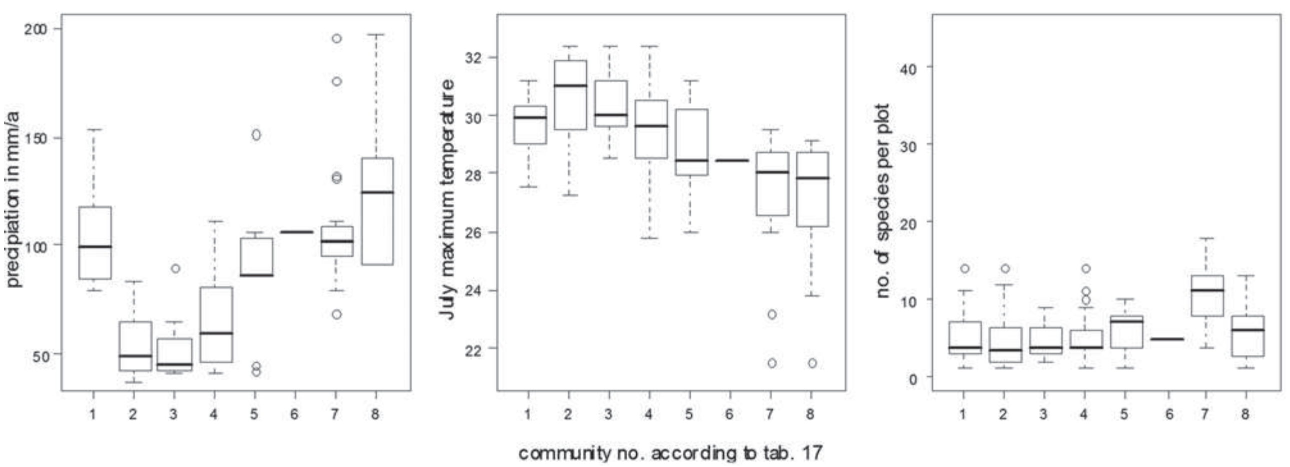

Fig. 19. Boxplots summarising the background information for salt-tolerant vegetation; the y-labels follow fig. 3, the x-labels table 8

Table 8. Constancy table for vegetation of saline sites (for explanation of constancy classes see Table 2).

Unit	1	2	3	4	5	6	7	8
no. of relevés	29	16	11	29	9	1	19	16
NITRARIO-KALIDIETUM – PHRAGMITES VARIANT								
Nitraria sibirica	II	II	II	II	II	.	+	.
Kalidium gracile	+	+	.	r	I	.	.	.
Kalidium foliatum	.	.	.	+	.	.	I	.
Phragmites communis	r	II	II	II	IV	.	II	.
ULMUS PUMILA COMMUNITY (1)								
Ulmus pumila	V	.	.	.	.	.	.	.
Ulmus pumila shrub	II	.	.	.	.	.	.	.
GLYCYRRHIZO-POPULETUM COMMUNITY (2-3)								
Populus diversifolia	.	V	V	.	.	.	.	.
Populus diversifolia shrub	.	II	I	.	.	.	.	.
Glycyrrhiza uralensis	.	+	I	I	.	.	.	.
TAMARIX RAMOSISSIMA COMMUNITY (4)								
Tamarix ramosissima	r	.	V	V	.	.	.	.
Reaumuria soongorica	I	III	III	II	.	.	.	.
SALICORNIA EUROPAEA COMMUNITY (5)								
Salicornia europaea	.	.	.	.	V	1	.	.
CRYPSIETUM ACULEATAE (6)								
Crypsis aculeate	.	.	.	.	.	1	.	.
Suaeda corniculata	.	.	.	.	.	1	I	.
Suaeda glauca	.	.	.	.	.	1	.	.
BLYSMETUM (7)								
Triglochin maritimum	.	.	.	r	III	.	IV	.
Halerpestes salsuginosa	.	.	.	.	II	.	IV	.
Glaux maritima	.	.	.	r	II	.	IV	.
Juncus gerardii	.	.	.	.	I	.	III	.
Puccinellia hauptiana	.	.	.	.	I	1	III	.
Taraxacum leucanthum	.	.	.	.	.	.	III	.
Triglochin palustre	.	.	.	.	I	.	II	.
Blysmus rufus	.	.	.	.	I	.	II	.
Potentilla anserina	.	.	.	.	I	.	II	.
Carex enervis	.	.	.	.	II	.	II	r
Carex stenophylla	.	.	.	.	.	.	III	+
Elymus chinensis	.	.	.	r	.	.	II	+
REPLACEMENT COMMUNITIES								
Achnatherum splendens	IV	I	+	+	.	.	I	
Peganum nigellastrum	II	.	.	r	.	.	+	II
Chenopodium acuminatum	.	.	.	.	.	.	.	II
Chenopodium "album"	.	.	.	.	.	.	+	II
Lepidium densiflorum	.	.	.	r	.	.	.	II
Tribulus terrestris	r	.	.	.	I	.	.	II
Ptilotrichum canescens	.	+	.	.	.	.	.	II
COMPANIONS								
Puccinellia tenuiflora	.	.	.	r	.	.	+	.
Puccinellia altaica	.	.	.	.	.	.	I	.
Cnidium salinum	.	.	.	.	.	.	I	.
Hordeum spp.	.	.	.	.	.	.	I	.
Saussurea davurica	.	.	.	.	I	.	I	.
Carex orbicularis	.	.	.	.	.	.	I	.
Lactuca tatarica	I	+	+	I	.	.	+	.
Iris lactea	.	.	.	r	I	.	+	r.
Elymus angustus	.	.	.	+	.	.	I	r
Achnatherum inebrians	.	.	.	r	.	.	+	I
Artemisia macrocephala	.	.	.	.	.	.	+	+
Artemisia dracunculus	.	.	.	+	.	.	+	r
Anabasis brevifolia	r	I	.	.	.	.	.	r
Ajania fruticulosa	.	.	.	+	.	.	.	r
Ajania achilleoides	I	.	.	.	.	.	.	I
Caragana leucophloea	r	.	I	.	.	.	.	.
Stipa gobica	r	.	.	.	.	.	.	I
Salsola passerina	r	I	.	.	.	.	.	.
Stipa glareosa	I	I	.	.	.	.	.	II
Sympegma regelii	I	.	.	II	.	.	.	r
Salsola arbuscula	r	I	.	.	.	.	.	.
Ephedra przewalskii	.	.	.	II	.	.	.	.
Asterothamnus centrali-asiaticus	II	.	+	+	.	.	.	+
Nitraria sphaerocarpa	r	.	.	+	.	.	.	.
Allium mongolicum	r	+	.	.	.	.	+	II
Allium polyrrhizum	r	.	.	.	.	.	.	II
Eurotia ceratoides	r	I	.	.	.	.	.	II
Heteropappus altaicus	+	.	.	.	.	.	.	I
Zygophyllum xanthoxylon	II	I	+	I	.	.	.	.
Haloxylon ammodendron	r	II	I	II	.	.	.	.
Lagochilus ilicifolius	r	.	.	.	.	.	.	+
Oxytropis aciphylla	.	+	.	.	.	.	.	I
Convolvulus ammanii	.	.	.	.	.	.	.	II
Ceratocarpus arenarius	.	.	.	.	.	.	I	r
Cistanche salsa	.	+	+	.	.	.	.	.
Dontostemon elegans	r	.	.	.	.	.	.	r
Dontostemon senilis	+	.	.	.	.	.	.	I
Iris tenuifolia	.	.	.	.	.	.	.	r

Unit	1	2	3	4	5	6	7	8
no. of relevés	29	16	11	29	9	1	19	16
Bassia dasyphylla	r	+	.	r	.	.	+	II
Iris bungei	.	.	.	.	I	.	+	I
Cleistogenes songorica	+	+	+	r	.	.	.	III
Scorzonera pseudodivaricata	I	.	.	r	.	.	.	I
Micropeplis arachnoidea	r	I	.	I	.	.	+	I
Lycium ruthenicum	.	.	+	r	.	.	.	.
Artemisia gobica	.	.	.	.	.	.	.	I
Artemisia pectinata	r	.	.	.	.	.	.	I
Artemisia scoparia	.	I	.	+	.	.	.	I
Artemisia xanthochroa	r	.	.	.	.	.	+	+
Artemisia xerophytica	.	I	.	.	.	.	.	r
Asparagus gobicus	.	.	.	+	.	.	.	I
Astragalus brevifolius/junatovii	.	.	.	.	.	.	+	r
Astragalus vallestris	.	.	.	.	.	.	.	I
Atraphaxis pungens	.	.	.	r	I	.	.	.
Atriplex sibirica	.	+	.	r	.	.	.	r
Calligonum mongolicum	.	+	.	I	.	.	.	.
Caragana korshinskii	r	.	.	.	.	.	.	r
Echinops gmelinii	r	.	.	.	.	.	.	r
Eragrostis minor	.	.	.	.	.	.	.	II
Halimodendron halodendron	.	.	.	r	.	.	.	.
Halogeton glomeratus	.	.	.	r	I	.	.	I
Haplophyllum dahuricum	.	.	.	.	.	.	.	r
Kalidium cuspidatum	.	.	.	r	I	.	.	.
Kochia cf. krylovii	.	.	.	.	.	.	.	I
Salsola jacquemontii & collina	.	.	.	.	.	.	.	I
Salsola paulsenii	.	+	.	r	.	.	.	I
Scorzonera divaricata	r	.	.	.	.	.	.	.
Panicum miliaceum	.	.	.	.	I	.	.	.
Saussurea salsa	.	.	.	.	II	.	I	.
Bolboschoenus popovii	.	.	.	.	I	.	II	.
Elaeagnus moorcroftii	.	+	.	.	II	.	I	.
Eleocharis uniglumis	.	.	.	.	.	.	I	.
Potentilla multifida	.	.	.	.	.	.	I	.
Taraxacum sp.	.	.	.	.	.	.	I	.
Halerpestes sarmentosa	.	.	.	.	.	.	I	.
Carex reptabunda	.	.	.	.	.	.	I	.
Crepis flexuosa	.	.	.	.	.	.	I	.
Elymus secalinus	r	.	.	.	.	.	.	.
Elymus sibiricus	.	.	.	.	.	.	+	.
Limonium erythrorhizum	+	.	+	.	.	.	.	.
Orobanche cumana	.	.	.	r	.	.	.	.
Peganum harmala	.	.	.	.	.	.	.	r
Poa tibetica	.	.	.	r	.	.	II	.
Polygonum argyrocoleum	.	.	.	r	.	.	+	.
Potaninia mongolica	.	+	.	.	.	.	.	r
Potentilla dealbata	.	.	.	.	.	.	I	.
Primula sp.	.	.	.	.	.	.	I	.
Suaeda heterophylla	.	.	.	r	I	.	I	.

ad 1: Arnebia fimbriata, Atraphaxis frutescens, Limonium tenellum, Ptilagrostis pelliotii, Salsola laricifolia, Setaria viridis, Zygophyllum potaninii
ad 2: Zygophyllum pterocarpum
ad 3: Convolvulus gortschakovii, Polygonum sibiricum, Silene repens
ad 4: Agriophyllum pungens, Amygdalus pedunculata, Atraphaxis frutescens, Nitraria roborovskii, Polygonum angustifolium, Rheum nanum, Salix turanica, Salsola laricifolia, Suaeda acuminata, Suaeda prostrata, Youngia stenoma, Zygophyllum rosovii
ad 5: Schoenoplectus sp., Scirpus sp.
ad 7: Arabidopsis mollissima, Artemisia frigida, Calamagrostis macilenta, Chenopodium glaucum, Cnidium sp., Elymus ovatus, Elymus paboanus, Gentiana decumbens, Hordeum brevisubulatum, Hordeum roshevitzii, Linum pallescens, Odontites rubra, Oxytropis glabra, Pedicularis flava, Peucedanum falcaria, Phlojodicarpus sibiricus, Plantago minuta, Ranunculus pedatifidus, Suaeda prostrata
ad 8: Allium prostratum, Artemisia anethifolia, Artemisia sphaerocephala, Astragalus brachybotrys/miniatus, Astragalus grubovii, Axyris hybrida, Chenopodium hybridum, Chenopodium prostratum, Convolvulus arvensis, Iris potaninii, Kochia melanoptera, Lappula intermedia, Lappula stricta, Lepidium amplexicaule, Polygonum aviculare, Rheum nanum, Setaria viridis, Stipa sp., Urtica cannabina, Vincetoxicum sibiricum

trees were recorded, with some 3000 growing along one single valley.

The trees grow along dry riverbeds and other sites with higher water surpluses. Stands are often heavily grazed; and individuals may grow in a shrub-like shape. Even the adult trees usually have the lower parts of their crowns grazed by camels. Tree felling seems to be rare, since the trees are held sacred by the Mongolians. The highest tree encountered reached 12 metres in height (see Fig. 20), yet the average height was lower. Seedlings and saplings were hardly seen in the field and it is doubtful whether stands are still regenerating under the current climate / land use conditions (Lindeman et al. 1994).

The syntaxonomical status of this community is unclear. The accompanying species do not allow for

Fig. 20. *Ulmus pumila* tree in the Bordzongijn Gobi, the surrounding vegetation is mainly formed by the Salsolo passerinae-Reaumurietum songaricae and the Nitrario sibiricae-Kalidietum gracilis.

a clearer designation; most of them however are typical associates for dry riverbeds, such as *Zygophyllum xanthoxylon* and *Asterothamnus centrali-asiaticus*. Species from the surrounding zonal sites may also intrude (e.g. *Sympegma regelii, Reaumuria songarica*), while other elements hint at disturbance (=*Peganum nigellastrum, Achnatherum splendens*) or are typical for saline habitats (e.g. *Nitraria sibirica, Kalidium gracile*). As there are probably no untouched forests of *Ulmus pumila* left in the Central Asian drylands (including China), clarification of the syntaxonomy will most likely remain doubtful. We propose to regard *U. pumila* stands of eastern Central Asia as a rankless community with *U. pumila* as the sole regional character species. Stands from southern Mongolia show affinities to the Stipetea glareosae-gobicae, but stands in northern and central Mongolia differ widely in their sets of accompanying species, which may derive from grass steppes or even floodplain forests (see comments in Hilbig 1987). Any definite conclusions would depend on a synopsis of all *U. pumila* communities in Mongolia, which has as yet not been attempted.

Glycyrhizo uralensis-Populetum euphraticae (Table 8, no. 2)
Diagnostic species: *Populus diversifolia, Glycyrhiza uralensis*
The other prominent tree species of the southern Mongolian Gobi is *Populus diversifolia* (=*euphratica*). It reaches its easternmost distribution limit in the western Alashan Gobi, where it is gradually replaced by *U. pumila*. Poplar trees are more strongly confined to true oases (Hilbig 1995), hence the accompanying species (e.g. *Reaumuria songarica, Phragmites communis*) show an even greater adaptation to salt than those of the elm stands, which occur more typically in riverbeds or sayrs with transient groundwater. *Reaumuria songarica* was previously described as a differential species of a sub-association within the Transaltay region (von Wehrden et al. 2006a). Poplar forests of the Gobi range from having dozens to hundreds and even thousands of stems, which may grow up to 20 metres in height, with most being smaller than 10 metres. Regrowth is only recorded where stands are protected from grazing, when root suckers may quickly grow to several metres in height. Seedlings are hardly ever observed and indeed most Central Asian poplar stands seem to consist of huge clones several hectares in size (Bruelheide 2003). These clones are often covered by moving sand dunes and what looks like a forest with many individuals may rather be a multi-stemmed tree that was buried but survived by continuous resprouting.

The syntaxonomical assessment is likewise difficult as it is for the elm stands; this is not surprising since the habitats of the two species are comparably heterogenous. Suggestions have been presented (placement in the Populetea euphraticae, Kürschner 2004; Glycyrhizo uralensis-Populetum euphraticae: von Wehrden et al. 2006a), which we follow. A sub-community can be differentiated based on the presence of *Tamarix ramosissima*. This shrub grows up to four metres in height and often accompanies the poplars (see Table 8, no. 3).

Tamarix ramosissima community (Table 8, no. 4)
Diagnostic species: *Tamarix ramosissima*
Salt cedars are typical for all types of oases in the southern Mongolian Gobi (Hilbig 1995); the shrubs achieve metres or even decametres in diameter and they also seem to grow clonally (Qong et al. 2002). *Tamarix ramosissima* is certainly the most common species, growing on a wide range of soil textures from fine clay within depressions to coarse sand on dunes. Stands have also been described for Inner Mongolia (Kürschner 2004). Salt cedars are highly adapted to the special conditions of temporarily flooded sites in dry environments; detailed studies are available from the United States where this species is highly invasive (Cleverly et al. 1997, Glenn & Nagler 2005). It barely allows any understorey growth, but in between the *Tamarix* individuals other species occasionally occur, which indicate the dry habitat (*Sympegma regelii, Haloxylon ammodendron*) and often also the saline conditions (*Nitraria sibirica, Lactuca tatarica*). *Reaumuria songarica* differentiates a sub-community (von Wehrden et al. 2006a), which was not separated in our synoptic Table 8. If the salt content in the soil increases, *Phragmites communis* occurs and links to the Nitrario sibiricae-Kalidietum gracilis described above.

Salicornia europaea community (Table 8, no. 5)
Diagnostic species: *Salicornia europaea*
Within the lowermost depressions salty swamps (*takyrs*) are found, which are often colonised by annual species that are highly adapted to alkaline and saline soils. Here, the occurrence of *Salicornia europaea* depends on fluctuating water levels; in a wet year depressions may be covered by a lake, which is bordered by *S. europaea*, while in a dry year the same location may contain a dried clay-depression lacking any plant cover. Other annuals of Chenopodiaceae, especially *Suaeda* spp., may grow on the same sites as *S. europaea*, but occurrences are too erratic to merit community status.

Crypsietum aculeatae (Table 8, no. 6)
Diagnostic species: *Crypsis aculeate*
Stands dominated by the short-lived grass *Crypsis aculeata* are described by Hilbig (2000) for the Valley of Lakes, the Uvs-Nuur and the eastern Gobi. We sampled one stand in the central depression north of the Zoolongyn-uul in the Gobi-Altay region (Wesche et al. 2005b), where it was in contact with the *S. europaea* community. Salt efflorescences indicated the high salt content of the clayey substrate.

Fig. 21. Salt meadow (Blysmetum rufi) north of the Tsagaan Bogd in the Transaltay Gobi. In the background a small *Achnatherum* belt is visible; the riverbed in the background is populated by larger semi-desert shrubs such as *Ephedra przewalskii*, *Zygophyllum xanthoxylon* and *Sympegma regelii*.

Blysmetum rufi (Table 8, no. 7)
Diagnostic species: mainly *Triglochin maritimum, Halerpestes salsuginosa, Glaux maritima, Blysmus rufus*
Whenever a permanent water surplus during the vegetation period is guaranteed, saline meadows develop. In the Dzungarian Gobi numerous stands were sampled along rivers and within basins. In the Transaltay Gobi only two stands were found, one in Ekhin Gol, the other one north of the Tsagaan Bogd. In the Gobi-Altay stands were sampled in the higher mountains as well as in the lower depressions. In the Alashan Gobi most stands were restricted to the aquifers reaching the surface and the depressions. This list demonstrates the wide ecological distribution, ranging from the highest (and wettest) mountains down to the driest depressions. Stands are heterogenous regarding their species composition, but are less so in terms of their vegetation structure. Some stands form small bands along brooks, and hence contain introgressive species of other vegetation types and indicators of disturbance including bunch grasses or shrubs. In more extensive meadows, the vegetation layer is almost exclusively composed of herbs and grasses forming a closed sward. Saline meadows are practically always grazed by both livestock and wildlife; hence the vegetation layer rarely exceeds 10 centimetres in height (see Fig. 21). Sites nonetheless contain a high biodiversity compromising exclusively salt-tolerant species. The typical species are *Halerpestes salsuginosa, Glaux maritima, Triglochin maritimum, T. palustre, Taraxacum leucanthum, Blysmus rufus* and *Juncus gerardii*. A detailed syntaxonomical placement is difficult, although sample plots clearly belong to the Halerpestion salsuginosae. The general species set points to either the Halerpesto-Hordetum brevisubulati or the Blysmetum rufi (Hilbig 2000), but the name-giving character species are not always present, or character species of different associations occur together (*Blysmus rufus*, *Hordeum brevisubulatum*). Instead of assigning the few characteristic stands to the two associations and leaving the majority of samples as intermediates, we have refrained from providing a finer syntaxonomical classification.

Replacement communities of the semi-deserts and their riparian ecosystems (Table 8, no. 8)
Diagnostic species: *Achnatherum splendens, Peganum nigellastrum, Chenopodium acuminatum, Chenopodium "album", Lepidium densiflorum*
Due to grazing and trampling, meadows are sometimes transformed into secondary replacement communities, which are unstable and hard to classify. We incorporated the respective sample plots into a single column in Table 8, even though stands differ widely in their species composition and environmental context. Relevés thus represent replacement communities of several associations/communities, but a finer classification is not possible with the available data.

The *Achnatherum* species forms stands which are easily recognised due to their tall and dense tussocks. Wesche et al. (2005b) described the different altitudinal distribution of the two *Achnatherum* species, with *A. inebrians* being restricted to montane sites in southern Mongolia. Stands of the latter are described above (see Table 2), details on *Achnatherum splendens* stands of lower altitudes are provided by Hilbig (2000), von Wehrden et al. (2006a) and von Wehrden et al. (2006c). Proper syntaxonomical placement (e.g. Glycyrrhizo-Achnatheretum splendentis) is again compromised due to the heterogeneity of the plots.

Peganum nigellastrum is the common species on heavily disturbed sites around villages and along roads (Hilbig 1990). Stands often lack other companions, but *P. nigellastrum* is frequently found in the semi-deserts as well, where it also indicates heavy disturbance. In the Transaltay Gobi and eastwards, similar sites may also be occupied by the closely related *Peganum harmala*.

Much as in the montane regions (see above), deserted winter places at water surplus sites of the region may host similar stands, but where trampling and nutrient input is increased and where moisture input is sufficiently high, dense layers of annuals are found. These include several Chenopodiaceae species, such as *Chenopodium album, Axyris hybrida, Kochia melanoptera, Bassia dasyphylla* and others, but also species of other families such as *Lepidium densiflorum*, *Tribulus terrestris* and annual *Artemisia* species. Several of the communities were described as associations (Chenopodio prostrati-Lepidietum densiflori, see Hilbig 2000), but ruderal stands of southern Mongolia have not yet been comprehensively assessed (but see Hilbig 1988). Our sample set here is certainly not sufficient because we concentrated on zonal vegetation, so we refrain from making any finer classification.

5. Synopsis

5.1. Representive profiles of the vegetation of the southern Mongolian Gobi

In order to illustrate the distribution of the vegetation in the southern Mongolian Gobi we present six schematic profiles from different regions; these represent the main zonal precipitation regimes, which are modified by altitudinal gradients. We present transects extending from the highest peaks down to the depressions. Only the easternmost region lacks mountain ranges, in which case we merely present profiles through the lowlands.
Dzungarian Gobi: Khavtagijn Nuruu – Dzungarian depression (Fig. 22)
The highest mountain along the Chinese-Mongolian boundary reaches almost 3000 metres asl. It is covered by dense mountain steppes; mainly of the typical subassociation of the Hedysaro pumili-Stipetum krylovii, yet the highest and relatively moist pastures constitute a regional variant of the Hedysaro-

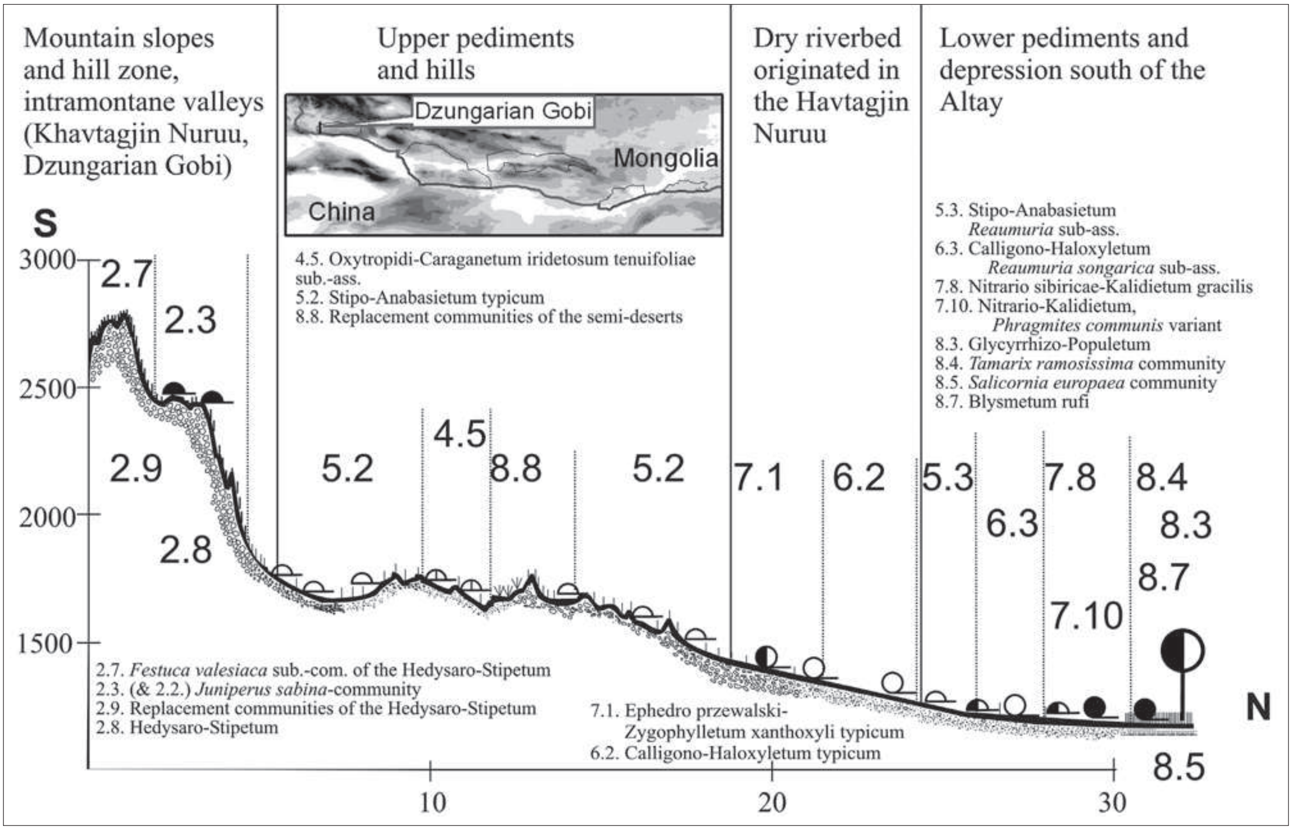

Fig. 22. Vegetation profile of the Dzungarian Gobi. The horizontal distance is given in kilometres, vertical elevation in metres asl. Soil parameters are given as a schematic signature: larger signatures indicate rocks and stones; smaller points and short lines indicate a sandy/silty matrix; horizontal lines indicate a clayey matrix. The numbers indicate the position and column in the syntaxonomic tables. The insert provides the position of the transect within the southern Mongolian Gobi – the greyscale indicates the altitudinal zonation within the study region.

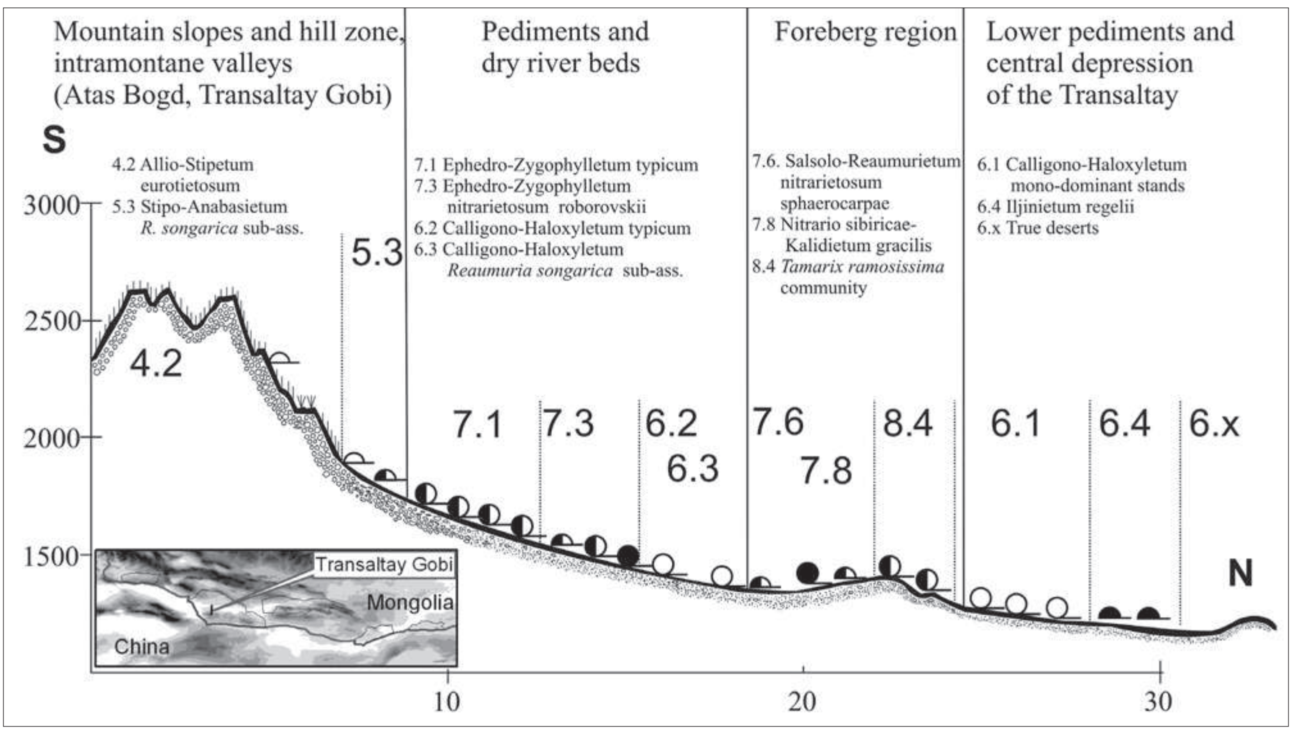

Fig. 23. Vegetation profile of the western Transaltay Gobi. Scales and signatures are as in Fig. 22.

Stipetum. Some 200 metres downhill dense juniper stands are found, which often host shrubs of *Lonicera hispida* in their centres where they are protected from grazing (see Fig. 4).

Near ger-places and within rivers disturbed communities, which are dominated by *Achnatherum splendens*, are common, while the surroundings are again constituted by the Hedysaro-Stipetum. The transition zone between mountain communities and semi-deserts is rather abrupt. The forelands are mainly dominated by the Stipo glareosae-Anabasietum brevifoliae; the Eurotio ceratoidis-Caraganetum leucophloeae iridetosum tenuifoliae grows on some smaller foothills. A nearby military station is surrounded by totally disturbed replacement communities dominated by *Peganum nigellastrum*. A one kilometre wide riverbed dissects the pediment and collects occasional downflow from all catchments including even the high mountains towards the south. It represents a huge sediment trap and is widely covered with coarse sand, which offers suitable habitats for high *Haloxylon* stands, often accompanied by *Reaumuria songarica.* Gravel substrates support the Ephedro przewalskii-Zygophylletum xanthoxyli. The surrounding pediments are dominated by the Stipo-Anabasietum, and *R. songarica* becomes more frequent in this association towards the depression. There, the abundance of salt indicators increases; such areas are surrounded by Nitrario sibiricae-Kalidietum gracilis scrub growing on fine clays. Higher sand dunes (up to three metres) are inhabited by *Tamarix ramosissima* and *Populus diversifolia*. The central salt pan contains a *Phragmites communis* reed bed, which is surrounded by the Nitrario sibiricae-Kalidietum gracilis – *Phragmites communis* variant. A small saline meadow is also present where some *Salicornia europaea* plants grow among large salt crystals.

The northern, largely deflated pediments (not drawn) linked to the Altay are covered by desert steppes of the Artemisio sublessingianae-Nanophytetum erinacei.

Transaltay Gobi: Atas Bogd – Transaltay depressions (Fig. 23)

This is the driest region of the southern Mongolian Gobi, since both western disturbances and the East Asian monsoon are sheltered by the surrounding mountains and the Dzungarian depression (Hijmans et al. 2005, see also Fig. 2). The highest peaks are therefore not covered by mountain steppes, which are replaced by impoverished variants of the Allio polyrrhizi-Stipetum glareosae eurotietosum ceratoidis. The lower slopes of the Atas Bogd are covered by heterogenous vegetation dominated by the Stipo-Anabasietum, which is often accompanied by *Sympegma regelii*. The Ephedro przewalskii-Zygophylletum xanthoxyli grows in most dry riverbeds and dry pediments reaching down to the depressions. On the middle pediments these *Ephedra* stands are modified by the presence of *Nitraria roborovskii*. Further down, *Haloxylon ammodendron* accompanies the *Ephedra* stands; *Reaumuria songarica* also becomes abundant indicating a higher salt content. Around small depressions, the Nitrario sibiricae-Kalidietum gracilis occurs, and riverbeds there are occasionally covered with *Tamarix* scrub on sites with higher water surpluses. The lowest hills contain almost no vegetation, yet at smaller water-favoured sites the Iljinietum regelii is found along with some annual Chenopodiaceae. The lowest depressions are devoid of any

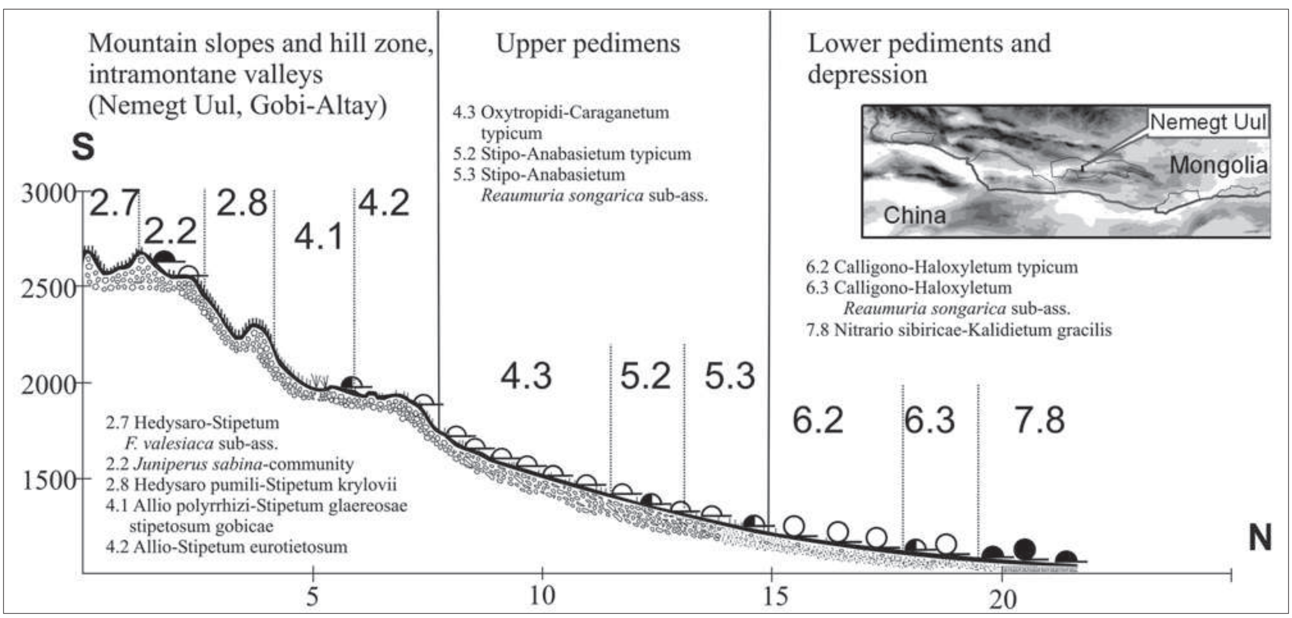

Fig. 24. Vegetation profile of the south-western Gobi Altay. Scales and signatures are as in Fig. 22.

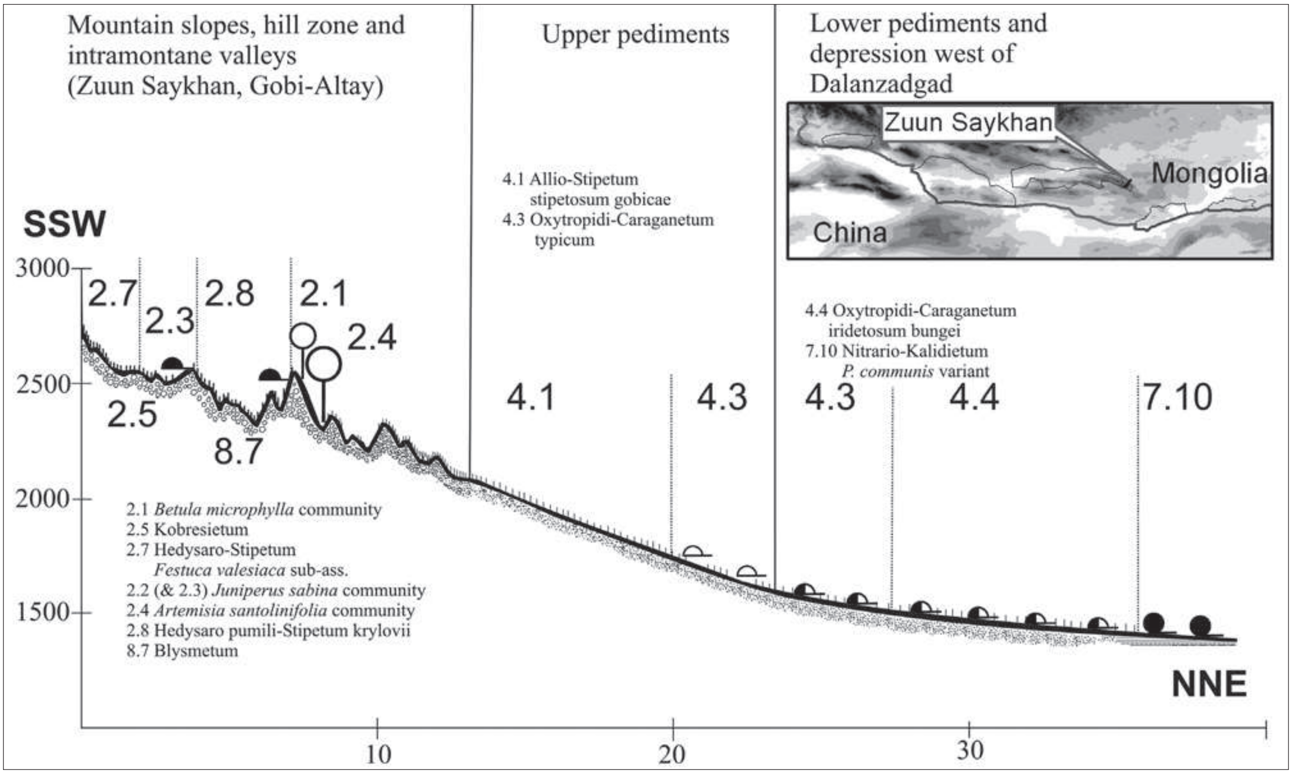

Fig. 25. Vegetation profile of the eastern Gobi Gurvan Saykhan National Park. Scales and signatures are as in Fig. 22.

vegetation, and a thick layer of almost pure gypsum is found below the deflation pavement. Here, precipitation is presumably below 40 mm/a.

South-Western Gobi-Altay: Nemegt Uul – northern depression (Fig. 24)

Towards the east, the influence of the east-Asian monsoon becomes more pronounced; hence the Nemegt Uul Mountain receives more precipitation than the Atas Bogd and hosts a greater biodiversity. A few juniper stands are also found, mainly at water surplus sites with northern exposures. Mountain steppes (Hedysaro pumili-Stipetum krylovii) are limited and are somewhat impoverished; rock steppes (Hedysaro-Stipetum) are even rarer. Stipo-Anabasietum stands cover the lower parts of the mountain, and most of the pediments. Stands are infrequently interspersed with Allio polyrrhizi-Stipetum glareosae steppes at the mountain foot zone and some higher pediments; on drier pediments the Oxytropidi aciphyllae-Caraganetum leucophloeae is found, indicating seldom yet heavy episodic rainfall. The Stipo-Anabasietum Reaumuria songarica sub-ass. becomes more abundant at lower elevations, while the lowest pediments are covered with the Salsolo passerinae-Reaumurietum soongaricae, indicating a high salt content. In the basin a Calligono mongolici-Haloxyletum ammodendronis belt grows on clayey soils, often accompanied by *Reaumuria songarica*.

Eastern Gobi-Altay: Zuun Saykhan – Dalanzadgad (Fig. 25)

At the highest and most humid peaks of the Gobi-Altay precipitation is around 200 mm/a and thus supports alpine mats of the Kobresietum myosuroidis along the northern exposures (Fig. 5). The surrounding highlands are mainly covered by rock steppes with *Festuca valesiaca* on north-facing slopes; southern exposures are covered by scree slopes and host dense and large patches of juniper, which avoid the summit region. The northern slopes of the valley shoulders, around Yolin-Am (the "Lammergeier-valley"), represent the habitat of some of the last *Betula microphylla* forests in the Mongolian Gobi. The high rainfall has given rise to brooks in the valley which support stands of the Blysmetum. Hedysaro pumili-Stipetum krylovii mountain steppes dominate the lower slopes and the higher pediments, but further down these are replaced by the Allio polyrrhizi-Stipetum glareosae stipetosum gobicae. Ger-places and camps are often surrounded by replacement communities, while *Achnatherum inebrians* tussocks grow in erosion gullies. Small springs support salt meadows, which are always heavily grazed. On hills and pediments, the Oxytropidi aciphyllae-Caraganetum leucophloeae occupies stony or even rocky habitats. On sandy spots, *Iris bungei* accompanies these stands forming a characteristic sub-association. Towards the depression, small dunes covered by the Nitrario sibirica-Kalidietum gracilis are found. Within

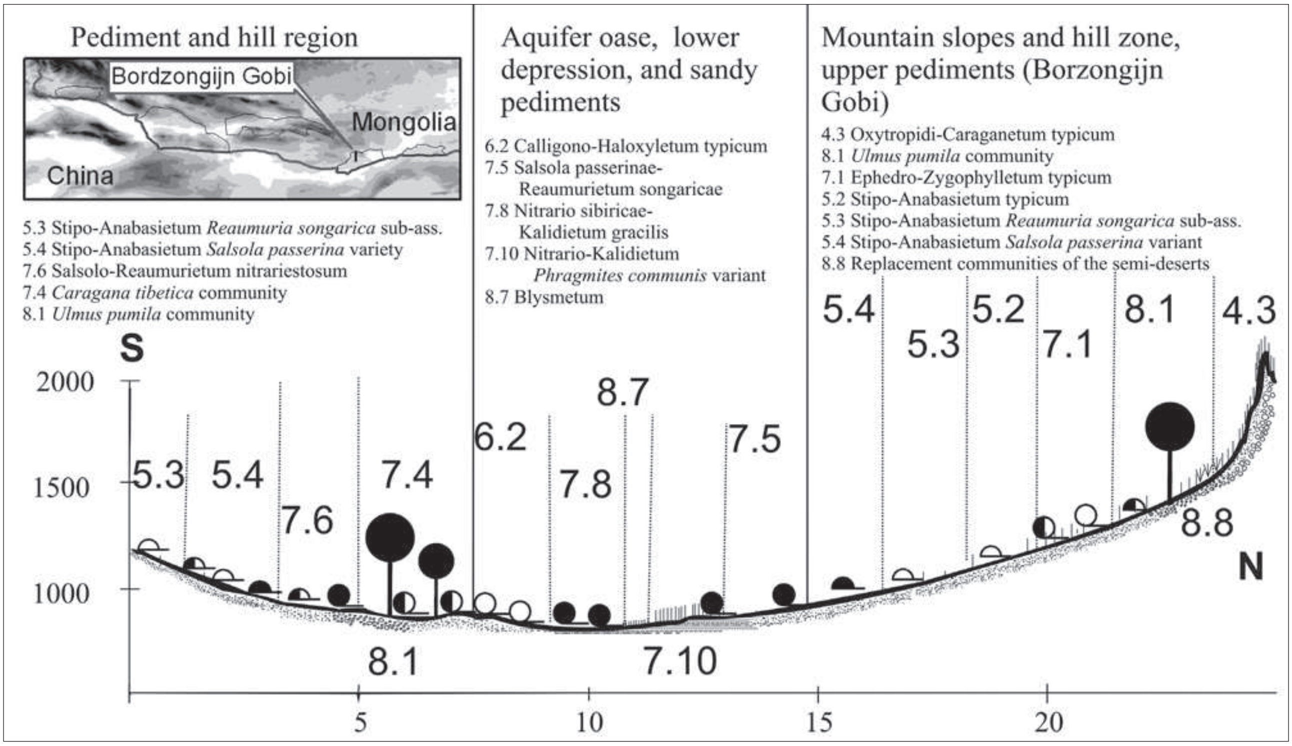

Fig. 26. Vegetation profile of the Small Gobi A strictly protected area. Scales and signatures are as in Fig. 22.

the vicinity of the Aymak capital Dalanzadgad the vegetation is often disturbed and overgrazed, hence replacement communities dominated by *Achnatherum* spp. and *Peganum nigellastrum* are common.

Bordzongijn Gobi: Khorhijn Uul – Selerniin Uul (Fig. 26)

Impoverished variants of the Oxytropidi aciphyllae-Caraganetum leucophloeae are common in the summit regions of small mountains. In the valleys some elm trees are found, and replacement communities are abundant. Most of the lower mountains and hills are however dominated by the Stipo-Anabasietum, which also covers large parts of the pediments. The dry riverbeds are dominated by larger shrubs; the Ephedro przewalskii-Zygophylletum xanthoxyli is often accompanied here by *Amygdalus* spp. The dry riverbeds are also often populated by extensive *Ulmus pumila* forests accompanied by an otherwise heterogenous species set. Some 15 kilometres south-west of the mountains, an aquifer reaches the surface, supporting dense oasis vegetation. Small hummocks of the Nitrario sibiricae-Kalidietum gracilis are found on these sites. Springs support salt meadows (=Blysmetum) and reed beds (=Phragmitetum), yet due to heavy grazing the vegetation is often made up of replacement communities. Westwards some oases are even used to cultivate vegetables. Towards the depression the vegetation contains mainly salt-adapted species, including diagnostics of the Salsolo passerinae-Reaumurietum soongaricae, which are sometimes accompanied by *Kalidium* species. Small nebkahs of the *Nitraria sibirica* community surround these basins. Deflated pediments host the *Salsola passerina* variant of the Stipo-Anabasietum, while the larger parts of the salt pans are devoid of vegetation. South of the depression sand becomes more prominent, modifying the environment and supporting some few *Haloxylon* stands. At slightly higher elevations, elm trees are again abundant in riverbeds, and gullies within the hills often host the *Caragana tibetica-Ammopiptanthus mongolicus* community, which forms impressive stands. On the upper hills and their pediments, the Stipo-Anabasietum becomes widespread again, often accompanied by *Reaumuria songarica* and *Salsola passerina* on stone pavements.

Eastern Small Gobi strictly protected area (Fig. 27)

No high mountains are found within this region (note the altitudinal scaling in Fig. 27), but the precipitation increases towards the south-east (see Fig. 2). At the south-eastern border of the Small Gobi B strictly protected area the precipitation is comparable to that of the highest peaks of the Gobi-Altay, although elevations are 1700 metres lower (Fig. 2). Relatively dense grass-dominated semi-deserts are found, which support comparable vegetation to that of the higher pediments of the Gobi-Gurvan Saykhan, including a dry aspect of the Allio polyrrhizi-Stipetum glareosae eurotietosum ceratoidis. On small depressions salt-adapted and disturbed vegetation occurs, such as the Nitrario sibirica-Kalidietum and *Achnatherum* spp. stands. Here, an elm

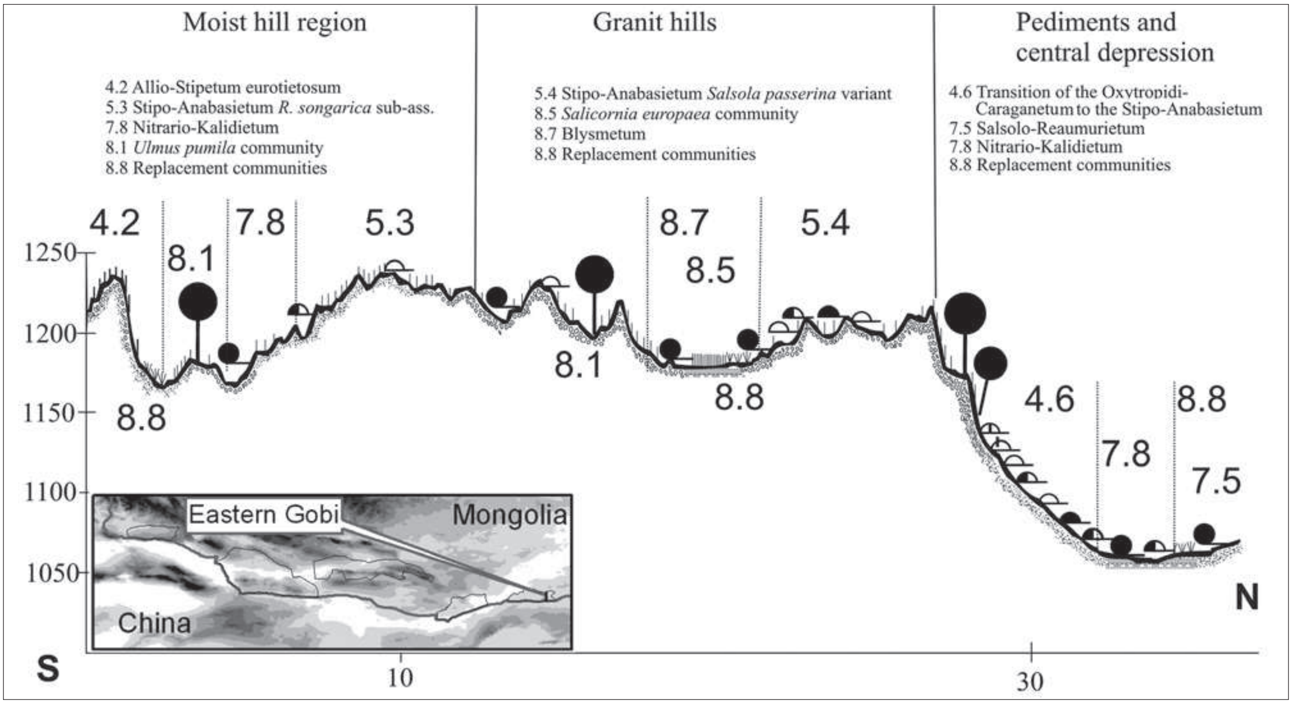

Fig. 27. Vegetation profile of the Small Gobi B strictly protected area. Scales and signatures are as in Fig. 22.

tree was even growing on a hill flank, which indicates that these trees are not necessarily restricted to ravines in this environment. On the pediments, stands of the Stipo-Anabasietum *reaumurietosum* are common and are often accompanied by *Salsola passerina*, which is very abundant in this region. Dry river beds dissect the pediments of higher hills and often contain extensive *Ulmus* woodlands. The lowermost depression is surrounded by the Salsolo passerinae-Reaumurietum songaricae, whilst the inner depression is covered by the Nitrario sibiricae-Kalidietum gracilis; overgrazed *Peganum nigellastrum*-stands are also common. The hills are dominated by the Stipo-Anabasietum, which always contains salt indicators. Along dry riverbeds, disturbed *Achnatherum*-stands and elm-trees occur.

5.2. Syntaxonomic overview

Short overview of the vegetation units mentioned in the text, and their syntaxonomical position according to the current state of knowledge (ammended from Hilbig 2000; communities and associations in bold letters).

Phragmitetea communis R. Tx. et Prsg. 1942
- Phragmitetalia communis (W. Koch 1926) R. Tx. et Prsg. 1942
  - Phragmition communis W. Koch 1926
    - **Phragmitetum communis** (Gams 1927) Schmale 1939

Thero-Salicornietea Pignatti 1953 em. R. Tx. in R. Tx et Oberd. 1958
- Thero-Suaedetalia Br.-Bl. et De Bolos 1957 em. Beeftink 1962
  - Thero-Suaedion Br.-Bl. (1931) 1933 em. R. Tx. 1950
    - *Salicornia europaea* **community**

Crypsietea aculeatae Vicherek 1973
- Crypsietalia aculeatae Vicherek 1973
  - Cypero-Spergularion salinae Slavnic 1948
    - **Crypsietum aculeatae** (Bojko 1932) Wenzl 1934

Achnatheretea splendentis (Mirkin in Kasapov et al. 1987) Mirkin et al. 1988 nom. Nud.[1]
- Achnatheretalia splendentis (Mirkin in Kasapov et al. 1987) Mirkin et al. 1988
  - Achnatherion splendentis Mirkin et al. ex Hilbig 2000
    - **Glycyrrhizo-Achnatheretum splendentis** Hilbig (1987) 1990

Asteretea tripolium Westh. et Beeftink in Beeftink 1965
- Halerpestetalia salsuginosae Mirkin et al. ex Golub 1994
  - Halerpestion salsuginosae Mirkin et al. ex Golub 1994
    - **Blysmetum rufi** Du Rietz 1925

Cleistogenetea squarrosae Mirkin et al. ex Korotkov et al 1991 (=Agropyretea cristati Hilbig et Koroljuk 2000)

1 The syntaxon lacks exclusive character species and is thus under debate

Stipetalia krylovii Kononov, Gogoleva et Mironova 1985
Stipion krylovii Kononov, Gogoleva et Mironova 1985
Hedysaro pumili-Stipetum krylovii Hilbig (1987) 1990 corr. 1995
typicum Hilbig *(1987) 1990* corr. *1995*
Festuca valesiaca subcommunity (see Wesche et al. 2005)
stipetosum gobicae sub-ass. (=*Astragalus inopinatus* sub-association – Hilbig 1995)
Helictotrichetalia schelliani Hilbig 2000
Helictotrichion schelliani Hilbig 2000
Androsaco ovzcinnikovii-Helictotrichetum schelliani Hilbig 1987 (1990)
Stipetea glareosae-gobicae Hilbig 2000
Allietalia polyrrhizi Hilbig 2000
Allion polyrrhizi Hilbig 2000
Allio polyrrhizi-Stipetum glareosae Hilbig (1987) 1990
stipetosum gobicae sub-ass. nov. hoc loco
eurotietosum ceratoidis sub-ass. nov. hoc loco
Stipo glareosae-Anabasietum brevifoliae Hilbig (1987) 1990
typicum (=*Convolvulus ammanii* sub-ass.)
stipetosum gobicae sub-ass. nov. hoc loco
Reaumuria songarica sub-association von Wehrden et al. (2006)
Salsola passerina variant
Artemisia sublessingianae-Nanophytetum erinacei hoc loco
Caraganion leucophloeae Hilbig 2000
Oxytropidi aciphyllae-Caraganetum leucophloeae Hilbig (1987) 1990
typicum
iridetosum bungei sub-ass. nov. hoc loco
iridetosum tenuifoliae sub-ass. nov. hoc loco
Reaumuria songarica sub-community
Sympegmo regelii-Caraganetum leucophloeae von Wehrden et al. 2006
Convolvulus gortschakovii **community** Hilbig 2000
Lappula stricta sub-community
Oxytropis aciphylla sub-community
Psammochloa villosa-**community** (position unclear, transitional to Brometea korotkyi Hilbig et Koroljuk 2000)
Reaumurio soongoricae-Salsoletalia passerinae (Mirkin in Kasapov et al. 1988) Mirkin et al. 1988 em. Hilbig 2000
Reaumurio soongoricae-Salsolion passerinae (Kasapov et al. 1988) Mirkin et al. 1988 em. Hilbig 2000
Salsolo passerinae-Reaumurietum soongoricae Kasapov et al. ex Hilbig 2000
nitrarietosum sphaerocarpae sub-ass. nov. hoc loco
(see also von Wehrden et al. 2006a)
western regional variant *(=Reaumuria songarica*
Nitraria sphaerocarpa community Hilbig 2000)
Nitrario sibiricae-Kalidietum gracilis Hilbig 2000
(including the *Nitraria sibirica* community)
Phragmites communis-variant
Iljinietum regelii ass. nov. hoc loco
Zygophyllo xanthoxyli-Brachanthemetalia gobici (Mirkin in Kasapov et al. 1988)
Mirkin et al. 1988
Zygophyllo xanthoxyli-Brachanthemion gobici (Mirkin in Kasapov et al. 1988) Mirkin et al. 1988
Ephedro przewalski-Zygophylletum xanthoxyli ass. nov. hoc loco
typicum
sympegmetosum regelii sub-ass. nov. hoc loco
nitrarietosum roborovskii sub-ass. nov. hoc loco
(see von Wehrden et al. 2006a)
Calligono mongolici-Haloxyletum ammodendronis Hilbig (1987) 1990
typicum Hilbig (1987) 1990 (including mono-dominant stands)
Reaumuria songarica sub-association (see von Wehrden et al. 2006a)
Caragana tibetica-Ammopiptanthus mongolicus-**community** (Kürschner 2004)
Populetea euphraticae Zohary 1962
Populetalia euphraticae Zohary 1962
Populion euphraticae Eig 1938
Glycyrrhizo uralensis-Populetum euphraticae (von Wehrden et al. 2006a)
Tamarix ramosissima **sub-community**
Carici rupestris-Kobresietea bellardii Ohba 1974
Kobresietalia myosuroidis Mirkin et al. (1983) 1986
Kobresion myosuroidis Mirkin et al. 1983 em. Hilbig 2000
Kobresietum myosuroidis Mirkin et al. ex Hilbig 2000
Juniperetea pseudosabinae Mirkin et al. 1986 nom. nud.[2]
Juniperetalia pseudosabinae Mirkin et al. 1986
Juniperion pseudosabinae Mirkin et al. 1986
Juniperus sabina-**community**
Lonicera microphylla sub-community
typical sub-community
Artemisia santolinifolia-**community** (position unclear)
Sisymbrietea officinalis Gutte et Hilbig 1975
Sisymbrietalia officinalis J. Tx. in Lohm. et al. 1962

2 Alternatively, stands could be placed in the Artemisio santolinfoliae-Berberidetea sibiricae (Ermakov et al. 2006), but a larger scale synopsis is needed to solve this question.

Sisymbrion officinalis R. Tx., Lohm. et Prsg. in R. Tx. 1950 em. Hejný 1979
Chenopodio prostrati-Lepidietum densiflori Hilbig (1987) 1990
(=Replacement communities of the Hedysaro pumili-Stipetum krylovii)
Class?
Ulmion pumilae Mirkin et al. ex Hilbig 2000
Ulmus pumila-**community** (position unclear)
Salicetea purpureae Moor 1958
Salicetalia miyabeanae Hilbig 2000
Salicion viminalis Hilbig 2000
Tamarix ramosissima-**community** (position unclear, see Hilbig 2000)
Class?
Betula microphylla-**community** (position unclear)
Populetea laurifolio-suaveolentis Hilbig 2000
Populetalia laurifolia-suaveolentis Mirkin et al. 1986 em. Hibig 2000
Populion laurifoliae Mirkin et al. ex Hilbig 2000
Populus laurifolia-**community** (position unclear)

5.3. Human impact on the vegetation of the southern Mongolian Gobi

Naturally, livestock density is related to the quality and quantity of available feeding grounds. The precipitation gradient thus widely determines the presence of livestock, and the highest density is therefore found in the Gobi-Altay. There, the pronounced altitudinal zonation of precipitation and vegetation determines the grazing regime, leading to concentrations of livestock in the mountain steppes (Fernandez-Gimenez 2000). In the easternmost region, precipitation and thus human presence increases; the highest density of herds was found in the south-east, where the vegetation was almost comparable to the pediments of the Gobi Gurvan Saykhan. Towards the west the influence of the monsoon decreases, supporting less livestock in the western part of the Gobi Altay, which usually live at relatively high altitudes. A similar pattern is found for the Transaltay, where grazing is restricted to the forelands of the Altay. The Dzungarian Gobi represents a somewhat special situation. The influence of livestock grazing is very limited, which might be due to the general dryness of the environment in combination with an established administration of the protected area, which allows grazing only in the buffer zone.

Due to the presence of Mongolian military the grazing by livestock is increased in the vicinity of their stations. This affects the wider surroundings but grazing nonetheless has an at most limited spatial extent in the border region.

The widespread prevalence of grazing is reflected at the level of plant physiognomy. The Stipo-Anabasietum, for example, is the most widespread association on dry pediments, and the low growth of the name-giving species *A. brevifolia* can be interpreted as an adaptation to grazing. The twigged growth forms of higher shrubs of the semi-deserts, most prominently *Haloxylon ammodendron*, also testify to a grazing influence, as reported by Helmecke & Schamsram (1979). Comparisons between stands grazed by livestock with sites grazed by wildlife suggest that major changes only occur near water sites. The extrazonal salt-adapted communities on water surplus sites indeed face the most tremendous grazing impact, and are often overgrazed and trampled since these areas contain wells and natural water sources. Effects are even more severe in China (Kürschner 2004), which raises concern that degradation may increase in Mongolia as well.

In summary, in terms of changes in plant community composition, grazing degradation in southern Mongolia appears to be currently limited or restricted to some spatially smallspread high use sites.

5.4. Concluding remarks on nature conservation in southern Mongolia

In principle, Mongolian nomadic land use should be sustainable (Fernandez-Gimenez 1999): Grazing has always been an important factor in this ecosystem, even before humans introduced livestock. Some recent developments should nevertheless be observed with caution. Improved veterinary care reduces the mortality of the livestock. Digging of wells may result in changing vegetation in the direct surroundings, since areas which were previously only grazed by camels or wildlife become accessible to sheep and goats (Bedunah & Schmidt 2004). The Mongolian government currently supports well digging, which should be limited, at least in the protected areas.

The harvesting and collection of wood for fuel has a long tradition in this nomadic ecosystem, yet harvesting *Haloxylon* stands with trucks for transporting firewood is a recent practise and is most certainly not sustainable. At least in protected areas firewood collection should be monitored and controlled.

Due to the political changes in the 1990s, the nomadic economy shifted towards greater cashmere production (Janzen 2005). Therefore the number of goats increased, while the overall number of animals remained almost stable. This development is critical for two reasons: it increases Mongolia's dependency on international market prices (Finch 2001), and goats may be more detrimental to rangeland health than other livestock species (Tsagaan Sankey et al. 2006). The consequences for the environment should be closely monitored.

Almost all large wildlife species found in Central Asia have declined in number during the last decades (e.g. Peters & von den Driesch 1997, Reading et al. 1999, Milner-Gulland et al. 2001, Reading et al. 2001). The most abundant wildlife species are surely gazelles, with numbers of the Mongolian gazelle still reaching several tens of thousands (Milner-Gulland & Lhagvasuren 1998). Other species include the Mongolian Wild Ass (Reading et al. 2001), Wild Camel, Saiga (Milner-Gulland et al. 2001) and Przewalski horse (see Fig. 9). The current populations represent only relics of their former much larger distribution ranges (Zevegmid & Dawaa 1973). The wild horse was even extinct in the wild for decades (Ryder 1993). Most of the named species undertake large migrations in search of suitable grazing grounds, and only the wild horse remains close to watering sites (http://www.takhi.org).

The grazing grounds of Mongolia are important habitats to most of these species, since few or no protected areas are established within their range outside the Mongolian Republic. Accepting this responsibility is one of the challenges Mongolia currently faces.

5.5. Outlook

The vegetation description presented here is one step towards completing a general assessment of the habitats of these protected areas. Availability of sound data on spatial distribution of these vegetation types is a second precondition for the protection of the vast ecosystems of Mongolia (Gunin et al. 1999). Vegetation maps of the southern Mongolian Gobi are mostly available on a rough scale (Anonymous 1990, Gunin & Vostokova 1995), but more detailed maps will increasingly become available. Recent results proved that vegetation mapping is possible based on Landsat data (von Wehrden & Tungalag 2004, von Wehrden 2005, von Wehrden et al. 2006b), and the resulting maps and GIS databases are already employed in improving protection of the wildlife (von Wehrden & Wesche 2007b, Kaczensky et al., in press).

Still, more information is urgently needed; one example is provided by the hitherto largely unstudied consequences of climate change (see Christensen et al. 2003). Challenges are potentially huge, but unfortunately much of the impressive geobotanical research in Mongolian drylands has been discontinued as a result of political changes in Mongolia and Russia. We hope that our work will help to revive some interest in the Mongolian flora and vegetation and trigger new research on some of the pressing issues.

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