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Limnological aspects of the Uvs Nuur Basin in northwest Mongolia

Dissertation zur Erlangung des akademischen Grades
Doctor rerum naturalium (Dr. rer. nat.)

vorgelegt von
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geb. 14.03.1968

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Abstract

The Uvs Nuur Basin is an endorheic catchment of 71 100 km^2 at the northwestern border of Mongolia. The cold continental climate, a flat, arid inner part with the terminal salt lake Uvs in its center, and bordering humid mountain ranges that rise steeply up to 4 037 m ASL shape its character. The extreme gradients of altitude and climate that bring about all vegetation zones from alpine tundra and forest steppe to grass steppe and semidesert, and the little anthropogenic alteration made the basin an interesting subject of geoecological research. However, comparably little and fragmentary results of limnological research in this region were published. It was the goal of the Mongolian-German research project "Limnological Particularities of Characteristic Waterbodies in the Uvs Nuur Basin" to develop a systematic inventory of waters, describe their morphological, hydrophysical, -chemical and biological characteristics and to generalize the framework of abiotic and biotic factors that determine their character.

The field work was carried out in the years 1996 to 1999, each August to the middle of September. Samples of water, sediments, benthic and planktonic biota were taken from 76 places at 15 stagnant water bodies, 21 streams and several groundwater bodies; morphological, hydrological, physical and hydrochemical measurements were made. Chemical and biological analyses were carried out in Germany. The most important taxonomical groups were determined by German and international specialists.

The results of the work are presented and discussed separately for running waters, lakes and groundwater. Based on these findings, several general topics are dealt with: factors shaping the character of water bodies, food webs, biogeography, spatial sequence of water bodies, typology and protection issues.

The morphology of streams was characterized by a high bed dynamic due to summerly storm floods, wide and bare floodplains, mainly inorganic sediments, and often missing or sparse bank vegetation. A common feature of all streams except the big Tesiyn Gol was the complete freezing during some four winter months. The chemical character of most streams apart from some alpine headwaters was distinctly calcareous with pH values above 8.0. The TP concentrations during baseflow conditions were well below 50 µg/l, but up to 1.5 mg/l during floods. Signs of eutrophication in the form of an increased biomass of eutraphentic phytobenthos species were found in places with high cattle density.

The benthic colonization was sparse in alpine rivers and in lowland streams with sandy substratum. Higher biomass of phyto- and zoobenthos was found in alpine headwaters, mountain streams and lowland streams with stable substratum. The macrozoobenthos was dominated in most alpine and numerous mountain streams by filter feeders and detritus feeders – mainly Ephemeroptera, Plecoptera and Diptera (Simuliidae, Diamesinae). In the phytobenthos of alpine brooks, *Hydrurus foetidus* and crust forming Cyanobacteria were dominating. Mosses, diverse filamentous algae (above all *Cladophora*, Zygnematales), Oscillatoriales and submerged macrophytes (particularly *Stuckenia pectinata*) were growing in the mountain brooks. The almost complete absence of emergent macrophytes, Rhodophyta, Amphipoda and Mollusca from the streams can be seen as a peculiarity caused by harsh environmental conditions. The main factors structuring the benthic biocenoses were hydromorphology (sediment grain size, bed stability, flow velocity and variability), temperature, salinity and trophic level (phosporus concentration).

The lakes in the Uvs Nuur Basin were mainly formed by vertical tectonic movements, eolian and glacial forces. Terminal lakes in tectonic depressions were large, usually saline and typically had a low relative depth. Because of their high absolute depth and low volume quotient they were mostly oligotrophic. The small lakes formed by wind or dead ice were very shallow and meso- to eutrophic. The turbidity of these lakes was often high, macrophytes were only sparsely developed. The pH value in all lakes was above 8.4, in most cases at about 9. The TP concentration in the lakes was in a range of 5 to 230 µg/l, in the large lakes below 35 µg/l. Phosphorus was not in all lakes the limiting resource for phytoplankton growth: light, nitrogen and possibly micronutrients are the limiting or co-limiting resources in some shallow, turbid lakes. The calcium content in most lake sediments is high enough for a good phosphorus binding capacity.

The phytoplankton of most lakes was dominated by cyanobacteria. Most important was *Planktolyngbya contorta*. Chlorococcales and Dinophyta were often subdominant. Chrysophyceae and centric diatoms only reached high biomass proportions in freshwater lakes. In the zooplankton, Calanoida were mostly dominant in terms of biomass, the most abundant species was *Arctodiaptomus salinus*. Cladocera reached significant proportions in some small lakes and in freshwater lakes. The zooplankton of the shallow, alkaline Baga Nuur was composed almost completely of Rotifera that were important in Uvs Nuur, too. An important factor for the structure of zooplankton was the absence of fish in some small lakes. The latter and the factors trophic state (determined mainly by morphology), salinity and altitude were the most important determinants of the character of the planktonic biocenoses.

From the biological samples, a checklist of 298 animal taxa and 298 plant taxa was compiled; 109 additional taxa were included that are reported for the Uvs Nuur Basin in the Russian and Mongolian literature. Two species (*Cyclops glacialis* Flößner 2001 and *Acanthocorbis mongolica* Paul 2011) were new for the science and 103 species were new reports for Mongolia. Most of the benthic taxa have an East Palearctic or Palearctic distribution, whereas the majority of plankton taxa are cosmopolitans.

A regional stream typology with 13 different types was developed using the criteria ecoregion, altitude and catchment area. The typology developed for stagnant waters comprises nine types based on altitude, lake area, existence of an outflow and relative depth. These typologies would enable assessment of the ecological quality of the waters if reference conditions are provided. The most important anthropogenic threats of the water bodies – eutrophication caused by overgrazing, decrease and salinization of groundwater due to agricultural water abstractions, and pollution by potential mining activities – could be counteracted best with a strict management of economic activities and improvement of the environmental awareness of the local population.

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Names, definitions and abbreviations

Translation of Mongolian words describing geographic objects

Mongolian (Cyrillic letters)	(English transcription)	English	German
аймаг	Aimag	province	Provinz
алтан	Altan	golden	golden
бага	Baga	small	klein
баруун	Baruun	western, right	westlich, rechts
баян	Bayan	rich	reich(lich)
булаг	Bulag	spring	Quelle
давс	Davs	salt	Salz
давст	Davst	lagoon	Lagune
дөрөө	Döröö	stirrup	Steigbügel
элс	Els	sand, dunes	Dünen
гол	Gol	river, stream	Fluss, Bach
хархираа	Kharkhiraa	growl, grumble	Brummen, Grollen
хар	Khar	dark, black	dunkel, schwarz
хот	Khot	town	Stadt
мөрөн	Mörön	river	Fluss
ногоон	Nogoon	green	grün
нуруу	Nuruu	mountain range	Gebirge
нуур	Nuur	lake	See
сайр	Sair	"pebble" (arroyo, gully)	"Kies" (Trockental)
шаварт	Shavart	loamy	lehmig
сум	Sum / Somon	county	Kreis
тэс	Tes	thoroughgoing	komplett, (durchgehend?)
тогоо	Togoo	pot, kettle	Topf
цагаан	Tsagaan	white	weiß
тургэн	Turgen	swiftly	schnell
улаан	Ulaan	red	rot
урт	Urt	long	lang
ус	Us	water	Wasser
уул	Uul	summit, mountain	Gipfel; Berg
үүрэг	Üüreg	burden	Fracht, Last
зүүн	Zuun	eastern, left	östlich, links

Mongolian geographic names and their Russian counterparts

The names of transborder geographic objects are always given in their Mongolian version, whereas in Russian publications the following names are mentioned:

Mongolian (Cyrillic letters)	Mongolian (English transcription)	Russian	Russian (English transcription)
Увс нуур	Uvs Nuur	Убсу-нур	Ubsu-Nur
Тэсийн гол	Tesiyn Gol	Тэс-Хэм	Tes-Khem
Дөрөө нуур	Döröö Nuur	Тере-Холь	Tere-Khol

Definitions

Date values in tables are given in the American format: month/day/year, but time in 24 hours format.

"Lake" means any body of standing surface water independent of its size, "stream" means any running water independent of its size and runoff permanence.

Abbreviations

ASL	above sea level (in altitude measurements)
BP	before present (in geographical age data)
DIN	dissolved inorganic nitrogen (NH_4-N + NO_3-N + NO_2-N)
DN	dissolved nitrogen (organically and inorganically bound)
DOM	dissolved organic matter
CPOM	coarse particulate organic matter
FPOM	fine particulate organic matter
IBP	index of lake basin permanence
LOI	loss on ignition
NTU	nephelometric turbidity unit
PCA	principal component analysis
PP	particular phosphorus
SRP	soluble reactive phosphorus (PO_4-P)
TN	total nitrogen
TP	total phosphorus
TSi	total silicon
TSI	trophic state index
T.U.	Tritium unit

1 Introduction

1.1 Significance of the investigations

Large areas of the Earth are characterized by an arid climate. They are often sparsely populated and relatively modestly influenced by man. Huge salt lakes are located in these areas, and despite the fact that about half the volume of the inland waters of the world is salty (WILLIAMS, 1993) there is comparably little limnological knowledge about these waters. Especially the waters of Central Asia have been investigated quite incompletely. This is due to the often poor accessibility of the areas and the limited scientific potential of the Central Asian countries. Another problem is the minimal international knowledge and availability of publications about these waters that are often written in Russian, Chinese or Mongolian.

The majority of salt lakes are located in endorheic drainage areas where all streams of water and matter end in one terminal lake (WILLIAMS, 1981). This implies a distinctively strong influence of the catchment on that lake. Consequently these lakes are especially susceptible to natural and anthropogenic perturbations. The most serious threats according to WILLIAMS (1993, 1996, 2002) are changes of the hydrologic regime of the lake and its tributaries (diversion of tributaries for irrigation and industry and groundwater overuse, influencing lake level and salinity), of the soil and vegetation cover in the catchment (overgrazing, erosion, salinization and intensified import of ions and suspended matter), mining, discharge of waste water (eutrophication, contaminant accumulation) and the introduction of alien species (repression of endemic species, gene pool changes of existing populations).

The other Central Asian waters, especially the tributaries of salt lakes, likewise deserve attention, as they are ecosystems shaped by the extreme climate and still scarcely influenced by man. Their lasting exploitation for industrial and drinking water is particularly important due to water shortage. Moreover, knowledge of the distribution of aquatic species is quite fragmentary for the whole region.

Both of these factors – the insufficient limnological basic knowledge and the particularly high potential of imperilment – make the water bodies in Central Asia interesting objects of investigation. In the case of Mongolia such research draws on a good and long tradition of cooperation between Mongolian and German scientists, which should be continued and intensified.

The main area of investigation is the Uvs Nuur Basin in Northwest Mongolia, an endorheic catchment covering 71 100 km² (DAVAA et al., 1991) on both sides of the Mongolian-Russian border, which equals the area of Bavaria. It is a unique area of great landscape diversity, featuring the world's northernmost desert and southernmost (on the northern hemisphere) tundra and permafrost soils, according to KHASLAVSKAYA et al. (1994). The basin is seen as a model region for geographical, climatological and geoecological research in Central Asia, as it contains most of its typical landscapes like desert, semi-desert, desert steppe, forest steppe, taiga, tundra, alpine mountain zones, salty marshes, sand dunes, flood plain forest and wetlands in a relatively limited area (BUGROVSKIY, 1990; USSR ACADEMY OF SCIENCES, 1991; OPP, 1998; TRETER, 1999). This high diversity of landscapes is due to sharp climatic and altitude gradients. The area is very sparsely populated, and the main human impact on the landscape elements is nomadic pasture farming with nearly unchanged intensity over many centuries. There is, however a high potential of threatening by increasing human activities, as is obvious in other Central Asian endorheic regions like the Aral Sea (LÉTOLLE & MEINGUET, 1996; ALADIN et al., 1998), Lake Balkhash (WILLIAMS, 1993; KAWABATA et al., 1999) or Lop Nor (WILLIAMS, 1993). Furthermore, the geologically long period of endorheic drainage make the basin, especially its lake sediments, a valuable archive for the development of climate and ecosystem since the Pleistocene (SEVASTYANOV et al, 1991, 1994; GRUNERT et al., 2000).

Faced with the uniqueness and vulnerability, since the 1990s Russia and Mongolia have taken efforts to protect important parts of the basin: both countries have set up several Strictly Protected Areas. This has culminated in the inscription into the UNESCO World Heritage List in 2003 (UNESCO, 2003 a, b). The site is made up of five Mongolian (8102 km²) und seven Russian (2586 km²) protected areas representing each of the major biomes of eastern Eurasia. Furthermore, the Uvs Nuur Basin is one of the International Geosphere-Biosphere Programme study areas for global change research and since 1997 part of the UNESCO Programme on Man and the Biosphere (UNESCO, 2005).

The water bodies of the region – reaching from alpine lakes and glacier streams to dune springs and salt lakes – can be supposed to show a high diversity too. Lakes (especially Uvs Nuur, which is Mongolia's largest lake) are an important feature of the basin, and have been investigated with different intensity since 1879 (SHIL'KROT et al., 1993). The work of Mongolian and Russian scientists, mainly from the 1960's onward, focused mostly on Lake Uvs. Despite the growing general scientific interest in the region, only few results of limnological investigations have been published internationally. Scattered, partially contradictory and by no means comprehensive data have been published among others by DULMAA (1979), USSR ACADEMY OF SCIENCES (1991), STATE COMMITTEE FOR NATURE AND ENVIRONMENTAL PROTECTION OF MPR (1991), SHIL'KROT et al. (1993), EGOROV (1993) and SEVASTIANOV et al. (1994).

In the year 1995 the interdisciplinary Mongolian-German joint research project "Palaeogeographical and Biospherical Conditions of Landscape Development in Northern Central Asia" has been started as unit of ten working groups with support of the Deutsche Forschungsgemeinschaft (DFG) and Gesellschaft für Technische Zusammenarbeit (GTZ). To study the limnological peculiarities of the area, the Mongolian-German research project "Limnological Particularities of Characteristic Waterbodies in the Uvs Nuur Basin" has been carried out as part of the joint project in the years 1996 to 2000. Participants were Prof. Dietrich UHLMANN, Dr. Wolfgang HORN, Markus PAUL (hydrobiologists, all Saxon Academy of Sciences, working group Limnology), Prof. Ayuryn DULMAA (hydrobiologist, ichthyologist; Mongolian Academy of Sciences, Ulaanbaatar), Dr. Gombyn DAVAA (hydrologist; Institute of Meteorology and Hydrology, Ulaanbaatar) and Noryingijn TSEVEENDORJ (meteorologist; Institute of Meteorology and Hydrology, weather station Ulaangom). The project was funded by Deutsche Forschungsgemeinschaft (DFG; grants UH 54/2-1, HO 1778/1-2 and HO 1778/1-3) and Gesellschaft für Technische Zusammenarbeit (GTZ; contract No. 81011694).

1.2 Aims of the investigations

With the presented work the limnological peculiarities of the region are to be characterized. A central question in that context is the influence of exogenous environmental factors on the formation of abiotic and biotic water body types in the region. The following tasks had been set up:

1. Description of the most important exogenous factors influencing the water bodies, using mainly results of the Mongolian project partners, other working groups and from the literature:
    - climate (precipitation, temperature, wind, insolation, climatic altitude level resp. vegetation zone)
    - catchment (geology, soils, vegetation, floodplain structure, settlements and economic activities)
    - shaping geological and geomorphological processes (tectonics, glaciation, erosion, water- and wind-driven transport, accumulation)
2. Spot check inventory of selected running and stagnant waters as well as exposed ground waters according to the following limnological aspects:
    - morphology (shape of valley and riverbed, slope, choriotope types, lake basin shape, hypsographic curves, wind exposition, structure of shore and littoral, examples for changes during the last 50 years)
    - hydrology (longtime runoff statistics, extreme runoff, flow characteristics, icing, lake level fluctuations and water balance, estimations of water age using its tritium content)
    - water chemistry: main ions, conductivity, pH, oxygen, chlorophyll-a, main nutrients (SRP, NO_3, NH_4 on-site; TP, DP, TN, DN, NO_3, Si, Fe in the laboratory)
    - lake sediment characteristics (water content, organic and carbonate content, cations, P content)

- hydrophysics (thermal regime, vertical structure of the water body, visibility, horizontal distribution of turbidity, chlorophyll content and surface temperature) using temperature data of Mongolian hydrologists, own data loggers and satellite images
- hydrobiology (macrophytes, phytobenthos, macrozoobenthos, phytoplankton, zooplankton, waterfowls, fishes and stygobios): assembly of species lists, semi-quantitative records

3. Using these primary data the following topics had to be dealt with:
   - outline of the regional particularities in the framework of natural and anthropogenic influences on state and biocenoses of the water bodies
   - sequence of water bodies corresponding to altitude, and matter fluxes (ion and nutrient load from spring through river and ground water to the lakes)
   - development of the water bodies during the last years and decades (changes of morphological, hydrological and chemical parameters)
   - coarse structure of food webs (trophic levels, final consumers, dominance and diversity), living conditions of important organisms (salinity, pH, temperature, icing, water runoff)
   - biogeographical classification
   - classification of rivers according to hydrological, morphological and biocenotic criteria
   - classification of lakes according to morphological, hydrological, thermal, trophical and salinity criteria
   - state of endangering and need of protection

1.3 Sequence of field research activities

From August 27th to September 2nd 1996 an initial expedition took place to explore the possibilities and conditions for fieldwork, to get a first impression of the huge area and its water bodies, and to take first samples. Its participants were D. UHLMANN, W. HORN, A. DULMAA and N. TSEVEENDORJ.

A conclusion for the following expeditions was, that the period of fieldwork should be in August when the condition of the steppe tracks and the weather are most suitable, and that most of the chemical and all biological analyses had to be made in Germany. Regarding the high possible interannual variation in the state of the waters it was decided to sample the most important water bodies during each expedition. In most cases a Russian off-road UAZ van was suitable to reach the sampling sites; in the Turgen Mountains horses had to be taken. In order to visit a great variety of water bodies, no fixed base camp was set up but instead the camp was changed daily or after a maximum of three days.

The fieldwork of the 1997 expedition was done from August 12th to 29th. The route led to the Turgen Gol, from its spring in the mountains to its trickling away end in the inner basin, to the northwest and southwest shore of Uvs Nuur and small lakes and springs in the vicinity, and to the Bayan Nuur and surrounding waters in the dunes east of Uvs Nuur.

The third expedition in 1998 was in the investigation area from August 9th to 30th. Its route started at Khyargas Nuur, led again to the rivers of the Turgen Mountains, the Borshoo Gol northwest of Uvs Nuur and to the Uvs Nuur itself, via the eastern bay of Uvs Nuur and the Nariyn Gol to the lakes Döröö and Bayan in the eastern dunes. Participants of two expeditions in 1997 and 1998 were W. HORN, M. PAUL, A. DULMAA, G. DAVAA and N. TSEVEENDORJ.

The fieldwork of the last expedition in 1999 took place from August 4th to 28th. Beginning with the headwaters of Tesiyn Gol, the route led again to Borshoo Gol, to the northwest shore of Uvs Nuur and waters in the Turgen Mountains, then to the Üüreg Nuur and two rivers at the eastern slope of the Turgen Mountains, to a lagoon at the southern shore of Uvs Nuur and further to the downstream reaches of Tesiyn Gol. In the end, the Bayan Nuur and some surrounding waters have been visited. Participants were W. HORN, M. PAUL, A. DULMAA and N. TSEVEENDORJ.

1.4 Area of investigation

1.4.1 Topographic situation and morphology

The endorheic Uvs Nuur Basin is shared between Mongolia (73%) and Russia (27%, mostly the northern delimiting mountains). Its northern boundaries are the west to east stretching Tannu-Ola and Senghilen Mountains, reaching about 3 000 m ASL. The headwater region of the largest river, the Tesiyn Gol that arises in the Bulnay Mountains, forms the basin's eastern end. In the south the Khan Khökhiyn Mountains delimit the basin with a maximum altitude of 2 928 m while the Turgen and Kharkhiraa Mountains west of the basin reach 4 037 m (National Atlas, 1990). In a wider geographic context, to the north the Yenisey Valley and farther the Sayan Mountains, to the west the mountain ranges of Altai are enclosing the basin. In the east and southeast the Khangay Mountains further extend, and only to the southwest the basin opens to the "Valley of the Great Lakes", a depression connecting to the Gobi Desert farther southeast.

The inner part of the basin at an altitude below 1 200 m covers one third of the whole catchment area. Large plains sloping with about 1% towards Uvs Nuur (759 m ASL) characterize it. Wind transport is a major force of landscape shaping: east of Uvs Nuur a dune area of about 170 km length and 30 km width, the Böörög Deliyn Els, stretches east southeastward. It was formed in the dry-cold late Pleistocene (KLEIN, 2000) and large areas are still active (GRUNERT & KLEIN, 1998). At the southwest shore of Uvs Nuur marshes scattered with small lakes are extending. The northeastern part of the inner basin is formed by the large floodplain of Tesiyn Gol.

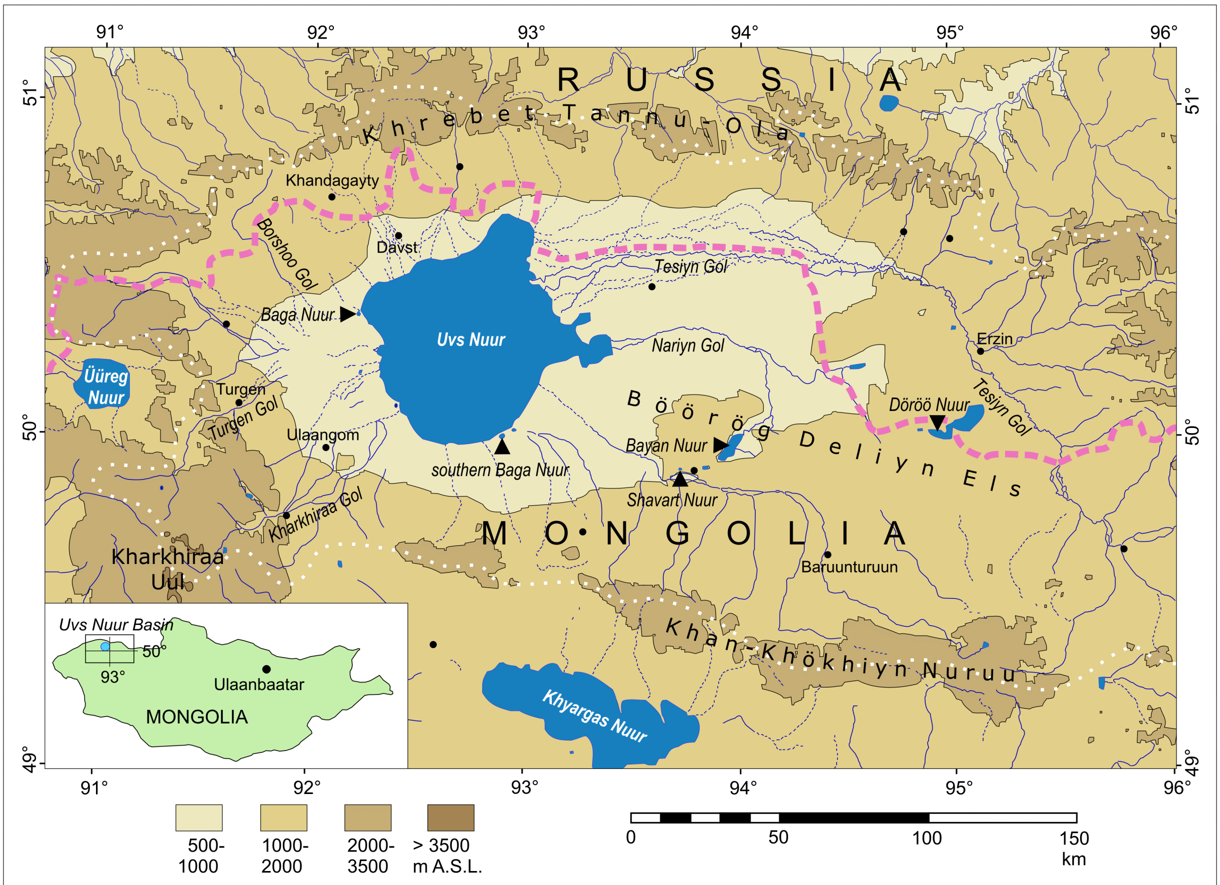


Fig. 1 Overview map of the central part of the Uvs Nuur Basin. White stippled line = Uvs Nuur Basin catchment boundary, dashed line = international border, black dots = settlements, names in italics = important sampled rivers and lakes. A detailed relief map of the whole basin with all sampling points is provided in the appendix.

The area of foothills between the surrounding mountains and the basin is formed of quaternary sediments and debris cones of the mountain rivers, often overlain with loess. The Tannu-Ola and Turgen-Kharkhiraa ranges in the north and west start rising at about 1 000 to 1 500 m ASL very steep from the foothills to altitudes of some 3 000 m. Alpine rivers break through the delimiting ranges, forming deep valleys. The southern and eastern mountains have more gradually rising slopes; especially the rich structured valley of the middle and upper reaches of Tesiyn Gol slopes only with 0.2 to 0.5%. The Turgen and Kharkhiraa Mountains are glaciated in their highest regions and the whole Turgen-Kharkhiraa massif is glacially shaped. The valleys have slopes between 0.5 and 10% making the rivers fast running.

1.4.2 Climate

The climate of the area must be designated as highly continental with very cold winters and warm summers. This is the result of several factors: First, the basin belongs to the world's areas farthest from the ocean, as the nearest open seas (Yellow Sea, Arctic Ocean) are some 2 500 km away – thus the amount of precipitation is generally quite low and the equalizing effect of the sea is completely lacking. Secondly, the northern and western mountain ranges shield the basin from the northwestern air current, receive most of the precipitation coming with it and cause a strong inner basin air circulation. Thirdly, the very stable Siberian winter high-pressure system (the Central Asian anticyclone with maximal air pressures of 1 055 hPa) with a temperature inversion provides for calm, very cold and dry winters (USSR Academy of Science, 1991). Fourthly, as the southern delimiting mountain ranges are quite low, hot and dry air from the desert area of the "Valley of the Great Lakes" reaches the basin easily during summer. The geographic latitude is with about 50 ° N the same as of Central Europe, thus the annual amount of incoming solar radiation is comparably high (1.2 to 1.3 MWh/m^2; National Atlas, 1990), and the summer in the inner basin can get hot.

Data used for the following detailed climatic characteristics were kindly provided by N. TSEVEENDORJ and G. DAVAA, Institute of Meteorology and Hydrology, Ulaangom and Ulaanbaatar (Table 1).

Table 1 Evaluated meteorological data series provided by the Mongolian Institute of Meteorology and Hydrology.

measured parameter	place / water body	period
air temperature [°C], monthly mean	Ulaangom	1943–1996
air temperature [°C], monthly absolute max., min.	Ulaangom	1980–1996
precipitation [mm], monthly sum	Ulaangom	1943–1996
wind speed [m/s], monthly mean	Ulaangom	1961–1990
water vapor pressure [mbar], monthly mean	Ulaangom	1961–1990
air temperature, precipitation, wind speed – daily values for August	Ulaangom	1996–1998

As a numeric measure for the degree of aridity, the index of aridity (DE MARTONNE & KÖPPEN, cited by KELLER, 1962) can be calculated according to the following equation:

$$i = \frac{P}{(T + x)} \qquad (1)$$

i = index of aridity,
P = mean annual precipitation [mm],
T = mean annual temperature [°C],
x = parameter describing the seasonal distribution of the precipitation (winter rain: x = 0; aperiodical rain: x = 7, summer rain: x = 14).

Using the data for Ulaangom (P=143 mm, T=-3.6°C, x=14) an index of 13.8 is obtained, which means semiarid to arid climate.

In addition to these general characteristics there is a strong climatic altitude gradient between the inner basin and the mountains. Whereas the area around Uvs Nuur has a fully arid climate with an annual precipitation sum of about 100 mm, mean July temperatures above 18°C and a potential evaporation of 600 mm, the highest parts of the western and northern mountain ranges receive more than 300 mm of precipitation which leads together with mean July temperatures below 10°C and a lower potential evaporation of less than 400 mm to a humid climate (National Atlas, 1990) and glaciated peaks in the Turgen-Kharkhiraa Mountains. Furthermore the lee effect of the northern and western mountain ranges that shield the cyclonal northwestern current makes the northern shore of Uvs Nuur (station Davst) an exceptionally dry place, whereas Baruunturuun on the northern slope of the Khan Khökhiyn Mountains gets twice an amount of precipitation (Fig. 3).

The air temperature reaches an annual average of only -3.6°C (monthly means at station Ulaangom 1943–1996) with very low winter values (mean temperature in January -32.5°C) and relatively warm summers (mean temperature in July 19.5°C) which results in an annual temperature amplitude between the monthly means of 52 K. The amplitude between the mean January minimum (-42.2°C) and mean July maximum (30.9°C) amounts to 73 K (data between 1980 and 1996). Due to the wintry temperature inversion the lowest temperatures ever have been measured in the inner basin, not in the mountains. The absolute minimum temperature near Uvs Nuur is -58°C (UNESCO, 2003a), whereas the highest summer temperatures in the inner basin reach 40°C.

The mean annual weather sequence at Ulaangom (935 m ASL), as shown in Fig. 2 and Table 2, has the following peculiarities: the calm, very dry (precipitation sum November–March is 20 mm) and cold winter lasts from mid-October to mid-April (about 185 days; HILBIG et al., 1999). The temperature falls relatively slowly in November to reach its minimum in January, stays cold in February to rise very fast (19 K per month) between March and April. The short spring comes with stronger winds and still little precipitation – so dust storms are common in spring. In the end of May a mean temperature of about 15°C is reached and the summer begins with rainy June and July and a dryer August. The precipitation sum of these three months amounts with 94 mm to two thirds of the annual sum. Autumn is short like spring; the temperature drops a bit more slowly, however.

Besides this distinct annual rhythm of temperature and precipitation there are also long-term trends and fluctuations. The global temperature rise since the 1980s can be observed in the Uvs Nuur Basin too, as visible in Fig. 4, especially for the winter months (see also BARSCH, 2003). Between 1980 and 1995 the mean winter temperature (December through February) increased by 4.0 degrees. In contrast to these 15 years, between 1943 and 1980 there is no trend and only slightly warmer winters in the 1950s and '60s. Otherwise, the summer temperatures show no trend and much smaller fluctuations from year to year. From the available data it is not clear whether the trend towards warmer winters will last through the next 10 years or if the mean temperatures are now decreasing again. One consequence of the higher winter temperatures is an increasing winter runoff of the glacier-fed Kharkhiraa Gol, as Fig. 5 shows.

The annual precipitation sum shows very strong year-to-year fluctuations (the coefficient of variation amounts to 43%). There seems however to be a long term periodicity of wetter and dryer years. SEVASTYANOV et al. (1991) mention cycles of 20 years. There are several hypotheses dealing with this periodicity (BATJARGAL et al., 1993; ZARETSKAYA et al., 1992) that will be discussed in connection with lake level fluctuations of Uvs Nuur.

More detailed climatic data and weather observations of the expedition period can be found in Fig. 66 in the appendix. Further climatic data for the time of field expeditions can be found in KRÜGER (2001); BLANK & KRÜGER (2001) provide information on the dynamics of soil water in the steppe region.

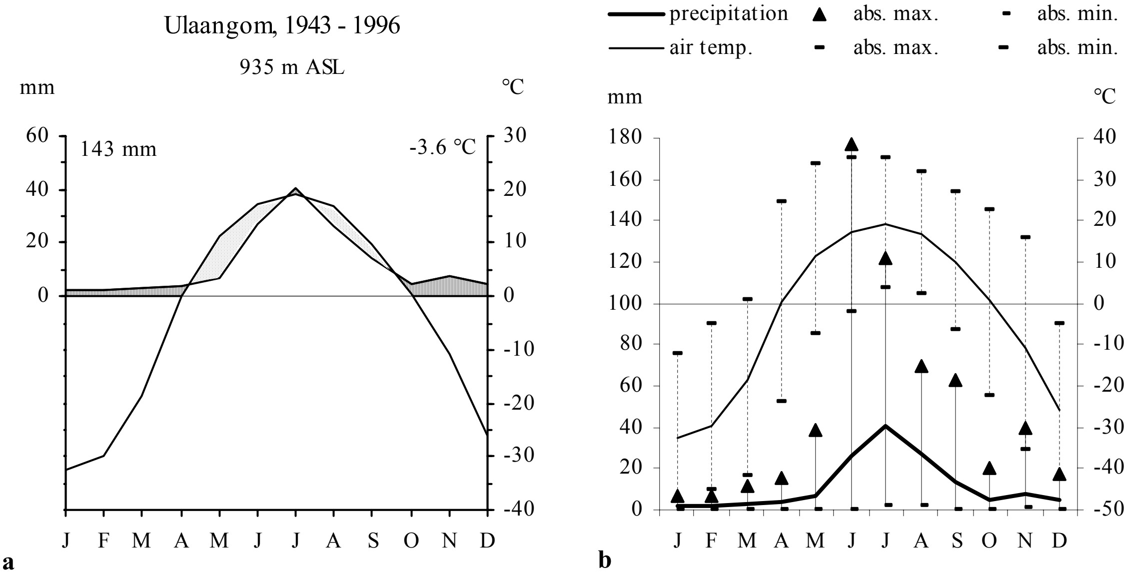


Fig. 2 a Climate diagram for Ulaangom; b - Mean values (1943-1996) and absolute monthly maxima and minima of precipitation (1943-1996) and air temperature (1980-1996) for Ulaangom.

Table 2 Monthly characteristics of climatic parameters for Ulaangom (all data from Mongolian Institute of Meteorology and Hydrology, Ulaanbaatar and Ulaangom).

	interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
absolute minimal temperature [°C]	1980-96	-47.6	-45.0	-41.7	-23.9	-7.4	-2.0	3.7	2.1	-6.5	-22.3	-35.3	-42.1
mean minimal temperature [°C]	1980-96	-42.2	-39.9	-34.6	-15.8	-4.2	2.5	7.1	4.8	-2.6	-12.6	-23.6	-37.7
mean air temperature [°C]	1943-96	-32.5	-29.8	-18.8	0.1	11.5	17.5	19.2	16.8	9.9	0.7	-10.9	-26.0
mean maximal temperature [°C]	1980-96	-20.1	-14.3	-2.8	18.5	27.1	31.0	30.9	29.3	23.3	17.0	3.0	-11.5
absolute maximal temperature [°C]	1980-96	-12.1	-5.2	1.0	24.4	33.5	35.0	35.3	31.9	27.0	22.5	15.9	-5.1
minimal precipitation [mm]	1943-96	0.0	0.1	0.0	0.0	0.0	0.0	2.1	1.8	0.0	0.0	1.1	0.2
25-percentile of precipitation [mm]	1943-96	0.8	0.9	1.4	0.9	2.3	8.5	19.7	11.7	5.7	0.2	5.0	1.9
mean precipitation [mm]	1943-96	2.2	2.1	3.5	4.0	6.7	26.9	40.2	26.5	14.1	4.5	7.9	4.8
75-percentile of precipitation [mm]	1943-96	3.2	2.6	5.3	5.5	8.0	35.1	50.8	34.5	19.0	6.4	9.1	6.9
maximum precipitation [mm]	1943-96	6.7	6.4	12.0	15.4	38.7	177.0	122.4	69.3	63.2	19.9	39.9	17.4
mean air humidity [%]	1961-90	84	86	96	67	50	55	64	65	69	76	92	93
mean wind speed [m/s]	1961-90	0.7	0.8	1.0	1.8	2.2	1.9	1.5	1.5	1.5	1.4	1.2	0.8

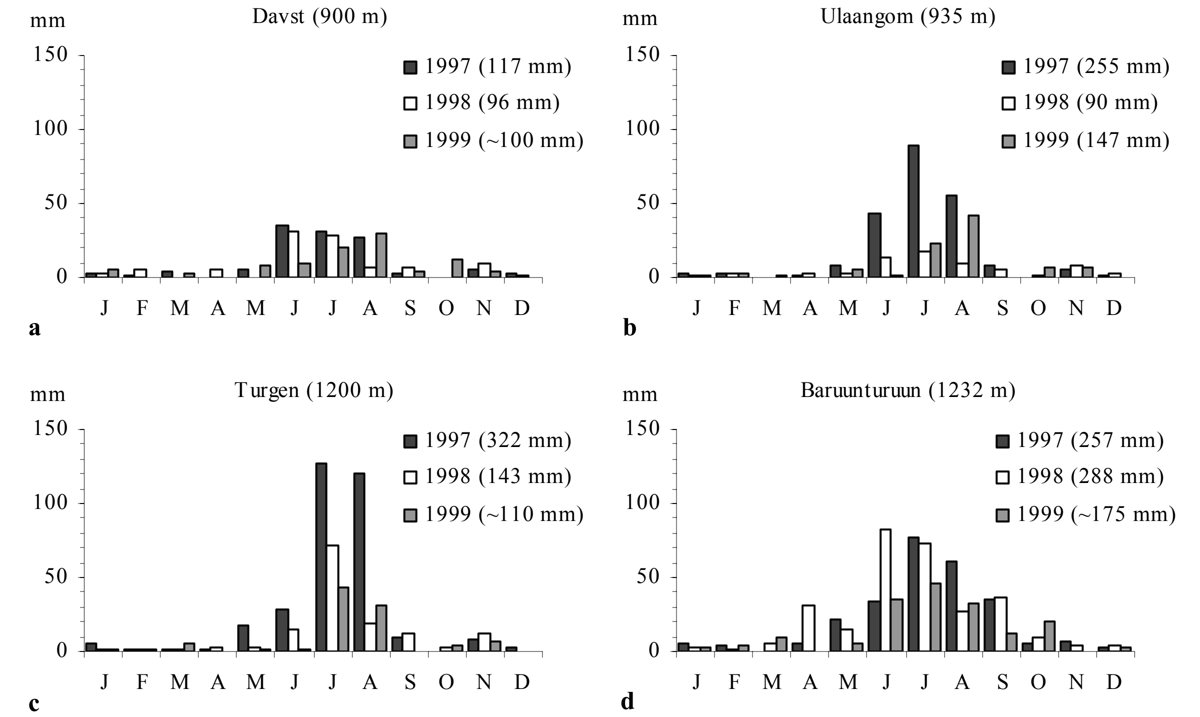


Fig. 3 Monthly precipitation sums of the years 1997-1999 for the stations **a** Davst (92°23'E, 50°38'N), **b** Ulaangom (92°03'E, 49°58'N), **c** Turgen (91°40'E, 50°08'N) and **d** Baruunturuun (94°25'E, 49°40'N) – see map in Fig. 1. Several annual sums are estimated due to some missing monthly values.

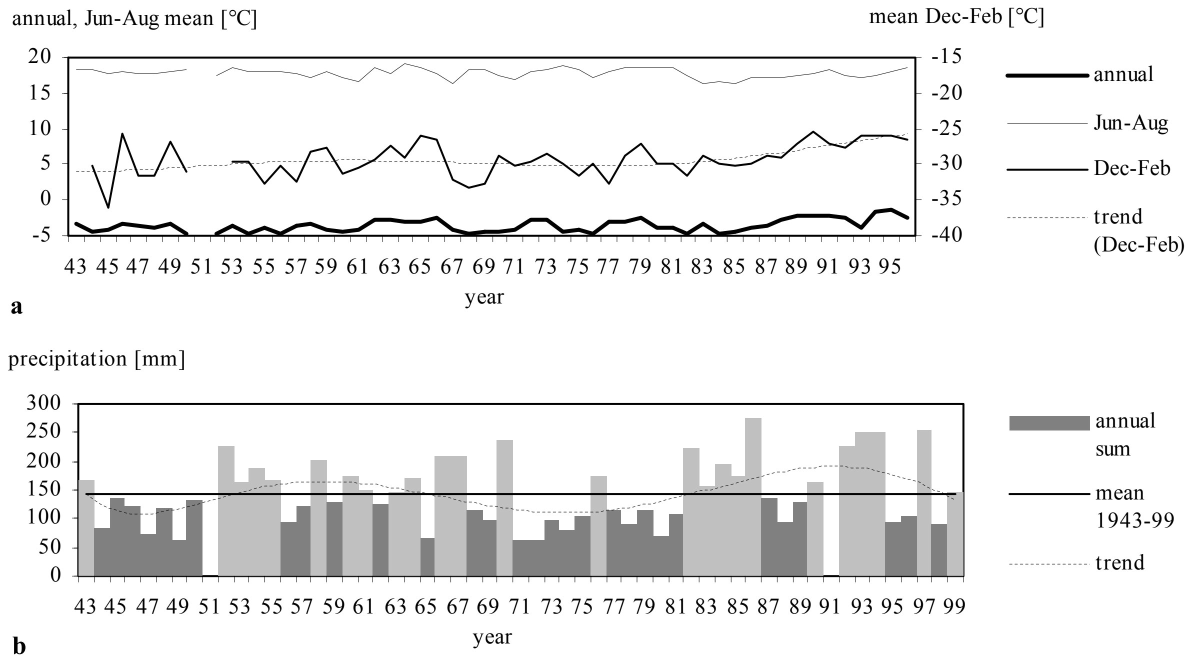


Fig. 4 Long term climatic trends, station Ulaangom. **a** - air temperature, annual means and means of the months December through February (trend line: 5th order polynomial best fit); β - annual precipitation sum (years 1997-99 from Barsch, 2003); light gray = wet years, dark gray = dry years (trend line: 6th order polynomial best fit).

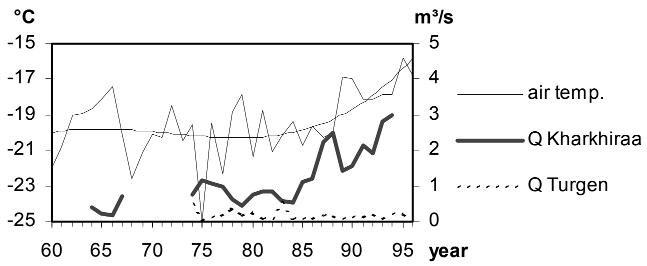


Fig. 5 Winter air temperature (mean value Nov–Apr) at Ulaangom and runoff Q of Kharkhiraa and Turgen Gol (mean value Nov–Apr).

1.4.3 Geology and soils

The Uvs Nuur Basin was formed tectonically. It lies between the Eurasian and Chinese plate and is until present tectonically active (MURZAEV, 1954; BALJINNYAM et al., 1993; BADARCH et al., 2000; LEHMKUHL, 2000). Prominent signs of the neotectonic activities in Western Mongolia are shifts of some 30 meters across quaternary alluvial depositions (LEHMKUHL, 2000; GRUNERT et al., 2000), major earthquakes during the last 100 years and large active fault lines like the Bulnay Fault forming the southern border of the eastern Uvs Nuur Basin, as well as the SW-NE running fault that crosses the inner basin east of Uvs Nuur, where granitic inselbergs can be found (WALKER et al., 2006; see relief map in the appendix). These tectonic activities influence the river network as well as the formation of lakes.

The whole region has been dry land since the Permian. A huge basin formed the Central Asian lake landscape. The present shape of the basin has been formed during the Alpidic orogeny, when the delimiting mountain ranges started lifting and the Khan Khökhiyn Mountains divided the Uvs Nuur basin from the southern "Valley of Great Lakes" (MURZAEV, 1954).

These ranges consist of various paleozoic rock types (National Atlas, 1990) – metamorphites and sedimentites (schists, limestone, sandstone), intermixed with plutonites (granite, granodiorite) and volcanites (basalt). The Khan Khökhiyn Mountains are formed of Precambrian tonalites, granodiorites and plagiogranites alternating with oceanic basalts and andesito-basalts of the early Cambrian. The eastern promontories of the Turgen-Kharkhiraa Mountains consist of oceanic basalts and andesito-basalts of the early Cambrium, siliceous respectively carbonatic schists of the Ordovician, Silurian rocks and middle Devonian sandstones, conglomerates and others. The main massif of these mountains was formed of siliceous and carbonatic schists of the late Cambrian and middle Devonian, granodiorites and granites of the Ordovician (upper reaches of Turgen Gol), volcanites of the early Devonian (upper reaches of Dshibertu Gol) and Devonian granites or granosyenites (southern part of the massif). In the mountains north of Uvs Nuur, sedimentites (sandstones, conglomerates and others) of the Devonian, Carbonian and Jurassic are found. The quite high pH values of the investigated surface waters are a clear sign for the dominance of alkaline rock. Furthermore, the ion analyses (especially Na^+, Ca^{2+} und Si) of springs and streams show how small-scaled the mineral composition of rock changes in the Turgen-Kharkhiraa Mountains – see chapters 3.1.4 and 3.2.6.

The inner basin is characterized by mighty quaternary rubble, gravel, sand and clay layers of riverine, lacustrine and eolian genesis and often high calcium content. The latest accumulation phase of alluvial fans (gently sloped sediment cones on the mountain foot) and sand dunes was during the Pleistocene (GRUNERT & LEHMKUHL, 2004). During this time the Turgen and Kharkhiraa Mountains were widely glaciated and permafrost soil formed that still today is present above 2 200 m ASL (LEHMKUHL, 1999).

The soil formation is strongly influenced by climatic conditions. The predominating soil types in the areas with high groundwater distance – the dry inner basin, sand dunes and hillsides – are zonal steppe soils. Light Kastanozems of different development and thickness and Burozems (brown desert steppe soils) that are characterized by a high carbonate content and alkalinity. Often lime and gypsum is enriched. In groundwater affected areas (around Uvs Nuur, floodplain of Tesiyn Gol), intrazonal humus rich Gleysols and Fluvisols occur. In dry depressions and in the shore areas of salt lakes salt soils (Solonchak, Solonetz) and salty floodplain soils are found. In the mountain region the soils follow the climatic altitude zones. Kastanozems of the forest steppe are followed by alpine tundra and crude soils (Dernozems and Leptosols) that are formed by frost processes. Under a thin stony humic layer permafrost prevails (BARSCH, 2003; OPP & HILBIG, 2003; KNOTHE et al., 2001; HILBIG et al., 1999).

1.4.4 Vegetation

The vegetation shows most impressively the effect of the sharp climatic gradients. There are vegetation zones along the altitude gradient in an unusually close sequence as well as azonal wetlands. The peaks of the Turgen and Kharkhiraa Mountains (3 500 to 4 000 m ASL) are glaciated and almost free of vegetation. Then (between 2 500 and 3 500 m ASL) alpine tundra with grasses, dwarf shrubs, mosses and lichens follows. The slopes of the Turgen Mountains (1 400 to 2 500 m ASL), the slopes of the Khan Khökhiyn Mountains with north exposition and most of the Tannu Ola and Senghilen Mountains are grown with forest steppe and mountain taiga where *Larix sibirica* dominates and is mixed at some places with an undergrowth of *Betula nana*. The larch trees reach ages up to 400 years. These forests are subject to fires (clearly visible on Landsat satellite images) that destroy the younger trees, leaving behind only the old trees with a very thick bark (TRETER, 2000; SOMMER & TRETER, 1999). The upper forest limit is set by the low temperatures and permafrost soils. The lower forest limit that results from water shortage due to high summer temperatures and less precipitation often is additionally influenced by largely uncontrolled logging. Once a forest stand with unfavorable conditions is clear-cut, the chance for a natural reforestation is low due to changed microclimate and livestock grazing.

Below the forest steppe on the mountain slopes and alluvial fans a rich grass and herb steppe grows, sometimes spotted with shrubs of *Caragana*. The mountain steppe shows with decreasing altitude and from west to east a transition over dry steppe to semidesert, which dominates the inner basin. Furthermore, the vegetation in the inner basin depends on the soil type. On the Boorig Deliyn Els dunes psammophytes grow; in salty depressions around Uvs Nuur halophytes are found. Large areas in river floodplains or with upwelling groundwater – most noticeably west and north of Uvs Nuur and the large delta of Tesiyn Gol – are densely grown with shrubbery and trees (*Salix ledebouriana*, *Populus laurifolia*, *Betula microphylla* and more seldom *Larix sibirica*), and meadows as a degradation stadium. Shallow amphibian zones along the shores of Uvs Nuur and Döröö Nuur are grown over with dense, extended *Phragmites australis* canebrakes (HILBIG & OPP, 2005; HILBIG et al., 1999; HILBIG, 1995). Almost everywhere the vegetation is influenced by human activities – most of all livestock grazing, but also logging and car traffic on steppe tracks. With increasing grazing pressure the well edible grasses and herbs give way to inedible herbs and dwarf shrubs; the vegetation cover is thinned out.

1.4.5 Population and economy

The population density in the whole area is one of the lowest worldwide. In the regions west of Uvs Nuur, the delta and the upstream region of Tesiyn Gol it reaches 1.0 to 1.5 inhabitants per km², whereas in the desert steppe southeast of Uvs Nuur less then 1 inhabitant per km² is living (National Atlas, 1990). There is one town of some 30 thousand inhabitants – the Uvs Aimag capital Ulaangom, with little industry (food, building materials, sawmill, garages), some commerce and administrational, educational, cultural, and medical facilities. Only a few houses are attached to a drinking water network; a sewage system is mostly lacking. In the countryside most of the people live as nomadic or seminomadic herdsmen. The countryside population lives somewhat concentrated in the Somon centers, small villages of yurts and cottages with a population of some 1 000 inhabitants. Generally the nomads live in small groups of one or more families with 2 to 6 yurts and their livestock – above all herds of several hundred sheep and goats, but also cattle, horses and camels. They change their place in a regular manner about 4 times a year seeking the best pastures according to the annual change of vegetation. The most important prerequisite for setting up a yurt camp is the access to potable water, which brings about an uneven distribution of people and livestock with a concentration near water sources – mainly wells, but also clean rivers or freshwater lakes. Due to the bad condition of many wells – the whim pumps often have been destroyed – the uneven distribution of livestock has increased since 1990. The total amount of livestock in the Uvs Nuur Basin is roughly about 2 million units. Tillage areas, mainly for grain and fodder, covered about 1.5% of the whole basin before 1990 (National Atlas, 1990). As satellite imagery shows, most of these fields now are used as pasture again.

The road network is poorly developed – it consists of unpaved roads, that often are simply tracks through the steppe. Electricity is often unavailable. Because of the poor infrastructure geological resources like coal, salt and some other minerals are exploited only in small scale. Some mines are working in the Uvs Aimag – one traditional salt pit north of Uvs Nuur, some small coal mines in the mountains south of the Uvs Nuur Basin, and after 1990 two gold mines started working – one in the Turgen Mountains 10 km northeast of Turgen-Delgermörön, the other 30 km south of Kharkhiraa Gol outside the Uvs Nuur Basin (N. TSEVEENDORJ, pers. comm.). Neither of these mines is big enough to be visible in Landsat satellite images taken after 2001, in contrast to the huge gold placer mines along the River Tuul west of Ulaanbaatar.

Rivers and lakes are not very important for the economic activities in the Uvs Nuur Basin. There is until now no usage of water power, negligible industrial water use, only locally important water use for irrigation and nearly no fisheries. The morphology of the rivers is virtually unaffected by human activities – one reservoir for irrigational purposes, some small irrigation channels and bridges are the only hydraulic engineering buildings.

In the years after 1990 major changes occurred in the economy of Mongolia. The conversion from the socialist centralized planned economy to a market economy with little regulations led to a decrease of industrial production and tillage, an increase of people living as herdsmen, but also a strong migration towards the cities (most of all the capital Ulaanbaatar). Especially from the Uvs and other western aimags many herdsmen moved to central Mongolia to have better access to markets for selling their products (JANZEN, 2000; SHIIREV-ADIYA, 2000). Arable land use has drastically reduced since 1990 due to unfavorable climatic and economic conditions as well as soil degradation (AVAADORJ et al., 2000). For instance, satellite images show an extreme decrease of the watered area near Baruunturuun: 200 km^2 in 1991, only 10 km^2 in 2002. As the marketing of animal products has become more difficult, livestock numbers increased by about 40% to a level at which overgrazing becomes a regionally major problem. The structure of herds has changed towards a higher percentage of Cashmere goats in the mixed sheep and goat herds. Their wool can be sold at a better price, however their grazing causes a higher pressure on the steppe vegetation than sheep do (TUMURJAV & TSOLMON, 2000; NYAMDAVAA, 2000; BASTIAN, 2000).

The land-use by nomadic pasture lasting for several thousand years has transformed the natural steppe and forest steppe ecosystems into anthropogenic biomes that mainly belong to the types “Remote Rangelands” and “Populated Rangelands” according to ELLIS & RAMANKUTTY (2008).

1.4.6 Former limnological investigations in the Uvs Nuur Basin

This short depiction describes the publications known to the author and most probably is not complete. Investigations by Russian scientists date back to the end of the 19th century. The Russian geographer G. N. POTANIN was the first to describe the Uvs Nuur Basin and took water samples of Uvs Nuur on his expedition through Northwest Mongolia in 1879 (POTANIN, 1883). Since then the huge salt lake has drawn the attention of researchers. Until the 1940s mainly Russian scientists investigated the area – in 1926 V. A. SMIRNOV (in SHIL’KROT et al., 1993) and in 1941 SH. D. BESPALOV (in DAVAA, 1996a). Beginning after World War II, Mongolian scientists in increasing numbers were working and publishing on the waters. S. LAMZHAV (1948) and D. DAVAASUREN (1956, 1958) are cited by DAVAA (1996a). Investigations of aquatic biota by Mongolian scientists seem to have been sparsely published – DULMAA (1979, 1981) gives an overview. Russian monographs on limnological topics of whole Mongolia were published since the 1950s (for instance BORUTSKIY, 1959; KUZNETSOV, 1961; KOZOVA et al., 1975; SOKOLOV & SHATUNOVSKIY, 1983; BUL’ON, 1985; RASSAKAZOV & ABRAMOV, 1985; SEVASTYANOV & DOROFEYUK, 1992; EGOROV, 1993; KOZHOVA et al., 1994; SEVASTYANOV et al., 1994). In the 1960s intensive studies of Hungarian, German and Czechoslovakian hydrobiologists in Mongolia began to found a long tradition of investigations and cooperation with scientists from Middle Europe and the Soviet Union (STUBBE & BOLOD, 1971; MANNHEIMS & SAVCHENKO, 1973; MINAR, 1976; ZHILTZOVA, 1975; SOLDAN & LANDA, 1977; SOLDAN, 1978; BAJKOVA, 1978; BRAASCH, 1977, 1979, 1982, 1983, 1986; MEY, 1978, 1980 in ZIMMERMANN, 1982, 1986; KASZAB, 1983; BRTEK et al., 1984; FLÖßNER, 1986). Unfortunately, the Uvs Nuur Basin was covered only by a few of these research projects. A real boom of investigations in the Uvs Nuur Basin began in the 1990s. Russian researchers within the project "Experiment Ubsu-Nur", Mongolian and later German research teams studying the whole ecosystem of the Basin also intensified the investigations of the lakes and rivers in the area, now focusing not only on Uvs Nuur. The results mainly were published in conference proceedings (BUGROVSKIY, 1990; USSR Academy of Sciences, 1991; State Committee for Nature and Environmental Protection of MPR, 1991; Russian Academy of Sciences, Siberian Branch, 1993, 1994, 1996; Tuva Republic Government, Russian Academy of Science, Siberian Branch, 1997; Mongolian Ministry of Nature and the Environment & World Wide Fund for Nature, 1999). In the years after 2000 several international and national hydrobiological research projects were started. A Mongolian-American research group investigated the paleolimnology of 64 Western Mongolian lakes, including Bayan, Üüreg and Uvs Nuur (EDLUND et al., 2003; SHINNEMAN, 2008, 2009; VAN DER MEEREN et al., 2010); another ongoing project involving the Uvs Nuur Basin is the Mongolian Aquatic Insect Survey (GELHAUS et al., 2008).

This listing suggests that a wealth of limnological information for the area of investigation should be available. However, as many of the papers are in Russian and Mongolian languages and were published in only locally available journals they are little known to western scientists. Also, the waters of the Uvs Nuur Basin are covered poorly in many general publications on Mongolian waters due to their remote locality. Some important general publications are DULMAA (1979, 1981), WILLIAMS (1991), EGOROV (1993), SHIL'KROT et al. (1993) and SEVASTYANOV et al. (1994). SEVASTYANOV & DOROFEYUK (2000) give an overview of Russian-Mongolian limnological research activities.

1.4.7 Short description of the investigated waters

Most of the running waters in the Uvs Nuur Basin originate in the more humid mountain ranges as alpine rivers with high discharge variability or more steady mountain rivers. Some of them reach the Uvs Nuur as surface waters, smaller streams seep into the ground leaving behind a dry bed. Sometimes they come back to the surface in the inner basin in the form of river bed springs, wetlands or desert streams. During floods most of the rivers can reach the lake directly.

Most of the numerous lakes in the basin are found in the two landscape forms of high mountains and the flat inner basin. The foothills and sloped alluvial fans are free of them. Whether they contain freshwater or saline water depends essentially on the climatic conditions in their catchment and the existence of an outflow that can at least be reached by a moderate rise of the water level.

Groundwater flow plays an important role for the connection of discontinuous rivers and feeds many of the lakes in the inner basin. Residence time and chemical properties of the groundwater bodies depend on the structure of the aquifers and the rate of groundwater recharge that is determined by climate, soil and vegetation cover.

From this wealth of water bodies, the most important, representative and well accessible were chosen for investigations. There are nine rivers and nine lakes that had been visited two or three times, and fourteen other rivers and six lakes that were sampled once. The seventeen groundwater sampling points – springs and wells – represent at least seven different groundwater bodies. A short description of all water bodies follows in Table 3 – details are given in chapter 3. Table 45 in the appendix contains a complete list of sampling places together with geographic coordinates and altitudes.

Table 3 Short description of investigated water bodies. No. = numbers of sampling places corresponding to those in Table 45.

No.	Name	Description
Running waters		
3	Baruunturuun Gol	Stony and gravelly mountain river at the northern slope of the Khan Khökhiyn Mountains, some water abstraction for agriculture, seeps into the Böörög Deliyn Els dunes in its lower reach.
5 - 9	Borshoo Gol	Slightly eutrophic low mountain stream with rich floodplain vegetation (meadow and shrubbery), rises in the southern slopes of the Western Tannu Ola Mountains and seeps into the ground before reaching the NW shore of Uvs Nuur. Single-channel, slightly meandering, gravelly bed with typical change of riffles and pools.
17	Burgastay Gol	Mountain stream running towards the S shore of Üüreg Nuur, low runoff, little floodplain vegetation.
20 - 24	Dshibertu Gol	Small alpine river, biggest left tributary of Turgen Gol, stony braided bed with relatively narrow flood-plain, fast running.
25 - 26	Endert Gol	Short eutrophic groundwater fed meadow stream in the Turgen Mountains, rises from a flat swampy pasture, stony bed, fast running.
27	Gurmosyn Gol	Muddy eutrophic lowland river with increased salt content (cond. 1230 µS/cm), extension of the Baruunturuun and Khangiyltsagiyn Gol after groundwater passage, reaches the SE shore of Uvs Nuur only during flood.
28	Jireeg Gol	small groundwater fed stream on the N shore of Uvs Nuur
29	Khangiyltsagiyn Gol	Stony and gravelly braided mountain river at the northern slope of the Khan Khökhiyn Mountains, parallel to the Baruunturuun Gol, wide stony floodplain, seeps into the ground near the dunes.
30	Kharig Gol	Mountain river west of Üüreg Nuur, rises in the Russian part of the Tsagaan Shivetiyn Mountains, most important tributary of Üüreg Nuur, at sampling place braided with wide bare floodplain.
31	Kharkhiraa Gol	Big, stony, fast running alpine river in the southern part of the Turgen-Kharkhiraa Mountains. Rises from the glaciers of Kharkhiraa Mountain, divides into three branches after leaving the mountains.
32	Khoyd Gol	Outflow of Bayan Nuur, sandy meandering lowland stream, discharges into Nariyn Gol.
34 - 36	Khustay Gol	Sandy and gravelly, meandering, spring fed stream in the in the dunes east of Bayan Nuur. Floodplain with rich shrubbery and meadow, deep incised into the sand dunes, biggest tributary of Bayan Nuur.
41 - 44	Nariyn Gol	Sandy, shallow, groundwater fed lowland river east of Uvs Nuur, rises in the Böörög Deliyn Els dunes some km west of Döröö Nuur, receives the outflow of Bayan Nuur and several other spring fed tributaries, discharges into the eastern bay of Uvs Nuur, rich algal and macrophyte growth, water in the upper reaches clear, near mouth very turbid (silt); floodplain meadow without shrubs.
46	Sagil Gol	Gravelly low mountain stream, parallel to the Borshoo Gol, rises in the Tsagaan Shivetiyn Mountains and seeps into the ground before reaching the NW shore of Uvs Nuur.
58 - 64	Tesiyn Gol	Biggest river of the basin, rising in the Bulnay Mountains ~400 km east of Uvs Nuur at 2300 m ASL, flowing westward through mountainous meadow steppe as stony-gravelly mountain river, receiving many tributaries from the Senghilen Mountains. Often changes its character between meandering and braided, more straight, depending on the slope; mostly multiple channels and many oxbow lakes. When reaching the inner basin it is forced to bend north by the sand masses of Böörög Deliyn Els. Lower reaches sandy, heavily meandering, with wide and densely vegetated floodplain; over the last 30 km branching into two main arms before discharging into Uvs Nuur.
66	Teylin Gol	Gravelly river in the SW of the inner basin, the southernmost of the three branches of Kharkhiraa Gol.
68	Torkhilog Gol	Mountain river north of Uvs Nuur, rises in the Tannu-Ola Mountains at 2200 m ASL and reaches the Uvs Nuur directly, slope at sampling point 1.4%, rich floodplain vegetation.
69 - 71	Tsunkheg Gol	Alpine stream in the easternmost range of the Turgen Mountains, high slope, stony, partially canyon-like, discharges into Turgen Gol.
72 - 85	Turgen Gol	Alpine river rising as glacier stream in the Turgen Mountains, stony with high slope, after receiving some big tributaries braided with extended stony floodplain, flowing through an intramountainous basin. Breaking through the eastern range of the Turgen Mountains in a narrow canyon-like valley. Divides after leaving the mountains into four branches and loses most of its water by trickling into the gravelly ground. Farther towards Uvs Nuur the groundwater flow reaches the surface again as small springs and rills and forms an extended wetland with rich shrubbery. High flooding potential.
86	Ukhug Gol	Sandy, swampy, eutrophic lowland stream in the floodplain of the downstream Tesiyn Gol, probably fed by the groundwater stream of that river; surrounded by rich shrubbery and reed.
87	Urt Bulag Gol	Sandy lowland stream in the Böörög Deliyn Els dunes, similar to Khustay Gol, with rich floodplain vegetation, discharges into Khoyd Gol.
Stagnant waters		
1	alpine lake near Turgen Gol	Very small (0.5 ha) alpine freshwater (cond. 88 µS/cm, pH 8.2) lake in the Turgen Mountains not far from, but without connection to Nogoon Nuur. Only a few meters deep, bottom coarse stony, very likely fishless.

Table 3 continued.

no.	name	description
2	Baga Nuur	Eutrophic, groundwater fed, shallow lake at NW shore of Uvs Nuur, very turbid, subsaline (cond. ~1800 µS/cm, pH ~10), calcareous mud sediment layer on gravel, scarcely submerged macrophytes (*Potamogeton*), wide reed belt. "Baga" means "small", but the lake has an area of 1.2 km².
4	Bayan Nuur	Large, deep oligo- to mesotrophic, dimictic freshwater lake (cond. 430 µS/cm, pH 9.0). Surrounded by semidesert and fed from dune springs, with outflow to Uvs Nuur. Muddy, calcareous sediment with Characeae and *Potamogeton pectinatus*, no reed belt.
19	Döröö Nuur	Large, mesotrophic, relatively shallow polymictic steppe lake in the Böörög Deliyn Els dunes, subsaline (cond. 710 µS/cm, pH 9.2), groundwater fed, with exclusively subterranean outflow. Sandy/muddy sediment overgrown with Characeae, *Potamogeton pectinatus*, wide reed belt.
33	Khukhu Nuur	Channel shaped high mountain lake in the easternmost range of the Turgen Kharkhiraa Mountains, deep, presumably oligotrophic, dammed by a landslide.
37	Khyargas Nuur	Very large, deep (80 m; National Atlas), oligotrophic, hyposaline lake (9 mS/cm) south of Uvs Nuur Basin; the northernmost in the Valley of Great Lakes. Surrounded by desert and fed by Zavkhan Gol.
38 - 39	lagoons 1 and 2 at Üüreg Nuur	Very small, shallow, eutrophic, saline (cond. 6-7 mS/cm) coastal lagoons at the S shore of Üüreg Nuur, gravelly sediment, rich growth of benthic and planktic algae, no vegetation in the surroundings.
40	lagoon 2	small, shallow groundwater fed lake near the SW shore of Uvs Nuur, very similar to Seepage Lake
45	Nogoon Nuur	Small, deep (> 30 m), oligotrophic high alpine freshwater lake (cond. ~50 µS/cm) in the Turgen Mountains, fishless, coarse stony bottom without macrophytes, rain and melt water fed. Surroundings mountain tundra.
47	Seepage Lake	Nameless, small, shallow (3 m max. depth), mesotrophic, weakly humic groundwater-fed lake at the SW shore of Uvs Nuur. Subsaline (cond. 2.5 mS/cm, pH 8.9), influenced by infiltrating lake water of Uvs Nuur. Sediment gravelly/muddy, overgrown with filamentous algae and macrophytes; rich reed stands.
48	Shavart Nuur	Medium large, shallow, eutrophic, subsaline (cond. 1840 µS/cm, pH 9.2) steppe lake at the southern rim of the Böörög Deliyn Els dune field, fine sandy sediment with *Potamogeton pectinatus*, but no reeds. Used for livestock watering, high mineral turbidity.
49	Southern Baga Nuur	Big, shallow (area 2.8 km² and depth 2–3 m), mesotrophic, mesosaline lake (cond. 23.6 mS/cm, pH 9.4) near the S shore of Uvs Nuur, without inflow and surface outflow, very likely fishless. Shore with rich reed belt, muddy sediment without macrophytes. Salt precipitations at the shore. Old shore lagoon of Uvs Nuur, now ~3 m above the water level of Uvs Nuur.
61a	Tesiyn Gol-3.5a (oxbow pond)	Oxbow pond isolated from Tesiyn Gol in the floodplain forest 150 m away from the river. Rich macrophyte and algal growth on muddy sediment.
65	Tesiyn Gol-5.5 (oxbow pond)	Very small, muddy oxbow pool in the 20 km wide floodplain of the downstream Tesiyn Gol, only connected to the 3 km distant river during high flood, surrounded by Salix shrubbery. Fresh water.
67	Togoo Nuur	Small, very shallow, subsaline (cond. 990 µS/cm), eutrophic steppe pond 12 km from the eastern shore of Uvs Nuur. Muddy, grown with filamentous algae and reed stands, many water birds.
88 - 90	Üüreg Nuur	Large, deep, oligotrophic, hyposaline terminal lake (cond. 6.2 mS/cm, pH 9.2) at an altitude of 1425 m in a separate basin west of the Uvs Nuur Basin. Most tributaries rising in the Tsagaan Shivetiyn Mountains. Gravelly sediment without macrophytes, western shore with extended reed belt, otherwise mostly bare surf shore.
91 - 94	Uvs Nuur	Terminal lake of the Uvs Nuur Basin: very large, relatively shallow, oligotrophic hyposaline lake (cond. 19.1 mS/cm, pH 9.0) at 761 m ASL. Sediment mostly sandy, partly shallow shore with extended reed belt, partly gravelly surf shore without macrophytes. Several small lagoons behind the gravel bar. NW bay with steeply declining bottom, SW shore shallow, rich structured, E bay mesotrophic, influenced by the fresh water of Nariyn Gol (which is certainly also the case at the shallow NE shore, where Tesiyn Gol discharges).
Ground water		
16	Burat Usu Bulag	Freshwater pot type spring near the NW shore of Uvs Nuur, surrounded by rich shrubbery; literally "spring of boiling water".
15, 18	Butsaldag Bulag	Freshwater spring near Burat Usu Bulag at the NW shore of Uvs Nuur, surrounded by rich shrubbery; running as small gravelly stream to Uvs Nuur.
54	spring at Borshoo Gol-2	Floodplain spring amidst shrubbery near the bed of Borshoo Gol, fed by the hyporheic underflow of the stream.
56	spring at Urt Bulag Gol	Sandy spring at the foot of a dune slope in the Böörög Deliyn Els dunes NE of Bayan Nuur, aquifer confined by a thin upper chalk layer.
57	spring-1 at Bayan Nuur	Extended sandy spring at the foot of a dune slope near the SW shore of Bayan Nuur, fed by groundwater that infiltrates from a lake 3.5 km to the SW at 50 m higher altitude.
95, 97	well 1, well 3	Dug wells in the dunes east of Uvs Nuur, water table 6 m resp. 15 m under terrain level.
96	well 2	Artesian well near the south shore of Üüreg Nuur, capacity 150 l/min.

2 Methods

The methods and devices used for fieldwork have been chosen for simplicity, robustness, small size and weight and independence from electric power and laboratory media like big amounts of deionized water. Furthermore, as some of the sampling and analytical procedures and measuring devices had to be changed from 1996/97 to 1998/99, not all physico-chemical data have been acquired with the same method over the four years. A comprehensive overview of differing methods for sampling and analysis of water and sediments can be seen in Table 48 in the appendix.

Chemical analyses were made for 102 water samples and 18 sediment samples from 70 sampling places, about 150 spot measurements and 17 depth profiles of physical parameters were taken, 34 runoff measurements were made and 34 water samples taken for measurement of tritium content. For biological analyses some 540 samples of water organisms were taken from 76 different places.

2.1 Sampling

1. Water samples: River water and lake water from the surface was scooped directly into 1 liter polyethylene bottles. For lake water samples from deeper layers, a RUTTNER sampler was used. Mixed samples of epilimnetic water were made of equidistant (mostly 2 m) samples from the surface to the thermocline. At the latest in the evening of the same day the water samples had been preserved using 1 ml of a 5% $HgCl_2$ solution per liter of sample water to stop all biological activity without changing the chemical properties. The effectiveness of preservation had been tested before in the laboratory with a preserved water sample that was stored at room temperature for three months, and in which no decrease of nitrate and sulphate concentration was found. In 1998 and 1999, a 100 ml subsample for analysis of major ions and DP was filtered through a Macherey & Nagel GF-5 glass fiber filter using a Nalgene hand pressure filtration device. The samples were filled into polyethylene screw bottles of different volumes (100 to 500 ml) that were pre-rinsed with deionized water.

   The phosphorus content of the filters as well as the phosphorus amount leached from the plastic bottles was tested in the laboratory. The TP concentration of bidistilled water increased after filtration and three months of storage in a polyethylene bottle at room temperature by 2-3 µg/l, that is much below the detection limit of the SRP quick test and the total phosphorus method. The increase of total phosphorus concentration by adding the $HgCl_2$ preservative was found to be 5 µg/l which was subtracted as blind value from the measured TP and DP values.

   Water samples for measurement of tritium content were filled immediately into 250 ml polyethylene screw bottles without conservation.

2. Sediment samples: Lake sediments were taken with an EKMAN-BIRGE grab. As with this type of sampler it is not possible to get undisturbed sediment in its original layering, the analytical values have to be seen as means for the uppermost 5 to 10 centimeters of sediment. In 1997, the wet sediment was filled into 20 ml polyethylene vials and preserved with 5% $HgCl_2$ solution to stop microbial activity. The necessary thorough mixing of the sediment altered the water content to some degree, thus in the years 1998 and 1999 no preservative was used but a subsample of fresh sediment for determination of the water content was filled into a 250 ml polyethylene bottle, with enough free space in the bottle for gas development. The rest of the sample was immediately spread out on a plastic foil and air dried for about 10 hours. The residual water content of the dried sediment was always below 10% as measurements in the laboratory showed – so microbial activity very likely was stopped. This dry sediment was filled into 20 ml polyethylene vials.

3. Phytoplankton samples: These were taken as a subsample of lake water samples, filled into 250 ml polyethylene screw bottles and immediately fixed with Lugol's iodine solution (about 4 ml per liter of water). As the plastic bottle absorbs the iodine very fast, after some hours 38% formaldehyde solution was added to a final concentration of 2 to 4%.

4. Zooplankton samples: Two standard plankton nets of 55 µm and 180 µm mesh width were used. Semiquantitative samples were taken as vertical hauls from the thermocline to the surface, the sampled water volume calculated as area of the net opening multiplied by the sampled depth. Qualitative samples were taken as horizontal hauls. Immediately after sampling, the zooplankton was fixed with 38% formaldehyde solution to a final concentration of 2% and stored in 20 ml plastic vials.
5. Macrozoobenthos: For sampling benthic animals, hand nets and sieves of 2 mm and 0.8 mm mesh width were used. Most samplings were qualitative or semiquantitative; thus abundances had to be estimated. Quantitative samplings were taken with the kick sampling method using a Surber sampler of 0.1 m^2 sampling area and a mesh width of 0.8 mm. Animals attached to stones were hand sampled with pincers. Mud sediments were sieved through sieves of 2 mm and 0.8 mm mesh width to separate the animals. Immediately after sampling, the animals were fixed in 70% ethanol; sometimes formaldehyde solution with a final concentration of 2 to 4% was used. The samples were stored in plastic screw vials of 10 to 100 ml volume. Flying insect imagines were caught in the late afternoon and evening with an insect net and preserved with 70% ethanol.
6. Groundwater fauna: Ground water from wells and springs was poured with a bucket through a plankton net of 55 µm mesh size. In one spring where the water was running very shallow over sandy ground, the plankton net was brought directly into the current of the spring water. All samples were preserved with 2% formaldehyde.
7. Phytobenthos and macrophytes: Macrophytes and macroscopic algae were sampled from river bed and lake littoral sediments. Benthic diatoms were brushed from large stones with a carefully cleaned toothbrush. All samples were preserved in 2% formaldehyde solution. Sampling was qualitative and often did not cover all microhabitats due to limited sampling time.
8. Fish: The investigations on fishes were done by A. DULMAA. In rivers fishes were caught with a hand net or by angling. In lakes, gill nets with mesh sizes of 30 x 30 and 40 x 40 mm were used. The nets were left overnight in place and sampled the next morning. Sometimes also seining was used. The catch was immediately weighed (total body and eviscerated weight, gonad weight) and measured (total fork length); sex and gonad development were determined. Opercular bones and dorsal fin rays were taken for age determination and some specimens were preserved in 4% formaldehyde solution.

2.2 Field measurements

1. Geographic position: During the fieldwork a Garmin GPS 12XL device was used to determine the geographic position in the latitude-longitude system with the WGS 84 datum. The mean horizontal position error was ± 20 m, at maximum ± 100 m. For altitude measurements, a barometric altimeter (Oregon Scientific, scale interval 20 m) was used. It had to be calibrated whenever possible at points of known altitude. Russian military topographic maps with scale 1:100,000 were used for that purpose. The water depth of lakes was measured along transects perpendicular to the shore using a plummet.
2. Weather: The following weather phenomena were recorded at least two times on all expedition days: cloud cover in%, precipitation qualitatively, wind speed according to the Beaufort scale or measured with a hand anemometer, and air temperature. In 1999 the relative humidity was also measured.
3. Water temperature: For spot check measurements, the temperature sensor of a WTW MultiLine P4 measuring device with an accuracy of ± 0.5 K was used. Continuous recordings of the water temperature at several places were made with two Driesen & Kern pillbox temperature data loggers with a measuring range of 0 to 25°C and a time interval of 512 seconds. So the daily temperature interval could be measured. To get evidence of internal seiches in Uvs Nuur, in 1998 two pillbox loggers were attached to a buoy after determining the vertical temperature gradient – one at 0.5 meter above, the other 1 meter below the thermocline. The lower one did not deliver data due to battery failure. As water temperatures and icing conditions are an important environmental factor for the survival of fishes,

a long time temperature recording from 1998 to 1999 was made at the sampling place Borshoo Gol-2 using a Hotdog DT1 temperature logger (measuring range -40…+70°C, hourly measurements).

4. Oxygen content, conductivity, pH value in surface water: For spot measurements in 1998 and 1999 a WTW MultiLine P4 measuring device with electrodes for dissolved oxygen concentration (CellOx 325), electric conductivity (TetraCon 325) and pH value (SenTix 97T), each with integrated temperature sensor were used. Oxygen readings were altitude and salinity corrected, conductivity was corrected for a reference temperature of 25°C. In 1996 and 1997 similar, single WTW devices were used.
5. Oxygen content, conductivity, pH value, turbidity and chlorophyll in depth profile: In 1997 a Hydrolab Multiprobe H20 was used to measure water depth (pressure sensor), temperature, oxygen concentration, conductivity, pH and turbidity in water depths up to 50 m. The oxygen values had to be altitude and salinity corrected, conductivity was corrected for a reference temperature of 25°C. Turbidity readings were in nephelometric units (NTU). In 1998 and 1999, a YSI 600R probe without turbidity sensor was used. The characteristics are very similar to those of the Hydrolab Multiprobe. For measurement of turbidity a four-beam IR back scattering turbidity meter TMS 200/H from SMT&Hybrid (Dresden, Germany) was used in 1998 and 1999. From 1997 until 1999, chlorophyll-a was measured with a MiniBackScat fluorometric probe from Dr. Haardt (Kiel, Germany). It had a narrowband blue LED (450 nm) for excitation; the measuring wavelength was 680 nm. The characteristics of the probe allowed for measuring the concentration of photosynthetically active chlorophyll-a, mainly of eukaryotic algae. Its sensitivity for chlorophyll of Cyanobacteria was low due to their different excitation spectrum. As no correction for light scattering or absorption was made, measurements in very turbid or colored waters tend to underestimate the chlorophyll concentration. Generally, the measured chlorophyll concentration was lower than with standard extractive measuring methods (ethanol or acetone extraction and photometric measurement). For measurement of visibility, a Secchi disk was used.
6. Chemical analyses: As the concentrations of dissolved nutrients in the water samples were very low and would have changed substantially during the long transport, these were measured at selected sampling places immediately on site. To this end, quick test kits („Visocolor“ tests from Macherey & Nagel, Germany) were used that work on the visual color comparator method. The following parameters were measured at the latest 2 hours after sampling: SRP = PO_4-P (detection limit 10 µg/l), NO_3^- (detection limit 1 mg/l) and NH_4^+ (detection limit 20 µg/l).
7. Hydrological measurements and calculations: The flow velocity was measured with a Flo-Mate 2000 inductive current meter from Marsh-McBirney. Measuring results are a 20 seconds average with an error of 1%. The velocity range is 3 to 200 cm/s. To determine the mean flow velocity in a given sector of a river cross section the simplified method of measuring the flow velocity at 40% of the water depth (measured from the bottom) was used. For runoff calculations the river width was measured with a tape measure and the depth at every meter of width with a measuring staff. At the measuring points the choriotope type was recorded (see number 8). The cross sectional area and runoff were calculated with the following formulae:

$$A_c = \sum_{i=1}^{n-1} 0.5 \cdot (x_{i+1} - x_i) \cdot (z_i + z_{i+1}) \tag{2}$$

A_c: cross section area [m²] as sum of n sectors
x: distance from left bank [m]
z: water depth [m]

$$Q = \sum_{i=1}^{n-1} 0.25 \cdot (x_{i+1} - x_i) \cdot (z_i + z_{i+1}) \cdot (v_i + v_{i+1}) \tag{3}$$

Q: runoff [m³/s] as sum of n sectors of cross section
v: mean flow velocity [m/s] ≈ velocity at 40% of depth from bottom

The mean flow velocity at a cross section and the mean water depth were calculated according to

$$v_m = \frac{Q}{A_c} \qquad (4)$$

v_m: mean flow velocity [m/s]

$$z_m = \frac{A_c}{x_w} \qquad (5)$$

z_m: mean depth [m]; x_w: bed width at water surface [m]

8. River morphology and sediment classification: The valley cross sections of several rivers between the highest unflooded banks or terraces were surveyed using GPS for long distances and tape measure for distances up to 300 meters. Vertical steps in the terrain were measured with a measuring staff. Vegetation cover and sediment grain size distribution were recorded. For the latter, choriotope types according to MOOG (1994) as shown in Table 4 were visually assigned. At selected places perpendicular photographs of a 1 x 1 m square were taken and evaluated. For calculations, the descriptive strings were converted into choriotope class (in steps of 0.5) using the choriotope type code. To enable calculation of maximal, mean and minimal grain sizes, the following regression equation between choriotope type and mean grain size as stated in Table 4 was set up:

$$GS = 0.006335 \cdot CC^{6.08833} \qquad r^2 = 0.998 \qquad (6)$$

GS: calculated grain size [mm]
CC: choriotope class [1.0, 1.5, .. , 6.5, 7.0]

Table 4 Choriotope types of stream sediments and corresponding grain size ranges (after MOOG, 1994), with added mean grain size (calculated as geometric mean of the class limits). As in most cases the sediment was a mixture of choriotope types, to describe a sediment the abbreviations of the dominant choriotope types were combined according to their volume proportion. Choriotope types with more than 40% proportion are written in bold type, those with less than 5% proportion were omitted (for instance "AKmeps" means: > 40% akal, mesolithal > psammal).

choriotope type	class	abbreviation	description	grain size range	mean grain size
pelal	1	pe	silt, clay, organic mud	< 63 µm	6.3 µm
psammal	2	ps	sand	63 µm–2 mm	0.35 mm
akal	3	ak	coarse sand to medium gravel	0.2–2 cm	0.63 cm
lithal: microlithal	4	mi	coarse gravel	2–6.3 cm	3.5 cm
mesolithal	5	me	fist to hand sized stones	6.3–20 cm	11 cm
macrolithal	6	ma	head sized stones, coarse blocks	20–40 cm	28 cm
megalithal	7	meg	large blocks, bedrock	> 40 cm	89 cm

9. Transport and storage of the samples: All samples were stored dark in aluminum boxes. During car transport from the Uvs Nuur Basin to Ulaanbaatar they were exposed to changing temperatures between 5 and 30°C and strong vibrations. In 1996 and 1999, the samples were transported as air freight and reached the laboratory after two weeks. In the years 1997 and 1998, air transport of the samples was not possible. They were transported to Germany by rail. The transport started in late September and lasted 3 and 6 months, respectively. Being transported through Russia during winter in 1998, the water and fresh sediment samples were frozen. After arrival in the laboratory, all water and sediment samples were stored in the dark at 4°C. Biological samples were stored at room temperature.

2.3 Laboratory analyses and data evaluation

1. Chemical water analyses: As stated above, the analytical procedures partially changed from year to year due to changes of the available analytical instruments, third party institutions or as a consequence of problems (precipitation of carbonates, high ion balance errors) that had been recognized. Thus, here a general description of the analytical procedures used for most of the samples is given.

   Before other analyses, pH value and conductivity were measured in the samples to check for the amount of change during transport. It was found that in most of the samples that were transported by plane the conductivity changed by less than 5%, whereas in the frozen samples of 1998 in most samples the conductivity decreased by 20% as a mean. The pH value changed quite irregularly, with an increasing amount of change at lower ion content. In most samples, the pH changed by less than 0.5.

   The concentrations of the elements Na, K, Ca, Mg, Si and Fe in the water samples were determined with ICP-AES (Zeiss Plasmaquant 110) according to standard DIN EN ISO 11885-E22. The configuration was: circular nebulizer, carrier gas Argon (38 l/min), excitation level 6, observation level 3, Merck multi element standard Nr. 4. The filtered samples were acidified with 0.1 ml of 40% HNO_3 per 20 ml of sample, and diluted with bidistilled water for measurement as required.

   The concentrations of the anions F^-, Cl^-, Br^-, NO_3^-, SO_4^{2-} were determined with ion chromatography (Dionex AS 200) according to DIN EN ISO 10304-D19-1. The samples (if not filtered after sampling) were filtered through 0.45 µm cellulose acetate membrane filters and diluted as required. The concentrations of HCO_3^- and CO_3^{2-} were determined by measurement of pH value, alkalinity and acidity according to DIN 38409-H7, and calculation according to German Standard DIN 38405-D8-1. As the pH value changed noticeably in most samples as stated above, the results for HCO_3^- and CO_3^{2-} were the most incorrect of all anions. The ion chromatographic analyses of the samples taken 1996 and 1997 were carried out by Mrs. BRÜCKNER of the Institute of Urban Water Management, Dresden Technical University.

   Total phosphorus was determined in the unfiltered samples, using an acidic breakdown and the molybdate blue method according to DIN EN 1189-D11. Dissolved phosphorus was determined the same way in the samples that were filtered immediately after sampling through GF-5 glass fiber filters. Total and dissolved nitrogen was determined in the unfiltered samples respective those filtered after sampling with an oxidizing breakdown according to DIN EN ISO 11905-H36-1. Screw test tubes were filled with 20 ml of sample and 20 ml of a mixture of 0.05 M $K_2S_2O_8$ and 0.3 M NaOH and closed, then digested for 30 minutes at 120° in a pressure cooker. The digested sample was filtered through 0.45 µm membrane filter and frozen until measurement of nitrate at -20°C. The concentration of total suspended solids (TSS) in some river water samples was determined according to DIN 38409-H2 gravimetrically after filtration through 0.45 µm membrane filters and drying to a constant weight at 105°C. All these analyses were done by the author and laboratory staff at the Ecological Station Neunzehnhain, Dresden Technical University.

   For measurement of nitrate in the saltwater samples and the digested TN and DN samples, a FIA device (RFA 300 from Alpkem) was used, applying the cadmium reductor method according to DIN EN ISO 13395 (D28). These analyses were carried out at the Laboratory Zingst of Rostock University (Mr. BAUDLER, Mrs. WULFF).

   The sum of the mass concentrations of Na, K, Ca, Mg, F^-, Cl^-, Br^-, NO_3^-, SO_4^{2-}, HCO_3^- and CO_3^{2-} is the calculated value of salinity. WILLIAMS & SHERWOOD (1994) recommend using a mass-per-mass expression (g/kg) for the salinity of inland salt lakes, but as the maximum difference between per-mass and per-volume concentrations for the salinities found in the Uvs Nuur Basin is 1%, salinity is expressed in g/l here. For classification of the waters according to salt content, several salinity scales exist. Here the system of HAMMER (1983) for athalassic waters was chosen – see Table 5.

Table 5 Salinity classification system for inland waters according to HAMMER et al. (1983) in HAMMER (1986).

salinity [g/l]	< 0.5	0.5–3	3–20	20–50	> 50
salinity level	fresh	subsaline	hyposaline	mesosaline	hypersaline

For an estimation of the general inaccuracy due to changes in the sample during transport and measuring error, the ion balance error was calculated using formula 7:

$$E_{IB} = 100\% \cdot \frac{\sum_{kations} e_i - \sum_{anions} e_i}{\sum_{all\_ions} e_i} \qquad (7)$$

E_{IB}: ion balance error [%]
e_i: equivalent concentration [mval/l] of ion *i*

This error was in most cases less than 10%, often less than 5%. Only some samples with very high pH change during transport had errors of maximal 34%. As the error almost always was positive, the amount of hydrogen carbonate and carbonate was often underestimated.

The limits of quantification for the measured substances were as follows:

Table 6 Limits of quantification for chemical parameters in water samples measured in the laboratory.

substance	quantification limit [mg/l]	substance	quantification limit [mg/l]	substance	quantification limit [mg/l]
Na	0.1	F^-	0.01	NO_3^- (FIA)	0.006
K	0.2	Cl^-	0.02	TP	0.002
Ca, Mg	0.05	Br^-	0.06	TN, DN	0.05
Si	0.03	SO_4^{2-}	0.06		
Fe	0.01	NO_3^- (IC)	0.05		

2. Chemical sediment analyses: After a thorough homogenization the water content of the sediment sample was determined gravimetrically by drying at 105°C to constant weight according to DIN 38414-S2. A subsample was weighed and combusted in a muffle furnace for 2 hours at 550°C to determine gravimetrically the content of ash (ignition residue) and organic substances (loss on ignition) according to DIN 38414-3. The ignition residue was stored in a desiccator to cool down before weighing again. After weighing, the residue was combusted again for 5 hours at 870°C to determine the content of carbonates that are supposed to have completely escaped as CO_2.

For all chemical sediment analyses, the air dried sediment subsamples were used. Before analysis the samples were oven dried at 105°C to constant weight. Fractionated analyses of phosphorus and metals were not possible as drying irreversibly alters the fractionation of these elements (PSENNER et al., 1988; BORDAS & BOURG, 1998).

For the determination of the content of the cationic elements Na, K, Li, Ca, Mg, Fe, Al, Mn, Sr and Ba, an acidic digestion and measurement with ICP-AES according to ULRICH & NEUBERT (1996) were used. The dried sediment was homogenized and pulverized in a mortar, 35 mg were weighed into a PTFE vessel and 20 ml bidistilled water, 1.25 ml of 40% HNO_3, and 3.75 ml of 40% HNO_3 were added. The digestion was made in a microwave oven under pressure. After cooling the liquid was filled up to 25 ml, filtered through 0.45 µm membrane filter and the element content measured with the ICP-AES (Zeiss Plasmaquant 110).

For the determination of total phosphorus an acidic peroxodisulphate digestion according to STURM & ZWYSSIG (1989) was used. For the duplicate determination, 30 mg of the homogenized and pulverized dry sediment was weighed into a vessel, and 25 ml of 25% HCl was added. The mixture was homogenized for 1 minute with an ultrasonic probe, shaken, and 1 ml pipetted into a Duran screw test tube. Then 5 ml $K_2S_2O_8$ solution (40g/l) and 10 ml bidistilled water were added and the closed vessels boiled for 90 minutes in a pressure cooker. After cooling, PO_4-P was measured in the supernatant according to DIN EN 1189-D11.

Three sediment samples (from Uvs Nuur, Bayan Nuur and Southern Baga Nuur) were analyzed with infrared spectroscopy for information on the mineral content of the sediments. The analyses were carried out by ROSEMARIE PÖTHIG at Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin.

3. Tritium measurement and age determination of water samples: A data series of the original tritium content in precipitation (input function) for Mongolia was provided by GOMBYN DAVAA from the Mongolian Institute of Meteorology and Hydrology, Ulaanbaatar. The tritium content in the water samples was measured at the Institute of Applied Physics of the Technical University Bergakademie Freiberg. The data evaluation and calculation of water ages and mixing ratios was carried out by DETLEF HEBERT, Freiberg (HEBERT, 2004).
4. Counting and determination of phytoplankton: For counting, an inverted microscope (Sedival, Zeiss Jena) with 400- and 1000-fold magnification and phase contrast, counting strip and sedimentation chambers according to UTERMÖHL (1958) was used. For each taxon at least 20 cells were measured and the cell volumes for approximate geometric bodies calculated. The arithmetic mean of these volumes was used for the calculation of that taxon's biovolume per liter. For the determination of diatoms, subsamples of the phytoplankton samples were filtered over 0.45 µm membrane filters. The residue on the filter was resuspended in a small amount of water, dropped on cover glasses and dried. Then the cover glasses were combusted for 30 minutes at 550°C and mounted with Naphrax® mountant on slides. For species determination GEITLER (1932), KOMAREK & ANAGNOSTIDIS (1999, 2005), KOMAREK & KOMARKOVA (2006), KOMAREK & ZAPOMELOVA (2008), STARMACH (1985), HUBER-PESTALOZZI (1955, 1968), POPOVSKY (1990), KRAMMER & LANGE-BERTALOT (1991a, b, 1997, 1999), KOMAREK & FOTT (1983) and FÖRSTER (1982) were used.
5. Counting and determination of zooplankton: Quantitative zooplankton samples were quantitatively subsampled and counted in 10 ml sedimentation chambers using the same inverted microscope as for phytoplankton. All counted animals were measured (length to furca for copepods, total length for others). Copepods were counted for each species in the categories copepodids, females and males. Cladoceran species were counted in the categories juveniles and females. Nauplia were differentiated into cyclopoid and calanoid. Then, for each counting category the sample-specific geometric mean of the length was calculated. For calculation of dry weight, different formulae from VON TÜMPLING & FRIEDRICH (1999), DUMONT et al. (1975) and DOWNING & RIGLER (1984) were used. Protozoan plankton was determined in the phytoplankton samples. For species determination GROSPIETSCH (1972), KAHL (1930 – 1935), FOISSNER & BERGER (1996), KOSTE (1978), FLÖßNER (1972, 2000), LIEDER (1996), KIEFER & FRYER (1978), RYLOV (1948), Academia Sinica (1979) and EINSLE (1993) were used. All species determinations of Cladocera and Copepoda (also of benthic Cladocera) were carried out by DIETRICH FLÖßNER, Jena, who also revised the author's preliminary determinations.
6. Determination of zoobenthos: All zoobenthos samples were presorted – mostly on family or order level – and counted by the author. Selected specimens or complete subsamples consisting of a certain taxonomic group were sent to specialists for determination. The species *Branchinecta orientalis* SARS (Anostraca) was determined by WOLFGANG HORN and confirmed by the late DENTON BELK, San Antonio, Texas; Cladocera and Copepoda were determined by DIETRICH FLÖßNER, Jena; *Gammarus lacustris* SARS (Amphipoda) was determined by KRZYSZTOF JAZDZEWSKI, Lodz, Poland; all Ephemeroptera were determined by DIETRICH BRAASCH, Potsdam; the Plecoptera were determined by the late WOLFGANG JOOST, Gotha; Heteroptera were determined by PETER SCHÖNEFELD, Berlin; Trichoptera were determined by WOLFGANG MEY, Berlin; Chironomidae were determined by RAI-

NER SAMIETZ, Gotha; Blephariceridae and Deuterophlebiidae were determined by PETER ZWICK, Schlitz.

Many groups (Hydrozoa, Turbellaria, Nematoda, Nematomorpha, Mollusca, Annelida, Arachnida, Ostracoda, Collembola, Odonata, Coleoptera, Tipulidae, Limoniidae, Ceratopogonidae, Simuliidae, Psychodidae, Culicidae, Stratiomyiidae, Athericidae, Tabanidae, Dolichopodidae, Ephydridae, Sciomycidae) – mostly with low abundance in the samples – were not determined by specialists. For these, the taxonomic level remains on the result of presorting, respectively on what the author could achieve using Russian literature: ZHADIN (1940, 1952) and POPOVA(1953).

7. Determination of phytobenthos and macrophytes: For determination of benthic algae besides the literature mentioned above for phytoplankton, PRINTZ (1964) was used. Charophyceae were determined using GOLLERBAKH & KRASAVINA (1983); several specimens were determined by ANGELA DOEGE, Miltitz, KLAUS VAN DE WEYER, Nettetal and JOOP VAN RAAM, Hilversum. FRANK MÜLLER, Dresden, determined the mosses. For determination of Spermatophyta, CASPER & KRAUSCH (1980, 1981) was used; specimens of *Potamogeton* were determined by ZDENĚK KAPLAN, Průhonice.
8. Determination of fish and water birds: The fishes were determined by AYURYN DULMAA, Ulaanbaatar. Water birds were observed and determined by ANGELA VON DEN DRIESCH, München, and the author.
9. Analysis of satellite imagery and map data: To obtain morphometrical data of lakes (surface area, shoreline length) and rivers (length measurements, tortuosity, channel number, width of active floodplain, catchment area) satellite images were evaluated. Satellite imagery is available on the internet with the software Google Earth™ as a seamless mosaic of Landsat ETM+ multispectral scenes from the years 2000 through 2005 with a minimum resolution of 15 m per pixel, occasionally superimposed with higher resolution imagery. Placement within the viewer software was in very close correspondence with our own GPS position measurements – the maximum position error was about 100 m. The imagery includes a global Digital Elevation Model with an interval of altitude points of 3 arc seconds (about 70 meters). This imagery was used for distance measurements and determination of geographic positions for objects where no GPS measurement was made. Altitude readings were used only for places of low gradient, as the interpolation between data points gets inaccurate at steep gradients.

Furthermore, georeferenced Landsat multispectral scenes (processing level 08/1G) with all spectral bands and a size of 170 x 183 km were available for the inner basin of the acquisition dates 07/07/1977, 06/15/1991, 06/25/1992, 06/18/1998, 08/16/1999, 05/20/2002, 08/08/2002, 08/08/2008, 10/11/2008, 08/22/2010, and for the eastern part around Döröö Nuur of 08/11/1977, 07/10/1991, 07/16/2002, 08/01/2008 and 08/31/2010. The 1998 scene was kindly provided by Ms. S. ITZEROTT, Potsdam University, who was involved in the joint project "Palaeogeographical and Biospherical Conditions of Landscape Development in Northern Central Asia". All other scenes are since 2009 freely available from the United States Geological Survey (http://glovis.usgs.gov). For position, length and area measurements in the Landsat scenes, creation of river and lake vector shapes, map creation and multispectral image analysis several free GIS and imaging software (SAGA, JUMP, fGIS, TatukGIS Viewer, MapWindow GIS, GIMP and UNESCO Bilko) was used. For a technical description of the Landsat imaging devices and the image format see NASA (2008), UNIVERSITY OF MARYLAND (2004) and TUCKER et al. (2004).

The maps at the author's disposal are copies of Russian military maps in the scale 1:100,000 with a publishing date between 1949 and 1951 and scanned files of the publishing date 1970. They cover the basin from Üüreg Nuur and the Turgen Mountains to the dunes around Bayan Nuur. They were used to read out altitude information as the contour line interval of 20 m is sufficiently small, and to investigate temporal changes of river and lake shapes.

10. Analysis of hydrological data: these very valuable data were kindly provided by N. TSEVEENDORJ and G. DAVAA, Institute of Meteorology and Hydrology, Ulaangom and Ulaanbaatar. The following data series were evaluated, parts of the data can be found in the appendix:

Table 7 Evaluated hydrological data series provided by the Institute of meteorology and Hydrology.

measured parameter	water body / gauging station	period
water discharge [m^3/s], monthly mean	Tesiyn Gol - Bayan Uul	1971–1990
water discharge [m^3/s], monthly mean daily	Borshoo Gol - gauging station	1972–1999 1980–1999
water discharge [m^3/s], monthly mean	Baruunturuun Gol - Baruunturuun	1993–1998
water discharge [m^3/s], monthly mean daily	Turgen Gol - Delgermörön	1973–1999 1980–1999
water discharge [m^3/s], monthly mean	Kharkhiraa Gol	1974–1994
water temperature [°C], 10-day mean	Tesiyn Gol-Bayan Uul	1970–1990
water temperature [°C], 10-day mean	Borshoo Gol - gauging station	1990–1999
water temperature [°C], 10-day mean	Turgen Gol - Delgermörön	1990–1999
water temperature [°C], monthly means of whole period	Baruunturuun Gol Kharkhiraa Gol	1960–1968 1964–1968
icing conditions (begin and end of ice cover, begin and end of any ice phenomena), ice thickness [cm] – daily	Borshoo Gol - gauging station Turgen Gol - Delgermörön	1980–1997 1980–1997
water level [cm], monthly mean	Uvs Nuur-N	1963–1999
water temperature [°C], 10-day mean	Uvs Nuur-N	1991–1999 (without 1992)
icing conditions (begin and end of ice cover, begin and end of ice phenomena), ice thickness [cm], 10-day mean	Uvs Nuur-N	1980–1997

11. Morphological calculations for rivers: Besides the on-site measurements of river bed cross sections, some longitudinal morphological parameters were determined on satellite images with resolutions between 1 and 15 m per pixel. The following parameters according to WARD et al. (1999) were measured: river length and catchment area for the whole river, and at least for the sampling places: mean number of channels, tortuosity (quotient of river channel length between two points and the direct distance along the valley bottom between these points), width of meander belt (maximal amplitude of meanders), width of active floodplain (bare bed sediment without vegetation) and valley width (= total floodplain width; alluvial plain of less than 2 to 5 meters altitude above the river bed). The reaches for which measurements are valid have a length of 2 to 10 km. To quantify stream bed instability the Pfankuch stability index (PFANKUCH, 1975) was calculated for these reaches. For the index that can reach values between 38 and 152, scores for 15 easily visible morphological features are summed up.
12. Morphological and physical calculations for lakes: For the hypsographic functions of Uvs Nuur and Bayan Nuur, isobath maps of both lakes published in WALTHER (1999) and NAUMANN & WALTHER (2000) that are based on sonar measurements were used. The lake volume was calculated with the formula

$$V = \frac{0.001}{3} \cdot \sum_{i=1}^{n-1} (A_{i+1} + A_i + \sqrt{A_i \cdot A_{i+1}}) \cdot (z_{i+1} - z_i) \quad (8)$$

V: lake volume [km^3]; (V_n: volume of partially filled lake for different depths)
A_i: areas of different isobath depths [km^2]
z_i: depths of the isobaths [m]

The surface area of lakes was measured using Landsat channel 5 (wavelength 1.55 – 1.75 μm) where water areas are differentiated distinctly from land. Water pixels of lakes were masked, counted and the surface area calculated from the number of pixels and given pixel size. The shoreline development (quotient of shoreline length and circumference of a circle with the same area) was calculated. Measurements of catchment area were made on Russian 1:100,000 topographic maps or within GIS software.

The horizontal distribution of surface temperature in Uvs Nuur was determined using the thermal infrared channel 6 (wavelength 10.4–12.5 µm) of Landsat TM/ETM+ and formulae 9 and 10 (from NASA, 2008). The direct calculation of surface temperatures from the pixel values (8 bit, 1 to 255) requires back conversion of the pixel values into spectral radiance values according to the following formula:

$$L = \frac{(L_{max} - L_{min}) \cdot (Qcal - Qcal_{min})}{Qcal_{max} - Qcal_{min}} + L_{min} \qquad (9)$$

L: radiance [$W \cdot m^{-2} \cdot ster^{-1} \cdot \mu m^{-1}$]
L_{max}, L_{min}: highest and lowest radiances used for conversion of sensor data into pixel values
$Qcal_{max}$, $Qcal_{min}$: highest and lowest possible pixel values [dimensionless]
Qcal: pixel value to be transformed [dimensionless]

From these radiance data the surface temperature without correction of the atmospheric effect can be calculated:

$$T = \frac{K2}{\ln\left(\frac{K1}{L} - 1\right)} - 273.15 \qquad (10)$$

T: surface temperature [°C]
K1, K2: sensor specific constants, K1 [$W \cdot m^{-2} \cdot ster^{-1} \cdot \mu m^{-1}$], K2 [K]

The constants for images taken with the ETM+ channel 6 (high gain) are:

L_{max}: 12.65, L_{min}: 3.2, $Qcal_{max}$: 255, $Qcal_{min}$: 1, K1: 666.09, K2: 1282.71.

With these formulae the surface temperatures for the images from 08/16/1999, 05/20/2002, 08/08/2002 and 10/11/2008 were calculated. These constants were not available for images taken with Landsat TM, thus another approach of directly calibrating the image with ground truth temperature values was used: as all images were taken in the summer under cloudless conditions between 10 and 12 p.m. it can be assumed that the snow on the glaciers in the Turgen Mountains was melting and its temperature was set to 0°C according to OESCH et al. (2002). For the 1998 image, the surface of a half ice covered mountain lake was set to 0°C. The other ground truth value is the water temperature of Uvs Nuur at the north coast (10-day mean as seen in Fig. 37). To get an approximate function for the surface temperature depending on the pixel value, a linear interpolation was used which is sufficiently accurate to achieve a mean temperature error of ±1.5 K.

For quantitative calculations of the concentrations of Chlorophyll-a (GALAT & VERDIN, 1988; SVÁB et al., 2005; TYLER et al., 2006; EL-MAGD & ALI, 2008), Phycocyanin (VINCENT et al., 2004), suspended solids (TYLER et al., 2006) or Secchi disc depth (BREZONIK et al., 2002; NELSON et al., 2003) no fixed formulae are available. Instead, empirical equations using channel ratios in the visible spectral bands were used that must be calibrated with acquired ground data measured on the date of image acquisition. Chlorophyll calculation is further complicated by highly variable concentrations of suspended sediments (SVÁB et al., 2005 and TYLER et al., 2006), as is the case in Uvs Nuur, and the wide spectral bands of Landsat that cover chlorophyll absorbance minima and maxima together with peaks due to scattering from suspended sediment particles (KLOIBER et al., 2002). As no acquired ground data for the evaluated satellite images are available, only qualitative images for the horizontal distribution of suspended sediment and algal particles from the visual channels 1, 2 and 3 were generated and contrast enhanced (see Fig. 83), which at the least reveals large scale patterns of circulation, phytoplankton density and water turbidity (MOORE, 1980).

A qualitative evaluation of the average long term distribution of turbidity in the Uvs Nuur was made with three Landsat scenes (channel 1, 0.450–0.515 µm) and 11 cloudless NOAA AVHRR grayscale images (channel 1, 0.58–0.68 µm) from 1997 and 1998 with a resolution of 1.1 km per pixel. The images were resized to be congruent, contrast enhanced and the mean value of all 14 images calculated to produce an image of mean turbidity distribution.

The estimation of the annual heat budget and heat exchange rates of Uvs Nuur was made on the basis of water temperature and ice cover data provided by the Mongolian Institute of Meteorology and Hydrology, the hypsographic function for Uvs Nuur and our measurements of vertical temperature profiles. The following generalizations and assumptions were made: the heat content during spring and autumn overturn (April 20th and November 10th) was set to 0 J, a mean winter temperature of 1°C (the temperature of maximal density at a salinity of 13 g/l), mean summer thermocline depth of 16 m (corresponding to a hypolimnion volume of 7.5 km^3), mean hypolimnion temperature during summer stratification of 11°C, mean epilimnion temperature on July 15th of 19.5°C, summer stratification from May 25th to September 20th, lake area of 3600 km^2 and total volume of 48.4 km^3 were assumed.

With these assumptions and the mean ice thicknesses, the heat content of the lake at 8 dates over the year was calculated using formula 11. The exchange rates (fluxes) were calculated with formula 12.

$$H(t) = c_{H_2O} \cdot (\Delta T_{epi} \cdot V_{epi} + \Delta T_{hypo} \cdot V_{hypo}) - q_{ice} \cdot z_{ice} \cdot A_{lake} \quad (11)$$

H: heat content of the lake at moment t [J]
c_{H2O}: heat capacity of water [4190 J·kg^{-1}·K^{-1}]
q_{ice}: melting heat of ice [334000 J·kg^{-1}]
$\Delta T_{epi,\ hypo}$: difference between temperature of epilimnion or hypolimnion and the temperature of spring and autumn overturn (1°C)
$V_{epi,\ hypo}$: volume of epilimnion and hypolimnion [dm^3]
z_{ice}: ice thickness [dm]
A_{lake}: lake surface area [dm^2]

$$F(t) = \frac{Q(t) - Q(t-1)}{\Delta t} \quad (12)$$

F(t): mean heat flux in the time interval (t-1, t) [W/m^2]
Δt: time interval [s]

The density of saline water as function of salinity and temperature was calculated using the sea water formula of MILLERO & POISSON (1981). For the calculation of the oxygen saturation concentration as function of salinity and temperature the sea water formula of MILLERO & SOHN (1992) was used.

13. Multivariate statistical analyses of biological and abiotic data were made with the library FactoMineR of the R statistics package (R Development Core Team, 2010).

3 Results and discussion

In the following chapters, the results of investigations are presented and discussed separately for rivers, lakes and groundwater. The complete results of chemical analyses and the determination of biota are listed in the appendix. Summarizing analyses and interpretations covering all limnological aspects can be found in chapter 4.

Preliminary results of these investigations were published in HORN & UHLMANN (1999), HORN et al. (1999a, b, c, d), HORN & PAUL (2000), PAUL et al. (1999a, b, c) and PAUL & HORN (2000a, b).

3.1 Rivers

3.1.1 Morphology and hydrology

The rivers in the Uvs Nuur Basin are morphologically and hydrologically unaltered by man with minor exceptions: there are a reservoir of 2.2 km² for irrigation near Baruunturuun Somon that dams the Baruunturuun Gol, and some water withdrawals for the same purpose at the Tesiyn, Turgen and Kharkhiraa Gol. As the irrigated areas at Tesiyn, Turgen and Kharkhiraa Gol generally are not very large (< 1 to 4 km²), it can be assumed that the percentage of water withdrawn from these rivers has no noticeable effect on their hydrology. The Baruunturuun Gol which normally is dry in its lower reaches could be affected by irrigating croplands of about 10 km². It can be concluded that the hydro-morphological properties of the investigated rivers widely reflect the natural conditions of morphogenesis under the cold semiarid climatic conditions typical for northern Central Asia.

Longitudinal morphological profiles (Fig. 71 to Fig. 78 in the appendix) were measured for the rivers listed in Table 8. Detailed river bed cross sections are presented in Fig. 67 to Fig. 70 in the appendix, valley cross sections for Turgen and Tesiyn Gol, partially with choriotope recordings, in Fig. 6 to Fig. 12, as well as in Table 10. Some examples for the morphological dynamics of Tesiyn Gol, Gurmosyn Gol and Turgen Gol in a temporal frame of 10 to 50 years are shown in Fig. 79 and Fig. 80 in the appendix.

Table 8 Main physiographic characteristics of the rivers for which detailed longitudinal profiles are presented.

River (= Gol)	type	discharge into	length [km]	catchment area [km²]	spring altitude [m ASL]
Baruunturuun	mountain to lowland	groundwater*	246	6600	2120
Borshoo	mountain	groundwater*	76	860	1595
Dshibertu	alpine	Turgen Gol	24	164	2775
Kharkhiraa	alpine	groundwater*	121	1000	3130
Nariyn	lowland	Uvs Nuur (direct)	174	3000	1035
Tesiyn	mountain to lowland	Uvs Nuur (direct)	878	33000	2500
Torkhilog	alpine	Uvs Nuur (direct)	87	1230	2400
Turgen	alpine	groundwater*	138	1100	2950

* during flood also directly to Uvs Nuur

These rivers generally can be classified into four hydromorphological types: alpine rivers with a crenal subtype (alpine spring stream), mountain rivers, lowland rivers (the term ‘lowland’ stands for flat relief rather than very low altitude because these rivers are often at an altitude of about 1 000 m A.S.L.). The distribution of aquatic organisms mirrors these river types, as shown in chapter 3.1.5.

In the Uvs Nuur Basin 25 000 km of river courses exist, the density of the river network reaches 0.32 to 0.44 km/km² (DORJ et al. 1991). This relatively high value results mainly from the numerous gullies that exist in the foothills and the edge of the inner basin which are only episodically water-bearing (after heavy thunderstorms or during thaw and the raining period in June and July) but commonly they are dry. These river beds were not the object of investigations.

Strong discontinuity of surface runoff in space and time is a common feature of most rivers in the Uvs Nuur Basin. The hydrologic exchange between surface and groundwater in alluvial streams is known to be intense and important for the structure of the benthic communities. Downwelling zones where DOM and FPOM is transported into the interstitial are characterized by increased hyporheic biological activity while in upwelling zones algal growth is stimulated by nutrient enriched groundwater (VALETT et al., 1994; JONES et al., 1995, BRUNKE & GONSER, 1997). Whereas the mountain streams are permanent in the area of runoff formation (in the upper and middle reaches), they often divide into many branches and seep away into the gravelly ground of the debris cones after 10 to 20 kilometers and reach the Uvs Nuur only during periods of flood in spring or during heavy rainfalls. The groundwater flowing towards Uvs Nuur emerges again at places with decreased gradient and/or lower water permeability near the lake, forming springs and extended wetlands. Permanent along the whole river course are the Tesiyn Gol, Nariyn Gol and most probably Torkhilog Gol. Tesiyn Gol is perennial because of its large catchment (33 000 km² = 47% of the Uvs Nuur basin), high discharge (48 m³/s in August 1999 near the mouth) and the water-rich tributaries from Siberia. In the case of the lowland river Nariyn Gol the sandy, water-saturated bed prevents high infiltration losses. Torkhilog Gol has a comparably short and steep lower reach before discharging into Uvs Nuur, so the losses into groundwater are limited.

General features of the alpine and mountain rivers are their pronounced winter runoff minimum or even drought, extended bare gravel bars of some hundred meters width (examples in Fig. 6 to Fig. 12) and often unforested banks. Even brushwood is not a common feature. Thus the shady forest streams of the temperate zone with tree roots stabilizing the banks are not found here. Furthermore, large woody debris that plays an important role in structuring the river bed (formation of islands with perennial vegetation according to WARD et al., 1999) is not abundant due to the low forest productivity caused by the climate. Because of the mostly sparse vegetation cover the water retention capacity of the watersheds is low, which rises the probability of strong floods that alter the river bed. An indicator of the relatively high dynamics of riverbed morphology (rate of sediment movement as well as lateral displacement of the river bed) is the Pfankuch stability index (see Table 10): half of the values are greater than 75 on a scale from 38 (excellent) to 152 (very poor stability).

The lowland rivers are mainly fed by ground water, either originating from rain or seepage from mountain rivers covered by dune sand, as in the case of Khustay Gol, whose spring is fed by the seeped waters of Baruunturuun and Khangiyltsagiyn Gol (GRUNERT & KLEIN, 1998). KLEIN (2000) states that damming of rivers by dunes is not a singular case, as another one is found in the Bor Khar Els dune field SE of Khyargas Nuur. A different case are small wetland streams in areas of high groundwater level, for instance Ukhug Gol in the floodplain of the lower Tesiyn Gol or the brook of Butsaldag Bulag near the NW shore of Uvs Nuur. They have quite stable, sandy beds without signs of floods. Only the lower Nariyn and Tesiyn Gol with their higher runoff show significant bedload transport and a widened active floodplain.

Morphological peculiarities of the individual rivers are as follows:

The **Baruunturuun Gol** originates in the flat, rounded western heights of the Khan Khökhiyn Nuruu with comparably low slope to form a lake after some kilometers of flow. Then a long mountainous reach follows with a partly braided river bed and slopes between 5 and 15‰ that ends with a man-made reservoir near the village Baruunturuun. Downstream of that reservoir, the river and its biggest tributary, the Khangiyltsagiyn Gol, rapidly lose their water into the groundwater body of the coarse gravelly bed and eventually completely dry out when reaching the Böörög Deliyn Els dune field where the river is forced to bend westward. A large part of the groundwater flows northwestward below the dunes to feed the springs of Khustay Gol and those around Bayan Nuur. The other part arises again in the river's sandy middle reaches below Zuungovi Somon (now called Gurmosyn Gol) with slopes still of 2 to 3‰, but the Uvs Nuur is reached only during floods. A large flood that happened in August 1995 completely altered Gurmosyn Gol's river bed in the lower reaches (see Fig. 80) and piled up a conic sand layer at its mouth on the SE shore of Uvs Nuur with an area of 1.9 km² and a thickness of probably about 1-2 meters (approximately 50 000 tons of sediment).

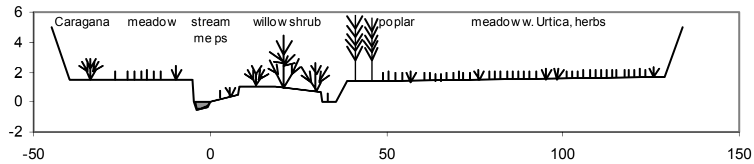


Fig. 6 Valley cross section at Borshoo Gol-2. Distances in meters, gray areas = water. Abbreviated choriotope types are explained in Table 4.

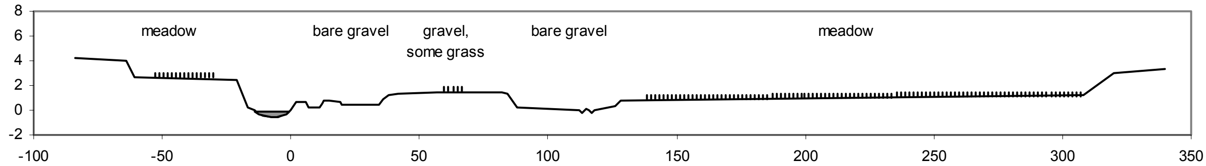


Fig. 7 Cross section of the active floodplain at Tesiyn Gol-2. Distances in meters, water is shown in gray.

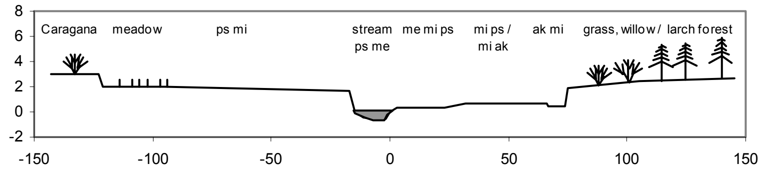


Fig. 8 Cross section of the active floodplain at Tesiyn Gol-3.5. Distances in meters, gray areas = water. Abbreviated choriotope types are explained in Table 4.

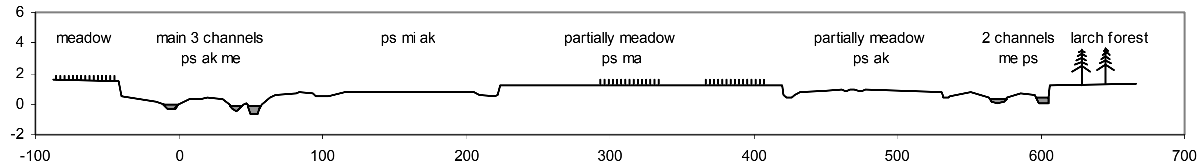


Fig. 9 Cross section of the active floodplain at Tesiyn Gol-4. Distances in meters, gray areas = water. Abbreviated choriotope types are explained in Table 4.

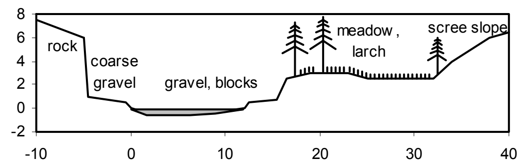


Fig. 10 Valley cross section at Turgen Gol-0.3. Distances in meters, gray areas = water.

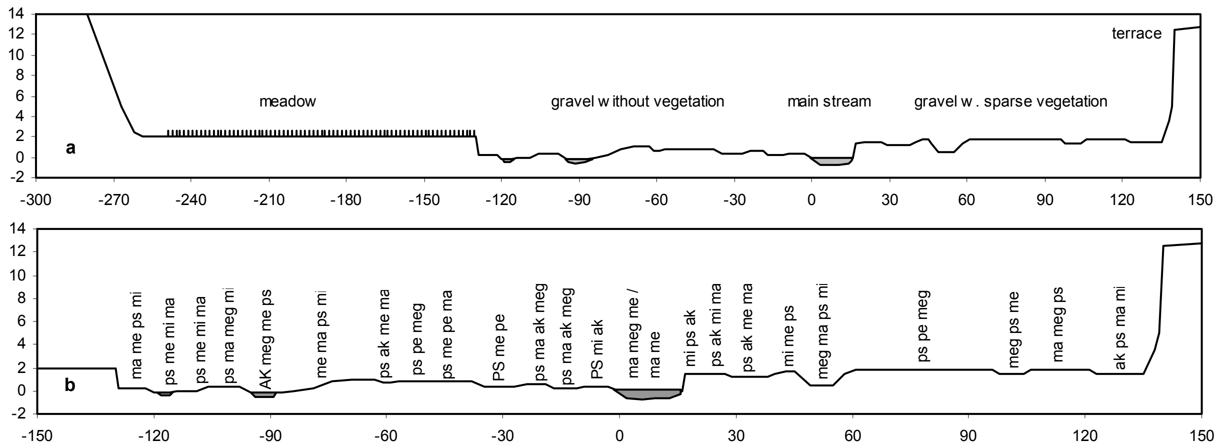


Fig. 11 a Valley cross section at Turgen Gol-1 and **b** choriotope distribution in the active floodplain. Distances in meters, gray areas = water. Abbreviated choriotope types explained in Table 4.

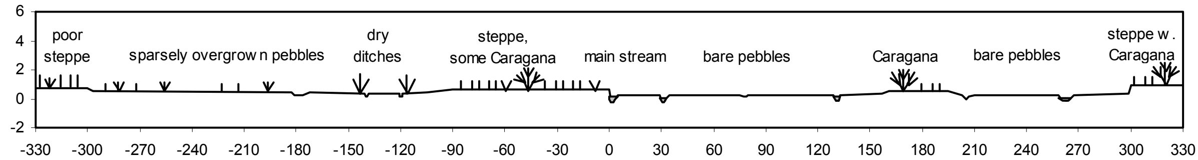


Fig. 12 Cross section of the active floodplain at Turgen Gol-4. Distances in meters, water is shown in gray.

Borshoo Gol is in its whole length a mountain stream with little bed dynamic. It rises in a wide shallow valley at the southern slope of the Western Tannu Ola Mountains as meandering, willow-lined meadow stream, receives some small tributaries and then, after some 30 km having its lowest slope of 4‰, breaks through a low mountain range towards Uvs Nuur, forming a narrow, flat valley with quite dense willow and poplar growth. Below this point, the slope stays at 10‰. When reaching the inner basin, after 80 km the valley widens, and the stream trickles into the sediment and disappears.

The 24 km long alpine stream **Dshibertu Gol** is the biggest tributary of Turgen Gol and resembles the latter morphologically. It is, however, not glacier fed and has a little less slope. There are only few places where larch trees grow near the river, it runs mostly through alpine meadows.

Kharkhiraa Gol in its upper reaches has the most alpine character of the investigated rivers. It rises as glacier fed stream at about 3 100 m and after the passage of three small alpine lakes it runs northeastwards through an U-shaped valley much wider that that of Turgen Gol. After receiving its biggest tributary, another glacier fed river, the valley widens further, giving room for an active gravel bed of 100 to 200 m. Here the river is of the braided type with several channels. When breaking through the easternmost range at our only sampling place the valley narrows again to a V-shape. The current is very fast here, the river bed consisting of coarse stones. After about 60 km the river leaves the mountains, enters the gravelly debris fan and immediately splits into 5 diverging, still fast running channels that lose water into the ground. One channel runs directly towards Ulaangom, waters the meadows and plantations there and like the others trickles away. The only channel to reach Uvs Nuur, albeit as small stream, is called Teylin Gol. Its slope decreases gradually, but not until 10 km away from Uvs Nuur the slope becomes low enough for meanders. Probably it is water-bearing in this lowest reach only during floods.

Nariyn Gol is the biggest true lowland river of the Uvs Nuur Basin. It rises in the Böörög Deliyn Els dune field some kilometers west of Döröö Nuur. As a result of backward erosion at the spring, a 100 m deep valley has formed where the stream starts slightly meandering with a slope of 4‰ right from the spring funnel. The stream runs with a slowly decreasing slope through this narrow, sandy valley northwestward, its banks lined by willows and rich grass. The valley gradually gets shallower and when it widens after 70 km, the slope decreases to 1‰ with strong meandering and forking. Here (near sampling place Nariyn Gol-2) the stream was forced to bend southward by the tectonic fault running through the inner basin. Its abandoned, 50 m deep and 1.5 km wide valley, lifted by about 10 m, is clearly visible in the relief map (94°15'E, 50°15'N) in the appendix. After following the fault line for 6.5 km southwestward, the stream runs northwestward again. After receiving its biggest tributary, the Khoyd Gol, the stream transforms into a wide, shallow, braided river carrying much sand and silt. No trees or shrubs are growing on its highly mobile sand bars. Near the eastern bay of Uvs Nuur the river forks into two main arms and after 175 km discharges into Uvs Nuur.

The big mountain river **Tesiyn Gol** has a very long stretched catchment and receives 6 big right side tributaries from the Senghilen and Khorumnug Taiga mountains. It arises at an altitude of 2500 m in the Bulnayn Nuruu range, but as these mountains do not rise very high above their local erosion basis, the slope decreases soon. After some initial bends the river takes a general westward direction. In the upper reaches down to sampling place Tesiyn Gol-4 flat and wide valleys with grass steppe several times interchange with steeper, narrower breakthroughs of mountain bars with patches of mixed larch forest and oxbow pools in the floodplain (sampling place Tesiyn Gol-3.5, Fig. 8). In the flat reaches with slopes well below 2‰ (for instance at sampling place Tesiyn Gol-1) the tortuosity increases to values around 1.7 (meandering), but when slope increases again the tortuosity falls back to values below 1.3. Braided reaches with wide gravel bars are quite common here (sampling places Tesiyn Gol-2 and 4, Fig. 7 and Fig. 9). The sediment generally is fine gravelly with a tendency to a high sand ratio in the flat reaches. In its upper and middle reaches the rivers receives runoff from several big northern tributaries, but no significant southern tributary exists. At the sampling place Tesiyn Gol-4 the river takes a bend towards northwest. When the river touches the easternmost end of the Böörög Deliyn Els dunes where a balance of eastward dune growth and erosion by the river seems to be effective, it starts carrying a large bedload of sand. The river character changes to a meandering, single channel lowland stream. LEBEDEV et al. (1997) advance a theory that Tesiyn Gol followed its western direction and flowed through the bed of the current Nariyn Gol into the eastern bay of Uvs Nuur before the formation of the dune field in the Pleistocene. If this is true then Tesiyn Gol can not have flown through this valley for a very long period since the width of the lower Nariyn Gol valley (1.5 to 2.5 km) is small compared to the 8 km of the recent Tesiyn Gol valley in the geomorphologically comparable region about 30 km SW of the village Bert Dag. After receiving its largest tributary, the Erzin Gol, the river forms for two kilometers a narrow breakthrough at the prominent SW-NE running fault, the Khairkhan mountains. LEBEDEV et al. state that in the Pleistocene during uplift of the fault the Tesiyn Gol was dammed and formed a lake. Some kilometers downstream, SW of Bert Dag (94°30' E, 50°28' N), two terraces of 10 and 20 m height are a further witness of the tectonic uplift. In this area Tesiyn Gol finally transforms into a wide, strongly meandering lowland river with an extended floodplain of 20 km width, many abandoned river beds and oxbows. The vegetation is a patchwork of willow thickets, poplar stands and open meadow areas (possibly formed by fires), often intensely grazed or used for haymaking. Here around sampling place Tesiyn Gol-5 the river is about 50 meters wide and up to two meters deep. It shows strong bank erosion with well-developed coarse sandy point bars. The time frame for horizontal shifts of the river bed in the scale of several hundred meters is decades as can be seen in Fig. 79: in nearly 50 years over a valley length of 20 km six bends were cut off and one large side channel was abandoned. Between 1992 and 2002 some meanders shifted for about 50 meters. Further downstream the river forks about 30 km from Uvs Nuur and reaches the lake as two channels.

Torkhilog Gol, that was sampled only at one point near Uvs Nuur is the largest mountain river of the Tannu Ola Range discharging into Uvs Nuur. As the debris cone of these mountains ends directly at Uvs Nuur, the river has a nearly constant slope of 10 to 20‰ right to its mouth. Its upper reaches in a comparably wide, west-east stretching U-shaped valley at some 2 000 m ASL have much less alpine character than the rivers of the Turgen-Kharkhiraa Mountains, concerning slope and active floodplain width. The valley narrows to a V-shape when the river turns southward, breaking though the southern ridge of the Tannu Ola Range. Then the terrain widens, giving space for a floodplain of several kilometers with rich vegetation and strong furcation of the river. After breaking though the southernmost, much lower mountains forming the boundary of the inner basin, the river forks again on its debris cone, starts discharging into groundwater and reaches Uvs Nuur as several small streams.

Turgen Gol rises as slightly turbid glacier stream out of a blocky moraine at nearly 3 000 m. Its bed consists of angular blocks indicating little sediment transport. The stream receives groundwater inflow from the wet meadow slopes of the U-shaped valley and some tributary streams, growing in size and beginning to show signs of bedload transport (rounded blocks and stones). Further downstream the valley bottom becomes narrow (Fig. 10) and the stream passes through the forest zone between about 2 300 and 1 900 m ASL with larch trees sometimes growing near the river. After joining with Dshibertu Gol, the river forms a 300 m wide, bare floodplain with a high diversity of choriotope types (Fig. 11). The mean flow velocity is high (0.7 to 1.3 m/s) from sampling place Turgen Gol-0.1 down to Turgen Gol-3, the water is only slightly turbid and the river often divides into several channels that changed their position over some years (Fig. 80). Subsurface flow through the gravel bed is significant and sometimes comes to the surface in shallow side channels with slow current. Breaking through the easternmost range of the Turgen-Kharkhiraa Mountains, the river forms a very narrow V-shaped valley nearly without floodplain. Immediately at the edge of the mountains the river continues through a sloped, very dry alluvial fan where the gravel bed widens again. After some kilometers, the river forks into 4 channels of which only one continues to Uvs Nuur in a very wide, sandy floodplain (Fig. 12). Most of the runoff trickles into the sandy ground. The rest carries a significant load of suspended silt. The slope, that is still at 20‰ on the alluvial fan, decreases quite abruptly to about 3‰ where the fan ends in the inner basin.

At that point, the groundwater flow that receives additional water from Sagil Gol enters the surface again in small springs or at least comes near the surface enabling growth of a willow brushwood extending over some 90 km^2. Turgen Gol is now a 6 m wide stream meandering through this brushwood and reaching Uvs Nuur after 138 km.

Common morphological characteristics of the rivers are summarized in the following.

Fig. 13 and Fig. 14 contain diagrams that show some significant relationships between hydro-morphological variables, Table 11 shows the correlation coefficients between these variables. The most important parameters that determine the morphological character of the investigated running waters were runoff (approximated by river length = distance from spring) and slope. The former was the key factor for river bed depth and width and valley width. The streams generally were quite shallow (at 90% of all sampling places between 8 and 36 cm mean depth) and wide: large brooks of about 1 m^3/s runoff were 5 to 15 m wide. The width:depth ratios of the river beds varied between 13 and 180 (mostly between 20 and 50). Values above 50 were only found at slopes < 20‰, minimum values between 15 and 30 were found at slopes from 40 to 80‰.

Slope, which varied between 100 and 0.4‰, determined the degree of tortuosity in a strong indirect proportionality with an r^2 of 0.90. Intense meandering (tortuosity > 2) was not observed with slopes above 2‰. There was no linear relationship governing the number of parallel channels and the relative width of the active floodplain. Braided river channels mostly occurred in middle ranges with high runoff dynamics and high sediment load where a wide gravelly active floodplain cannot be filled by mean runoff.

The sediment characteristics, which were additionally modified by the catchment geology (hardness and erosion characteristics of bedrock), were mostly determined by slope and flood hydrograph characteristics. Both mean and maximum grain size decreased with lower altitude, but maximum grain size decreased significantly less, which resembles the findings of PETTS et al. (2000). Whereas the maximum grain size and degree of grain size variation showed a somewhat stronger dependence on slope and altitude (i.e. maximum flow velocity at flood and probability of strong floods), the minimum grain size was more related to mean flow velocity. The often big differences between maximum and mean sediment grain size (for instance 110 and 2.5 mm in the downstream reaches of Turgen Gol) show that the extreme flood events have the carrying capacity to transport coarse stony sediment down to areas of low gradient and normally modest flow velocity. The content of coarse and fine organic detritus in the sediments of almost all sampling places was low because of the lowly productive steppe vegetation and frequent lack of trees in the river floodplains. One river with remarkable amounts of coarse woody debris and larch needle detritus was Tsunkheg Gol.

Mean flow velocity, which varied between 0.14 and 1.21 m/s, is a result of complex interactions between slope, runoff (i.e. water depth) and bed roughness that are described for instance by the Manning-Strickler formula. It therefore shows no linear correlations. The low specific discharge that increased with altitude shows the aridity of the investigated area. It amounted to 1.5 $l/s \cdot km^2$ for the lower reaches of Tesiyn and Nariyn Gol. For all other lowland and mountain rivers the value was below 5 $l/s \cdot km^2$, and only the alpine rivers Turgen and Kharkhiraa Gol attained values of about 10, in the upper reaches up to 50 $l/s \cdot km^2$.

Another important hydrologic feature of rivers is their sediment transport. There are no data available for bedload which should be significant in the alpine rivers and in sandy, fast running lowland rivers. At the sampling places Khustay Gol, Nariyn Gol-5 and Tesiyn Gol-5, strong sand movement as suspended and bedload was observed. A few measurements of the concentration of suspended sediments were made (Table 9). They show that under normal runoff conditions the suspended sediment load, especially in the mountain rivers, was quite low. Flooding rivers however could be very turbid (especially in the inner basin with finer bed sediment) and transported large amounts of suspended fine sediments and bedload, as the example of the flooding lower Kharkhiraa Gol (= Teylin Gol) shows. Its suspended sediment load was estimated to about 200 tons per hour for the example in Table 9.

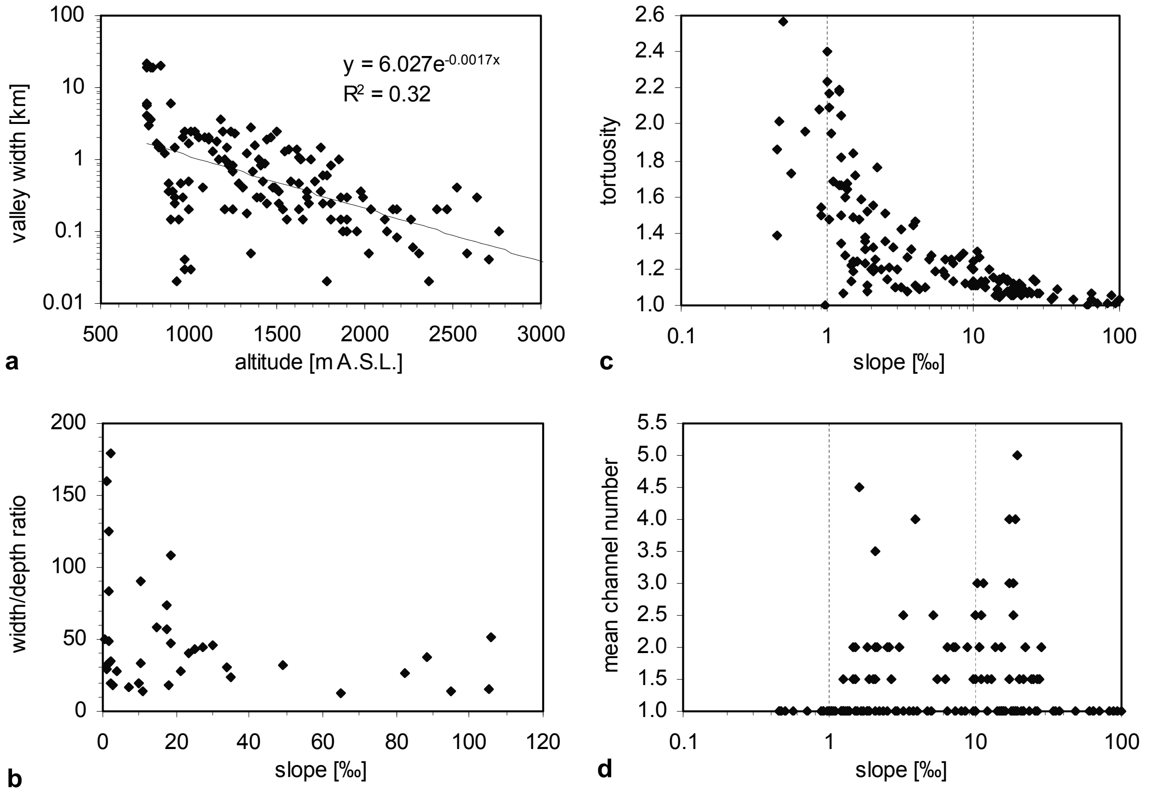


Fig. 13 Relationships between morphological variables measured at 150 points along 10 rivers, with best fit regression equations. **a** Width of river valley vs. altitude. **b** Width/depth ratio at normal discharge vs. slope. **c** Tortuosity vs. slope. **d** Mean channel number of river range vs. slope.

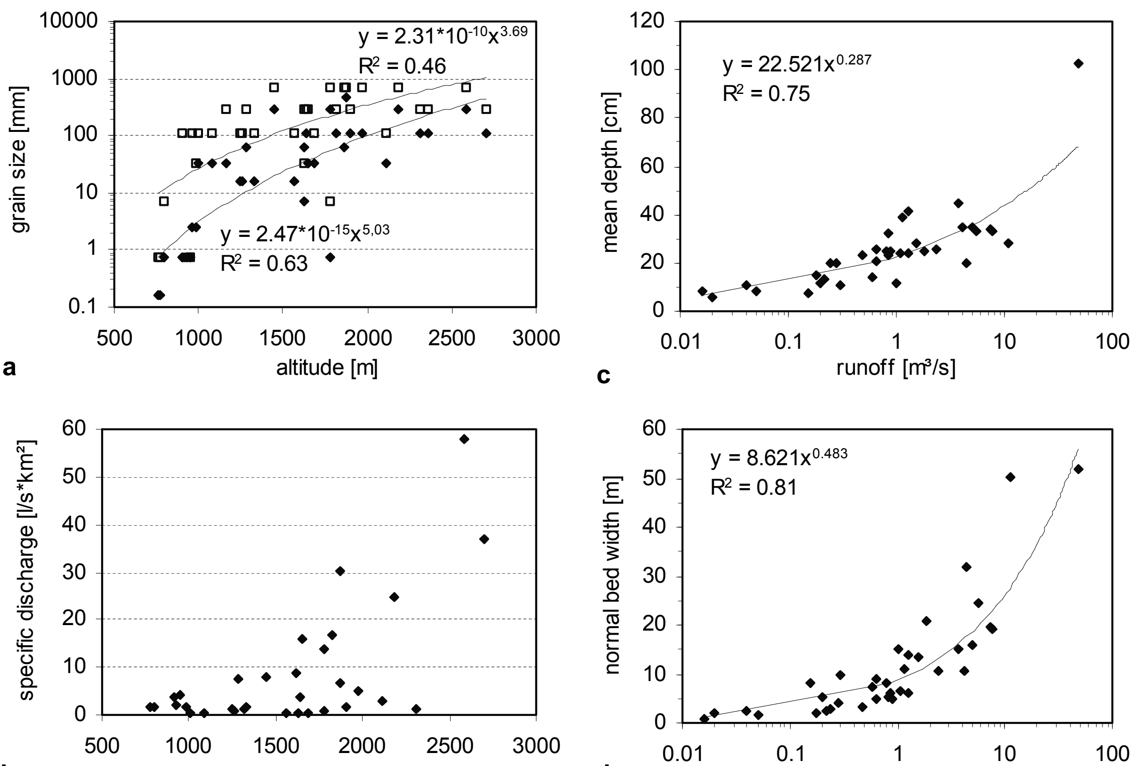


Fig. 14 Relationships between morphological and hydrological variables measured at 34 sampling points, with best fit regression equations. **a** Mean (black diamonds; lower trend line) and maximum (open squares; upper trend line) grain size of bed sediment vs. altitude. **b** Specific discharge at time of measurement vs. altitude. **c** Mean water depth at time of measurement vs. runoff. **d** Normal bed width vs. runoff.

Table 9 Measurements of suspended sediments in river water samples.

sampling place	date	runoff [m³/s]	filterable solids [mg/l]	loss on ignition [%]
Teylin Gol	1999/08/09	estimated 10-20 (flooding)	4084	5%
Kharkhiraa Gol	1999/09/06	4.7	10	
Kharkhiraa Gol	1999/07/17	25.1	80	4%
Tesiyn Gol-5	1999/08/23	47.6	89	6%

Table 10 Morphological, runoff and choriotope characteristics for 34 sampling places. Mean depth, normal bed width, runoff and flow velocity are for the sum of all channels; all values are no long term means but as measured during field work. Interpretation of the Pfankuch stability index: 39–76 good, 77–114 fair, > 114 poor channel stability (according to PFANKUCH, 1975). Abbreviations of choriotope types are explained in Table 4.

sampling place	catchment area [km²]	slope [‰]	tortuosity	channel number	mean depth [cm]	normal bed width [m]	runoff [m³/s]	spec. discharge [l/s*km²]	mean flow velocity [m/s]	Pfankuch stability index	choriotope
Dshibertu Gol-0	25	88.4	1.06	1	8	3.0					me ma ak
Dshibertu Gol-0.1	35	34.8	1.05	1	11	2.6	0.04	1.1	0.14	51	me ma ak
Dshibertu Gol-0.2	67	27.3	1.06	1	12	5.4	0.20	3.0	0.30	65	mi ps me
Dshibertu Gol-0.3	128	24.9	1.07	1	21	9.1	0.64	5.0	0.33	72	mi ma ak meg
Dshibertu Gol-0.4	162	21.2	1.11	1	24	6.6	1.07	6.6	0.69	81	meg ak mi
Endert Gol	58	18.0	1.08	1	13	2.3	0.22	3.8	0.75	45	ma ak mi
Turgen Gol-0	16	105.9	1.04	1	14	7.2	0.59	36.9	0.58	48	ma me mi
Turgen Gol-0.1	22	82.2	1.01	1	24	6.2	1.27	57.7	0.87	52	meg ma me
Turgen Gol-0.3	95	23.6	1.06	1	26	10.5	2.37	24.9	0.87	74	ma me meg
Turgen Gol-0.4	137	33.9	1.04	1	35	10.6	4.15	30.3	1.11	81	meg ma me
Turgen Gol-1	305	30.1	1.02	1	35	16.0	5.06	16.6	0.73	83	ma mi me ak
Turgen Gol-2	644	17.2	1.08	2	33	24.3	5.55	8.6	0.70	83	me ma ak
Turgen Gol-3	1050	14.9	1.04	2	33	19.3	7.77	7.4	1.21	85	ma ps me
Turgen Gol-3.1	1051	18.7	1.05	3		8.0				91	me ma ps ak
Turgen Gol-4	1051	18.5	1.05	4	8	8.2	0.16		0.25	96	ps pe me mi
Turgen Gol-4.1	1060	10.5	1.06	1	6	2.0	0.02		0.22		PS pe mi me
Kharkhiraa Gol	922	17.4	1.07	2	34	19.5	7.32	7.9	1.11	93	meg ma me
Tesiyn Gol-1	1573	2.1	1.25	1	41	14.0	1.28	0.8	0.23	72	PS ak
Tesiyn Gol-2	4425	1.8	1.31	1	28	13.5	1.54	0.3	0.41	74	me mi ps
Tesiyn Gol-3	5465	1.5	1.49	1	25	21.0	1.84	0.3	0.35		ak ps mi
Tesiyn Gol-3.5	8568	1.9	1.52	1	45	15.0	3.77	0.4	0.55	73	ps me
Tesiyn Gol-4	16975	2.0	1.19	5	28	50.0	11.08	0.3	0.79	83	mi ps me
Tesiyn Gol-5	31167	0.7	1.96	1	103	52.0	47.60	1.5	0.88	130	PS ak
Borshoo Gol-0	561	3.9	1.45	1	23	6.3	0.85	1.5	0.59	75	ps mi me
Borshoo Gol-2	619	9.7	1.21	1	25	4.7	0.88	1.4	0.76	72	me ps mi ak
Borshoo Gol-4	844	11.0	1.26	1	23	3.3	0.48	0.6	0.63		mi me ak
Borshoo Gol-5	863	10.6	1.30	1	11	10.0	0.30	0.3	0.28	71	mi ak me
brook of Butsaldag Bulag		2.5	1.35	1	8	1.5	0.05		0.40	48	ak ps mi
Khoyd Gol	550	0.9	1.50	1	39	11.2	1.15	2.1	0.27		PS
Khustay Gol-confluence	160	10.0	1.24	1	20	4.0	0.28	1.8	0.34	101	PS mi
Khustay Gol-lower reach	240	1.5	1.84	1	12	15.0	1.01	4.2	0.54	105	PS pe
Urt Bulag Gol	180	2.2	1.76	1	26	5.0	0.65	3.6	0.49	79	PS
Nariyn Gol-5	4675	1.3	1.28	1	20	32.0	4.46	1.5	0.69	102	pe ps
Nariyn Gol-mouth	4825	1.3	1.34	1	25	8.0	0.80		0.40	86	pe ps

Table 11 Matrix of Pearson correlation coefficients for some morphological and hydrological variables measured at 41 sampling places (some variables could not be measured for all data sets – minimum number of values was 34). The coefficients are shown in gray for significance levels between 0.90 and 0.99, black for significance levels ≥ 0.99 and bold for significance levels ≥ 0.999. Explanations: 1/slope = river length per altitude difference; mean channel number = mean over several kilometers upstream the sampling site; mean depth and normal bed width (for all channels if braided) as measured during field work; valley width = width of the flat valley bottom (altitude differences less than 2 meters), if applicable; width:depth ratio of the river bed as measured during field work; flood:bed ratio = width ratio of the bare active floodplain and the normal river bed; mean choriotope class = weighted mean of choriotope classes; grain size variation = difference of maximum and minimum grain size; all grain sizes calculated from choriotope classes (see Table 4); mean flow velocity and runoff as measured during field work; specific discharge = discharge per unit catchment area.

	distance from spring	catchment area	altitude	1/slope	tortuosity	mean channel number	mean depth	normal bed width	valley width	width:depth ratio	flood:bed ratio	mean choriotope class	mean grain size	grain size variation	min. grain size	max. grain size	mean flow velocity	runoff	specific discharge
distance from spring	-	**0.99**		0.53	0.40		**0.76**	**0.82**	**0.91**	0.35		-0.37		-0.35		-0.34		**0.89**	
catchment area	**0.99**	-		**0.69**	0.54		**0.76**	**0.83**	**0.90**									**0.90**	
altitude			-	-0.51	-0.53				-0.37			**0.74**	0.55	**0.61**	0.43	**0.61**			**0.64**
1/slope	0.53	**0.69**	-0.51	-	**0.90**		**0.60**	**0.59**	**0.67**			**-0.70**	-0.44	**-0.61**		**-0.59**		0.55	-0.36
tortuosity	0.40	0.54	-0.53	**0.90**	-		0.49	0.38	0.54		-0.38	**-0.66**	-0.47	**-0.62**		**-0.61**		0.45	-0.41
mean channel number						-					0.42								
mean depth	**0.76**	**0.76**		**0.60**	0.49		-	**0.67**	**0.81**								0.41	**0.86**	
normal bed width	**0.82**	**0.83**		**0.59**	0.38		**0.67**	-	**0.66**	**0.69**							0.40	**0.77**	
valley width	**0.91**	**0.90**	-0.37	**0.67**	0.54		**0.81**	**0.66**	-			-0.38						**0.93**	
width:depth ratio	0.35							**0.69**		-									
flood:bed ratio					-0.38	0.42					-								
mean choriotope class	-0.37		**0.74**	**-0.70**	**-0.66**				-0.38			-	**0.82**	**0.85**	**0.65**	**0.86**	0.44		0.57
mean grain size			0.55	-0.44	-0.47							**0.82**	-	**0.80**	**0.90**	**0.85**	0.53		**0.68**
grain size variation	-0.35		**0.61**	**-0.61**	**-0.62**							**0.85**	**0.80**	-	**0.65**	**0.99**	0.41		0.55
min. grain size			0.43									**0.65**	**0.90**	**0.65**	-	**0.73**	0.56		**0.73**
max. grain size	-0.34		**0.61**	**-0.59**	**-0.61**							**0.86**	**0.85**	**0.99**	**0.73**	-	0.45		**0.60**
mean flow velocity							0.41	0.40				0.44	0.53	0.41	0.56	0.45	-	0.40	0.40
runoff	**0.89**	**0.90**		0.55	0.45		**0.86**	**0.77**	**0.93**								0.40	-	
specific discharge			**0.64**	-0.36	-0.41							0.57	**0.68**	0.55	**0.73**	**0.60**	0.40		-

3.1.2 Runoff dynamics

The annual hydrograph of most rivers was marked by the precipitation peak from June to August and the dry, cold winter with low or totally ceasing surface runoff from December till March. If there was some surface runoff during winter depended on the permeability and depth of the bed and floodplain sediments, upwelling of deep groundwater flows, the general proportion of groundwater in the whole river runoff and its size. The beginning of the snow melt runoff depended on the catchment altitude. The peak could be distinct for rivers of the lower mountains (Borshoo, Tesiyn) or superimposed by the rain peak for high alpine rivers (Kharkhiraa, Turgen). Fig. 15 shows these characteristics.

The summer runoff characteristics show two types:

- The pluvio-glacial type (Turgen and Kharkhiraa), where runoff follows the amount of often strong rainfall, mixed with a base flow of glacier melt water. These alpine rivers tend to have strong, short storm floods.
- The pluvio-nival type (Tesiyn, Borshoo and Baruunturuun), where the season begins in April to May with a snowmelt flood originating mainly from the northern mountain ranges, followed by slowly decreasing runoff during summer with less severe flooding than in the case of alpine rivers. Baruunturuun Gol with its high August runoff is a special case: as only six years of runoff data were available, the strength of summer rain flooding could be exaggerated to some degree.

A third type could be the groundwater fed with nearly constant runoff (Nariyn and Khustay), but no hydrological data are available. It is questionable whether these streams do have runoff under a winterly ice cover or completely dry up.

NATSAGDORJ & ADYABADAM (1991) state that all rivers in the Uvs Nuur Basin show a clearly marked spring snow melt flood which constitutes the annual runoff maximum in the case of mountain rivers. They also mention the catastrophic flood of June 23rd to 26th in 1986 which caused inundations and damages in the catchment of several rivers.

The statistics in Table 12, the daily hydrographs and flow duration curves of Borshoo Gol and Turgen Gol (Fig. 17 and Fig. 18) show exemplary the difference between the first two types. The pluvio-nival type has a much more steady hydrograph than the pluvio-glacial type where due to its high catchment altitude and low water retention capacity the probability of strong cyclonic rain or storm floods is much higher. The large catchment area and many tributaries of Tesiyn Gol make short storm runoff peaks in the downstream region less probable. Statistics for annual sums of Tesiyn Gol's runoff vs. precipitation in Ulaangom shows a significant correlation ($r^2=0.62$) while the correlation for monthly data is much weaker ($r^2=0.26$) indicating that short term weather events in the catchment of Tesiyn Gol differ from that in Ulaangom. The long term cyclonic weather course however seems to affect the whole Uvs Nuur Basin and is important for the function of Tesiyn Gol as the largest single source in the water balance of Uvs Nuur.

Table 12 Statistical variables characterizing the runoff dynamics of five rivers (see CLAUSEN & BIGGS, 1997). * monthly runoff means used for statistics, # daily runoff values used. The relative flood flow volume can be depicted as the area between the flood hydrograph and the given threshold runoff, relative to the annual runoff volume.

River	Baruunturuun *	Borshoo #	Kharkhiraa *	Tesiyn *	Turgen #
gauging station	Baruunturuun	Borshoo	Tarialan	Bayan Uul	Delgermörön
catchment area at gauge [km²]	1114	625	738	11816	456
period	1993-1998	1980-1999	1974-1994	1971-1990	1980-1999
statistics for whole period					
flowless days in winter	~ 100	95	0	0	131
specific discharge [l/s*km²]	3.5	1.7	8	1.2	6.8
annual mean runoff [m³/s]	3.9	1.1	5.9	14.8	3.1
median runoff [m³/s]	2.2	0.85	2.6	8.8	0.9
runoff being exceeded 5% of the time [m³/s]	14.5	3.8	13.1	50	10.3
Coefficient of variation	156%	120%	257%	117%	377%
statistics only for days with runoff > 0					
median runoff [m³/s]	3.2	1.2	2.6	8.8	2.9
Coefficient of variation	127%	90%	257%	117%	296%
flood statistics (only for runoff days)					
mean frequency of floods using a threshold of x times the median [1/year]					
FRE 3		1.55			4.35
FRE 5		0.70			1.25
FRE 7		0.50			0.70
FRE 9		0.15			0.45
FRE 20		0.00			0.07
mean duration of floods using a threshold of x times the median [days]					
DUR 3		15.5			6.8
DUR 5		8.7			6.6
DUR 7		3.0			6.4
DUR 9		1.7			6.6
DUR 20		0.0			6.2
mean number of days in a year in flood, using a threshold of x times the median [days/year]					
TIM 3		24.1			29.6
TIM 5		6.1			8.3
TIM 7		1.5			4.5
TIM 9		0.3			3.0
TIM 20		0.0			0.4
relative flood flow volume: mean volume of flood water using a threshold of x times the median, divided by the mean annual runoff volume					
VOL <1 ("base flow")		60.0%			42.5%
VOL 1		40.0%			57.5%
VOL 3		10.4%			23.8%
VOL 5		2.3%			16.0%
VOL 7		0.4%			12.9%
VOL 9		0.1%			11.0%
VOL 20		0.0%			6.7%

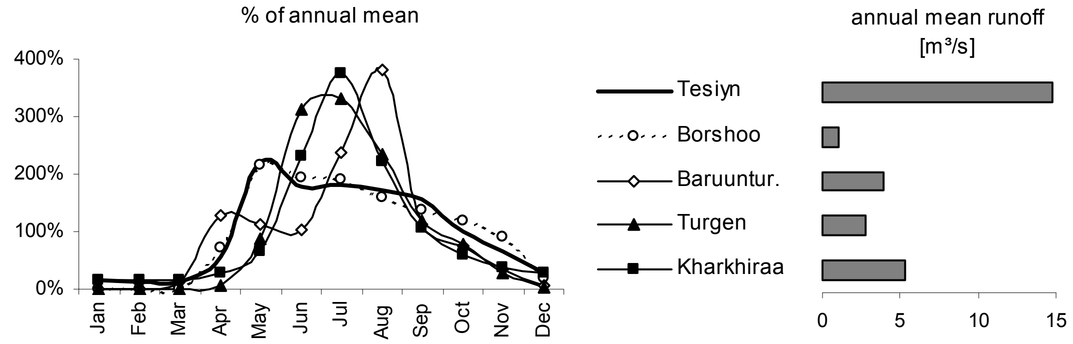


Fig. 15 Mean runoff characteristics of five rivers: relative annual hydrographs and absolute annual mean runoff. Note that the mean discharge of Tesiyn Gol at its mouth is about twice as high as at the gauging station.

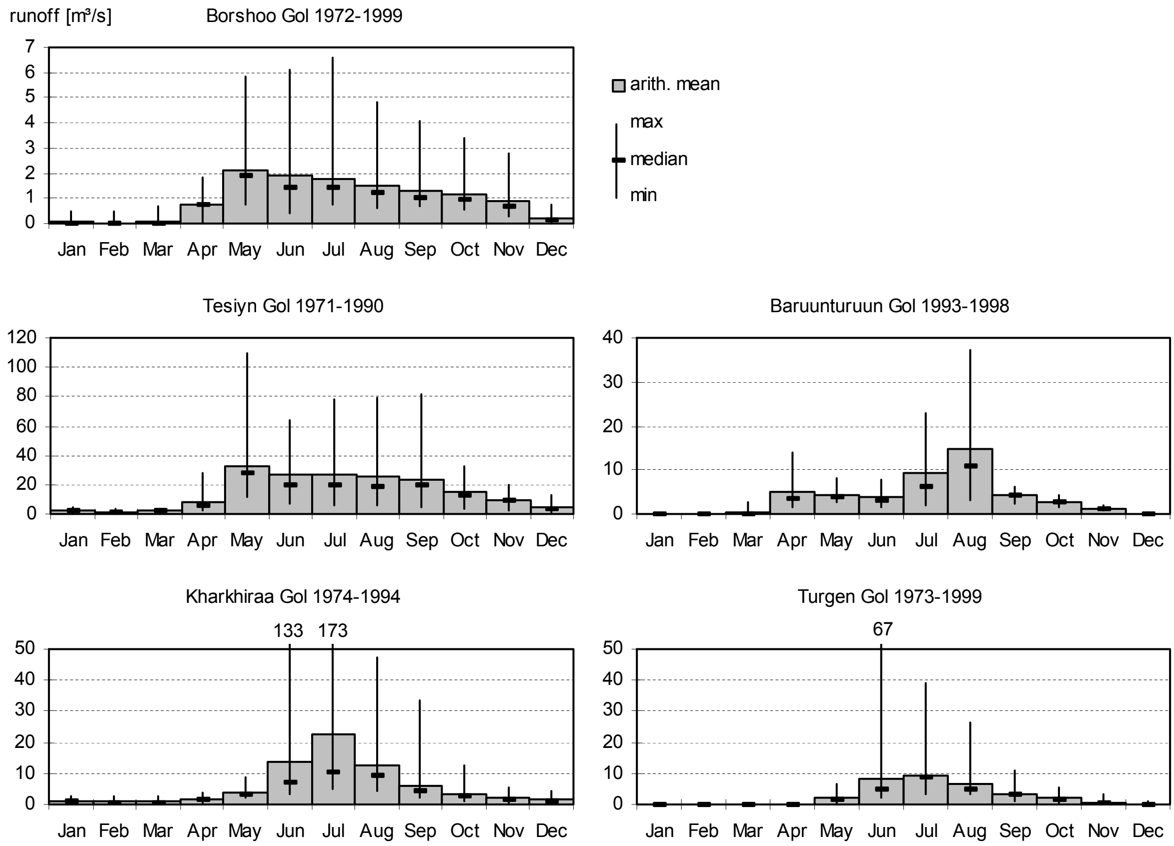


Fig. 16 Means, maxima, median and minima of monthly runoff means [m³/s] as measured at the gauging stations of 5 rivers.

Most remarkable in the daily hydrographs (Fig. 17 and Fig. 18) was the extreme flood of Turgen Gol from 06/24 till 06/29/1986 which peaked at 677 m^3/s (= 250 times the annual mean runoff). Considering the valley profile in Fig. 11a and assuming a mean flow velocity of 2 m/s the gravel bed in its whole width of 250 m must have been flooded. The runoff volume of these six days amounted to 166% of the river's mean annual runoff volume. In the Kharkhiraa Gol the 1986 flood must have been even more extreme, as the monthly mean runoff in July (173 m^3/s) was 41 times the median of monthly means whereas the monthly mean of Turgen reached "only" 23 times the median. Flood events of this magnitude are responsible for the general appearance of the alpine rivers in the Uvs Nuur Basin and their floodplains. Their frequency seems to be in the range of several decades.

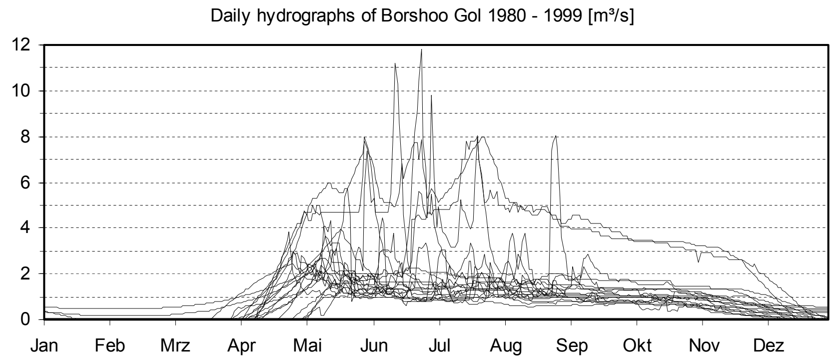


Fig. 17 Daily hydrographs of Borshoo Gol for the years 1980 to 1999 [m³/s]. The years with high base flow were 1993 and 1994.

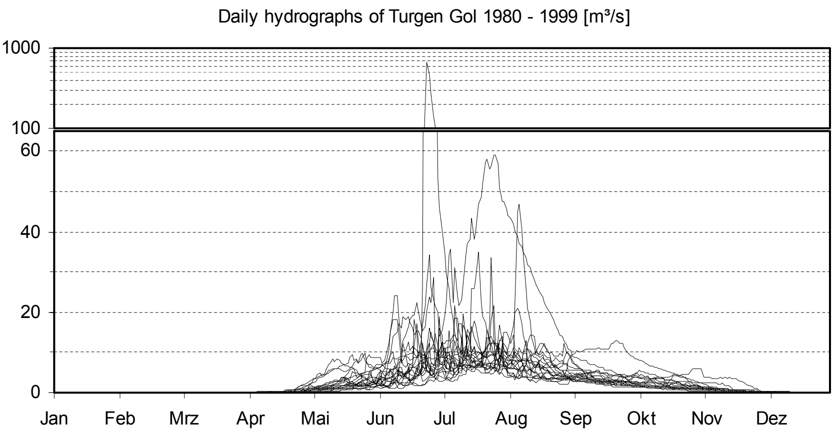


Fig. 18 Daily hydrographs of Turgen Gol for the years 1980 to 1999 [m³/s]. The maximum flood runoff of 677 m³/s was measured on 06/25/1986. Note the logarithmic scale on the upper part of the diagram!

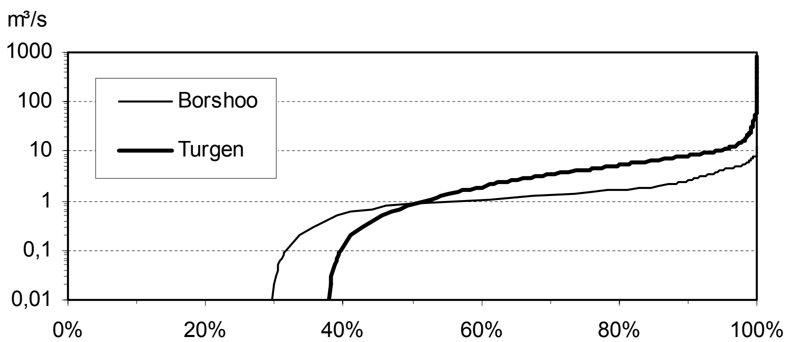


Fig. 19 Flow duration curves (percentage of days with runoff below given value) for Borshoo Gol and Turgen Gol.

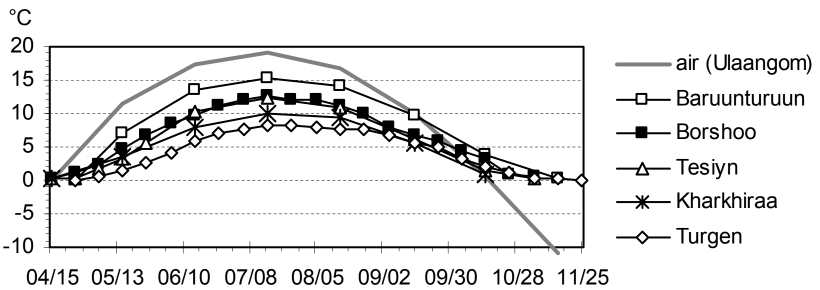


Fig. 20 Long term means of air and water temperature for 5 rivers. See Table 13 for explanations.

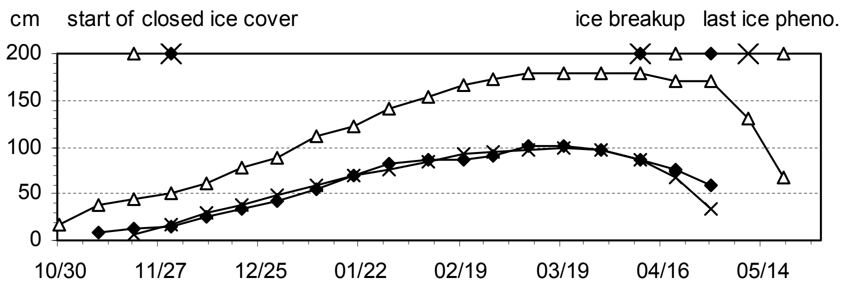


Fig. 21 Long term means of ice thickness and mean dates of formation and breakup of a closed ice cover and last icing phenomena;
white triangles = Turgen Gol-Delgermörön
black diamonds = Borshoo Gol-Borshoo
X-crosses = Uvs Nuur-N
(see chapter 3.2.3).

3.1.3 Water temperature and freezing

The long time recordings of water temperature for the same five rivers as in chapter 3.1.2 show the influence of the hard winter on the rivers. The water temperature in the alpine and mountain rivers reaches values above 0.2°C only during 6 to 7 months; in Turgen and Kharkhiraa Gol 10°C is exceeded only occasionally. A closed ice cover exists for 5 to 6 months, exceeding 1 m thickness in March. From the beginning of ice breakup till the last ice phenomena it takes 3 to 4 weeks.

A linear regression of our own temperature measurements at 61 sampling places vs. altitude gives a mean altitude gradient of -145 m/K (r^2 = 0.43) for the water temperature in rivers and streams during August. The diurnal temperature fluctuations in August as measured with temperature data loggers (11 measurements) were, depending on shading of the river, weather conditions, water depth and runoff between 2.1 and 7.6 degrees. The number of degree-days which is an indicator of growth and development time of water organisms differs between 1 000 and 1 500 for the alpine and mountain rivers. Baruunturuun Gol is a special case as the gauging station is downstream from a reservoir that warms up the water.

The continuous temperature measurements with a data logger exposed in a pool of 1.1 m water depth at sampling place Borshoo Gol-2 for 1 year gave insight into the general temperature and icing regime of this stream. The daily mean temperature was decreasing from mid of July when it reached 15°C until end of October when nearly 0°C were reached. The mean daily temperature amplitudes also decreased from 4 degrees to 0. From the end of November till mid of January the temperature was constantly at 0°C indicating no runoff, but stagnant water under the ice cover. Thus at least in pools of this depth there is sufficient water for hibernating fishes. From mid of January till mid of April a period of small, irregular temperature fluctuations between 0.7 and 1.8°C followed, which can be interpreted as weak, groundwater fed runoff. With the ice breakup on April 5th the normal diurnal rhythm started again whereas the daily minimum stayed at 0°C until beginning of May. The daily mean temperature rose from 1°C in mid April quite fast to 10°C at the end of May. May and June were the months of maximum daily amplitudes (on most days > 6 degrees). The further increase of the daily mean temperature considerably slowed down until reaching the maximum of 14°C mid of July.

No data are available for the lowland rivers. Water temperatures in the groundwater fed spring regions are probably more constant, but fluctuations and mean temperatures downstream can be expected to be higher than in the mountain rivers due to the shallow water depth, slow flow, higher air temperature and less cloud cover in the inner basin. The duration of freezing seems to be comparable to that of the mountain rivers as a satellite image from April 29th 1997 showed large ice areas in the Nariyn Gol river bed.

Table 13 Statistical variables characterizing water temperature and freezing of five rivers. * monthly means used for statistics, # 10-day means used.

River	Baruunturuun *	Borshoo #	Kharkhiraa *	Tesiyn #	Turgen #
gauging station	Baruunturuun	Borshoo	Tarialan	Bayan Uul	Delgermörön
altitude of gauging station [m ASL]	1250	1200	1440	1406	1750
period	1960-1968	1990-1999	1964-1968	1970-1990	1990-1999
mean maximum temperature [°C]	21.5	17.5	15.1	17.9	11.5
abs. maximum temperature [°C]		21.6		21.0	12.2
day of max. temperature	07/18	07/10	07/14	07/15	08/10
temperature exceeded in spring					
0.2°C	04/20	04/15	04/16	04/18	05/02
4°C	05/12		05/18		
10°C		06/14	06/19		06/24
temperature falling below threshold in autumn					
10°C	09/28	08/28	08/17		09/20
4°C	10/13	10/06	09/30		10/04
0.2°C	11/14	10/29	10/19	10/24	10/22
days >0.2°	208	198	186	189	172
degree-days	1952	1484	1160	1401	969
ice phenomena					
days of ice cover		143			171
days of ice phenomena		190			216
begin of ice cover		11/25			11/17
end of ice cover		04/08			04/16

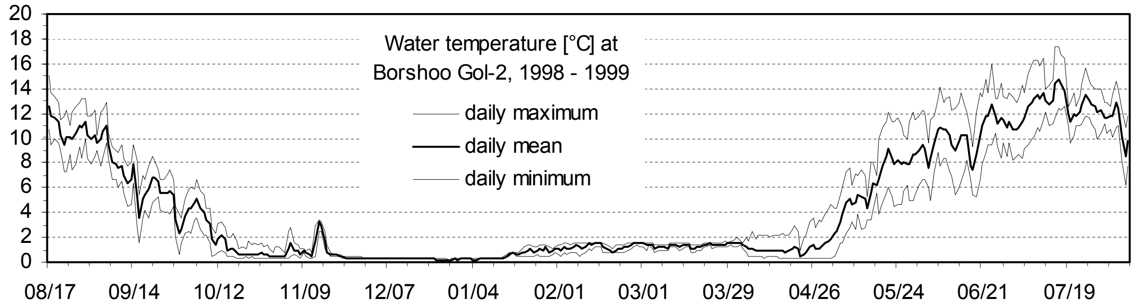


Fig. 22 Water temperature continuously measured from August 1998 to August 1999 at sampling point Borshoo Gol-2 in 1.1 m water depth – daily mean, maximum and minimum.

3.1.4 Chemical properties

A summary of chemical properties is given in Table 14; for a complete overview of chemical measurements taken in all water samples see Table 46 in the appendix. Several parameters were measured only in some samples, therefore in the following the different numbers of available values are indicated as (n=…).

There are little literature data on river chemistry in the Uvs Nuur Basin: according to BULGAN & NYAMYA (1991) the total salinity of rivers in the basin is roughly between 100 and 300 mg/l, but can be up to 550 mg/l. Tesiyn Gol at Bayan Uul has a salinity of 200–450 mg/l while Turgen and Kharkhiraa Gol only reach 90–200 mg/l. The water hardness is between 0.7 and 3.3 meq/l. They state that the river water shows no signs of anthropogenic pollution, what can be questioned as eutrophication due to high livestock densities should be taken into account – see maximum TP and NO_3-N concentrations in Table 14.

Table 14 Chemical properties of river water samples – minima, averages and maxima for all rivers and mean values for the three river types. * = flooding rivers excluded from means.

	conduct. [µS/cm]	pH	salinity [g/l]	Na^+	K^+	Ca^{2+}	Mg^{2+} [mg/l]	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	TP [µg/l]	NO_3-N
n samples	68	64	45	45	45	45	45	45	45	45	45	40	43
minimum	50	7.5	0.05	0.7	0.3	3.9	1.0	0.0	0.8	30.5	0.0	1	10
mean value	304	8.4	0.25	11.8	2.1	35.3	9.0	5.6	18.6	119.7	1.4	64	535
maximum	1226	9.1	0.99	127.0	15.0	90.0	44.8	37.5	117.0	328.2	7.2	1540	3280
alpine average	215	8.3	0.19	3.4	1.3	27.3	7.3	2.1	12.1	93.3	0.9	13	449
mountain ave.	334	8.4	0.27	14.3	2.3	41.4	9.1	7.4	22.4	130.5	2.0	22 *	440
lowland ave.	410	8.5	0.35	24.9	3.6	40.8	12.4	9.4	25.3	154.7	1.1	39	927

3.1.4.1 Oxygen content, pH value and conductivity

The oxygen saturation of the river water (n=44) was at most sampling places between 90 and 110% indicating the minimal organic pollution and sparse growth of macrophytes and benthic algae. The only exceptions were slight oversaturations between 110 and 130% at places with moderate phytobenthos growth (Dshibertu Gol-0.3, Gurmosyn Gol, Tesiyn Gol-1, Tesiyn Gol-3, Tsunkheg Gol-3 and Ukhug Gol) and an oversaturation of 153% at Nariyn Gol-mouth with dense growth of *Potamogeton* and filamentous algae. Noticeable undersaturation was only measured at Kharig Gol (58%) and Turgen Gol-4.2 (52%). At both sampling places groundwater was upwelling in the dry riverbed.

The pH values (n=64) mostly were in a range between 8.0 and 8.8 which mirrors the overall carbonatic geology of the whole region. There were only two mountain rivers with lower values: Dshibertu Gol-0 (7.8) and Kharig Gol (7.5). The only place with a higher pH value was Nariyn Gol-mouth with 9.1 which reflects pH increase due to photosynthesis of the phytobenthos. There was no significant correlation between pH and altitude or single chemical parameters like conductivity, concentrations or percentages of calcium, sodium or carbonate ions.

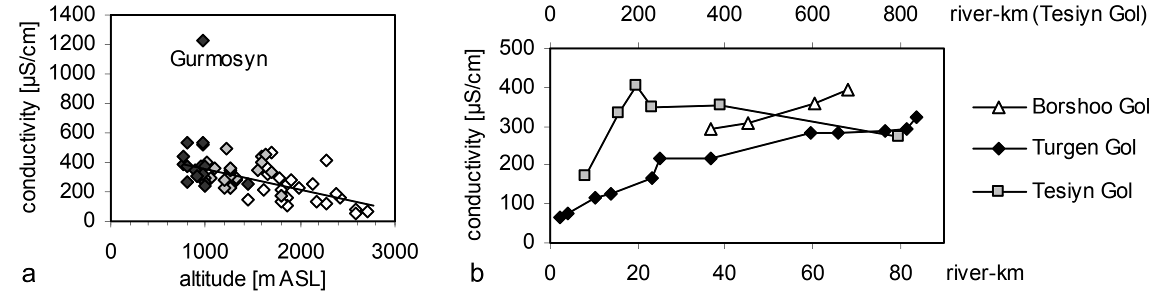


Fig. 23 a Electric conductivity of 68 river water samples vs. altitude. White = alpine rivers, light gray = mountain rivers, dark gray = lowland rivers. Linear trend line for all samples except Gurmosyn Gol (r^2 0.38).
b Conductivity along the course of Borshoo (measured 1998), Turgen (measured 1997) and Tesiyn Gol (measured 1999).

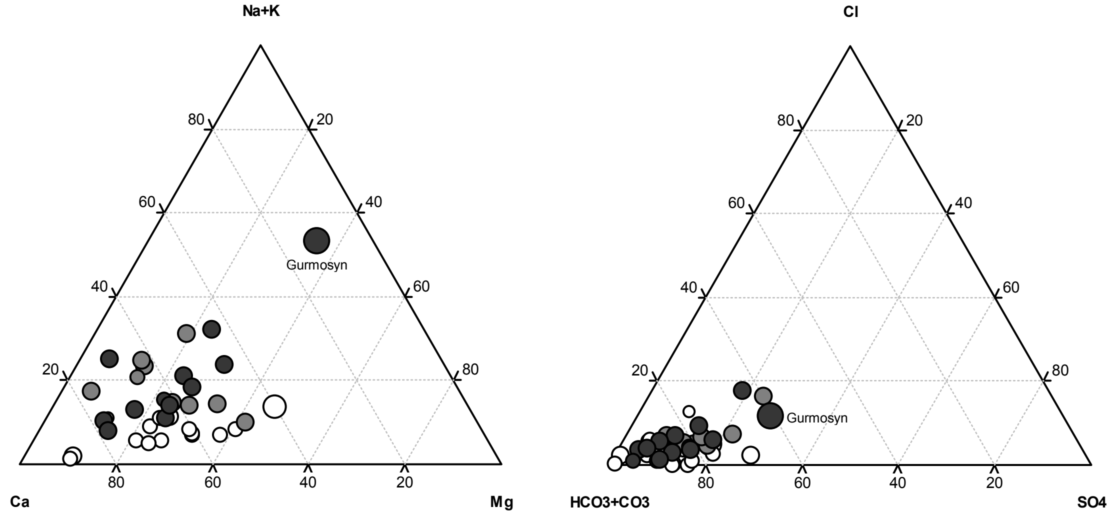


Fig. 24 Ternary diagrams for the percentage of Ca^{2+}, Mg^{2+}, $Na^{+}+K^{+}$ in the equivalent concentrations of cations (left) and $HCO_3^{-}+CO_3^{2-}$, SO_4^{2-}, Cl^{-} in the equivalent concentrations of anions (right) in 36 river water samples. Axis labels are at the top (100%) of the axes. The area of the circles approximately corresponds to salinity. White = alpine rivers, light gray = mountain rivers, dark gray = lowland rivers.

The total content of dissolved ions expressed as electric conductivity of all river water samples (n=68) with the exception of Gurmosyn Gol (1226 µS/cm) was between 50 and 532 µS/cm, salinity between 50 and 450 mg/l (Gurmosyn Gol 990 mg/l). In terms of salinity all streams except the subsaline Gurmosyn Gol can be classified as fresh water. The mean salinity of typical mountain rivers was at about 150 mg/l; the value rose to about 260 mg/l for lowland rivers. The conductivity changed significantly along the river course, particularly when mountain rivers enter the inner basin where seepage and evaporation processes were dominating. There was a significant inverse relationship between altitude and conductivity (r^2=0.37), indicating an increasing load of dissolved ions along the river courses. Several factors bring about this increase: decreasing proportion of rain water with low conductivity in the total runoff and higher conductivity of inflowing groundwater from the mountains to the inner basin, increasing dissolution of ions from the bed sediment as grain size becomes finer along the river's course, the general tendency towards underground flow and stronger evaporation in the inner basin.

Examples of longitudinal changes are given for Borshoo, Turgen and Tesiyn Gol (Fig. 23b). It has to be noted that the time between samplings at Tesiyn Gol was up to 24 days. The figure shows for the two smaller rivers the increase of conductivity as stated above. The abrupt conductivity increase of Turgen Gol at river kilometer 25 marks the confluence with Dshibertu Gol. Tesiyn Gol likewise exhibits a strong conductivity increase in its upper reaches with probably quite dry climate until river kilometer 220 where the first of six big, water-rich tributaries from the northern mountains starts diluting the river water.

The temporal changes of conductivity can only be estimated by means of the few measurements taken, but it seems that in streams with smaller catchment and high, dynamically changing percentage of rain runoff the conductivity can vary by more than 50% of the mean. Borshoo Gol-2 (228 to 328 µS/cm) and Turgen Gol-1 (133 to 217 µS/cm) are examples for this, while Tesiyn Gol with its large catchment shows only small fluctuations (341 to 361 µS/cm). Groundwater fed streams also have quite stable conductivity values – Nariyn Gol-1 (264 and 270 µS/cm) and Urt Bulag Gol (309 and 313 µS/cm) are examples.

3.1.4.2 Ionic composition

Almost all river water samples (n=36) were of the normal freshwater Ca/Mg-HCO_3 type, however with a transition to higher Na and SO_4 contents, ending with a Mg/Ca/Na-HCO_3/SO_4 type . This transition can be observed along the altitude gradient from alpine to lowland rivers, albeit not very clearly along the course of single rivers, which was partly due to analytic problems (see chapter 2.3). Generally, the sodium, magnesium, chloride and sulphate concentrations were increasing whereas the concentrations of calcium and hydrogen carbonate were much less variable. The Mg:Ca ratio seems to be more related to the geologic composition of the catchment than to altitude. Sodium shared normally less then 30%, only Gurmosyn Gol was an exception with more than 50% sodium and only 15% of calcium. The differences in the composition of cations were higher than those of the anions, where chloride and sulphate together never reached more than 40% of the total equivalent concentration of anions.

The absolute concentration of calcium in the rivers was between 10 and 90 mg/l, for magnesium between 1 and 45 mg/l, for sodium mostly between 0.7 and 40 (only Gurmosyn Gol 127) mg/l. The water hardness was in the soft range (0.6 to 2.6 meq/l). The anion concentrations were between 30 and 273 mg/l (Gurmosyn Gol 330 mg/l) for the sum of hydrogencarbonate and carbonate, between 0.8 and 56 mg/l (Gurmosyn Gol 117 mg/l) for sulphate and 0 to 29 mg/l (Gurmosyn Gol 38 mg/l) for chloride.

The high salinity and Na:Ca ratio of the periodic (or episodic?) river Gurmosyn Gol can be understood as result of evaporation, drying out and re-dissolution processes that take place in sequence depending on the runoff of Baruunturuun Gol, and the fact that the river water at sampling time consisted only of upwelling groundwater. A high variability of the chemical composition of Gurmosyn Gol must be assumed.

ZHANG et al. (1995) found similar conditions and processes in mountain rivers around the Taklimakan Desert, where the river water salinity increased remarkably when the rivers entered the arid inner basin. On the other hand, the ionic composition (Na:Ca, Mg:Ca and K:Ca ratios) was largely controlled by rock and soil geochemistry of the catchments.

3.1.4.3 Nutrients and conditions for primary productivity

Although the concentrations of plant-available nutrients (PO_4-P, NH_4-N and NO_3-N) were near the detection limits, and the known high temporal variations of N and P concentrations can not be covered by a few spot check samples, some general conclusions can be made.

The PO_4-P concentrations (n=17) were most often below detection limit of 10 µg/l, only 3 values were a little higher: 10, 15 and 25 µg/l, the latter at the slightly eutrophicated point Tesiyn Gol-1. The concentrations of NH_4-N (n=9) were always below detection limit (20 µg/l), the NO_3-N concentrations however (n=43) were in a wide range between 18 and 3280 µg/l, six values were below detection limit (differing between 24 and 230 µg/l due to different dilution factors and instrument configurations). The values above 1 mg/l were measured in groundwater fed streams (brook 4, Nariyn Gol-1 and -2, Urt Bulag Gol) and Teylin Gol during flood.

Total phosphorus and nitrogen concentrations measured in the laboratory were never below detection limit. The TP concentrations (n=40) were between 1 and 1540 µg/l. For dry weather runoff and rivers with sediment coarser than silty (n=34) the mean and maximum TP concentrations were only 12 and 48 µg/l. Even in the lower Tesiyn Gol at sampling place Tesiyn Gol-5 (catchment area 31 167 km²) only 22 µg/l were measured, while at the slightly eutrophicated Tesiyn Gol-1 48 µg/l were found. TP concentrations above 50 µg/l were found in only six cases: the turbid, silty rivers Gurmosyn Gol, Nariyn Gol-5 and Turgen Gol-4, the glacier stream Turgen Gol-0 with significant amount of glacial flour and the flooding

Teylin Gol (1540 µg/l) and Tesiyn Gol-4 (161 µg/l). The total nitrogen concentration under dry weather runoff conditions (n=5) was between 0.24 and 0.47 mg/l.

The presumably high variability of TP concentrations in most rivers (depending on runoff) can be seen exemplary for some sampling places with several analyses: for Nariyn Gol-1 (5 and 12 µg/l), Tesiyn Gol-4 (5 and 161 µg/l), Turgen Gol-0.4 (3 and 19 µg/l), Turgen Gol-1 (5 and 11 µg/l) and Turgen Gol-3.1 (4 and 25 µg/l) the variability is high while Borshoo Gol (16, 16 and 19 µg/l) showed a quite stable TP concentration. DJODJIC et al. (2000) found for rivers with clay catchments that as well the concentration of PO_4-P (leaching losses) as of TP (erosion losses) significantly correlated with discharge. Thus, rivers with frequent strong floods are likely to carry the highest phosphorus loads. BEHRENDT & OPITZ (1999) established a model of TP and TN retention based on empirical data from European rivers. They found a strong inverse relationship between specific discharge and nutrient retention rate. The low specific discharges of mountain and lowland rivers of our area of investigation would correspond to retention rates of 80–90% for TP and 70–80% for TN. It is yet not clear whether this model can be applied to the rivers of the sparsely populated, semiarid Uvs Nuur Basin.

The concentration of silicon (n=43) as essential nutrient for diatoms was between 1.2 and 13.5 mg/l and that of the micro-nutrient iron (n=22) was in four cases below detection limit (0.01 mg/l), otherwise between 0.01 and 0.24 mg/l.

From these values can be concluded:

- There are only at some places signs of moderate anthropogenic eutrophication in the sampled rivers, as the TP concentrations under dry weather runoff conditions are below 50 µg/l. That seems to be an upper threshold of natural background loading (see SMITH et al., 2003, BEHRENDT et al., 1999, SCHÖNFELDER et al., 2005 and STEIN & YOON, 2007). In a study of North American rivers DODDS (2006) found the upper threshold of TP in oligotrophic rivers to be at 23 to 29 µg/l, for TN some 300 µg/l. According to these criteria most rivers in the Uvs Nuur Basin are oligotrophic.
- Visual signs of eutrophication and increased saprobity (high phytobenthos growth, partially sapropel under stones) were found at places with very high livestock density as Tesiyn Gol-1, -2 and -3, and Turgen Gol-4. The floodplain near the river at these places is full of dry livestock excrements, the vegetation very short due to grazing. Thunderstorms can partially inundate the floodplain and wash away masses of these excrements as has been observed. The river water is very turbid then and foam can form. After one or two days base flow conditions with clear water prevail again.
- The total phosphorus concentration which at dry weather runoff is below 50 µg/l can be much higher during floods due to soil erosion.
- The DIN:SRP ratio for alpine and mountain rivers (n=14) was most often > 50 (phosphorus is clearly the limiting nutrient). Only in places with strong phytobenthos growth and possibly anoxic groundwater conditions in the floodplain (Borshoo Gol-2 to 5, Tesiyn Gol-1) it was below 20, indicating the possibility of nitrogen limitation. For lowland streams no DIN:SRP ratios are available.

The primary productivity of streams depends not only on the availability of nutrients but also on water temperature, light availability and other growth conditions (flow time for phytoplankton, runoff velocity and abrasion due to sediment movement for phytobenthos). The flow time of Tesiyn Gol which can be estimated (assuming a mean flow velocity of 0.7 m/s) to about 13 days from the headwaters to Tesiyn Gol-5 was surely long enough to enable significant phytoplankton development. No phytoplankton samples were taken, but there was no sign of chlorophyll color at Tesiyn Gol-5. Light limitation due to high suspended sand and silt concentrations as well as phosphorus limitation are the probable reasons.

For phytobenthos, no biomass measurements were made, but qualitative estimates for some visually recognizable growth forms are given in Table 15, for taxonomic details see chapter 3.1.5.1!

3.1.5 Aquatic biota

3.1.5.1 Phytobenthos

Samples of macroscopically visible phytobenthos and benthic diatoms were taken qualitatively, thus all biomass data are based on a five-tier semiquantitative scale (macroscopically invisible = 1, few = 2, modest = 3, much = 4, mass = 5). An overview of the relative biomass in the sampled rivers is given in Table 15. Complete taxonomic results can be seen in Table 49 in the appendix. The benthic (and to some degree also planktic) diatoms were not completely determined by the author. An in-depth examination of the samples will be made and published elsewhere. For some of the most interesting or rare benthic algal species microscopic images and short descriptions are given in chapter 6.3 of the appendix.

Published results of Russian investigations of benthic algae are sparse: NAUMENKO (1996, 1997) gives short reports on the phytobenthos of three Rivers of the Eastern Tannu Ola Mountains and the Russian part of Tesiyn Gol. In Tesiyn Gol he found 100 algal species, among them 5 Cyanobacteria, 90 Bacillariophyta, 3 Dinophyta and 24 Chlorophyta. Unfortunately, no species list is given. Only the dominant rheophilic diatoms are named, which are more or less cold stenothermic diatoms with Holarctic distribution: *Hannaea arcus*, *Meridion circulare*, *Diatoma hiemale*, *D. hiemale var. mesodon*, *Achnanthes minutissima*, *Didymosphenia geminata* and *Cymbella sinuata*.

Benthic macrophytes and macroscopic algae were not abundant in most rivers of the Uvs Nuur Basin. Extended stands of helophytes were missing, and larger plaits of higher plants or macroalgae oscillating in the current were seldom found. While those are missing in alpine and many mountain streams anywhere in the world due to instable and coarse substratum, for the lowland streams special factors must be taken into account. These are most probably the long winter with often completely frozen riverbeds, the low number of degree days that slows down macrophyte growth, the strong runoff periodicity and at some places trampling by watering livestock.

In the following, the distribution of dominant and characteristic taxa is given for the rivers arranged by altitude. The results of a multivariate statistical analysis (see chapter 4.1.1) show that the altitude-related variables current velocity, temperature, substratum type are the most influential factors. They are complemented and in some places surpassed by the azonal factor eutrophication. Another determining factor for the composition of benthic algal communities is seasonality that obviously can not be addressed here as all samples were taken in August and September.

In **Dshibertu Gol**, macroscopically visible phytobenthos was found in the riverbed sections with highest water depth. The chrysophyte *Hydrurus foetidus* grew there in long plaits. It is a characteristic Holarctic species of cold, fast running alpine streams with high light input (WARD, 1994; HIEBER et al., 2001). BRODSKY (1980) found it in the Tien Shan only at temperatures < 8°C. On these plaits, *Gomphonema*, *Cymbella*, *Meridion* and other diatoms were growing in great numbers. On stones in faster running areas, characteristic brown cyanobacterial spots and crusts were formed by *Chamaesiphon polonicus*, *Homoeothrix janthina*, *H. varians*, *Gloeocapsa* sp., *Clastidium setigerum* and unidentified coccal algae. *Chamaesiphon polonicus* and *Gloeocapsa* spp. are characteristic species of alpine streams with frequently changing water level and have a high desiccation tolerance; *Homoeothrix janthina* is common in non-calcareous alpine and spring streams (KAWECKA, 2003; GESIERICH & ROTT, 2004).

The small, mesotrophic **Endert Gol** had dense growths of the moss *Drepanocladus aduncus* and oligo-mesotraphentic filamentous algae (*Ulothrix zonata*, *Microspora amoena* var. *gracilis*) on the immobile stones, providing a habitat for phytophilic zoobenthos (Limnephilidae).

In the main river bed of **Turgen Gol**, macroscopically visible phytobenthos was very sparse. However, there were refugia of slower current in side channels where filamentous algae can grow. Rich growth of macroscopic algae has only been observed at Turgen Gol-0, where *Hydrurus foetidus* and the thallose green alga *Prasiola fluviatilis* grew on the immobile stones. The latter is known from other small, slowly flowing glacial streams in high mountains and arctic regions of the northern hemisphere (PRINTZ, 1964; HAMILTON & EDLUND, 2004). As soon as the flow velocity became high enough to move the stones, macroscopic phytobenthos disappeared: at sampling place Turgen Gol-0.2 there was still some *Hydrurus foetidus* visible, that can cope with higher flow velocity (PFISTER, 1993), while further downstream at Turgen Gol-0.4 and -1 in the main channel only diatoms and cyanobacterial crusts of *Chamaesiphon polonicus*, *Gloeocapsa* sp. and *Clastidium setigerum* – very similar to that in Dshibertu Gol – were found. In secondary channels of the widened river bed at Turgen Gol-1 where hyporheic flow was upwelling, some *Hydrurus*, *Ulothrix zonata* and *Zygnema* sp. were growing. At the sampling site Turgen Gol-3, besides diatoms, only a few calcareous crusts of *Phormidium* cf. *calcareum* were found on the stones. At the sampling places of Turgen Gol further downstream in the seepage zone no visible phytobenthos was found.

The torrential **Kharkhiraa Gol** at the sampling place Tarialan had only one main channel where no visible benthos was found; the diatoms were dominated by *Reimeria sinuata*.

In the upper, less steep reaches of **Tsunkheg Gol**, rich masses of *Hydrurus foetidus*, mixed with diatoms (*Diatoma hiemalis*, *Eunotia*, *Fragilaria arcus*, *Cymbella*, *Gomphonema*) and *Ulothrix aequalis* were growing. On the stones in the strong current, crusts of *Chamaesiphon polonicus* and *Homoeothrix crustacea* were found. In the steeper, partially shady downstream regions the biomass, particularly of *Hydrurus* and *Ulothrix*, decreased.

In **Borshoo Gol**, a rich growth of submerged phytobenthos attached to stones and gravel indicated favorable hydrological conditions and was a visual sign of a moderate eutrophication. Macroscopic filamentous algae (*Cladophora glomerata*, *Vaucheria* sp., *Stigeoclonium* sp.), *Stuckenia pectinata* (synonym *Potamogeton pectinatus* – for a revision of the genus see KAPLAN, 2008), mosses (mainly *Fontinalis antipyretica*, some *Hygrohypnum ochraceum*) – all species that are indicative of meso- to eutrophic conditions – and a number of microphytobenthos species were found in increased abundance. Among the latter, Cyanobacteria (*Chamaesiphon incrustans*, *Heteroleibleinia kuetzingii*, *Phormidium autumnale*, *Nostoc sphaericum* and others), Diatoms and moss-dwelling Desmidiaceae (*Closterium acerosum*, *C. dianae*, *C. ehrenbergii*, *C. littorale* var. *crassum*) were the most important. Macroscopic tufts of the diatom *Didymosphenia geminata* were present on some stones, but without the nuisance effect of overgrowing the whole river bed described by SPAULDING & ELWELL (2007), BLANCO & ECTOR (2009) and WHITTON et al. (2009). The find of *Audouinella* sp. was the second in our samples. In a small floodplain spring *Hydrurus foetidus*, *Microspora amoena*, *M. stagnorum* and *Spirogyra* sp. were found.

The phytobenthos of the large **Tesiyn Gol** changed significantly along the river course. In its upper reaches where the floodplain was intensely grazed, it showed signs of eutrophication, that diminished in the middle reaches. The total amount of phytobenthos had a decreasing tendency towards the lower reaches, where at Tesiyn Gol-5 due to instable, sandy substratum and high turbidity no phytobenthos was found.

At the probably less eutrophicated site Tesiyn Gol-1, besides few macrophytes (*Ranunculus* subg. *Batrachium*, *Potamogeton* aff. *berchtoldii*), numerous filamentous algae were present: *Spirogyra* spp. and *Mougeotia* sp. as well as *Ulothrix* sp. can be seen as trophically tolerant while the dominant *Cladophora glomerata* as well as *Stigeoclonium* sp., and *Oedogonium* sp. represent eutraphentic taxa. *Pseudochaete crassiseta*, *Aphanochaete repens*, *Chamaesiphon incrustans*, *Heteroleibleinia kuetzingii* and *Calothrix* cf. *kossinskajae* were found in the periphyton of filamentous algae (mainly *Cladophora*). The *Calothrix* species was always without terminal hairs that are described for *C. kossinskajae*. On stones, *Oscillatoria sancta*, *Anabaena* sp., *Merismopedia glauca* and *Didymosphenia geminata* were apparent.

At sampling site Tesiyn Gol-2, eutrophication became more obvious in shape of higher biomass of *Cladophora glomerata* with masses of epiphytic *Cocconeis pediculus*, *Heteroleibleinia kuetzingii* and some *Chamaesiphon incrustans*, accompanied by *Oedogonium*. Few macrophytes (*Ranunculus* subg. *Batrachium*, *Stuckenia pectinata*) were present. An interesting find were *Nostoc verrucosum* and *N. sphaericum*, the latter with endogloeic *Pseudanabaena* cf. *mucicola*, that grew in abundance on the stones.

Table 15 Relative amount of phytobenthos in 33 places of the sampled streams.
Biomass scale: ○ = macroscopically invisible (1), ◷ = few (2), ◔ = modest (3), ◑ = much (4), ● = mass (5), ? = not found in the samples, but probably present. Chlorophyceae = filamentous Ulothrichales, Microsporales, Chaetophorales, Prasiolales and Oedogoniales; other microalgae = Bacillariophyceae, Chrysophyceae and Rhodophyta.

Sampling place	total phytobenthos	Cladophora sp.	Vaucheria sp.	Chlorophyceae	Zygnematales	Hydrurus foetidus	Cyanobacteria	other microalgae	Spermatophyta	Bryophyta
Dshibertu Gol-0.1	◷					◷	◷	○		
Dshibertu Gol-0.2	◔					◔	◷	◷		
Dshibertu Gol-0.3	◔					◔	◷	◷		
Dshibertu Gol-0.4	◷					◷	○	○		
Endert Gol	◔			◷				◷		◔
Turgen Gol-0	◷			◷		◷	◷	○		
Turgen Gol-0.2	◷					◷	○	○		
Turgen Gol-0.4	○						○	○		
Turgen Gol-1	◷				◷	◷	◷	○		
Turgen Gol-3	○						○	○		
Turgen Gol-4	◷						○	○		
Kharkhiraa Gol	○							○		
Tsunkheg Gol-1	◑			◔		◑	◔	◷		
Tsunkheg Gol-2	◔			◷		◔	◔	○		
Tsunkheg Gol-3	◷			◷		◷	◷	○		
Borshoo Gol-0	◑	◑	◷	◔			◔	◷	◔	◔
Borshoo Gol-2	◔	◔	◷	◷	○		◷	◷	◷	◷
Borshoo Gol-5	◷	○	◷				◷	◷	○	◷
Tesiyn Gol-1	◔	◔		◔	◔		◔	◷	◷	
Tesiyn Gol-2	◑	◑		◷			◔	◔	◔	
Tesiyn Gol-3.5	◔	◔		◷	◷		◔	◷		◔
Tesiyn Gol-4	◷	○			◷		○	◷	○	
Tesiyn Gol-5	○							○		
Ukhug Gol	◔	?					?	?	◔	◔
Burat Usu Bulag	◑				◑		◔	○		
brook of Butsaldag Bulag	◔	◔		◔			○	○		◔
spring at Torkhilog Gol	◔						◷	◷		◷
Jireeg Gol	◔	◔		◔	◷		◷	○	◔	
Khoyd Gol	◷	◷					○	◷	◷	
Khustay Gol-lower reach	◷			◷	◷		◷	◷		
Nariyn Gol-2	◑	?			?		?	?	◑	
Nariyn Gol-5	◔				◔		?	?	?	
Nariyn Gol-mouth	◑	◔			◑		◷	◷	◑	

At the next site, Tesiyn Gol-3.5, the species inventory changed again: the only macrophyte was the moss *Drepanocladus aduncus*. The filamentous *Cladophora glomerata* (with epiphytic *Chamaesiphon incrustans* and *Heteroleibleinia kuetzingii*), *C. fracta*, *Oedogonium* sp., *Ulothrix zonata* and *Spirogyra* were again a mix of eutraphentic and mesotraphentic taxa. Rich epilithic growth of *Phormidium autumnale* and the diatoms *Didymosphenia geminata*, *Diatoma vulgaris*, *Cymbella* spp., *Fragilaria ulna*, *Nitzschia* spp. and others indicated the still increased nutrient level.

The sampling site Tesiyn Gol-4 was characterized by stronger runoff dynamic and high current velocity. Thus, in the main channel besides diatoms no phytobenthos was found. However, in the side channels with weak current, some Zygnemataceae (*Spirogyra*, *Mougeotia* and *Zygnema*), *Phormidium* cf. *simplicissimum* and the only characean of the investigated rivers – *Chara vulgaris* – were found. Thus, the obvious signs of eutrophication of the upper reaches have vanished.

Though in the main channel of Tesiyn Gol in its lower reaches (sampling site Tesiyn Gol-5) no phytobenthos was present, in small floodplain streams and oxbow ponds many species of phytobenthos could be found. This also applies for the middle reaches where numerous oxbows exist. The exemplarily sampled sites Tesiyn Gol-3.5a and Tesiyn Gol-5.5 showed some of the diverse species inventory of these short-lived waterbodies that were mostly obliterated in densely populated countries.

The relatively big **oxbow pond Tesiyn Gol-3.5a** was densely grown with submerged macrophytes – *Ranunculus* subg. *Batrachium*, *Potamogeton berchtoldii*, *Stuckenia pectinata*, *Potamogeton perfoliatus*, *Myriophyllum sibiricum*, *Persicaria* sp., *Hippuris vulgaris*, *Equisetum fluviatile*, *Chara contraria* and some filamentous algae (*Mougeotia* sp.).

In the small, shallow **oxbow pond Tesiyn Gol-5.5** the only macrophyte was the moss *Leptodictyum riparium*, possibly indicating a higher risk of drying out. A rich growth of filamentous algae (*Mougeotia* sp., *Zygnema* sp., *Microspora amoena* var. *gracilis*, *Microspora stagnorum*, *Tribonema* sp., *Oedogonium* sp.) with interesting epiphytes (*Aphanochaete repens*, *Calothrix* cf. *kossinskajae*, *Microchaete tenera*, *Oscillatoria* cf. *curviceps*, *Aphanocapsa* spp., *Epipyxis* cf. *borgei*, *Epipyxis marchica*, *Salpingoeca* aff. *vaginicola*) and numerous diatom species were found there.

The floodplain stream **Ukhug Gol** that is part of the Tesiyn Gol delta was lined with *Phragmites australis* and other reeds. The submerged mosses *Fontinalis antipyretica* and *Leptodictyum riparium* and unsampled filamentous algae grew in abundance in the sandy-gravelly bed.

The small spring streams northwest of Uvs Nuur – Burat Usu Bulag, brook of Butsaldag Bulag, spring at Torkhilog Gol and Jireeg Gol – had a rich, quite heterogeneous phytobenthos with some rare species. In the spring pond of **Burat Usu Bulag** masses of *Spirogyra* were growing. In the brook of the nearby **Butsaldag Bulag** the moss *Drepanocladus aduncus* grew together with *Cladophora glomerata*, *Microspora amoena* and *Ulothrix zonata*. In the alluvial spring at **Torkhilog Gol** the moss *Fontinalis antipyretica*, the red algae *Batrachospermum* sp. and *Audouinella* sp. and the cyanobacteria *Phormidium caucasicum* (rope-like twisted thallus) and *Homoeothrix gloeophila* (on *Batrachospermum*) were found. According to EDLUND et al. (1999) the genus *Batrachospermum* is extremely rare in Mongolia – they quote only two localities of *B. gelatinosum*. *Audouinella* sp. that is often associated with *Batrachospermum*, seems to be much less frequent than in European mountain streams as it was only found twice in our samples. The small **Jireeg Gol** was likewise species-rich: *Hippuris vulgaris*, *Stuckenia pectinata*, *Cladophora glomerata*, *Spirogyra* sp., *Microspora amoena*, *Oedogonium* sp. and *Calothrix* cf. *kossinskajae* were found there.

The sandy **Khoyd Gol** was sampled near its outflow from Bayan Nuur. It was loosely grown with *Myriophyllum spicatum*, *Hippuris vulgaris*, *Stuckenia pectinata*, *Chara* sp. and some *Cladophora* cf. *fracta*. In the periphyton *Geitlerinema splendidum* and other (mostly planktic) cyanobacteria were found.

In the spring-fed **Khustay Gol** only few phytobenthos was present due to sand drift. At some places near the banks filamentous algae grew: *Spirogyra* sp., *Microspora* cf. *aequabilis* and *Oedogonium* sp. Lime incrusted *Leptolyngbya* sp. formed crusts on small stones. On the sandy substratum, besides *Heteroleibleinia* sp., *Komvophoron schmidlei*, *Merismopedia glauca*, *Pseudanabaena minima* and many diatom species mostly tychoplanktic algae were found: *Synechocystis* cf. *aquatilis*, *Woronichinia* sp., *Scenedesmus disciformis*, *S. obliquus*, *Oocystis* sp. and *Cosmarium reniforme*.

In the sandy **Nariyn Gol** at the site Nariyn Gol-2 there was a rich growth of submerged macrophytes (probably *Potamogeton*) visible, however no samples were taken. At the downstream site Nariyn Gol-5 the sediment was unstable and the water very turbid. No emergent or submerged macrophytes were visible, however in still waters near the banks some *Spirogyra* grew. At the mouth of Nariyn Gol flow velocity was low and macrophytes (*Stuckenia pectinata*, *Carex* sp.) and filamentous algae (*Spirogyra* sp., *Cladophora fracta*) were present in abundance on the sandy-loamy sediment.

These results can be summarized as follows:

In alpine rivers, due to strong current and abrasion by bedload and glacier flour, macroscopically visible phytobenthos was mainly confined to headwaters or side channels with stable substratum. Rheophilic, cold-stenotherm and oligo-mesotraphentic species prevailed. Crust-forming cyanobacteria (an association of *Chamaesiphon polonicus* and *Homoeothrix* spp.) and *Hydrurus foetidus* were found on stable stones in the current. In calm side channels, *Ulothrix*, *Microspora* or *Zygnema*, accompanied by *Phormidium* spp. were able to form dense, relatively short-lived masses prone to drying or outwash depending on the hydrological situations. Diatoms formed sparse layers with mostly low diversity.

The phytobenthos of mountain rivers had a wide range of manifestations depending on substratum, current and trophic state. Emergent helophytes were missing, but mosses (mainly *Drepanocladus aduncus* and *Fontinalis antipyretica*) were often present and formed dense cushions at nutrient enriched sites. Spermatophytes (*Stuckenia pectinata*, *Ranunculus* sp.) were present at few places, probably due to the fact that the small rivers freeze to the bottom during winter. Filamentous algae of the genera *Mougeotia*, *Spirogyra*, *Zygnema* and *Microspora* formed dense waddings at places with low current and mostly soft bottom substratum while on stones and gravel under stronger current *Cladophora*, *Oedogonium*, *Stigeoclonium*, *Tribonema*, *Ulothrix* and *Vaucheria* could be found. The Zygnematales, *Microspora*, *Tribonema* and *Ulothrix* were found at oligo- or mesotrophic sites; the findings of *Cladophora glomerata*, *Oedogonium*, *Stigeoclonium* and *Vaucheria* were signs of eutrophication (Borshoo Gol, Tesiyn Gol-1 and 2). Red algae (*Audouinella* and *Batrachospermum*) were rare and seemed to prefer small streams and springs. The diatom flora in the gravelly streams was species-rich; macroscopically visible gelatinous tufts of *Didymosphenia geminata* could be seen sporadically. Thalli of Oscillatoriales (*Oscillatoria*, *Phormidium*, especially *P. autumnale*, and *Leptolyngbya*) and *Nostoc* grew on the stones at eutrophic places. In the periphyton of the green filamentous algae (mainly *Cladophora*), *Chamaesiphon incrustans*, *Heteroleibleinia kuetzingii*, *Calothrix* cf. *kossinskajae*, *Aphanochaete repens* and *Pseudochaete crassisietum* were most important. Some *Closterium* species were found between mosses and filamentous algae.

Oxbow ponds were biotopes particularly rich colonized by phytobenthos – numerous limnophilic macrophytes and filamentous algae grew there. *Myriophyllum* species, *Hippuris vulgaris*, *Persicaria*, *Ranunculus*, several *Potamogeton* species, *Chara* and sometimes mosses were the most common macrophytes. *Microspora*, *Mougeotia*, *Spirogyra*, *Zygnema*, *Oedogonium* and *Tribonema* were typical genera of filamentous algae that can form dense masses with a rich periphyton.

Lowland streams with mostly sandy or silty sediment were densely populated by macrophytes as long as the current was not strong enough to carry a substantial bedload or suspended sediment load, and the channel flow was not only intermittent. *Stuckenia pectinata* can form dense plaits, *Hippuris vulgaris* and *Myriophyllum spicatum* grew submergedly, *Phragmites australis* was found on the banks at a few places where cattle had no access. Filamentous algae (*Cladophora fracta*, *Spirogyra*, *Microspora* and some Oscillatoriales) could be found at shallow stagnant water zones near the shore.

The total phytobenthos biomass was mainly determined by the physical factors current velocity, substratum stability and grain size, permanence of channel flow and temperature: the highest biomass can be expected in moderately fast flowing gravelly mountain or lowland streams with quite steady runoff regime. The chemical factor phosphorus concentration – in the range observed here – was of secondary importance for total biomass, but changed species composition and dominance (see chapter 4.1).

3.1.5.2 Zoobenthos

As only few of the zoobenthos samples were taken quantitatively, all analyses are based on the same semi-quantitative abundance scale as for phytobenthos. The groups Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Chironomidae, Deuterophlebiidae, Blepharoceridae and Amphipoda were determined to the highest taxonomic level possible by German specialists, covering the most abundant taxa. All other zoobenthos was determined by the author; the taxonomic level reached was not better than family or genus.

It has to be considered that some places (especially along Turgen Gol; Borshoo Gol-2, Tesiyn Gol-4) were sampled in several years while most others were sampled only once. Furthermore, as all samples were taken during August and begin of September, surely many taxa that emerge in spring and early summer were not found. Thus, the species inventory given here is only a fraction of the true figure. From the long-time Russian investigations there is some literature available: PETROZHITSKAYA (1996) found 23 species from 10 genera of Simuliidae in the Russian part of the Uvs Nuur Basin; but no taxa names are given. ZAIKA (1996) gives an overview of 107 taxa of aquatic insects found in rivers and lakes of the Uvs Nuur Basin during the 1989 field campaign of the Russian research project "Experiment Ubsu-Nur"; a further extended list of stonefly species is given in ZAIKA (2009b). These taxa are listed in Table 49 in the appendix. In two other articles on Ephemeroptera (ZAIKA, 2008) and Trichoptera (ZAIKA, 2009a) of the Altai Mountains, Tuva and northwest Mongolia, the author gives only species lists for the whole of northwest Mongolia.

Of the species determined in our samples, *Micropsectra recurvata* (Goetghebuer 1928) found in Borshoo Gol was new for Mongolia (R. SAMIETZ, pers. comm.). Additional new findings for Mongolia were made outside the Uvs Nuur Basin at the Selenge River near the Town Hutag-Under (49°23' N, 102°51' E): *Limnephilus politus* Curtis 1834 (W. MEY, pers. comm.), *Polypedilum (Pentapedilum) nubens* (Edwards 1929), *Cricotopus (Cricotopus) trifascia* Edwards 1929 and *Cryptochironomus rostratus* Kieffer 1921 (R. SAMIETZ, pers. comm.).

A qualitative overview of the zoobenthos colonization is given in Table 16. The most abundant or interesting species will be listed in the following for every river. From a zoogeographical point of view, the macroinvertebrate fauna has to be seen as a mixture of Western Palaearctic and East Siberian species. Endemites and Sino-Tibetan forms are found only scarcely.

Dshibertu Gol was populated mainly by abundant Ephemeroptera (*Cinygmula cava*, *C. irina*, *C. putoranica*, *Baetis* sp. 2, *Ameletus camtschaticus*, *Siphlonurus lacustris*), Plecoptera (abundant *Mesocapnia variabilis* and some *Skwala pusilla* and *Suwallia teleckojensis*), some Limnephilidae, abundant Diamesinae, Simuliidae and Turbellaria. Shredders and detritivores lived mainly in the shallow side branches, while in the main channel filter feeders and grazers were most abundant. The population structure changed along the first few kilometers with increasing runoff and flow velocity from a dominance of small shredders and detritivores to grazers, filter feeders and predators.

The small alpine meadow stream **Endert Gol** with its stable bed and some moss and filamentous algae was populated by abundant Simuliidae and some Plecoptera (*Suwallia teleckojensis*), Baetidae (*Baetis feles*), Limnephilidae (*Apatania* sp.), Chironomidae, Limoniidae, Turbellaria and Coleoptera.

The zoobenthos population of **Turgen Gol** showed three zones: the alpine spring region, the alpine river with high flow velocity and coarse substratum and the downstream infiltration zone with low, unsteady runoff and fine gravelly substratum. In the alpine spring region where rich phytobenthos grew on the stones, only some small Plecoptera (*Mesocapnia variabilis*, *Arcynopteryx* sp.), Diamesinae and *Dugesia* sp. were found, the main feeding types being shredders, sediment feeders and predators. In the following alpine reach with highly mobile substratum and much lower amount of phytobenthos more species of Plecoptera (*Skwala pusilla*, *Suwallia teleckojensis*), abundant Ephemeroptera (*Baetis* spp., *Baetis vernus*, *Baetiella* sp., *Ephemerella aurivilii*, *E. ignita*, *Cinygmula* sp., *C. cava*, *Rhithrogena* sp., *Ameletus* sp. and *Siphlonurus* sp.), some Trichoptera (*Glossosoma* sp., *Apatania* sp., *Apatania impexa* and Limnephilidae) and Diptera (Simuliidae, Tipulidae, Limoniidae, Ceratopogonidae and two species of the highly rheophilic Deuterophlebiidae and Blephariceridae: *Bibiocephala maxima* and *Deuterophlebia sajanica*) were found. *Bibiocephala maxima* is distributed from the Altai Mountains to the Russian Far East (ZWICK & AREFINA, 2004). The dominating feeding types in this region were grazers, sediment feeders, active filter feeders and predators. The absolute population density nowhere was high, but it decreased considerably in the infiltration zone downstream of Turgen Gol-3. The number of zoobenthos taxa found in the whole river system of Turgen, including Dshibertu and Endert Gol was 47, which is surely only a fraction of the species richness to be expected here.

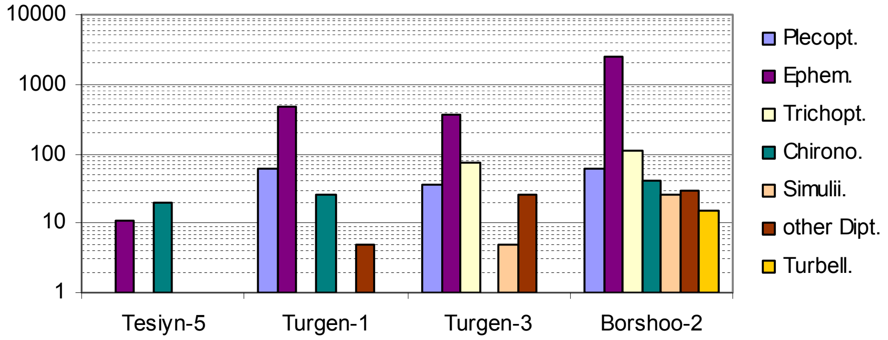


Fig. 25 Quantitative abundance [n/m²] of macrozoobenthos groups at four sampling places.

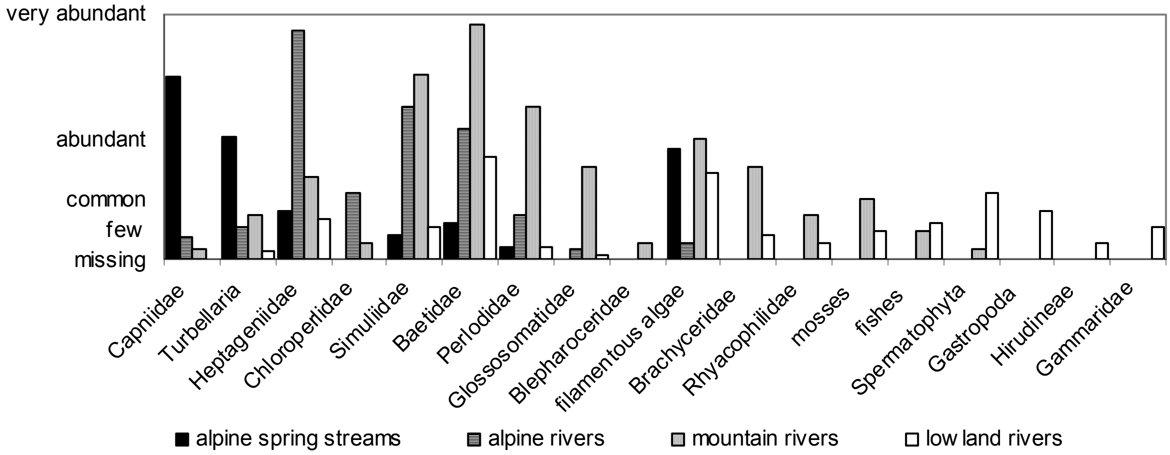


Fig. 26 Mean qualitative abundances of 18 taxonomic groups of benthic organisms for four types of running waters. Based on the same data as the PCA in chapter 4.1.1, but only groups selected with a distribution that depends particularly strong on the river type.

The zoobenthos of the small, alpine **Tsunkheg Gol** changed its character from mainly shredders, sediment feeders and predators (Plecoptera – *Mesocapnia variabilis*, *Skwala pusilla*, Chironomidae, Tipulidae, Turbellaria) in the upper reach where rich phytobenthos grew to a dominance of grazers, filter feeders and predators in the faster running lower reaches (*Baetis vernus*, *Baetis* sp. 1, *Cinygmula cava*, *Apatania impexa*, Simuliidae, Plecoptera – *Skwala pusilla*, *Suwallia teleckojensis*).

At the only sampling site of the big, fast running alpine river **Kharkhiraa Gol** the zoobenthos was dominated by rheophilic Ephemeroptera (*Baetis vernus*, *Baetis* sp. 2, *Cinygmula cava*, *Rhithrogena* sp.), and some Plecoptera (*Suwallia teleckojensis*), Simuliidae, Chironomidae, Trichoptera (*Glossosoma* sp., *Apatania* sp.) and *Deuterophlebia sajanica*.

In the mountain rivers **Burgastay** and **Kharig Gol** mainly Ephemeroptera and Trichoptera (*Baetis vernus*, *Baetis* sp. 1, *Rhyacophila*, *Glossosoma intermedium*, *Brachycentrus americanus*, *Limnephilus*, *Philarctus rhomboidalis*) and some Chironomidae and Simuliidae were found.

The rich zoobenthos population of **Borshoo Gol** was dominated by grazers, sediment feeders (Ephemeroptera, Trichoptera, Chironomidae and other Diptera) and predators (Plecoptera, Trichoptera): *Baetis vernus*, *Cinygmula cava* and *Ecdyonurus inversus* were very abundant; *Ephemerella ignita*, *Siphlonurus lacustris,* Chironomidae, *Psychodidae* as well as *Rhyacophila* sp., *Glossosoma intermedium*, *Diura* sp., *Isoperla lunigera* and *Skwala pusilla* were subdominant. The abundance of filter feeders (Simuliidae, *Brachycentrus americanus*) and Turbellaria was comparably low. The absence of Mollusca and Amphipoda is a bit astonishing as well as the presence of the rheobiontic *Deuterophlebia sajanica*. The structure of the zoobenthos did not change markedly between the sampling places, but the overall abundance at Borshoo Gol-5 where surface runoff starts decreasing was reduced.

Table 16 Relative abundances of macrozoobenthos groups in 39 places of the sampled streams (qualitative sampling only). Abundance scale: ○ = rare (1), ◷ = few (2), ◔ = common (3), ◑ = abundant (4), ● = very abundant (5).

sampling place	dist. from spring [km]	total zoobenthos	Plecoptera	Ephemeroptera	Trichoptera	Chironomidae	Simuliidae	other Diptera	Turbellaria	Coleoptera	Gammaridae	Mollusca	Heteroptera	Odonata	Hirudinea
Dshibertu Gol-0.1	7.6	◑	◑	◔	○	◑	○	◷	◔						
Dshibertu Gol-0.2	14.8	◑	◷	◑		◷	◔		◷						
Dshibertu Gol-0.3	20.5	◑	◷	◑	○	◷	◑								
Dshibertu Gol-0.4	25.1	◑	◷	◑	◷	◷	◔								
Endert Gol	1.0	◑	◔	◷	◔	◷	◑	◷	◔						
Turgen Gol-0	0.1	◔	◷			◔			◔						
Turgen Gol-0.1	1.4	◔	◔	◷		◔	○	○							
Turgen Gol-0.2	7.5	◔	◷	◔	○	◔	◷	○	○	○					
Turgen Gol-0.3	11.2	◑	○	◔	○	◷	◷	◷	◷						
Turgen Gol-0.4	19.5	◔		◔	◷	◷	◔								
Turgen Gol-1	21.8	◔	◷	◑	○	◷	◷	○	○						
Turgen Gol-2	33.2	◔	◷	◔	◷		◔	◷		◷					
Turgen Gol-3	54.9	◔	◷	◔	◔		◔	◷							
Turgen Gol-3.1	61.3	○	○	○											
Turgen Gol-4	72.2	○		◷			◷								
Turgen Gol-4.2	77.4	○	○	◷			○			◷					
Kharkhiraa Gol-Tarialan	50.5	◔	◷	◔	◷	◷	◷	○							
Tsunkheg Gol-1	4.4	◔	◷	◔	◷	◔		◷	◔	◷					
Tsunkheg Gol-2	5.6	◑	◔	◑	◔	◷	◑	◷	◷						
Tsunkheg Gol-3	7.3	◑	◔	◑	◷	◷	◷								
Burgastay Gol		◔		◑		◷	◔								
Kharig Gol		◷		◔											
Borshoo Gol-0	39.1	◑	◑	◑	◑	◔		○							
Borshoo Gol-2	46.0	●	◑	●	◑	◔	◑	◔	○	○					
Borshoo Gol-5	65.3	◔	◔	◔	◔	◷	◷		○						
Tesiyn Gol-1	52.0	◷		◔	◷	○		◷				◷			
Tesiyn Gol-2	106.0	◔	◷	◔	◷	◷		○		○		◷			
Tesiyn Gol-3.5	162.0	◑	◔	◑	◔	◔	◷								
Tesiyn Gol-4	281.0	◔	◷	◔	◔	◷	◔	○		○					
Tesiyn Gol-5	559.0	○	○	○	○	○	○							○	
Ukhug Gol	80.0	◑	◷	◔	◑	◔					◔	◷			◔
brook of Butsaldag Bulag	1.3	◔		◔	◔	◔	◷				◷	◷			
Jireeg Gol		◔	◷	◔	◷	◔	◷			○	◷		○		
Torkhilog Gol		◔	◷	◔	◔		◷								
Urt Bulag Gol	4.2	◔		◷	◔	◔	◷	◷							
Khustay Gol-confluence	1.5	◷		◷	◷	◷	◷	○	◷						
Khustay Gol-lower reach	9.0	◷		◷		◷							◷		
Nariyn Gol-5	113.0	◷		◔		◷				◷		◷	◷		
Nariyn Gol-mouth	126.2	◔		◔		◔		◷		◷	◷	◷	◷	○	

The zoobenthos of **Tesiyn Gol** was species-rich albeit not as abundant as in Borshoo Gol. The species inventory partially differed from that of the rivers in the Turgen-Kharkhiraa Mountains. This is not surprising if one considers the large catchment and high runoff dynamic of this river as well as the geographic distance from the western part of the Uvs Nuur Basin. The dominant feeding types are grazers and sediment feeders (Heptageniidae, Ephemerellidae, Baetidae, Glossosomatidae), filter feeders (Arctopsychidae, Hydropsychidae, Brachycentridae, Simuliidae) and predators (Plecoptera). Filter feeders were only found in abundance at the sampling place Tesiyn Gol-4, less abundant at Tesiyn Gol-3.5 and Tesiyn Gol-5.

The most abundant species were *Ephemerella ignita*, *Epeorus pellucidus*, *Heptagenia sulphurea*, *Baetis vernus*, *Rhithrogena* sp., *Glossosoma* sp., *Arctopsyche ladogensis*, *Hydropsyche* sp., *Brachycentrus americanus*, *Skwala pusilla* and *Phasganophora extrema*. Of the Diptera some Chironomidae, Simuliidae, Tipulidae, Limoniidae, Tabanidae and Blepharoceridae (*Bibiocephala maxima* at Tesiyn Gol-4) were found. Tesiyn Gol was the only mountain river where Mollusca (Lymnaeidae) and Amphipoda (*Gammarus lacustris*) were found, albeit only in the upper reaches (Tesiyn Gol-1 to -3) and in very low abundance.

The lowland streams in the NW part of the Uvs Nuur Basin (**brook of Butsaldag Bulag**, **Jireeg Gol)** were characterized by a mixture of rhithral (*Baetis vernus*, *Brachycentrus americanus*, *Rhyacophila* sp.) and potamal (Lymnaeidae, *Gammarus lacustris*, *Brachycercus harrisella*, *Paracorixa armata*) grazers, sediment feeders and shredders while in the mountain river **Torkhilog Gol** a rhithral community of grazers, filter feeders and predators (*Cinygmula putoranica*, *Baetis vernus*, *Glossosoma angaricum*, *Brachycentrus americanus*) was found.

The zoobenthos of the lowland rivers in the Böörög Deliyn Els dune field (**Urt Bulag Gol**, **Khustay Gol** and **Nariyn Gol**) accommodate diverse communities of potamal and littoral species. Most abundant were sediment feeders (Chironomidae, *Cloeon simile*, *Baetis tricolor*, *Siphlonurus alternatus*, Corixidae); some grazers (Lymnaeidae, *Baetis vernus*) and shredders (*Gammarus lacustris*) were also present. In the upper region of Khustay Gol some krenal and rhithral species (Turbellaria, Simuliidae, *Baetis vernus*, *Ephemerella ignita*, *Brachycentrus americanus* and *Rhyacophila* sp.) were found; Plecoptera were missing. At the mouth of Nariyn Gol lake littoral species (*Paracorixa armata*, *P. concinna*, *Gammarus lacustris*) were found.

The results of the few quantitative zoobenthos samplings are shown in Fig. 25. The total colonization density was highest in the mountain river Borshoo Gol; it was about one order of magnitude higher than in Turgen Gol, where the colonization was much poorer due to lower primary productivity and temperature, and an instable sediment with lower habitat diversity.

The structure of benthic colonization of the rivers clearly reflected their hydrological-morphological type: many taxonomic groups show strong preferences for the physical river type as can be seen in Fig. 26 where the mean relative abundances of taxonomic groups for the four river types are shown.

Alpine spring streams with always very cold water and a low runoff dynamic are characterized by growth of cold-stenothermic organisms like Diamesinae, Turbellaria and small Plecoptera of the family Capniidae. In alpine rivers almost no big Plecoptera with a larval development time of more than one year are found, as they are obviously incapable of migrating deep enough into the interstitial to avoid freezing. The same is true for fishes, which have due to the mostly dry downstream reaches no possibility of migrating into Uvs Nuur, and thus would need deep pools in the riverbed for wintering, which do not exist in alpine rivers. As the phytobenthos (as well as slowly moving or sessile animals like Mollusca and Blepharoceridae larvae) is dependant on a stable substratum, in the alpine rivers with strong sediment movement no trichal algae, mosses or spermatophytes were found; only diatoms grew in thin layers on the stones. That limits the primary production to a great extent and thereby also the food sources for invertebrates. Filter feeders (Simuliidae), rheophilic grazers (especially Heptageniidae) and big predatory Perlodidae are found here in quite high abundances. Small springs and water-filled depressions in the gravel bed are refugia for trichal algae, some groups of Diptera and Ephemeroptera.

The streams of the lower mountains with their moderate current and runoff dynamics, high diversity of substrate grain sizes and moderately cold water offer good living conditions for a greater variety of organisms. Mosses and algae grow on the stones and *Stuckenia pectinata* in fine gravelly sediment, offering rich structured habitats and food for abundant invertebrates. Filter feeders (Simuliidae, *Arctopsyche* sp., *Hydropsyche* sp.), grazers, detritus feeders (Baetidae, Ephemerellidae, Heptageniidae, Siphlonuridae; Chironominae, Limoniidae, Psychodidae, Tipulidae) and predators (Perlodidae, Perlidae, *Rhyacophila* sp.) are found here. The flow characteristics are changing in a small-scaled mosaic, thus rheophilic organisms like Heptageniidae, Deuterophlebiidae and Blepharoceridae can be found as well as still-water forms like water beetles. Mollusca are despite the sufficiently high calcium concentrations astonishingly rare, only a few Lymnaeidae have been found in the upper reaches of Tesiyn Gol.

Mollusca as well as Amphipoda (*Gammarus lacustris*) are typical for the lowland rivers with direct connection to the lakes of the inner basin. In these slowly running, meandering, sandy watercourses often rich growth of filamentous algae and macrophytes (*Potamogeton*), densely populated with invertebrates (Limnephilidae, Brachycentridae, Baetidae, leeches), is found. At places with stronger current, for instance Tesiyn Gol in its lower reaches (Tesiyn Gol-5), the sediment is instable and drifting. No vegetation and only very few invertebrates were found there. Other lowland rivers as well as the lower reaches of mountain rivers after entering the inner basin dry out periodically (for instance the lower reaches of Turgen Gol, Sagil Gol, Borshoo Gol, Baruunturuun and Gurmosyn Gol) and are therefore only sparsely colonized. The importance of the hyporheic interstitial as refuge for the zoobenthos in river sections with intermittent surface runoff has been shown by COOLING & BOULTON (1993) and CLINTON et al. (1996). As no interstitial samples have been taken, no statement concerning the population dynamics in temporary dry reaches can be made for the Uvs Nuur Basin.

The altitude distribution of taxonomic groups as outlined above was found in a very similar manner for Rocky Mountain streams by WARD (1986), FINN & POFF (2005), by BRODSKY (1980) for Rivers of the Tien Shan Mountains and for European alpine streams by MILNER et al. (2001). Especially the low species number and dominance of Diamesinae in glacier fed streams as well as the virtual absence of Mollusca, Hirudinea, Amphipoda, Coleoptera and Odonata in alpine streams were stated by most authors.

3.1.5.3 Fishes

The data on fish populations in the rivers are most likely incomplete as no systematic catches were tried. Nevertheless, the fish fauna of the Uvs Nuur Basin must be characterized as poor: only three species were found. *Triplophysa gundriseri* (Nemacheilidae) lives in lowland streams around Uvs Nuur (brook of Butsaldag Bulag, Khoyd Gol, Turgen Gol-4.2 and Ukhug Gol) and Tesiyn Gol. *Thymallus brevirostris* (Thymallidae) was found only in Borshoo Gol, where 8 specimens of up to 30 cm length were angled within one hour. Small specimens of *Oreoleuciscus humilis* (Cyprinidae) were found in Khoyd Gol, Nariyn Gol and Tesiyn Gol. No fishes were seen or caught in alpine and all other mountain rivers. The paucity of the fish fauna can be explained by three factors: first of all, migration of fish into the endorheic basin is impossible. Then, populations in smaller rivers are at risk of extinction by drought and third, they have to avoid freezing which is only possible in pools deeper than one meter or the hyporheic interstitial of very coarse sediment. Bearing in mind the low water depth of all smaller streams discharging into Uvs Nuur it seems justified to assume that the fish populations migrate into the lake for overwintering.

Little more data are published on fishes for the rivers of the Uvs Nuur Basin: DULMAA (1973) mentions *Oreoleuciscus humilis* and *Neomacheilus strauchii* (qualified as misidentified *Triplophysa gundriseri* by KOTTELAT, 2006) for the Kharkhiraa Gol which might have been confused with Tesiyn Gol which is mentioned in the same sentence. In OCOCK et al. (2006) the following occurrences are stated: *Triplophysa gundriseri* in Tesiyn Gol, *Oreoleuciscus potanini* in Tesiyn Gol, *Oreoleuciscus humilis* in Tesiyn and Nariyn Gol. For a discussion of taxonomic problems see chapter 3.2.9.4!

3.2 Lakes

Lakes are a prominent feature of the Uvs Nuur Basin, making up 5.3% of the basin's area. There are 16 stagnant water bodies with an area larger than 1 km², including the single artificial reservoir at Baruun-turuun Gol (area 2.2 km²). Their total area sums up to 3 841 km², Uvs Nuur alone making 95% of it. The number of lakes with an area between 0.01 and 1 km² can be estimated to at least 110, most of them situated near the SW shore of Uvs Nuur, near Nariyn Gol-5, in the floodplain of upper Tesiyn Gol and in its downstream area (here as true oxbow lakes), but also in the Turgen-Kharkhiraa, Tannu-Ola and Bulnayn Nuruu mountains. Twelve of these lakes were investigated with different intensity, additionally Khyargas and Üüreg Nuur outside the Uvs Nuur Basin.

3.2.1 Formation and morphometry

Many of the known processes of lake formation were and are acting in the Uvs Nuur Basin. Most important are tectonic processes, including earthquakes that can evoke landslides. These processes formed most of the larger lakes. Wind and wave action, permafrost processes and riverbed movement are the forming forces of the smaller lakes outside the mountains. High alpine lakes are formed by glacial processes. The morphometric parameters of the lakes given in Table 17 reflect these processes.

As the lakes' surface areas vary by five orders of magnitude one can expect them to be quite different with respect to most of the other morphological parameters, too. The tectonic lakes are most often large, quite deep, have a low relative depth and small volume quotient; deflation lakes and backwater lagoons are small to medium-sized, shallow and tend to have a high volume quotient. The numerous small lakes in the gravelly wetland area west of Uvs Nuur probably formed by thermokarst , as well as the oxbow lakes along Tesiyn Gol most probably have a high relative depth. Cirque lakes are small and deep with a very high relative depth and often have a low volume quotient.

The relative depth of the lakes depends on the geomorphology, i.e. it is highest in alpine lakes and lowest in lakes of the inner basin, with the one exception of Seepage Lake. The high relative depth of this lake is an indication that the hypothesis of its formation by melting dead ice is true. Mean and maximum lake depths do not show a general altitude dependence or dependence from the lake's area. The shoreline development of many of the lakes is relatively low; islands are virtually nonexistent. The channel-like Khukhu Nuur and Döröö Nuur with its long, curved shape have the highest values of shoreline development. The volume development of the lakes Bayan and Nogoon is near one – their lake basin resembles a cone. In contrary, the lakes Baga, Southern Baga, Üüreg and Uvs with values around 2 are formed more like truncated cones. The Index of Basin Permanence of the large lakes Khyargas, Uvs and Üüreg is above ≈100 (for comparison: Lake Erie has an IBP of 450) while all small lakes (i.e. those with a volume under 10 Mio. m³) have an IBP lower than 1.

Table 17 Morphometric data for 14 investigated lakes in the Uvs Nuur Basin and neighboring basins (Khyargas, Üüreg). All data from own measurements, calculations or estimations unless otherwise stated. Maximum depth as to our punctual measurements unless otherwise stated; no area-wide surveys were made by us. * estimated; [1] WALTHER (1999); [2] calculated from isobath map in WALTHER (1999); [3] NAUMANN & WALTHER (2000); [4] calculated from isobath map in 3; [5] SEVASTYANOV et al. (1994); [6] lake level in February 2000 (SRTM radar satellite measurements); [7] I. HEYMANN, pers. comm.; [8] main lake basin; [9] W basin; [10] E basin, SVIRIDENKO et al. (2007)

Lake	Uvs	Baga	Seepage	Southern Baga	Togoo	Bayan	Shavart
formation	tectonic depression	backwater lagoon	thermokarst lake [7]	backwater lagoon	eolian deflation	tectonic fault	eolian deflation
has outflow?	no	yes	yes	underground?	underground?	yes	underground?
altitude [m ASL]	761 [6]	762	761	763	782	932	982
area [km^2]	3600	1.21	0.038	2.79	0.03	32.0	0.97
volume [Mio. m^3]	48400 [2]	0.73 *	0.057	5.6 *	0.009 *	327 [4]	1.0 *
maximum depth [m]	22.1 [1]	1.0	3	3 *	0.5 *	29.2 [3]	3
mean depth [m]	13.4	0.6 *	1.5 *	1.5 *	0.3 *	10.2	1 *
relative depth [%]	0.03	0.08	1.4	0.16	0.26	0.46	0.27
catchment area [km^2]	70220	211 *	5 *	80 *	30 *	730 *	42.5
area quotient	19	174	132	29	1000	23	44
volume quotient	1.4	291	88	14	3300	2.2	44
max. length [km]	85.5	1.60	0.25	2.70	0.75	12.3	1.50
mean width [km]	42.7	0.76	0.15	1.03	0.04	2.60	0.65
shore length [km]	415	6.8	0.76	9.5	1.7	30.7	3.9
shore development	1.9	1.7	1.1	1.6	2.8	1.5	1.1
volume development	1.8	1.8	1.5	2.0	1.8	1.0	1.0
IBP	119	0.1	0.1	0.6	0.01	10.7	0.2

Lake	Khyargas	Döröö	Üüreg	oxbow Tesiyn-3.5a	Khukhu	Nogoon	alpine lake near Turgen
formation	tectonic depression	eolian	tectonic depression	oxbow	dammed by landslide	glacial cirque lake	glacial cirque lake
has outflow?	no	underground	no	underground	underground	yes	yes
altitude [m ASL]	1029 [6]	1148	1425	1565	1925	2695	2730
area [km^2]	1407 [5]	72.4	245	0.0015	2.9	0.092	0.005
volume [Mio. m^3]	66030 [5]	500 *	6500 [5]	0.0009 *	58 *	1.38 *	0.020 *
maximum depth [m]	92 [5]	10 [9]; 38.8 [10]	42 [5]	1	80 *	35	5 *
mean depth [m]	47 [5]	5 * [9]; 20-30 [10]	26.5	0.6 *	20 *	15 *	4 *
relative depth [%]	0.22	0.40	0.24	2.3	3.1	10.2	6.3
catchment area [km^2]	185000 [5]	900 *	3430		124	4.5	3.5
area quotient	131	12	14		43	49	700
volume quotient	2.8	1.8	0.53		2.1	3.3	175
max. length [km]	75.3 [5]		19.8	0.14	4.20	0.56	0.18
mean width [km]	18.7 [5]		12.4	0.01	0.5 [8]	0.16	0.03
shore length [km]	253 [5]	63.3	66.9	0.29	15.7	1.5	0.44
shore development	1.9	2.1	1.2	2.1	2.6	1.4	1.8
volume development	1.5		1.9	1.8	1.0	1.3	2.4
IBP	266		97	0.003	3.7	0.9	0.05

Explanatory notes on the morphometric measures:

- maximum depth z_{max}: highest measured depth value, ideally at the deepest point of the lake
- mean depth = volume/area
- relative depth (HUTCHINSON, 1957; WETZEL & LIKENS, 1991): maximum depth as percentage of the lake's mean diameter z_r [%] = $0.0005 \cdot z_{max} \cdot (\pi/area)^{1/2}$;
- area quotient = catchment area/lake area;
- volume quotient (also known as Schindler's Ratio)= catchment area [km^2]/ lake volume [Mio. m^3];
- mean width (WETZEL & LIKENS, 1991) = lake area/max. length;
- shore development (HUTCHINSON, 1957): degree of deviation of lake surface from a circle; D_L= shore_length/$(2 \cdot (area \cdot \pi)^{1/2})$;
- volume development (HUTCHINSON, 1957): degree of deviation of the lake basin from cone shape; cone: D_V=1; hemisphere or truncated cone with bottom area=0.38·surface area: D_V=2; cylinder: D_V=3; D_V = 3·volume/(area·max_depth);
- Index of Basin Permanence (KEREKES, 1977): measure of importance of littoral areas for the whole lake's volume; can be taken as rough measure of ageing of the lake and the lake's "life expectancy";
  IBP = volume [Mio. m^3]/shore length [km].

The following morphometric data differing from the table above were given in the literature:

- Uvs Nuur: DULMAA (1979): depth (max. or mean?) 6 m; WILLIAMS (1991): mean depth 6 m, volume 20.1 km³; EGOROV (1993): water level 763.3 m for year 1988; SEVASTYANOV et al. (1994): water level 759 m, area 3 350 km², shore length 425 km, volume 39.6 km³, max. depth 20 m, percentage of lake bottom with 0 to 6 m depth 44.7%, percentage of lake bottom with 6 to 12 m depth 32.5%; DAVAA (1996a): water level 759.9 m (without year), lake area 3518 km², volume 35.7 km³, mean depth 10.1 m, area quotient 20.2; BATNASAN (1999): max. depth 21.5 m, isobath map and hypsographic curves with much smaller area of depth >20 m than in WALTHER (1999); BATNASAN & BATIMA (2000): water level 759 m for year 1986, 760.5 m for year 1997.
- Bayan Nuur : SHIL'KROT et al. (1993): area 30 km², max. depth 15 m
- Khyargas Nuur: DULMAA (1979): max. depth 80 m; DAVAA (1996a): water level altitude 1 035.3 m, lake area 1481 km², volume 75.2 km³, mean depth 50.7 m, area quotient 114.8
- Döröö Nuur : SHIL'KROT et al. (1993): area 100 km², volume 0.75 km³, mean depth 10 m
- Üüreg Nuur: DULMAA (1979): mean depth 15 m

The hypsographic functions given for Uvs and Bayan Nuur in Fig. 27 and the cross-sections in Fig. 28 reflect the form of the lake basins and their different formation.

Uvs Nuur is pan-shaped with a flat central bottom at 20 – 22 m depth and gradually rising slopes (see Fig. 28 and Fig. 32). The isobaths in WALTHER (1999) are based on echo sounding measurements only in the NW and E bays and some part of the S shore; the rest was extrapolated from the terrestrial geomorphology, taking into account the depositions of rivers. An independent measurement of the area of the 8 m isobath resulted in some 2 500 km² – a value that matches well to WALTHER's isobaths. The measurement was made by the author using the visual channels of the satellite image of May 2002 (Fig. 83) when the turbidity in most parts of the lake was very low. In this image a mostly well defined boundary between the visible littoral bottom and uniformly dark blue water exists which was found to be at about 8 m depth from comparisons with the measured profile section in the NW bay (Fig. 29).

Thus, as it seems to be the best available estimation, WALTHER's isobaths were used for morphometric calculations. About 1/3 of the lake's area has a water depth of 20 to 22 m, and some 40% a depth of less than 10 m. In general, the slopes down to 20 m water depth are similar to those in the surrounding landscape. The deep bottom part comes very close to the NW and S shore, where no tributaries unload their sediment cones into the lake. The western shore of the north bay has a steep slope as well (unlike suggested by the isobaths), as the shoreline shift between 1949 and 1998 is minimal (Fig. 32) and in the May 2002 satellite image dark blue water deeper than some 8 m was visible. The largest shallow areas are in the SW and NE where the shoreline is richly structured by reed stands that form tiny islands. The flat lake bottom, where over 30 to 50 km there is nearly no slope, resembles a salt pan. This seems plausible, since the lake is supposed to have been dry in the Pleistocene for several thousand years (WALTHER, 1999). During this time, as known from recent salt pans, phases of very low water level must have taken change with completely drought, rearranging the sediment to form a flat pan. The low relative depth has also been discussed by BATNASAN (1999) who emphasizes the very long period of Uvs Nuur being the accumulative basis of an endorheic basin and the lack of upstream lakes that could act as sediment traps (BATNASAN & BATIMA, 2000).

One special feature of Uvs Nuur are the two eastern bays (Fig. 30). The larger, shallower one, where Nariyn Gol unloads its sediments, can be seen as continuation of the river's valley formed during the dry late Pleistocene when the lake supposedly was dry (WALTHER, 1999). This is supported by a subhydric channel of about 15 m depth reaching some 15 km from the opening of the bay out into the lake. The smaller, east-west stretched 5 x 3 km large bay with a maximum depth of 22 m is isolated from the main lake by a narrow, shallow channel. East of it follows another, smaller, dry hollow with a bottom altitude of 745 m, which is actually the lowest point of the Uvs Nuur Basin rather than the lake's water surface. The surrounding, completely plain steppe east of this bay is at an altitude of 780 m and shows no sign of a river valley. The slope from the surrounding plain to the center of each depression is with 4% higher than normally found in the landscape of the inner basin. Thus, I believe that the origin of these two small, comparably deep depressions is not related to the formation of Uvs Nuur itself nor have they be formed by ice or wind forces. A possible explanation would be meteorite impact craters. The meteorite would have broken up into two pieces and impacted in an oblique angle, flying in east-west (or opposite) direction, leaving elliptic craters. The morphology of the smaller hollow with a central elevation some ten meters above the bottom of the hollow supports this hypothesis that certainly could only be validated by field explorations.

Another important morphological feature of Uvs Nuur are the (partly submerged) series of gravel and sand bars surrounding the lotic shore sectors, and the spits at the NW and W shore of Uvs as well as Khyargas and Üüreg Nuur. They were formed during phases of constant lake level and can be used for reconstruction of the climatic history when dating is possible (see SEVASTYANOV et al., 1994, WALTHER, 1999, NAUMANN & WALTHER, 2000, GRUNERT et al., 2000, WALTHER et al., 2003). The most noticeable is the currently submerged gravel bar along the southern coast (Fig. 31, Fig. 32) that is present at the same altitude on the NW and SW shores (Fig. 29). On the Landsat satellite image from 1992 it is still above the water level and isolated a 28 km long and 0.2 to 1 km wide shoreline lagoon from the main lake. This lagoon's water was protected from waves and had noticeably less mineral turbidity, but slightly higher chlorophyll content than the main lake's pelagic zone, and at some places large reed stands were developed. In 2002 with higher lake level the gravel bar is submerged and, additionally, eroded by wave action. It provides no protection for the shallow former lagoon zone that is now turbid due to eroded fine sediments; the reed stands have disappeared. Other shallow water areas where larger parts of the lake bottom are visible in Landsat images (water depth there is likely less than 5 m) extend along the SW shore and at the mouth of Tesiyn Gol. Especially at the SW shore many subhydric depressions of some 100 m extend are visible, continuing the on-shore geomorphology of thermokarst depressions.

The narrow, deep **Bayan Nuur** fills a graben depression in the fault that runs SW-NE through the inner basin. In the west it is protected by a mountain ridge 400 m higher than the lake from being filled by sand blown along the Böörög Deliyn Els dunes. The lake has an outflow and hence the water level is stable. At the western bank after a very shallow shore platform a steep slope follows right down to the lake bottom. The eastern shore has a wider shore platform and features several small and one larger (Khustay Gol) sandy tributaries that unload their sediment into the lake, some of them forming small deltas.

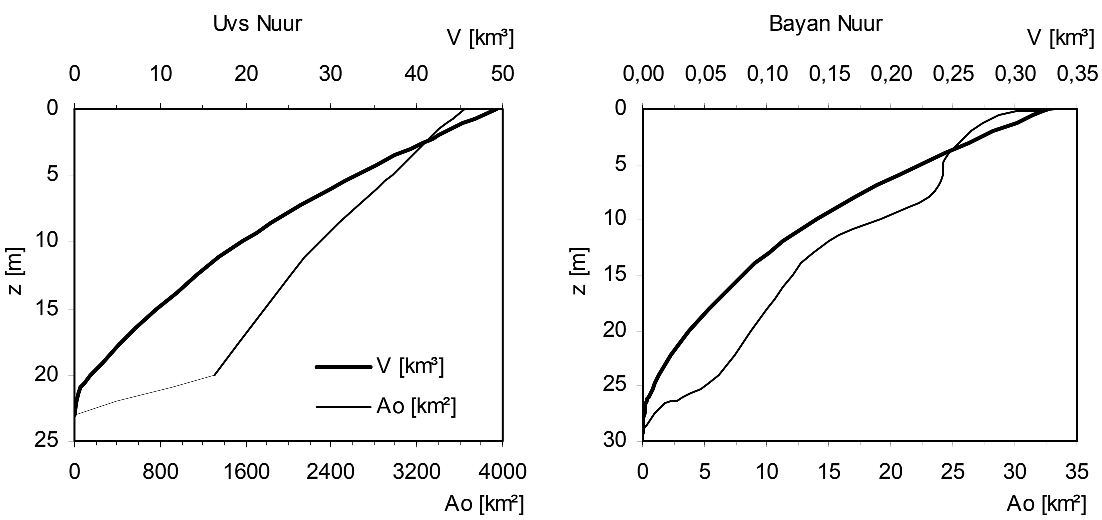


Fig. 27 Hypsographic curves for Uvs and Bayan Nuur, calculated using isobath maps in WALTER (1999) and NAUMANN & WALTHER (2000).

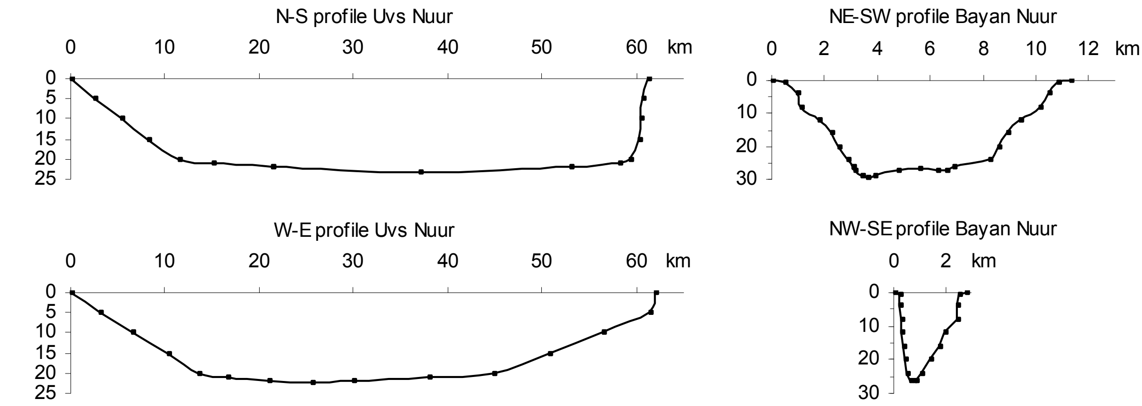


Fig. 28 Cross sections through the center points of Uvs Nuur and Bayan Nuur, based on isobath maps in WALTHER (1999) and NAUMANN & WALTHER (2000). Depth in meters. Note the different horizontal scales for Uvs and Bayan Nuur.

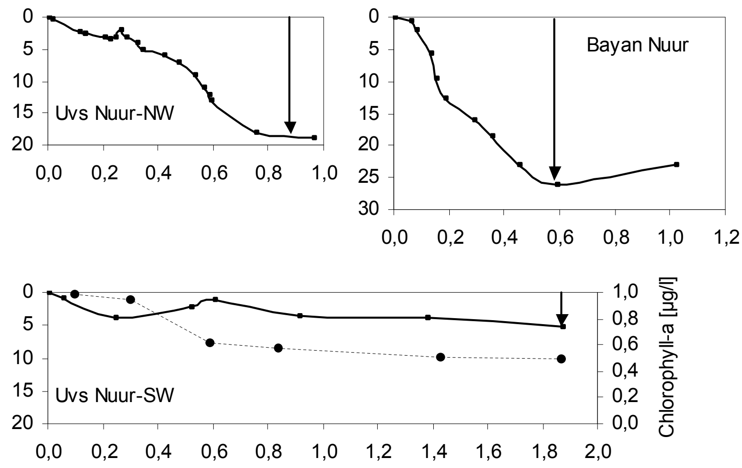


Fig. 29 Profile sections of lake bottom depth measured by plummet at the sampling stations Uvs Nuur-NW, -SW and Bayan Nuur. Horizontal axes in kilometers, vertical axes in meters. Arrows mark the points where the depth probe measurements, water and plankton samplings were taken. Chlorophyll concentrations at Uvs Nuur-SW (dotted line) were measured near the water surface. Note the submerged gravel bars in a water depth of 1.5 to 2 m at Uvs Nuur-NW and Uvs Nuur-SW!

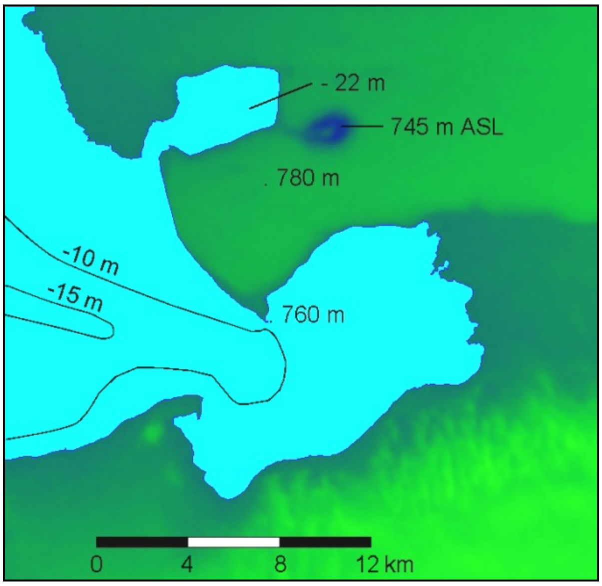


Fig. 30 Relief map of the eastern bays of Uvs Nuur. Lighter colors are higher areas. Isobaths and water depth from WALTHER (1999). South of the greater bay the beginning of the Böörög Deliyn Els dune field is visible. The isobaths show the subhydric continuation of the Nariyn Gol valley.

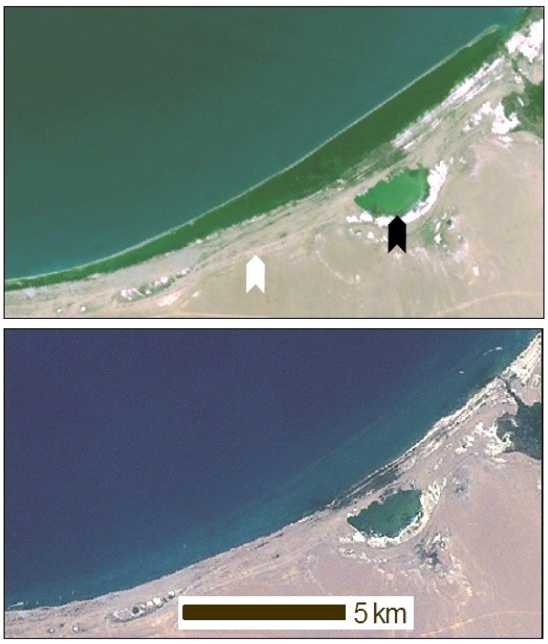


Fig. 31 Landsat images (visible channels 1, 2, 3) of a part of the lagoon at the shore of Uvs Nuur near Southern Baga Nuur (black arrow). Upper image: June 1992, lower image: August 2002.
Note the gravel bar that formed the lagoon in 1992 and is submerged in 2002, and the series of higher gravel bars south of the shore (white arrow).

Baga Nuur and **Southern Baga Nuur** (Fig. 31) both are lagoons formed when the water level of Uvs Nuur was 3 meters higher than presently. With decreasing water level they were isolated from Uvs Nuur. WALTHER (1999) suggests from sediment core data that Baga Nuur was first isolated from Uvs Nuur 3 000 to 5 000 years B.P. It is very shallow with a gravelly bottom covered by a thick autochthonous layer of mud. Southern Baga Nuur also has a muddy bottom, but its southern shore bears a salt crust.

Khyargas Nuur and **Üüreg Nuur** belong to the large, deep salt lakes in the sense of MELACK (1983), being not very common among salt lakes on a global scale. The circular Üüreg Nuur is surrounded by lotic, gravelly, vegetation-less shores, partially with bars forming long coastal lagoons. Only the western shore where the main tributary Kharig Gol enters the lake, is shallow and vegetation covered. The only rocky shore sector is around the sampling place Üüreg Nuur-S.

Togoo and Shavart Nuur are shallow, sandy, groundwater fed deflation lakes of different size. There are several other very small deflation lakes around the lower reaches of Nariyn Gol. Generally they can be found in areas with weakly overgrown fine soil and high groundwater level.

Döröö Nuur has an wound channel-like shape with its western, Mongolian basin being smaller and shallower than the eastern, Russian basin. The lake is surrounded by sand dunes on its southern shore. One kilometer from the western end, two smaller lakes amidst the dunes are following, connected by a brook. On satellite images there is a deep subhydric trench with a width of only 70 m visible in the narrow junction between the two basins, that continues into the western basin. It seems to be the flow path of water running from one lake basin into the other at times of a lower water level rather than the remainder of the ancient Pleistocene valley of Tesiyn Gol, which is the hypothesis of LEBEDEV et al. (1997). Probably the lake was formed when sand dunes were piled up in the south-sloping terrain south of the present Döröö Nuur, resulting in a hollow that filled with groundwater.

Khukhu Nuur is a channel shaped lake consisting of two connected narrow valleys in the Turgen-Kharkhiraa Mountains dammed by a landslide. From the valley morphology can be concluded that the maximum depth must be considerable and the deepest point be near the “dam”.

3.2.2 Water level changes and water balance

There are different time scales and magnitudes of lake water level changes. HOFMANN et al. (2008) point them out:

- Long term changes in a magnitude of several decimeters to many meters are caused by the annual weather cycle, climatic changes or anthropogenic influences on the catchment hydrology. They take months to many years, cause changes in the water chemistry, mixing dynamics, near-shore sediment characteristics and displace the littoral boundary, therewith changing the habitat availability for terrestrial, amphibian and most aquatic organisms. Their impact increases with decreasing shore slope.
- Short term changes with a magnitude of some centimeters to decimeters and periods of some seconds up to hours are caused by wind waves and basin-wide oscillations (surface seiches). They mainly affect the littoral where they cause near-sediment current velocities of some centimeters to decimeters per second that impose mechanical stress to organisms, determine the sediment characteristics (grain size, stratification, decomposition of organic material) and water turbidity (hence primary productivity), depending on the shoreline exposure.

For terminal lakes the long term changes are more significant and can affect the existence of the ecosystem as a whole. The reason lies in the particularities of the water balance equation for a lake:

$$P + S + U - O - E = dV; \qquad O = 0 \text{ for terminal lakes} \qquad (13)$$

All terms are in mm; P = direct precipitation, S = surface inflow, U = underground inflow, O = outflow, E = direct evaporation, dV = lake volume change.

In the water balance of terminal lakes, the loss term consists only of evaporation. An imbalance between precipitation + inflows (that are affected by precipitation and evapotranspiration in the catchment) and evaporation from the lake leads to changes in the lake's storage volume, and hence water level and surface area, until the balance reconstitutes. This makes terminal lakes sensitive indicators of climatic changes in their catchment area, and markers of ancient lake levels valuable for reconstruction of the climate history, provided no human influences changed their water balance.

The lake level of **Uvs Nuur** was subject to great, climatically caused fluctuations. MURZAEV (1954) suggests that during the cold, more humid high Pleistocene a continuous lake of 92 000 km² at a level of 1 500 m ASL covered the present "Valley of Great Lakes" and the Uvs Nuur Basin. WALTHER (1999) and NAUMANN & WALTHER (2000) see indications of a high Pleistocene lake level at 1 000 m ASL and a late Glacial (14 000 to 10 000 years BP) level at 800 m. During the dry and cold last glacial maximum at about 24 000 to 13 000 years BP the lake had a very low level or was even dry, being a rich source of fine sediments to form the Böörög Deliyn Els dunes (GRUNERT et al., 2000). According to GRUNERT & DASCH (2000) the beginning of dune formation from sand blown out of the (partially?) dry Uvs Nuur lake basin should even date back to 300 000 years BP. For the Holocene several phases of higher and lower lake levels between –7 and +10 m were detected (WALTHER, 1999; GRUNERT et al., 2000; WALTHER et al., 2003).

During the last century the lake level had a rising trend which led to a significant increase of its water area, as can be seen on historical maps and satellite images (Table 18, Fig. 32). Between the end of the 1940s and 1998 the lake increased its area by 11.1% or 364 km² (for comparison: 2/3 of the area of Lake Constance). The fast rising that begun 1985 stopped at the end of the 1990s and (as evidence from satellite images shows) at present the lake level is decreasing very slowly. The question of the absolute altitude ASL of the lake is not easily answered as the water level data collected by the Mongolian Hydrometeorological Institute are relative ones. Altitude measurements on the Russian maps are not exact to the meter, as on the 1950 maps a lake altitude of 759 m ASL is given, while on most 1970 maps (when the lake was 142 km² larger) 758.9 m ASL are indicated. In EGOROV (1993) a time series of absolute water level data for Uvs Nuur is given. It started with 761.9 m ASL in 1964 and ended with 763.3 m in 1988. When extrapolated to the end of 1999 using the relative lake level data, Uvs Nuur would have reached then an absolute altitude of 464.0 m ASL, which seems about 3 m too high, compared with SRTM radar satellite altitude values measured in February 2000.

Given the possibly higher accuracy of more recent altitude measurements, the altitude data of the 1970 maps and the radar altitude measurements of the SRTM satellite mission can be taken as a reference. From the calculation of average values of a large array of SRTM altitude data in the middle of the lake, one gets 761.2 ± 1.0 m ASL. This value together with the 1970 map value of 758.9 m fits quite well into the time series of relative water levels of Uvs Nuur. Extrapolating, in 1949 the lake level must have been at some 758 m ASL.

Measurements of relative lake level (transformed into absolute altitude ASL: Fig. 33) and other quantitative hydrological data are available for Uvs Nuur since 1964. DAVAA (1996) has modeled its water balance for the years 1964 through 1989 (Fig. 34a) based on measurements of precipitation, runoff of the most important tributaries, lake level, and modeled evaporation values. The underground inflow has been calculated as missing term from the water balance equation. BATNASAN & BATIMA (2000) give the following figures for the water balance of Uvs Nuur that widely coincide with DAVAA's data:

P = 97–140 mm, S = 395–490 mm, U = 197–270 mm, E = 689–913 mm.

Table 18 Lake areas of Uvs Nuur measured on historical maps and satellite images and corresponding water level altitudes.

date	lake area [km²]	water level [m ASL]	source
1949	3263	758 (extrapolated)	Russian maps 1:100,000 issued 1950
between 1965 and 1970	3405	758.9 (reference)	Russian maps 1:100,000 issued 1970
1977 Jul	3454	760.0	Landsat 2 (MSS) image 1977 Jul
1992 Jul	3480	760.3	Landsat 4 (TM) image 1992 Jun
1998 Jun	3627	761.0	Landsat 5 (TM) image 1998 Jun
2002 Aug	3607	760.9 (extrapolated)	Landsat 7 (ETM+) image 2002 Aug
2008 Aug	3600	760.9 (extrapolated)	Landsat 7 (ETM+) image 2008 Aug

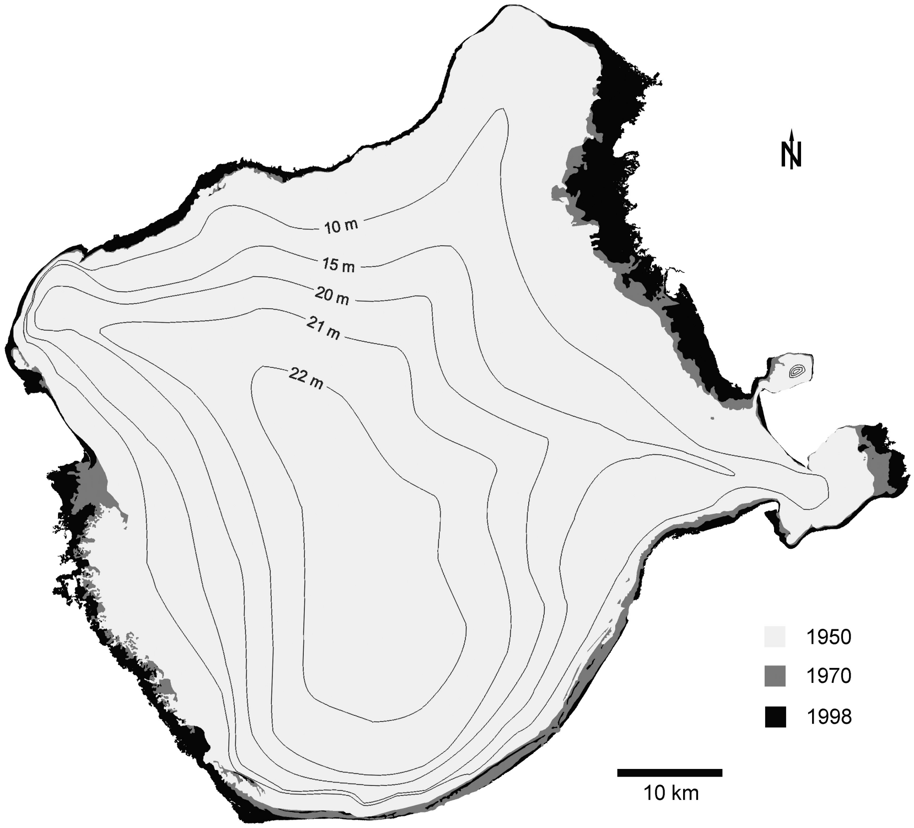


Fig. 32 Water area increase of Uvs Nuur in the second half of the 20th century. Isobaths from WALTHER (1999). The 5 m isobath was omitted because of interference with the coast-line.
Light gray: from maps issued 1950, medium gray: from maps issued 1970, black: from Landsat image of June 1998.
The color of islands indicates when they were inundated. Note the gravel bars that marked the southern shore in 1950, formed offshore spits in 1970 and are now submerged.

Table 19 Tritium content of rain and lake waters and estimated water residence time of lakes Uvs, Üüreg, Döröö and Nogoon. From HEBERT (2004).

water sample	sampling date	Tritium units	estimated maximum residence time
Rain, Tariat (100.1°E 48.1°N)	08/02/1999	37 ± 3	
Rain, Tes somon (98.3°E 49.3°N)	08/04/1999	40 ± 4	
Rain, Uvs Nuur-E (93.4°E 50.3°N)	08/22/1998	42 ± 4	
Rain, Ulaangom (92.1°E 50.0°N)	08/17/1998	42 ± 4	
Rain, Turgen mountains (91.4°E 49.9°N)	08/14/1998	46 ± 4	
Uvs Nuur	08/30/1996	70 ± 6	40 years
”	08/13/1997	68 ± 5	
”	08/10/1999	59 ± 5	
Üüreg Nuur	08/15/1999	48 ± 4	30 years (uncertain)
Döröö Nuur	08/25/1998	48 ± 4	fed by groundwater with an age of 20 to 40 years
Nogoon Nuur	08/13/1999	40 ± 3	short (< 10 years)

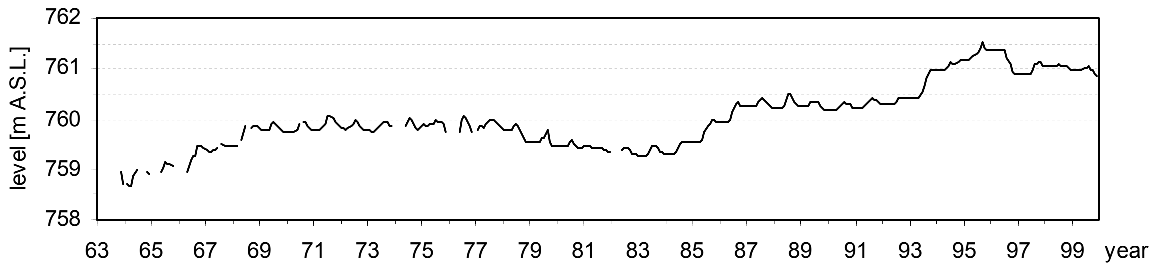


Fig. 33 Water level of Uvs Nuur, gauging station Davst, monthly means from 1963 to 1999, transformed into absolute altitude.

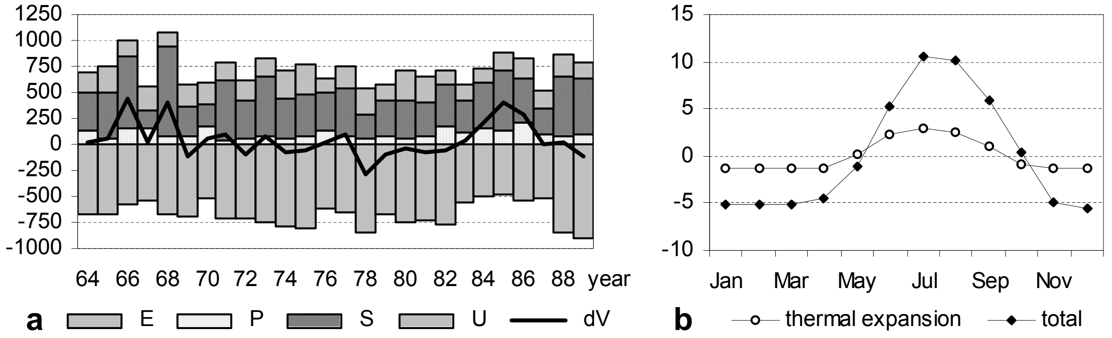


Fig. 34 **a** Water balance [mm] of Uvs Nuur for the years 1964 to 1989 from DAVAA (1996). Symbols according to equation (13). **b** Water level fluctuation [cm] of Uvs Nuur around the annual mean: total and portion due to thermal expansion, trend corrected average of 16 years.

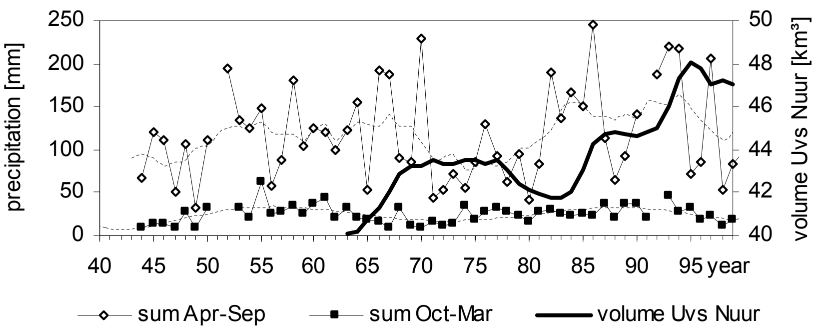


Fig. 35 Time series of precipitation sums for the summer (April till September) and winter (October till March) months, station Ulaangom with trend lines (stippled) and water volume of Uvs Nuur.

Using DAVAA's data and the newer morphometric function based on data from WALTHER (1999) one gets a mean annual water budget (sum of evaporation and volume change) of 2.56 km^3. The portion of underground inflow was 27%, direct precipitation only 14% of the total inflow. Surface inflow of rivers had a proportion of 59% in the total budget, Tesiyn Gol alone delivering one third of it. With that annual budget and a lake volume of 48.4 km^3, a mean residence time of 18.9 years can be calculated, which has no practical meaning for a terminal lake since only the water molecules, not the dissolved substances are exchanged. Another possibility to determine residence time are isotopic measurements. HEBERT (2004) estimated mean water renewal times based on Tritium measurements (Table 19).

The discrepancy between the water residence times of Uvs Nuur calculated from the water balance and from Tritium content can be explained with a high percentage of evaporated lake water in the precipitation due to strong basin-internal air circulation (KHASLAVSKAYA, 1994) that keeps the Tritium content higher than expected. Evidence of this is the tritium content of the rain water sample from the Turgen mountains that is considerably higher than in a rain sample from Tariat (southeast of the Uvs Nuur Basin).

The annual fluctuations of the lake level (Fig. 34b) show a mean amplitude of about 16 cm with the maximum in July, caused by the periodicity of precipitation and evaporation (to 73%) and thermal expansion of the water body (to 27%). The total water level rise of about two meters from 1965 till 1999 shows a tendency to wetter climatic conditions, against the trend in many other large saline lakes (WILLIAMS, 1993). Salinity measurements from the first half of the 20th century with significantly higher values than now (up to 19.7 g/l in 1941 – DAVAA, 1996), which implicate lower lake levels, suggest that this rise seems to have a long-term trend. WALTHER et al. (2003) discuss as a possible reason an increase in snowfall and earlier begin of snowmelt, leading to an increasing snowmelt runoff; PHAM et al. (2009) found for Canadian endorheic prairie lakes that changes in winter precipitation (that only contributes 30% of the annual sum) and groundwater inflow had much higher influence on the lakes' water balance than evaporation. Though, runoff data till 1990 of Tesiyn Gol, the most important tributary, do not support the winter precipitation thesis. Instead, it and some other rivers had high summer runoff in the mid 1980s and mid 1990s when Uvs Nuur rose by one meter each time. Only the glacially fed Kharkhiraa Gol showed significantly increasing runoff for the winter months October till March from 1970 on. While the importance of increased snowmelt water and heavy summer rain for groundwater discharge into Uvs Nuur is unknown, it seems from the lag of several years between high or low precipitation and lake volume change (see Fig. 35) that groundwater plays a more important role for the water balance of Uvs Nuur than calculated by DAVAA (1996).

The water level rise is not continuous but seems to follow a sinoid function with a period of roughly 20 years. The periodicity still can only be assumed as the water level time series is too short for statistically significant conclusions. However, a periodicity of climatic parameters, most of all precipitation, has been found in other regions too.

HELMS et al. (2005) found for the Caspian Sea that the annual runoff of its main tributary, the Volga River, shows a long term fluctuation pattern that is the result of the superposition of the runoff oscillations of three partial catchments, with periods of 14 to 30 years. ZARETSKAYA et al. (1992) demonstrated that the runoff of northwest Russian rivers has a periodicity in the range of 10 to 12 and 30 to 31 years which corresponds to the periodicity of solar activity, while TOMASINO & DALLA VALLE (2000) found periods of about 8 years for discharge maxima of the river Po. Similar influences could be assumed for the Uvs Nuur Basin: BATJARGAL et al. (1993) hypothesize about an influence of movement of the solar system's mass center, which has a nearly 11-year periodicity, on the annual precipitation sum and hence water level of Uvs Nuur. The time series of the annual precipitation sum for Ulaangom (Fig. 4) shows no strong correlation with the water level of Uvs Nuur. However, it has to be considered that the most important areas of runoff formation are the northern and northeastern mountain ranges that feed Tesiyn Gol, and that a time lag exists between changing precipitation sum and underground runoff into Uvs Nuur.

For **Bayan Nuur** some lake level data from the late Glacial and Holocene are given by NAUMANN & WALTHER (2000): the lake was part of the Uvs Nuur basin in the high Pleistocene. It was probably dry at the Last Glacial Maximum when dune sands were blown over the present day Khoyd Gol valley, creating a closed basin. The lake filled again 13 000 years BP to a maximum level of 980 m ASL which slowly dropped to the present 932 m due to incision of the outflow Khoyd Gol into the dune sands north of Bayan Nuur.

Our own runoff measurements in 1997 and 1998 gave the following values for the water balance of Bayan Nuur in the month of August: inflow 2–2.5 m^3/s, outflow 1–1.4 m^3/s, evaporation 1.2–1.5 m^3/s. Taking into account the annual change of runoff and evaporation a mean water residence time of 7 to 12 years can be estimated.

Baga Nuur, Southern Baga Nuur and other small lakes with a water level only one or two meters above that of Uvs Nuur most likely will become part of Uvs Nuur, with their chemical and biological structure completely altered, still in this century if the raising trend of its lake level continues.

Khukhu Nuur has no surface outflow, but some water leaks through the debris masses of the landslide. The inflow is not sufficient to let the water level rise to the altitude of the "dam" some 40 meters above the present lake level. Thus, the water level fluctuates for some meters, adjusting to interannual changes in the amount of precipitation, which is visible when comparing satellite images from 1992 (lower level), 1998 (higher level, mountain crest between the two lake basins was an island) and 2002 (lower level).

For **Khyargas Nuur** lake level data are given by BATNASAN & BATIMA (2000) indicating a two meter rise from the mid 1970s on, roughly parallel to Uvs Nuur. Evidence for higher lake levels give numerous old gravel bars around the lake, the one at 1 145 m ASL (due to satellite altitude measurements; 1 190 m due to DEVIATKIN & MURZAEV, 1989 in GRUNERT et al., 2000) being the highest with great continuity and at a constant altitude. As it is obviously not disturbed by tectonic uplift, it should be younger than middle Pleistocene when the Khan Khökhiyn Mountains were lifted up (GRUNERT et al., 2000).

3.2.3 Temperature and overturn dynamics of the water body

The surface temperatures measured during August in dependence of altitude are shown in Fig. 36. Shallow and wind protected lakes reach higher surface temperatures, while the deep Üüreg Nuur (at 1425 m ASL) has a relatively low temperature, probably due to cold winds from the mountains encircling it quite closely. At an altitude of about 3 000 m the surface temperatures reach only 5 to 6 degrees and no summer stratification is likely to exist even in wind protected alpine lakes.

Daily temperature amplitudes some centimeters under the water surface near the shore were depending on weather conditions and morphology: daily amplitudes of 7 to 8 degrees were measured on sunny, stormy days at surf shores of Uvs Nuur while the amplitude on a cloudy day reached only 4 degrees. On the very shallow beach of Bayan Nuur during calm, cloudless days amplitudes of up to 16 degrees (while the air temperature had an amplitude of 25 degrees) were measured. Measurements in a water depth of 0.5 m showed amplitudes of only 1 to 2 degrees.

Heat exchange of the lakes is determined by the extreme continental climatic conditions. Because of very cold winters and fast decreasing temperatures in autumn, the ice-covered period with minimal heat exchange is quite long for many lakes. Exact data are only available for Uvs Nuur (mean values of the years 1980 to 1997, see Fig. 21): the duration of a closed ice cover is 150 days, the overall period of icing phenomena is 190 days. The time between the first ice phenomena and the beginning of a closed ice cover is 22 days, the time between the beginning of ice break-up and the last ice phenomena is 32 days. The maximum ice thickness reaches 98 cm on average. Other lakes reach even higher ice thickness (Bayan 150 cm, Döröö 125 cm, Üüreg 110 cm; DULMAA, pers. comm.). Because of the rising trend of winter temperatures (see 1.4.2), the maximum ice thickness of Uvs Nuur decreased from about 120 cm in the first half of the 1980s to 97 cm in the 1990s.

The annual heat exchange cycle of Uvs Nuur in Fig. 38 shows the high energy uptake during spring circulation in May (energy uptake roughly 75% of the global radiation) which corresponds to the delayed warming shown in Fig. 37, compared with the air temperature of Ulaangom. After mid July when the water temperature begins to decrease, the thermal regime of the lake changes after four months from receiving to emitting heat (of course the transition is a gradual one, not sharp as shown in Fig. 38). Autumn full circulation in October and November is the time of highest heat release rate (yet much lower than the uptake rate in May) which is represented by a marked delay in temperature decrease, compared to air temperature. During growth of the ice cover there is still some heat emission, though only at half to one third of the autumn rate. The total annual heat budget of Uvs Nuur sums up to $1.3x10^9$ J/m², which is in the range of most temperate lakes ($1x10^9$ J/m², IMBODEN & WÜEST, 1995) and about 60% of lake Baikal ($1.4\text{-}2.6 \cdot 10^9$ J/m², KOZHOVA & IZMEST'EVA, 1998) which is due to the much lower summer mixing depth as compared with lake Baikal.

The question, how far the stabilizing effect of Uvs Nuur on the climate in its surroundings reaches, is not easily answered due to the lack of data. The cooling effect of Uvs Nuur is clearly visibly in the air temperatures of the first two measuring stations SW of Uvs Nuur in BARSCH (2003) – the first and second white circles from left in Fig. 36 – that are lower than expectable according to the climatic altitude gradient that amounts to 0.8 K/100 m. It must be assumed that the cooling effect reaches some kilometers further than 8.5 km, which is the distance of the second measuring station from Uvs Nuur. The climate of the town Ulaangom seems to be minimally influenced by Uvs Nuur as it is 27 km away from the shore and the wind

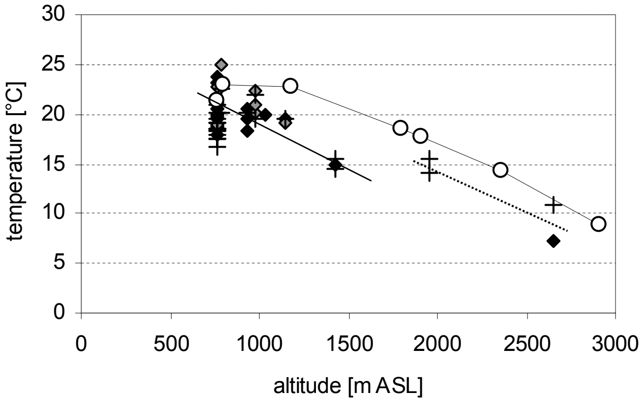


Fig. 36 Surface temperatures of investigated lakes and mean air temperatures.
White circles: mean air temperatures measured in a transect from the SW shore of Uvs Nuur into the Turgen Mountains, second decade of August 1998 (from BARSCH, 2003).
Measured water temperatures: black diamonds: deep lakes, gray diamonds: shallow lakes.
Crosses: water surface temperatures calculated from Landsat ETM+ channel 6 values, images from the first decade of August 2002 and 2008.
Solid line: water temperature trend for the wind exposed lakes, dotted line: trend for the wind protected alpine lakes.

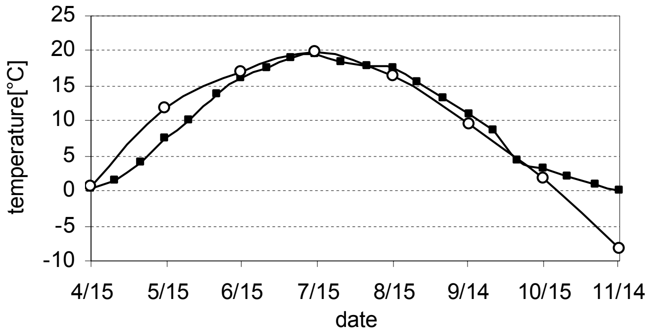


Fig. 37 Surface water temperatures (black squares) of Uvs Nuur, gauging station Davst, and air temperatures, Ulaangom (white circles). Decadal and monthly means of 1990-1999.

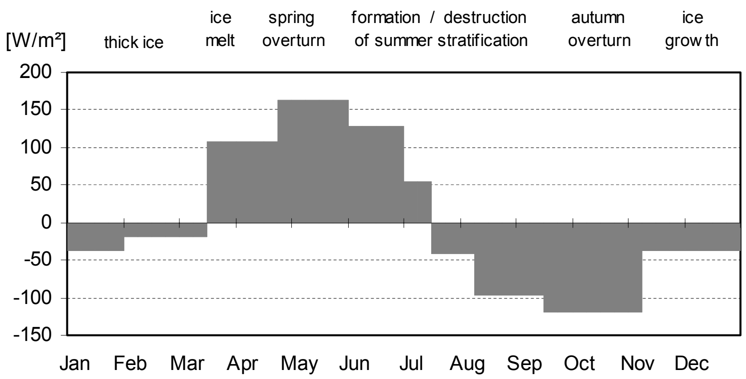


Fig. 38 Mean heat exchange rates of Uvs Nuur [W/m²]. For the data used as calculation basis see Chapter 2.3!

Table 20 Vertical mixing characteristics of 9 investigated lakes. All depths in meters, T_{epi}, T_{hypo} = measured epilimnion and hypolimnion temperatures, z_{mix} = mixing depth, * = lowest measured temperature at 28 m depth. Calculated mixing depths according to ARAI (1981) and PATALAS (1984); FTD = fall turnover date calculated according to NÜRNBERG (1988); mixis type according to LEWIS (1983).

lake	T_{epi} [°C]	T_{hypo} [°C]	max. depth	z_{mix} measured	z_{mix} ARAI	z_{mix} PATALAS	FTD NÜRNBERG	LEWIS mixis type
Baga	19-23	-	1	1				continuous polymictic
Bayan	18-22	8-9	29	10-15	10.7	9.5	10/05	dimictic
Döröö	20	-	9	9				continuous / discontinuous polymictic
Nogoon	7	4	35	15	4.3	2.8		discontinuous polymictic
Seepage	18-21	-	3	3				continuous polymictic
Shavart	20-22	-	3	3				continuous polymictic
Southern Baga	23	-	3	3				continuous polymictic
Üüreg	15	12 *	42	25	14.3	14.1	09/30	dimictic
Uvs	19-23	11-12	22	13-18	21.4	24.4	09/30	dimictic or discontinuous polymictic

most frequently comes not from the lake. At the SE shore, along the main wind direction, this influence could reach much further. This is supported by the higher amount of precipitation at the measuring station Baruunturuun, and the comparably good state of the vegetation cover in the steppe south of Uvs Nuur and the dune field east of the lake (BURKART et al., 2000), given the naturally high groundwater distance in the latter.

The temperature depth profiles of 5 deep lakes in August 1997 till 1999 are shown in Fig. 39. The temperature gradients in the alpine lakes Nogoon and Üüreg were much weaker than in the lakes of the inner basin due to cold nights and less heating of the uppermost layer during daytime. The conspicuously linear course of the profile in Uvs Nuur 1998 resulted from strong winds before and during the measurements. Most stratified lakes had high hypolimnion temperatures of 8 to 12°C which is due to the low thermic stability in spring, caused by strong winds, together with an already high solar radiation and air temperature (ice break-up at the end of April). During the summer, calm periods were interrupted by stronger winds and thus multiple thermoclines can be found (Bayan Nuur in 1997). Shallow, completely mixed lakes reached temperatures between 18 and 25°C in August.

The measured mixing depths are compared with theoretical midsummer mixing depths that were calculated as function of maximum wind fetch using empirical formulae from ARAI (1981) and PATALAS (1984). These and the mixing types according to the extended mixis classification of LEWIS (1983) are shown in Table 20. The high discrepancy between modeled and real mixing depths of Nogoon and Üüreg Nuur comes from their high altitude and low stability of stratification, a factor that is not included in the used models. On the other side, in Uvs Nuur the measured thermocline was only at about 2/3 of the calculated depth. This could be explained by the fact that the density difference between surface and hypolimnion is not only a result of different temperatures but to an extend of up to 25% (according to our measurements, maybe more in July when the dilution of surface water due to rainfall is maximal) also of a slight salinity difference. Furthermore, PATALAS (1984) states that his empirical relation is not applicable for lakes with a fetch > 25 km as their thermocline depth tends to be size independent. The predicted beginning date of fall turnover calculated with a regression formula from a worldwide dataset (NÜRNBERG, 1988) seems a bit late, probably because temperatures in autumn drop faster in the arid steppe than in other regions of the temperate zone.

No measurements of short term water level changes as mentioned in 3.2.2 were made, but it was attempted to observe internal seiches by measurement of temperature time series above and below the thermocline of Uvs Nuur in 1998. As the observation time was only 22 hours, and only one temperature data logger was working properly, no complete seiche cycle was observed. However, the logger above the thermocline at 15 m depth, where constantly 23°C was recorded, measured a temperature drop to 18°C which lasted, with some oscillations, five hours. That means, that based on the measured depth profile, a temporary shift of the thermocline by at least 1.5 m was observed. Internal seiches in a large, round lake like Uvs Nuur are strongly deflected by the Coriolis force into a circulating motion and can have amplitudes of several meters and periods of one to four days (DE LA FUENTE et al., 2008; ANTENUCCI & IMBERGER, 2003). Regular circulating water movements in Uvs Nuur do exist – see chapter 3.2.5.

3.2.4 Vertical gradients of physico-chemical parameters and chlorophyll

The measured ranges of oxygen saturation, pH and conductivity on the water surface of all sampled lakes are shown in Table 21. Vertical profiles of temperature, oxygen saturation, pH, conductivity and turbidity for deep lakes that were measured at the deepest point in reach with a small boat (at least 400 m from the shore) are shown in Fig. 39, measurements of Chlorophyll, turbidity and Secchi depth for all investigated lakes are shown in Fig. 40 and Fig. 41.

Table 21 Oxygen saturation, pH and conductivity: minimum and maximum values at the surface of standing water bodies.

sampling place	years of measurement	O_2 saturation [%]	pH	conductivity [mS/cm]
alpine lake near Turgen Gol	1997		8.2	0.09
Baga Nuur	1998, 1999	140-160	10.0-10.1	1.64-1.97
Bayan Nuur	1997, 1998, 1999	104-114	8.8-9.0	0.43-0.44
Döröö Nuur	1998	105	9.2	0.71
Khukhu Nuur	1999		8.5	0.40
Khyargas Nuur	1998		9.3	9.04
lagoon 1 at Üüreg Nuur	1998	120-300	9.4	6.40
lagoon 2 at Üüreg Nuur	1998	110-150	9.3	7.12
lagoon 2 at Uvs Nuur	1997		8.3	1.18
Nogoon Nuur	1999	110	8.4	0.05
Seepage Lake	1996, 1997, 1999	80-116	8.9-9.1	2.32-2.80
Shavart Nuur	1997, 1999	110-120	9.1-9.2	1.70-1.84
Southern Baga Nuur	1999	140	9.4	23.6
Tesiyn Gol-5.5 (oxbow pond)	1999	50	7.7	0.39
Togoo Nuur	1999	135	9.3	0.99
Üüreg Nuur	1996, 1999	100-110	9.2-9.3	6.22-6.44
Uvs Nuur-E	1998	93	9.1	13.8
Uvs Nuur-NW	1997, 1998, 1999	99-109	8.9-9.1	18.9-19.1
Uvs Nuur-SW	1996, 1997, 1999	98-196	9.0-9.1	18.9-19.7

The profiles of oxygen saturation followed the known dependence on mixing regime and trophic state (see chapter 3.2.7): the polymictic shallow lakes Baga Nuur, Southern Baga Nuur, Seepage Lake, Shavart Nuur (no depth profiles measured, but certainly orthograde) and Döröö Nuur (nearly orthograde oxygen profile) mostly had a considerable oxygen oversaturation in the afternoon which is an indication of an eutrophic state. The stratified Uvs Nuur showed the typical profile of an oligotrophic lake: in the epilimnion the oxygen saturation was always around 100% and dropped to about 70% in the hypolimnion (1997; in the other years the thermocline was very deep). In USSR Academy of Sciences (1991) a summerly oxygen concentration of only 6.8 mg/l is quoted for Uvs Nuur which would mean a saturation of only 80%. This might not be valid for the open epilimnetic water body as the exact measuring place is not given.

The weakly stratified, oligotrophic Nogoon Nuur had an orthograde profile with a slight oversaturation. Üüreg Nuur had an almost ideal orthograde profile with values very close to 100% and only a slight hypolimnetic oxygen depletion, an indication of its ultraoligotrophic state. The oxygen profile of Bayan Nuur showed a prominent metalimnetic maximum in 1998 and a drop to 25% saturation in the hypolimnion – characteristics of mesotrophic lakes. In the small, very shallow Lagoons 1 and 2 at Üüreg Nuur oversaturation up to 300% have been measured.

The pH value in all investigated lakes was over 8.2, which is a sign of high alkalinity – a general characteristic of the surface waters in the Uvs Nuur Basin. In the dimictic, oligotrophic (Uvs, Üüreg, Nogoon) and most polymictic lakes (Döröö, Shavart, Southern Baga, Togoo Nuur and Seepage Lake) it was with little variation in the range of 8.9-9.4. The highest pH value of 10.1 was measured in Baga Nuur on a calm, sunny afternoon. The stratified, mesotrophic Bayan Nuur was the only lake with a strong pH gradient, dropping from 8.9 in the epilimnion to 7.8 in the hypolimnion which indicates a hypolimnic accumulation of CO_2 due to decomposition of sinking plankton, typical for mesotrophic lakes.

Electric conductivity as a parameter equivalent to salinity had a wide range for all investigated lakes – from 49 μS/cm to 23.6 mS/cm. In the inner basin, we found no standing water with a conductivity less than 390 μS/cm. The vertical gradient of conductivity in stratified lakes mostly was very weak. However, in Uvs Nuur it accounted for 26% in 1997 and 11% in 1998 (Fig. 39) of the density difference between epilimnion and hypolimnion.

The optical properties of the lakes' water were crucially depending on their relative and absolute depth: shallow, comparably big lakes with a maximum depth less than 3 meters (Baga and Shavart Nuur) as well as the shallow eastern bay of Uvs Nuur were very turbid: Secchi depths of less than 0.5 m and turbidities between 50 and 70 NTU were common. In the case of Uvs Nuur, the predominant northwestern winds caused a high turbidity along the whole east coast as can be seen in satellite images. In the large oligotrophic lakes Üüreg and Uvs Nuur, having a low relative depth, turbidity was comparably high due to sediment resuspension, leading to a lower Secchi depth than expected from the Chlorophyll-a concentration. In the deep northwest bay of Uvs Nuur, a Secchi depth of only 3.7 m was measured after strong wind; at less windy weather 4.7 and 5.7 m were measured. Bayan Nuur, quite well protected from wind and having a moderate relative depth, reached Secchi depth values of 4.8 to 6.0 m, although its trophic index was higher than that of Uvs Nuur. Üüreg Nuur was with 5.7 m in the same range. In Döröö Nuur the Secchi depth measured only 2 m due to a dominance of picoplanctic cyanobacteria and probably strong calcite precipitation. The comparably low Secchi depth in Seepage Lake was due to humic substances coloring its water brownish. The low Secchi depth of Nogoon Nuur, given its oligotrophic state and high relative depth, was possibly due to mineral turbidity from glacier flour.

Vertical profiles of turbidity show some remarkable metalimnetic maxima in Bayan and Üüreg Nuur. The turbidity at Uvs Nuur-NW in 1997 was considerably increased and showed two strong peaks at four and eight meters depth, roughly corresponding with two small conductivity minima. These peaks can be interpreted as plumes of resuspended fine sediment transported from the shore into the open pelagic zone. The reason were strong winds on the day before measurement of the vertical profile.

The mixing depths in lakes Baga, Döröö, Nogoon, Shavart, Uvs and Üüreg exceeded the euphotic depths which can be estimated as the product of Secchi depth and 1.7 (REYNOLDS, 1984) or 2 (SOMMER, 1993) – see Table 22. Thus, light availability for phytoplankton was less than optimal in these lakes. In Uvs Nuur-E and Shavart Nuur, where mixing depth was about five times of euphotic depth, strong light limitation has to be assumed.

Table 22 Measured values of maximum depth, mixing depth and Secchi depth, and calculated euphotic depth according to REYNOLDS (1984) and SOMMER (1993). Lakes sorted as in Fig. 41; * = mixed to the bottom. Mixing depths in bold exceed euphotic depth.

lake	year	max. depth [m]	mixing depth [m]	Secchi depth [m]	euphotic depth [m] REYNOLDS	euphotic depth [m] SOMMER	z_{eu} / z_{mix} (REYNOLDS)
Nogoon Nuur	1999	35	**15**	3.8	6.5	7.6	0.4
Üüreg Nuur	1999	42	**25**	4.8	8.2	9.6	0.3
Uvs Nuur-SW	1997	22	5 *	3.0	5.1	6.0	1.0
Uvs Nuur-SW	1999		5 *	2.5	4.3	5.0	0.9
Uvs Nuur-NW	1997		**13**	3.7	6.3	7.4	0.5
Uvs Nuur-NW	1998		**16**	5.7	9.7	11.4	0.6
Uvs Nuur-NW	1999		**17**	4.7	8.0	9.4	0.5
Southern Baga Nuur	1999	3	2 *	3.0	5.1	6.0	2.6
Uvs Nuur-E	1998		**5** *	0.4	0.6	0.7	0.1
Bayan Nuur	1997	29	9	4.8	8.2	9.6	0.9
Bayan Nuur	1998		11	6.0	10.2	12.0	0.9
Bayan Nuur	1999		11	5.5	9.4	11.0	0.9
Döröö Nuur	1998	10	**10** *	2.0	3.4	4.0	0.3
Baga Nuur	1998	1	**1** *	0.4	0.6	0.7	0.6
Baga Nuur	1999		**1** *	0.5	0.8	0.9	0.8
Seepage Lake	1997	3	3 *	1.5	2.6	3.0	0.9
Seepage Lake	1999		3 *	2.2	3.7	4.4	1.2
Shavart Nuur	1999	3	**3** *	0.4	0.6	0.7	0.2

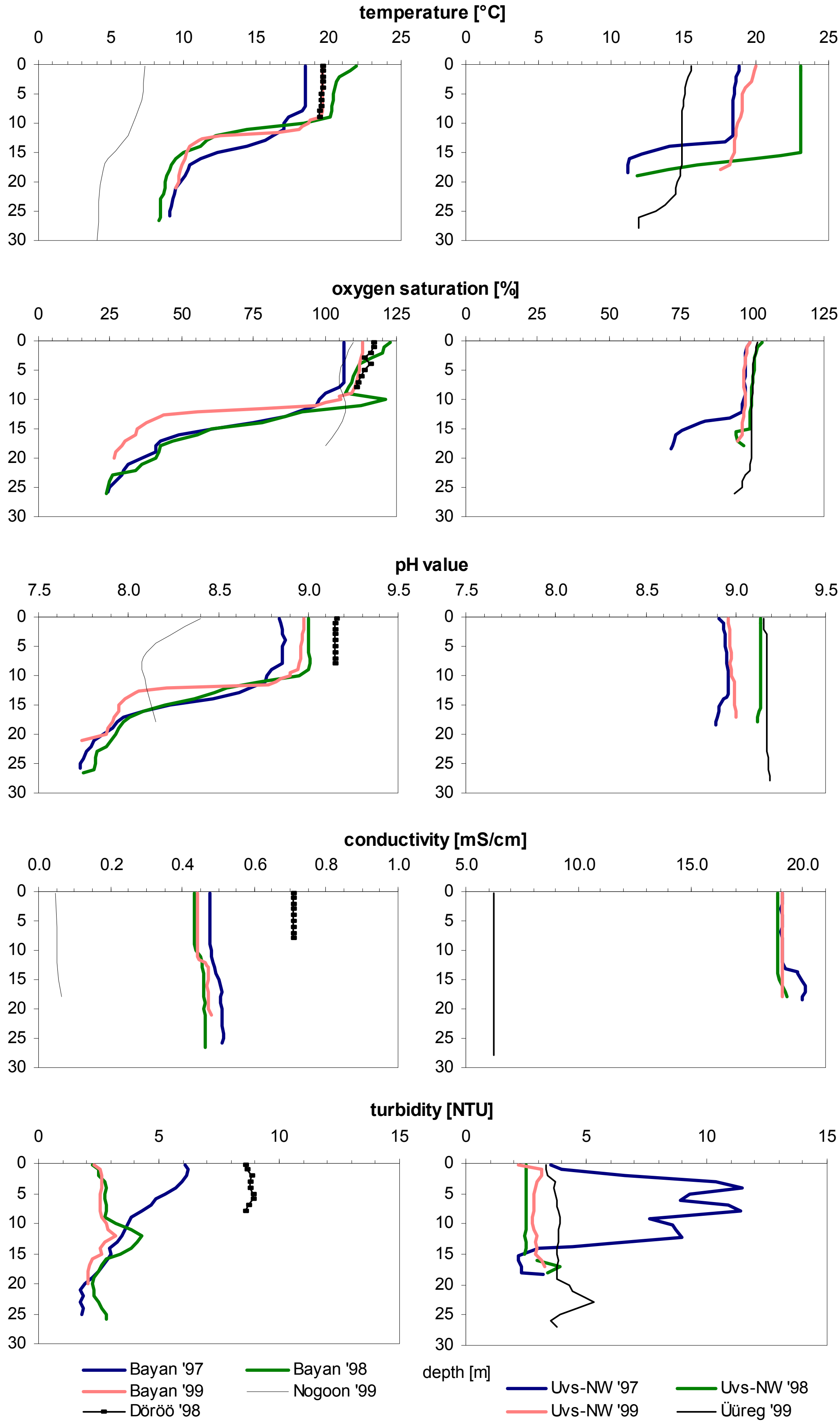


Fig. 39 Vertical profiles of oxygen saturation, pH, conductivity and turbidity in five deep lakes, measured in August 1997-1999. In Nogoon Nuur turbidity was not measured.

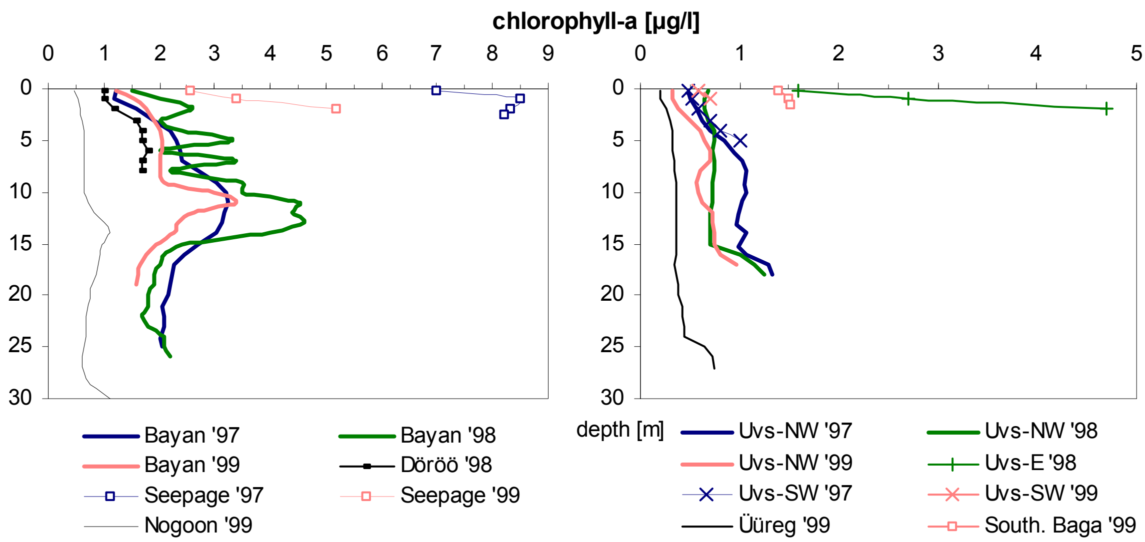


Fig. 40 Vertical profiles of chlorophyll-a concentration (uncorrected – see 3.2.7) in seven lakes, measured in August 1997-1999.

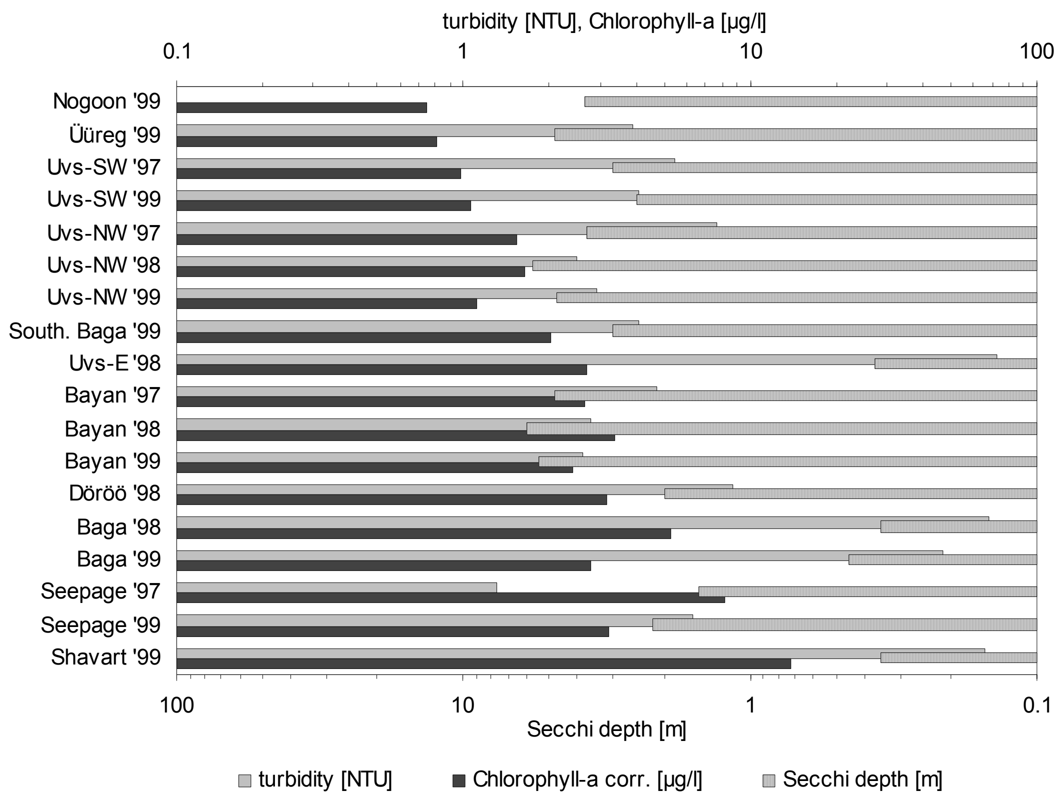


Fig. 41 Turbidity, chlorophyll-a (corrected – see 3.2.7) and Secchi depth in nine lakes, sorted according to the assumed trophic state. For turbidity and chlorophyll, average values were calculated for the water column from surface to Secchi depth. Note the inverse axis for Secchi depth!

3.2.5 Horizontal gradients in Uvs Nuur: surface temperature and suspended matter

The physical and chemical properties of the water body of Uvs Nuur were not only inhomogeneous in the vertical dimension but likewise horizontally: Large, wind driven, due to the Coriolis force counter-clockwise rotating eddies existed during the open water season (most impressively visible in the satellite image of August 1999), near river estuaries silty plumes extended up to six kilometers into the lake (visible in the image of May 2002 at the mouth of Tesiyn Gol). Some of these structures were visible in the visual spectral range, some were only detectable by temperature differences. Fig. 81 and Fig. 83 in the appendix show exemplary for spring, midsummer and autumn distributions of temperature and suspended matter.

The absolute temperature differences were highest in spring: in the May 2002 satellite image, the minimum temperature of 0°C was measured around the last ice floes in the N bay and near the S shore, while the maximum of 12°C was reached in the most shallow water at the NE and SW shore, as well as in the lagoonal lakes Baga Nuur and Southern Baga Nuur. In the open lake, 5 to 6°C were measured, with a large spot of 8°C warm water in the center which may be interpreted as coastal water drifted away from the NE shore. In a prominent, perfectly circular eddy with a diameter of 5 km in the E bay, the temperatures vary between 4.5 and 10°C. In the June 1998 image (not shown in Fig. 81), a difference of 3 degrees over a distance of some 100 m was measured in an eddy; on the open lake temperatures differed between 10 and 17°C. In midsummer, the differences were much smaller – in August 1999 and 2002 in the E bay 16.0 resp. 20.5°C were reached while the central part had about 13.5 resp. 17°C. The autumn cooling of the water body started at the shallow coastal areas as the image of October 2008 shows. While the open lake was still at 8.5°C, at the shores only 5°C were measured.

Although not proven by measurements, it is unlikely that the measured surface temperature differences continue to the full extent into deeper water layers. Instead, eddies or large spots with warmer water most probably are thin layers of coastal water blown by the wind into the open lake.

The qualitative distribution of suspended sediments and planktic algae in Fig. 83 is based on the color of the water in the visual spectral range (Landsat channels 1, 2 and 3), with clear water penetration depths of up to some 8 m (May 2002) for reflected blue light. Thus, for interpretation of the images it is important to distinguish between lake bottom features shining through and turbid water with different portions of suspended sediment and planktic algae. In May 2002 at the end of the ice melt the whole lake was very clear, except a plume of highly turbid water from the flooding Tesiyn Gol and the always turbid E bay. Thus, submerged lake bottom features (the wavy relief at the SW shore, dunes at the SE shore, spits at the W shore, sand bars at the S shore and dark organic sediment at the NE shore – see Fig. 84) were very clearly visible. In August 1999, strong winds had stirred up the sediment at the SE and NE shores and transported several large eddies of turbid water into the middle of the lake. Similar, less distinctive currents were visible in August and October 2002.

Horizontal differences in the chemical composition of Uvs Nuur are significant, as the most important tributaries flow into the lake at the eastern shore, where large shallow areas predominate. Examples of these differences can be seen in the chemical analyses of the NW bay, the shallow, turbid E bay and the likewise shallow, but less wind-exposed SW shore (Table 23). An increased amount of planktic Chlorophyll was only found in the E bay and along the shallow NE coast. Thus, the deep NW bay with its gravelly shore seems to be most representative for the deepwater areas and about 96% of the water volume of Uvs Nuur, whereas the eastern bay is influenced by inflowing fresh water and high amounts of suspended solids, which causes the high concentration of total phosphorus found.

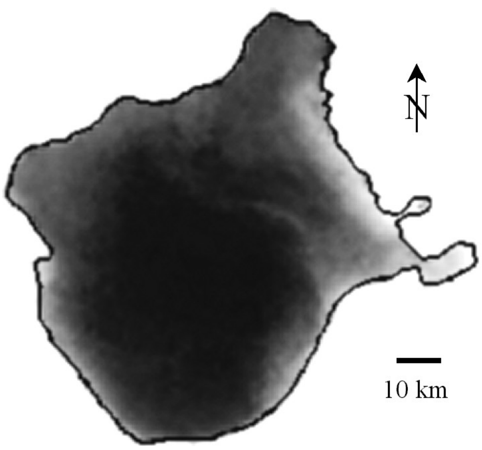


Fig. 42 Average distribution of turbidity in Uvs Nuur, contrast enhanced overlay of 14 satellite images from the months June to October, years 1997 and 1998.
Lighter color = higher turbidity.

The almost permanent existence of large eddies is visible in the average turbidity distribution (Fig. 42): the winds blowing from northwest induce strong waves that erode the sandy and silty SE shore and E bay, and a counter-clockwise current transporting suspended solids into the central part of the lake. The water at the very shallow NE shore where Tesiyn Gol unloads sand and silt is very turbid and probably eutrophic. TSEREVSAMBUU (1990) points to the fact that the turbid, more nutrient-rich waters near the shores of Uvs Nuur, especially at the estuary of Nariyn Gol, both inhibit primary production by worsening light availability in the deeper water, and enhance it in the very shallow near-shore areas.

3.2.6 Salinity and ionic composition

The salinity of the investigated lakes differs over almost three orders of magnitude, from 0.04 to 20.2 g/l, which is mainly caused by the vertical climatic gradient. Table 23 gives an overview; for complete ion analyses see Table 46. Whilst the water of the alpine Nogoon Nuur had a salinity similar to that of rain water, the salt accumulation in the mesosaline Southern Baga Nuur was so high, that Na_2SO_4 precipitated (see chapter 3.2.8).

The salinity differences between lakes reflect the sequence of hydrochemical processes in standing waters where evaporation has an increasing part in the loss term of the water balance and eventually being the only loss term. These processes are dissolution, concentration, precipitation and redox reactions, which remove the less soluble Ca ions as carbonates from the water, leaving mainly Na, Cl and SO_4 in increasingly higher concentrations – see Fig. 43 and Fig. 44.

The freshwater lakes Nogoon, Khukhu and Bayan Nuur are of the Ca/Mg-HCO_3 type, the proportion of calcium becoming lower with increasing salinity. The subsaline Döröö, Shavart Nuur and Seepage Lake are of the transition type Na/Mg-HCO_3 with increasing fraction of sodium. The subsaline Baga Nuur and the hypo- and mesosaline lakes Üüreg, Khyargas, Uvs and Southern Baga Nuur are of the Na/Mg-SO_4/Cl type, Üüreg Nuur being the only one with a sodium fraction below 70%. An explanation for the quite different anionic compositions of the salt lakes Üüreg, Khyargas, Uvs and Southern Baga is not easily found, as climatic and geologic influences, the chemical composition of the tributaries and the history of the water bodies play a role in the accumulation and precipitation of salts.

As WILLIAMS (1991) observes, "salinities in the larger Mongolian salt lakes are not high". Actually, the maximum salinity of the lakes investigated by us is just in the oligo- to mesosaline range. However, smaller lakes with much higher salinities do exist in the Uvs Nuur Basin: ARAKCHAA et al. (1996) provide data measured in 1990 for three lakes, located in the Russian part of the basin west of the settlement of Erzin: the very shallow, solely groundwater fed, hypersaline lake Dus-Khol (50°23' N, 94°52' E) has an approximate area of 0.4 km^2, a salinity of 143 g/l, pH of 6.2 and is of the Na/Mg-Cl type. The sediment is covered by some 50 cm of Halite that precipitates from the brine. The mesosaline lake Shara Nuur (50°14' N, 94°34' E) with an area of 5 km^2 receives some water from a branch of Nariyn Gol, has a salinity of 41 g/l and is of the Na-Cl/SO_4 type. The smaller Bai-Khol (50°20' N, 95°01' E) near Tesiyn Gol has a salinity of 31 g/l and is of the Na/Mg-Cl/SO_4 type.

Temporal changes of salinity have been observed in Uvs Nuur, but are surely present in the shallow lakes Baga, Shavart, Seepage and Southern Baga, too. Short term fluctuations from changing freshwater inflow and rain are not documented, their impact could be locally important. The change of salinity and ionic composition due to freezing and thawing of the ice cover must be assumed as substantial. It is an important process of calcite precipitation in shallow lakes where the ice cover has a significant proportion of the lake's volume (CANFIELD et al., 1983; RENAUT & LONG, 1987). Given the low maximum depth of Baga Nuur (1 m) and Southern Baga Nuur (3 m) and an ice thickness of at least one meter, salinity in these lakes probably fluctuates between winter and summer by more than 50%.

Table 23 Chemical characteristics of lake waters (surface or epilimnetic samples): salinity (calculated as sum of the ions), pH and concentrations of the main ions. Mean values from given number of samples.

lake	#samples	salinity [g/l]	pH	major ions [mg/l] Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
Nogoon	1	0.04	8.4	0.6	1.0	6.5	1.3	0.0	2.9	26	0.0
Khukhu	1	0.36	8.5	12	3	43	28	4	23	246	2
Bayan	3	0.35	8.9	36	4	26	25	9	53	171	6
Döröö	1	0.56	9.2	48	19	9	61	19	8	354	37
Baga	2	1.26	10.1	290	9	13	18	220	220	76	70
Seepage	3	2.03	9.0	540	25	15	65	245	112	969	57
Shavart	2	1.48	9.2	206	45	10	62	47	32	589	67
Üüreg	1	5.02	9.2	894	90	10	472	719	1830	896	112
Khyargas	1	6.96	9.3	1949	205	10	254	1189	1806	1343	207
Uvs-E	2	9.13	9.1	2560	115	19	372	2960	2360	683	69
Uvs-NW	5	13.39	9.0	3870	164	20	569	4350	3430	889	99
Uvs-SW	4	13.61	9.1	3810	175	14	600	4520	3490	888	119
Southern Baga	1	20.23	9.4	6420	83	8	360	2820	8600	1620	307

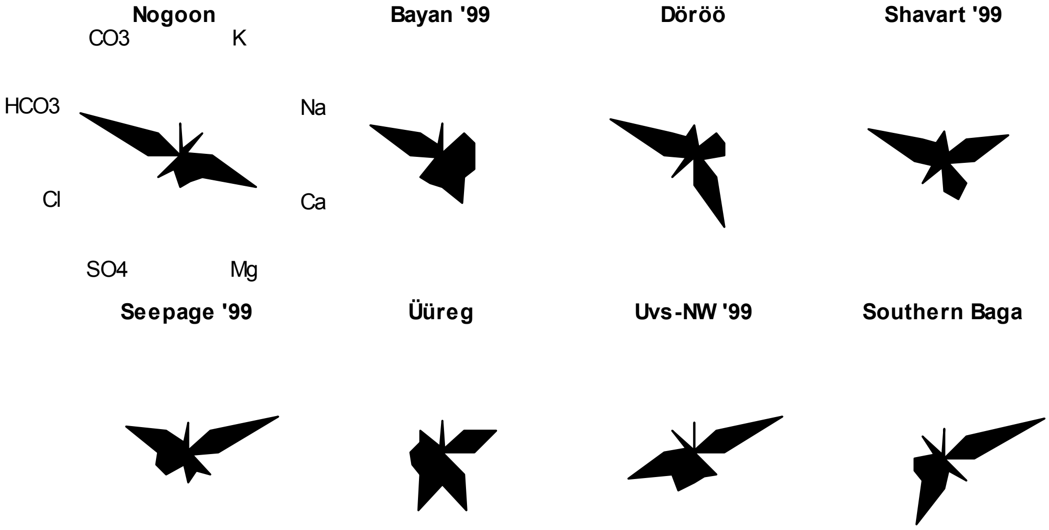


Fig. 43 Maucha ion field diagrams for eight lakes with characteristic chemical types (surface or epilimnetic samples), salinity increasing from upper left to lower right. The relative proportion of each ion in the sum of equivalent concentrations for anions and cations is shown.

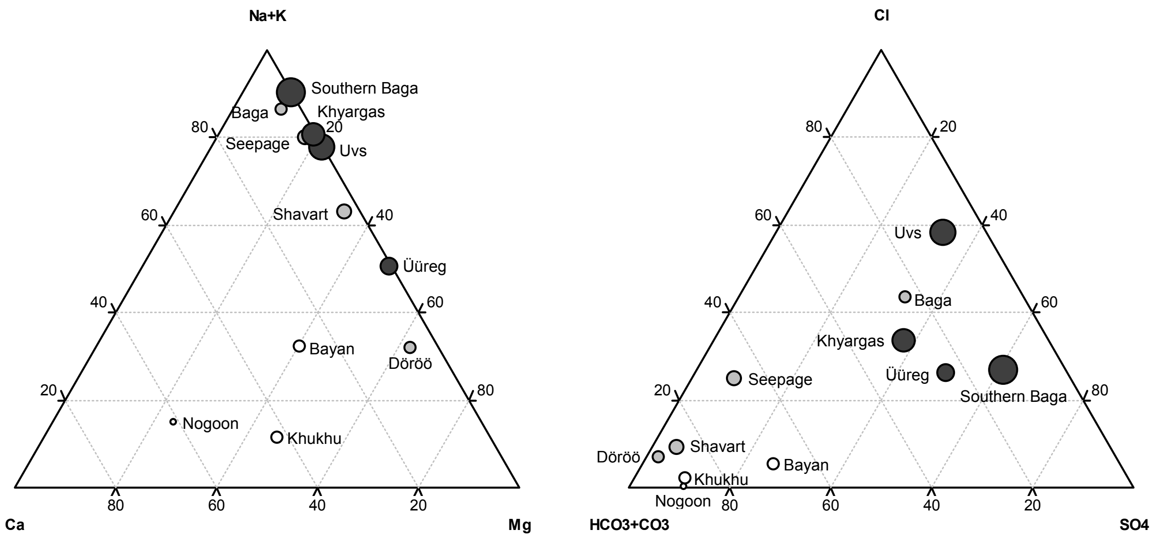


Fig. 44 Ternary diagrams for the percentage of Ca^{2+}, Mg^{2+}, Na^++K^+ in the equivalent concentrations of cations (left) and HCO_3^- +CO_3^{2-}, SO_4^{2-}, Cl^- in the equivalent concentrations of anions (right) of 11 lakes. Axis labels are on top (100%) of the axes, the area of the circles roughly corresponds to salinity. White = freshwater lakes, light gray = subsaline lakes, dark gray = salt lakes.

Table 24 Historical development of salinity and major ion concentrations (all in g/l) in Uvs Nuur. Values in italics are probably not representative for the whole lake.

year	place at shore	literature reference	salinity [g/l]	Na+K	Ca	Mg	Cl	SO_4	HCO_3 $+CO_3$
datable references									
1879	NW	Potanin (1883) in Davaa et al. (1997)	11.4						
1926	S	Smirnov (1932) in Davaa et al. (1997)	18.7						
1941		Bespalov (1951) in Davaa et al. (1997)	19.7						
1948		Lamzhav (1948) in Davaa et al. (1997)	*15.8–17.6*						
1956		Davaasuren (1961) in Davaa et al. (1997)	18.4						
1958		Davaasuren (1961) in Egorov (1993)	18.8	5.47	0.01	0.84	6.15	4.93	1.21
1966	N	Pinneker (1968) in Davaa et al. (1997)	16.4						
1990		Sevastyanov et al. (1994)	*18.7*	4.23	0.02	0.65	4.67	*7.78*	1.30
1996	N	this study	14.2	4.19		0.75	4.59	3.55	1.10
1999	NW	this study	13.8	4.08	0.02	0.60	4.58	3.53	0.98
other references									
minimum		Davaa et al. (1997) for years 1980–1997	*7.7*	*2.6*	*0.005*	*0.3*	*4.1*	*0.6*	*0.2*
mean		Davaa et al. (1997) for years 1980–1997	13.4	4.5	0.005	0.4	5.3	2.4	0.8
maximum		Davaa et al. (1997) for years 1980–1997	*21.5*	*6.8*	*0.004*	*0.7*	*8.0*	*4.3*	*1.7*

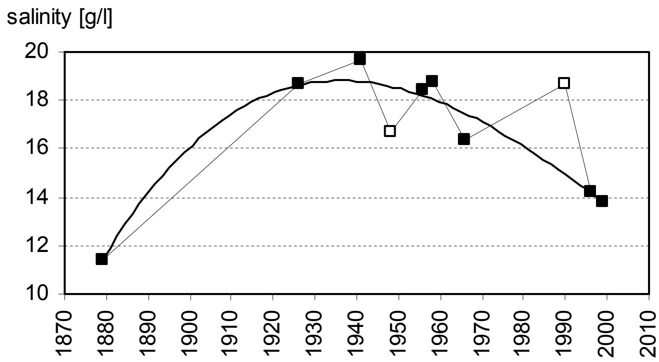


Fig. 45 Salinity changes of Uvs Nuur from 1880 to 2000 with trend line. White squares are measurements considered to be unrepresentative.

Generally, "the extent to which salinity fluctuates in time and space is little known" for Mongolian saline lakes (Williams, 1991). This is also true for Uvs Nuur: nearly no data exist for the spatial salinity distribution or short term fluctuations in shallow areas. For long term salinity changes, data of early salinity records and the recent chemical composition are presented by Davaa et al. (1997) – see Table 24. They state from measurements regularly taken by the Mongolian Hydrometeorological Institute that in the years 1980 to 1997 the salinity fluctuated between 7.8 g/l in wet years and 21 g/l in dry years, the average being 13.4 g/l, however without giving dateable figures. The whole range of salinity values in the literature (besides those extremes cited above) lies between 11.4 (measured 1879) and 19.7 g/l (1951); most often cited is 18.78 g/l (Dulmaa, 1979; Williams, 1991; Egorov, 1993), however there are also absurd statements like "five times saltier than the oceans" (Uvs Nuur Basin Strictly Protected Area Administration Center, 1997). The representativeness of these literature data for the whole lake is not clear, as no data of sampling site (near shore or offshore?) and season are given. Our own measurements suggest that salinities can be substantially lower near the mouth of bigger rivers (Nariyn and Tesiyn Gol) and in shallow shore areas where groundwater discharges into the lake. Temporal fluctuations near shore are controlled by wind speed and direction, precipitation and icing processes.

The main processes that change salinity in terminal lakes, due to Hammer (1986) are dilution and concentration by volume changes, precipitation and dissolution of salts due to salinity and temperature changes and icing, import of salty dust, blowout of salt from the shores or within spray, and changes in the salinity of tributaries. Bearing in mind these processes it has to be asked which are likely to have caused the salinity fluctuations in Uvs Nuur. Volume change surely is the most important factor for the whole water body in a sufficiently deep lake as Uvs Nuur is. The following measured data can be taken as basis: between 1949 and 1998 the lake volume increased by 26% from 39 to 49 km^3 according to our hypsographic function. Salinity was at 11.4 g/l in 1879, measured as evaporation residue (which can deviate from salinity according to WILLIAMS & SHERWOOD, 1994). It rose to some 19 g/l which prevailed from the 1930s to the 1950s and decreased again by 26% to about 14 g/l in the late 1990s (Fig. 45). The percentages of volume increase and salinity decrease between 1949 and 1998 match very well. Thus, it seems reasonable, taking into account only the dilution effect, to extrapolate the lake volume in 1879 as about 55 km^3 which would correspond to a lake level 1.5 m higher than present. Salinity values in italics in Table 24 do not fit well into this model and are considered not representative for the whole lake. Especially the maximum and minimum values of DAVAA et al. (1997) are probably from samples taken in a shallow, isolated shore area where freshwater inflow, local freezing and evaporation effects can play an important role.

3.2.7 Nutrients and trophic state

The analysis of nutrients, especially in the low concentration range, unfortunately was of reduced reliability due to the long sample transport. The measuring methods for SRP and NH_4-N available in the field had insufficiently high limits of quantification. Thus, nearly no exact SRP data are available as in most cases the concentrations were below the quantification limit of 10 µg/l. Likewise, in the saline lakes the NO_3-N concentration often fell below the limit of quantification as these samples had to be diluted for measurement. Another important measure of trophic state, the chlorophyll concentration, was underestimated in lakes with high biovolume fraction of Cyanobacteria due to the technical constraints of the fluorometric probe. For assessment of the trophic state these data had to be corrected. Assuming that the fluorescence response of Cyanobacteria at the excitation wavelength of 450 nm is roughly 1/3 of eukaryotic algae (norm spectra in BEUTLER, 2003, p. 29) and that the chlorophyll content per unit biovolume of Cyanobacteria is roughly the same as in eukaryotic algae, formula (14) was used for correction. The results are not meant to be very precise, but much more plausible than the uncorrected data.

$$Chl_{meas} = (1 - f_{Cyano}) \cdot Chl_{korr} + 0.33 \cdot f_{Cyano} \cdot Chl_{korr} \tag{14}$$

Chl_{meas}: measured, uncorrected total chlorophyll
Chl_{korr}: corrected total chlorophyll (approximation of real chlorophyll concentration)
f_{Cyano}: fraction of Cyanobacteria in the total phytoplankton biovolume

Rearranged to corrected chlorophyll this gives:

$$Chl_{korr} = \frac{Chl_{meas}}{1 - 0.67 \cdot f_{Cyano}} \tag{15}$$

Another constraint in the usability of the data is their spot check character. The methods to assess trophic state demand mean values of the indexed parameters for at least one vegetation period. As this condition cannot be fulfilled the results are somewhat uncertain. The available data – mean values shown in Table 25 – allow nevertheless to characterize the trophic state of the lakes (last column in Table 25) quite well by combining different approaches.

Some often used approaches to determine trophic state and limiting resources primarily rely on nutrient concentrations and ratios. The P loading concept published for TP by VOLLENWEIDER & KEREKES (1982) predicts the trophic state (lake internal TP and chlorophyll concentrations) from mean water residence time and TP concentration in the inflow and is only suitable for lakes with an outflow – only Bayan Nuur fulfills these criteria. As the annual P load is unknown, but the in-lake TP and chlorophyll concentrations are known, the approximate allowable TP concentration of the inflowing ground water can be estimated. With a residence time of some 10 years and internal concentrations of 5 µg/l TP and some 2 to 3 µg/l chlorophyll, one gets inflow TP concentrations of 15 to 30 µg/l. Looking at the TP concentrations of groundwater around Bayan Nuur (spring of Khustay Gol: 36 µg/l, spring-1 at Bayan: 15 µg/l, well 3: 30 µg/l, spring at Urt Bulag Gol: 30 µg/l) this corresponds well.

Table 25 Mean nutrient and chlorophyll concentrations and trophic level of all lakes sampled between 1996 and 1999. The number of samples used for averaging is a maximum that not applies for all parameters. TN:TP mass ratio (values < 23 bold) can be converted to molar ratio by multiplying by 2.2. Chlorophyll values corrected according to formula (15). Trophic levels in brackets are estimated.

sampling place	# samples	SRP µg/l	NO_3-N µg/l	NH_4-N µg/l	TP µg/l	TN µg/l	TN:TP mass/mass	TSi µg/l	chlorophyll µg/l	assigned trophic level
Nogoon Nuur	2		240	<1	3	280	93	1.0	0.7	**ultraoligo**
Üüreg Nuur	2	<10	1	11	5	200	40	0.4	0.8	**ultraoligo**
Uvs Nuur-NW	7	<10	<1	<1	19	380	**20**	1.8	1.4	**oligo**
Uvs Nuur-SW	4	<10	<1	14	33	620	**19**	0.8	1.0	**oligo**
Khyargas Nuur	1		37		29	370	**13**	4.9		**(oligo)**
Bayan Nuur	3	<10	74	<1	5	230	46	1.2	2.8	**oligo-meso**
Döröö Nuur	1	<10	2		8	200	25	1.4	3.2	**oligo-meso**
Uvs Nuur-E	2	<10	19		84	1300	**15**	2.5	2.7	**meso**
Seepage Lake	3	<10	170	3	29	830	29	7.8	5.7	**meso**
Baga Nuur	2	<10	7		86	1200	**14**	6.1	5.0	**meso-eu**
Southern Baga Nuur	1	<10	<1	58	140	1600	**11**	1.8	2.0	**meso-eu**
Shavart Nuur	3	10	15	69	230	2100	**9**	4.6	13.9	**eu**
lagoon 2 at Üüreg Nuur	2	170	<1	43	420	1900	**5**	2.2		**(hyper)**

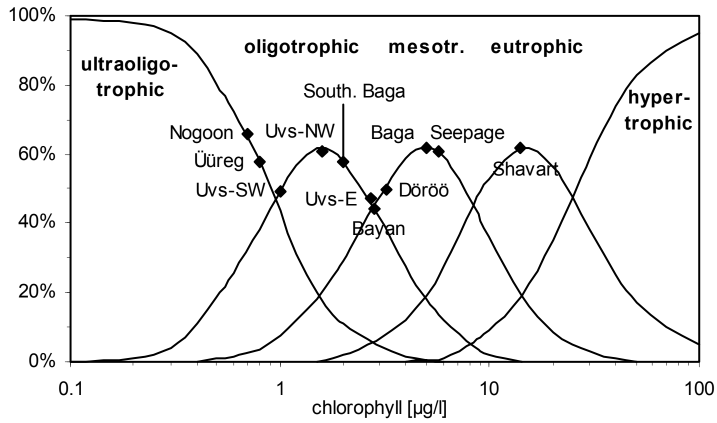


Fig. 46 Lake trophic level according to probability distribution of mean chlorophyll concentration according to VOLLENWEIDER & KEREKES (1982).

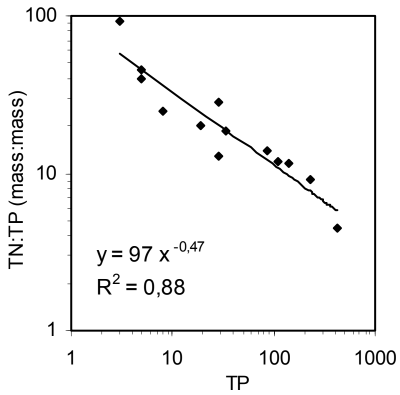


Fig. 47 TN:TP mass ratios vs. TP concentration of the lakes listed in Table 25.

The molar TN:TP ratio is widely used to determine whether nitrogen or phosphorus is the limiting nutrient. SMITH (1982, 1990) states that low N:P ratios decrease the biomass yield per unit of TP. In a study of TN and TP concentrations of 221 lakes DOWNING & MCCAULEY (1992) found a strong inverse relationship between overall lake trophic state (expressed as TP concentration) and TN:TP ratio. They state that the most important determining factor for the TN:TP ratio is the composition of the lakes' nutrient sources. The mentioned relationship can be found in the investigated lakes too, as Fig. 47 shows. GUILDFORD & HECKY (2000) show in a study evaluating several hundred sample data of lakes and oceans, that for both marine and freshwater phytoplankton, nitrogen deficiency is indicated by molar TN:TP ratios below 20 (or mass ratios below 9) while at ratios between 20 and 50 either N or P can be deficient. Phosphorus deficiency was indicated by TP concentrations below 0.5 µmol/l (= 16 µg/l) and molar TN:TP ratios over 50 (or mass ratios over 23). Applied to our lakes it means that Bayan, Döröö, Nogoon, Üüreg Nuur and (possibly) Seepage Lake are P-limited, while lagoon 2 at Üüreg Nuur and Shavart Nuur are surely not P-limited.

For the assessment of trophic state – understood in the sense of CARLSON & SIMPSON (1996) as the level of total biomass in a lake – different approaches are used: the empirical relationship between TP and chlorophyll and the probability distribution of chlorophyll concentration over the different trophic levels

(VOLLENWEIDER & KEREKES, 1982) – see Fig. 48 and Fig. 46, trophic state indexes (TSI) according to CARLSON (1977) with an extension for N-limited lakes by KRATZER & BREZONIK (1981) – see Fig. 50, and extended interpretations of these indexes according to OSGOOD (1982) and HAVENS (2000) – see Fig. 49. Saline lakes have physico-chemical growth conditions for phytoplankton that tend to be worse than in freshwater. BIERHUIZEN & PREPAS (1985) found in Canadian saline lakes a negative correlation between chlorophyll and conductivity, pH and major ions except calcium. All lakes showed a lower chlorophyll concentration than predicted by models of TP-chlorophyll relationships developed for freshwater lakes. Many of these lakes had very low TN:TP ratios, thus TP was not the limiting nutrient and the abovementioned relationships were not applicable.

The concept of TSI assumes that the partial indexes for chlorophyll, Secchi depth and total phosphorus should not differ much from each other in normal, P-limited lakes. If the index for TP is much higher than the other two indexes we may have an N-limited lake. Thus KRATZER & BREZONIK introduced a fourth index for total nitrogen based on data from N-limited lakes of Florida. Ideally, the smaller one of the indexes for TP and TN should represent the limiting resource. To test for nutrient limitation, the difference between the partial indexes for chlorophyll and the lesser of the TP and TN indexes was calculated. Positive values indicate that the available nutrients were maximally utilized, negative values stand for a high nutrient surplus. Light can be the limiting resource if either the amount of non-algal turbidity is very high (constant external limitation) or algae not limited by nutrients reach extremely high biomass (self-limitation). In the first case the difference between the chlorophyll partial index and the Secchi depth index is negative, in the second case about zero. As Secchi depth actually measures the backscattering of light it is not only a function of the concentration of algal and other particles but also of their size spectrum. Thus, also picoplankton dominance can cause a negative difference of the indexes while large algae (for instance dinoflagellates, colony-forming Volvocales and Nostocales) evoke positive differences.

In Shavart Nuur, the trophic index for TN was significantly lower than for TP, also the TN:TP ratio was very low (even more in lagoon 2 at Üüreg Nuur) – this indicates nitrogen limitation which is often found in lakes of arid regions (GOLDMAN & HORNE, 1983 in HORNE & GALAT, 1985; GALAT & VERDIN, 1988).

The TP and TN concentrations in the lakes Uvs (SW shore and E bay), Baga and Southern Baga were relatively high, while chlorophyll stayed at a low level. Besides the top-down effect of high grazing pressure (see 3.2.9.2), it can be assumed therefore, that these macronutrients were not the limiting resource for the growth of phytoplankton. In Baga Nuur, Uvs Nuur-E and -SW the index for Secchi depth was significantly higher than the chlorophyll index what points to light limitation due to mineral turbidity. In Uvs Nuur-NW and Southern Baga Nuur where the difference between the indexes for chlorophyll and Secchi depth was quite small, light limitation is less likely. Possibly one of the micronutrients iron, manganese or molybdenum was deficient. These elements were below detection limit (that was as high as 0.5 mg/l due to dilution of salt water samples necessary for measurement) in all salt lakes; thus no exact information is available. Iron that is often deficient in oceanic waters (BEHRENFELD et al., 1996) was also found to be growth limiting in alkaline salt lakes with high P content (EVANS & PREPAS, 1997) and can be co-limiting together with P and N even in freshwater, as was found for lake Erie by NORTH et al. (2007). In sulphate-rich waters (as Uvs and Southern Baga Nuur) molybdenum deficiency could limit algal nitrogen fixation and thus productivity (WURTSBAUGH, 1988; MARINO et al., 1990).

Literature data on nutrient concentrations and trophic state of lakes of the Uvs Nuur Basin are rare. SHIL'KROT et al. (1993) found Uvs Nuur to be meso- to eutrophic. The discrepancy to our findings and those of TSEREVSAMBUU (1990) can be seen as a sign of the spatial heterogeneity of this large lake, as these authors investigated among others the shallow northeastern part beyond the Russian borderline where Tesiyn Gol discharges. Measurements of primary productivity using ^{14}C were made by TSEREVSAMBUU – see Table 26 for values of phytoplankton productivity and chlorophyll concentration.

Table 26 Data on phytoplankton productivity from TSEREVSAMBUU (1990).

lake	Üüreg	Uvs (near shore)	Uvs (deep water)	Khyargas
phytoplankton primary production [µg C/l·day]	31 ± 5	120 – 153	26 ± 3	24 ± 2
Chlorophyll-a concentration [µg/l]	0.5 ± 0.1		0.7 ± 0.1	0.4 ± 0.0
trophic state	oligotrophic		oligotrophic	oligotrophic

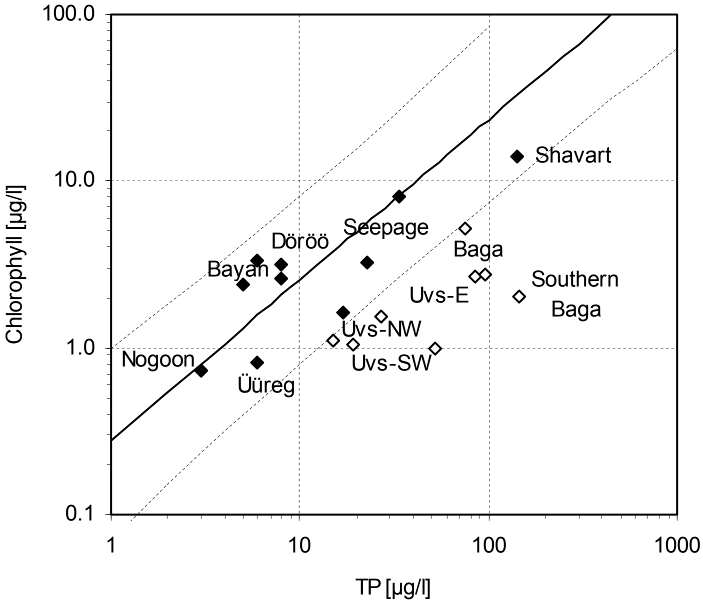


Fig. 48 Corrected chlorophyll concentration vs. total phosphorus for 11 lake sites. Solid and dashed lines: regression model for P-limited freshwater lakes with 95% confidence intervals (OECD eutrophication study, VOLLENWEIDER & KEREKES, 1982). Black diamonds: P-limitation model applicable, white diamonds: probably no P-limitation.

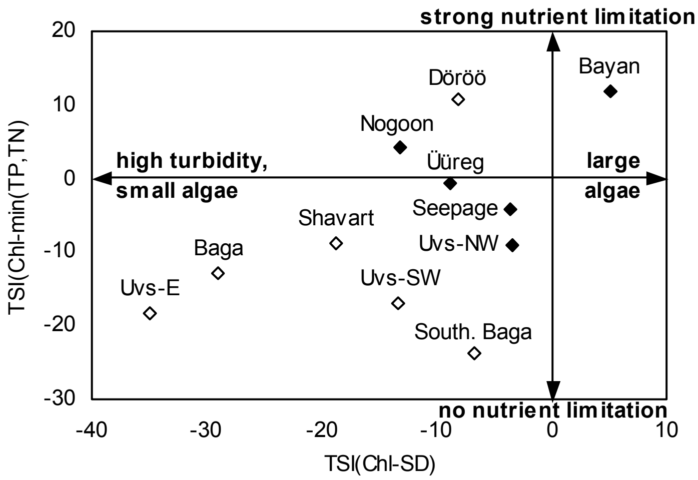


Fig. 49 Difference between partial trophic state indices (TSI according to CARLSON, 1977 and KRATZER & BREZONIK, 1981) for the investigated lakes.
Abscissa: difference between TSI for chlorophyll and Secchi depth.
Ordinate: difference between TSI for chlorophyll and the minimum of the indices for TP and TN.
Black diamonds: TSI(TP) < TSI(TN), white diamonds: TSI(TP) > TSI(TN).
Axis interpretations written in bold type after HAVENS (2000). "Nutrient limitation" means P and/or N are the limiting resources.

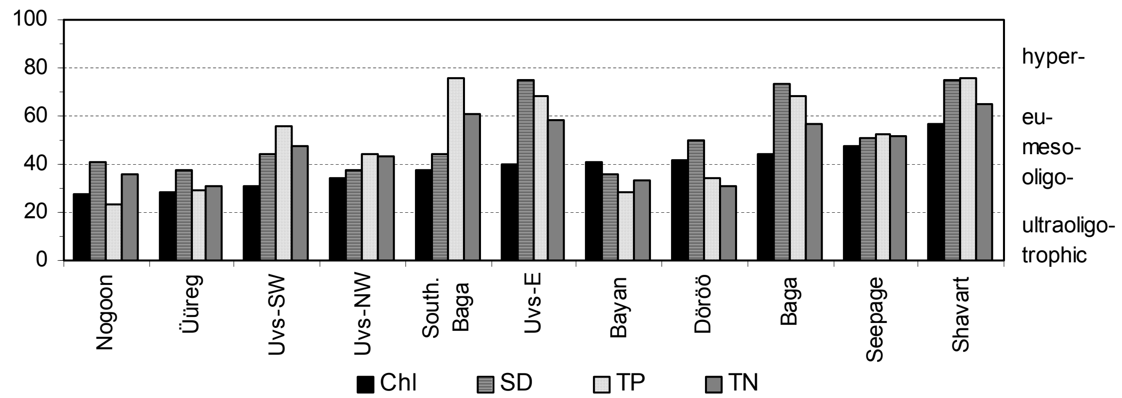


Fig. 50 Trophic state indices (TSI) for Chlorophyll, Secchi depth and TP after CARLSON (1977) with extension for TN by KRATZER & BREZONIK (1981). Lakes sorted according to TSI(Chl). Grey shaded bars mark the transitions between trophic levels (right vertical axis).

All above findings can be summarized as follows:

- The concentrations of ortho-phosphorus (SRP) were very low in all lakes with the exception of the small, shallow lagoon 2 at the shore of Üüreg Nuur. Dissolved inorganic nitrogen (DIN) concentration was low (< 100 µg/l) in most lakes.
- High total phosphorus concentrations (> 100 µg/l) were only found in Shavart Nuur (probably bound to clay particles) and Southern Baga Nuur, where most of the TP was non-particulate phosphorus.
- Only one of the sampled lakes – the eutrophic Shavart Nuur – reached a chlorophyll concentration > 10 µg/l; the others were in the ultraoligotrophic to mesotrophic range (Fig. 46).
- The trophic level (expressed as chlorophyll concentration) showed the known dependence on the lakes' mean depth (inverse function with r^2 of 0.69). All lakes with a mean depth > 5 m were oligo- or mesotrophic.
- Phosphorus limitation can be assumed for Nogoon, Üüreg, Bayan Nuur and Seepage Lake, as indicated by the chlorophyll to phosphorus ratio.
- Nitrogen seems to be the limiting resource in shallow lakes with higher trophic level (lagoon 2 at Üüreg Nuur, Shavart and possibly Baga Nuur) as indicated by TN:TP ratios and the differences between the components of TSI (Fig. 49).
- In the shallow Baga Nuur and the eastern bay of Uvs Nuur, the high mineral turbidity probably causes light limitation of phytoplankton growth.
- In Southern Baga Nuur and possibly the open water body of Uvs Nuur neither the macronutrients P and N nor light seem to be the limiting resources; co-limitation or lack of micronutrients (iron, manganese, molybdenum) could be assumed.

3.2.8 Sediments

The sediment samples taken from the lakes Baga, Bayan, Döröö, Seepage, Shavart, Southern Baga and Uvs have been characterized physically and chemically – see Table 28 and Fig. 51. The differences in grain size (qualitative), content of water, organic matter, calcium and carbonates are most obvious. They originate mainly from the intensity and frequency of wave exposure. The minimum water depth for stable depositions of cohesive fine sediment (mean particle size < 23 µm, water content > 60%) was calculated according to ROWAN et al. (1992). An alternative method is the calculation of the boundaries between zones of sediment erosion, transport and deposition according to HÅKANSSON & JANSSON (1983). The results of both methods are given in Table 27.

Table 27 Characteristics of sediment dynamics calculated with empirical models. Mean effective fetch for deepwater areas calculated according to HÅKANSSON & JANSSON (1983). Mud DBD = mud deposition boundary depth (equivalent to a sediment water content of 60%) calculated with formula (14) in ROWAN et al. (1992). BD E-T = boundary depth between erosion and transport of fine sediment (equivalent to a sediment water content of 50%), BD T-A = boundary depth between transport and accumulation of fine sediment (water content 75%), all according to HÅKANSSON & JANSSON (1983). Area E+T = percentage of lake bottom area affected by erosion and transport of fine sediment, calculated using hypsographic functions, values in brackets are estimated.

lake	max. depth [m]	eff. fetch [km]	Mud DBD [m]	BD E-T [m]	BD T-A [m]	area E+T [%]
Baga	1	0.8	> 1			100
Bayan	29	4	7.2	3.2	7.2	29
Döröö (W basin)	10	3	6.3	2.5	5.6	(80)
Seepage	3	0.1	0.8	0.1	0.3	(20)
Shavart	3	0.7	1.9	0.6	1.5	(60)
Southern Baga	3	1	2.3	0.9	2.0	(70)
Üüreg	42	12	11.0	7.9	16.4	(26)
Uvs	22	55	23.6	18.7	32.9	100

Table 28 Organoleptic characteristics of lake sediment samples.

sampling place, water depth, date		organoleptic characteristics
Uvs-NW, 7m	08/18/98	dark medium sand, low water content, crumbly, not layered, no smell; no benthos
Uvs-NW, 12m	08/13/97	well oxidized medium sand layered with sapropel; very few zoobenthos
Uvs-NW, 15m, upper layer	08/18/98	light brown silty soft sediment layer of some cm with higher water content, no smell
Uvs-NW, 15m, lower layer	08/18/98	brownish sand with lower water content, without smell
Uvs-E, 2m	08/23/98	blackish gray, sandy silt with much CPOM, very heterogeneous, weak H_2S smell
Uvs-SW, 3m	08/27/97	black sapropel, distinct H_2S smell (only in lentic area behind gravel bar); no zoobenthos
Uvs-SW, 1m	08/20/99	fine gravel, compact, with few small roots and other CPOM
Bayan, 6m	08/28/98	dark gray compact sandy mud, much CPOM, very weak H_2S smell; much zoobenthos
Bayan, 15m	08/23/97	light brown, very viscose sapropel with distinct H_2S smell
Bayan, 17m	08/28/98	light brown, viscose fine sandy mud with high water content and slight H_2S smell
Döröö, 2m	08/25/98	black sandy mud, low water content, some CPOM, slight H_2S smell; much zoobenthos
Döröö, 9m	08/25/98	reddish brown gel-like silty mud, high water content, weak H_2S smell; few zoobenthos
Seepage, 3m	08/28/97	light brown gel-like mud with calcite flakes on surface, weak H_2S smell; few zoobenthos
Shavart, 1m	08/26/99	gray brownish compact sand with low water content, without smell
Baga, 1m	08/18/98	light gray brownish, floccose mud with high water content; no zoobenthos
Southern Baga, 1m	08/21/99	greenish black gel-like mud, slight H_2S smell

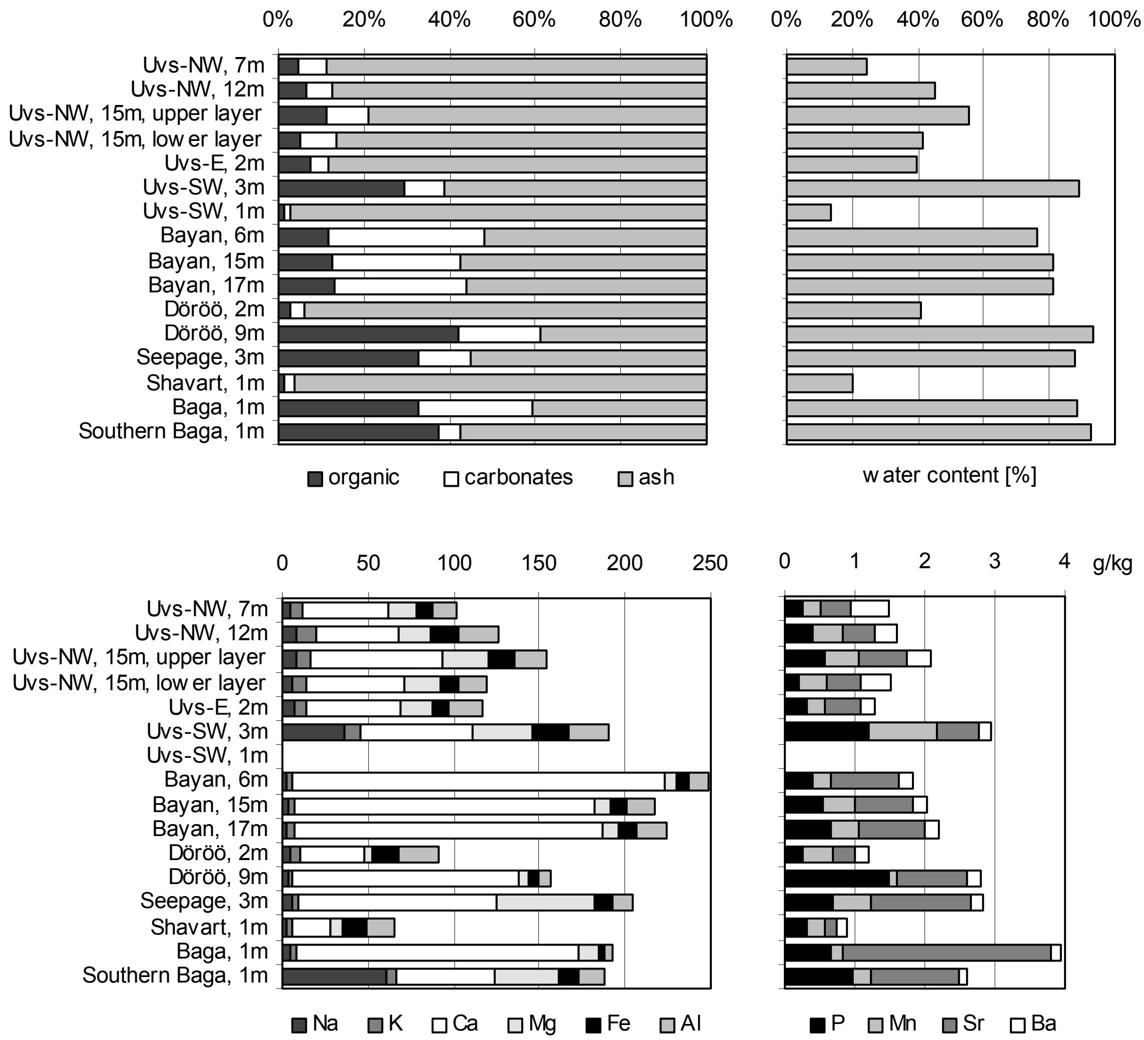


Fig. 51 Physical and chemical composition of lake sediment samples. Upper left: mass percentage of organic matter (= loss on ignition at 550°C), carbonates (= loss on ignition at 870°C multiplied by 1.36 according to HEIRI et al., 2001) and ash in the dry sediment; upper right: mass percentage of water in the fresh sediment; lower left and right: cation element content in the dry sediment [g/kg].

The sediments of **Uvs Nuur** at most sampling places were sandy and with low water and organic content. This indicates erosion of fine sediments at the sampling sites with a water depth of less than 15 m, according to the water content limits for erosional sites (< 50%) and sites with sediment transport (50–75%) of HÅKANSSON (1977). The upper, silty layer in the NW bay at 15 m depth with its water content of 55% indicated the beginning of a transition zone between erosion and transport of fine sediments. The main calcium mineral of this layer was Aragonite as IR spectroscopic examination showed (R. PÖTHIG, pers. comm.). The low organic content of most Uvs Nuur sediments was a sign of intensive oxic decomposition of detritus due to sediment resuspension and transport of fine sediment into the central area. Possibly the whole lake bottom of Uvs Nuur was affected by sediment resuspension, at least during the strongest storms. Exceptions were wave protected sites near the shore, allowing for the accumulation of organic rich sapropel. An example is a 3 m deep site at the SW shore, sheltered by a submerged gravel bar, where anoxic sediments with intensive sulfide formation were found. There seems to be a relocation of fine sediments towards the central lake bottom: WALTHER (1999) found in the surface layer (characterized as calcareous sapropel) of a sediment core taken 10 km offshore in the NW bay at 21 m depth an organic content of 20% and carbonate content of 30%, indicating much finer grain size than our samples.

All samples from **Bayan Nuur** were very rich in calcium carbonate and had a water content > 75%, indicating stable fine sediment deposition conditions in a water depth of at least 6 m and intensive precipitation of Calcite (confirmed by IR spectroscopy). KOSCHEL et al. (1983) found biogenic calcite precipitation and associated self-flocculation and enhanced precipitation of phytoplankton to be an important mechanism counteracting eutrophication in the hard water lake Breiter Luzin. In some places with groundwater inflow, larger, very porous Calcite chunks, probably formed by biogenic precipitation on Characeae, were found at the sediment surface. Calcified Characeae can contribute effectively to phosphorus removal from the water, as SIONG & ASAEDA (2006) found. In Döröö Nuur, the sample from 2 m depth near the reed belt was only representative for the littoral while the sample from 9 m depth with a high water and calcium content indicated stable fine sediment deposition and some calcium carbonate precipitation. Its high organic content indicated an increased productivity and a low intensity of decomposition processes.

The shallow **Baga Nuur**, **Southern Baga Nuur** and **Seepage Lake** had similar sediments with high water and organic content. Stable fine sediment deposition can be assumed for Seepage Lake and parts of Southern Baga Nuur. The floccose sediment in Baga Nuur had a high organic and calcium carbonate content. It was subject to frequent resuspension. As the whole lake was very shallow, no sediment focusing seemed to take place. In the small, slightly dystrophic Seepage Lake an undisturbed organic mud with some calcium minerals has formed. Southern Baga Nuur with its higher salinity and sulphate dominance had a sediment with low carbonate content and remarkably high sodium content, which gives a hint that Mirabilite ($Na_2SO_4 \cdot 10\ H_2O$) precipitation could take place. The IR spectrum of that sediment showed the presence of Calcite, Aragonite and a sulphate component, probably Mirabilite. As Mirabilite forms only at quite high salinity (solubility 45.6 g/l at 0°C), and Calcite and Aragonite do not form together in aqueous solution (K.-U. ULRICH, pers. comm.), some sediment components must have been formed at the shore and blown into the lake (R. PÖTHIG, pers. comm.). In fact, at the shore of Southern Baga Nuur a salt crust existed on the wet mud that consisted according to our measurements mainly of Mirabilite, one of the most common precipitates of salt lakes (HAMMER, 1986), and some $MgSO_4$.

When evaluating the sediment data, one must consider the hydrological situation: only Baga and Bayan and sometimes Seepage Lake had a surface outflow that allows export of particulate and dissolved substances; the amount of groundwater outflow from Döröö Nuur is unknown. Export of substance other than water from Uvs Nuur is virtually not existent. Thus, the sediment characteristics reflect the sum of imported suspended substances, and the chemical equilibria in the lake, transforming imported dissolved substances into precipitates. Lakes fed by groundwater of medium ionic strength (and sometimes increased SRP concentration – see 3.3.2) like Baga, Bayan and Döröö Nuur that received no suspended sediment from rivers tended to have autochthonous calcareous sediment. Southern Baga Nuur seemed to be fed by groundwater of increased salinity where hydrogencarbonate is replaced by sulphate.

One important question is to what extent the sediments can contribute to the nutrient loading of the lakes' water. As no data on nitrogen are available, it was only attempted to estimate the phosphorus release potential. For reliable statements about it, fractionated extractions of fresh, undisturbed sediment are a well established method (GOLTERMAN, 2001; LUKKARI et al., 2007). As such data are not available, only an estimation using total concentrations of P and metals, sediment texture, resuspension intensity, pH, oxygen and other environmental conditions can be made. Most sediment TP concentrations were between 0.2 and 0.7 mg/g; only in Döröö Nuur (1.5 mg/g), Southern Baga Nuur (1.0 mg/g) and the sapropel at Uvs Nuur-SW (1.2 mg/g) somewhat higher concentrations were found. These values are in the lower range of published data for lake sediments that mostly are between 0.5 and 2 mg/g, extremes being 0.01 and 10 mg/g (DILLON & EVANS, 1992; JENSEN & ANDERSEN, 1992; LEBO et al., 1994; NÕGES & KISAND, 1999; KROGERUS & EKHOLM, 2003; HUPFER et al., 2005; KAPANEN, 2008; NIEMISTÖ et al., 2008).

Important determinants for sediment P concentration are the physical characteristics of the sediment: grain size, that correlates with water content, and organic content (NÕGES & KISAND, 1999). The large active surface of silt, clay and Calcite or Aragonite particles can adsorb much more PO_4 than sand, and much phosphorus is stored in organic substance. This is reflected by the good correlation for our sediment samples between P concentration and LOI at 550°C (organic substance) with an r^2 of 0.88 and water content with an r^2 of 0.60.

The roles of iron and calcium for the phosphorus retention capacity of lake sediments are discussed by GOLTERMAN (1998), NÕGES & KISAND (1999) and SØNDERGAARD et al. (2003). GOLTERMAN shows that P bonding in calcareous sediments depends on the level of external P loading and pH: first the Fe(OOH) bonding capacity is saturated, at higher P loadings $CaCO_3 \approx P$ forms. At pH 9 $CaCO_3 \approx P$ dominates while at pH 7 and the same P loading Fe(OOH)≈P and free PO_4 dominate. NÕGES & KISAND found the highest proportion of Ca-bound P in sandy sediments with low water content, while Fe- and Al-bound P dominated in organic soft sediments. SØNDERGAARD states that the phosphorus retention of oxic sediments is high as long as the Fe:P mass ratio is above 15. This would be the case for all sediment samples except the organic rich samples from Döröö, 9 m (Fe:P 4), Baga Nuur (5) and Southern Baga Nuur (12). However, in lakes with high sulphate concentration the availability of iron for phosphorus retention can be much lower due to FeS formation (HUPFER & LEWANDOWSKI, 2008). It is accepted that the release potential of calcium bound sediment P under natural conditions is much lower than that of P bound to iron or adsorbed to clay particles (GUNATILAKA et al., 1988).

The influence of pH depends on the sediment composition: OLILA & REDDY (1995), JENSEN & ANDERSEN (1992) and KOSKI-VÄHÄLÄ & HARTIKAINEN (2001) found increased P release rates at pH 9 compared with pH 7 in soft organic mud sediments where most phosphorus was bound to iron, aluminum and organic substance. HUPFER & LEWANDOWSKI (2008) point to calcite formation, P co-precipitation and hydroxylapatite formation in calcareous sediments at high pH as P binding mechanism, and calcite dissolution together with P desorption when the pH decreases.

Sediment resuspension in shallow lakes with high pH can cause release of iron bound P from clay particles under aerobic conditions, whereas calcium bound P is rather inactive. The actual release rate depends on the equilibrium conditions between sediment and water, i.e. release is more likely when P-rich sediment is suspended in water with low P concentration (KOSKI-VÄHÄLÄ & HARTIKAINEN, 2001; SØNDERGAARD et al., 2003).

Summarizing our measurements with findings in the literature, it can be concluded that

- large sediment areas in Uvs, Baga, Southern Baga, Shavart and Döröö Nuur are affected by wind-driven resuspension while in Bayan, Üüreg Nuur and Seepage Lake (and surely in the deep alpine Khukhu and Nogoon Nuur too) areas of undisturbed profundal sediment dominate,
- allochthonous mineral particles are dominating in the sediments of Uvs and Shavart Nuur. The sediment of Bayan Nuur is dominated by autochthonous calcite, while Baga, Southern Baga, Döröö Nuur and Seepage Lake have sediments with high content of autochthonous organic substance and varying content of autochthonous carbonates (or sulphate in the case of Southern Baga Nuur),
- all analyzed sediments are sufficiently rich in calcium and (with the exception of Baga and Döröö Nuur) iron for high phosphorus retention,
- the probability and intensity of phosphorus release from the sediment seems highest in organic sediments with comparably low iron and calcium content like in Döröö, Southern Baga and some near-shore areas of Uvs Nuur.

3.2.9 Aquatic biota

3.2.9.1 Phytoplankton

Phytoplankton biovolume, composition and diversity were determined for nine lakes. The data are summarized in Fig. 52, and Table 29 gives an overview of the most important species in each lake. As for most lakes only data from one sample are available and seasonal variability is not covered, generalizations must be made with care, especially for eutrophic lakes where the annual succession was particularly strong. Furthermore, the quotient between fluorometrically measured chlorophyll and biovolume can vary over a wide range depending on taxonomic composition, size distribution and light conditions of the phytoplankton (ALPINE & CLOERN, 1985; KASPRZAK et al., 2008). Thus one cannot expect a very good correlation between chlorophyll which is the most often used measure of trophic state, and biovolume values. In the following, the phytoplankton composition of the investigated lakes will be outlined.

Nogoon Nuur with its very low concentration of nutrients and dissolved solids, water temperatures below 10°C and a deep thermocline brought about a species assembly that was completely different from all other sampled lakes. Oligotraphentic freshwater species from several taxonomic groups were found: dominating *Cyclotella sibirica*, *C. radiosa*, mixotrophic *Gymnodinium helveticum* and several flagellates of the genera *Ochromonas* and *Chlamydomonas*, and picoplanctic Cyanobacteria.

In **Üüreg Nuur** the coiled filamentous Cyanobacterium *Planktolyngbya contorta* which is typical for many sub- and mesosaline lakes in the northern hemisphere (HAMMER, 1986), was with a proportion of 75% by far the dominant species. Aside from *Cyclotella sp.* and some Chroococcales there were little more phytoplankton species found in this lake. Consequently the diversity index Hs for biovolume was the lowest of all lakes. The proportion of easily edible small nannoplankton was remarkably low.

In **Uvs Nuur**, with the exception of the less saline eastern bay, Cyanobacteria (*Planktolyngbya contorta*, *Coccopedia limnetica* and *Merismopedia* spp.) had the highest biovolume proportion, too. Other important species were the Chlorococcales *Monoraphidium minutum* and *Tetrachlorella incerta*, and the Chroococcales *Aphanothece* cf. *bachmannii* and *Merismopedia warmingiana*. The proportion of Chlorococcales obviously increased towards the shores, especially in the less salty, mesotrophic eastern bay where *Monoraphidium minutum* had the highest biovolume proportion, and with *Gymnodinium* sp., *Nitzschia* sp. and *Ochromonas* sp. some other groups became more abundant. Halophilic diatoms (e.g. *Chaetoceros wighamii*, *Cyclotella choctawhatcheeana*, *Campylodiscus bicostatus*, *C. clypeus*, *Entomoneis alata*, *E. paludosa* and *Mastogloia* spp.) were found at all three sampling places, yet with low abundance. The taxonomic groups Chrysophyceae, Conjugatophyceae, Euglenophyta and Xanthophyceae were missing completely in Uvs Nuur as well as in Üüreg and Southern Baga Nuur. This may be due to the unfavorably high salinity.

Table 29 Dominant phytoplankton species (according to biovolume) of nine lakes.

sampling place	species and their biovolume proportion
Nogoon Nuur	*Cyclotella sibirica* (37%), cf. *Ochromonas* spp. (27%), *Gymnodinium helveticum* (18%), *Cyclotella radiosa* (8%), *Rhodomonas* sp. (5%)
Üüreg Nuur	*Planktolyngbya contorta* (75%), *Cyclotella radiosa* (12%), *Merismopedia warmingiana* (4%), *Coelomoron* sp. (4%), *Merismopedia* sp. (2%), *Aphanothece* cf. *bachmannii* (1%), *Oocystis marina* (1%), *Amphikrikos nanus* (1%)
Uvs Nuur-NW	*Planktolyngbya contorta* (72%), *Monoraphidium minutum* (10%), *Tetrachlorella incerta* (8%), *Amphikrikos nanus* (3%), *Coccopedia limnetica* (2%), *Cyclotella caspia* (2%), *Aphanothece* cf. *bachmannii* (2%), *Oocystis marina* (1%)
Uvs Nuur-SW	*Planktolyngbya contorta* (54%), *Tetrachlorella incerta* (15%), *Monoraphidium minutum* (14%), *Amphikrikos nanus* (5%), *Aphanothece* cf. *bachmannii* (4%), *Coccopedia limnetica* (3%), *Oocystis submarina* (2%), *Oocystis marina* (1%)
Uvs Nuur-E	*Monoraphidium minutum* (26%), *Planktolyngbya contorta* (18%), *Gymnodinium* sp. (16%), *Tetrachlorella incerta* (9%), *Lagerheimia genevensis* (6%), *Nitzschia* sp. (5%), *Merismopedia* sp. (4%), *Schizochlamydella* sp. (4%), *Merismopedia warmingiana* (4%)
Bayan Nuur	*Ceratium hirundinella* (24%), *Cyclotella ocellata* (20%), *Peridiniopsis borgei* (17%), *Anabaena minderi* (9%), cf. *Ochromonas* (12%), *Synechocystis crassa* (5%), *Fragilaria ulna* (3%), *Peridiniopsis elpatiewskyi* (2%)
Döröö Nuur	*Aphanocapsa* cf. *elachista* (60%), *Aphanothece clathrata* (9%), *Coelomoron* sp. (9%), *Oocystis submarina* (3%), *Ceratium hirundinella* (3%), *Peridiniopsis borgei* (2%), *Tetraedron minimum* (2%), *Cyclotella radiosa* (2%), *Rhodomonas* sp. (1%)
Southern Baga Nuur	*Synechocystis salina* (42%), *Oocystis submarina* (17%), Chlorococcales indet. (15%), *Schizochlamydella* sp. (14%), *Oocystis* sp. (10%), cf. *Choricystis* (1%)
Seepage Lake	*Peridiniopsis borgei* (45%), *Tetraedron minimum* (17%), *Lagerheimia* cf. *cingula* (10%), *Cyclotella radiosa* (6%), *Schizochlamydella* sp. (6%), *Coelomoron pusillum* (3%), *Cosmarium subtumidum* (3%), *Lagerheimia genevensis* (2%), *Rhoicosphenia abbreviata* (2%), *Peridinium umbonatum* (2%)
Baga Nuur	*Rhabdoderma* cf. *tenuissimum* (34%), *Peridiniopsis borgei* (33%), *Synechocystis salina* (7%), *Planktolyngbya contorta* (5%), *Komvophoron* cf. *pallidum* (4%), *Peridinium umbonatum* (4%), *Anabaena* sp. (1%)
Shavart Nuur	*Planktolyngbya contorta* (22%), *Aphanocapsa* sp. (19%), *Merismopedia* sp. (19%), *Merismopedia warmingiana* (11%), *Monoraphidium contortum* (7%), cf. *Choricystis* (6%), *Monoraphidium tortile* (4%), cf. *Ochromonas* (3%), *Kirchneriella* sp. (2%)

The phytoplankton of **Bayan Nuur** was quite diverse as well taxonomically as functionally. It was characterized by a co-dominance of Dinophyta (*Ceratium hirundinella*, *Peridiniopsis borgei*, *Peridinium umbonatum*), Bacillariophyceae (*Cyclotella ocellata*, *Fragilaria ulna*, *Cyclotella radiosa*) and Cyanobacteria (*Anabaena minderi*, *Synechocystis crassa*), changing slightly from year to year. Subdominant groups with some interesting species were Chrysophyceae (*Ochromonas*-type, *Dinobryon sociale* var. *americanum*, *Epipyxis* cf. *alata*), Chlorophyceae and Cryptophyta. Flagellates able to migrate to higher nutrient concentrations in the metalimnion consequently were of high significance in this lake.

Döröö Nuur that had much similarity with Bayan Nuur with respect of chemical composition and trophic state, had a very different phytoplankton composition: it was absolutely dominated by small-celled Chroococcales (*Aphanocapsa* cf. *elachista* with 60% biovolume, *Aphanothece clathrata*, *Coelomoron* sp.) forming gelatinous colonies. This seems to be an indication of high zooplankton grazing pressure as these colonies were not easily edible by the Cladocera dominating here. As subdominant taxa some Chlorococcales and Dinophyceae (*Ceratium hirundinella*, *Peridiniopsis borgei*) were found.

The mesosaline **Southern Baga Nuur** was dominated by the unicellular *Synechocystis salina*, together with *Oocystis submarina*, *Oocystis* sp., *Schizochlamydella* sp. and an undetermined Chlorococcal. The dominance of easily edible coccal types is astonishing when considering the high zooplankton biomass (3.2.9.2). The production rate of the comparably low phytoplankton standing crop must have been high as the oxygen saturation on the calm sampling day was at 129%.

In the subsaline, mesotrophic **Seepage Lake**, a high number of phytoplankton species was found; the SHANNON diversity index (calculated for cell numbers) was the highest of all investigated lakes. Chlorococcales (*Tetraedron minimum*, *Lagerheimia* spp., *Oocystis* spp., *Scenedesmus* spp. and others) and Dinophyceae (*Peridiniopsis borgei*, *Peridinium umbonatum*) were dominant; Bacillariophyceae, Cyanobacteria, Desmidiaceae, Chrysophyceae and Cryptophyta played a minor role. The species composition was a mixture of mesotraphentic, mostly halotolerant freshwater species and, with low abundance, some halophilic species that were found in Uvs Nuur, too (*Oocystis marina*, *O. submarina*, *Entomoneis paludosa*, *Mastogloia braunii*).

Table 30 Phytoplankton assemblages in the investigated lakes: functional groups according to REYNOLDS et al. (2002).

lake	group code	description of habitat	typical phytoplankton taxa
Nogoon	A, E	mixed, oligotrophic, low salinity lakes	*Cyclotella*, Chrysophyceae
Üüreg	S_1	turbid, deeply mixed lakes	*Planktolyngbya contorta*
Uvs-NW	S_1	turbid, deeply mixed lakes	*Planktolyngbya contorta*
Uvs-E	S_1, X_1	turbid, eutrophic, mixed lakes	*P. contorta*; *Monoraphidium*
Bayan	L_O, H_2	large, mesotrophic, N-deficient lakes	*Peridinium*, *Ceratium*, *Merismopedia*; *Anabaena*
Döröö	K(?), L_O	shallow, large, meso-eutrophic lakes	*Aphanothece*, *Aphanocapsa*; *Ceratium*, *Peridinium*
Southern Baga	-	association governed by salinity	
Seepage Lake	J, X_1	shallow, mixed, eutrophic ponds	*Pediastrum*, *Scenedesmus*; *Monoraphidium*
Baga	K, H_1	shallow, eutrophic, N-deficient lakes	colonial Chroococcales; *Anabaena*
Shavart	K, S_1, X_1	shallow, eutrophic, turbid, mixed lakes	*Aphanocapsa*; *P. contorta*; *Monoraphidium*

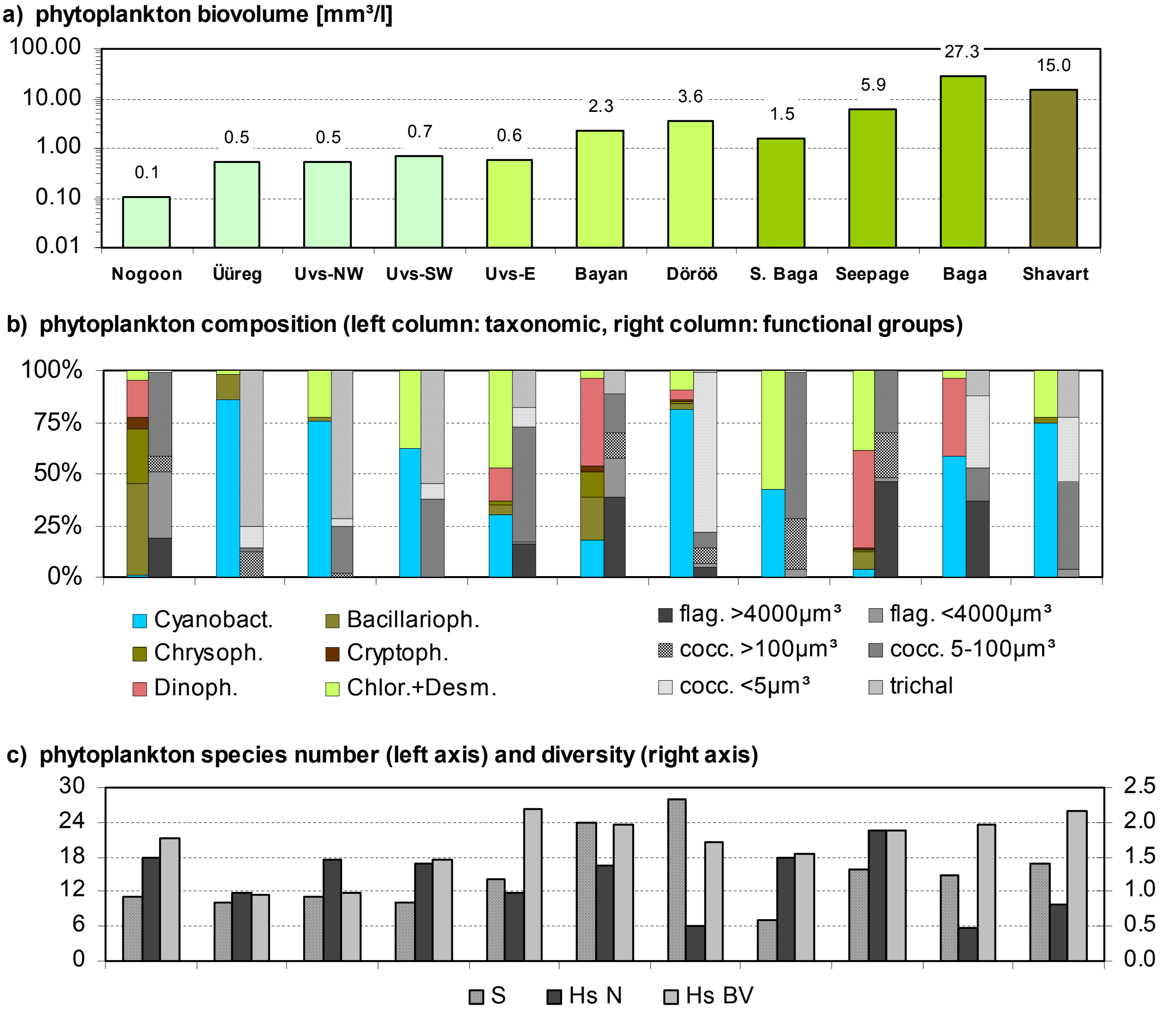


Fig. 52 a Biovolume of phytoplankton in nine lakes. Lakes are sorted according to increasing trophic state which is indicated by the colors of the columns.
b Phytoplankton composition (biovolume percentage of major taxonomic and functional groups) of these lakes. Chlorophyceae and Desmidiaceae are shown together as the latter had only an insignificant proportion. Functional groups were flagellates, coccal and trichal forms of different size classes.
c Number of dominant species S (those covered by counting; left axis) and diversity index (right axis). The Shannon-Weaver diversity index Hs (SHANNON & WEAVER, 1949) was calculated for cell numbers (Hs N) and for biovolume (Hs BV).

The phytoplankton of **Baga Nuur** was mainly a mixture of Cyanobacteria (*Rhabdoderma* sp., *Anabaena* sp., *Synechocystis salina*, *Planktolyngbya contorta*) and Dinophyta (*Peridiniopsis borgei*, *Peridinium umbonatum*). The size spectrum of these algae – only *Synechocystis* and some less abundant taxa were of edible size for the dominating Rotifera – suggests low grazing pressure. The dominant *Rhabdoderma* has a very efficient carbonic anhydrase system capable of maintaining a high intracellular concentration of CO_2 at increased pH and salinity (DUDOLADOVA et al., 2007). It seems to be responsible for the very high pH value of 10.1 measured in the lake in 1998.

In **Shavart Nuur**, similarly to Uvs Nuur-E, trichal and colony-forming halophilic Cyanobacteria (*Planktolyngbya contorta*, *Aphanocapsa* sp., *Merismopedia* spp.) were most important, accompanied by eutraphentic Chlorococcales (*Monoraphidium* spp., cf. *Choricystis*, *Kirchneriella* sp., *Scenedesmus* spp.) and few flagellates (*Ochromonas* sp., *Ceratium hirundinella*).

Other systematic algological investigations in lakes of the Uvs Nuur Basin are rare: NAUMENKO (1999) gives an overview of the planktic and benthic algae of the mesosaline lake Bai-Khol (area 3 km^2) which is located in the Russian part of the Uvs Nuur Basin some 15 km northwest of the settlement of Erzin. Green algae seem to play only a minor role, cyanobacteria and diatoms were dominating among the 79 taxa found. In NAUMENKO (2003), benthic and planktic algal taxa found in August 1993 and 1994 at the shore of the northern bay of Uvs Nuur are dealt with in greater depth. He lists 155 taxa of Bacillariophyceae, 37 Cyanobacteria, and a few Dinophyta, Euglenophyta and Chlorophyta. Astonishingly, he did not find such dominant taxa as *Planktolyngbya contorta*, *Coccopedia*, *Aphanothece* or any Chlorococcales (besides one *Scenedesmus* species). In SHINNEMAN (2008) diatom species which were found in recent sediment cores of Western Mongolian lakes, among others Bayan, Üüreg and Uvs Nuur, are listed. Unfortunately, the species list is given only for the whole lake dataset.

Some peculiarities common to the phytoplankton of all lakes are discussed in the following.

The range of total biovolume between 0.1 and 27 mm^3/l reflects the different trophic states quite well, however with some exceptions: Uvs Nuur-E had lower biovolume than expected, probably due to light limitation by suspended mineral solids; in Southern Baga Nuur the very low biovolume can be seen as a sign of possible micronutrient limitation (Fe, Mn – see 3.2.7) and high zooplankton grazing pressure (see 3.2.9.2). In contrast, the very high biovolume in Baga Nuur can be partially explained by the low grazing pressure of the zooplankton which consists only of Rotifera; underestimation of chlorophyll due to mineral turbidity is another possibility.

The phytoplankton of lakes Baga, Döröö, Southern Baga, Shavart, Uvs and Üüreg (all with pH $\geq$ 9 and/or possible N-limitation) was more or less dominated by Cyanobacteria. This dominance seems to be independent of the trophic state. Numerous studies try to explain cyanobacterial dominance in lake phytoplankton with the following factors: increased nutrient concentrations, low N:P ratio, low light intensity, the ability to float and form surface scums, low edibility, high pH and low CO_2 concentration (SHAPIRO, 1984, 1990, 1997; SMITH, 1986; BLOMQVIST et al., 1994; SCHEFFER et al., 1997; WATSON et al., 1997; LEVINE & SCHINDLER, 1999; DOKULIL & TEUBNER, 2000; DOWNING et al., 2001; FERBER et al., 2004; LÓPEZ-ARCHILLA et al., 2004). As suggested by SHAPIRO (1990), the most important factor for the success of Cyanobacteria is their superior capability to use HCO_3 as source of inorganic carbon at high pH values. In eutrophic lakes the high phytoplankton productivity can drive the pH up to values above 9 while in oligotrophic salt lakes the pH has values around 9 due to their ionic composition.

Green algae (mainly Chlorococcales, only few Volvocales and Ulothrichales) were the second important group in most lakes. Their proportion tended to increase with increasing trophic state in lakes with not too high pH value. Another important group in fresh and hyposaline lakes were Dinophyceae, represented by *Ceratium hirundinella* and different *Gymnodinium*, *Peridinium* and *Peridiniopsis* species. In the Uvs Nuur Basin Chrysophyceae and (to a lesser extend) Cryptophyceae seemed to be restricted to oligo- and mesotrophic freshwater lakes. As WATSON et al. (1997) found, their relative biomass contribution tends to be less than 10% at TP concentrations above 20 to 40 µg/l. Bacillariophyceae that play a major role in many lakes of the temperate climatic zone were only of secondary importance. This is, however, only true for the phytoplankton biomass; the number of species was highest in Diatoms and Chlorococcales. Diatoms, mainly of the genera *Cyclotella* and *Fragilaria*, reached their highest proportion in the freshwater lakes Nogoon and Bayan, but were also present in the salt lakes Uvs and Üüreg. The total phytoplankton species number of the saline lakes Uvs, Üüreg and Southern Baga was significantly lower than that of the mesotrophic freshwater or subsaline lakes Bayan and Döröö.

The quite high dissimilarity of phytoplankton species composition among closely neighboring lakes as Uvs Nuur, Baga Nuur, Southern Baga Nuur and Seepage Lake seems to be due to differences in salinity, trophic state and morphology – similar to the situation described by RODRIGO et al. (2003) for Mediterranean coastal ponds.

Trying to find functional phytoplankton assemblages in the sense of REYNOLDS et al. (2002) leads to the summary in Table 30. For most lakes no single typical association could be assigned. This may indicate transitions between seasonal associations. However, as some of the abiotic conditions (short vegetation period, increased salinity and turbidity) were quite different from that of lakes in the less continentally influenced temperate zone, there might be the need for special subtypes which would require more data and samples over the whole vegetation period.

3.2.9.2 Zooplankton

A summary of zooplankton biomass and diversity as determined in nine lakes is given in Fig. 53, and an overview of the dominant species in each lake in Table 31. The total number of determined planktic protozoan taxa was 14 (4 Rhizopoda, 4 Choanoflagellata, 6 Ciliophora); a total of 29 rotiferan species was found. In the crustacean zooplankton and –benthos 38 cladoceran and 16 copepod species were found, among them 12 new findings for Mongolia; *Cyclops glacialis* FLÖßNER was described as new species (FLÖßNER, 2001). A complete overview of planktic and benthic Cladocera and Copepoda with some taxonomical and morphological remarks is given in FLÖßNER et al. (2005). The species compositions for individual lakes were quite different, and characteristic for the lake types. They are summarized in the following.

In **Nogoon Nuur** only a few species, mostly characteristic for high alpine lakes were found: *Daphnia pulicaria*, *Arctodiaptomus alpinus* (new for Mongolia) and the newly described *Cyclops glacialis* were dominating. They were accompanied by *Daphnia galeata*, three ubiquitous freshwater rotiferan species and quite large specimens of *Gammarus lacustris* that were found in the plankton of this (most probably) fishless lake. Morphometric data suggest that Nogoon Nuur exists since the last glaciation, i.e. for some 10 000 years. Thus, *Cyclops glacialis* could have had enough time to evolve from an isolated ancestor population. It is questionable if this species is endemic to only this lake, and FLÖßNER (2001) supposes it to be present in other alpine lakes of the area, but hitherto no record was made.

From the small **alpine lake near Turgen Gol**, situated near Nogoon Nuur, but only some meters deep, only qualitative samples were taken. This lake seems to be fishless, too, as *Branchinecta orientalis* SARS was found there. It is a rare, but widespread anostracan species with a Palaearctic distribution from the Iberian Peninsula to eastern Mongolia, living in fishless fresh to slightly saline stagnant waters in the lowland and alpine areas (HORN & PAUL, 2004); ZHAO & HE (1999) found the species in small hyposaline lakes in northern China. Other crustaceans were *Daphnia zschokkei* (new for Mongolia), *D. pulicaria*, *Chydorus sphaericus* and *Acanthodiaptomus denticornis* (new for Mongolia) – mostly cold-stenothermic alpine species.

The zooplankton of the large **Üüreg Nuur** was surprisingly species-poor and had (like with phytoplankton) the lowest diversity index of all sampled lakes. There was a strong dominance of *Arctodiaptomus salinus* that only was accompanied by *Megacyclops viridis* and four rotiferan species. This may partly be due to the phytoplankton structure which offers few food for filter feeders. In the highly eutrophic and very shallow lagoon 2 at the shore of Üüreg Nuur two more species were found: *Daphnia magna* and *Eucyclops serrulatus*.

Table 31 Dominant zooplankton species (in terms of dry weight) of nine lakes.

sampling place	species and their biomass proportion
Nogoon Nuur	*Arctodiaptomus alpinus* (56%), *Cyclops glacialis* (24%), *Daphnia pulicaria* (20%), *Kellicottia longispina* (0.4%)
Üüreg Nuur	*Arctodiaptomus salinus* (99%), *Megacyclops viridis* (1%), *Hexarthra fennica* (0.1%)
Uvs Nuur	*Arctodiaptomus salinus* (62%), *Brachionus plicatilis* (25%), *Hexarthra fennica* (10%), *Mesocyclops leuckarti* (1%), *Moina salina* (1%), *Brachionus quadridentatus* (0.1%)
Bayan Nuur	*Arctodiaptomus salinus* (53%), *Cyclops vicinus* (19%), *Daphnia* x *krausi* (9%), *Diaphanosoma mongolianum* (8%), *Mesocyclops leuckarti* (6%), *Leptodora kindtii* (2%), *Bosmina fatalis* (1%), *Keratella cochlearis* (1%), *Scapholeberis rammneri* (0.2%), *Asplanchnella* cf. *brightwelli* (0.2%)
Döröö Nuur	*Ceriodaphnia pulchella* (36%), *Daphnia galeata* (23%), *Arctodiaptomus salinus* (19%), *Acanthodiaptomus denticornis* (13%), *Bosmina longirostris* (4%), *Mesocyclops leuckarti* (2%), *Diaphanosoma mongolianum* (2%), *Cyclops vicinus* (1%), *Keratella cochlearis* (0.2%)
Southern Baga Nuur	*Arctodiaptomus salinus* (63%), *Moina salina* (36%), *Hexarthra fennica* (1%), *Brachionus plicatilis* (0.2%)
Seepage Lake	*Bosmina longirostris* (29%), *Ceriodaphnia pulchella* (22%), *Mesocyclops leuckarti* (16%), *Filinia longiseta* (9%), *Asplanchnella* sp. (5%), *Asplanchnella* cf. *brightwelli* (5%), *Polyarthra vulgaris* (5%), *Arctodiaptomus salinus* (3%), *Hexarthra mira* (2%), *Brachionus angularis* (1%), *Keratella quadrata* (1%), *Hexarthra fennica* (1%)
Baga Nuur	*Filinia longiseta* (42%), *Hexarthra fennica* (21%), *Brachionus plicatilis* (17%), *Lepadella patella* (10%), *Hexarthra oxyuris* (4%), *Mesocyclops leuckarti* (1%), *Lecane luna* (1%), *Tripleuchlanis* sp. (1%), *Brachionus quadridentatus* (1%), *Synchaeta* sp. (0.4%), *Polyarthra vulgaris* (0.2%)
Shavart Nuur	*Arctodiaptomus bacillifer* (83%), *Thermocyclops kawamurai* (10%), *Keratella* sp. (3%), *Daphnia longispina* (2%), *Hexarthra mira* (1%), *Brachionus plicatilis* (1%)

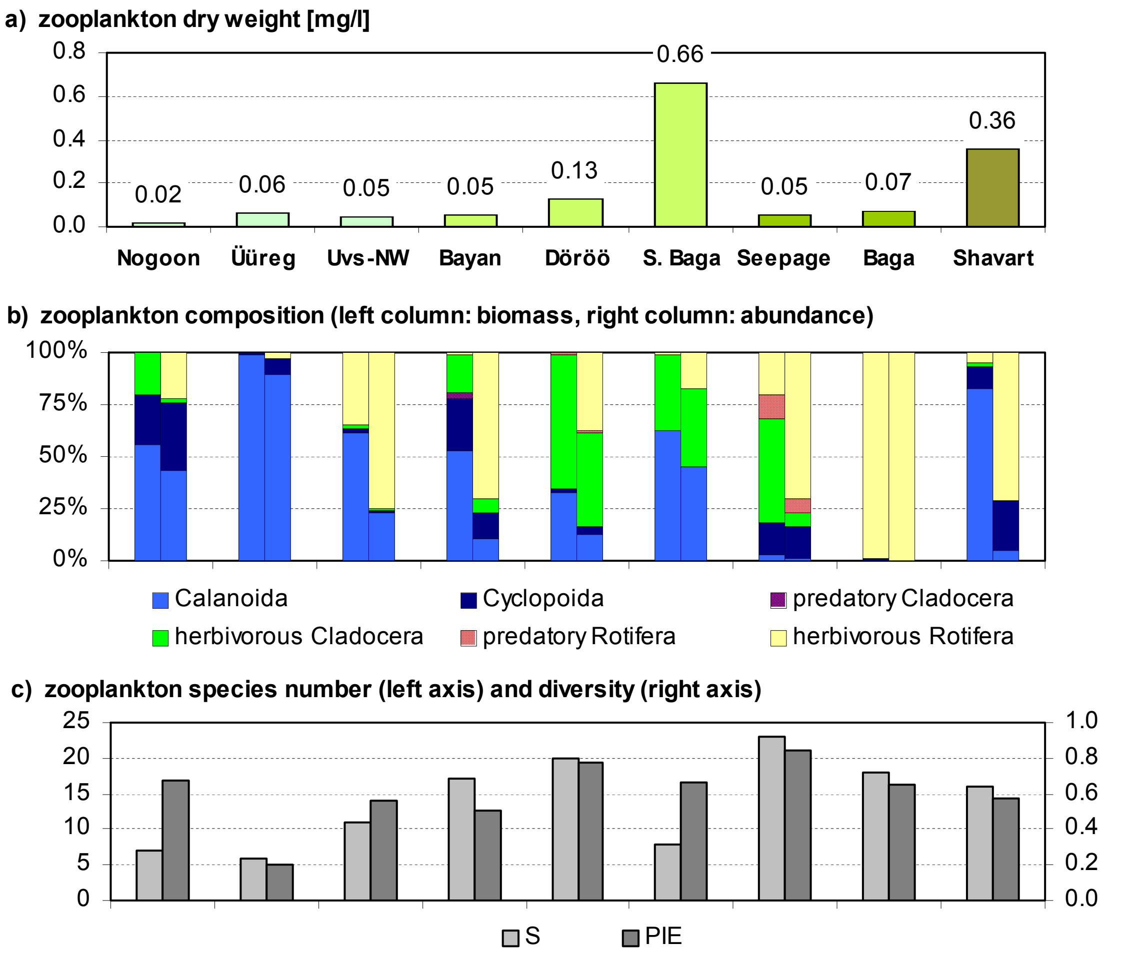


Fig. 53 a Biomass (mean values of dry weight) of zooplankton in nine lakes, **b** zooplankton composition (major taxonomic and functional groups), **c** zooplankton species number and diversity. Lakes are sorted according to increasing trophic state which is indicated by the colors of the columns in Fig. c. The diversity index PIE (Probability of Interspecific Encounter; right axis) was calculated using abundances according to HURLBERT (1971).

In **Uvs Nuur**, the zooplankton had a considerably higher species number and diversity. This may be partially due to the fact that it was investigated with higher intensity than most other lakes. *Arctodiaptomus salinus* was the dominating species here, too, however less strong, and accompanied by the Rotifera *Brachionus plicatilis* and *Hexarthra fennica* with a high biomass proportion. These two rotifers are cosmopolitan inhabitants of saline and brackish waters with a minimum salinity of 1 g/l, feeding on various algae with a preferred size less than 15 µm (WALKER, 1981; HAMMER, 1986). Furthermore, seven additional rotiferan species (mainly Brachionidae), the planktic cladoceran *Moina salina* (of which the name *M. mongolica* cited by DULMAA is a junior synonym – NEGREA, 1984), two benthic cladocerans (*Alona rectangula* and *A. elegans* – the latter new for Mongolia) and three cyclopoid species (*Megacyclops viridis*, *Mesocyclops leuckarti* and *Acanthocyclops robustus*) were found. All species (except *Kellicottia longispina*) are known from athalassic saline waters (HAMMER, 1986), although some exceed the cited salinity maximum. Some protozoa that were found in the plankton are the thecamoebae *Cyphoderia ampulla* and *Arcella hemisphaerica*.

The zooplankton of **Bayan Nuur** was quite diverse and had a unique composition: the dominating copepods were *Arctodiaptomus salinus*, *Cyclops vicinus* and *Mesocyclops leuckarti* – all halophilic species. They were accompanied by several filter feeding cladocerans (*Daphnia* x *krausi* which is new for Mongolia, *Diaphanosoma mongolianum* and *Bosmina fatalis*) and the predatory *Leptodora kindtii*, all typical for large, deep freshwater lakes. Rotifers were not important – only *Keratella cochlearis*, *Polyarthra vulgaris*, *Collotheca* sp. and *Asplanchnella* sp. were found. Some Protozoa were present in the plankton, most interesting are two choanoflagellates – *Desmarella* sp. and *Acanthocorbis mongolica*, the latter being new to the science (PAUL, 2012). It belongs to the mainly marine order Acanthoecida that form delicate, species-specific loricae of siliceous costae (LEADBEATER, 2008). It is the first of this group that was found in freshwater, and is probably endemic to Bayan Nuur. The benthic cladoceran fauna consisted of *Alona affinis*, *A. quadrangularis*, *Scapholeberis rammneri, Iliocryptus sordidus* and *Rhynchotalona falcata* (the latter two new for Mongolia).

Döröö Nuur with its high proportion of nannoplanktic Chroococcales supported a diverse zooplankton that showed no strong dominance of one species. It was one of the few investigated lakes with cladoceran dominance: *Ceriodaphnia pulchella* and *Daphnia galeata* reached the highest proportions and were accompanied by *Bosmina longirostris, Ceriodaphnia dubia* and *Diaphanosoma mongolianum*. Copepods were represented by *Arctodiaptomus salinus*, *Acanthodiaptomus denticornis*, *Mesocyclops leuckarti* and *Cyclops vicinus*. Rotifers were found with six species among which *Keratella cochlearis* and *Filinia longiseta* were most important. In the rich macrophyte and phytobenthos belt the benthic cladocerans *Acroperus harpae*, *Alona affinis*, *A. rectangula*, *Alonella nana*, *Chydorus sphaericus*, *Macrothrix rosea* (new for Mongolia), *Pleuroxus aduncus*, *Scapholeberis mucronata*, *S. rammneri* and *Simocephalus vetulus* were found.

In **Southern Baga Nuur** – most probably due to the high salinity – the species number was low: the halophilic crustaceans *Arctodiaptomus salinus* and *Moina salina* were dominating, all living in Uvs Nuur, too. *Hexarthra fennica*, *Brachionus plicatilis* and four further halophilic rotiferan species were found in low abundances. The very high zooplankton biomass stands out among all investigated lakes. The plankton of this fishless lake seemed to be in a condition that resembles that of biomanipulated lakes: high biomass of large, effective grazers and low phytoplankton biomass in relation to the quite high nutrient concentrations (DE BERNARDI & GIUSSANI, 1995).

The zooplankton of **Seepage Lake** had no clear dominances: cladocerans (*Bosmina longirostris* and *Ceriodaphnia pulchella*) shared half of the biomass, Rotifera (*Filinia longiseta*, *Asplanchnella* spp., *Polyarthra vulgaris*, *Hexarthra* spp. and others) one third; copepods (*Mesocyclops leuckarti*, *Arctodiaptomus salinus*) were least important. Some Protozoa (*Arcella* sp., *Desmarella* sp. and *Salpingoeca* sp.) were recorded as well. The following benthic cladocerans were found: *Alona rectangula*, *Chydorus sphaericus*, *Iliocryptus sordidus* and *Simocephalus vetulus*. It shows that freshwater species were dominating here while some of the halophilic species were present too. The mesotrophic state and low, however fluctuating salinity seemed to be the reason for the highest zooplankton diversity of all investigated lakes.

The zooplankton of **Baga Nuur** had a very special composition – it consisted almost exclusively of Rotifera (16 species). The only crustaceans that were found are some *Bosmina longirostris*, *Alona rectangula* and *Mesocyclops leuckarti*. This might be due to predation by small planktivorous fish. Among the Rotifera *Filinia longiseta*, *Hexarthra fennica*, *Brachionus plicatilis*, *Lepadella patella* and *Hexarthra oxyuris* had the highest proportion. The extreme lack of large, efficient filterers seems to be one reason for the very high phytoplankton biomass in Baga Nuur – just the opposite condition of Southern Baga Nuur.

In **Shavart Nuur** the zooplankton biomass was quite high, too. It consisted mainly of copepods and Rotifera: *Arctodiaptomus bacillifer* and *Thermocyclops kawamurai* were the dominating species; among the Rotifera *Keratella* sp., *Hexarthra* spp. and *Brachionus plicatilis* were most important. Cladocerans did not reach high biomass, but were found with five species (*Daphnia longispina*, *D. galeata*, *D. magna, Bosmina fatalis* and *Diaphanosoma mongolianum*). Furthermore, *Gammarus lacustris* was found in the plankton near the shore which is an indication that the lake was probably fishless. The crustaceans were a typical assembly of eutrophic, saline waters (FLÖßNER et al., 2005). The species *Thermocyclops kawamurai* is new for Mongolia, but widely distributed in northern China (GUO, 1999).

Other, only qualitatively sampled, small ponds were rich in benthic cladocerans: The **oxbow ponds in the floodplain of Tesiyn Gol** (sampling places Tesiyn Gol-3.5a and 5.5) accommodated a wealth of Cladocera and Cyclopoida typical for small, weedy ponds: *Acroperus harpae*, *Alona affinis*, *Alonella excisa*, *Ceriodaphnia laticaudata*, *C. quadrangula*, *C. reticulata*, *C. rotunda*, *Chydorus sphaericus*, *Daphnia rosea*, *Scapholeberis mucronata*, *S. rammneri*, *Simocephalus exspinosus*, *S. vetulus*, *Cryptocyclops bicolor*, *Eucyclops denticulatus*, *Eucyclops macruroides* and *Megacyclops viridis*.

In the small, very shallow steppe lake **Togoo Nuur,** the crustacean species *Ceriodaphnia dubia*, *Daphnia longispina*, *Diaphanosoma brachyurum*, *Macrothrix laticornis*, *Acanthodiaptomus denticornis* and *Eucyclops serrulatus* were found.

Other data on zooplankton species from the area (aside from DULMAA, 1991a that is contained in Table 49) are quite rare: In BORUTZKY (1959) the following Calanoida species are mentioned for Northwest Mongolia: *Acanthodiaptomus denticornis* (Wierzejski), *Arctodiaptomus salinus* (Daday), *Arctodiaptomus anudarini* Borutzky, *Arctodiaptomus acutilobatus* (Sars), *Arctodiaptomus paulseni* (Sars), *Neutrodiaptomus incongruens* (Poppe), *Mixodiaptomus incrassatus* (Sars) and *Hemidiaptomus ignatovi* (Sars).

BRTEK et al. (1984) found in the freshwater lake Baga Nuur (located southwest of Bayan Nuur near the settlement of Zuungovi – see map) the following Branchiopoda species: *Ceriodaphnia reticulata* (JURINE), *Simocephalus vetulus elizabethae* (King), *S. exspinosus* (Koch), *Scapholeberis rammneri* Dumont & Pensaert, *Acroperus harpae* (Baird), *Oxyurella tenuicaudis* (Sars), *Pleuroxus truncatus* (O. F. Müller), *P. trigonellus* (O. F. Müller), *P. aduncus* (Jurine) and *Chydorus sphaericus* (O. F. Müller).

The general distribution of species was largely determined by salinity: of the 54 crustacean species, 23 were found only in freshwater lakes, 14 only in saline lakes, and 17 were found in fresh and saline waters. The most frequently found species were *Chydorus sphaericus*, *Alona affinis*, *Scapholeberis rammneri* and *Arctodiaptomus salinus* – all euryhaline species. The very low proportion or absence of Cyclopoida in the lakes Üüreg, Uvs and Southern Baga seems to be salinity related: BOS et al. (1996) found for Canadian salt lakes that Calanoida can live at higher salinities than Cyclopoida. The Rotifera did not show such a strong discrimination between freshwater and saline species – no species was only found in freshwater, and only three (*Notholca acuminata*, *N. marina* and *Encentrum* sp.) were exclusively found at salinities above 10 g/l. The Rotifera species number was highest in the shallow hyposaline steppe and lagoonal lakes (total 25 species) whereas in the deep freshwater lakes only seven species were found. Most of the Rotifera species found are distributed over the whole Palaearctic, or even cosmopolitan. Of the 11 Brachionidae species found in our samples, all but *Notholca marina* were also found in lakes of Inner Mongolia, northern China (RONG et al., 1998).

The total zooplankton biomass correlated less well with trophic state (in the sense of phytoplankton biomass) than with nutrient concentrations (see 4.1.2) which can be explained with strong grazing effects in fishless lakes. In the lakes Nogoon, Shavart and Southern Baga no fish were caught nor indications for the presence of fishes (fish-eating birds) seen; thus predation pressure on zooplankton can be assumed to be low. Still, Southern Baga Nuur had a strikingly high biomass which seems to be due to missing predation and well edible, highly productive phytoplankton (see 3.2.9.1). Extreme patchiness in the crustacean distribution cannot be ruled out, though, as the net samples were taken on a calm day at one single place of this big, shallow lake.

3.2.9.3 Benthos

Benthic algae, macrophytes and zoobenthos were not systematically surveyed along transects or shore stretches, but spot check sampled. Only information on large emergent macrophytes that were easily visible over great distances due to completely missing trees on the shore can be assumed to be nearly complete. Much more than for plankton, the number of benthic species found in a certain lake reflects to a large degree the intensity of sampling and determination effort. As most samples were taken from the eulittoral, many species inhabiting only the sublittoral and profundal were probably not found. Because of this incompleteness the results of phyto- and zoobenthos are not presented in separate chapters.

There is not much literature on benthic species for lakes of the Uvs Nuur Basin. NAUMENKO (2003) gives a list of planktic and benthic algal species from the northern bay of Uvs Nuur, mainly diatoms and Cyanobacteria. In SVIRIDENKO et al. (2007) the following Characeae are listed from Tere-Khol (= Russian part of Döröö Nuur, together with *Stuckenia pectinata*): *Chara altaica*, *Chara aspera* and *Chara vulgaris*. In a small shore lagoon of Tere-Khol, *Typha* sp., *Eleocharis palustris*, *Hippuris vulgaris*, *Potamogeton pusillus*, *Stuckenia pectinata*, *Myriophyllum spicatum* and *Lemna minor* were found by HILBIG & OPP (2007). Records of several zoobenthos species (though without exact location) from the center of the Uvs Nuur Basin are given by ZAIKA (1996) and DULMAA (1991a) – they are listed in Table 49.

SCHÖNEFELD et al. (2002) give a complete record of aquatic Hemiptera species from the research project described here, together with some remarks on their distribution. In the following, the benthic species inventory of the sampled lakes is summarized.

In the alpine lake **Nogoon** no macrophytes or macroscopic benthic algae were found; the zoobenthos consisted of three species that were found in the nearby Dshibertu Gol too: *Ameletus* sp. (Ephemeroptera), *Suwallia teleckojensis* (Plecoptera) and *Apatania* sp. (Trichoptera).

At the gravelly southern shore of **Üüreg Nuur** no phytobenthos was found; the zoobenthos consisted of *Gammarus lacustris*, *Ylodes* sp., Ephydridae and several Chironomidae (*Tanypus punctipennis*, *Cricotopus sylvestris*, *Chironomus* sp., *Cryptochironomus albofasciatus*, *Cryptotendipes darbyi*, *Cladotanytarsus* sp., *Tanytarsus gracilentus*). In contrast, the eutrophic **shoreline lagoons 1 and 2 at Üüreg Nuur** were overgrown with dense masses of *Mougeotia*, *Oedogonium* and *Utricularia* sp.; the zoobenthos was much more diverse: *Gammarus lacustris*, Heteroptera (*Paracorixa armata*, *P. concinna*, *Notonecta reuteri* and Corixinae), and Chironomidae were dominating; furthermore Hydrachnidia, some coleopteran species, Zygoptera, Trichoptera (Limnephilidae, *Ylodes reuteri*), Ceratopogonidae and Ephydridae were present.

The littoral zone in the NW bay of **Uvs Nuur** was fine gravelly and a typical lotic environment with strong wave action. Behind the first gravel bar the shore was bordered with shallow puddles and pools overgrown with halophilic vegetation and filamentous algae. The eulittoral was colonized by *Stuckenia pectinata* and few *Chara altaica*; *Cladophora glomerata* and other filamentous algae grew on pebbles, *Potamogeton* and sparse stalks of *Phragmites australis*. This vegetation zone ended at some meters depth because of the relatively poor light availability – in a sediment sample from seven meters depth no plant remainders were found. At the shallower sampling place Uvs Nuur-SW the shoreline und underwater relief were rich structured and somewhat sheltered from the waves. Therefore, the *Phragmites* stands were well developed, although eroded by the rising lake level: reed clumps of up to one square meter were scoured, torn away from the shore and drove around as islands on the lake. In the surf area and seaward probably up to a depth of several meters the gravelly substrate was rich covered with *Cladophora glomerata* and *Oedogonium* sp. In the shallow, eutrophic eastern bay, where wave action was much weaker, *Stuckenia pectinata* grew in higher abundance on the sandy to muddy sediment.

The zoobenthos of Uvs Nuur was dominated by *Gammarus lacustris*, Heteroptera (*Sigara assimilis*, *Saldula* sp.), Chironomidae (*Tanypus punctipennis*, Orthocladiinae, *Cryptotendipes* sp., *Glyptotendipes barbipes*, *Microchironomus* sp., *Polypedilum bicrenatum*), Culicidae and other Diptera (Limoniidae, Ceratopogonidae, Stratiomyiidae, *Ephydra* sp., Sciomycidae, Dolichopodidae). Nematoda, Oligochaeta, Hydrachnidia, Collembola (*Isotoma viridis*), Odonata (Coenagrionidae), Trichoptera (*Philarctus rhomboidalis*, *Oecetis intima*), Coleoptera (Hydrophilidae) and one mollusk species (*Gyraulus* sp.) were found in lower abundances.

The phytobenthos of **Bayan Nuur** was much richer than that of Uvs Nuur. From the shallow epilittoral down to the sublittoral the sediment was covered by a dense carpet of Characeae (*Chara fischeri*, *Chara gobiana*, *Chara tomentosa*), *Stuckenia pectinata, Myriophyllum spicatum* and *Najas marina ssp. intermedia*. The *Chara* species had thick lime coverings due to strong biogenic calcite precipitation. The find of the very rare *C. gobiana* is the northernmost one (J. VAN RAAM, pers. comm.). In the periphyton, *Mougeotia* sp. and *Cladophora fracta* were found. *Phragmites australis* grew only sparsely at a few places; most stretches of the shore were bare.

The species-rich zoobenthos was dominated by Ephemeroptera (*Cloeon simile*, *Cloeoptilum* cf. *maritimum*, *Caenis horaria*), Chironomidae (*Ablabesmyia monilis*, *Ablabesmyia phatta*, *Psectrocladius sordidellus*, *Chironomus tentans*, *Cryptochironomus supplicans*, *Endochironomus tendens*, *Polypedilum nubeculosum*, *Xenochiromomus xenolabis*, *Cladotanytarsus* sp., *Paratanytarsus dimorphis*, *Paratanytarsus inopertis*, *Tanytarsus glabrescens*), Gastropoda (Planorbidae, Valvatidae, *Pisidium* sp.), Hirudinea and *Gammarus lacustris*. Furthermore, Odonata, Heteroptera (*Paracorixa armata*), Trichoptera (*Cyrnus fennicus*, *Oecetis ochracea*, *Ylodes reuteri*, Limnephilidae) and Coleoptera were found.

In contrast to the otherwise similar Bayan Nuur, the Mongolian part of **Döröö Nuur** was surrounded by a dense *Phragmites australis* belt of up to 100 m width. In the shallow water of the reed belt, *Utricularia* cf. *vulgaris* was often found in masses. *Chara fischeri* grew in the sublittoral. Dominant zoobenthos groups were Mollusca (Lymnaeidae, Planorbidae, *Bathyomphalus* sp., Valvatidae, *Pisidium* sp.), Hirudinea, *Gammarus lacustris*, Odonata and Heteroptera (*Callicorixa gebleri*, *Sigara jaczewskii*, *Micronecta* sp.). Baetidae, Caenidae, Hydrachnidia, Coleoptera, Chironomidae (*Ablabesmyia monilis*, *Procladius choreus*, *Cricotopus* sp., *Eukiefferiella* sp., *Nanocladius distinctus*, *Chironomus* sp., *Tanytarsus medius*, *Tanytarsus verralli*), Ceratopogonidae and Culicidae were found with lower abundances.

The shore of the mesosaline **Southern Baga Nuur** was lined with *Phragmites australis* which probably grew there on its upper salinity limit: the ability of *Phragmites australis* to live in water with a salinity of up to 22.5 g/l, with increasing mortality above 15 g/l, has been shown by LISSNER & SCHIERUP (1999); HOOTSMANS & WIEGMAN (1998) found it to grow at a salinity of 18 g/l. On the muddy sediment, some filamentous algae (*Cladophora* sp., *Oedogonium* sp.) and one species of Heteroptera (Corixinae indet.) were found.

The small **Seepage Lake** was lined with *Phragmites australis*; *Stuckenia pectinata*, *Utricularia* cf. *vulgaris* and filamentous algae grew on the gravelly sediment. The zoobenthos was composed of Hirudinea, *Gammarus lacustris*, some snails, Zygoptera and Trichoptera (*Oecetis intima*). This is few when compared with the number of zooplankton species – apparenly due to the low number of samples taken.

The shallow **Baga Nuur** was surrounded by a fairly wide belt of *Phragmites australis* that measured 150 m at some places. On the gravelly sediment that was covered with a floccose, calcite and organic rich mud, *Chara canescens*, *Chara fischeri*, *Chara tomentosa*, *Stuckenia pectinata* and *Najas marina* ssp. *intermedia* were found. The incompletely sampled zoobenthos consisted of *Gammarus lacustris*, Mollusca (Planorbidae), Hirudinea, *Nepa cinerea*, *Argyroneta* sp., Hydrachnidia, Zygoptera and Culicidae.

In the turbid, sandy **Shavart Nuur** only *Stuckenia pectinata* grew, a reed belt was lacking. The only zoobenthos organisms found in the few samples were *Gammarus lacustris* and Chironomidae.

The small, very shallow **Togoo Nuur** featured a dense stand of *Phragmites australis* in the inner, deeper part; the sediment near the shore was grown with filamentous algae and *Chara tomentosa*, but lacked a reed belt. Two identified zoobenthos species were *Paracorixa armata* and *Paracorixa concinna*.

There were some common peculiarities that can be summarized as follows:

- The only submerged spermatophyte found in sub- and hyposaline lakes was *Stuckenia pectinata* which is known as an extremely variable cosmopolitan species with high salinity and trophic tolerance (HAMMER, 1986; VAN WIJK et al., 1988; KAPLAN, 2008)
- The absence of reed belts in some lakes of the inner basin (Bayan, Shavart, eastern bay of Uvs) seems to be caused mainly by cattle trampling, but also strong wave action could be a reason. The reed stand in the middle of the shallow Togoo Nuur is an indication of the first cause.
- Typical representatives of the bottom fauna in the salt lakes were *Gammarus lacustris*, Corixidae, Chironomidae, Ceratopogonidae, Culicidae, Ephydridae, Stratiomyiidae, Hydrachnidia and at some places Coleoptera and Odonata. Mollusca were virtually absent in the hypo- to mesosaline lakes. This is accordant with HAMMER (1986) who states that "mollusks are not usually considered to be important in saline lakes".
- In the freshwater and subsaline lakes mollusks were numerous; also Ephemeroptera, Trichoptera, Hirudinea and (in the alpine lake Nogoon) Plecoptera were found there.
- The ecological amplitude of *Gammarus lacustris* for salinity is astonishingly high – it reached from 0.04 to 14 g/l in the Uvs Nuur Basin; in the Siberian Lake Shira it lives at a salinity of 14–18 g/l (YEMELYANOVA et al., 2002) and the highest value cited by HAMMER (1986) for Canadian prairie lakes is about 17 g/l.

3.2.9.4 Fishes and waterfowl

The available information about fishes in the lakes is combined from literature, personal data of A. DULMAA and catches during the expeditions. Gillnet catches of fish were made by A. DULMAA in the lakes Bayan, Döröö, Üüreg and Uvs. In Bayan Nuur, some 30 *Oreoleuciscus* sp. of 40 to 50 cm length were caught in 1998, in Döröö Nuur a catch of six *Esox lucius* was made, and at Uvs Nuur-NW some 300 *Oreoleuciscus* sp. with a body length between some 15 and 25 cm were caught after 42 hours using a net with 1.5 cm mesh. Larger specimens seemed to be rare in Uvs Nuur as the net with 4 cm mesh yielded no catch. In 1998 and 1999, the nets yielded no catch in Uvs Nuur, as well as 1998 and 1999 in Bayan Nuur and 1999 in Üüreg Nuur.

Detailed fecundity data for *Oreoleuciscus* species in the lakes Bayan, Döröö and Uvs are given in DULMAA et al. (2000). In Table 32 an overview of the fish species inhabiting the sampled lakes is given, considering newer taxonomic insight.

There is some literature available about fishes in the lakes of the Uvs Nuur Basin, however with controversial taxonomic opinions. DULMAA (1973) lists the following species for the basins of Uvs Nuur and Üüreg Nuur without giving exact locations: *Oreoleuciscus potanini* Kessler, *O. pewzowi* (Herzenstein), *Phoxinus phoxinus ujmonensis* Dybowski and *Neomacheilus strauchi* (Kessler). In DULMAA (1991b) the following species are mentioned for the lake Uvs: *Oreoleuciscus humilis* Warpachowski, *O. potanini*, *O. pewzowi* and *N. strauchi*. In a later article (DULMAA et al., 2000) the following occurrences are stated: *O. humilis* "in the littoral zone of lakes", lakes Uvs and Bayan, *O. potanini* in lakes Üüreg, Uvs and Bayan, and *O. pewzowi* in lakes Khyargas, Üüreg and Döröö.

In OCOCK et al. (2006) the following occurrences are stated: *Oreoleuciscus angusticephalus* Bogutskaya (which is the valid name for *O. pewzowi*) in Lake Üüreg and *Oreoleuciscus humilis* in Lake Terekhol (= Döröö Nuur).

Table 32 Fish species present in the sampled lakes.

lake	fish species present	source of data / evidence
Nogoon Nuur	presumably none	predation-prone *Gammarus lacustris* present in the pelagic zone; isolated alpine lake
alpine lake near Turgen Gol	presumably none	predation-prone *Branchinecta orientalis* present; isolated alpine lake
Üüreg Nuur	*Oreoleuciscus angusticephalus*	KOTTELAT (2006), OCOCK (2006)
Uvs Nuur	*Oreoleuciscus humilis*	catches (*O. potanini* and *O. humilis* sensu DULMAA), BOGUTSKAYA (2001)
Bayan Nuur	*Oreoleuciscus humilis*	catches (*O. potanini* and *O. humilis* sensu DULMAA), BOGUTSKAYA (2001)
Döröö Nuur	*Oreoleuciscus humilis*, *Esox lucius*	catches (*O. pewzowi* sensu DULMAA), BOGUTSKAYA (2001); catches (DULMAA, pers. comm.)
Southern Baga Nuur	presumably none	no fish-eating birds, high zooplankton biomass, mesosaline
Baga Nuur	unknown small fish (young *Oreoleuciscus*?)	own visual observation
Seepage Lake	unknown small fish (young *Oreoleuciscus*?)	own visual observation
Shavart Nuur	presumably none	predation-prone *Gammarus lacustris* present in high abundance; no fish-eating birds

DULMAA (1973, 1999b) gives an overview of the Mongolian fish fauna with a bias towards usability as an economic resource. In that context also the introduction of alien species into Mongolian lakes should be considered – for instance *Esox lucius* was introduced to Döröö Nuur in the 1980s by Russians (DULMAA, 1992, 1999a).

The genus *Oreoleuciscus* is endemic to Mongolia and some rivers in the upper catchment of River Ob (KOTTELAT, 2006). The genus is nearly eurybiont: it adapts to a wide range of salinities (from freshwater to the mesosaline level), lives in lakes and rivers up to 2000 m ASL and feeds on plankton, detritus, benthic invertebrates and (cannibalistic) on fish (BOGUTSKAYA, 2001). According to DULMAA (pers. comm.) it may be capable to survive some years of drought buried in the muddy sediment. In the tributaries of some lakes a benthivorous dwarf form exists, being a reservoir for the foundation of new lake populations after drought. Normally the lake populations are planktivorous; the largest specimens of lake populations become piscivorous, often cannibalistic (DGEBUADZE, 1995). There is still discussion on the infrageneric taxonomy, whether they should be considered forms or species. KOTTELAT (2006) states about the systematic status of *Oreoleuciscus*, that "their systematics should absolutely be revisited, based on large scale surveys, well-preserved material and modern concepts". GOLUBTSOV et al. (1999) clarify the taxonomic situation of the holotype of *Oreoleuciscus pewzowi* as a specimen of *O. potanini*; for the Uvs Nuur Basin they (as well as KOTTELAT, 2006) are of the opinion that the *Oreoleuciscus* species found in the Uvs Nuur Basin is *O. humilis* and that small specimens found in the Döröö Nuur could either be dwarf forms of *O. humilis* or belong to *O. potanini*. In a comparative study of several hundred specimens from the whole distribution range of the genus, BOGUTSKAYA (2001) created the new name *Oreoleuciscus angusticephalus* for the piscivorous form previously called *O. pewzowi*. She states that in the whole Uvs Nuur Basin only *O. humilis* is found in a larger lake form and a dwarf form inhabiting rivers. Others support the thesis of only one polymorphic species (BORISOVETS et al., 1985: the genus *Oreoleuciscus* comprises five formae; TRAVERS, 1989: only *O. potanini*).

The extensive wetlands and rich fish populations of Uvs Nuur and other large lakes provided food for a diverse yet seldom numerous fauna of waterfowl. Most of them have a Palaearctic distribution. The 31 species listed in Table 49 were observed by A. VON DEN DRIESCH and the author – a list that most probably is incomplete, especially for the smaller lakes. These species can be seen as breeding birds due to the time of observation in August. Among them were some fish-eating species (*Ardea alba*, *A. cinerea*, *Larus argentatus*, *L. ridibundus*, *Larus* sp., *Phalacrocorax carbo*, *Sterna albifrons*, *S. hirundo*) and several Limicoles.

3.3 Groundwater

3.3.1 Hydrology

The sampled springs and wells represent different groundwater bodies. To characterize them hydrologically, mean residence times were derived from Tritium measurements (HEBERT, 2004).

Table 33 Tritium content and estimated residence time of groundwater. From Hebert (2004).

sampling place	sampling date	Tritium units	estimated residence time, remarks
spring of Endert Gol	08/15/1999	46 ± 4	young water (precipitation)
well no. 2 (50 m, artesian)	08/16/1999	34 ± 3	fed by water of < 10 years age (infiltrated precipitation)
Burat Usu Bulag	08/19/1998	3.1 ± 0.5	> 100 years, aquifer well protected from surface water
”	08/11/1999	5.0 ± 0.7	
Butsaldag Bulag	08/11/1999	3.2 ± 0.5	> 100 years, aquifer well protected from surface water
Nariyn Gol-1 (near spring)	08/24/1998	2.3 ± 0.4	≈ 500 years, large groundwater body, mixed with less than 5% young water
”	08/09/1999	2.2 ± 0.4	
well no. 1 (8 m deep)	08/23/1998	6.3 ± 0.7	mixture of 90% old (> 100 years) groundwater and 10% young (precipitation) water
”	08/22/1999	8.1 ± 0.8	
well no. 3 (15 m)	08/24/1999	9.5 ± 1.0	mixture of 80% old groundwater and 20% precipitation water
spring at Urt Bulag Gol	08/25/1999	3.3 ± 0.6	> 100 years, aquifer well protected from surface water
spring of Khustay Gol	08/24/1997	5.9 ± 0.7	mixture of old ground water and a changing portion of young water
”	08/25/1999	33 ± 3	
spring 1 at Bayan Nuur	08/28/1998	168 ± 14	fed by a tritium-rich reservoir of some 40 years age
”	08/26/1999	47 ± 4	

From these measurements and the chemical properties (Fig. 54) the following conclusions can be drawn:

- In the Turgen-Kharkhiraa Mountains (spring of Endert Gol, well no. 2), the groundwater residence times seemed to be low due to high amount of precipitation and hence infiltration rate, and a short distance between the area of ground water formation and the spring/well.
- In the western part of the inner basin where the areas of groundwater formation are some 15 to 30 km away in the surrounding mountains and the groundwater travels through alluvial fans partially covered with loess, springs emerging near Uvs Nuur (Burat Usu Bulag, Butsaldag Bulag) represent possibly the typical ground waters of the area with a mean age of more than 100 years and a low fraction of young precipitation water.
- In wells in the dune field between Uvs and Bayan Nuur (wells no. 1 and 3), a mixture of tritium-poor water with a residence time > 100 years and a fraction of infiltrated young precipitation water between 10 and 20% was found. That indicates that the groundwater body has some connection to the surface, being affected by infiltration as well as evaporative concentration. This is confirmed by the chemical composition (increased fraction of Na and SO_4) and increased salinity.
- Springs in the dune field east of the Bayan Nuur (spring of Nariyn Gol, spring at Urt Bulag Gol) had tritium-poor water with a residence time > 100 years and a very low fraction of infiltrated young precipitation water of < 5%. They represent a confined groundwater body with low evaporative losses – probably the typical groundwater of the central and eastern part of the dune field. The high age can be explained with the low infiltration rate of precipitation combined with a large volume of the groundwater body. The sand masses of the central part of the dune field between Bayan and Döröö Nuur have an approximated volume of 80 km^3 (length 80 km, width 25 km, mean height 30 m), thus a groundwater volume of around 12 km^3 seems to be possible, assuming a pore space between the sand particles of 20% and the water level being 10 m below ground. With a residence time of 200 years, this would result in a total mean discharge of about 2 m^3/s and a specific runoff of 1 $l/s \cdot km^2$ which is a reasonable value (compare Table 10!).

- The spring of Khustay Gol as well as spring 1 at Bayan Nuur differed from the other dune springs by a significantly higher, changing tritium content. The tritium content of the spring of Khustay Gol can be interpreted as a mixture of old ground water and a changing fraction of seeped young river water of Baruunturuun Gol that travels fast through the Pleistocene gravel bed of this river buried under the dunes (GRUNERT et al., 2000). The changing fraction of river water could be due to interannual fluctuations of precipitation. In the case of spring 1 at Bayan Nuur, the most likely explanation is infiltrated lake water: the spring at least partially must be fed from a tritium rich reservoir with an original content of some 1 600 T.U. (the tritium content in the precipitation at the beginning of the 60s) and an approximate underground flow time of 30 to 40 years. This reservoir is most probably the small dune lake Baga Nuur (49°55.5' N 93°51' E; not to be confused with Baga Nuur at the NW shore of Uvs Nuur), 3.5 km away and 40 m higher. The flow velocity through the sands would be some 0.3 m/d, a value characteristic for fine sands. KLEIN (2000) suspected the connections between Baruunturuun and Khustay Gol, Baga Nuur and "spring 1" and verified it using water chemistry and geomorphology.

3.3.2 Chemical composition

The chemical composition of the groundwater samples is summarized in Table 34, Fig. 55 and Fig. 56. It reflects the climatic and geochemical conditions of the groundwater regions: in the humid mountains the groundwater temperature was little above 0°C, salinity was low and the ionic type was Ca-HCO_3. In the semiarid inner basin, the temperature was between 6 and 10°C, and the increased salinity and higher proportion of sodium, sulphate and chloride pointed to an increased importance of evaporative and exchange processes between soil and water. Still, judging by salinity, all groundwater samples were considered as drinkable by humans and livestock, though high nitrate concentrations can be harmful to children.

There were some distinct differences between the springs in the western part of the inner basin and the groundwater in the Böörög Deliyn Els dune field: the groundwater in the alluvial fans west of Uvs Nuur was chemically quite homogenous of the Ca/Na-HCO_3/SO_4/Cl type and contained little nitrate and TP. Significant denitrification could take place here as the groundwater level was comparably high.

The dunes contained several groundwater bodies of obviously different origin: in the dunes between Uvs and Bayan Nuur the groundwater was of the Na/Ca/Mg-HCO_3/SO_4 type with nitrate concentrations between 15 and 84 mg/l. This speaks for strong evaporative enrichment. The observed high nitrate concentrations could be an effect of high cattle densities around the wells – for instance LAGERSTEDT et al. (1994) found in the arid savanna of Botswana nitrate concentrations of some 30-50 mg/l to be caused by high cattle densities. However, SPALDING & EXNER (1993) report about dug wells in bad condition at rural US sites in the loess zone, where high nitrate concentrations were due to manure leachate entering the well through soil fissures, and thus the measured concentration not being representative for the whole aquifer. This could as well be the case with wells no. 1 and 3.

The springs east of Bayan Nuur (Nariyn Gol, Urt Bulag Gol and Khustay Gol) were of the Ca/Mg-HCO_3 type and contained only between 5 and 17 mg/l nitrate. This indicated that evaporation from these ground water bodies was low due to confinement or short residence time. In fact, we found that the spring at Urt Bulag Gol emerged under a chalk plate of several centimeters thickness. Despite their similar chemical composition the water of these springs was of different origin, as Tritium measurements show – see 3.3.1.

The high salinity and Na/Mg-SO_4/HCO_3 type of the water of spring 1 at Bayan Nuur indicate strong influence of evaporation, another evidence of its origin from a lake.

Table 34 Chemical properties of groundwater samples – minima, means and maxima for all samples and means for three main groundwater regions.

	conduct. [µS/cm]	pH	salinity [g/l]	Na^+	K^+	Ca^{2+}	Mg^{2+} [mg/l]	Cl^-	SO_4^{2-}	NO_3^-	HCO_3^-	SRP	TP [µg/l]	NO_3-N
n samples	24	24	21	21	21	21	21	21	21	21	21	9	13	22
minimum	120	6.5	0.22	4	1	12	4	0	4	0	65	5	1	20
arithm. mean	508	7.9	0.44	46	4	46	18	30	67	10	183	24	18	2300
maximum	1135	8.4	0.79	157	13	88	45	159	232	84	294	70	70	19000
mountain mean	379	7.8	0.34	10	1	64	14	7	13	3	231			750
W basin mean	639	8.0	0.48	65	2	46	9	59	77	1	138	10	6	280
dune field mean	532	8.0	0.46	53	5	36	25	24	88	24	186	36	37	4400

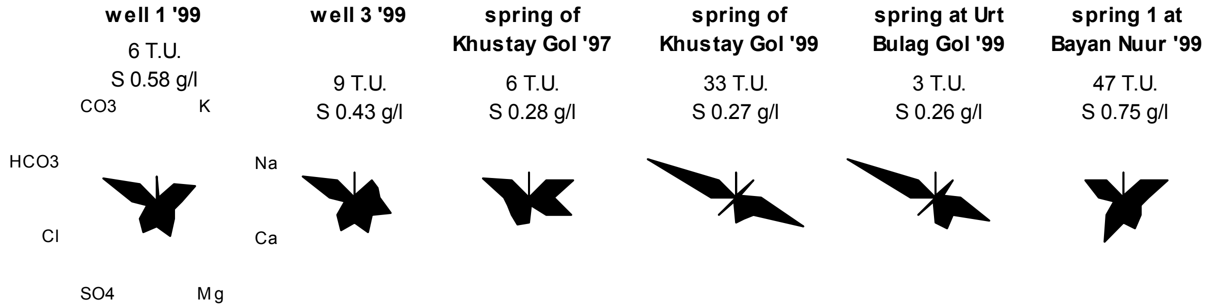


Fig. 54 Maucha ion field diagrams for six groundwater samples from the Böörög Deliyn Els dune field. The percentages of each ion in the sum of equivalent concentrations for anions and cations, the Tritium content (T.U.) and salinity (S) are shown.

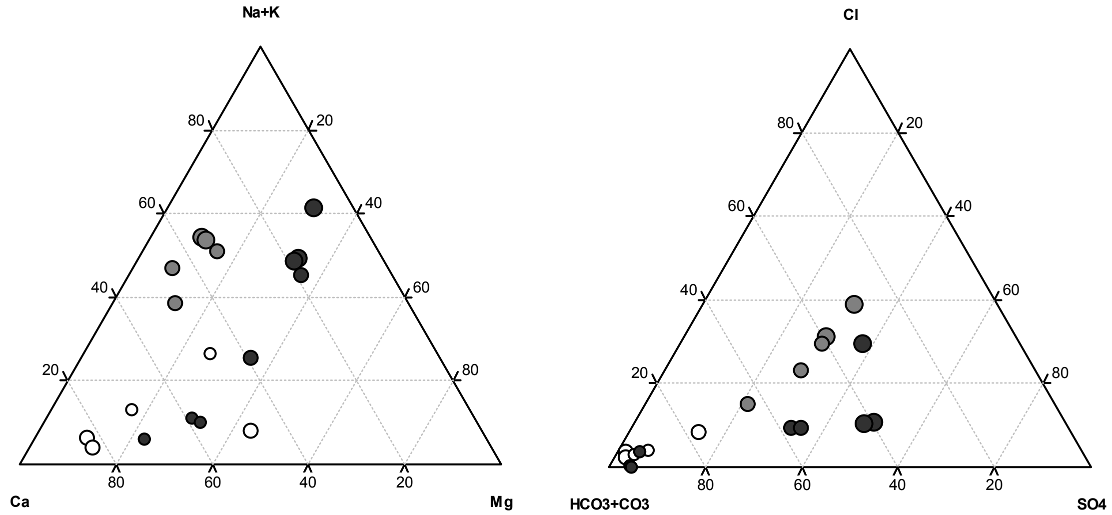


Fig. 55 Ternary diagrams for the percentage of Ca^{2+}, Mg^{2+}, Na^++K^+ in the equivalent concentrations of cations (left) and HCO_3^-+CO_3^{2-}, SO_4^{2-}, Cl^- in the equivalent concentrations of anions (right) in 18 groundwater samples. Axis labels are at the top (100%) of the axes. The area of the circles approximately corresponds to salinity. White = mountain springs, light gray = springs at western shore of Uvs Nuur, dark gray = springs and wells in the dunes east of Uvs Nuur.

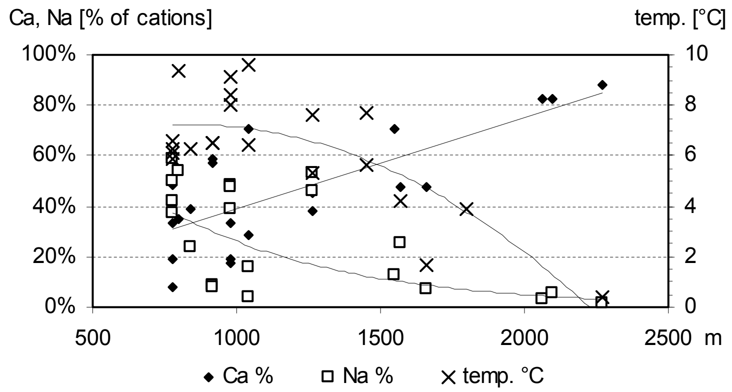


Fig. 56 Percentage of Ca and Na in the cation sum, and temperature of groundwater samples depending on altitude of the sampling place.
The trend lines for percentages of Ca and Na are an indication of ion exchange, dissolution and precipitation processes during groundwater flow from the mountains to the inner basin.
The non-linear temperature trend can be explained with the very low winter temperatures in the inner basin. This decreases the annual mean temperature of the groundwater.

Some information on groundwater chemistry in the Russian part of the inner Basin is given in an overview on the mineral content and mineralization types by MAKAROV (1997). Four main types of chemical composition – hydrogencarbonatic, sulphatic, chloridic and a mixed type – were found, with lowest mineral content (between 0.1 and 1.4 g/l) in the hydrogencarbonatic waters which are most common in alluvial depositions and the steppe. The sulphate and chloride types mostly were found at tectonic faults, their mineral content being up to 4.8 g/l. There was evidence of rising groundwater salinity at some spots over 20 years, and anthropogenic nitrate enrichment near places with high cattle concentration.

3.3.3 Biota

In the 8 samples of groundwater filtered through a 55 μm drift net to collect stygobionts unfortunately nearly no animals were found. Probably the sampling method was not appropriate. Due to the fine sandy sediment, other methods (kick sampling of the spring bottom sediment, digging and washing out sediment) were not applicable. The few found Nematoda, Ostracoda and Copepoda were not determined further.

4 Conclusions and synthesis

4.1 Exogenous factors influencing the character of water bodies

As stated in chapter 1.2, an important aim of this work is to describe the exogenous factors specific to the Uvs Nuur Basin that shape the character of the water bodies. The main factors acting on all types of waters are the combined effects of climate, orography and (to a lesser extent) human activities that can be summarized as in Table 35 and Fig. 57. These factors primarily affect the waters' physical and chemical properties which are further modified by medium-scaled variations of geological, vegetational and land-use properties of the catchment area. Several additional morphometrical and catchment features influence the water quality of lakes – see Table 36. The influence of the physico-chemical, hydrological and morphological properties on the biological structure will be discussed for rivers and lakes separately.

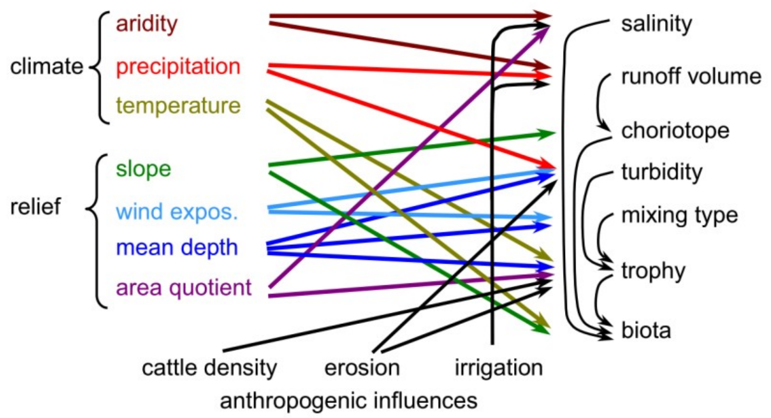


Fig. 57 Scheme of important physical (left) and anthropogenic (bottom) factors influencing characteristic aspects of running and stagnant waters (right) and the main connections between them.

Table 35 Main physical factors affecting all water bodies of the Uvs Nuur Basin.

factor		effect
• orography: steep slope from high mountains into endorheic basin	→	strong altitude gradient of morphometric characteristics for rivers (slope, tortuosity, grain size) and lakes (relative depth, area quotient)
	→	centripetal transport of particulate and dissolved matter with strong enrichment of dissolved solids and change of ionic composition towards dominance of highly soluble ions
• climate: altitude gradient of air temperature	→	altitude gradient of water temperature and freezing
• climate: altitude gradient of precipitation and evaporation	→	altitude gradient of specific runoff, salinity and ionic composition
• climate: dry winter and moderately wet summer	→	common winter drought and high runoff variability of rivers
• climate: long, cold winter and fast rising spring temperatures accompanied by strong winds	→	short vegetation period; high hypolimnion temperature of stratified lakes with deep mixolimnion

Table 36 Most important factors influencing water quality of lakes in the Uvs Nuur Basin. Arrows indicate direction and strength of influence, ≈ means no significant influence.

	water quality parameter				
factor	salinity	pH value	O_2 fluctuations	turbidity	trophic state
area quotient	↑	≈	↑	≈	**↑**
mean depth	↓	≈	↓	**↓**	**↓**
wind exposition	≈	≈	↓	**↑**	≈
groundwater influx	**↑**	↓	≈	≈	≈
aridity index	**↑**	↑	≈	≈	≈
soil erosion	↑	↑	↑	**↑**	↑
cattle density	≈	↑	↑	↑	**↑**

4.1.1 Biological structure of running waters

To emphasize the connections between abiotic factors and the abundance of several phytobenthos and macrozoobenthos groups, the relative importance of these factors and the essential characteristics of sampling points along selected rivers, principal component analyses (PCA) coupled with cluster analyses of the most significant principal components were made using abiotic and biotic variables from 35 sampling points (see Table 37). As BOWMAN & BAILEY (1997) showed, the taxonomic resolution for a multivariate description of benthic macroinvertebrate communities has not necessarily to be on species or genus level. Thus, the biological variables used are relative abundances on order or family level for zoobenthos and most phytobenthos groups. Some of the physical variables were log-transformed for better approximation of a normal distribution. The results are shown in Fig. 58 and Fig. 59.

Table 37 Principal Component Analyses for benthos in running waters: description of data used and first four principal components. Abiotic variables used to construct principal component axes, biotic variables are supplementary (= depend on abiotic variables). # cases relates to the number of sampling points, variables are specified in the captions of Fig. 58 and Fig. 59.

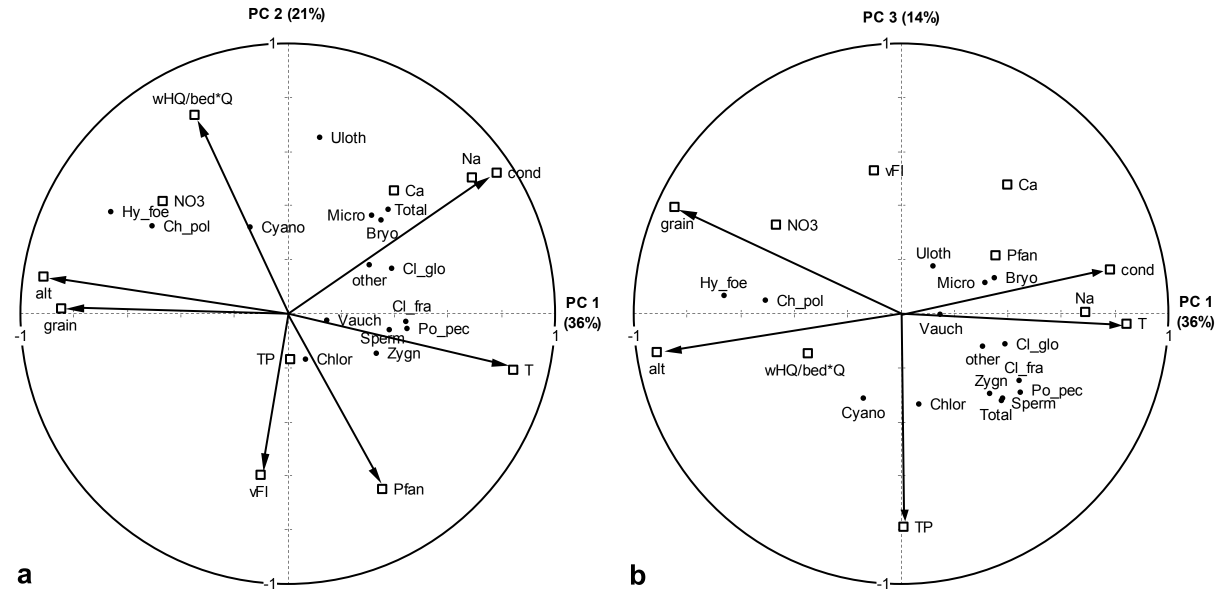
				percentage of total variance			
	# cases	# abiotic vars.	# biotic vars.	PC 1	PC 2	PC 3	PC 4
phytobenthos	27	11	15	36.2%	21.1%	13.7%	9.8%
zoobenthos	35	11	14	34.9%	20.4%	12.4%	10.5%

The most important exogenous factors determining the abundance of benthos organisms are those with the highest loadings for the first primary components. When interpreting these figures one has to bear in mind the small number of sampling points and even smaller number of individual rivers covered by the data set. Thus, generalizations must be made with care.

The structure of **phytobenthos** seems to be determined mainly by the hydromorphological and, to some degree, by the chemical character of the rivers: the diametrically opposed variables grain size and temperature are associated with the first, most influential principal component, that is best described as altitude factor. The second principal component (summarized as hydromorphology) is composed of flow velocity, the stability of bed substratum (represented by the Pfankuch index) and the diametrically opposed composite variable wHQ/bed*Q (calculated as "width of active floodplain" /("width of river bed" · runoff)) that represents variability and scarcity of runoff – higher values imply a higher chance of drying out. The third principal component is mainly determined by total phosphorus concentration, thus represents trophic status. Ion concentrations (represented by conductivity) are related to the first and second principal components in equal parts. The first three principal components contribute 71% of the total variance, thus all others are of minor importance.

Autecological preferences of taxa with high component loadings are clearly visible: *Hydrurus foetidus* and *Chamaesiphon polonicus* are found in high altitude, coarse stony, cold rivers with high runoff variability. On the opposite side of the component space, spermatophytes like *Stuckenia pectinata*, Zygnematales and *Cladophora* show their preference for lowland streams with higher temperatures, more stable runoff and somewhat higher phosphorus concentrations. As the phosphorus gradient among the investigated rivers is not very distinct, there are only few taxa with marked trophic preferences: the *Ulothrix* species found here that are oligotraphentic, and the eutraphentic genera *Prasiola*, *Oedogonium* and *Stigeoclonium* summarized under "other trichal Chlorophyta".

The main factors determining **zoobenthos** abundance are in principle the same as for phytobenthos. The component loadings of zoobenthos groups show their mean autecological preferences: Ephemeroptera and Simuliidae are particularly rheophilic and prefer stable substratum; Turbellaria are cold-stenothermic, rheoxenic and often found in small streams with high substratum stability; Mollusca and Gammaridae live in waters with sandy substratum, higher temperatures and conductivity and prefer sites with rich phytobenthos; Coleoptera, Heteroptera and Odonata are rheoxenic and prefer eutrophic sites. As autecological characteristics of the species in most groups are not homogenous, these generalizations can only be taken to estimate the probability of finding organisms of a group under certain environmental conditions.



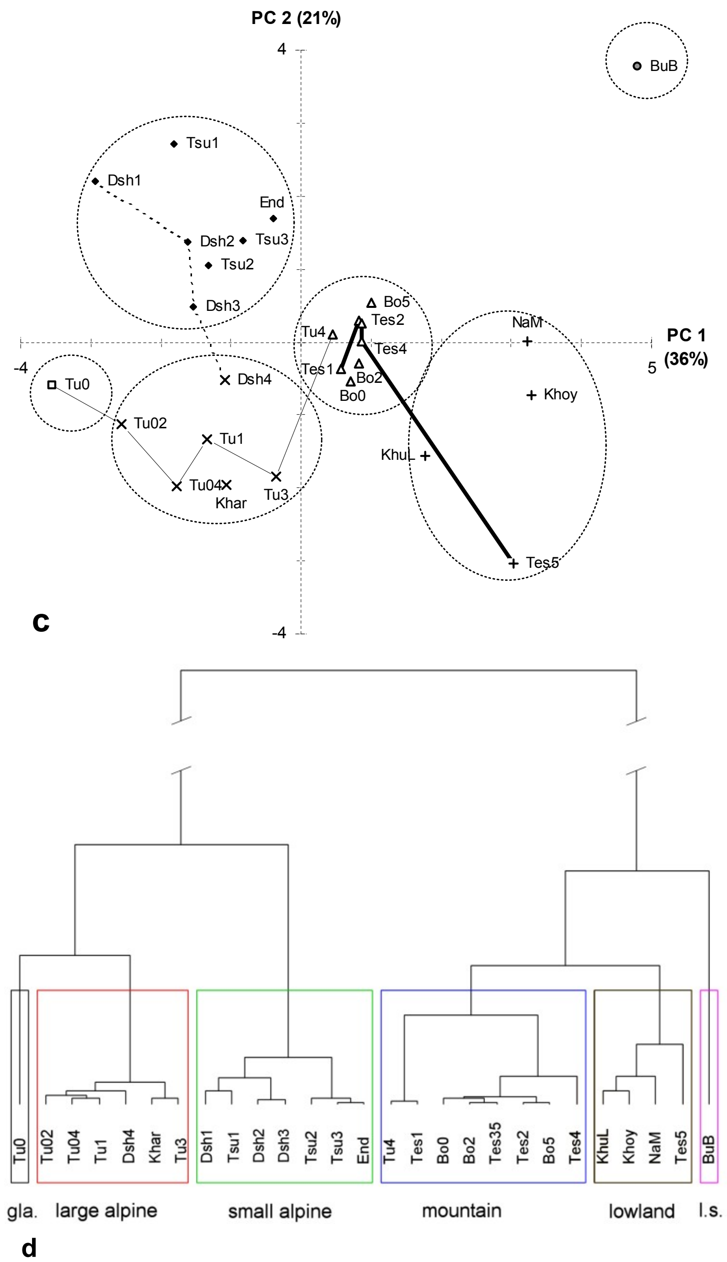


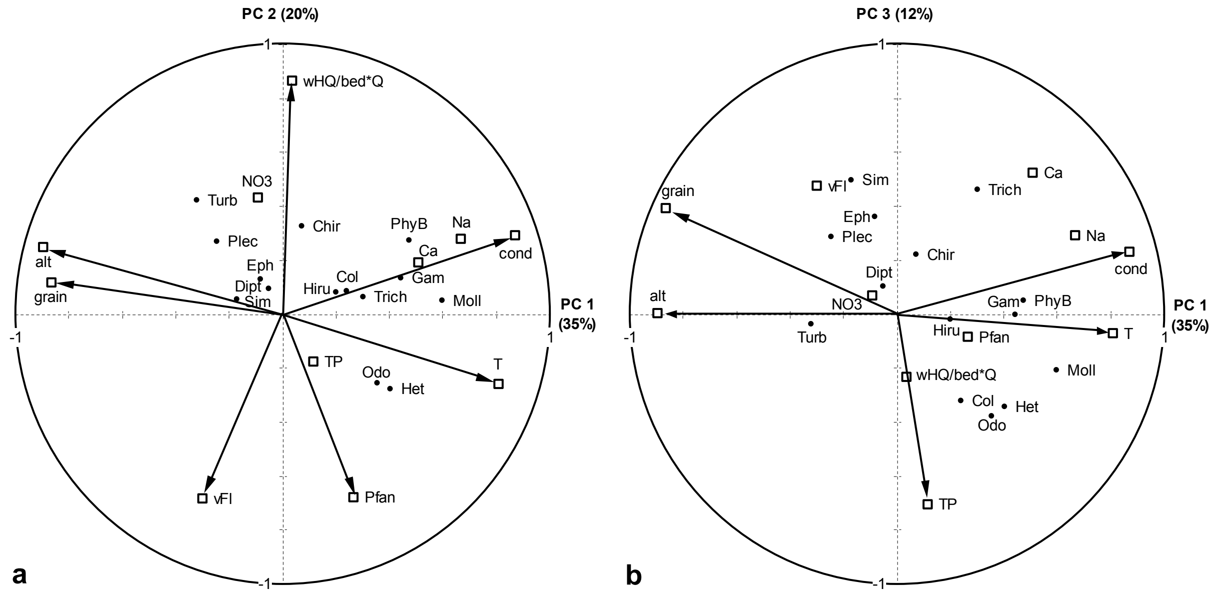
Fig. 58 Principal Component Analysis (PCA) for abiotic variables and phytobenthos groups of 27 sampling points at running waters in the Uvs Nuur Basin.

a, b Loadings of the first three principal components for abiotic variables (white boxes). Biotic variables (black dots) are supplementary. Arrows mark variables with high loadings that are most important for the structure of phytobenthos.

c Scores of the first two principal components for all sampling places. Lines connect the sampling places at Dshibertu, Tesiyn and Turgen Gol in their sequence. White square=cluster 1, X=cluster 2, black dots= cluster 3, white triangles=cluster 4, crosses=cluster 5, grey circle=cluster 6. Description of clusters in Fig. d!

d Cluster analysis of sampling places based on the first three principal components. Cluster 1 (gla.)= glacier stream, cluster 2=large alpine streams, cluster 3= small alpine streams, cluster 4= mountain streams, cluster 5=lowland streams, cluster 6 (l.s.)=lowland spring stream.

The included abiotic variables are: alt=altitude ASL, concentrations of Ca, Na, TP and NO3, cond= conductivity, grain=log(mean grain size), Pfan=stability index according to PFANKUCH (1975), T=temperature, vFl=flow velocity, wHQ/bed*Q=log((width of active floodplain)/(width of river bed · runoff)).
Biotic variables are the relative abundances of 14 taxonomic groups of phytobenthos and the estimated total phytobenthos biomass.
Bryo=Bryophyta, Ch_pol= *Chamaesiphon polonicus*, Chlor=other trichal Chlorophyta, Cl_glo= *Cladophora glomerata*, Cl_fra=*Cladophora fracta*, Cyano=other Cyanobacteria, Hy_foe=*Hydrurus foetidus*, Micro=*Microspora*, other=other microalgae (Diatoms, Chrysophyceae, Rhodophyta), Po_pec=*Potamogeton pectinatus*, Sperm= other Spermatophyta, Total=total phytobenthos biomass (estimated), Uloth=*Ulothrix*, Vauch= *Vaucheria*, Zygn=Zygnematales



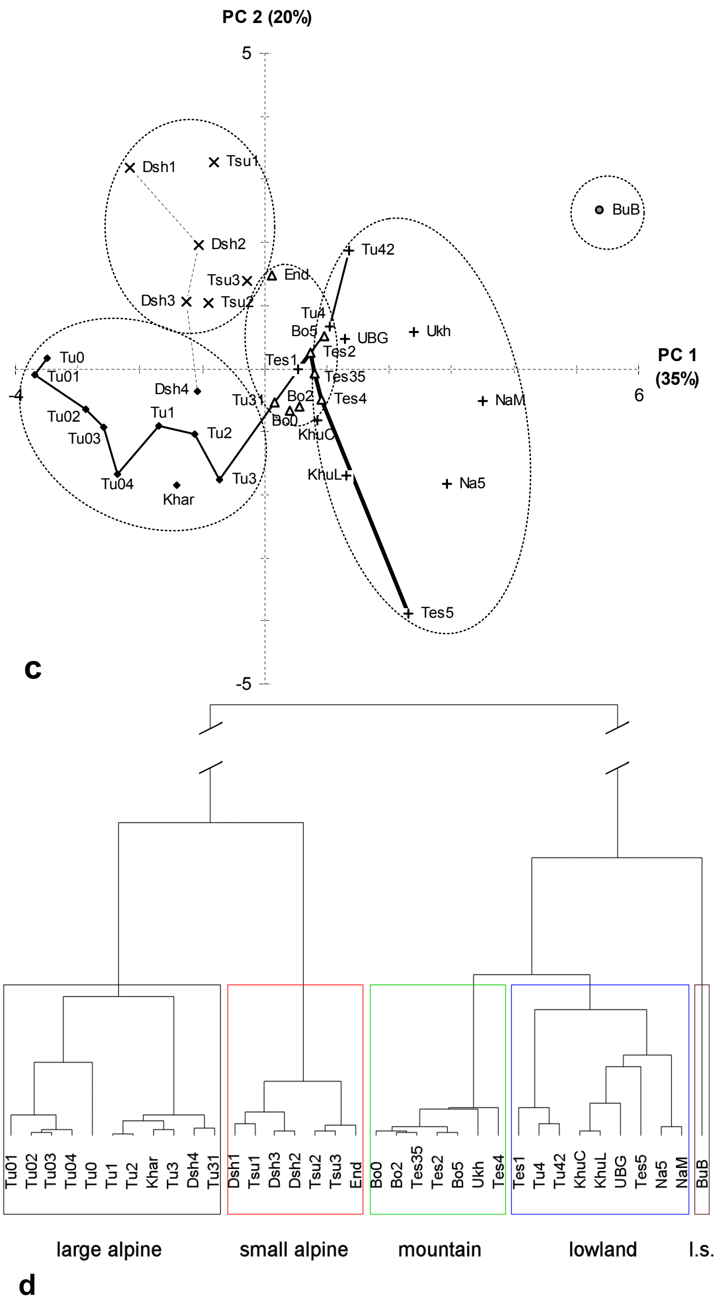


Fig. 59 Principal Component Analysis (PCA) for abiotic variables and zoobenthos groups of 35 sampling points at running waters in the Uvs Nuur Basin.

a, b Loadings of the first three principal components for abiotic variables (white boxes). Biotic variables (black dots) are supplementary. Arrows mark variables with high loadings that are most important for the structure of zoobenthos.

c Scores of the first two principal components for all sampling places. Lines connect the sampling places at Dshibertu, Tesiyn and Turgen Gol in their sequence. Black dots=cluster 1, X=cluster 2, white triangles=cluster 3, crosses=cluster 4, grey circle=cluster 5. Description of clusters in Fig. d!

d Cluster analysis of sampling places based on the first four principal components. Cluster 1= large alpine streams, cluster 2=small alpine streams, cluster 3= mountain streams, cluster 4=lowland streams, cluster 5 (l.s.)= lowland spring stream.

The included abiotic variables are: alt= altitude ASL, concentrations of Ca, Na, TP and NO_3, cond=conductivity, grain=log(mean grain size), Pfan= stability index according to PFANKUCH (1975), T= temperature, vFL=flow velocity, wHQ/bed*Q= log((width of active floodplain)/(width of river bed · runoff)).
Biotic variables are the squared relative abundances of 13 taxonomic groups of macrozoobenthos and the sum of phytobenthos abundance. Chir=Chironomidae, Col= Coleoptera, Dipt= Diptera other than Chir and Sim, Eph=Ephemeroptera, Gam=Gammaridae, Het= Heteroptera, Hiru=Hirudinea, Moll=Mollusca, Odo= Odonata, Plec=Plecoptera, Sim=Simuliidae, Trich= Trichoptera, Turb=Turbellaria, PhyB=macroscopically visible phytobenthos (included as zoobenthos habitat and food source).

The character of sampling places as well as type changes along the rivers' course can be seen in parts c and d of both figures: cluster analysis of phytobenthos as well as zoobenthos (though slightly less sharp) clearly differentiates small alpine streams (with less vehement current and bedload movement), large alpine streams, mountain streams and lowland streams. Two special types are glacier brooks and lowland spring streams. The gravelly sites Turgen Gol-4 and Tesiyn Gol-1 form a distinct subcluster, for phytobenthos among the mountain streams, for zoobenthos among lowland streams. They stand at the transition from mountains to lowland.

Type changes along the river course are most interesting for Turgen Gol as its hydromorphological character does not show the normal succession from a small upland to a large lowland stream (as is the case for Tesiyn Gol), but inverts downstream of Turgen Gol-3 to a small stream that eventually trickles away. Dshibertu Gol develops from a small stream towards a river and maintains its alpine character over the whole length. The character of Tesiyn Gol as a mountain river stays remarkably stable between sampling places Tesiyn Gol-1 and -4, spanning a length of 310 km. Only the trophic state (principal component 3, not shown in the Fig.) shows some change from eutrophic in the upper reaches to oligotrophic at Tesiyn Gol-4 and back to mesotrophic in the lower reaches. The same is true for Turgen Gol: the spring is eutrophic due to high TP concentrations from glacier flour which decrease very fast, making the main part of the river oligotrophic. The silty lower reaches with upwelling groundwater are eutrophic again.

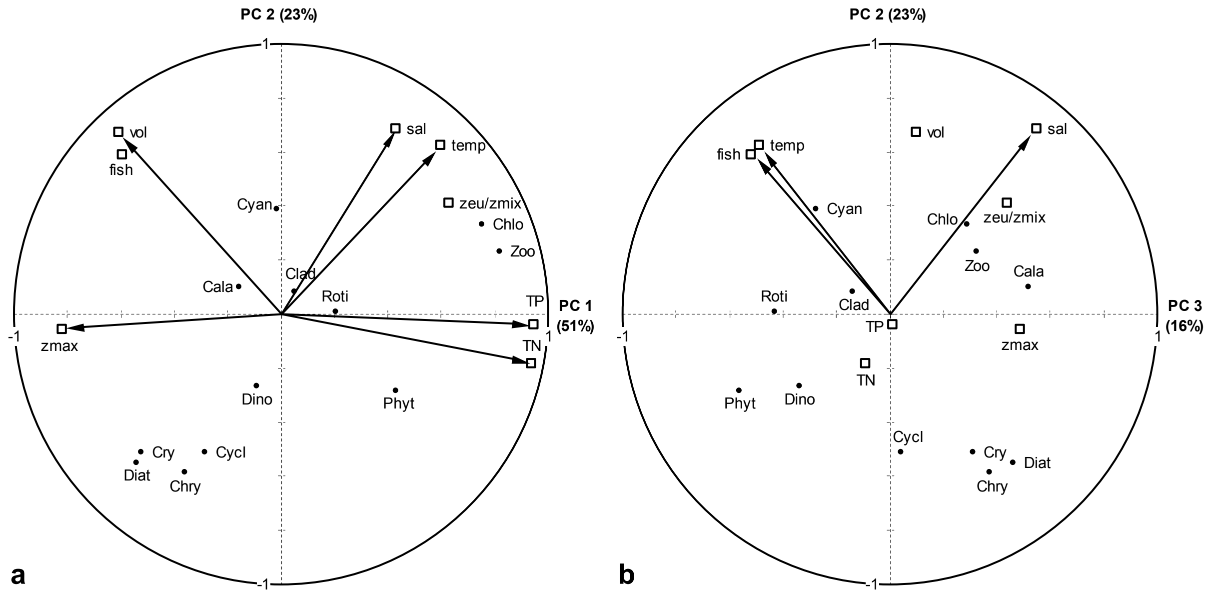
Species diversity of the river sites was not calculated due to the incomplete inventory of benthic species. However, a qualitative statement can be made. Alpine streams with strong bedload movement (Turgen Gol-0.4 to -3, Dshibertu Gol-4, Kharkhiraa Gol) were colonized by a low number of zoobenthos species. Even lower species numbers and abundances were found in sandy lowland streams with strong bedload movement (Tesiyn Gol-5, Nariyn Gol-5) and mountain streams with loss of subsurface runoff (Turgen Gol-4). The highest species numbers were found in mountain rivers with moderately strong runoff dynamic (Borshoo Gol) and oxbow ponds near large rivers (oxbows Tesiyn Gol-3.5 and -5.5). This is in accordance with the findings of TOWNSEND et al. (1997) who showed that species richness and diversity of macroinvertebrates in streams are highest at sites with medium frequency and intensity of bed substratum movement, supporting the "intermediate disturbance hypothesis".

A particularly unfavorable condition of most rivers in the Uvs Nuur Basin is the complete freezing and cease of runoff during the long winter. Stream macroinvertebrates in arctic and continental temperate zones have adapted to freezing conditions. The four known strategies (IRONS et al., 1992) are overwintering in generally not freezing habitats, avoidance of freezing by actively moving away from a freezing front, physiological avoidance of freezing by production of antifreeze compounds, and physiological freeze tolerance by producing compounds that prevent cell destruction by ice crystals. IRONS et al. (1992) showed for Alaskan streams, that the active movement away from freezing fronts into the hyporheic sediment is the strategy used by most aquatic invertebrates. Areas of groundwater upwelling are also important refugia. Only larvae of Chironomidae and Empididae were found to survive in frozen sediment. LENCIONI (2004) addresses adaptations in behavior and life cycle that comprise diapause, longer larval development, hatching and mating at subzero temperatures in late winter and basking in the sun.

From the investigated rivers no samples were taken in winter, but temperature and ice data suggest that in rivers with a water depth less than one meter no liquid water remained. At alluvial sites with a well developed hyporheic interstitial (Turgen Gol-0.4 to Turgen Gol-3, Kharkhiraa Gol, Tesiyn Gol-2 to Tesiyn Gol-4) freezing avoidance is an option for small invertebrates. In sandy lowland streams only the smallest larval instars are capable of moving deep into the interstitial. However, in bedrock channels (Turgen Gol-0 to -0.3, Tsunkheg Gol-2) all zoobenthos must survive complete freezing or find the few gaps to move underground. For many species, for instance the immotile pupae of *Deuterophlebia sajanica*, the possible survival strategies are unknown. Altogether, freezing seems to be one important reason for the low species numbers in rivers of the Uvs Nuur Basin when compared with less continental temperate zones.

4.1.2 Biological structure of lakes

The influence of abiotic factors on the plankton communities can be shown by principal component analysis like for river benthos, however less reliable due to the low number of cases (only nine lakes, yet including all major lakes). The results are shown in Fig. 60. The first principal component which contains 51% of the total variance can be named "trophic state". It is formed of the morphometrical variable maximum depth and, diametrically opposed, the nutrients TP and TN. The second and third principal components are less easily described as the contributing variables salinity, water temperature (representing the lakes' altitude), lake volume and fish presence (which stand for the lakes' size) are correlated with both principal components. The presence of fishes is well correlated with lake volume (and permanence – see IBP values in Table 17) which seems to be an indication for their problems to colonize small, isolated water bodies which are not permanent for more than some thousand years or freeze to the bottom during winter. The "realized" trophic state as represented by phytoplankton biovolume does not correlate very well with the first principal component (Fig. 60a).



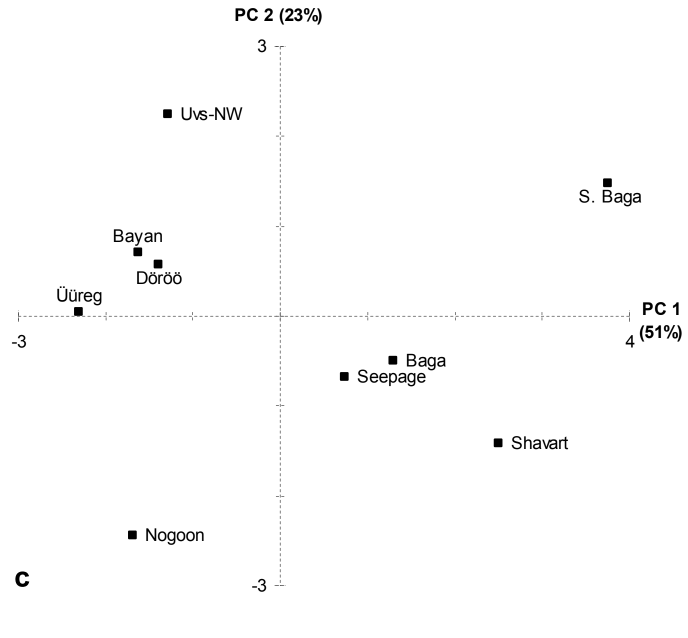


Fig. 60 Principal Component Analysis (PCA) for abiotic variables and plankton groups of 9 lakes of the Uvs Nuur Basin.

a, b Loadings of the first three principal components for abiotic variables (white boxes). Biotic variables (black dots) are supplementary. Arrows mark variables with high loadings that are most important for the plankton structure.

c Scores of the first two principal components for the sampled lakes.

The included abiotic variables are: fish=presence of fishes, sal=salinity, temp=water temperature, TP, TN, vol=log(lake volume), zeu/zmix=quotient of euphotic and mixing depth, zmax= max. depth. Biotic variables are the mean biovolumes of phyto- and zooplankton and the relative proportions of taxonomic groups. Chlo=Chlorophyceae, Chry=Chrysophyceae, Cry= Cryptophyta, Cyan=Cyanbacteria, Diat=Bacillariophyceae, Dino=Dinophyta; Cala= Calanoida, Clad=Cladocera, Cycl=Cyclopoida, Roti=Rotifera.

Phytoplankton biovolume shows an, albeit weak, inverse dependence on salinity (Fig. 60b). This seems to be a real characteristic, as KRAVTSOVA (1989) found a strong inverse relationship between salinity and phytoplankton biomass as well as productivity in a study on phytoplankton in some dozens of continental lakes and reservoirs of the U.S.S.R.. Maximal biomass was found at salinities between 3 and 5 g/l while at salinities beyond 10 g/l the maximum biomass was well below 30 mg/l. However, in another study HÅKANSON & EKLUND (2010) found for a large set of marine areas, coastal and inland lakes the maximum of the quotient between chlorophyll and phosphorus at salinities between 10 and 15 g/l; at lower and higher salinities the chlorophyll yield was less.

Another reason for the inverse dependence of phytoplankton on salinity most probably is the grazing effect of zooplankton, whose biovolume in contrast correlates better with nutrient concentrations and has an increasing tendency with increasing salinity and temperature, i.e. lower altitude. Thus, by top-down coupling it decreases phytoplankton biovolume.

The biovolume proportion of Bacillariophyceae, Cryptophyceae and Chrysophyceae showed an inverse dependence on salinity and temperature while the portions of Chlorophyceae and, to a lesser degree, Cyanobacteria increased with these variables. Other than expected, no clear relation between nutrients and phytoplankton groups became evident which may be due to the small number of lakes. AUER et al. (2004) in a study of 50 North German lakes of different trophic level and salinity found strong relations: the portion of Cyanobacteria in the total phytoplankton biomass increased from some 10 to 45% with increasing trophy while the proportion of Chrysophyceae and Dinophyta decreased from some 15% each to less than 5%.

Like with phytoplankton, Fig. 60 shows no clear relationships between zooplankton groups and abiotic variables. One reason besides the low number of sampled lakes may be the taxonomic resolution being too low for autecological conclusions. However, a PCA of the same abiotic data using zooplankton biomass proportions on species level (results not shown) delivers little more significant relations: only *Moina salina* was found to be well correlated with nutrient concentrations and (less well) with salinity, and *Arctodiaptomus salinus* correlated with lake volume and less well with salinity. There are autecological preferences for other species, too – for instance BORONAT et al. (2001) found in Spanish lakes the occurrence of Cladocera on species level to depend mainly on the lakes' permanence, salinity and littoral development.

The data of benthic species were not suitable for the use of statistical methods. For the qualitative statements that can nevertheless be made see chapter 3.2.9.3.

4.2 Food webs

From the available biological data, it is not possible to reconstruct complete food webs for the streams and most lakes. Instead, some regional peculiarities will be outlined.

The most significant feature of some **alpine streams** (probably Turgen, Dshibertu, Tsunkheg Gol) was the lack of fishes. This may be the case in most of the alpine streams with shallow, completely freezing river bed, and no permanent connection to a larger lowland stream or lake where a fish population could overwinter. A possible top predator still could be the dipper (*Cinclus cinclus*) that was observed at Tsunkheg Gol. Otherwise, the trophic level of tertiary consumers was vacant. The structure of the benthic invertebrate community in fishless streams can differ substantially from that of streams with fish (POWER, 1990; WINKELMANN et al., 2011). However, a prediction of changes that could be expected when the one benthivorous fish species common in small streams of the Uvs Nuur Basin (*Triplophysa gundriseri*) would be present for instance in the upper Turgen Gol, can not be made due to the high complexity of interactions. The primary food sources in the alpine streams were thin layers of epilithic algae and allochthonous FPOM. As an example, the food web of Turgen Gol in its upper reaches can be outlined as follows: the primary consumers were dominated by grazers (Heptageniidae, Baetidae, Glossosomatidae) and filter feeders (Simuliidae), and complemented by some collectors and shredders (Diamesinae, Capniidae) at places with slower current. On the primary consumers lived a considerable number of predators (Perlodidae and Chloroperlidae) – their individual number was about 10-15% of the number of primary consumers. The low species number and the simplicity of this food web may be due to the harsh conditions in this glacier-fed stream which is supported by findings of FÜREDER et al. (2001) from the Alps.

In the mountain stream **Borshoo Gol**, a much more complex food web existed. Autochthonous primary production by diatoms, filamentous and other algae, mosses and macrophytes, imported CPOM and FPOM served as a rich food source for a variety of primary consumers. These were mainly grazers (Baetidae, Heptageniidae, Ephemerellidae, Glossosomatidae) and detritus feeders (Psychodidae, Chironomidae), some filter feeders (Simuliidae, Brachycentridae) and few shredders (Tipulidae, *Gammarus*). The guild of predatory secondary (and partially tertiary) consumers (Perlodidae, Chloroperlidae, Rhyacophilidae, Turbellaria) was relatively small – their individual numbers were only about 5% of the number of primary consumers, which may be due to selective predation by the top consumer *Thymallus brevirostris*.

In most of the **lowland streams**, at least one fish species was present, exerting predatory pressure on the macrozoobenthos. Primary producers were *Cladophora* spp., other trichal Chlorophyta and Cyanobacteria, *Potamogeton* and mosses. The zoobenthos seemed to be dominated by grazers and detritivores (mainly Chironomidae, Ephemeroptera, Hemiptera and Gastropoda); the few Coleoptera and larvae of Odonata were the only invertebrate predators.

The most important shaping factor for the **pelagic food webs** of lakes, besides lake size, salinity and trophic state (see chapter 4.1.2), was the presence of fish which shifts the zooplankton community structure towards Rotifera and smaller Cladocera and Copepoda and reduces or eliminates all large invertebrates (REISSIG et al., 2006; SCHILLING et al., 2009). The pelagic food webs of lakes Uvs and Bayan (without bacteria and protozoa, valid for the time of late summer) can be presented as semiquantitative diagrams, as the most important involved organisms were sampled sufficiently complete. No own investigations were made on the food sources of zooplankton, thus the feeding links had to be reconstructed using literature data: In BRANDL (2005) information is compiled about predatory Crustacea feeding on Rotifera. For *Arctodiaptomus salinus*, omnivory with a high proportion of phytoplankton diet (mainly *Planktolyngbya contorta*) was reported from the Siberian salt lake Shira by TOLOMEYEV (2002). ALCORLO et al. (2001) found short food webs with *Hexarthra fennica* as an important intermediate species in ephemeral Spanish salt lakes with an Anostraca species as the only predator. They state that *H. fennica* was cannibalistic. In a multi-prey study, RAO & KUMAR (2002) found that *Mesocyclops thermocyclopoides* preferred *Brachionus calyciflorus* and *Moina macrocopa* as prey while *Hexarthra mira* which is capable of quick evasive movements was avoided. The predatory impact of *Leptodora kindtii* on Crustacea and Rotifera with a preference on Cladocera is a well-known fact (e.g. PICHLOVÁ & BRANDL (2003)). DRENNER et al. (1984) and LANDAU et al. (1988) found that the small filter-feeding fish *Dorosoma cepedianum* and Cyprinid larvae were feeding on *Ceratium* and *Peridinium*, which are examples for direct phytoplankton grazing by fishes.

The resulting scheme of the pelagic food web for **Uvs Nuur** (Fig. 61) has four trophic levels. The primary producers were dominated by the trichal *Planktolyngbya contorta* which was mainly ingested by the large, omnivorous *Arctodiaptomus salinus*. Besides these two dominant components, an important part of the phytoplankton consisted of well edible, small (and probably fast growing) Chlorococcales and, less important, Chroococcales forming small colonies, and few diatoms. They were the main food source for the rotifers *Brachionus plicatilis* and *Hexarthra fennica*. These two species are often found in saline waters (PEJLER, 1995). The only filter feeding cladoceran was *Moina salina*, with much lower biomass than the rotifers. This is coincident with findings from chemostat experiments where *M. salina* had low competitive strength against *B. plicatilis* (CHEN et al., 2004). The role of secondary consumers is split up between *A. salinus* and *Mesocyclops leuckarti*. While the latter had very low biomass during the sampling period, it may be more important in other seasons. The single fish species *Oreoleuciscus sp.* is omnivorous (DULMAA et al., 2000), larger individuals becoming cannibalistic (KOTTELAT, 2006).

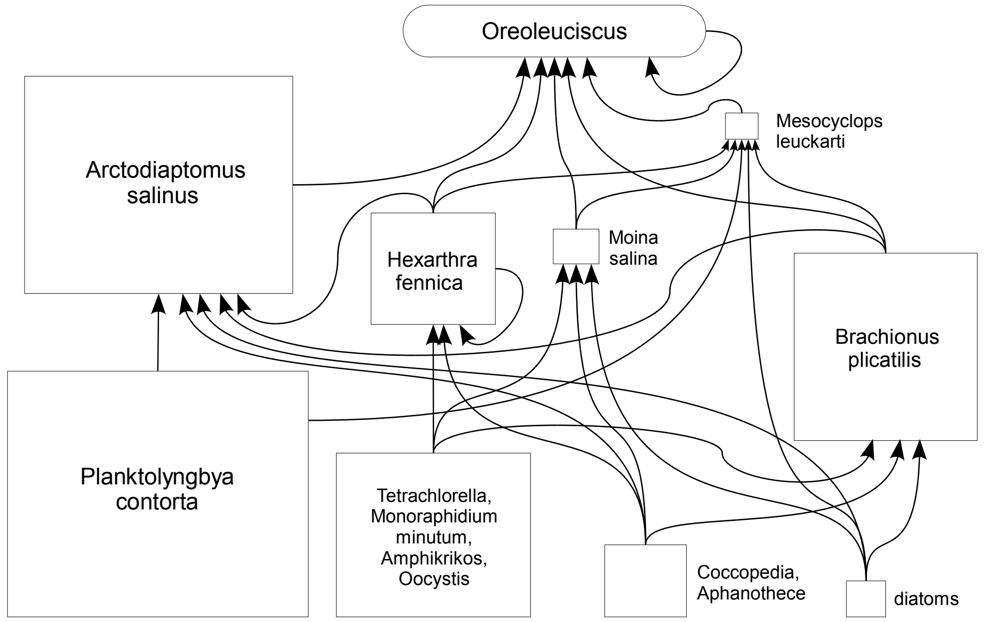


Fig. 61 Scheme of the pelagic food web of Uvs Nuur. Only species with a biomass proportion > 1% are shown. Area of boxes corresponds to mean biomass; for the rounded box no biomass data are available.

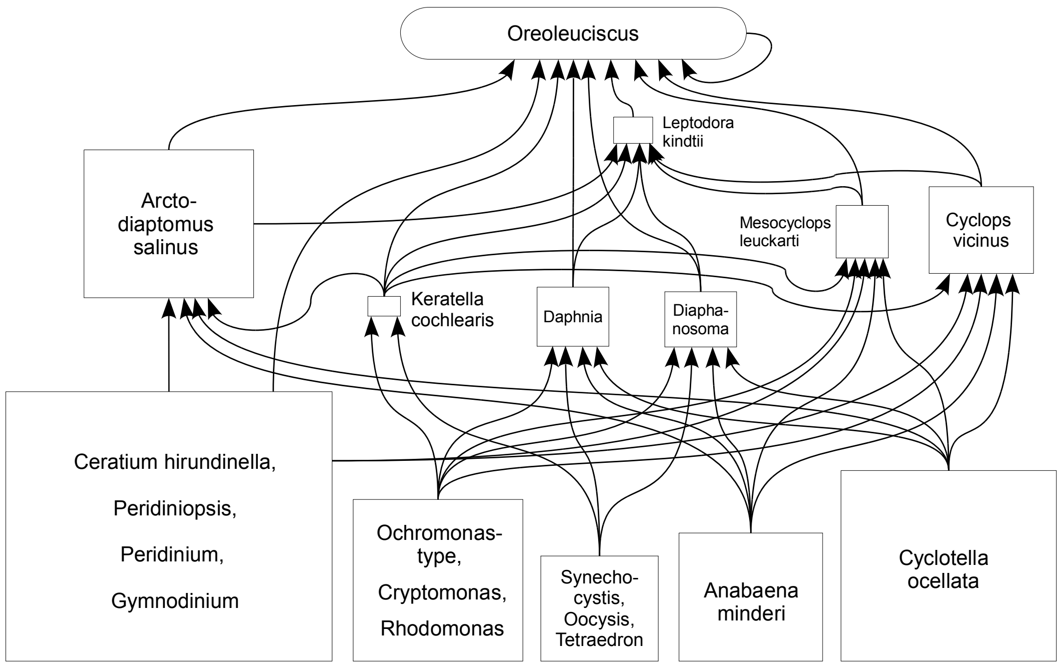


Fig. 62 Scheme of the pelagic food web of Bayan Nuur. Only species with a biomass proportion > 1% are shown. Area of boxes corresponds to mean biomass; for the rounded box no biomass data are available.

For **Bayan Nuur**, the pelagic food web (Fig. 62) comprised five trophic levels. In contrast to Uvs Nuur, the quotient of phytoplankton to zooplankton biomass was four times higher and there were more functional groups in the phytoplankton and zooplankton; the feeding pathways were more diverse. The grazing pressure on the large dinoflagellates was probably much lower than on chrysoflagellates, centric diatoms and small coccal algae, as dinoflagellates are not a preferred food source of Copepoda (SANTER, 1996). The biomass of Rotifera was quite low as only small species were present; instead, the niche of filter feeders was filled by several cladoceran species. As in Uvs Nuur, the omnivorous *A. salinus* was an important intermediary species in the food web, though accompanied by quite abundant Cyclopoida. The invertebrate predator *Leptodora kindtii* competed with *Oreoleuciscus* sp. for Crustacean prey, at the same time being a preferred prey for the fishes.

In **Nogoon Nuur**, the filter feeder *Daphnia pulicaria* grazed upon diverse chrysoflagellates, *Rhodomonas* and *Cyclotella*. The omnivorous copepods *Arctodiaptomus alpinus* and *Cyclops glacialis* fed on *Gymnodinium helveticum*, larger *Cyclotella* and juvenile *Daphnia*. *Gammarus lacustris* played the role of the top predator in the pelagic food web, however in very low abundances. WILHELM & SCHINDLER (1999) found *Gammarus lacustris* to be feeding on zooplankton in a fishless, oligotrophic Canadian alpine lake, playing an important role in phosphorus recycling and in the benthic-pelagic coupling (WILHELM et al., 1999). This might be the case here, too.

The pelagic food web of **Üüreg Nuur** was similar to that of Uvs Nuur, though much more concentrated on the two key species *Planktolyngbya contorta* and *Arctodiaptomus salinus* that had a biomass proportion of 75% in the phytoplankton and 99% in the zooplankton, respectively. Together with the only fish species *Oreoleuciscus angusticephalus*, the most important feeding pathway was a simple chain with three nodes.

In **Döröö Nuur**, the dominant small, colony forming Chroococcales, some Chlorococcales, *Cyclotella* and *Rhodomonas* were a food source for the filter feeding *Ceriodaphnia pulchella*, *Daphnia galeata*, *Bosmina longirostris* and *Diaphanosoma mongolianum*. The omnivorous copepods *Arctodiaptomus salinus*, *Acanthodiaptomus denticornis*, *Mesocyclops leuckarti* and *Cyclops vicinus* fed on large Dinophyceae, other phytoplankton and, probably, on cyanobacterial colonies and young cladocerans. *Oreoleuciscus humilis* was the tertiary consumer, and *Esox lucius* was the top predator.

The food web in **Southern Baga Nuur** was quite simple: *Moina salina* and very few Rotifera were filter feeding on *Synechocystis salina* and several small Chlorophyceae. The omnivorous *Arctodiaptomus salinus* was the only secondary consumer. Some mainly benthic Corixinae might have been the top predators in this fishless lake. The very high biomass quotient between zooplankton and phytoplankton was an outstanding feature of this saline lake. A similar case was reported by EVANS et al. (1996) who found low phytoplankton biomass and high zooplankton biomass as compared with model predictions based on phosphorus concentration in Redberry Lake in the Canadian prairie with a salinity similar to Southern Baga Nuur. They concluded that the high zooplankton grazing rate was one of the reasons why the phytoplankton could not accumulate higher biomass in spite of high production rates.

The planktonic food web in **Seepage Lake** was rather complex, which may be due to the low salinity enabling life for very many freshwater species as well as many saline species. Small Cladocera and Rotifera (*Bosmina longirostris*, *Ceriodaphnia pulchella*, *Filinia longiseta*, *Hexarthra spp.*, *Brachionus*, *Keratella*, *Polyarthra*) were grazing on Chlorococcales, centric diatoms, Desmidiaceae and Chroococcales. Dinoflagellates (*Peridiniopsis borgei*, *Peridinium umbonatum*) and the small zooplankton species were the food source for predatory Rotifera (*Asplanchnella* spp.) and Copepoda (*Mesocyclops leuckarti* and *Arctodiaptomus salinus*). As the lake was small and shallow, benthic predators (*Gammarus lacustris* and larvae of Odonata) may have been of some importance, too. Some small fishes were observed that probably were the top predators.

In **Baga Nuur**, the food web was based on Cyanobacteria (*Rhabdoderma*, *Anabaena*, *Synechocystis salina*, *Planktolyngbya contorta*, *Komvophoron*) and Dinophyceae (*Peridiniopsis borgei, Peridinium umbonatum*). No effective, large grazers were present in the zooplankton; only Rotifera (*Filinia longiseta*, *Hexarthra* spp., *Brachionus* spp., *Lepadella patella*, *Lecane luna, Synchaeta* and *Polyarthra vulgaris*), and very few specimens of the predatory *Mesocyclops leuckarti* were found. The capability of the rotifers to feed on voluminous colonies of Chroococcales or trichomes of *Anabaena* and *Planktolyngbya* was most probably low. The overall grazing pressure on the phytoplankton as well as the energy flow in the planktic food web can be assumed to be quite low. The low number of crustaceans and the complete absence of Cladocera may have been due to predation by the observed small fishes, or unsuitable living conditions, i.e. the high pH value of 10.1. Evidence for the latter cause are findings of O'BRIEN & DENOYELLES (1972) who reported a high mortality of *Ceriodaphnia reticulata* at pH values above 11, of HANSEN et al. (1991) who found a decreasing density of several cladoceran species at pH values increasing above 9, while two *Cyclops* species were not affected. A decreased egg viability of *Daphnia galeata* at pH above 10 was found by VIJVERBERG et al. (1996).

The food web of the highly eutrophic **Shavart Nuur** was characterized by a dominance of big, omnivorous Copepoda (*Arctodiaptomus bacillifer* and *Thermocyclops kawamurai*), and a few filter feeders (*Keratella* sp., *Hexarthra mira*, *Brachionus plicatilis* and *Daphnia longispina*). The latter were feeding on *Aphanocapsa* spp., *Merismopedia*, *Monoraphidium* spp. and other small Chlorococcales. *Planktolyngbya contorta* and Rotifera were the main food source of Copepoda. *Gammarus lacustris* was the planktic tertiary consumer in this fishless lake.

Table 38 Characteristics of pelagic food webs of the investigated lakes. Salinity in g/l; BV=biovolume in mm³/l, zooplankton biovolume was converted from dry weight using a factor of 10 mm³/mg DW; P/Z= biovolume quotient of phytoplankton/zooplankton; the number of zooplankton species includes only Rotifera, Cladocera and Copepoda; the number of trophic levels includes phyto-, zooplankton and fish, but excludes bacteria and protozoa, as no data are available for these groups.

lake	salinity	fish	BV phytopl.	BV zoopl.	quotient P/Z	zoopl. species	trophic levels
Nogoon Nuur	0.04	-	0.10	0.20	0.5	7	4
Üüreg Nuur	5.07	+	0.53	0.64	0.8	5	3 (4?)
Uvs Nuur (NW bay)	13.2	+	0.54	0.48	1.1	11	4
Bayan Nuur	0.36	+	2.34	0.55	4.3	17	5
Döröö Nuur	0.55	+	3.58	1.26	2.8	20	5
Southern Baga Nuur	20.2	-	1.54	6.61	0.2	8	3
Seepage Lake	2.03	+	5.92	0.54	10.9	23	5 (6?)
Baga Nuur	1.26	+	27.28	0.73	44.2	19	3
Shavart Nuur	1.48	-	15.03	3.57	4.2	16	4

For comparison of the pelagic food webs described above, some simple descriptive numerical data are given in Table 38. These food webs are highly simplified in several ways: they exclude whole compartments like decomposers and benthic pathways, do not consider changing trophic links of different life stages of a species ("trophic species"), and completely exclude temporal variability of feeding behavior and biomass ratios. Studies of POLIS (1991) and MARTINEZ et al. (1999) showed that numerical descriptors of the structure of food webs that were investigated with insufficient taxonomic resolution, temporal and spatial completeness, underestimate the real complexity. Thus, no deeper structural analysis of the presented food webs was made. Nevertheless, the following conclusions can be drawn:

- The complexity of the pelagic food webs, which is closely related to species number, seems to be highest in oligo- to mesotrophic freshwater and subsaline lakes. The lowest species numbers were found in ultraoligotrophic lakes. This is in concordance with DODSON et al. (2000) who found in data sets of 33 well studied lakes unimodal relationships between species richness and primary productivity that peaked at the oligo- to mesotrophic level.
- The phytoplankton/zooplankton biomass ratio increased significantly with the trophic level, which was also reported from shallow Danish lakes and attributed to increasing predation pressure on zooplankton due to an increase of fish biomass at higher trophic levels (JEPPESEN et al., 1997).
- In fishless lakes, the phytoplankton/zooplankton biomass ratio was much lower, and big invertebrate predators (*Gammarus lacustris*, Corixinae) were found in the pelagic zone.
- The zooplankton species richness was higher in fresh and subsaline waters than in lakes with salinities above 3 g/l (see also FLÖßNER et al., 2005). The same may be true for phytoplankton, but can not be demonstrated with the available data due to different, sometimes insufficient levels of taxonomic resolution. It is an often stated thesis that the species richness decreases with increasing salinity at a large scale (i.e. between 0.3 and 300 g/l) and in the lowest part of the salinity scale between 0 and 10 g/l (DE DECKKER & GEDDES, 1980, TIMMS, 1983). As WILLIAMS et al. (1990) showed for Australian salt lakes, there is little correlation between salinity and species richness in the intermediate salinity range of 10 – 30 g/l, which is an indication of the wide salinity tolerance of many salt lake biota. WILLIAMS (1998a) found salinity to be an important factor for the biological structure of salt lakes in the low salinity range (less than about 50 g/l) with decreasing species richness at higher salinities.

4.3 Biogeographical classification

For the definition of biogeographic regions, knowledge of the geographic distribution of species from sufficiently well studied taxonomic groups is needed. These species should be macroscopic to be well detectable, and should not be cosmopolitan. Consequently, the definition of global biogeographic regions (realms, kingdoms) is mainly based on the distribution of vertebrates or vascular plants (UDVARDY, 1975). According to this author, the Uvs Nuur Basin belongs to the "Altai Highlands" province of the Palearctic Realm. However, for the purpose of conservation of freshwater ecosystems, a mesoscaled regionalization based on aquatic organisms is needed. The delineation of ecoregions for freshwater ecosystems of the world (inland waters would be the more precise term) by ABELL et al. (2008) tried to meet this requirement by combining data on fish species distribution with catchment boundaries and physiographical features. According to this regionalization, the Uvs Nuur Basin is part of the ecoregion Nr. 622 "Western Mongolia", which furthermore comprises the catchments of Üüreg and Achit Nuur in the Mongolian Altai, the drainage areas of Khovd and Zavkhan Gol with the large lakes Khyargas, Khar and Khar-Us Nuur (the "Valley of Great Lakes"), and the catchments of some lakes in the western Khangay Mountains (BOGUTSKAYA, 2008).

Mollusks are another taxonomic group suitable for zoogeographic regionalization. In an overview of the zoogeography of freshwater mollusks in Central Asia, IZZATULLAEV & STAROBOGATOV (1985) establish a West Mongolian superprovince of the Palaearctic, covering the Uvs Nuur Basin and the Basin of Great Lakes and thus being widely identical with the fish-based ecoregion. For this superprovince they mention as characteristic the endemic species *Lymnaea nogoonica* Kr. et Star., *L. tsalolikhini* Kr. et Star., *L. mongolitumida* Kr. et Star., *L. gundrizeri* Kr. et Star., *L. ulaganica* Kr. et Star., *Odhneripisidium popovae* Star. et Str., *O. terekholicum* Izz. et Star. and *O. tuvaense* Izz. et Star., co-occurring with species of the European-Siberian subregion.

A closer analysis of the geographical distribution of the important zoobenthos groups Ephemeroptera, Plecoptera, Trichoptera, of fishes and the mainly planktic Cladocera and non-bdelloid Rotifera was made on the level of species present in the Uvs Nuur Basin. For assessment of the biogeographical situation of Ephemeroptera, Plecoptera and Trichoptera of the Uvs Nuur Basin in comparison with whole Mongolia, the checklists given by SURENKHORLOO (2009) and Mongolian Benthological Society (2011a, b) were used. The results are summarized in Table 39.

The almost complete endemism of fish species native to the Uvs Nuur Basin is quite unique (the Holarctic *Esox lucius* was introduced by man; the *Oreoleuciscus* species are found aside from the "Valley of Great Lakes" in some headwater streams of the neighboring catchment of the river Ob). Therefore, the taxonomy of the genera *Triplophysa* and *Oreoleuciscus* deserves further studies; the latter can be seen as an example of local adaptive radiation (BOGUTSKAYA, 2008). The distributions of the most important zoobenthos groups Ephemeroptera, Plecoptera and Trichoptera are characterized by a majority of East Palearctic species. Species with Palearctic and Holarctic distribution are slightly less frequent. Amphipacific and West Palearctic species play only a minor role. The dominance of East Palearctic species is particularly manifest for Plecoptera that are poor flyers and distribute slowly across catchment boundaries.

The situation is different for plankton organisms: they have a tendency towards cosmopolitism, however with great variations between taxonomic groups. As BOXSHALL & DEFAYE (2008) state, "more than 90% of all freshwater copepods are endemic to a single zoogeographic region" and the Holarctic harbors the greatest number of species. The distribution of Cladocera largely depends on water temperature – the species numbers are encountered in the tropics and subtropics, and many species are distributed over a whole latitude belt, especially the Holarctic (FORRÓ et al., 2008). In contrast, "cosmopolitism is important" for Rotifera (SEGERS & DE SMET, 2008) which can be explained mainly with a high dispersal capacity due to their small size and drought resistant resting stages (SEGERS, 2008).

Table 39 Biogeographical distribution of aquatic organisms found in the Uvs Nuur Basin, summarized on class level. Proportions of species which are cosmopolitan (COS), endemic to the Uvs Nuur Basin and closely neighboring waters (END), and of species with East Palearctic (EPA), Palearctic (PA), Holarctic (HA), Amphipacific (APA) and West Palearctic (WPA) distribution, given as percentages in the total number of species (for which distribution data were available) that were found in the Uvs Nuur Basin (# species; see Table 49), and percentage of the latter in the total number of species given in checklists for whole Mongolia (%Mong), with literature source for the distribution data. Cosmopolitism was assumed for planktic species which are found in at least six of the eight zoogeographical regions.

group	COS	END	EPA	PA	HA	APA	WPA	# species	%Mong	source of distribution data
Ephemeroptera			46%	38%	11%	3%	3%	37	27%	KLUGE (2011)
Plecoptera			83%		13%	4%		25	42%	FOCHETTI et al. (2010), TESLENKO (2003)
Trichoptera			35%	37%	19%	7%	2%	43	21%	MORSE (2011)
Osteichthyes		83%			17%			6	8%	KOTTELAT (2006)
Cladocera	41%			18%	41%			34		KOTOV et al. (2010)
Rotifera	71%			10%	19%			21		SEGERS (2007)
Charophyceae & Spermatophyta	35%		12%	12%	35%	6%				GOLLERBAKH & KRASAVINA (1983); CASPER & KRAUSCH (1980,1981)

Most of the macrophytes found in the Uvs Nuur Basin (Characeae and Spermatophyta) have a cosmopolitan and Holarctic distribution, which can be explained with the easy dispersal of oospores and seeds by waterfowl. The water mosses found here have a Palearctic distribution and are common to Mongolia (TSEGMED, 2001).

Algae as mostly microscopic organisms exist in very high individual numbers, are often dispersed over long distances by vectors (mainly birds), and some are able to spread through the air (KRISTIANSEN, 1996). Thus, cosmopolitan distribution of microalgae (as well as other microscopic eukaryotes) in suitable habitats has been an often corroborated (e.g. FINLAY & FENCHEL, 2004), but also challenged (HOFFMANN, 1996; FOISSNER, 2008; COESEL & KRIENITZ, 2008, VANORMELINGEN et al., 2008, WEISSE, 2008) theory. The highest degree of cosmopolitism might be found among plankton algae, especially from eutrophic or saline waters, as they are highly mobile and exist in much greater individual numbers than benthic algae. There are some benthic algae in the Uvs Nuur Basin (*Homoeothrix crustacea* Voronichin, *Phormidium caucasicum* (Elenkin & Kosinskaya) Anagnostidis, *Calothrix* cf. *kossinskajae* Poljansky) which were only found in the East Palearctic. It is, however, for two reasons not possible to give reliable data on the geographical distribution of algal species found in the Uvs Nuur Basin: there are no distributional data available for many species, and the possibility that endemic East Palearctic species were misidentified as morphologically similar species known from Europe cannot be ruled out, especially given the fact that most of the available modern determination literature is focused on European species. The considerable number of algal species which could only be determined to the genus level may be an indication of taxa not covered in the used literature or even being new. Furthermore, the number of 66 algal species that were found for the first time in Mongolia (Table 40), compared to the checklist of DOROFEYUK & TSETSEGMAA (2002) comprising 1574 species (among them 657 non-diatom algae), shows that the knowledge of algae in the Mongolian waters is still far from being comprehensive.

To complete this chapter of biogeographical questions, a list (Table 40) was compiled with species that were found for the first time in Mongolia as a result of this project. Because of the lack of checklists of Mongolian species for several taxonomic groups, this list had to be conservative. Most of the 103 species are algae, Cladocera and Chironomidae. For the latter two groups, D. Flößner and R. Samietz provided the information of being new records.

Table 40 Newly described species and new species records for Mongolia.

new species	taxonomic group	sampling places
Acanthocorbis mongolica Paul 2011	Choanoflagellata, Acanthoecida	Bayan Nuur
Cyclops glacialis Flößner 2001	Crustacea, Copepoda	Nogoon Nuur
new records for Mongolia		
Alona elegans Kurz 1865	Crustacea, Branchiopoda	Uvs Nuur-SW
Ceriodaphnia rotunda Sars 1862	Crustacea, Branchiopoda	Tesiyn Gol-5.5 oxbow
Daphnia zschokkei Stingelin 1894	Crustacea, Branchiopoda	alpine lake near Turgen Gol
Daphnia x *krausi* Flößner 1993	Crustacea, Branchiopoda	Bayan Nuur
Ilyocryptus sordidus (Liévin 1848)	Crustacea, Branchiopoda	Bayan Nuur
Macrothrix laticornis (Jurine 1820)	Crustacea, Branchiopoda	Togoo Nuur
Macrothrix rosea (Jurine 1820)	Crustacea, Branchiopoda	Döröö Nuur
Rhynchotalona falcata (Sars 1862)	Crustacea, Branchiopoda	Bayan Nuur
Acanthodiaptomus denticornis (Wierzejski 1887)	Crustacea, Copepoda	Döröö Nuur, Togoo Nuur, alpine lake near Turgen Gol
Arctodiaptomus (Rhabdodiaptomus) alpinus (Imhof 1885)	Crustacea, Copepoda	Nogoon Nuur
Thermocyclops kawamurai Kikuchi 1940	Crustacea, Copepoda	Shavart Nuur
Ameletus camtschaticus Ulmer 1927	Ephemeroptera	Dshibertu Gol
Baetis tricolor Tshernova 1928	Ephemeroptera	Nariyn Gol
Cloeon simile Eaton 1870	Ephemeroptera	Khustay Gol, Nariyn Gol
Cinygmula irina Tshernova & Belov 1982	Ephemeroptera	Dshibertu Gol
Cyrnus fennicus Klingstedt 1937	Trichoptera	Bayan Nuur
Limnephilus politus Curtis 1834	Trichoptera	Selenge Gol (49°23' N, 102°51' E)
Cricotopus (Cricotopus) trifascia Edwards 1929	Diptera, Chironomidae	Selenge Gol (49°23' N, 102°51' E)
Cryptochironomus supplicans (Meigen 1830)	Diptera, Chironomidae	Bayan Nuur
Micropsectra recurvata (Goetghebuer 1928)	Diptera, Chironomidae	Borshoo Gol
Nanocladius distinctus (Malloch 1915)	Diptera, Chironomidae	Döröö Nuur
Polypedilum (Pentapedilum) nubens (Edwards 1929)	Diptera, Chironomidae	Selenge Gol (49°23' N, 102°51' E)
Tanytarsus medius Reiss & Fittkau 1971	Diptera, Chironomidae	Döröö Nuur
Xenochiromomus xenolabis Kieffer 1916	Diptera, Chironomidae	Bayan Nuur
Chamaesiphon polonicus (Rostafinski) Hansgirg 1892	Cyanobacteria, Chroococcales	Dshibertu, Tsunkheg, upper Turgen Gol
Chroococcus obliteratus Richter 1886	Cyanobacteria, Chroococcales	Uvs Nuur-NW
Clastidium setigerum Kirchner 1880	Cyanobacteria, Chroococcales	Dshibertu Gol, Turgen Gol-1
Coccopedia limnetica Troickaja 1922	Cyanobacteria, Chroococcales	Uvs Nuur
Coccopedia turkestanica Kiseleva 1931	Cyanobacteria, Chroococcales	Seepage Lake
Coelomoron pusillum (van Goor) Komarek 1988	Cyanobacteria, Chroococcales	Seepage Lake, Uvs Nuur-SW
Microcystis smithii Komarek & Anagnostidis 1995	Cyanobacteria, Chroococcales	Bayan Nuur
Synechocystis crassa Voronichin 1929	Cyanobacteria, Chroococcales	Bayan, Döröö Nuur, Seepage Lake
Synechocystis salina Wislouch 1924	Cyanobacteria, Chroococcales	Baga, Southern Baga, Uvs Nuur, Seepage Lake
Heteroleibleinia epiphytica (Wille) Komarek 2001	Cyanobacteria, Oscillatoriales	Uvs Nuur-NW
Heteroleibleinia kuetzingii (Schmidle) Compère 1985	Cyanobacteria, Oscillatoriales	Borshoo Gol-0, upper Tesiyn Gol
Homoeothrix crustacea Voronichin 1923	Cyanobacteria, Oscillatoriales	Tsunkheg Gol-1
Homoeothrix gloeophila Starmach 1960	Cyanobacteria, Oscillatoriales	spring at Torkhilog Gol
Homoeothrix janthina (Bornet & Flahault) Starmach 1957	Cyanobacteria, Oscillatoriales	Dshibertu Gol
Jaaginema subtilissima (Kützing) Anagnostidis & Komarek 1988	Cyanobacteria, Oscillatoriales	Uvs Nuur-NW
Komvophoron schmidlei (Jaag) Anagnostidis & Komárek 1988	Cyanobacteria, Oscillatoriales	Khustay Gol
Leibleinia epiphytica (Hieronymus) Compère 1985	Cyanobacteria, Oscillatoriales	Döröö Nuur, Turgen Gol-1
Lyngbya martensiana Meneghini ex Gomont 1892	Cyanobacteria, Oscillatoriales	Uvs Nuur-NW
Oscillatoria sancta Kützing ex Gomont 1892	Cyanobacteria, Oscillatoriales	Tesiyn Gol-1
Phormidium caucasicum (Elenkin & Kosinskaya) Anagnostidis 2001	Cyanobacteria, Oscillatoriales	spring at Torkhilog Gol
Phormidium lloydianum (Gomont) Anagnostidis & Komárek 1988	Cyanobacteria, Oscillatoriales	Uvs Nuur-E
Pseudanabaena catenata Lauterborn 1915	Cyanobacteria, Oscillatoriales	Seepage Lake
Pseudanabaena minima (G.S. An) Anagnostidis 2001	Cyanobacteria, Oscillatoriales	Khustay Gol, Uvs Nuur-NW
Spirulina labyrinthiformis Gomont 1893	Cyanobacteria, Nostocales	Baga, Southern Baga Nuur
Spirulina subsalsa Oerstedt 1842	Cyanobacteria, Nostocales	Baga, Uvs Nuur-E, Seepage Lake
Trichocoleus tenerrimus (Gomont) Anagnostidis 2001	Cyanobacteria, Nostocales	Uvs Nuur-NW
Anabaena (Dolichospermum) mendotae (Trelease) Wacklin, Hoffman & Komarek 2009	Cyanobacteria, Nostocales	Uvs Nuur-NW

Table 40 continued.

new records for Mongolia	taxonomic group	sampling places
Anabaena minderi Huber-Pestalozzi 1938	Cyanobacteria, Nostocales	Baga, Bayan, Döröö Nuur
Microchaete tenera Thuret ex Bornet 1880	Cyanobacteria, Nostocales	Tesiyn Gol-5.5 (oxbow pond)
Nostoc sphaericum Vaucher ex Bornet & Flahault 1888	Cyanobacteria, Nostocales	Borshoo, Tesiyn Gol-2
Rhodomonas lacustris var. *nannoplanctica* (Skuja) Javornicky 1976	Cryptophyta	Bayan, Döröö Nuur
Gymnodinium helveticum Penard 1891	Dinophyta	Bayan, Nogoon Nuur
Peridiniopsis borgei Lemmermann 1904	Dinophyta	Baga, Bayan, Döröö Nuur, Seepage Lake
Peridinium umbonatum var. *umbonatum* Stein 1883	Dinophyta	Baga, Bayan, Döröö Nuur, Seepage Lake
Chrysosphaerella solitaria Preisig & Takahashi	Chrysophyceae	Bayan Nuur
Epipyxis borgei (Lemmermann) Hilliard & Asmund	Chrysophyceae	Tesiyn Gol-5.5 (oxbow pond)
Epipyxis marchica (Lemmermann) Hilliard & Asmund 1963	Chrysophyceae	Tesiyn Gol-5.5 (oxbow pond)
Chaetoceros wighamii Brightwell 1856	Bacillariophyceae, Centrales	Uvs Nuur-NW
Pseudotetraedriella kamillae Hegewald, Padisak, Friedl 2007	Eustigmatophyceae	Bayan Nuur
Centritractus belenophorus Lemmermann	Xanthophyceae	Bayan Nuur
Chroodactylon ornatum (C.Agardh) Basson 1979	Rhodophyta	Döröö, Uvs Nuur, Seepage Lake
Amphikrikos nanus Hindák 1977	Chlorophyceae, Chlorococcales	Üüreg, Uvs Nuur
Coelastrum pseudomicroporum Korsikov 1953	Chlorophyceae, Chlorococcales	Döröö Nuur
Coelomoron pusillum (van Goor) Komárek 1988	Chlorophyceae, Chlorococcales	Bayan, Uvs Nuur-SW
Didymocystis bicellularis (Chodat) Komárek 1973	Chlorophyceae, Chlorococcales	Bayan Nuur
Kirchneriella subcapitata Korsikov 1953	Chlorophyceae, Chlorococcales	Shavart Nuur
Monoraphidium tortile (W.&G.S. West) Kom.-Legn. 1969	Chlorophyceae, Chlorococcales	Shavart Nuur
Oocystis marina Moewus 1951	Chlorophyceae, Chlorococcales	Uvs Nuur, Seepage Lake
Scenedesmus brevispina Chodat 1926	Chlorophyceae, Chlorococcales	Bayan Nuur
Scenedesmus disciformis (Chodat) Fott & Komárek 1960	Chlorophyceae, Chlorococcales	Khustay Gol
Siderocelis ornata Fott 1934	Chlorophyceae, Chlorococcales	Seepage Lake
Tetrachlorella incerta Hindák 1977	Chlorophyceae, Chlorococcales	Bayan, Uvs Nuur
Ulothrix aequalis Kützing 1845	Chlorophyceae, Ulothrichales	Tsunkheg Gol
Microspora amoena (Kützing) Rabenhorst 1868	Chlorophyceae, Microsporales	brook of Butsaldag Bulag, Jireeg, Borshoo Gol
Microspora amoena var. gracilis (Wille) De Toni 1889	Chlorophyceae, Microsporales	Tesiyn Gol-5.5 (oxbow pond)
Microspora stagnorum (Kützing) Lagerheim 1887	Chlorophyceae, Microsporales	spring at Borshoo Gol-2, Tesiyn Gol-5.5 (oxbow pond)
Pseudochaete crassisetum (W.&G.S. West) W.&G.S. West	Chlorophyceae, Chaetophorales	Borshoo Gol-0, Tesiyn Gol-1
Prasiola fluviatilis (Sommerfelt) Areschoug 1869	Chlorophyceae, Prasiolales	Turgen Gol-0
Closterium littorale var. *crassum* W.&G.S. West 1896	Conjugatophyceae, Desmidiales	Borshoo Gol-2
Cosmarium bioculatum var. *depressum* (Schaarschm.) Schmidle 1894	Conjugatophyceae, Desmidiales	Döröö Nuur
Cosmarium reniforme (Ralfs) W. Archer 1874	Conjugatophyceae, Desmidiales	Khustay Gol
Cosmarium subtumidum var. minutum Krieg & Gerloff 1965	Conjugatophyceae, Desmidiales	Seepage Lake
Euastrum insulare var. silesiacum W.Krieger 1937	Conjugatophyceae, Desmidiales	Baga Nuur
Chara fischeri Migula 1904	Charophyceae	Baga, Bayan & Döröö Nuur
Chara gobiana Vilhelm 1928	Charophyceae	Bayan Nuur

4.4 Spatial sequence of water bodies and material flows

The hydrological closedness and strong altitude gradients make the Uvs Nuur Basin an ideal subject to demonstrate the flow of water, dissolved and particulate matter through a typical sequence of surface and underground water bodies which is shown in Fig. 63. The involved processes take between hours (erosion, dissolution, precipitation) and several thousand years (dust blowout from lake basins, loess formation). An overview of hydrochemical and -biological characteristics of typical waterbodies in this sequence is given in Table 41.

The highest amount of precipitation falls in the alpine mountain ranges surrounding the basin in the west and north. It feeds the glaciers, permafrost soils and alpine streams, the largest being glacier-fed and rich in suspended silt (glacier flour). In periglacial cirques small, sometimes deep lakes exist with a water very low in nutrients and dissolved ions.

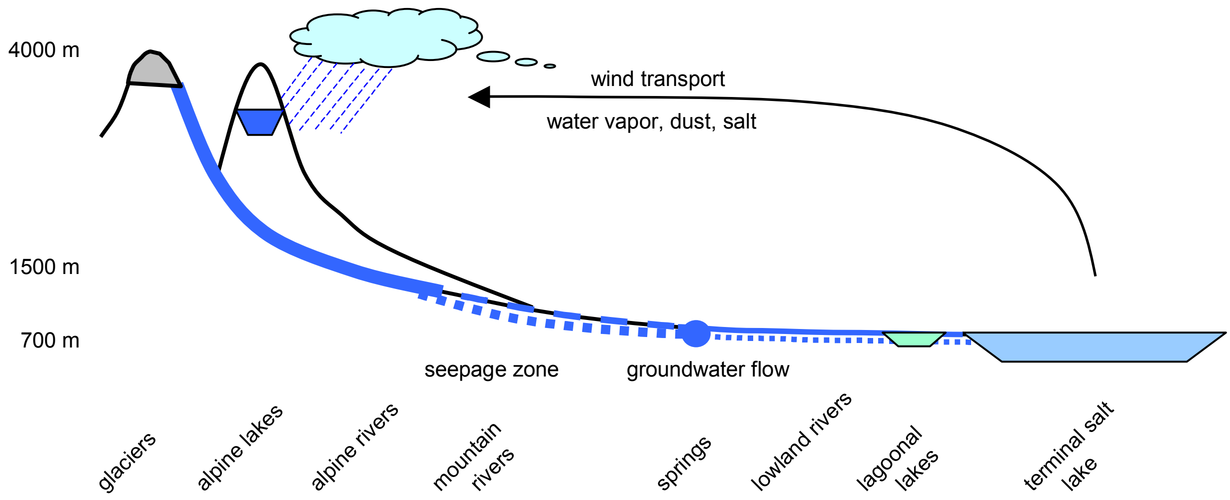


Fig. 63 Scheme of the sequence of water bodies from the western border to the center of the Uvs Nuur Basin.

When the alpine streams are large enough to form wide trough shaped valleys with extended coarse gravelly floodplains, a substantial amount of runoff flows through the hyporheic interstitial. There, the large active surface and low flow velocity intensify dissolution of ions from the sediment and act as filter decreasing the concentration of suspended silt. Where the bed substratum is stable enough, crusty algae, grazers and benthic filter feeders exist. Mountain rivers with lower runoff dynamic, gentle slope and moderately productive floodplain vegetation facilitate the existence of rich benthic ecosystems.

As soon as the rivers leave the confined bedrock valleys and enter the flat alluvial fans, they divide into several branches rapidly loosing their surface runoff by seepage. The decreased groundwater flow velocity caused by lower pore size and slope, and higher temperatures intensify the dissolution processes in the groundwater. Evaporation losses increase the concentration of dissolved ions too. At the evaporation front in the upper soil, calcium carbonate crusts are formed. The oxygen and (less distinctly) nitrate concentrations decrease during underground flow.

Further in the inner basin, where the terrain slope decreases to less than 1% and the hydraulic permeability of the soil decreases due to a higher silt content, a part of the groundwater emerges as small springs forming lowland streams with rich benthic biocenoses. Other parts of the groundwater feed small, mostly shallow lagoonal lakes near the terminal salt lake. These lakes often are influenced by salt lake water. At salinities of some 1 to 3 g/l and high pH values caused by intense planktic primary production, most of the calcium in the inflowing groundwater precipitates as carbonate. The imported phosphorus is incorporated in algal biomass or co-precipitated with calcium carbonate.

The sequence of water bodies and hydrochemical processes in the eastern part of the Uvs Nuur Basin partially differ from the above outlined. In the more arid inner basin east of Uvs Nuur, where large groundwater bodies with long residence time and low recharge rate exist, concentration effects are more important. For instance, the nitrate concentrations in the groundwater and in groundwater fed streams are markedly higher than that of the feeding rivers. In the extended middle and upper reaches of Tesiyn Gol, the tributary streams from the northern Senghilen Mountains tend to be continuous; seepage seems not to play such an important role as in the Turgen-Kharkhiraa Mountains.

The only phosphorus and salt export process from terminal lakes is blowing out of dried sediment from the shore which is considered insubstantial in the short term. A major part of the imported P accumulates in the sediment and can reach quite high concentrations in the water column during strong sediment resuspension. Nitrogen, in contrast, gets lost from the water through denitrification and ammonia volatilization at pH values > 9. The biomass of N_2 fixing cyanobacteria was negligible in the investigated terminal lakes. Thus, the proportion of N and P is shifted to P, and N is more likely to be the limiting nutrient in terminal lakes.

Table 41 Characteristics of typical water bodies in the sequence from glacier to salt lake and associated material conversion processes. Ions written in brackets reach lower percentages.

type of water body	salinity [g/l]	main ions	physical/chemical processes	biological processes
glacier stream	0.05	Ca, (Mg), HCO_3	silt transport and adsorption in the interstitial	low primary production (phytobenthos)
alpine groundwater	0.2–0.5	Ca, (Mg, Na), HCO_3	dissolution of ions	
alpine lake	0.05–0.1	Ca, (Mg,) HCO_3	sedimentation	low primary production (phytoplankton); biofiltration (zooplankton)
alpine rivers	0.1–0.4	Ca, (Mg), HCO_3	bedload transport; dissolution (mainly in the interstitial)	low primary production (benthic algae); biofiltration (zoobenthos)
mountain rivers	0.15–0.35	Ca, (Mg, Na), HCO_3, (SO_4)	bedload transport; dissolution (mainly in the interstitial)	primary production (phytobenthos); biofiltration and grazing (zoobenthos)
groundwater of the seepage zone	0.2–0.6	Ca, Na, (Mg), HCO_3, (SO_4)	adsorption of silt; evaporation; dissolution	respiration
lowland rivers	0.2–0.9	Ca, (Na, Mg), HCO_3, (SO_4)	sand and silt transport; evaporation	primary production (phytobenthos); evapotranspiration; biogenic calcite precipitation
lowland groundwater (springs)	0.3–0.8	Na, Ca, (Mg), HCO_3, SO_4	evaporation; dissolution of Na, Cl; crystallization of carbonates	respiration
lagoonal lakes near salt lake	1–3	Na, (Mg), HCO_3, (Cl)	precipitation of carbonates; crystallization of salts at the shore; blowout of silt and salts	intensive primary production (phytoplankton, -benthos); biogenic calcite precipitation
terminal salt lake	5–>20	Na, (Mg), Cl, (SO_4)	sedimentation; precipitation of carbonates and sulphates; crystallization of salts at the shore; blowout of silt and salts	primary production (phytoplankton, -benthos); biogenic calcite precipitation

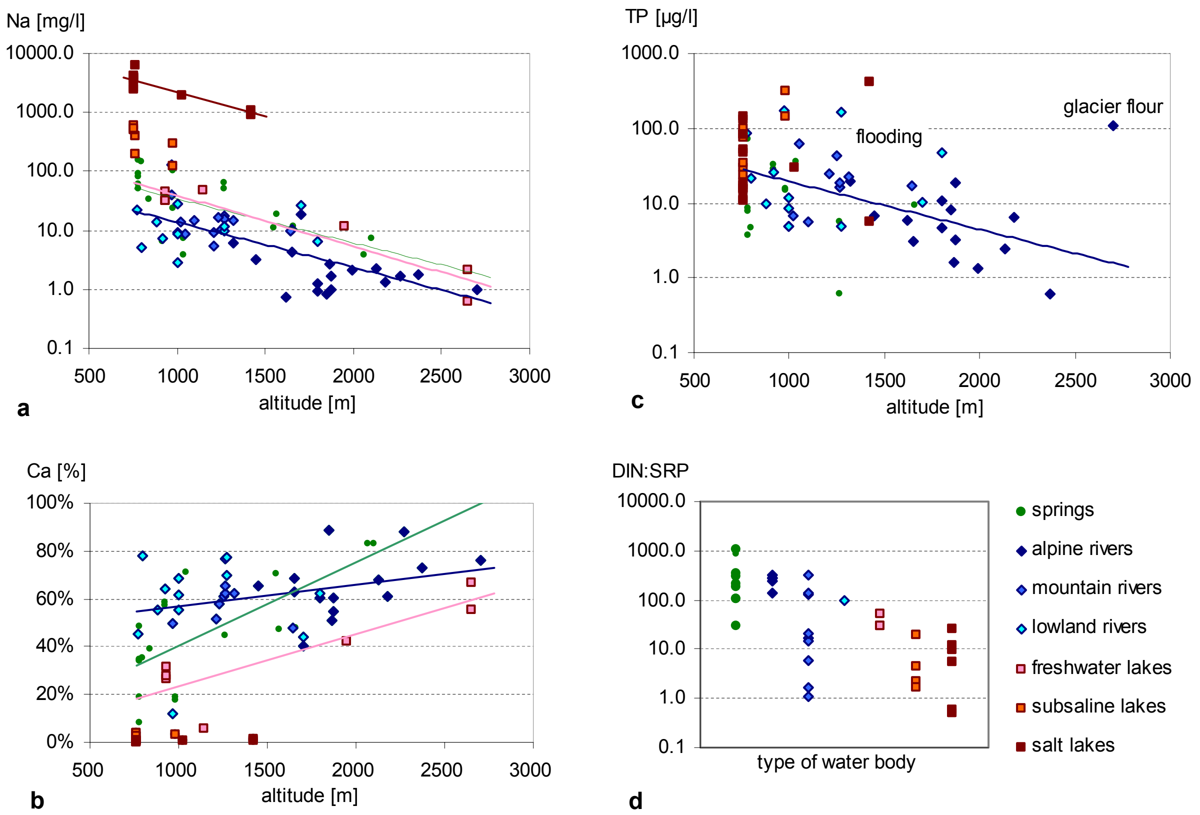


Fig. 64 Dependence of hydrochemical variables from altitude and type of water body in the Uvs Nuur Basin. **a** Concentration of Na vs. altitude. **b** Percentage of Ca in the sum of cations vs. altitude. **c** Concentration of TP vs. altitude. **d** Quotient of DIN/SRP for different types of water bodies (legend applies to all figs.). Regression lines are given for exponential (a and c) and linear relations (b). Note the logarithmic scales of figs. a, c and d!

The centripetal enrichment of highly soluble ions (Na, Cl, SO_4) and phosphorus, the decreasing proportion of calcium and the transition from strong P limitation to possible N limitation can be seen in Fig. 64. The accumulation of Na and TP along the flow path of running surface and groundwater is obvious. The slopes of the relation between altitude and Na concentration are equal for groundwater, rivers and lakes. Compared with this, the absolute concentration (not shown) of Ca shows no significant altitude dependence, and its proportion in the cation sum has a much lower slope for rivers than for freshwater lakes and groundwater. This suggests that the dissolution and evaporative accumulation of sodium depends mainly on climatic factors that change with altitude, while the process of calcium precipitation needs intense contact with soil or sediment particles and is further enhanced by strong primary production – both weak factors in rivers.

However, when considering not only recent processes but geological time scales of several 10000 years, the conception of the terminal salt lake as final accumulation place of all matter transported into it with the flowing water is put into perspective. In more arid climatic periods, when the lake dries out or looses most of its water, blowout of the exposed fine sediment is a landscape forming process: large dune fields and loess strata at the slopes of the surrounding mountains are formed (GRUNERT & LEHMKUHL, 2004); high percentages of the lake's accumulated fine sediments, salts and nutrients can be distributed over the catchment area and beyond, becoming again subject of erosion, dissolution and transport with the water. In this way semi-closed cycles of materials (and water, as a substantial amount of the precipitation comes from water that evaporated in the inner basin) can exist in closed arid basins.

A simple calculation of the theoretical accumulation time of chloride, which was chosen as it is a conservative element and does not precipitate at the prevailing salinities, supports the above thesis: The mean chloride concentration in Uvs Nuur is 4 350 mg/l, that makes 213 million tons in the whole lake volume of 48.4 km^3. The weighted mean chloride concentration in the tributaries (groundwater included) is about 7 mg/l. That makes for the mean annual inflow volume (groundwater included, but direct rain excluded) of 2.2 km^3 an imported mass flow of 15 400 t chloride per annum. Assuming that the mean lake volume, mean amount and chloride concentration of the inflow were roughly the same over the last some 10 000 years, and that no deposits of chloride salts were dissolved directly in the lake, one gets a time of about 13 700 years for the accumulation of the present chloride concentration. This is in quite good concordance with the statement of GRUNERT et al. (2000) that the lake between 24 000 to 13 000 years BP might have been dry. As the whole closed Uvs Nuur Basin is much older than this and a terminal lake is supposed to have existed there for several million years, the salt concentrations would be much higher without the assumed almost complete blowout of salts from the exposed lake bed in drier periods.

4.5 Transformation of the water bodies

From literature data, some conclusions can be drawn about the temporal development of rivers, lakes and groundwater in the Uvs Nuur Basin over time scales between some tens to several thousands of years. The main influential factors over the long time frame were climatic changes and the onset of nomadic pasture several thousand years ago. In the 20th century the advent, intensification and decline of irrigation husbandry and the strong increase in livestock density of the 1990s were events that influenced not only the terrestrial but also aquatic ecosystems. Indications for a recent general eutrophication due to the combined effects of increased livestock density and climatic change were found by SHINNEMAN et al. (2009) in changes of the diatom community structure in sediment cores from five lakes of western Mongolia. A tendency towards higher salinity and nitrate concentrations in groundwater bodies of the inner basin affected by livestock was reported by MAKAROV (1997).

The available data facilitate the reconstruction of major hydrological and morphological changes and significant events of the last decades.

1. The lake level of Uvs Nuur rose by three meters in the 50 years from the end of the 1940s to 1998. This change of lake volume was accompanied by a decrease in salinity from 19 to 14 g/l. The transgression was intermitted by longer phases of stagnating or decreasing lake level. At present the lake level it is slowly decreasing to levels like in the early 1990s. In view of climatic warming, the wish for a long-term prognosis of lake level development is understandable. However, as the exogenous influences on the moisture balance of this large catchment are still not fully understood and climatic data from the mountain ranges are lacking, at present only vague statements can be made. SELIVERSTOV & CHISTYAKOV (1996) discuss the climatic development of the Uvs Nuur Basin in the Holocene and come to the conclusion that currently there are no signs that the lake level of Uvs Nuur will drop dramatically and eventually dry up.
2. The level of the deep, alpine Khukhu Nuur fluctuates by several meters in a time frame of some years, influenced by annual weather conditions and climatic change.
3. The location of river channels shifted laterally by several hundred meters over the last 30 years; small side branches were abandoned and meanders cut. This happens continuously in large, perennial rivers with fine sediment (for instance lower Tesiyn Gol), and during catastrophic flood events in rivers with coarse stony sediment (Turgen Gol) and those with episodic runoff (Gurmosyn Gol). Such events were the flood of June 1986 in the Turgen-Kharkhiraa Mountains that widened the active floodplain and the flood of Baruunturuun Gol in August 1995 that altered its lower reach (Gurmosyn Gol) completely and piled up a large sand cone at the shore of Uvs Nuur.
4. The mean winter temperature increased by 4 degrees from 1980 to 1995. Six representative glaciers in the Turgen-Kharkhiraa Mountains retreated by up to 500 meters and the mean area of these glaciers decreased by about 10% from 1992 to 2000 (evidence from satellite images of June 1992 and August 2010). This increased the winter runoff of the glacier fed Kharkhiraa Gol (evidence from runoff data – see Fig. 5). Should the glaciated area further decrease, the annual hydrographs of Kharkhiraa and Turgen Gol will likely change to a less marked summer runoff.

4.6 Typology of water bodies

Numerous efforts were made by limnologists, hydrologists and geographers to classify lakes and streams. The classification systems served several purposes: to enhance the understanding of ecological processes, to predict complex ecosystem features of little investigated waters from a few known parameters, for hydraulic engineering and hydrological management of rivers, and, increasingly so in the last twenty years, as a basis for environmental management, conservation, assessment of the ecological quality and rehabilitation of water bodies degraded by human activities. For waters of the Uvs Nuur Basin, the main purpose is the description of common abiotic and biotic features based on a set of easily available geographic data. This typology should also be suitable to detect major anthropogenous disturbances.

Several established systems of stream typology were scrutinized if applicable to the investigated region. The general problems of an ecological classification of running waters were described by ILLIES & BOTOSANEANU (1963). They distinguish three main classification types: classification of whole streams according to physiography and hydrochemistry, classification by zonation and the habitat mosaic classification according to bed substrate. In our investigated area, the zonation approach seems better suited than the other two classification methods, as the altitude gradient is the strongest exogenous factor, and for most reaches no information on bed substrate is available. However, when trying to apply the classical sequence of Krenon – Rhithron – Potamon to streams of the Uvs Nuur Basin (which was mentioned as not applicable to the steppe region by ILLIES & BOTOSANEANU (1963) themselves), one finds a characteristic deviation: many streams have no Potamon as they seep away in the rhithral zone. Exceptions are the continuous Tesiyn Gol with an extended potamal zone in the inner basin and some groundwater fed lowland streams like Nariyn and Khustay Gol. The exclusively morphological classification system of

ROSGEN (1994) that was developed for North American streams is not very well applicable to streams of the Uvs Nuur Basin – there are contradictions between entrenchment ratio (= active floodplain width : bankfull width) and sinuosity for many mountain and alpine stream reaches. Newer approaches based on multivariate statistics of biotic and abiotic data are very effective in terms of consistency between stream type and biological structure. The RIVPACS system developed for British streams is based on the statistical evaluation of the macroinvertebrate community structure of undisturbed reference sites (WRIGHT et al., 1984; CLARKE et al., 2003). In a classification system developed for Australian streams, a large number of abiotic variables is used in addition to biological data (TURAK & KOOP, 2008). However, as these methods require large datasets from several hundred sampled sites they are not suitable for use with the few available data from the Uvs Nuur Basin.

One of the most ambitious long term projects of water protection is the European Water Framework Directive (WFD; European Parliament & Council, 2000). The WFD boosted the development of stream and lake typologies, which are mandatory for the assessment of the ecological status of surface waters. They shall be based on a fixed set of external descriptors including ecoregion, altitude, geology, area of the catchment, mean depth and surface area. Alternatively, both types of waters may be characterized by a set of "physical and chemical factors that determine the characteristics of the water body and hence the biological population structure and composition". Several studies confirmed that these abiotic types correspond to differences in the biological structure sufficiently well, even though improvements can be made using additional variables (VERDONSCHOT & NIJBOER, 2004; MOOG et al., 2004).

This classification approach – using a small set of easily deducible geographical features – was chosen for the surface waters of the Uvs Nuur Basin, too. It has the advantage that no large set of physico-chemical and biological data is needed to classify the streams, and it works also for unsampled sites, in this way serving as a predictive tool. Furthermore, after a complete biological survey of reference sites the system could be used to evaluate the ecological condition of a degraded water body by comparing its biological structure with the reference condition for that type.

The following criteria were chosen for the classification of streams:

- Region: three regions were distinguished that differ in the amount of precipitation, orography and potential influence of species endemic to the southern Mongolian deserts. The region of NW mountains with the highest slopes and specific runoff comprises the western and northern delimiting mountain ranges from the Turgen-Kharkhiraa Nuruu to the Tannu-Ola mountains and Khorumnug Taiga (see relief map in the appendix). The region of SE mountains with moderate slopes and somewhat lower specific runoff comprises the mountains and intramontane basins from Khrebet Senghilen and Bulnayn Nuruu to Khan Khökhiyn Nuruu and Togtokhyn Shil. The semiarid, flat central basin was defined as the area with an altitude below 1100 m ASL.
- Reach altitude and altitude of headwaters: these criteria were used to account for temperature, substrate structure, current and runoff variation. With the help of the headwaters' altitude, alpine and mountain streams can be distinguished. The altitude limits should be applied with some tolerance to avoid misclassification. In the case of the lower limit of alpine and mountain streams, the orographic boundary between mountains and plain should be relevant.
- Catchment area: brooks, small and large rivers can be distinguished with this criterion.

A further criterion often used in stream typology is the geological type of the catchment or bed substrate, i.e. siliceous or calcareous rock and soil. As the hydrochemical analyses show, there are no streams with clearly siliceous characteristics: in nearly all samples, the sum of calcium and magnesium was higher than 1 meq/l (equivalent to 50 mg $CaCO_3$/l) and the pH above 8, values exceeding that of typical siliceous waters. The only exception were the headwaters of Turgen Gol with a minimum Ca concentration of 0.6 meq/l which, however, did not justify establishing a siliceous type.

Table 42 Typology of running waters in the Uvs Nuur Basin. Headwaters altitude is the maximum altitude of headwaters of the classified stream reach. The regions were defined on the preceding page.

stream type	criteria				key features	examples
	region	reach alt. [m ASL]	headw. alt. [m ASL]	catchment area [km^2]		
glacial reach of alpine stream	NW	>2500	>2900	<50	>30% runoff from glacier, low temp., moderately stable, coarse sediment	Turgen Gol-0, uppermost reaches of Kharkhiraa Gol
headwaters of alpine stream	NW	>1800	<2900	<50	low temperature, moderate current and runoff variation, coarse sediment	headwaters of Turgen, Dshi-bertu, Tsunkheg Gol
	SE	>2000		<100		headw. of Tesiyn, Erzin Gol
alpine stream	NW	>1300	>1800	>50	low temp., high current and runoff variation, coarse, instable sediment, braided channel	Kharkhiraa, Turgen, Sagil, Torkhilog Gol
	SE	>1800		>100		upper Tesiyn, Erzin Gol
lowland reach of alpine stream	NW	<1300	>1800	<10000	decreasing / periodic runoff w. high variation, coarse to fine sediment	lower reaches of Kharkhiraa, Turgen, Sagil, Torkhilog Gol
mountain brook	NW	>1100	<1800	<500	medium temp., moderate current and runoff variation, medium sized and moderately stable sediment	Borshoo, Endert Gol
	SE	1100 to 1800		<1000		
mountain river	NW	>1100	<1800	>500	medium temp., moderate to high current and runoff variation, wide and moderately unstable bed	
	SE	1100 to 1800		>1000		Tesiyn Gol-1 to 4, middle reaches of Baruunturuun G.
lowland reach of mountain stream	basin	<1100	1100 to 1800	<10000	decreasing / periodic runoff w. moderate variation, medium sized sediment	lower reaches of Borshoo and Baruunturuun Gol
groundwater fed lowland brook	basin	<1100	<1100	<100	>50% runoff from groundwater, low temp., stable runoff	Khustay, Urt Bulag, Jireeg, upper reaches of Nariyn Gol
lowland brook	basin	<1100	<1100	<1000	high temp., slow current, fine sediment, moderately stable bed	Ukhug Gol
lowland river	basin	<1100	<1100	1000 to 10000	high temp., slow current; wide, moderately instable bed w. fine sediment	Khoyd Gol, middle and lower Nariyn Gol
large lowland river	basin	<1100		>10000	high, continuous runoff w. moderate variation, fine sediment, instable bed	lower Tesiyn Gol

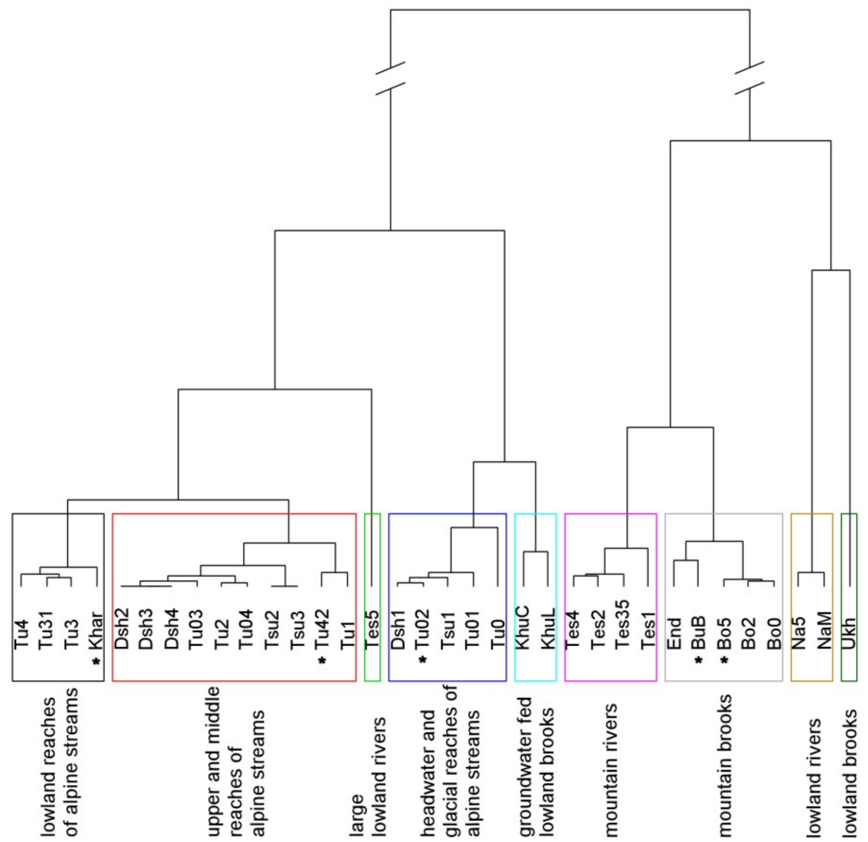


Fig. 65 Validation of the stream typology: cluster analysis of 34 stream sites of the Uvs Nuur Basin, based on the community structure of phyto- and zoobenthos.
The same taxonomic groups as in Fig. 58 and Fig. 59 were used. Abundance data were transformed into relative dominances for phyto- and zoobenthos, respectively, to compensate for differences in the absolute population density. These data were used for a PCA, and a cluster analysis of the first five principal components was performed, using Euclidean distances and Ward's method.
* = misclassified sampling site: Khar and Tu02 would correctly belong to cluster 2, Tu42 to cluster 1, BuB to cluster 9, and Bo5 should be in a separate cluster "lowland reaches of mountain streams".

The result is a system of eleven stream types that can be determined using the criteria described above (Table 42). The three main types (alpine, mountain and lowland streams) are subdivided according to size and – this is a regional peculiarity – constancy of runoff: headwaters and spring fed brooks with low runoff variability are separated as well as lowland reaches of alpine and mountain streams with decreasing or episodic runoff. To validate the types, a cluster analysis was made using the first five principal components of phyto- and zoobenthos dominance data (Fig. 65). The sampling sites in the resulting nine clusters of biotic river types were correctly assigned to the abiotic stream types in 85% of the 34 cases. Hence, the typology can be considered as sufficiently well-defined for ecological investigations.

For the classification of lakes, several typologies can be found in the literature that were developed on the basis of "external" orographical descriptors (mainly altitude, surface area, mean depth, volume quotient, catchment geology), "internal" descriptors (hydrophysical, -chemical and -biological variables like stratification, water temperature, salinity, calcium concentration, trophic state), or a combination of external and internal descriptors. A lake typology for the Central Asian part of the Soviet Union (ERGASHEV, 1979) is an example for a mixed approach. The author used the criteria origin, altitude, depth, water temperature, transparency and salinity for classification. However, for each criterion a separate set of lake types was established, and not consolidated into a complete, usable typology. DAVAA (1996a, b) developed a typology of Mongolian lakes based on vegetation zone and trophic state – see Table 43. He distinguished six types and counted Khyargas, Üüreg and Uvs Nuur into the "oligotrophic lakes without outlet" type. A disadvantage of this system is the inclusion of the criterion trophic state that makes it difficult to classify lakes which were not appropriately sampled, and does not allow to distinguish between natural and anthropogenous eutrophication. The latter statement is supported by a study of factors controlling the hydrochemical and trophic state of 86 European shallow lakes (NÕGES et al., 2003), which resulted in the statement, that "water quality parameters like Secchi depth, concentrations of suspended solids, total nitrogen, total phosphorus and chlorophyll were exponentially related with the presumed quality classes of the lakes".

Table 43 Typology of Mongolian lakes from Davaa (1996b).

lake type	mean summer temp. [°C]	salinity [mg/l]	dominating ions
ultra-oligotrophic alpine lakes	< 4	< 50	Ca^{2+}, HCO_3^-
oligotrophic mountain lakes	4–8	50–220	Ca^{2+}, HCO_3^-
mesotrophic steppe lakes	8–12	150–250	Ca^{2+}, HCO_3^-
mesotrophic desert lakes	2–14	200–5000	Na^+, HCO_3^-
eutrophic steppe lakes	> 14	200–500	Ca^{2+}, HCO_3^-
oligotrophic lakes without outlet	4–15	> 5000	Mg^{2+}, Na^+, SO_4^{2-}, Cl^-

The classification approach for lakes used here can only be a simple one, as the number of investigated lakes is too low to allow for a complete, sophisticated typology covering lakes down to a size of some hectares. The classification criteria are:

- Altitude: this criterion determines the thermal and mixing characteristics, the morphometry (mainly the relative depth), the hydrological conditions (balance between inflow and evaporation) and chemical characteristics.
- Surface area: this is the most commonly used measure of lake size, and related to the presence of fish.
- Existence of an outflow: this is the most important factor determining salinity. However, the salinity of endorheic lakes depends among others on the altitude difference between the lake bottom and the lowest possible outflow. If it is small enough, the water level can reach this outflow during wetter climatic periods and flush out the accumulated salts.
- Relative depth: this criterion is somewhat correlated with altitude and determines mixing characteristics and trophic state. However, as it is not available or unreliable for many lakes, it can only be used supplementary to improve the reliability of the classification.

No chemical criteria were used as they are not available for most of the smaller lakes. However, aside from the alpine lakes, all freshwater lakes were of the calcareous type. The resulting typology is presented in Table 44. Nine lake types can be distinguished that belong to the alpine, mountain and lowland regions. None of the investigated lakes is of the type "saline mountain lake", but two rather large lakes without outflow in the eastern part of the Uvs Nuur Basin are most probably of that type: Bust Nuur at 2041 m ASL with an area of 24 km², and Jugnay Nuur at 1999 m ASL with an area of 35 km². At least Bust Nuur is listed as saline lake in DAVIES (1989). The variability of small lakes certainly is higher than represented by the two types, but it would require an extensive sampling program to differentiate their types.

Table 44 Typology of stagnant waters in the Uvs Nuur Basin based upon orographical criteria. Temperatures are maximum surface temperatures in August. Absence of an outflow means no superficial and no substantial underground outflow.

	criteria					
type	alt. [m ASL]	area [km²]	outflow	rel. depth	key features	examples
alpine lake	>2100	<1	yes	>5%	temp. < 8°C, salinity <0.1 g/l, oligotrophic, (stratified)	Nogoon, alpine lake near Turgen
freshwater mountain lake	1300-2100		yes	>1%	temp. <15°C, salinity <0.4 g/l, oligo-mesotrophic, stratified	Khukhu Nuur
saline mountain lake	1300-2100	10-50	no		temp. <15°C, salinity <5 g/l, oligotrophic, (stratified)	Bust Nuur
large terminal salt lake	<1500	>100	no	<0.5%	temp. 15-25°C, salinity 5-20 g/l, oligotrophic, (stratified)	Uvs Nuur
large freshwater lowland lake	<1300	30-75	yes		temp. 18-25°C, salinity 0.3-1 g/l, oligo-mesotrophic, stratified	Bayan, Döröö Nuur
subsaline lowland lake	<1300	1-5	yes		temp. 18-25°C, salinity 1-3 g/l, meso-eutrophic, polymictic	Baga Nuur
saline lowland lake	<1300	1-5	no		temp. 18-25°C, salinity 5-50 (200) g/l, meso-eutrophic, polymictic	Southern Baga, Shara Nuur
small, deep lowland lake	<1300	<1	yes	>0.5%	temp. 18-22°C, salinity 0.3-1 g/l, mesotrophic, stratified/polymictic	Seepage Lake
small, shallow lowland lake	<1300	<1	(no)	<0.5%	temp. 20-27°C, salinity 1-3 g/l, eutrophic, polymictic	Shavart, Togoo Nuur

4.7 Protection of landscape and waters

The human impact on landscape, nature and waters in the Uvs Nuur Basin is low, compared with highly developed industrial countries. There are however signs of pollution, erosion and overgrazing, especially in the vicinity of Ulaangom and smaller populated places.

Most easily visible, unregulated **waste** dumps east of Ulaangom covered an area of some 50 hectares (based on our observations and recent satellite imagery). This seems to be a cultural problem as nomadic households normally generated only organic wastes that need no treatment and are disposed where they originate. This behavior often was carried over to modern times for the handling of non-organic, construction and packaging wastes. Even in the strictly protected area at the SW shore of Uvs Nuur, where people of Ulaangom used to go swimming, noticeable heaps of garbage were found. It can be assumed, however, that the probability of hazardous substances infiltrating the groundwater from the wastes is low given that they are mostly domestic. Another visible problem is car traffic. We observed that there is often little care in handling fuel and oil – once we saw a driver changing his car's motor oil directly on a river bank. Furthermore, soil erosion is increased due to multiple tracking on unimproved steppe roads.

Despite the above, direct discharge of harmful substances into waterbodies generally is negligible. The amount of **wastewater** from Ulaangom is comparably low as most citizens live in yurt districts where no wastewater system exists. The Ulaangom sewage treatment plant works on a low technological level (mainly ponds with a total area of some 1.5 hectares) and discharges into Gashun Gol, one of the branches of Kharkhiraa Gol, which reaches Uvs Nuur only as groundwater stream. Pollution of waterbodies by livestock excrements is a more important and widespread source of eutrophication. Especially small, sometimes temporary steppe lakes without outflow can accumulate big amounts of dried excrements washed there by strong precipitation. We observed closed layers of several centimeters thickness covering shallow depressions in the steppe. Furthermore, livestock is concentrated near rivers and freshwater lakes, often standing and also urinating in the water.

Another, more severe consequence of livestock grazing is eutrophication of lakes and rivers due to increased soil erosion on **overgrazed rangelands**. Although this is an eutrophication factor effective since at least 2000 years, the increase in livestock number seen in the 1990s from 23 million to 33 million animals (NYAMDAVAA, 2000) must have intensified its influence on the waters.

Large scale withdrawals of water from the tributaries of Uvs Nuur for **irrigation** would lead to a permanently decreasing lake level and increasing salinity as the examples of many endorheic lakes show (WILLIAMS, 1996; LETOLLÉ & MEINGUET, 1996), which is fortunately less likely due to the unfavorable climatic conditions for husbandry. COMÍN et al. (1999) demand "that the major objective for the conservation of saline lakes should be to preserve the fluctuation of the hydrological balance". NYAMJAV & OYUNTSETSEG (1991) point out that the required minimum river runoff to ensure hydrological and ecological stability of the Uvs Nuur Basin must be calculated for years with low precipitation, and that a hydrological management program based on the most unfavorable conditions should be set up. Based on a zonal hydrological model of runoff formation, DASHDELEG (1996) developed maximum allowable, ecologically safe percentages of water withdrawal from Mongolian mountain rivers. For rivers in the Central Asian endorheic area they amount to 5-10% of the annual runoff, but only in their middle reaches where the surface runoff reaches its maximum. Furthermore, they set up pricing principles for water resources usage. SHIL'KROT (1996) points to the vulnerability of the steppe ecosystems in the southern part of the Uvs Nuur Basin that depend on groundwater partially recharged by seeping river water. Larger withdrawals from the rivers Kharkhiraa and Baruunturuun could lead to decreasing level and worsening quality of the groundwater. As WILLIAMS (1998b) summarizes, irrigation husbandry in semiarid regions often leads to secondary salinization: irrigation rises the level of subsaline groundwater. This can lead to salinization of soils by the capillary ascending groundwater which evaporates at the surface, leaving salt deposits. Some of this salt gets blown or washed into surface waters subsequently, rising their salinity.

One of the most severe human impacts on aquatic ecosystems is the introduction of **alien species**, especially fish. One known example from the Uvs Nuur Basin is the introduction of *Esox lucius* into Döröö Nuur. It certainly altered the food web structure, likely by a reduction of larger, cannibalistic specimens of *Oreoleuciscus humilis*. This could have reduced the predation pressure on smaller, planktivorous specimens of this species, and thus decreased the biomass of big crustacean plankton. Other groups of alien species with high potential to disrupt food webs are mollusks, macrophytes, several parasites and disease vectors unintendedly introduced by human activity. The food web alterations caused by them could even be intensified by environmental stressors like hydrological changes or eutrophication (STRAYER, 2010).

The protection of endangered, especially endemic, aquatic species should be seen in the general context of the management of the protected areas in the Uvs Nuur Basin. Particular attention should be paid to the fish species *Oreoleuciscus* spp. and *Triplophysa gundriseri* that are endemic to the area. However, also smaller organisms, even protists deserve conservation as they often play key roles in the energy flux at the base of food webs, and can easily be extinguished by alterations of their habitat (COTTERILL et al., 2008). For instance, the newly described *Acanthocorbis mongolica* (Acanthoecida) that is likely endemic to its type locality Bayan Nuur, is probably an efficient filter feeder grazing on bacteria. Likewise, *Cyclops glacialis* was until now only reported from its type locality Nogoon Nuur. There may be several other rare or undescribed species in the high number of smaller, often very diverse water bodies of the Uvs Nuur Basin.

Probably the biggest recent threat to waterbodies would be large scale **mining** activities, especially open-pit gold placer mining which often releases huge amounts of silt, in the worst case even cyanide or mercury into the rivers. Until now the author knows of no such activities or plans in the Uvs Nuur Basin, but it is a fast growing sector of the Mongolian economy, and the use of illegal chemicals until now could not be suppressed completely. Improving the level of environmental education and awareness would surely be helpful avoiding some of these problems.

If new, significant economic activities in the Uvs Nuur Basin affecting aquatic ecosystems are planned, a management board should be set up, integrating policy makers, economists, nature protection authorities, hydrologists and limnologists – see PARPAROV & HAMBRIGHT (1996). Of great importance will be public awareness and non-governmental organizations to help protect these valuable but also highly vulnerable ecosystems (WILLIAMS, 2002). The importance of scientific knowledge and public awareness regarding wetlands was also emphasized in the RAMSAR National Report Mongolia (2008).

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6 Appendices

6.1 Tables

Table 45 Complete numbered (corresponding to numbers in Table 3), alphabetic list of sampling and measuring places with date of sampling, geographic coordinates and altitude, indication if biological samples (bio) and water or sediment samples for chemical analyses (chem) were taken and type of water body (1=spring/well, 2=alpine river, 3=mountain river, 4=lowland river, 5=freshwater lake, 6=subsaline lake, 7=salt lake). Names with attached hyphen and number or compass direction indicate different sampling places on a river or lake. Special sampling places: * samples were taken by the work group of W. KRÜGER et al.; # samples were taken by the work group of U. TRETER et al.

no.	name	date	coord. north	coord. east	alt. [m]	bio	chem	type	remarks
1	alpine lake near Turgen Gol	08/18/97	49° 45' 32"	91° 19' 07"	2730	x		5	
2	Baga Nuur	08/18/98	50° 23' 14"	92° 12' 53"	762	x	x	6	at NW shore of Uvs
		08/11/99				x	x		
3	Baruunturuun Gol	08/26/99	49° 39' 06"	94° 24' 09"	1250		x	3	
4	Bayan Nuur	08/23/97	49° 59' 29"	93° 56' 56"	932	x	x	5	
		08/28/98				x	x		
		08/25/99				x	x		
5	Borshoo Gol-0	08/16/98	50° 36' 10"	91° 42' 56"	1335	x	x	3	
6	Borshoo Gol-2	08/29/96	50° 34' 03"	91° 46' 44"	1252	x	x	3	
		08/16/98				x	x		
		08/10/99				x	x		
7	Borshoo Gol-Borshoo		50° 32' 12"	91° 47' 46"	1200			3	gauging station
8	Borshoo Gol-4	08/17/98	50° 28' 30"	91° 51' 26"	1085	x	x	3	
9	Borshoo Gol-5	08/17/98	50° 25' 48"	91° 53' 56"	1002	x	x	3	
10	brook 1-waterfall *	07/21/99	49° 54' 33"	91° 46' 04"	1980		x	2	
11	brook 1-holiday camp *	07/21/99	49° 55' 10"	91° 47' 09"	1650		x	2	
12	brook 3 (Turgen Mountains) #	08/20/97	49° 55' 40"	91° 34' 00"	2270		x	2	
13	brook 4 (Turgen Mountains) #	08/23/97	49° 56' 28"	91° 25' 28"	1700		x	2	
14	brook 5 (Turgen Mountains) #	08/24/97	49° 56' 05"	91° 21' 02"	1850		x	2	
15	brook of Butsaldag Bulag	08/18/98	50° 24' 01"	92° 12' 48"	765	x	x	1	spring stream
		08/11/99					x		
16	Burat Usu Bulag	08/19/98	50° 23' 35"	92° 10' 27"	780	x	x	1	
		08/11/99					x		
17	Burgastay Gol	09/01/96	50° 03'	91° 04'	1600	x		3	
18	Butsaldag Bulag	08/11/99	50° 24' 15"	92° 11' 20"	800		x	1	
19	Döröö Nuur	08/25/98	50° 00' 52"	94° 55' 00"	1148	x	x	6	
20	Dshibertu Gol-0	08/13/98	49° 52' 42"	91° 06' 50"	2365	x		2	
21	Dshibertu Gol-0.1	08/13/98	49° 52' 25"	91° 08' 01"	2310	x	x	2	
22	Dshibertu Gol-0.2	08/13/98	49° 52' 17"	91° 13' 30"	2115	x	x	2	
23	Dshibertu Gol-0.3	08/13/98	49° 52' 57"	91° 17' 44"	1973	x	x	2	
24	Dshibertu Gol-0.4	08/13/98	49° 53' 29"	91° 21' 08"	1867	x	x	2	
25	Endert Gol-spring	08/15/99	49° 58' 12"	91° 23' 27"	1660		x	1	
26	Endert Gol	08/19/97	49° 59' 12"	91° 24' 48"	1640	x	x	3	
27	Gurmosyn Gol	08/26/97	49° 53' 35"	93° 37' 50"	956	x	x	4	lower Baruuntur. G.
28	Jireeg Gol	08/30/96	50° 35'	92° 30'	800	x		4	
29	Khangiyltsagiyn Gol	08/31/97	49° 41' 47"	94° 18' 07"	1230		x	3	
30	Kharig Gol	09/01/96	50° 12'	90° 52'	1450	x		3	
31	Kharkhiraa Gol-Tarialan	08/19/99	49° 46' 47"	91° 51' 49"	1440	x	x	2	gauging station
32	Khoyd Gol	08/25/97	50° 01' 39"	94° 01' 15"	932	x		4	outflow of Bayan N.
		08/27/98							
33	Khukhu Nuur *	08/01/99	49° 50' 00"	91° 43' 04"	1925		x	5	
34	Khustay Gol-spring	08/24/97	49° 55' 42"	94° 06' 22"	1000	x	x	1	
		08/25/99				x	x		
35	Khustay Gol-confluence	08/24/97	49° 56' 05"	94° 05' 39"	980	x	x	4	
36	Khustay Gol-lower reach	08/25/97	49° 57' 49"	94° 02' 10"	950	x		4	
37	Khyargas Nuur	08/09/98	49° 10' 30"	93° 47' 24"	1029	x	x	7	

Table 45 continued.

no.	Name	date	coord. north	coord. east	alt. [m]	bio	chem	type	remarks
38	lagoon 1 at Üüreg Nuur	08/16/99	50° 05' 26"	91° 03' 00"	1425	x		7	
39	lagoon 2 at Üüreg Nuur	08/16/99	50° 05' 26"	91° 03' 00"	1425	x	x	7	
40	lagoon 2	08/28/97	50° 06' 47"	92° 21' 53"	770			6	at SW shore of Uvs
41	Nariyn Gol-1	08/24/98	50° 01' 28"	94° 37' 42"	980		x	4	spring stream
42	Nariyn Gol-2	08/24/98	50° 11' 20"	94° 17' 39"	881		x	4	
43	Nariyn Gol-5	08/24/98	50° 18' 43"	93° 34' 13"	777	x	x	4	
44	Nariyn Gol-mouth	08/23/98	50° 17' 03"	93° 25' 52"	760	x		4	
45	Nogoon Nuur	08/13/99	49° 49' 03"	91° 16' 12"	2695	x	x	5	
46	Sagil Gol	08/28/96	50° 18' 20"	91° 40' 08"	1000		x	4	
47	Seepage Lake	08/28/96	50° 06' 56"	92° 23' 00"	761	x	x	6	
		08/28/97				x	x		
		08/21/99				x	x		
48	Shavart Nuur	08/26/97	49° 54' 43"	93° 43' 37"	982	x	x	6	
		08/26/99				x	x		
49	Southern Baga Nuur	08/21/99	50° 01' 00"	92° 52' 23"	763	x	x	7	at S shore of Uvs
50	spring 1 (Turgen Mountains) #	08/19/97	49° 56' 05"	91° 33' 07"	2065		x	1	
51	spring 2 (Turgen Mountains) #	08/20/97	49° 56' 05"	91° 33' 07"	2100		x	1	
52	spring 6 (Malchin) #	08/27/97	49° 41' 08"	93° 06' 01"	1550		x	1	
53	spring 7 (Malchin) #	08/28/97	49° 40' 50"	93° 05' 00"	1570		x	1	
54	spring at Borshoo Gol-2	08/16/98	50° 34' 03"	91° 46' 44"	1265	x	x	1	
		08/10/99					x		
55	spring at Torkhilog Gol	08/31/96	50° 42'	92° 36'	1000	x		1	
56	spring at Urt Bulag Gol	08/25/97	50° 03' 26"	94° 09' 25"	920	x	x	1	
		08/25/99					x		
57	spring-1 at Bayan Nuur	08/28/98	49° 56' 57"	93° 53' 18"	980	x	x	1	
		08/26/99					x		
58	Tesiyn Gol-1	08/04/99	49° 16' 14"	98° 08' 41"	1780	x	x	3	
59	Tesiyn Gol-2	08/05/99	49° 29' 14"	97° 40' 46"	1690	x	x	3	
60	Tesiyn Gol-3	08/05/99	49° 28' 40"	97° 16' 39"	1625	x		3	
61	Tesiyn Gol-3.5	08/28/99	49° 31' 56"	97° 01' 00"	1565	x		3	
61a	Tesiyn Gol-3.5a (oxbow pond)	08/28/99	49° 32' 04"	97° 01' 10"	1563	x		4	
62	Tesiyn Gol-Bayan Uul		49° 44' 35"	96° 26' 14"	1406			3	gauging station
63	Tesiyn Gol-4	08/30/98	49° 39' 29"	95° 43' 47"	1263	x	x	3	
		08/27/99				x	x		
64	Tesiyn Gol-5	08/23/99	50° 34' 11"	93° 37' 34"	799	x	x	4	
65	Tesiyn Gol-5.5 (oxbow pond)	08/24/99	50° 32' 31"	93° 36' 37"	800	x		5	
66	Teylin Gol	08/31/97	49° 54' 27"	92° 12' 58"	950		x	3	
67	Togoo Nuur	08/24/99	50° 20' 17"	93° 34' 48"	782	x		6	
68	Torkhilog Gol	08/31/96	50° 42'	92° 36'	1003	x		3	
69	Tsunkheg Gol-1	08/18/99	50° 01' 16"	91° 38' 00"	1900	x		2	
70	Tsunkheg Gol-2	08/18/99	50° 01' 45"	91° 37' 24"	1780	x		2	
71	Tsunkheg Gol-3	09/02/96	50° 02' 35"	91° 37' 20"	1650	x		2	
		08/18/99				x	x		
72	Turgen Gol-0	08/17/97	49° 43' 56"	91° 19' 06"	2700	x	x	2	
73	Turgen Gol-0.1	08/18/97	49° 44' 37"	91° 18' 47"	2580	x		2	
74	Turgen Gol-0.2	08/18/97	49° 47' 35"	91° 20' 17"	2270	x		2	
75	Turgen Gol-0.3	08/18/97	49° 49' 18"	91° 21' 21"	2180	x	x	2	
76	Turgen Gol-0.4	08/18/97	49° 53' 20"	91° 21' 10"	1870	x	x	2	
		08/14/98				x	x		
77	Turgen Gol-1	08/16/97	49° 54' 04"	91° 22' 14"	1820	x	x	2	
		08/12/98				x	x		
		08/15/99				x			
78	Turgen Gol-Delgermörön	08/19/97	49° 55' 41"	91° 24' 10"	1750			2	gauging station
79	Turgen Gol-2	08/19/97	49° 59' 13"	91° 24' 57"	1620	x	x	2	

Table 45 continued.

no.	name	date	coord. north	coord. east	alt. [m]	bio	chem	type	remarks
80	Turgen Gol-3	08/20/97	50° 05' 18"	91° 37' 50"	1280	x	x	2	
		08/17/99				x			
81	Turgen Gol-3.1	08/20/97	50° 07' 34"	91° 41' 34"	1160	x	x	3	at road bridge
		08/11/98					x		
		08/09/99					x		
82	Turgen Gol-4	08/21/97	50° 11' 57"	91° 47' 03"	960	x	x	3	
83	Turgen Gol-4.1	08/21/97	50° 13' 35"	91° 49' 52"	900			4	seepage reach
84	Turgen Gol-4.2	08/21/97	50° 14' 06"	91° 50' 50"	890	x		4	upwelling groundwater in dry river bed
85	spring at Turgen Gol-4.2	08/21/97	50° 14' 05"	91° 50' 30"	890	x	x	1	
86	Ukhug Gol	08/22/99	50° 29' 41"	93° 36' 02"	800	x		4	
87	Urt Bulag Gol	08/25/97	50° 03' 26"	94° 09' 25"	917		x	4	
		08/25/99				x			
88	Üüreg Nuur-S	08/15/99	50° 05' 26"	91° 03' 00"	1425	x	x	7	
89	Üüreg Nuur-S '96	09/01/96	50° 05' 25"	91° 01' 00"	1425	x	x	7	
90	Üüreg Nuur-W	09/01/96	50° 07' 30"	90° 54' 00"	1425	x		7	
91	Uvs Nuur-E	08/23/98	50° 16' 07"	93° 25' 08"	761	x	x	7	
92	Uvs Nuur-N	08/30/96	50° 31'	92° 28'	761	x	x	7	
93	Uvs Nuur-NW	08/13/97	50° 25' 58"	92° 14' 16"	761	x	x	7	
		08/18/98				x	x		
		08/10/99				x	x		
94	Uvs Nuur-SW	08/27/96	50° 07' 11"	92° 22' 58"	761	x	x	7	
		08/27/97				x	x		
		08/20/99				x	x		
95	well 1	08/23/98	50° 15' 15"	93° 25' 25"	780	x	x	1	
		08/22/99					x		
96	well 2	08/16/99	50° 04' 38"	91° 00' 49"	1450		x	1	
97	well 3	08/24/99	50° 15' 22"	93° 40' 48"	840		x	1	

Table 46 Results of chemical water analyses. Samples ordered according to type and name of sampling place. Number of sampling place corresponds to Table 45. Numbers in "remark" column: distance from shore and sampling depth (in the given order). S.No. = sample number; T = water temperature, ϰ = conductivity, S = salinity, I.B.E. = ion balance error (negative, if anions overbalance cations). Conductivities and pH values in italics are measured in the laboratory; underscored salinities are corrected using conductivity, and ion concentrations in italics are of reduced reliability due to precipitations and salt losses in the sample.

	sampling place			on-site measurements						major ions [mg/l]										
S.No.	No. name	date	remark	T [°C]	ϰ [µS/cm]	pH	O_2 %	S [g/l]	I.B.E.	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	Br^-	NO_3^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
	springs and wells																			
52	16 Burat Usu Bulag	08/19/98 15h		6.3	530	8.00	90	0.43	6%	60.0	2.7	35.4	9.8	0.47	49.1		1.93	66.2	115	0.7
77	16 Burat Usu Bulag	08/11/99 13h		5.9	531	8.28	85	0.41	5%	51.4	2.1	57.6	9.4	0.64	28.8	<0.06	2.12	54.3	203	2.5
78	18 Butsaldag Bulag	08/11/99 14h		9.4	1140	8.02	85	0.79	0%	145	3.2	82.1	15.0	0.75	159	0.14	2.14	175	206	1.8
80	25 Endert Gol-spring	08/15/99 14h		1.7	590	7.84	72	0.49	4%	11.5	3.0	67.6	37.6	0.13	18.9	0.15	8.53	43.5	294	1.4
23	34 Khustay Gol-spring	08/24/97 14h		9.6	344	8.24	95	0.28	-3%	*7.2*	*5.3*	*11.5*	*11.9*		*3.6*		*5.40*	*11.1*	*104*	*0.0*
83	34 Khustay Gol-spring	08/25/99 13h		6.4	353	7.74	90	0.28	5%	3.7	2.6	53.5	10.5	0.21	0.3	<0.06	16.90	6.1	181	0.6
15	50 spring 1 (Turgen Mountains)	08/19/97 10h			*420*	*8.0*		0.36	6%	3.9	1.0	81.4	7.8		3.8		0.50	4.4	253	0.0
16	51 spring 2 (Turgen Mountains)	08/20/97 10h			*443*	*8.1*		0.37	8%	7.1	1.2	88.0	6.9		6.0		<0.20	3.5	261	0.0
19	52 spring 6 (Malchin)	08/27/97 17h			*344*	*7.9*		0.28	6%	11.3	0.8	54.8	7.8		3.7		2.80	6.2	193	0.0
20	53 spring 7 (Malchin)	08/28/97 10h		4.2	*275*	6.50		0.22	5%	18.3	0.7	29.3	9.9		3.8		3.10	8.0	151	0.0
44	54 spring at Borshoo Gol-2	08/15/98 19h		7.6	566	7.51	80	0.46	0%	*49.6*	*1.7*	*30.7*	*3.9*	*0.56*	*45.8*	*0.05*	*0.41*	*73.4*	*76.3*	*0.1*
73	54 spring at Borshoo Gol-2	09/12/99 08h		5.3	569	7.84	69	0.41	3%	63.2	1.9	53.5	5.7	0.65	46.0	<0.06	0.85	75.8	164	0.8
102	55 spring at Torkhilog Gol	08/31/96 16h			235	7.19														
13	85 spring at Turgen Gol-4.2	08/21/97 16h		8.0	504	8.22	55	0.41	8%	*23.1*	*2.1*	*17.3*	*8.2*		*25.7*		*0.09*	*18.1*	*64.7*	*1.2*
21	56 spring at Urt Bulag Gol	08/25/97 13h		6.5	306	7.90	58	0.24	5%	6.8	3.4	40.5	12.7		3.8		13.10	6.2	162	0.0
84	56 spring at Urt Bulag Gol	08/25/99 10h		6.5	308	7.83	55	0.26	4%	6.6	3.1	41.3	14.2	0.30	<0.02	<0.06	14.60	6.8	176	0.7
62	57 spring-1 at Bayan Nuur	08/28/98 16h		9.1	975	8.25	59	0.78	1%	103	4.8	32.7	37.7	1.50	33.6		9.42	213	210	2.9
85	57 spring-1 at Bayan Nuur	08/26/99 11h		8.4	600	7.82	60	0.75	5%	123	4.8	42.1	44.6	1.39	37.0	0.17	7.47	232	257	1.4
55	95 well 1	08/23/98 09h		6.1	785	8.32	42	0.78	1%	157	13.2	19.2	42.8	0.97	115		20.70	200	210	3.7
79	95 well 1	08/22/99 14h		6.6	755	7.95	8	0.58	5%	82.2	10.2	32.2	37.1	0.84	24.8	<0.06	15.00	118	259	1.7
108	96 well 2	09/01/96 14h		7.7	425	7.97														
137	96 well 2	08/16/99 18h		5.6	418	8.36	42													
82	97 well 3	08/24/99 14h		6.3	626	7.88	82	0.43	3%	33.5	4.8	48.3	26.4	0.17	14.8	0.08	84.00	74.1	148	0.7
	brooks and rivers																			
69	3 Baruunturuun Gol	08/26/99 17h		21.1	290	8.80		0.25	2%	10.1	3.0	42.5	10.3	0.28	6.4	<0.06	0.24	20.4	155	5.6
42	5 Borshoo Gol-0	08/16/98 12h		12.0	294	8.43	108	0.24	4%	14.3	1.2	34.5	4.7	0.36	4.6		0.12	18.0	120	1.8
4	6 Borshoo Gol-2	08/29/96 12h		8.6	328	8.39	102	0.28	37%	*18.0*	*9.1*	*90.0*	*4.5*		*6.6*			*11.0*	*140*	*0.0*
43	6 Borshoo Gol-2	08/16/98 16h		15.5	308	8.65	104	0.25	11%	15.3	1.2	35.1	4.4	0.41	3.8		0.11	19.7	102	2.5
125	6 Borshoo Gol-2	08/09/99 20h		12.2	232	8.29	97													
72	6 Borshoo Gol-2	08/10/99 08h		8.5	228	8.26	95	0.19	3%	11.7	0.8	33.6	4.4	0.32	3.9	<0.06	0.04	16.7	117	1.2
45	8 Borshoo Gol-4	08/17/98 11h		11.8	358	8.34	100	0.29	1%	*14.6*	*1.1*	*26.4*	*3.3*	*0.40*	*9.5*		*0.08*	*30.3*	*76.6*	*0.9*
46	9 Borshoo Gol-5	08/17/98 14h		12.0	395	8.37	98	0.32	8%	*14.1*	*1.1*	*35.0*	*3.1*	*0.41*	*7.5*		*0.21*	*27.9*	*86.4*	*1.1*

Table 46 continued: Results of chemical water analyses (Part 2 of 8).

S.No.	sampling place No. name	date	mg/l Si	Fe	nutrients [µg/l] PO_4-P	DP	TP	NO_3-N	NO_2-N	NH_4-N	DN	TN
	springs and wells											
52	16 Burat Usu Bulag	08/19/98 15h	7.6				4	440				
77	16 Burat Usu Bulag	08/11/99 13h	7.6	0.03	10	2	8	480		<1		
78	18 Butsaldag Bulag	08/11/99 14h	6.3	<0.01	<10	2	4	480		<1		
80	25 Endert Gol-spring	08/15/99 14h	5.7	0.02	<10	5	9	1900		<1		
23	34 Khustay Gol-spring	08/24/97 14h	*5.6*					1200				
83	34 Khustay Gol-spring	08/25/99 13h	6.0	<0.01	25	18	36	3800		<1		
15	50 spring 1 (Turgen Mountains)	08/19/97 10h	10.0					110				
16	51 spring 2 (Turgen Mountains)	08/20/97 10h	10.5					<40				
19	52 spring 6 (Malchin)	08/27/97 17h	11.4					630				
20	53 spring 7 (Malchin)	08/28/97 10h	11.5					700				
44	54 spring at Borshoo Gol-2	08/15/98 19h	*6.7*				1	92				
73	54 spring at Borshoo Gol-2	09/12/99 08h	6.3	<0.01	15		6	190				
102	55 spring at Torkhilog Gol	08/31/96 16h										
13	85 spring at Turgen Gol-4.2	08/21/97 16h	*7.4*				15	<20				
21	56 spring at Urt Bulag Gol	08/25/97 13h	14.0				33	3000				
84	56 spring at Urt Bulag Gol	08/25/99 10h	7.0	<0.01	25	22	29	3300		<1		
62	57 spring-1 at Bayan Nuur	08/28/98 16h	5.9				15	2100				
85	57 spring-1 at Bayan Nuur	08/26/99 11h	5.9	<0.01	20	5		1700				
55	95 well 1	08/23/98 09h	4.6	0.20			71	4700				
79	95 well 1	08/22/99 14h	4.1	0.01	70	52		3400				
108	96 well 2	09/01/96 14h										
137	96 well 2	08/16/99 18h						1100				
82	97 well 3	08/24/99 14h	6.8	0.02	40	33		19000				
	brooks and rivers											
69	3 Baruunturuun Gol	08/26/99 17h	2.9	0.04			42	53				
42	5 Borshoo Gol-0	08/16/98 12h	6.9	0.03	<10		23	28		<20		
4	6 Borshoo Gol-2	08/29/96 12h			<10		16					
43	6 Borshoo Gol-2	08/16/98 16h	7.0	0.02	<10		16	24		<20		
125	6 Borshoo Gol-2	08/09/99 20h										
72	6 Borshoo Gol-2	08/10/99 08h	5.5	0.10	15	14	19	10		<1	260	430
45	8 Borshoo Gol-4	08/17/98 11h	*6.8*				6	18				
46	9 Borshoo Gol-5	08/17/98 14h	*7.1*		<10		7	47				

Table 46 continued: Results of chemical water analyses (Part 3 of 8).

S.No.	sampling place No.	name	date	remark	on-site measurements T [°C]	ϰ [µS/cm]	pH	O_2 %	S [g/l]	I.B.E.	major ions [mg/l] Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	Br^-	NO_3^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
75	11	brook 1-holiday camp	07/21/99 00h			225	8.1		0.19	1%	4.2	1.8	34.6	6.9	0.05	3.1	<0.06	3.05	15.9	123	0.3
76	10	brook 1-waterfall	07/21/99 00h			192	8.0		0.16	1%	2.1	0.6	30.7	6.4	0.03	0.7	<0.06	2.58	16.6	103.6	0.2
17	12	brook 3 (Turgen Mountains)	08/20/97 16h			420	8.3		0.36	7%	1.6	1.2	87.8	6.0		3.8		<0.20	2.0	253	0.0
18	13	brook 4 (Turgen Mountains)	08/23/97 15h			463	8.2		0.45	4%	18.4	3.8	52.0	36.3		10.6		7.04	51.8	273	0.0
81	14	brook 5 (Turgen Mountains)	08/24/97 12h						0.16	29%	0.8	0.3	54.2	3.7	0.12	0.3	<0.06	<0.10	0.8	93.0	4.2
51	15	brook of Butsaldag Bulag	08/18/98 19h		17.9	790	8.10	103	0.64	5%	91.9	2.4	52.2	10.8	0.52	76.2		1.05	97.0	162	1.5
106	17	Burgastay Gol	09/01/96 12h		8.0	437	8.76														
107	17	Burgastay Gol	09/01/96 18h		12.0			110													
123	20	Dshibertu Gol-0	08/13/98 19h		5.8	160	7.75	100													
35	21	Dshibertu Gol-0.1	08/13/98 15h		6.2	193		94	0.16	8%	1.8	0.6	23.2	4.1	0.05	0.2		2.84	8.1	67.9	0.1
36	22	Dshibertu Gol-0.2	08/14/98 11h		10.5	256	8.35	102	0.21	5%	2.3	0.8	28.6	6.8	0.05	<0.02		2.72	14.5	92.9	1.1
37	23	Dshibertu Gol-0.3	08/14/98 14h		12.0	227	8.23	112	0.18	11%	2.1	1.6	19.2	7.5	0.04	0.5		2.40	10.6	65.2	0.6
38	24	Dshibertu Gol-0.4	08/14/98 16h		11.6	259	8.28	104	0.21	9%	2.7	2.1	21.2	10.2	0.05	<0.02		2.83	10.6	86.4	0.9
14	26	Endert Gol	08/19/97 17h		13.2	450	8.45		0.36	6%	10.0	3.2	49.9	26.4		9.4		3.10	21.1	235	0.0
26	27	Gurmosyn Gol	08/26/97 13h		22.7	1230	8.62	115	0.99	9%	127	3.7	24.9	44.8		37.5		<1.02	117	328	0.0
101	28	Jireeg Gol	08/30/96 17h		11.6	532	8.79	110													
33	29	Khangiyltsagiyn Gol	08/31/97 15h			494	8.4		0.38	6%	16.6	2.5	64.1	18.8		13.0		1.10	51.6	211.7	0.0
105	30	Kharig Gol	09/01/96 17h		7.4	260	7.50	58													
70	31	Kharkhiraa Gol	08/19/99 17h		15.8	142	8.31		0.12	1%	3.2	1.1	19.9	4.4	0.18	1.5	<0.06	2.50	14.1	68.6	0.1
24	35	Khustay Gol-confluence	08/24/97 15h		9.5	368	8.25	103	0.30	3%	2.8	0.7	18.0	3.5		0.7		0.30	4.6	68.3	0.0
120	36	Khustay Gol-lower reach	08/25/97 11h		12.5	380	8.45	110													
58	41	Nariyn Gol-1	08/24/98 16h		11.7	270	8.43	103	0.22	11%	9.1	2.1	27.2	8.0	0.18	3.6		8.72	6.9	94.9	1.4
68	41	Nariyn Gol-1	08/09/99 15h			264	8.3		0.23	2%	8.9	2.1	38.2	9.0	0.27	4.1	<0.06	9.51	8.0	152	0.7
57	42	Nariyn Gol-2	08/24/98 12h		14.7	350	8.38	108	0.28	5%	13.9	1.9	34.2	8.9	0.22	6.8		4.89	13.1	134	1.8
56	43	Nariyn Gol-5	08/24/98 10h		12.6	389	8.65	102	0.31	19%	22.0	3.1	39.8	16.3	0.29	6.3		1.54	26.6	130	3.3
124	44	Nariyn Gol-mouth	08/23/98 17h		23.2	440	9.09	153													
5	46	Sagil Gol	08/28/96 15h			239	8.60		0.31	34%	28.0	15.0	88.0	4.8		20.0			28.0	122	0.0
64	58	Tesiyn Gol-1	08/04/99 13h		17.4	174	8.40	118	0.15	2%	6.4	1.3	25.2	5.4	0.20	0.7	<0.06	<0.1	4.1	108	1.5
65	59	Tesiyn Gol-2	08/05/99 10h		15.8	335	8.62	102	0.27	5%	26.8	2.2	33.6	10.9	0.48	11.5	<0.06	<0.1	23.1	154	3.7
126	60	Tesiyn Gol-3	08/05/99 14h		21.6	403	8.65	127													
127	61	Tesiyn Gol-3.5	08/28/99 10h		10.5	351	8.35														
63	63	Tesiyn Gol-4	08/30/98 09h		10.5	341	8.43	95	0.27	31%	9.5	1.4	67.1	6.4	0.39	2.9		1.27	16.5	109	1.6
66	63	Tesiyn Gol-4	08/05/99 19h		17.8	352	8.37	105	0.30	6%	11.5	1.8	58.2	8.8	0.53	3.9	<0.06	2.75	20.3	185	2.6
128	63	Tesiyn Gol-4	08/27/99 10h		10.1	361	8.39														
129	63	Tesiyn Gol-4	08/27/99 15h		17.1	354															
67	64	Tesiyn Gol-5	08/23/99 14h		20.7	272	8.35	108	0.27	-3%	5.2	1.4	51.8	5.8	0.26	1.7	<0.06	0.98	16.5	186	2.4

Table 46 continued: Results of chemical water analyses (Part 4 of 8).

	sampling place			mg/l		nutrients [µg/l]							
S.No.	No.	name	date	Si	Fe	PO_4-P	DP	TP	NO_3-N	NO_2-N	NH_4-N	DN	TN
75	11	brook 1-holiday camp	07/21/99 00h	3.0	0.07				690				
76	10	brook 1-waterfall	07/21/99 00h	2.9	<0.01				580				
17	12	brook 3 (Turgen Mountains)	08/20/97 16h	8.1					<50				
18	13	brook 4 (Turgen Mountains)	08/23/97 15h	7.9					1600				
81	14	brook 5 (Turgen Mountains)	08/24/97 12h	*4.5*	*<0.01*			8	<24				
51	15	brook of Butsaldag Bulag	08/18/98 19h	7.1	0.02			8	240				
106	17	Burgastay Gol	09/01/96 12h										
107	17	Burgastay Gol	09/01/96 18h										
123	20	Dshibertu Gol-0	08/13/98 19h										
35	21	Dshibertu Gol-0.1	08/13/98 15h	3.3		<10		1	640				
36	22	Dshibertu Gol-0.2	08/14/98 11h	3.2				2	610				
37	23	Dshibertu Gol-0.3	08/14/98 14h	*2.8*				1	540				
38	24	Dshibertu Gol-0.4	08/14/98 16h	2.9		<10		2	640				
14	26	Endert Gol	08/19/97 17h	7.8		<10		17	700		<20		
26	27	Gurmosyn Gol	08/26/97 13h	12.2				180	<230				
101	28	Jireeg Gol	08/30/96 17h										
33	29	Khangiyltsagiyn Gol	08/31/97 15h	7.7					250				
105	30	Kharig Gol	09/01/96 17h										
70	31	Kharkhiraa Gol	08/19/99 17h	2.4	0.05	<10	5	6	560		<1	350	370
24	35	Khustay Gol-confluence	08/24/97 15h	*10.8*				5	68				
120	36	Khustay Gol-lower reach	08/25/97 11h										
58	41	Nariyn Gol-1	08/24/98 16h	6.9	0.01			12	2000				
68	41	Nariyn Gol-1	08/09/99 15h	6.6	<0.01			5	2100				
57	42	Nariyn Gol-2	08/24/98 12h	7.3	0.04			10	1100				
56	43	Nariyn Gol-5	08/24/98 10h	5.7	0.08		84	87	350				
124	44	Nariyn Gol-mouth	08/23/98 17h										
5	46	Sagil Gol	08/28/96 15h			<10		9					
64	58	Tesiyn Gol-1	08/04/99 13h	7.4	0.07	25		48	<24				
65	59	Tesiyn Gol-2	08/05/99 10h	4.0	0.12	<10	12	15	<24		<1	230	310
126	60	Tesiyn Gol-3	08/05/99 14h										
127	61	Tesiyn Gol-3.5	08/28/99 10h										
63	63	Tesiyn Gol-4	08/30/98 09h	*5.2*	*0.08*		0	160	290				
66	63	Tesiyn Gol-4	08/05/99 19h	4.8	0.02		5	5	620				
128	63	Tesiyn Gol-4	08/27/99 10h										
129	63	Tesiyn Gol-4	08/27/99 15h										
67	64	Tesiyn Gol-5	08/23/99 14h	4.2	0.20	<10	1	22	220		<1	200	240

Table 46 continued: Results of chemical water analyses (Part 5 of 8).

	sampling place			on-site measurements						major ions [mg/l]										
S.No.	No. name	date	remark	T [°C]	ϰ [µS/cm]	pH	O_2 %	S [g/l]	I.B.E.	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	Br^-	NO_3^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
32	66 Teylin Gol	08/31/97 10h			*521*	*8.5*		0.38	7%	41.1	2.2	58.9	13.7		28.7		14.50	55.6	178	0.0
140	66 Teylin Gol	08/06/99 15h																		
131	69 Tsunkheg Gol-1	08/18/99 12h		4.8	279	8.00														
132	70 Tsunkheg Gol-2	08/18/99 14h		7.0	295	8.50														
109	71 Tsunkheg Gol-3	09/03/96 11h		2.7	324	8.71	117													
74	71 Tsunkheg Gol-3	08/18/99 17h		6.0	354	8.47		0.30	1%	10.4	0.9	52.2	12.8	0.05	3.2	<0.06	3.22	53.6	163	2.9
6	72 Turgen Gol-0 (spring brook)	08/17/97 18h		1.1	67	8.24		0.05	1%	1.0	1.3	10.3	1.0		2.9		1.19	3.2	30.5	0.0
115	73 Turgen Gol-0.1	08/18/97 09h		1.9	78	8.35														
114	74 Turgen Gol-0.2	08/17/97 15h		6.7	116	8.33	100													
7	75 Turgen Gol-0.3	08/18/97 16h		7.6	128	8.27		0.10	3%	1.3	1.7	17.1	5.5		2.8		1.40	3.4	69.5	0.0
8	76 Turgen Gol-0.4	08/18/97 18h			*165*	*8.1*		0.13	5%	1.7	1.9	19.4	8.2		3.2		0.20	4.0	87.2	0.0
39	76 Turgen Gol-0.4	08/14/98 16h		8.8	104	8.11	104	0.08	7%	1.0	1.1	11.6	3.7	0.03	0.6	0.01	1.35	2.6	43.9	0.3
9	77 Turgen Gol-1	08/16/97 15h		9.7	217	8.34	101	0.17	0%	*0.9*	*0.5*	*8.7*	*2.5*		*0.7*		*0.40*	*1.7*	*38.4*	*0.0*
40	77 Turgen Gol-1	08/12/98 12h		9.6	133	8.27	100	0.11	14%	1.3	1.6	13.6	4.2	0.02	0.3		1.42	3.6	43.7	0.4
133	77 Turgen Gol-1	08/15/99 10h		7.4	177	8.26	99													
10	79 Turgen Gol-2	08/19/97 19h		13.6	216	8.47	100	0.17	0%	*0.7*	*0.4*	*10.0*	*1.5*		*0.6*		*0.40*	*1.6*	*37.2*	*0.0*
11	80 Turgen Gol-3	08/20/97 14h		13.3	284	8.44	100	0.23	0%	*6.3*	*1.8*	*4.5*	*8.0*		*5.8*		*1.90*	*11.1*	*34.2*	*6.6*
134	80 Turgen Gol-3	08/17/99 16h		14.4	279	8.55														
116	81 Turgen Gol-3.1	08/20/97 15h		17.7	284	8.53	100													
41	81 Turgen Gol-3.1	08/11/98 10h		11.0	231			0.19	2%	*5.5*	*1.9*	*14.2*	*6.3*	*0.05*	*0.4*		*1.29*	*8.2*	*72.2*	*1.5*
71	81 Turgen Gol-3.1	08/09/99 16h		17.1	280	8.50	100	0.22	2%	9.1	2.1	32.1	12.6	0.09	6.8	<0.06	3.43	22.2	132	2.4
12	82 Turgen Gol-4	08/21/97 10h		15.7	290	8.52	100	0.23	4%	*8.5*	*2.3*	*3.9*	*10.2*		*6.6*		*2.70*	*14.0*	*36.6*	*7.2*
117	83 Turgen Gol-4.1	08/21/97 16h		20.8	294	8.64	100													
118	84 Turgen Gol-4.2	08/21/97 17h	upwelling	16.4	325	7.97	0													
135	86 Ukhug Gol	08/22/99 17h		22.4	379	8.14	116													
22	87 Urt Bulag Gol	08/25/97 13h		14.0	313	8.41	106	0.26	4%	7.3	3.0	45.3	10.6		4.0		5.88	6.7	177	0.0
136	87 Urt Bulag Gol	08/25/99 10h		11.3	309	8.29	107													
	lakes																			
110	1 alpine lake at Turgen Gol	08/18/97 12h			88	8.25														
50	2 Baga Nuur	08/18/98 16h	at shore, 0 m	23.5	1640	10.12	143	1.30	1%	*197*	*6.3*	*11.1*	*13.1*	*1.65*	*154*		*0.02*	*147*	*51.5*	*57.5*
98	2 Baga Nuur	08/11/99 11h	200 m, 0 m	18.9	1970	9.98	165	1.21	3%	388	12.0	15.5	22.9	2.29	291		0.04	297	101	81.8
25	4 Bayan Nuur	08/23/97 12h	600 m, 0 m	18.4	428	8.84	106	0.37	10%	44.9	4.7	29.8	25.6		11.7		0.40	47.8	200	0.0
60	4 Bayan Nuur	08/28/98 10h	600 m, 0-9 m	20.5	434	9.00	104	0.35	8%	31.3	4.1	20.7	22.9	0.44	7.7		0.29	54.7	128	7.8
61	4 Bayan Nuur	08/28/98 10h	600 m, 16 m	9.5	458	8.08	52	0.37	7%	24.4	3.1	24.7	18.6	0.42	4.4		0.51	44.4	141	1.0
88	4 Bayan Nuur	08/26/99 07h	400 m, 0 m	19.6	440	8.98	114	0.35	2%	32.2	4.1	27.6	25.5	0.70	7.5	0.03	0.30	55.0	184	10.9
59	19 Döröö Nuur	08/25/98 12h	600 m, 0-7 m	19.5	710	9.15	105	0.56	2%	48.2	18.7	9.4	61.0	1.32	19.1		<0.01	8.2	354	36.7

Table 46 continued: Results of chemical water analyses (Part 6 of 8).

	sampling place		mg/l		nutrients [µg/l]							
S.No.	No. name	date	Si	Fe	PO_4-P	DP	TP	NO_3-N	NO_2-N	NH_4-N	DN	TN
32	66 Teylin Gol	08/31/97 10h	9.9					3300				
140	66 Teylin Gol	08/06/99 15h					1500					
131	69 Tsunkheg Gol-1	08/18/99 12h										
132	70 Tsunkheg Gol-2	08/18/99 14h										
109	71 Tsunkheg Gol-3	09/03/96 11h										
74	71 Tsunkheg Gol-3	08/18/99 17h	3.8	<0.01	<10		3	730				
6	72 Turgen Gol-0 (spring brook)	08/17/97 18h	1.2				110	270				
115	73 Turgen Gol-0.1	08/18/97 09h										
114	74 Turgen Gol-0.2	08/17/97 15h										
7	75 Turgen Gol-0.3	08/18/97 16h	2.7				6	320				
8	76 Turgen Gol-0.4	08/18/97 18h	3.0				3	45				
39	76 Turgen Gol-0.4	08/14/98 16h	1.4	0.24			19	300				
9	77 Turgen Gol-1	08/16/97 15h	*3.0*				5	90				
40	77 Turgen Gol-1	08/12/98 12h	1.7	0.21	<10		11	320				
133	77 Turgen Gol-1	08/15/99 10h										
10	79 Turgen Gol-2	08/19/97 19h	*1.8*				6	90				
11	80 Turgen Gol-3	08/20/97 14h	*3.2*				19	430				
134	80 Turgen Gol-3	08/17/99 16h										
116	81 Turgen Gol-3.1	08/20/97 15h										
41	81 Turgen Gol-3.1	08/11/98 10h	*2.5*	*0.06*	<10		25	290				
71	81 Turgen Gol-3.1	08/09/99 16h	2.7	0.06		3	4	770		<1	230	470
12	82 Turgen Gol-4	08/21/97 10h	*3.9*		10		61	610		<20		
117	83 Turgen Gol-4.1	08/21/97 16h										
118	84 Turgen Gol-4.2	08/21/97 17h										
135	86 Ukhug Gol	08/22/99 17h										
22	87 Urt Bulag Gol	08/25/97 13h	13.5				26	1300				
136	87 Urt Bulag Gol	08/25/99 10h										
	lakes											
110	1 alpine lake at Turgen Gol	08/18/97 12h										
50	2 Baga Nuur	08/18/98 16h	*5.5*		<10	50	75	5				300
98	2 Baga Nuur	08/11/99 11h	6.7		<10		97	10	5			2100
25	4 Bayan Nuur	08/23/97 12h	2.0				8	90				
60	4 Bayan Nuur	08/28/98 10h	0.9		<10	3	3	66				110
61	4 Bayan Nuur	08/28/98 10h	2.7		<10	5	6	120				80
88	4 Bayan Nuur	08/26/99 07h	0.8	<0.01	<10		5	67		<1	310	360
59	19 Döröö Nuur	08/25/98 12h	1.4		<10	7	8	<2				200

Table 46 continued: Results of chemical water analyses (Part 7 of 8).

	sampling place				on-site measurements						major ions [mg/l]										
S.No.	No.	name	date	remark	T [°C]	ϰ [µS/cm]	pH	O_2 %	S [g/l]	I.B.E.	Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	Br^-	NO_3^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}
92	33	Khukhu Nuur	07/16/99 12h	at shore, 0 m		*404*	*8.5*		0.36	4%	11.6	3.1	43.2	28.4	0.21	3.6	<0.06	0.75	22.6	246	2.2
34	37	Khyargas Nuur	08/09/98 18h	20 m, 0 m	20.0	9040	*9.3*		6.96	5%	1950	205	10.2	254	8.48	1190	1.41	0.17	1810	1340	207
141	38	lagoon 1 at Üüreg Nuur	08/16/99 18h		22.7	6340	9.40	300													
142	38	lagoon 1 at Üüreg Nuur	08/17/99 09h		14.7	6400	9.40	117													
121	40	lagoon 2	08/28/97 18h		22.5	1780	8.31														
91	39	lagoon 2 at Üüreg Nuur	08/16/99 18h	at shore, 0 m	17.0	7120	9.30	150	5.88	5%	1060	165	18.8	560	0.97	813	1.23	<0.01	2000	1080	183
143	39	lagoon 2 at Üüreg Nuur	08/17/99 09h		15.1	7140	9.30	107													
86	45	Nogoon Nuur	08/14/99 10h	80 m, 0 m	7.3	49	8.40	110	0.04	-2%	0.6	1.0	6.5	1.3	0.02	<0.02	<0.06	1.25	2.9	26.1	0.0
87	45	Nogoon Nuur	08/14/99 10h	80 m, 18 m	4.5	64	8.15	100	0.05	1%	2.1	1.1	6.8	1.8	0.02	0.1	<0.06	0.92	2.5	31.8	0.0
3	47	seepage lake	08/28/96 11h		18.5	2800	9.15		2.39	3%	587	45.0	12.0	92.0		322			145	1120	66.0
28	47	seepage lake	08/28/97 10h		17.9	2320	8.87	81	1.69	12%	500	12.0	19.0	44.0		147		1.50	60.5	867	42.0
97	47	seepage lake	08/21/99 10h	100 m, 0 m	20.6	2540	8.91	116	2.01	3%	533	16.7	14.2	59.8	2.27	267	0.31	<0.01	129	923	63.5
27	48	Shavart Nuur	08/26/97 12h	at shore, 0 m	20.2	1690	9.19	125	1.40	14%	*120*	*23.6*	*5.2*	*31.1*		*24.9*		*<0.18*	*14.8*	*287*	*24.0*
139	48	Shavart Nuur	08/06/99 12h	at shore, 0 m	22.4	1830	9.10														
100	48	Shavart Nuur	08/26/99 13h	10 m, 0 m	20.9	1840	9.16	108	1.59	3%	293	66.1	14.3	93.0	1.77	69.9	0.28	0.07	49.1	892	109
99	49	southern Baga Nuur	08/21/99 18h	300 m, 0 m	22.8	23600	9.35	142	20.2	3%	6420	82.6	7.6	363	4.99	2820	5.24	<0.01	8600	1620	307
130	65	Tesiyn Gol-5.5 (oxbow pond)	08/24/99 09h		9.0	390	7.70	53													
138	67	Togoo Nuur	08/24/99 13h	at shore, 0 m	25.0	995	9.31	134													
89	88	Üüreg Nuur-S	08/15/99 18h	800 m, 0-18 m	15.0	6220	9.17	100	5.02	2%	894	90.3	9.6	472	1.04	719	0.80	0.01	1830	896	112
90	88	Üüreg Nuur-S	08/15/99 18h	800 m, 26 m	11.9	6260	9.18	94	5.11	4%	916	91.1	10.1	508	0.76	727	0.69	<0.01	1850	894	115
103	89	Üüreg Nuur-S '96	09/01/96 14h		13.2	6440	9.26	107													
104	90	Üüreg Nuur-W	09/01/96 18h		10.9	5910	9.26	120													
53	91	Uvs Nuur-E	08/22/98 16h	at shore, 0 m	19.5	13800	9.11	93	9.42	0%	2640	131	17.5	376	1.45	3040	2.37	0.10	2420	724	79.0
54	91	Uvs Nuur-E	08/22/98 16h	400 m, 0 m	20.5	13800	9.01	93	8.85	0%	2480	99.6	20.3	368	1.32	2880		0.07	2300	642	59.6
2	92	Uvs Nuur-N	08/30/96 15h	at shore, 0 m	13.8	18600	9.23	96	14.2	3%	3970	220		748		4590			3550	964	138
30	93	Uvs Nuur-NW	08/13/97 15h	1000 m, 0 m	18.8	19100	8.91	99	13.0	0%	3780	140	18.8	481		4260			3300	844	144
31	93	Uvs Nuur-NW	08/13/97 15h	1000 m, 17 m	11.2	20100	8.90	73	13.7	1%	4040	131	17.3	497		4460			3470	911	134
47	93	Uvs Nuur-NW	08/18/98 09h	1000 m, 0-15 m	23.1	18900	9.14	101	12.5	5%	3650	150	22.2	616	1.73	3800	3.73	<0.01	3270	886	104
48	93	Uvs Nuur-NW	08/18/98 09h	1000 m, 0 m	23.1	18900	9.14	105	13.8	1%	4040	168	19.1	548	1.70	4550		<0.01	3510	882	103
49	93	Uvs Nuur-NW	08/18/98 09h	1000 m, 17,5 m	15.0	19200	9.12	96	11.5	5%	3540	130	16.1	444	1.64	3310	2.40	<0.01	3250	718	80.1
93	93	Uvs Nuur-NW	08/10/99 18h	900 m, 0 m	20.0	19000	8.96	109	13.8	1%	3910	174	19.8	596	2.28	4580	4.00	<0.01	3530	912	70.4
94	93	Uvs Nuur-NW	08/10/99 18h	900 m, 1-16 m	19.0	19100	8.98	107	13.9	2%	3990	188	22.4	603	2.04	4560	3.83	<0.01	3530	921	74.5
1	94	Uvs Nuur-SW	08/27/96 10h	50 m, 0 m	19.8	19700	9.07	128	14.4	4%	4040	232		752		4660			3590	933	162
29	94	Uvs Nuur-SW	08/27/97 10h	2000 m, 0 m	18.8	19500	9.02	98	12.5	-4%	3420	120	18.0	460		4260			3290	848	138
95	94	Uvs Nuur-SW	08/20/99 19h	50 m, 0 m	23.7	18900	9.09	196	13.8	0%	3860	172	19.2	599	2.28	4590	4.02	<0.01	3540	876	91.2
96	94	Uvs Nuur-SW	08/20/99 19h	440 m, 0 m	21.1	18900	9.04	122	13.8	1%	3910	176	18.9	590	1.97	4580	4.48	<0.01	3530	894	83.0

Table 46 continued: Results of chemical water analyses (Part 8 of 8).

	sampling place			mg/l		nutrients [µg/l]							
S.No.	No.	name	date	Si	Fe	PO_4-P	DP	TP	NO_3-N	NO_2-N	NH_4-N	DN	TN
92	33	Khukhu Nuur	07/16/99 12h	3.3	0.27			200	170				
34	37	Khyargas Nuur	08/09/98 18h	4.9	0.54			29	37				370
141	38	lagoon 1 at Üüreg Nuur	08/16/99 18h										
142	38	lagoon 1 at Üüreg Nuur	08/17/99 09h										
121	40	lagoon 2	08/28/97 18h										
91	39	lagoon 2 at Üüreg Nuur	08/16/99 18h	2.2		170	260	420	<1	8	43	1800	1900
143	39	lagoon 2 at Üüreg Nuur	08/17/99 09h										
86	45	Nogoon Nuur	08/14/99 10h	0.9	<0.01		3	4	280		<1	240	280
87	45	Nogoon Nuur	08/14/99 10h	1.1	<0.01		2	3	210		<1		
3	47	seepage lake	08/28/96 11h					30					
28	47	seepage lake	08/28/97 10h	10.9		<10		34	340				
97	47	seepage lake	08/21/99 10h	4.7		<10	1	23	<1		3	740	830
27	48	Shavart Nuur	08/26/97 12h	*4.2*				320	<40	3			
139	48	Shavart Nuur	08/06/99 12h										
100	48	Shavart Nuur	08/26/99 13h	5.0	0.25	10	29	140	16		69	1700	2100
99	49	southern Baga Nuur	08/21/99 18h	1.8		<10	127	140	<1	2	58	1500	1600
130	65	Tesiyn Gol-5.5 (oxbow pond)	08/24/99 09h										
138	67	Togoo Nuur	08/24/99 13h										
89	88	Üüreg Nuur-S	08/15/99 18h	0.4			1	6	1		11	200	200
90	88	Üüreg Nuur-S	08/15/99 18h	0.4		<10		3	<1		11		
103	89	Üüreg Nuur-S '96	09/01/96 14h										
104	90	Üüreg Nuur-W	09/01/96 18h										
53	91	Uvs Nuur-E	08/22/98 16h	4.1		<10	100	130	22				2400
54	91	Uvs Nuur-E	08/22/98 16h	2.5			76	84	17				1300
2	92	Uvs Nuur-N	08/30/96 15h					82					
30	93	Uvs Nuur-NW	08/13/97 15h	2.2		<10		15			<20		
31	93	Uvs Nuur-NW	08/13/97 15h	1.6				38					
47	93	Uvs Nuur-NW	08/18/98 09h	1.8		<10	12	17	<2				320
48	93	Uvs Nuur-NW	08/18/98 09h	2.0				11	<2				330
49	93	Uvs Nuur-NW	08/18/98 09h	1.2		<10	13	18	<2				240
93	93	Uvs Nuur-NW	08/10/99 18h	1.1			10	16	<1				
94	93	Uvs Nuur-NW	08/10/99 18h	1.6			9	15	<1		<1	640	640
1	94	Uvs Nuur-SW	08/27/96 10h			<10		48					
29	94	Uvs Nuur-SW	08/27/97 10h	1.9		<10		52					
95	94	Uvs Nuur-SW	08/20/99 19h	0.2		<10	3	11	<1		<1	570	620
96	94	Uvs Nuur-SW	08/20/99 19h	0.4		<10	1	19	<1		26	570	630

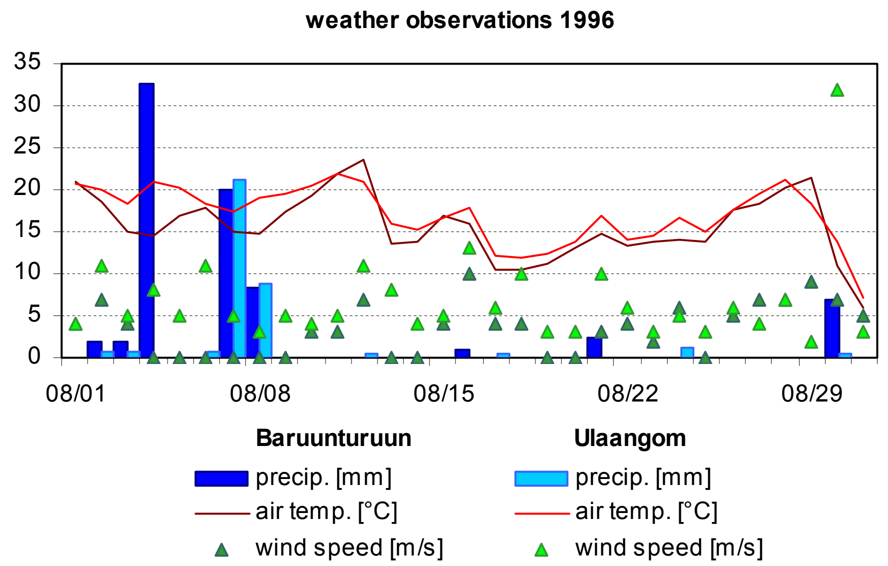
Table 47 Results of chemical analyses of lake sediments. % wet H_2O = mass percentage of water in the wet sediment, carbon. = carbonates.

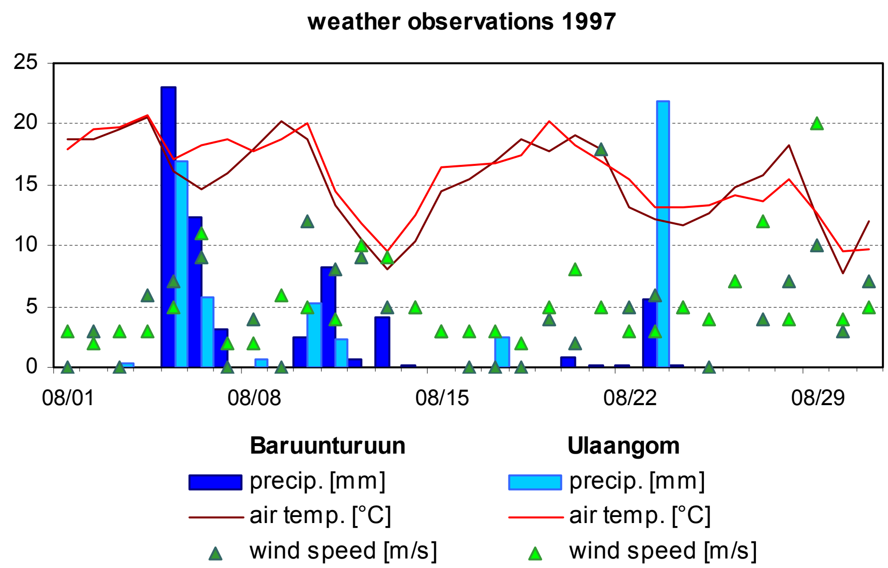
sampling place, depth	date	% wet H_2O	% dry weight organic	carbon.	ash	mg/g dry weight Na	K	Li	Ca	Mg	Fe	Al	Mn	Sr	Ba	TP
Baga Nuur, 1m	08/18/98	89%	33%	27%	41%	5.1	3.0	0.013	165	12.0	3.0	4.9	0.17	2.96	0.14	0.67
Bayan Nuur, 15m	08/23/97	81%	12%	30%	58%	3.2	4.3	0.003	175	9.4	9.3	16.4	0.45	0.83	0.19	0.55
Bayan Nuur, 17m	08/28/98	81%	13%	31%	56%	2.9	4.4	0.000	179	9.9	10.4	17.8	0.40	0.95	0.19	0.65
Bayan Nuur, 6m	08/28/98	76%	12%	37%	52%	2.5	3.3	0.003	217	7.8	6.2	12.1	0.26	0.99	0.18	0.39
Döröö Nuur, 2m	08/25/98	41%	3%	3%	94%	5.0	5.8	0.006	37	5.1	15.6	23.6	0.45	0.29	0.21	0.25
Döröö Nuur, 9m	08/25/98	94%	42%	19%	39%	3.1	3.3	0.004	132	5.5	5.3	7.4	0.10	1.03	0.19	1.49
seepage lake, 3m	08/28/97	88%	33%	12%	55%	6.0	3.6	0.017	115	57.7	10.6	11.0	0.54	1.43	0.20	0.67
Shavart Nuur, 1m	08/26/99	20%	1%	2%	96%	2.2	4.2	0.000	22	7.2	13.6	16.3	0.27	0.16	0.14	0.31
southern Baga Nuur, 1m	08/21/99	92%	38%	5%	57%	60.9	5.8	0.000	57	37.8	12.1	15.4	0.24	1.26	0.12	0.97
Uvs Nuur-E, 2m	08/23/98	40%	7%	5%	88%	7.1	6.4	0.006	55	19.7	8.7	20.2	0.26	0.50	0.20	0.33
Uvs Nuur-NW, 12m	08/13/97	45%	6%	6%	87%	7.9	11.9	0.016	48	19.4	16.2	22.9	0.45	0.45	0.32	0.39
Uvs Nuur-NW, 15m, lower layer	08/18/98	42%	5%	8%	87%	6.1	7.6	0.009	57	21.3	9.8	16.8	0.39	0.49	0.43	0.20
Uvs Nuur-NW, 15m, upper layer	08/18/98	55%	11%	10%	79%	7.6	8.3	0.012	78	26.5	14.5	19.1	0.51	0.68	0.33	0.56
Uvs Nuur-NW, 7m	08/18/98	24%	5%	7%	89%	4.8	6.4	0.009	51	15.7	9.6	14.1	0.27	0.41	0.54	0.25
Uvs Nuur-SW, 1m	08/20/99	14%	1%	1%	97%											
Uvs Nuur-SW, 3m	08/27/97	89%	29%	10%	61%	35.6	9.4	0.012	66	34.2	21.2	23.5	0.98	0.59	0.19	1.20

Table 48 Overview of differences in sampling, conservation and analysis of water and sediment samples between the years 1996 to 1999.

Water samples				
	1996	**1997**	**1998**	**1999**
sampling, on-site measurements	sampled with Ruttner sampler or filled directly into sample bottle; measurement of temp., O_2, pH, conductivity with WTW probes; measurement of PO_4, NO_3, NH_4 and Si with quick tests	sampled with Ruttner sampler or filled directly into sample bottle; measurement of temp., O_2, pH, conductivity with Hydrolab or WTW probes; measurement of PO_4, NO3, NH_4 and Si with quick tests	sampled with Ruttner sampler or filled directly into sample bottle; measurement of temp., O_2, pH, conductivity with YSI or WTW probes; measurement of PO_4, NO_3 and NH_4 with quick tests	
on-site filtration	none		with 0.4 µm glass fiber filter	
sample bottles	1 l polyethylene	500 and 100 ml polyethylene	250 ml polyethylene (unfiltered), 100 ml PE (filtered)	
conservation	none	1 ml/l 1% $HgCl_2$; samples for TP measurement unfixed	1 ml/l 5% $HgCl_2$	
transport; storage in the lab	2 weeks	3-4 months; stored in refrigerator	6 months (frozen!); stored in refrigerator	4 weeks; stored in refrigerator
precipitates, substance losses after storage	none	in some samples carbonatic precipitations	high losses of salinity in filtered samples (these were used only for DP measurement)	none
filtration in the laboratory	unknown	all 500 ml-bottles filtered through 0.4 µm	none	
analysis of HCO3, CO3	titration	samples filtered, manual titration according to DIN 38 405-D11-4 with 0.1n HCl / NaOH; calculation according to DIN 38 405-D8-1	unfiltered samples, titration with Metrohm titrator with 0.1n HCl / NaOH; calculation according to DIN 38 405-D8-1	
measured cations	Na, K, Ca, Mg	Na, K, Ca, Mg, Si	Na, K, Ca, Mg, Si, Fe	
measuring procedure for cations	ion chromatography	samples filtered, not acidified, if necessary diluted with deionized water, measurement with ICP-AES	unfiltered samples acidified with 2 drops HNO_3 40% per 20 ml sample, if necessary diluted with deionized water, measurement with ICP-AES	
measured anions	Cl, SO_4	Cl, NO_3, SO_4	F, Cl, Br, NO_3, SO_4	
measuring procedure for anions	ion chromatography	unfiltered samples filtered through 0.4 µm, if necessary diluted with deionized water, measurement with Dionex IC		
measured phosphorus species	TP		TP; in some lakes DP (0.4 µm filtration on-site)	
measuring procedure for P	double measurement; acidic breakdown according to DIN 38 405-D11-4			
measured nitrogen species	none		NO3 (as anion), in some lakes TN	NO3 (as anion), in some lakes DN, TN
measuring procedure for N	none		TN: unfiltered samples, DN filtered samples; breakdown as stated in chapter 2.3; measurement of breakdowns and NO_3 in saltwater samples with FIA	
calculation of salinity	sum of ions Na, K, Ca, Mg, Cl, SO_4, HCO_3, CO_3	sum of ions Na, K, Ca, Mg, Cl, SO_4, HCO_3, CO_3, NO_3		
corrections of measured values	none	for samples No. 9-13, 23, 24, 26, 27 salinity was corrected according to on-site conductivity value (regression: sal. [mg/l] = 0.805*cond. [µS/cm])	blank correction of Cl, SO_4, P measurements due to $HgCl_2$ conservation for all samples; salinity was corrected according to on-site conductivity value (regression: sal. [mg/l] = 0.805* cond [µS/cm]) for all samples except No. 43, 47-49, 53, 54, 55, 59	blank correction of Cl, SO_4, P measurements due to $HgCl_2$ conservation for all samples
measurements marked as "unreliable"	none	ion measurements of samples No. 9-13, 23, 24, 27; corrected salinity (see above) used for some assessments	ion measurements of samples No. 37, 41, 44-46, 50; corrected salinity (see above) used for some assessments	none

Sediment samples			
	1997	**1998**	**1999**
on-site drying	none	spread out on plastic foil, air dried within 10 h (final water content < 10%)	
sample bottles	20 ml polyethylene vials	250 ml polyethylene (wet sediment), 20 ml PE vials (air dried sediment)	
conservation	0.2 ml/l 1% $HgCl_2$ per 20 ml wet sediment, mixed thoroughly	none	none
transport; storage in the lab	3-4 months; stored in refrigerator	6 months (frozen!); stored in refrigerator	4 weeks; stored in refrigerator
analysis of water content	in the wet sample		
analysis of metals and P	wet sample dried at 105°C; all analyses in this dried sample	air dried sample dried at 105°C; all analyses in this double dried sample	





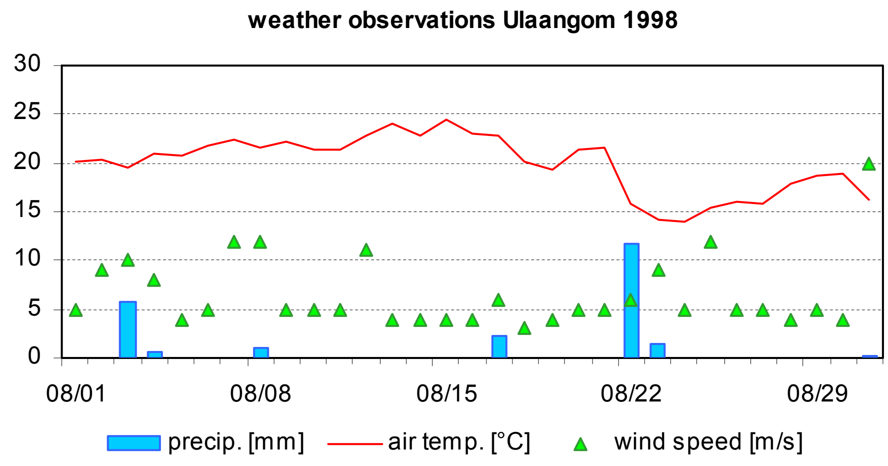


Fig. 66 Weather observations of the meteorological stations Baruunturuun and Ulaangom: daily means and precipitation sums for the month of August 1996 to 1998.

Table 49 Complete list of aquatic taxa found in the investigated area, compiled from own results and literature data. Localities: L=lakes, R=rivers; UvsB-N, UvsB-W, …, UvsB-C=data found in the literature for the northern, western, …, central part of the Uvs Nuur Basin. For an explanation of localities and a list of pooled sampling places see Table 50! Taxonomic groups: **large bold**=phylum, ***bold italics***=class, **small bold**=subclass or order, *small italics*=family. Abundance scale: x=taxon present, no abundance information; 1=rare, 2=few, 3=common, 4=abundant, 5=very abundant. Sources: [1]=DULMAA (1991a), [2]=DULMAA (1991b), [3]=MEY (1980) in MEY (1985), [4]=MEY (1985), [5]=SCHMID (1967) in MEY (1985), [6]=SCHMID (1970) in MEY (1985), [7]=ZAIKA (1996), [8]=ZAIKA (2009a), [9]=SVIRIDENKO et al. (2007). Taxon names in square brackets are as given by the cited author.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Rhizopoda																							
Arcella hemisphaerica Perty 1852	M. Paul								1														
Arcella cf. vulgaris	M. Paul					1	1			2								x					
Centropyxis sp.	M. Paul					1																	
Cyphoderia ampulla Leydig 1879	M. Paul							1	2														
Choanoflagellata																							
Acanthocorbis mongolica Paul 2011	M. Paul		1																				
Desmarella sp.	M. Paul		x				x																
Salpingoeca aff. vaginicola Stein	M. Paul																x						
Salpingoeca cf. napiformis Kent	M. Paul						1																
Ciliophora																							
Coleps sp.	M. Paul		x	x																			
Cothurnia maritima Ehrenberg	M. Paul								x														
Epistylis sp.	M. Paul			x	x				x														
Tokophrya infusionum Bütschli 1889	M. Paul								x														
Vorticella sp.	M. Paul								x	x													
Zoothamnium sp.	M. Paul								x														
Plathelminthes																							
Turbellaria indet.	M. Paul										x		x	x		x		x					
Rotifera																							
Asplanchnella cf. brightwelli (Gosse 1850)	M. Paul		2	2			2																
Brachionus angularis Gosse 1851	M. Paul						2																
Brachionus leydigi tridentatus (Sernov 1901)	M. Paul				1																		
Brachionus plicatilis O.F. Müller 1786	M. Paul				2	1			4	2													[1]
Brachionus quadridentatus Hermanns 1783	M. Paul					1	1		2														[1]
Brachionus sp.	M. Paul				1			1															
Cephalodella sp.	M. Paul					2																	
Collotheca cf. mutabilis Hudson 1885	M. Paul		2	2		x																	
Encentrum sp.	M. Paul									2													
Euchlanis incisa Carlin 1939	M. Paul						1																
Filinia longiseta (Ehrenberg 1834)	M. Paul			3	1	4	4																[1]
Hexarthra fennica Levander 1892	M. Paul					3	2	2	4	3													[1]
Hexarthra mira (Hudson 1871)	M. Paul				3		3																
Hexarthra oxyuris (Sernov 1903)	M. Paul					3	2		x														
Hexarthra sp.	M. Paul				x				x														
Kellicottia longispina longispina (Kellicott 1879)	M. Paul	3							x														[1]
Keratella cochlearis Gosse 1851	M. Paul		4	4			x	1	x														[1]
Keratella quadrata O.F. Müller 1786	M. Paul	1		1		1	2			1													[1]
Keratella sp.	M. Paul				4																		
Lecane lamellata (Daday 1893)																							[1]
Lecane luna O.F. Müller 1776	M. Paul			1		2	1																
Lepadella patella f. similis Lucks 1912	M. Paul					2																	[1]
Mytilinia sp. (cf. crassipes group)	M. Paul					x																	
Notholca acuminata (Ehrenberg 1832)	M. Paul								1	1													[1]
Notholca marina Focke 1961	M. Paul								x	x													
Polyarthra remata (Skorikov 1896)	M. Paul	1				x	x																
Polyarthra vulgaris Carlin 1943	M. Paul		2			1	4																
Synchaeta cf. pectinata Ehrenberg 1832	M. Paul					x	1																
Trichocerca rousseleti (Voigt 1901)																							[1]
Trichocerca sp.	M. Paul					2	1																
Tripleuchlanis plicata (Levander 1894)	M. Paul					2																	

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Nematoda																							
Nematoda indet.	M. Paul								2									x					
Chromadorita leuckarti (De Man 1876)																							[1]
Daptonema karabugasensis (Chesunov 1980)																							[1]
Leptolaimus longispiculus Alekseev & Rassadnikova 1977																							[1]
Mesodorylaimus parasubulatus (Meyl 1954)																							[1]
Mongolotheristus (=Daptonema) altaicus (Tsalolikhin 1985)																							[1]
Nematomorpha																							
Gordius sp.	M. Paul										x												
Mollusca																							
Gastropoda																							
Gastropoda indet.	M. Paul		x				x											x					
Lymnaeidae indet.	M. Paul			x											x		x						
Gyraulus sp.	M. Paul								1									x					
Radix sp.	M. Paul																x	x					
Planorbidae indet.	M. Paul		x	x		x																	
Bathyomphalus sp.	M. Paul			x																			
Valvatidae indet.	M. Paul		x	x																			
Bivalvia																							
Pisidium sp.	M. Paul		x	x																			
Annelida																							
Hirudinea indet.	M. Paul		x	x		x	x										x						
Oligochaeta indet.	M. Paul								3		x						x	x					
Arthropoda																							
Arachnida																							
Araneae																							
Argyroneta sp.	M. Paul					x																	
Acarina																							
Hydrachnidia spp.	M. Paul			x		x		x	x									x					
Branchiopoda																							
Anostraca																							
Branchinecta orientalis Sars 1901	W. Horn, Wünschendorf	x																					
Cladocera																							
Acroperus harpae (Baird 1835)	D. Flößner, Jena			x													x	x					
Alona affinis (Leydig 1860)	D. Flößner, Jena		x	2													x	x					[1]
Alona costata Sars 1862	D. Flößner, Jena																	x					
Alona elegans Kurz 1865	D. Flößner, Jena								x														
Alona quadrangularis (O.F. Müller 1776)	D. Flößner, Jena		x																				
Alona rectangula Sars 1861	D. Flößner, Jena			x		x	x		x														
Alonella excisa (Fischer 1854)	D. Flößner, Jena																x	x					
Alonella nana (Baird 1843)	D. Flößner, Jena			x																			
Bosmina fatalis Burckhardt 1924	D. Flößner, Jena		2		x																		
Bosmina longirostris (O. F. Müller 1785)	D. Flößner, Jena			3		x	3											x					[1]
Ceriodaphnia dubia Richard 1894	D. Flößner, Jena			x	x																		
Ceriodaphnia laticaudata P.E. Müller 1867	D. Flößner, Jena																x						
Ceriodaphnia pulchella Sars 1862	D. Flößner, Jena		x	4			2																
Ceriodaphnia quadrangula (O.F. Müller 1776)	D. Flößner, Jena																x						
Ceriodaphnia reticulata (Jurine 1820)	D. Flößner, Jena																x						
Ceriodaphnia rotunda Sars 1862	D. Flößner, Jena																x						
Chydorus sphaericus (O. F. Müller 1776)	D. Flößner, Jena	x		x			x										x	x					[1]
Daphnia galeata Sars 1863	D. Flößner, Jena	1		3	x																		
Daphnia longispina (OF. Müller 1776)	D. Flößner, Jena				x																		[1]
Daphnia magna Straus 1820	D. Flößner, Jena				2			x															
Daphnia pulicaria Forbes 1893	D. Flößner, Jena	1																					
Daphnia rosea Sars 1862	D. Flößner, Jena																x						
Daphnia zschokkei Stingelin 1894	D. Flößner, Jena	x																					
Daphnia x krausi Flößner 1993	D. Flößner, Jena		3																				
Diaphanosoma brachyurum (Liévin 1848)	D. Flößner, Jena				x																		

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Diaphanosoma mongolianum Ueno 1938	D. Flößner, Jena		3	3	x																		
Ilyocryptus sordidus (Liévin 1848)	D. Flößner, Jena		x				x																
Leptodora kindtii (Focke 1844)	D. Flößner, Jena		1																				
Macrothrix laticornis (Jurine 1820)	D. Flößner, Jena				x																		
Macrothrix rosea (Jurine 1820)	D. Flößner, Jena			x																			
Moina salina Daday 1888 [= M. mongolica Daday 1901]	D. Flößner, Jena								2	3													[1]
Pleuroxus aduncus (Jurine 1820)	D. Flößner, Jena			x																			
Pleuroxus truncatus (O. F. Müller 1785)	D. Flößner, Jena																	x					
Rhynchotalona falcata (Sars 1862)	D. Flößner, Jena		x																				
Scapholeberis mucronata (O. F. Müller 1776)	D. Flößner, Jena			x													x						
Scapholeberis rammneri Dumont et Pensaert 1983	D. Flößner, Jena		1	x													x	x					
Simocephalus exspinosus (Koch 1841)	D. Flößner, Jena																x						
Simocephalus vetulus (O. F. Müller 1776)	D. Flößner, Jena			x			x										x	x					
Ostracoda indet.	M. Paul			x		x		1	x									x					
Copepoda																							
Calanoida																							
Acanthodiaptomus denticornis (Wierzejski 1887)	D. Flößner, Jena	x		2	x																		
Arctodiaptomus (Rhabdodiaptomus) alpinus (Imhof 1885)	D. Flößner, Jena	2																					
Arctodiaptomus (Rhabdodiaptomus) bacillifer (Koelbel 1885)	D. Flößner, Jena				3																		
Arctodiaptomus (Rhabdodiaptomus) salinus (Daday 1885)	D. Flößner, Jena		2	3			2	3	4	3													[1]
Cyclopoida																							
Acanthocyclops robustus (Sars 1863)	D. Flößner, Jena			x					x														
Cryptocyclops bicolor (Sars 1863)	D. Flößner, Jena			x													x						
Cyclops glacialis Flößner 2001	D. Flößner, Jena	2																					
Cyclops vicinus Uljanin 1875	D. Flößner, Jena		3	2	x			x															
Eucyclops denticulatus (Graeter 1903)	D. Flößner, Jena																x	x					
Eucyclops macruroides (Lilljeborg 1901)	D. Flößner, Jena																x	x					
Eucyclops macrurus (Sars 1863)	D. Flößner, Jena																	x					
Eucyclops serrulatus (Fischer 1851)	D. Flößner, Jena				x			x															
Megacyclops viridis (Jurine 1820)	D. Flößner, Jena							2	2								x						
Mesocyclops leuckarti (Claus 1857)	D. Flößner, Jena		3	2		x	3		2														[1]
Microcyclops varicans (Sars 1863)	D. Flößner, Jena																	x					
Thermocyclops kawamurai Kikuchi 1940	D. Flößner, Jena				x																		
Harpacticoida																							
Harpacticoida indet.	M. Paul																	x					
Camptocercus rectirostris Schoedler 1862																							[1]
Canthocamptus staphylinus (Jurine 1820)																							[1]
Cletocamptus retrogressus Schmankevitch 1875																							[1]
Maraenobiotus mongolicus Sterba 1968																							[1]
Nitocra lacustris (Schmankevich 1875)																							[1]
Malacostraca																							
Amphipoda																							
Gammarus lacustris Sars 1863	K. Jazdzewski, Lodz	1	x	x	x	x	x	x	x						x	x	x	x					
Insecta																							
Collembola																							
Isotoma viridis Bourlet	M. Paul								x		x												
Ephemeroptera																							
Baetidae																							
Baetidae indet.	M. Paul			x							x				x	x	x	x					
Acentrella sp. (lapponica group)	D. Braasch, Potsdam										x						x		[7]				
Baetiella sp. (paracercus very short, hind wings missing)	D. Braasch, Potsdam										x												
Baetis bicaudatus Dodds 1923																			[7]	[7]	[7]		[7]
Baetis feles Kluge 1980	D. Braasch, Potsdam												x						[7]	[7]	[7]		[7]
Baetis fuscatus (Linné 1761)	D. Braasch, Potsdam																x		[7]	[7]	[7]		[7]
Baetis pseudothermicus Kluge 1983																			[7]		[7]	[7]	
Baetis tricolor Tshernova 1928	D. Braasch, Potsdam																	x					
Baetis ussuricus Kluge 1983																						[7]	
Baetis vernus Curtis 1834	D. Braasch, Potsdam										x	x	x	x	x	x	x	x	[7]			[7]	
Baetis sp.	D. Braasch, Potsdam										x		x	x			x	x					

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Baetis sp. 1 (paracercus very short, hind wings present)	D. Braasch, Potsdam										x	x	x	x									
Baetis sp. 2 (paracercus very short, hind wings present)	D. Braasch, Potsdam										x												
Baetis sp. 3 (paracercus very short, hind wings present)	D. Braasch, Potsdam										x												
Cloeon dipterum (Linné 1761)	D. Braasch, Potsdam																x						[7]
Cloeon simile Eaton 1870	D. Braasch, Potsdam		x															x					[7]
Cloeon sp.	D. Braasch, Potsdam																x						
Cloeoptilum cf. maritimum Kluge 1983	D. Braasch, Potsdam		x																				
Caenidae																							
Caenidae indet.	M. Paul			x																			
Brachycercus harrisella Curtis 1834	D. Braasch, Potsdam														x		x	x				[7]	
Caenis horaria (Linné 1778)	D. Braasch, Potsdam		x																				[7]
Caenis rivulorum (Eaton 1884)																							[7]
Caenis sp.	D. Braasch, Potsdam														x		x						
Ephemerellidae																							
Ephemerellidae indet.	M. Paul										x				x	x		x					
Ephemerella (Drunella) triacantha Tshernova 1949																			[7]			[7]	[7]
Ephemerella aurivillii (Bengtsson 1909)	D. Braasch, Potsdam										x						x		[7]	[7]			
Ephemerella ignita (Poda 1761)	D. Braasch, Potsdam										x				x	x	x	x	[7]		[7]	[7]	
Ephemerella thymalli Tshernova 1952																			[7]				[7]
Polymitarcyidae																							
Ephoron nigridorsum Tshernova 1952	D. Braasch, Potsdam																x					[7]	
Heptageniidae																							
Heptageniidae indet.	M. Paul										x			x	x								
Cinygmula cava (Ulmer 1927)	D. Braasch, Potsdam										x	x		x		x			[7]			[7]	
Cinygmula grandifolia Tshernova 1952																						[7]	
Cinygmula irina Tshernova & Belov 1982	D. Braasch, Potsdam										x												
Cinygmula putoranica Kluge 1980	D. Braasch, Potsdam										x				x				[7]	[7]	[7]	[7]	
Cinygmula sp.	D. Braasch, Potsdam										x												
Ecdyonurus inversus Kluge 1980	D. Braasch, Potsdam															x							
Ecdyonurus mongolicus (Bajkova & Varychanova 1978)																							[7]
Ecdyonurus sp.	D. Braasch, Potsdam																x						
Epeorus (Iron) aesculus (Imanishi 1934)																						[7]	
Epeorus (Iron) alexandri Kluge & Tiunova 1989																						[7]	
Epeorus (Iron) maculatus (Tshernova 1949)																			[7]			[7]	
Epeorus pellucidus Brodsky 1930	D. Braasch, Potsdam																x					[7]	
Heptagenia flava Rostock 1877	D. Braasch, Potsdam																	x					
Heptagenia sulphurea (Müller 1776)	D. Braasch, Potsdam																x					[7]	
Rhithrogena lepnevae Brodsky 1930	D. Braasch, Potsdam																					[7]	
Rhithrogena sp.	D. Braasch, Potsdam										x	x					x						
Siphlonuridae																							
Siphlonuridae indet.	M. Paul										x				x								
Ameletus camtschaticus Ulmer 1927	D. Braasch, Potsdam										x												
Ameletus gr. montanus																			[7]				[7]
Ameletus inopinatus Eaton 1887																			[7]				
Ameletus sp.	D. Braasch, Potsdam	x									x			x									
Siphlonurus alternatus Say 1824	D. Braasch, Potsdam																	x					
Siphlonurus lacustris (Eaton 1870)	D. Braasch, Potsdam										x					x							
Siphlonurus sp.	D. Braasch, Potsdam										x												
Odonata																							
Anisoptera indet.	M. Paul		x	x					x							x	x						
Zygoptera indet.	M. Paul		x	x		x	x	x										x					
Aeshna affinis van der Linden 1820																			[7]				
Aeshna coluberculus (Harris 1782)																			[7]				
Aeshna crenata Hagen 1856																			[7]				
Aeshna juncea (L. 1758)																			[7]				
Aeshna serrata Hagen 1856																			[7]			[7]	[7]
Coenagrion armatum (Charpentier 1840)																			[7]				[7]
Coenagrion concinnum (Johanson 1859)																							[7]
Coenagrion ecornutum (Selys 1872)																							[7]
Coenagrion vernale Hagen 1839																			[7]				[7]

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L. Alpine	L. Bayan	L. Döröö	L. steppe	L. Baga	L. seep	L. Üüreg	L. Uvs	L. sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Cordulia aenea (L. 1758)																						[7]	
Enallagma cyathigerum (Charpentier 1840)																			[7]				[7]
Enallagma cyathigerum mongolicum Benedek 1968																							[1]
Ischnura elegans (van der Linden 1820)																							[7]
Ischnura pumilio (Charpentier 1825)																							[7]
Lestes dryas Kirby 1890																			[7]				
Lestes sponsa (Hansemann 1823)																			[7]				[7]
Leucorrhinia dubia (van der Linden 1825)																							[7]
Ophiogomphus cecilia (Fourcroy 1785)																						[7]	
Orthetrum cancellatum orientale Belyshev 1958																			[7]			[7]	
Somatochlora graeseri Selys 1887																						[7]	
Sympecma paedisca (Brauer 1887) [Sympecma paedisca braueri Bianki sensu Zaika]																			[7]		[7]		[7]
Sympetrum flaveolum (L. 1758)																			[7]				
Sympetrum frequens (Selys 1883)																							[7]
Sympetrum pedemontanum (O.F.M. in Allioni 1766)																			[7]				
Sympetrum tibiale (Ris 1897)																			[7]				
Sympetrum vulgatum (L. 1758)																			[7]				[7]
Plecoptera																							
Perlodidae																							
Perlodidae indet.	M. Paul														x								
Arcynopteryx polaris Klapálek 1912 [=A. altaica Zapekina-Dulkeit 1957]																			[7]	[7]			
Arcynopteryx compacta (McLachlan 1872)																				[7]			
Arcynopteryx sajanensis Zapekina-Dulkeit 1957																			[7]	[7]	[7]		[7]
Arcynopteryx sp.	W. Joost, Gotha										x												
Diura bicaudata (Linnaus 1758)																						[7]	
Diura sp.	W. Joost, Gotha															x	x						
Isoperla altaica Šámal 1939																			[7]			[7]	
Isoperla eximia Zapekina-Dulkeit 1975																			[7]				
Isoperla lunigera (Klapálek 1923)	W. Joost, Gotha															x							
Isoperla mongolica Zhiltzova 1972																			[7]			[7]	
Pictetiella asiatica Zwick & Levanidova 1971																			[7]				
Skwala pusilla (Klapalek 1912)	W. Joost, Gotha										x			x	x	x	x		[7]		[7]	[7]	
Perlidae																							
Agnetina [=Phasganophora] brevipennis (Navás 1912)																					[7]	[7]	
Agnetina [=Phasganophora] extrema (Navás 1912)	W. Joost, Gotha																x				[7]	[7]	
Agnetina cocandica (McLachlan 1875) [=Phasganophora undata Klapalek 1923]																						[7]	
Chloroperlidae																							
Alloperla deminuta Zapekina-Dulkeit 1970 (?)																			[7]	[7]			
Alloperla mediata (Navás 1925)	W. Joost, Gotha															x			[7]	[7]			
Alloperla rostellata (Klapalek 1923)																			[7]	[7]			
Haploperla lepnevae Zhiltzova & Zwick 1971																						[7]	
Suwallia decolorata Zhiltzova & Levanidova 1978																			[7]				
Suwallia teleckojensis (Šamal 1939)	W. Joost, Gotha	x									x	x	x	x					[7]	[7]		[7]	
Nemouridae																							
Amphinemura cf. standfussi Ris 1902 (sp. nov.?)	W. Joost, Gotha														x								
Nemoura arctica Esben-Petersen 1910																			[7]				
Nemoura arctica mongolica Zhiltzova 1972																			[7]				
Capniidae																							
Capniidae indet.	M. Paul										x												
Mesocapnia variabilis (Klapálek 1920)	W. Joost, Gotha										x			x									
Taeniopterygidae																							
Taenionema japonicum (Okamoto 1922)																				[7]			
Pteronarcidae																							
Pteronarcys reticulata Burm. 1839																						[7]	
Hemiptera																							
Callicorixa gebleri (Fieber 1848)	P. Schönefeld, Berlin			2																			
Callicorixa praeusta (Fieber 1848)	P. Schönefeld, Berlin																1						
Paracorixa armata (Lundblad 1934)	P. Schönefeld, Berlin		1		1			1							1			2					[1]
Paracorixa concinna (Fieber 1848)	P. Schönefeld, Berlin				1			1										1					[1]
Paracorixa kiritshenkoi (Lundblad 1933)	P. Schönefeld, Berlin																	1					[1]

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Sigara assimilis (Fieber 1848)	P. Schönefeld, Berlin								3														[1]
Sigara jaczewskii Lundblad 1928	P. Schönefeld, Berlin			1														1					
Corixinae indet.	P. Schönefeld, Berlin		2	1	1			2		2								2					
Micronecta sp.	P. Schönefeld, Berlin			1																			
Nepa cinerea L. 1758	P. Schönefeld, Berlin					1																	
Notonecta reuteri Hungerford 1928	P. Schönefeld, Berlin							1															
Gerridae sp.	P. Schönefeld, Berlin																	1					
Saldidae sp.	P. Schönefeld, Berlin																	1					
Saldula sp.	P. Schönefeld, Berlin								1														
Coleoptera indet.	M. Paul		x	x				x	x		x		x	x	x	x	x	x					
Trichoptera																							
Rhyacophilidae																							
Rhyacophila egijnica Schmid 1968																				[4]		[6]	
Rhyacophila impar Martynov 1914																					[8]		
Rhyacophila lata Martynov 1918																						[6]	
Rhyacophila sibirica McLachlan 1879																			[7]				[7]
Rhyacophila cf. angulata Martynov	W. Mey, Berlin												x										
Rhyacophila sp. 1	W. Mey, Berlin															x							
Rhyacophila sp. 2	W. Mey, Berlin															x							
Rhyacophila sp.	W. Mey, Berlin														x	x		x					
Glossosomatidae																							
Glossosoma (Synafophora) altaicum (Martynov 1914)																			[7]	[7]		[6]	
Glossosoma (Synafophora) intermedium (Klapalek 1892)	W. Mey, Berlin												x			x							
Glossosoma angaricum Levanidova 1967	W. Mey, Berlin														x				[7]				
Glossosoma sp.	W. Mey, Berlin										x	x				x	x						
Hydroptilidae																							
Oxyethira flavicornis (Pictet 1834)																					[8]		
Arctopsychidae																							
Arctopsyche ladogensis Kolenati 1859	W. Mey, Berlin																x						
Arctopsyche palpata Martynov 1934																					[8]		
Hydropsychidae																							
Hydropsyche angustipennis (Curtis 1834)																					[7]	[7]	[7]
Hydropsyche newae Kolenati 1858																					[8]		
Hydropsyche valvata Martynov 1927																				[3]			
Hydropsyche sp.	W. Mey, Berlin																x						
Polycentropodidae																							
Cyrnus fennicus Klingstedt 1937	W. Mey, Berlin		x																				
Phryganeidae																							
Agrypnia colorata (Hagen 1875)																				[6]			
Agrypnia pagetana Curtis 1835																					[6]		
Agrypnia picta Kolenati 1848																				[6]			
Phryganea grandis L. 1758																					[8]		
Brachycentridae																							
Brachycentrus americanus Banks 1899	W. Mey, Berlin												x		x	x	x	x	[7]	[7]	[6]	[6]	
Limnephilidae																							
Allomyia sajanensis Levanidova 1967																					[8]		
Apatania crymophila McLachlan 1880																			[7]			[7]	[7]
Apatania doehleri Schmid 1954																				[3]			
Apatania zonella (Zetterstedt 1840)																				[5]			
Apatania sp.	W. Mey, Berlin	x									x	x	x	x									
Apataniana impexa Schmid 1970	W. Mey, Berlin										x			x						[3]			
Dicosmoecus palatus (McLachlan 1872)																			[7]	[3]			[7]
Ecclisomyia digitata (Martynov 1929)																				[3]			
Hydatophylax grammicus (McLachlan 1880)																					[8]		
Limnephilus abstrusus McLachlan 1872																							[5]
Limnephilus extricatus McLachlan 1865																					[8]		
Limnephilus major (Martynov 1909)																				[3]			
Limnephilus samoedus (McLachlan 1880)																				[6]			
Limnephilus asiaticus (McLachlan 1874) [L. subrufus Martynov 1927]																				[6]			
Limnephilus sp.	W. Mey, Berlin												x										

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Philarctus rhomboidalis Martynov 1924	W. Mey, Berlin								x				x							[6]			
Stenophylax lateralis (Stephens 1837)																					[8]		
Limnephilidae indet.	M. Paul		x					x			x				x		x						
Goeridae																							
Goera tungusensis Martynov 1909																						[6]	
Goera sp.	W. Mey, Berlin																x						
Leptoceridae																							
Erotesis baltica McLachlan 1877																					[8]		
Mystacides longicornis L. 1758																					[8]		
Oecetis furva (Rambur 1842)																							[5]
Oecetis intima McLachlan 1877	W. Mey, Berlin						x		x														[6]
Oecetis ochracea Curtis 1834	W. Mey, Berlin		x																				[7]
Triaenodes [Ylodes] reuteri McLachlan 1880	W. Mey, Berlin		x					x															
Ylodes sp.	W. Mey, Berlin							x															
Diptera																							
Tipulidae indet.	M. Paul										x			x		x	x						
Limoniidae																							
Limoniidae indet.	M. Paul								x		x		x			x	x						
Dicranota sp.																			[7]	[7]	[7]	[7]	[7]
Ceratopogonidae indet.	M. Paul			x				x	x		x												
Chironomidae																							
Chironomidae indet.	M. Paul		x	x	x			x	2		x		x	x	x	x	x	x					[1]
Tanypodinae																							
Ablabesmyia monilis (L. 1758)	R. Samietz, Gotha		3	3																			
Ablabesmyia phatta (Eggert 1963)	R. Samietz, Gotha		1																				
Procladius sp.																							[1]
Procladius choreus (Meigen 1804) (?)	R. Samietz, Gotha			1																			
Tanypus punctipennis (Meigen 1818)	R. Samietz, Gotha							1	2														
Diamesinae																							
Diamesinae indet.	M. Paul										3	x											
Diamesa sp.	R. Samietz, Gotha										1												
Orthocladiinae																							
Orthocladiinae indet.	M. Paul								3														
Cricotopus (Isocladius) sylvestris Fabricius 1794	R. Samietz, Gotha							2															
Cricotopus (Isocladius) sp.	R. Samietz, Gotha			1																			
Eukiefferiella sp.	R. Samietz, Gotha			1																			
Nanocladius distinctus (Malloch 1915)	R. Samietz, Gotha			1																			
Orthocladius (Orthocladius) sp.	R. Samietz, Gotha															1							
Psectrocladius sordidellus (Zetterstedt 1838)	R. Samietz, Gotha		1																				
Chironominae																							
Chironomini																							
Chironomus (Camptochironomus) tentans Fabricius 1805 (?)	R. Samietz, Gotha		1																				
Chironomus sp.	R. Samietz, Gotha			3				3															
Cryptochironomus albofasciatus (Staeger 1839)	R. Samietz, Gotha							1															
Cryptochironomus supplicans (Meigen 1830)	R. Samietz, Gotha		1																				
Cryptotendipes darbyi Sublet 1960	R. Samietz, Gotha							1															
Cryptotendipes sp. (sp. nov. ?)	R. Samietz, Gotha								1														
Endochironomus tendens (Fabricius 1775)	R. Samietz, Gotha		2																				
Glyptotendipes (Phytotendipes) barbipes (Staeger 1913)	R. Samietz, Gotha								3														
Glyptotendipes gripekoveni Kieffer 1913																							[1]
Microchironomus (?) sp. (sp. nov. ?)	R. Samietz, Gotha								3														
Polypedilum (Polypedilum) nubeculosum (Meigen 1804)	R. Samietz, Gotha		1																				
Polypedilum (Tripodura) bicrenatum Kieffer 1921	R. Samietz, Gotha								1														
Xenochiromomus xenolabis Kieffer 1916	R. Samietz, Gotha		1																				
Tanytarsini																							
Cladotanytarsus sp. 1 (sp. nov. ?)	R. Samietz, Gotha		1																				
Cladotanytarsus sp. 2 (sp. nov. ?)	R. Samietz, Gotha							1															
Micropsectra sp.	R. Samietz, Gotha															3							
Micropsectra recurvata (Goetghebuer 1928)	R. Samietz, Gotha															3							
Micropsectra bidentata-group (sp. nov. ?)	R. Samietz, Gotha															3							

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Paratanytarsus dimorphis Reiss 1965	R. Samietz, Gotha		2																				
Paratanytarsus inopertis (Walker 1856)	R. Samietz, Gotha		1																				
Tanytarsus glabrescens (Edwards 1929)	R. Samietz, Gotha		1																				
Tanytarsus gracilentus Holmgren 1883	R. Samietz, Gotha							3															
Tanytarsus medius Reiss & Fittkau 1971	R. Samietz, Gotha			3																			
Tanytarsus verralli Goetghebuer 1928 (?)	R. Samietz, Gotha			2																			
Simuliidae indet.	M. Paul										x	x	x	x	x	x	x	x					
Prosimulium sp.	M. Paul										3												
Psychodidae indet.	M. Paul															x		x					
Blepharoceridae																							
Bibiocephala maxima Brodsky 1954	P. Zwick, Schlitz										x						x						
Deuterophlebiidae																							
Deuterophlebia sajanica Jedlicka & Halgoš 1981	P. Zwick, Schlitz										x	x				x							
Culicidae indet.	M. Paul			x		x			x							x							
Stratiomyiidae																							
Stratiomyiidae indet.	M. Paul								x														
Stratiomyia sp.																							[7]
Odontomyia sp.	M. Paul								x														[7]
Tabanidae indet.	M. Paul																x						
Dolichopodidae indet.	M. Paul								x														
Psychodidae																							
Pericoma sp.	M. Paul															x			[7]				[7]
Ephydridae indet.	M. Paul							x	x														
Sciomycidae indet.	M. Paul								x														
Chordata																							
Osteichthyes																							
Triplophysa gundriseri Prokofiev 2002 [Neomacheilus strauchii sensu Dulmaa]	A. Dulmaa, Ulaanbaatar										x				x		x	x					[2]
Thymallus brevirostris Kessler 1879	A. Dulmaa, Ulaanbaatar															x							
Esox lucius L. 1758	A. Dulmaa, Ulaanbaatar			x																			
Oreoleuciscus potanini (Kessler 1879)																							[2]
Oreoleuciscus humilis Warpachowski 1889	A. Dulmaa, Ulaanbaatar		x	x					x								x	x					[2]
Oreoleuciscus angusticephalus Bogutskaya 2001 [= Oreoleuciscus pewzowi Herzenstein 1883]	A. Dulmaa, Ulaanbaatar							x															[2]
Osteichthyes indet.	M. Paul					x	x																
Aves																							
Actitis hypoleucos L. (Common Sandpiper)	A. v.d.Driesch, München								x														
Anas formosa Georgi (Baikal Teal)	A. v.d.Driesch, München		x																				
Anas platyrhynchos L. (Mallard)	A. v.d.Driesch, München								x														
Anas strepera L. (Gadwall)	A. v.d.Driesch, München		x																				
Anser anser L. (Greylag Goose)	A. v.d.Driesch, München		x						x								x						
Ardea alba L. (Great White Egret)	A. v.d.Driesch, München								x														
Ardea cinerea L. (Common Heron) light-colored form	A. v.d.Driesch, München								x								x						
Aythya marila L. (Greater Scaup)	A. v.d.Driesch, München								x														
Calidris minuta Leis. (Little Stint)	A. v.d.Driesch, München								x														
Calidris sp.	M. Paul							x	x														
Charadrius dubius Scop. (Little Ringed Plover)	A. v.d.Driesch, München								x														
Charadrius mongolus Pall (Mongolian Plover)	A. v.d.Driesch, München								x														
Cinclus cinclus L. (Eurasian Dipper)	M. Paul													x			x						
Cygnus cygnus L. (Whooper Swan)	A. v.d.Driesch, München			x					x								x						
Fulica atra L. (Common Coot)	M. Paul									x													
Grus grus L. (Common Crane)	A. v.d.Driesch, München								x														
Laridae indet.	M. Paul							x	x														
Larus argentatus Pont. (Herring Gull)	A. v.d.Driesch, München								x														
Larus ridibundus L. (Black-headed Gull)	A. v.d.Driesch, München		x						x														
Larus sp. (L. ichthyaetus?)	A. v.d.Driesch, München								x														
Motacilla alba L. (White Wagtail)	A. v.d.Driesch, München		x						x					x			x						
Motacilla cinerea Tuns (Gray Wagtail)	A. v.d.Driesch, München								x					x									
Numenius arquata L. (Eurasian Curlew)	A. v.d.Driesch, München								x														
Oxyura leucocephala Scop. (White-headed Duck)	A. v.d.Driesch, München		x																				
Phalacrocorax carbo L. (Great Cormorant)	A. v.d.Driesch, München							x	x														

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L seep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Oxyura leucocephala Scop. (White-headed Duck)	A. v.d.Driesch, München		x																				
Phalacrocorax carbo L. (Great Cormorant)	A. v.d.Driesch, München							x	x														
Phalaropus lobatus L. (Red-necked Phalarope)	A. v.d.Driesch, München				x					x													
Philomachus pugnax L. (Ruff)	A. v.d.Driesch, München								x														
Podiceps cristatus L. (Great Crested Grebe)	A. v.d.Driesch, München			x					x								x						
Sterna albifrons Pall. (Little Tern)	A. v.d.Driesch, München		x																				
Sterna hirundo L. (Common Tern)	M. Paul								x								x						
Tadorna ferruginea Pall. (Ruddy Shelduck)	A. v.d.Driesch, München							x	x														
Tringa erythropus Pall. (Spotted Redshank)	A. v.d.Driesch, München								x														
Vanellus vanellus L. (Northern Lapwing)	A. v.d.Driesch, München								x								x						
Cyanobacteria																							
Chroococcales																							
Aphanocapsa cf. elachista W.&G.S. West 1894	M. Paul		x	5																			
Aphanocapsa sp.	M. Paul				4																		
Aphanothece cf. bachmannii Kom.-Legn. & Cronberg 1994	M. Paul		x					3	4														
Aphanothece clathrata W.& G.S. West 1906	M. Paul		x	4		x																	
Aphanothece sp.	M. Paul		3			x																	
Chamaesiphon incrustans Grunow in Rabenhorst 1865	M. Paul										x				x	x	x						
Chamaesiphon polonicus (Rostafinski) Hansgirg 1892	M. Paul										x			x									
Chroococcus cf. dispersus (Keissler) Lemmermann 1904	M. Paul			3																			
Chroococcus cf. turgidus (kützing) Nägeli 1849	M. Paul					x																	
Chroococcus minutus (Kützing) Nägeli 1849	M. Paul		x															x					
Chroococcus obliteratus Richter 1886	M. Paul								x														
Clastidium setigerum Kirchner 1880	M. Paul										x												
Coccopedia limnetica Troickaja 1922	M. Paul								4														
Coccopedia turkestanica Kiseleva 1931	M. Paul						x																
Coelomoron pusillum (van Goor) Komárek 1988	M. Paul						4		x														
Coelomoron sp.	M. Paul			1				2		x													
Gloeocapsa sp.	M. Paul										x												
Gomphosphaeria aponina Kützing 1836	M. Paul						x																
Merismopedia glauca Nägeli 1849	M. Paul						x										x	x					
Merismopedia punctata Meyen 1839	M. Paul								x									x					
Merismopedia sp.	M. Paul				2			2															
Merismopedia tenuissima Lemmermann 1898	M. Paul		x						x														
Merismopedia warmingiana Lagerheim 1883	M. Paul				4		x	2	3														
Microcystis smithii Komarek & Anagnostidis 1995	M. Paul		x																				
picoplanktic Chroococcales	M. Paul	3																					
Rhabdoderma cf. tenuissimum Komárek & Kling 1991	M. Paul					4																	
Synechococcus sp.	M. Paul		2		1																		
Synechocystis aquatilis Sauvageau 1892	M. Paul																	x					
Synechocystis crassa Voronichin 1929	M. Paul		1	1			x																
Synechocystis salina Wislouch 1924	M. Paul					2	x		x	3													
Woronichinia sp.	M. Paul																	x					
Oscillatoriales																							
Geitlerinema splendidum (Greville ex Gomont) Anagn. 1989	M. Paul																	x					
Heteroleibleinia epiphytica (Wille) Kom. in Anagn. 2001	M. Paul								x														
Heteroleibleinia kuetzingii (Schmidle) Compère 1985	M. Paul															2	3						
Heteroleibleinia sp.	M. Paul														x			x					
Homoeothrix cf. varians Geitler 1927	M. Paul										x												
Homoeothrix crustacea Voronichin 1923	M. Paul													x									
Homoeothrix gloeophila Starmach 1960	M. Paul														x								
Homoeothrix janthina (Bornet & Flahault) Starmach 1957	M. Paul										2												
Homoeothrix sp.	M. Paul						x				x												
Jaaginema subtilissima (Kützing) Anagn. & Kom. 1988 (?)	M. Paul								x														
Komvophoron cf. pallidum (Skuja) Anagn. & Kom. 1988	M. Paul					2																	
Komvophoron schmidlei (Jaag) Anagn. & Kom. 1988	M. Paul																	x					
Leibleinia epiphytica (Hieronymus) Compère 1985	M. Paul			x							x												
Leptolyngbya sp. (forming limy crusts)	M. Paul															x		x					
Limnothrix planctonica (Woloszynska) Meffert 1988	M. Paul						x																
Lyngbya martensiana Meneghini ex Gomont 1892	M. Paul								x														
Lyngbya sp. (cells D 17 µm, L 1.5 µm, sheath 3 µm)	M. Paul				x																		

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Oscillatoria cf. curviceps C.Agardh ex Gomont 1892	M. Paul																x						
Oscillatoria sancta Kützing ex Gomont 1892	M. Paul																x						
Oscillatoria sp.	M. Paul									x													
Phormidium cf. calcareum Kützing ex Starmach 1966	M. Paul										2												
Phormidium ambiguum Gomont 1892	M. Paul						x																
Phormidium autumnale (Agardh) Trevisan ex Gomont 1892	M. Paul															x	3						
Phormidium caucasicum (Elenkin & Kosinskaya) Anagnostidis 2001	M. Paul										2				x								
Phormidium cf. fonticola Kützing ex Gomont 1892	M. Paul						x				x												
Phormidium cf. setchellianum Gomont 1892 (very strong granulation)	M. Paul										x												
Phormidium cf. simplicissimum (Gomont) Anagn. & Kom. 1988	M. Paul																x						
Phormidium lloydianum (Gomont) Anagn. & Kom. 1988	M. Paul								x														
Phormidium sp.	M. Paul						x				x					x							
Planktolyngbya contorta (Lemmermann) Anagn. & Kom. 1988	M. Paul			2	2	2		3	4														
Planktothrix agardhii (Gomont) Anagn. & Kom. 1988	M. Paul						x																
Pseudanabaena catenata Lauterborn 1915	M. Paul						x																
Pseudanabaena cf. mucicola (Naumann & Huber-Pestalozzi) Schwabe 1964	M. Paul																x						
Pseudanabaena minima (G.S. An) Anagnostidis 2001	M. Paul								x									x					
Pseudanabaena sp.	M. Paul			x	2	x																	
Spirulina labyrinthiformis Gomont 1893	M. Paul					x				x													
Spirulina major Kuetzing ex Gomont 1892																							[1]
Spirulina meneghiniana Zanardini ex Gomont 1892	M. Paul								x														
Spirulina sp.	M. Paul					x				x													
Spirulina subsalsa Oerstedt 1842	M. Paul					x	x		x														
Trichocoleus tenerrimus (Gomont) Anagnostidis 2001	M. Paul								x														
Nostocales																							
Anabaena (Dolichospermum) mendotae (Trelease) Wacklin Hoffman & Komárek 2009	M. Paul								x														
Anabaena minderi Huber-Pestalozzi 1938	M. Paul		2	1		x																	
Anabaena sp.	M. Paul		x			3												x					
Calothrix fusca Bornet & Flahault 1886	M. Paul			x																			
Calothrix cf. kossinskajae Poljansky 1927	M. Paul														x		x						
Microchaete tenera Thuret ex Bornet 1880	M. Paul																x						
Nostoc paludosum Kützing 1850	M. Paul			x																			
Nostoc sphaericum Vaucher ex Bornet & Flahault 1888	M. Paul															3	2						
Nostoc verrucosum Vaucher ex Bornet & Flahault 1888	M. Paul																3						
Tolypothrix tenuis Kützing 1843	M. Paul			x																			
Euglenophyta																							
Trachelomonas sp. (Spiniferae minutispinae group)	M. Paul		x																				
Cryptophyta																							
Cryptomonas sp.	M. Paul	1	1				2																
Cryptomonas sp. (erosa/ovata group)	M. Paul		1																				
Rhodomonas lacustris var. nannoplanctica (Skuja) Javornicky 1976	M. Paul		1	2																			
Rhodomonas sp.	M. Paul	1						1	x														
Dinophyta																							
Ceratium hirundinella (O.F. Müller) Dujardin 1841	M. Paul		2	x	1	x			x														
Gymnodinium helveticum Penard 1891	M. Paul	1	1																				
Gymnodinium sp.	M. Paul		1	x			x		1														
Peridiniopsis borgei Lemmermann 1904	M. Paul		3	x		x	2																
Peridiniopsis elpatiewskyi (Ostenfeld) Bourrelly 1968	M. Paul		2																				
Peridinium sp.	M. Paul								x														
Peridinium umbonatum var. umbonatum Stein 1883	M. Paul		2	x		x	2																

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Heterokontophyta																							
Chrysophyceae s.l.																							
Chromulina-type	M. Paul	2	2																				
Chrysococcaceae indet.	M. Paul		x																				
Chrysosphaerella solitaria Preisig & Takahashi	M. Paul		x																				
Dinobryon sociale var. americanum (Brunnth.) Bachmann 1911	M. Paul		2																				
Epipyxis borgei (Lemmermann) Hilliard & Asmund	M. Paul																x						
Epipyxis cf. alata Hilliard & Asmund	M. Paul		2																				
Epipyxis marchica (Lemmermann) Hilliard & Asmund	M. Paul																x						
Epipyxis sp.	M. Paul		1			x																	
Hydrurus foetidus (Villars) Trevisan 1848	M. Paul										3			4		x							
Mallomonas sp.	M. Paul		x																				
Ochromonas-type	M. Paul	1	3		2																		
Bacillariophyceae																							
Centrales																							
Aulacoseira cf. ambigua Simonsen 1979	M. Paul								x														
Aulacoseira cf. italica (Ehrenberg) Simonsen 1979	M. Paul			x		x																	
Chaetoceros sp.	M. Paul						1																
Chaetoceros wighamii Brightwell 1856	M. Paul								x														
Cyclotella choctawhatcheeana Prasad 1990	M. Paul								x														
Cyclotella meneghiniana Kützing 1844	M. Paul						x		x														
Cyclotella ocellata Pantocsek 1901	M. Paul		3	x																			
Cyclotella radiosa (Grunow in van Heurck) Lemmerm. 1900	M. Paul	1	1	x			2																
Cyclotella sibirica Skabichevskij 1967	M. Paul	3																					
Cyclotella sp. (C. uuregensis Shinneman, Edlund, Soninkhishig prov. nom.)	M. Paul							2															
Melosira moniliformis var. octogona Husted 1928	M. Paul								x														
Melosira varians C.Agardh 1827	M. Paul															x							
Stephanodiscus cf. medius Hakansson 1986	M. Paul		x																				
Pennales																							
Achnanthes brevipes Agardh 1824	M. Paul								x														
Achnanthes sp.	M. Paul																x						
Amphora cf. montana Krasske 1932	M. Paul								x														
Amphora commutata Grunow 1818	M. Paul								x														
Amphora delicatissima Krasske 1930	M. Paul								x														
Amphora libyca Ehrenberg 1840	M. Paul								x														
Amphora sp.	M. Paul		x				x			x							x						
Amphora subcapitata Husted 1959	M. Paul								x														
Aneumastus tuscula (Ehrenberg) Mann & Stickle 1990	M. Paul		x																				
Anomoeoneis sphaerohpora Pfitzer 1871	M. Paul								x	x													
Asterionella formosa Hassall 1850	M. Paul			x																			
Campylodiscus bicostatus W.Smith in Roper 1854	M. Paul						x		x														
Campylodiscus clypeus Ehrenberg 1840	M. Paul					x			x	x													
Cocconeis pediculus Kützing	M. Paul															x	x						
Cocconeis placentula Ehrenberg 1838	M. Paul		x				x		x			x		x		x	x						
Cymatopleura solea (Brébisson) W.Smith 1851	M. Paul															x							
Cymbella affinis Kützing 1844	M. Paul																x						
Cymbella cistula (Hemprich & Ehrenberg) O. Kirchner 1878	M. Paul										x			x									
Cymbella sp.	M. Paul		x				x				x						2						
Diatoma mesodon (Ehrenberg) Kützing 1844	M. Paul												x	x		x							
Diatoma moniliformis Kützing 1833	M. Paul								x														
Diatoma sp.	M. Paul						x				x												
Diatoma vulgare Bory de Saint-Vincent 1824	M. Paul																3						
Didymosphenia geminata (Lyngbye) M. Schmidt 1899	M. Paul															x	3						
Diploneis sp.	M. Paul								x														
Encyonema minutum (Hilse in Rabenhorst) D.G. Mann 1990	M. Paul										x	x		x									
Encyonema silesiacum (Bleisch) D.G. Mann 1990	M. Paul										x			x									
Entomoneis alata (Ehrenberg) Ehrenberg 1845	M. Paul							x	x														
Entomoneis paludosa (W. Smith) Reimer 1975	M. Paul						x		x														

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Epithemia cf. adnata (Kützing) Brebisson 1838	M. Paul		x				x	x	x	x													
Eucocconeis flexella (Kützing) Meister 1912	M. Paul																x						
Fallacia pygmaea (Kützing) Stickle & Mann 1990	M. Paul								x														
Fragilaria arcus (Ehrenberg) Cleve 1898	M. Paul										x			x									
Fragilaria capucina Desmaizieres 1925	M. Paul										x												
Fragilaria capucina var. vaucheriae (Kützing) Lange-Bertalot 1980	M. Paul								x		x												
Fragilaria crotonensis Kitton 1869	M. Paul		x	x																			
Fragilaria sp.	M. Paul								x														
Fragilaria sp. (ulna group)	M. Paul								x														
Fragilaria ulna (Nitzsch) Lange-Bertalot 1980	M. Paul		2	x			x		x							x	x						
Gomphonema olivaceum (Hornemann) Brébisson 1838	M. Paul										x												
Gomphonema sp.	M. Paul		x									x		x									
Gyrosigma attenuata (Kützing) Rabenhorst 1853	M. Paul															x							
Gyrosigma peisonis Husted 1930	M. Paul							1	x														
Haslea spicula (Hickie) Lange-Bertalot 1997	M. Paul						x		x														
Mastogloia baltica Grunow 1880	M. Paul								x														
Mastogloia braunii Grunow 1863	M. Paul						x		x														
Mastogloia pumila Cleve 1895	M. Paul								x														
Mastogloia smithii Thwaites ex W. Smith 1865	M. Paul								x														
Mastogloia smithii var. lacustris Grunow 1878	M. Paul		x																				
Meridion circulare (Greville) C.Agardh 1831	M. Paul										x					x		x					
Navicula cryptotenella Lange-Bertalot 1985	M. Paul										x												
Navicula lanceolata (C.Agardh) Ehrenberg 1838	M. Paul															x							
Navicula reinhardtii Grunow 1877	M. Paul		x																				
Navicula sp.	M. Paul		x				x		x		x						x						
Neidium iridis (Ehrenberg) Cleve 1894	M. Paul																x						
Nitzschia acicularis W.Smith 1853	M. Paul		x						x							x							
Nitzschia cf. dissipata (Kützing) Grunow 1862	M. Paul		x																				
Nitzschia elegantula Grunow 1881	M. Paul								x														
Nitzschia liebetruthii Rabenhorst 1864	M. Paul								x														
Nitzschia obtusa W.Smith 1853	M. Paul								x	x													
Nitzschia palea (Kützing) W. Smith 1856	M. Paul										x												
Nitzschia sp.	M. Paul	x					x		1														
Nitzschia sp. (Lanceolatae group)	M. Paul		x																				
Pinnularia sp.	M. Paul										x						x						
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot 1999	M. Paul										x												
Reimeria sinuata (Gregory) Kociolek & Stoermer 1987	M. Paul										x	2					x						
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot 1980	M. Paul						x		x														
Rhopalodia gibba (Ehrenberg) O.F. Müller 1895	M. Paul															x							
Rhopalodia musculus (Kützing) O.F. Müller 1900	M. Paul								x														
Stauroneis phoenicenteron (Nitzsch) Ehrenberg 1843	M. Paul																x						
Surirella ovalis Brébisson 1838	M. Paul								x														
Surirella peisonis Pantocsek 1901	M. Paul							2	x														
Surirella sp.	M. Paul							1															
Surirella striatula Turpin 1828	M. Paul								x														
Eustigmatophyceae																							
Pseudotetraedriella kamillae Hegewald, Padisak, Friedl 2007	M. Paul		x																				
Xanthophyceae																							
Centritractus belenophorus Lemmermann	M. Paul		x																				
Tribonema sp.	M. Paul																x						
Vaucheria sp.	M. Paul															x							
Rhodophyta																							
Audouinella sp.	M. Paul														x	x							
Batrachospermum sp.	M. Paul														x								
Chroodactylon ornatum (C.Agardh) Basson 1979	M. Paul			x			x		x														

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L sep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Chlorophyta																							
Chlorophyceae																							
Volvocales																							
Carteria sp.	M. Paul		x																				
Chlamydomonas sp.	M. Paul		3				1																
Dunaliella sp.	M. Paul									x													
Chlorococcales	M. Paul	2								2													
Amphikrikos nanus Hindák 1977	M. Paul							1	3														
Ankistrodesmus sp.	M. Paul				1																		
Ankistrodesmus spiralis Lemmermann 1908	M. Paul		1	x																			
Chlorella sp.	M. Paul						3		1														
Coelastrum pseudomicroporum Koršikov 1953	M. Paul			x																			
Coelomoron pusillum (van Goor) Komárek 1988	M. Paul		x						x														
Didymocystis bicellularis (Chodat) Komárek 1973	M. Paul		x																				
Didymocystis sp.	M. Paul						1																
Kirchneriella sp.	M. Paul			x	x	x																	
Kirchneriella subcapitata Korsikov 1953	M. Paul				1																		
Lagerheimia cf. cingula G.M. Smith 1926	M. Paul						2																
Lagerheimia genevensis Chodat 1895	M. Paul			x			2		x														
Lobocystis planctonica Fott 1975 (?)	M. Paul							x															
Monoraphidium cf. circinale Nygaard 1979	M. Paul				2		3		2														
Monoraphidium contortum (Thuret) Kom.-Legn. 1969	M. Paul				3																		
Monoraphidium minutum (Nägeli) Kom.-Legn. 1969	M. Paul		x						3														
Monoraphidium tortile (W.&G.S. West) Kom.-Legn. 1969	M. Paul				2																		
Oocystis marina Moewus1951	M. Paul						x		1														
Oocystis sp.	M. Paul			x				2	x	2								x					
Oocystis submarina Lagerheim1886	M. Paul		1				x		1	2													
Pediastrum boryanum Meneghin 1840	M. Paul		x	x		x	1			x													
Pediastrum duplex Meyen 1829	M. Paul		x																				
Scenedesmus acutus Meyen 1829	M. Paul				2		1																
Scenedesmus armatus Chodat 1913	M. Paul						1																
Scenedesmus brevispina Chodat 1926	M. Paul		x						x														
Scenedesmus cf. caribeanus Komárek 1983	M. Paul						1																
Scenedesmus disciformis (Chodat) Fott & Komárek 1960	M. Paul																	x					
Scenedesmus obliquus Kützing 1833	M. Paul						1											x					
Scenedesmus obtusus Meyen 1829	M. Paul						1																
Scenedesmus sp.	M. Paul				1																		
Schizochlamydella cf. capsulata (Guillard et al.) S. Watanabe 1977	M. Paul			x			2		x	x													
Schroederia setigera Lemmermann 1898	M. Paul						1																
Siderocelis ornata Fott 1934	M. Paul						1																
Tetrachlorella incerta Hindák 1977	M. Paul		1						2														
Tetraedron minimum Hansgirg 1888	M. Paul		x	x			3																
Tetraedron sp.	M. Paul	1																					
Ulothrichales																							
Elakatothrix sp.	M. Paul		1	x	x		1																
Ulothrix aequalis Kützing 1845	M. Paul													x									
Ulothrix sp.	M. Paul																x						
Ulothrix zonata (Weber & Mohr) Kützing 1843	M. Paul										x		2		x		x						
Microsporales																							
Microspora amoena (Kützing) Rabenhorst 1868	M. Paul														x	x							
Microspora amoena var. gracilis (Wille) De Toni 1889	M. Paul												x				x						
Microspora cf. aequabilis Wichmann 1937	M. Paul																	x					
Microspora stagnorum (Kützing) Lagerheim 1887	M. Paul															x	x						
Chaetophorales																							
Aphanochaete repens A. Braun 1851	M. Paul			x													x						
Pseudochaete crassisetum (W.&G.S. West) W.&G.S. West	M. Paul															x	x						
Stigeoclonium sp.	M. Paul															x							
Prasiolales																							
Prasiola fluviatilis (Sommerfelt) Areschoug 1869	M. Paul										3												

Table 49 continued: Complete list of all aquatic taxa.

Taxon	determined by	L Alpine	L Bayan	L Döröö	L steppe	L Baga	L scep	L Üüreg	L Uvs	L sBaga	R Turg	R Khar	R mount	R Tsun	R NW	R Borsh	R Tesiyn	R dune	UvsB-N	UvsB-W	UvsB-S	UvsB-E	UvsB-C
Oedogoniophyceae																							
Oedogoniales																							
Bulbochaete sp.	M. Paul			x			x																
Oedogonium sp.	M. Paul			x	x	x	x	x	x	x					x		x	x					
Bryopsidophyceae																							
Cladophorales																							
Cladophora fracta (O.F.Müller ex Vahl) Kützing 1843	M. Paul		x	x													x	x					
Cladophora glomerata (L.) Kützing 1843	M. Paul								x	x					x	x	x						
Conjugatophyceae																							
Desmidiales																							
Closterium acerosum Ehrenberg ex Ralfs 1848	M. Paul															x							
Closterium dianae Ehrenberg ex Ralfs 1848	M. Paul															x							
Closterium ehrenbergii Meneghini ex Ralfs 1848	M. Paul															x							
Closterium littorale var. crassum W.&G.S. West 1896	M. Paul															x							
Cosmarium bioculatum Brebisson ex Ralfs 1848	M. Paul		x	x																			
Cosmarium bioculatum var. depressum (Schaarschmidt) Schmidle 1894	M. Paul			x																			
Cosmarium cf. pseudoretusiforme Grönblad	M. Paul			x			2																
Cosmarium reniforme (Ralfs) W. Archer 1874	M. Paul																	x					
Cosmarium sp.	M. Paul			x		x	2				x						x						
Cosmarium subtumidum var. minutum Krieg & Gerloff 1965	M. Paul						2																
Cosmarium trilobulatum Reinsch 1866	M. Paul			x																			
Desmidium sp.	M. Paul		x																				
Euastrum insulare var. silesiacum W.Krieger 1937	M. Paul					x																	
Staurastrum paradoxum Meyen ex Ralfs 1848	M. Paul			x																			
Staurodesmus cuspidatus (Brébisson ex Ralfs) Teiling 1967	M. Paul		x																				
Zygnematales																							
Mougeotia sp.	M. Paul		x	x	x		x	x									x						
Spirogyra sp.	M. Paul				x										4	x	x	x					
Zygnema sp.	M. Paul				x						2						x						
Charophyceae																							
Chara altaica Braun in Braun & Nordstedt 1882	J. van Raam, Hilversum								x													[9]	
Chara aspera Willdenow 1809																						[9]	
Chara canescens Desvaux & Loiseleur 1810	A. Doege, Miltitz					x																	
Chara contraria A.Braun ex Kützing 1845	A. Doege, Miltitz		x														x						
Chara fischeri Migula 1904	J. van Raam, Hilversum		x	x		x																	
Chara gobiana Vilhelm 1928	J. van Raam, Hilversum		x																				
Chara tomentosa L. 1753	A. Doege, Miltitz		x		x	x																	
Chara vulgaris L. 1753	A. Doege, Miltitz																x					[9]	
Bryophyta																							
Drepanocladus aduncus (Hedwig) Warnstorf 1903	F. Müller, Dresden		x										3		x		x						
Fontinalis antipyretica Hedwig 1801	F. Müller, Dresden															2	x						
Hygrohypnum ochraceum Loeske 1903	F. Müller, Dresden															2							
Leptodictyum riparium (Hedwig) Warnstorf 1906	F. Müller, Dresden																x						
Pteridophyta																							
Equisetum fluviatile L.	M. Paul																x						
Spermatophyta																							
Carex. sp.	M. Paul																	x					
Hippuris vulgaris L.	M. Paul														x		x	x					
Myriophyllum sibiricum Komarov	M. Paul																x						
Myriophyllum spicatum L.	M. Paul		x															x					
Najas marina ssp. intermedia (Wolfg. ex Gorski) Casper	M. Paul		x			x																	
Persicaria sp.	M. Paul																x						
Phragmites australis (Cav.) Trin. ex Steud.	M. Paul		x	5	x	4	4		4	3					x		x						
Potamogeton berchtoldii Fieber	Z. Kaplan, Pruhonice																x						
Potamogeton perfoliatus L.	M. Paul																x						
Potamogeton pusillus L.	Z. Kaplan, Pruhonice																x						
Ranunculus subg. Batrachium sp. (cf. aquatilis?)	M. Paul																x						
Stuckenia filiformis (Pers) Börner	Z. Kaplan, Pruhonice														x	2	x						
Stuckenia pectinata (L.) Börner	Z. Kaplan, Pruhonice		x		x		3		3						x		x	x					
Utricularia cf. vulgaris L.	M. Paul			4			3	x															

Table 50 List of sampling places pooled as "locality" in Table 49 .

abbreviation	locality	sampling places
L Alpine	alpine lakes in the Turgen Mountains	Nogoon Nuur, alpine lake near Turgen Gol
L Bayan	Bayan Nuur	Bayan Nuur
L Döröö	Döröö Nuur	Döröö Nuur
L steppe	small steppe lakes	Shavart Nuur, Togoo Nuur
L Baga	Baga Nuur	Baga Nuur
L seep	Seepage Lake	Seepage Lake
L Üüreg	Üüreg Nuur	Üüreg Nuur-S, -W
L Uvs	Uvs Nuur	Uvs Nuur-E, -N, -NW, -SW
L sBaga	Southern Baga Nuur	Southern Baga Nuur
R Turg	Turgen and Dshibertu Gol	Dshibertu Gol-0 to -0.4, Turgen Gol-0 to -4.2
R Khar	Kharkhiraa Gol	Kharkhiraa Gol
R mount	streams in the Turgen Mountains	Burgastay Gol, Endert Gol, Kharig Gol
R Tsun	Tsunkheg Gol	Tsunkheg Gol-1 to -3
R NW	streams and springs NW of Uvs Nuur	Burat Usu Bulag, brook of Butsaldag Bulag, Jireeg Gol, Torkhilog Gol, spring at Torkhilog Gol
R Borsh	Borshoo Gol	Borshoo Gol-0 to -5, spring at Borshoo Gol-2
R Tesiyn	Tesiyn Gol + tributaries	Tesiyn Gol-1 to -5.5, Ukhug Gol
R dune	streams and springs of the dune field	Gurmosyn Gol, Khoyd Gol, Khustay Gol-spring to -lower reach, Nariyn Gol-5 and -mouth, Urt Bulag Gol

6.2 Cross sections and longitudinal profiles of rivers

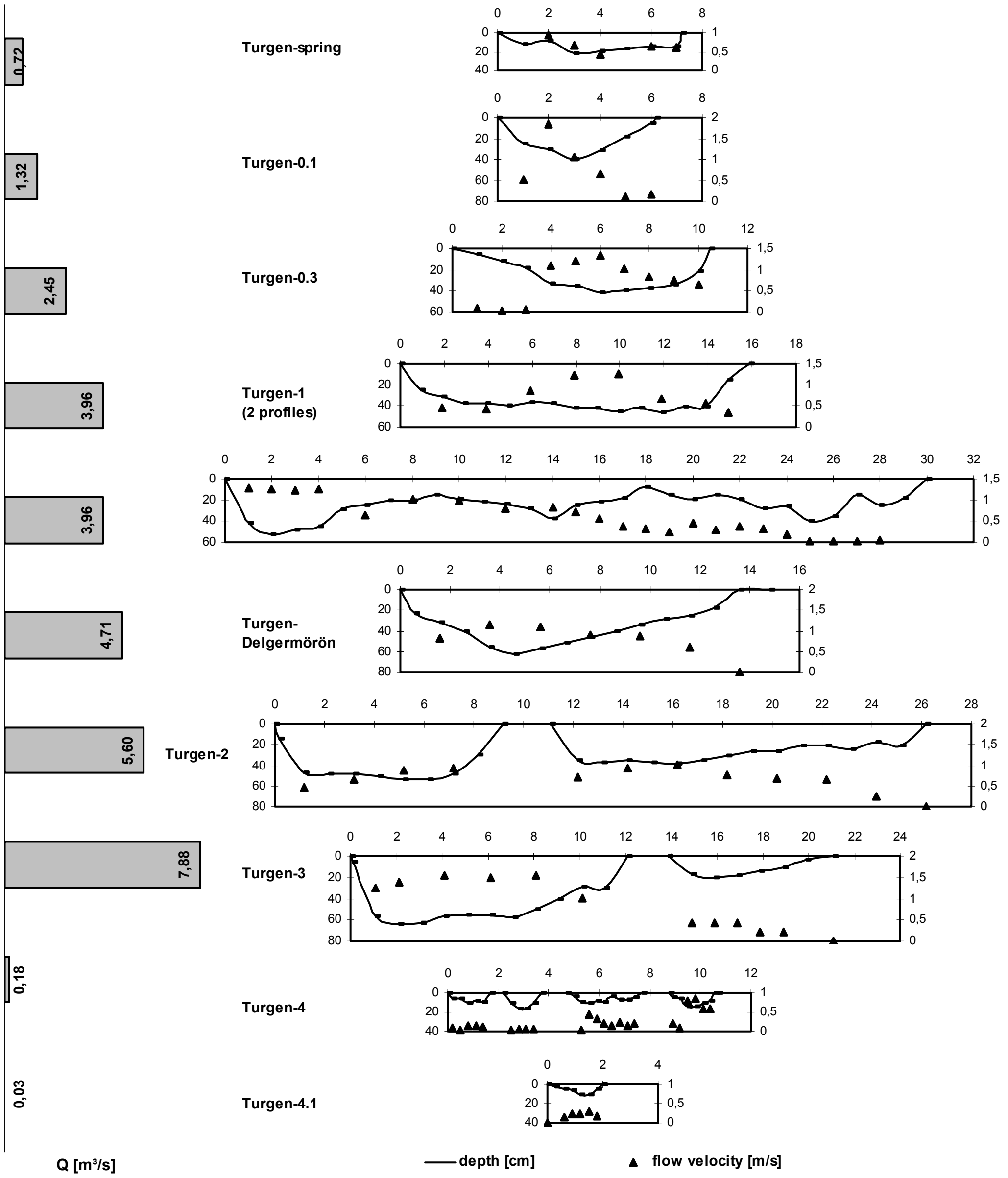


Fig. 67 River bed cross sections with flow velocity measurements and runoff for Turgen Gol. Measurements taken August 16th to 21st 1997. The distances between multiple channels are shortened to fit into the diagrams.

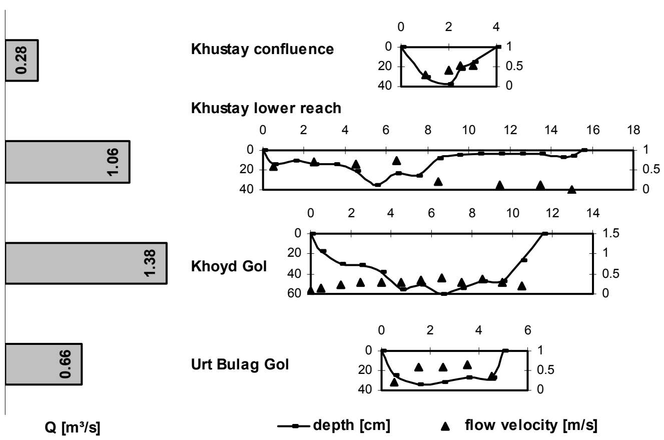


Fig. 68 River bed cross sections with flow velocity measurements and runoff for sampling places Khustay Gol-confluence, Khustay Gol-lower reach, Khoyd Gol and Urt Bulag Gol. Measurements taken August 24th and 25th 1997.

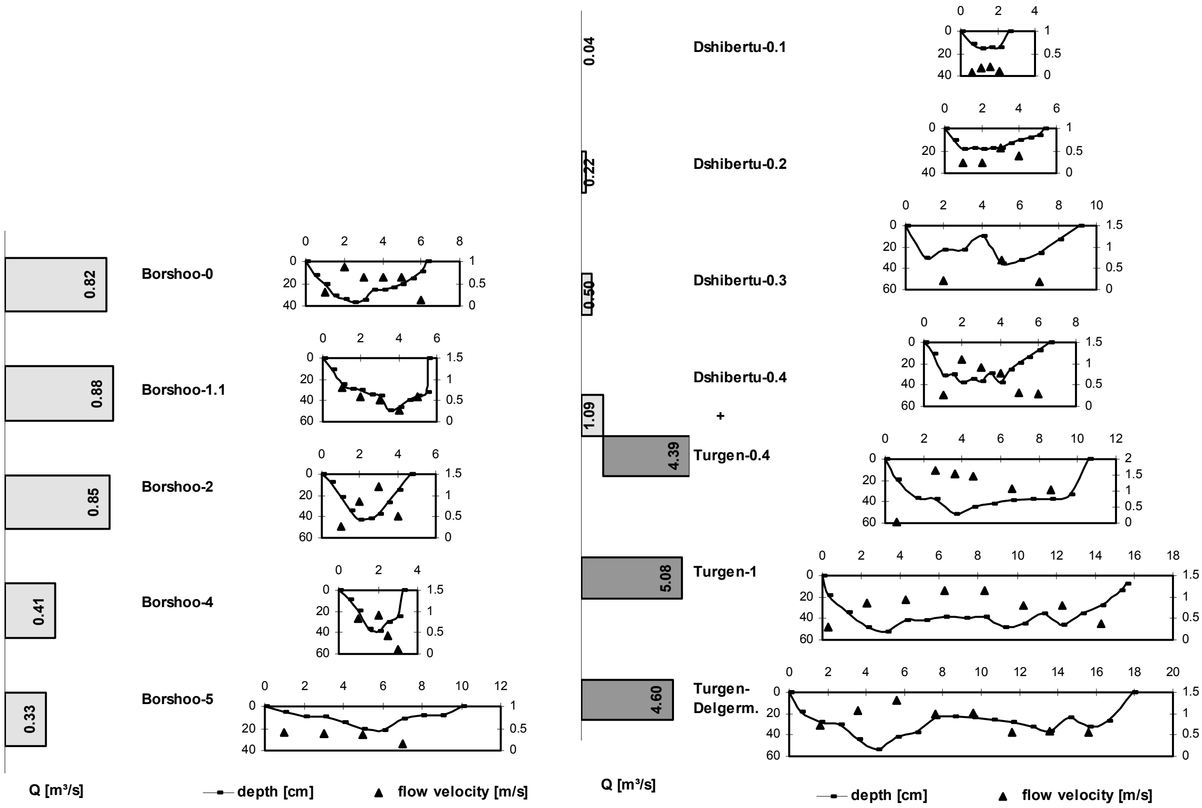


Fig. 69 River bed cross sections with flow velocity measurements and runoff. Left: Borshoo Gol, measurements taken August 16th and 17th 1998; Right: Dshibertu Gol (runoff light gray) and Turgen Gol (dark gray), measurements taken in August 11th to 14th 1998.

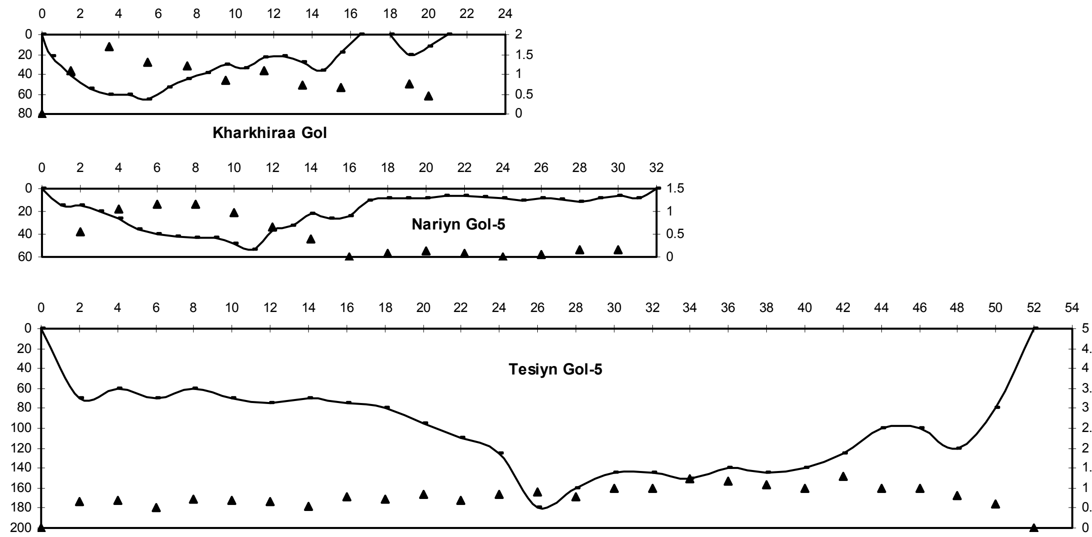


Fig. 70 River bed cross sections with flow velocity measurements for Kharkhiraa Gol (runoff 7.3 m^3/s, measurement taken 08/19/99), Nariyn Gol-5 (runoff 4.5 m^3/s, measurement taken 08/24/98) and Tesiyn Gol-5 (runoff 47.6 m^3/s, measurement taken 08/23/99). The distances between multiple channels are shortened to fit into the diagrams.

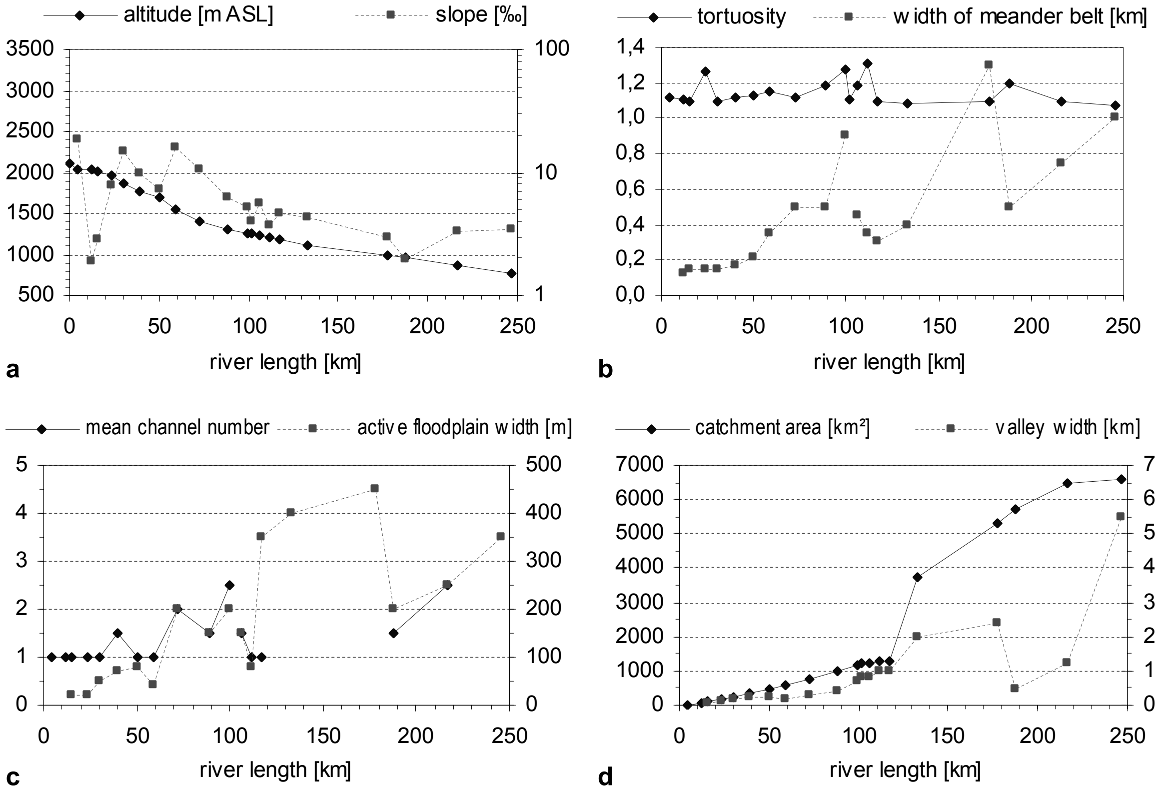


Fig. 71 a-d Morphological longitudinal profile of Baruunturuun Gol.

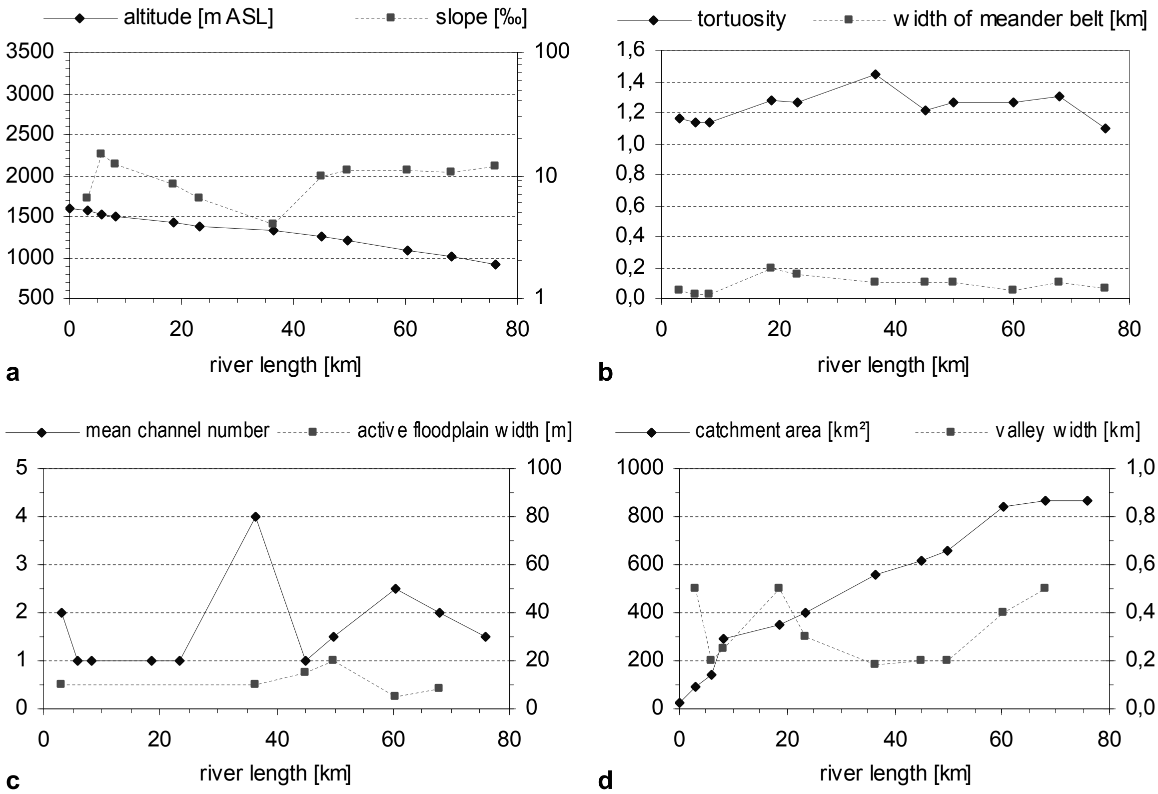


Fig. 72a-d Morphological longitudinal profile of Borshoo Gol.

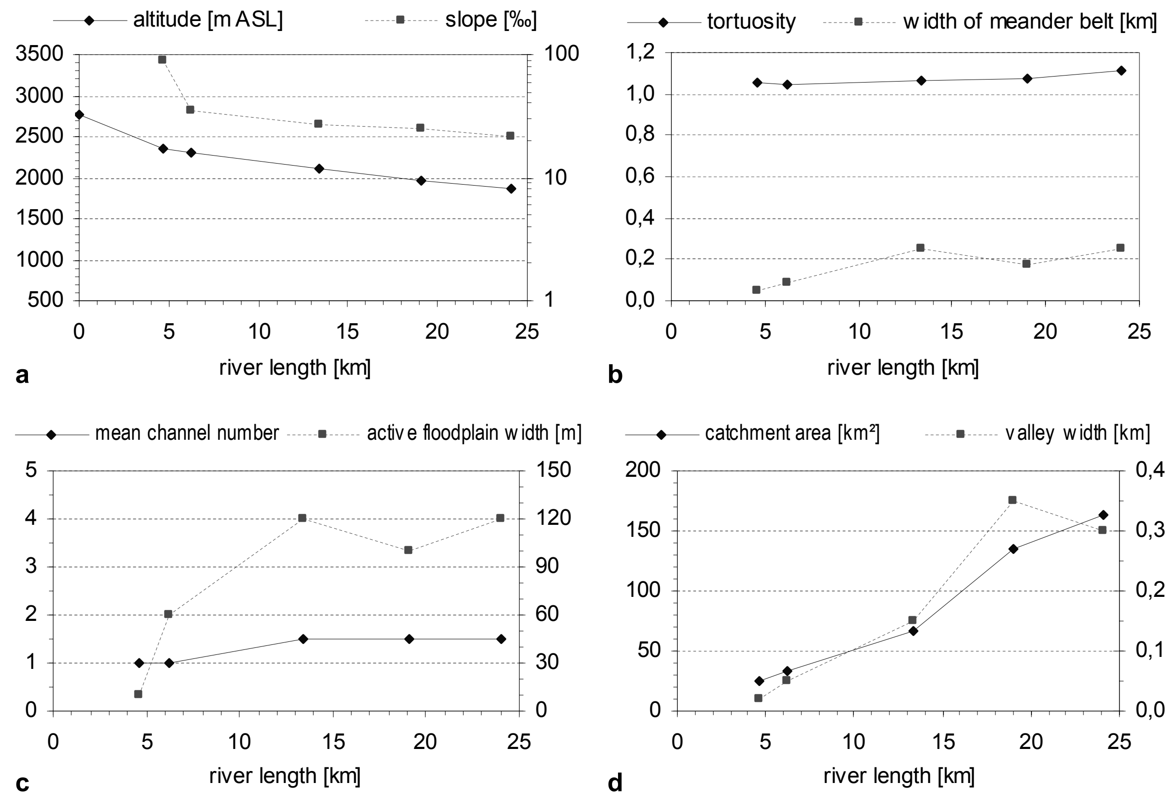


Fig. 73a-d Morphological longitudinal profile of Dshibertu Gol.

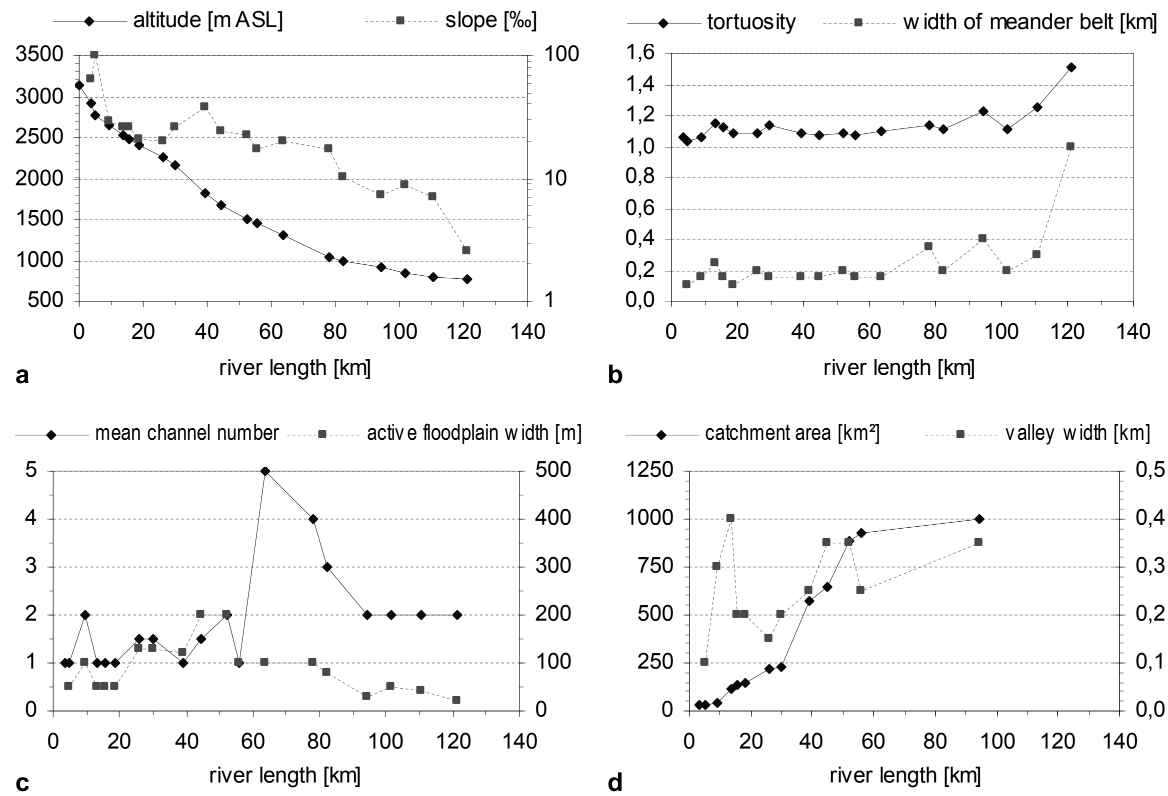


Fig. 74a-d Morphological longitudinal profile of Kharkhiraa Gol.

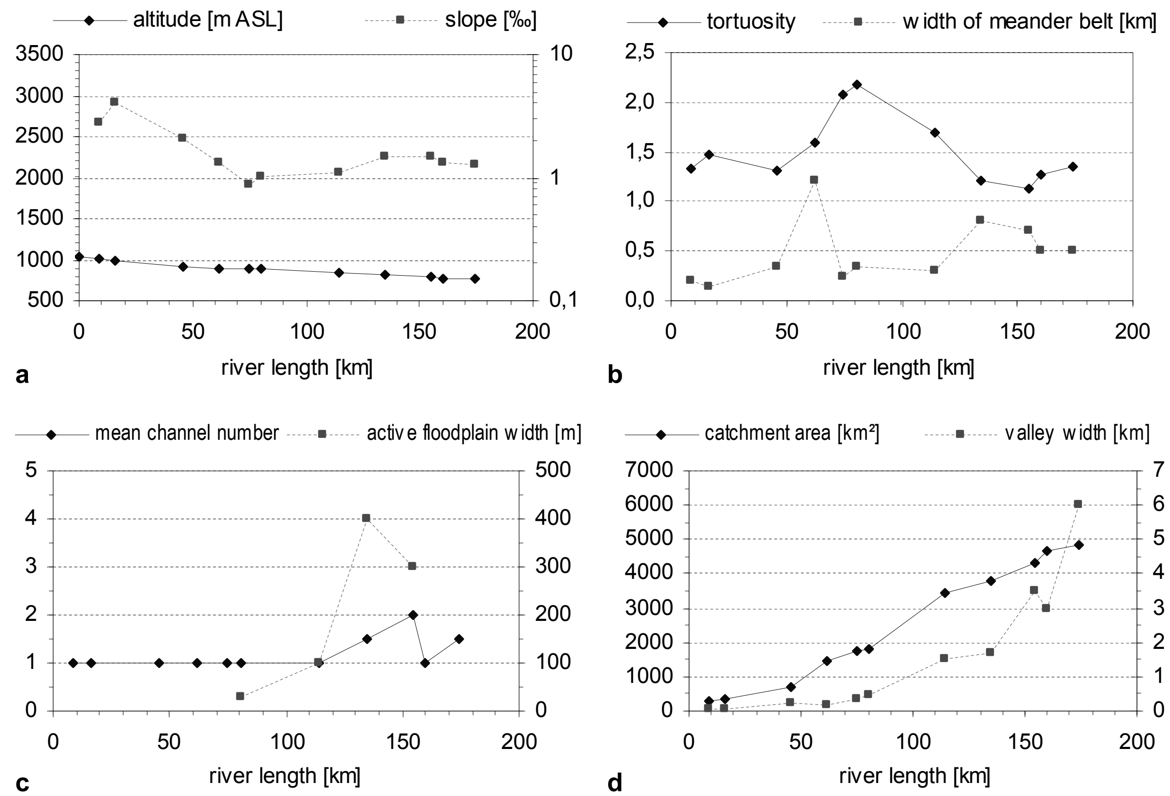


Fig. 75a-d Morphological longitudinal profile of Nariyn Gol.

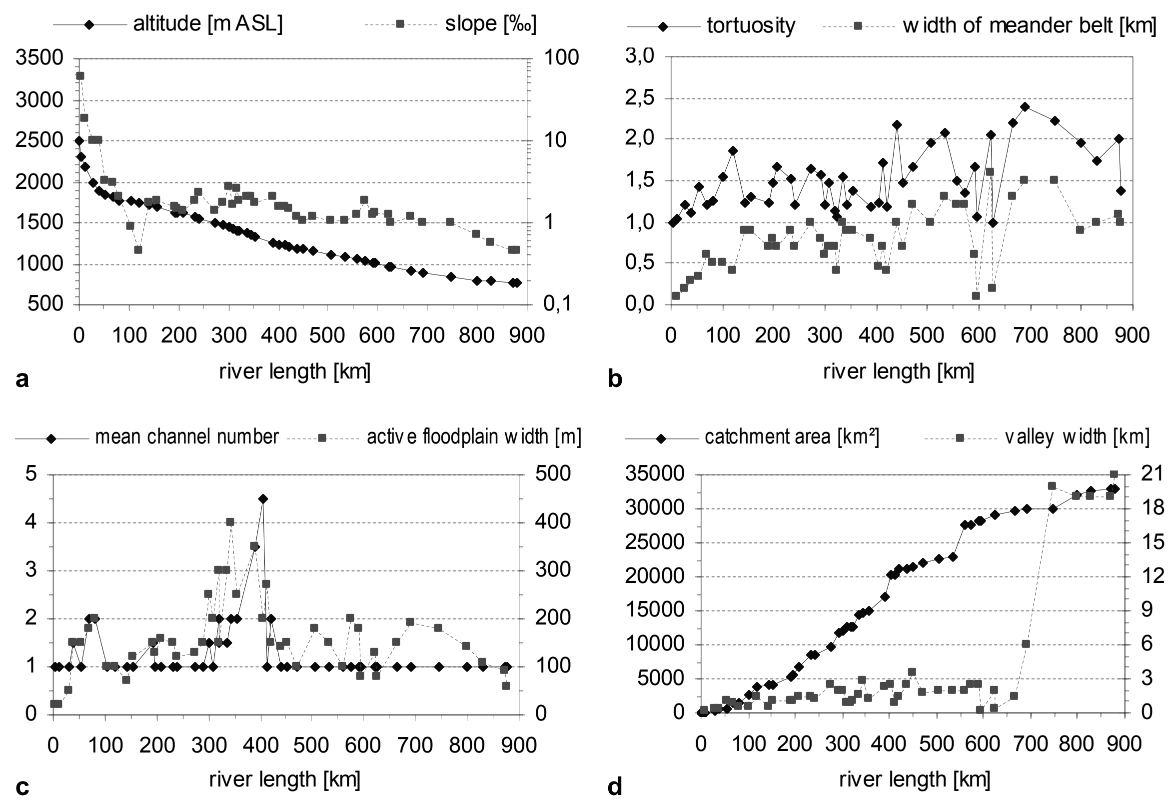


Fig. 76a-d Morphological longitudinal profile of Tesiyn Gol.

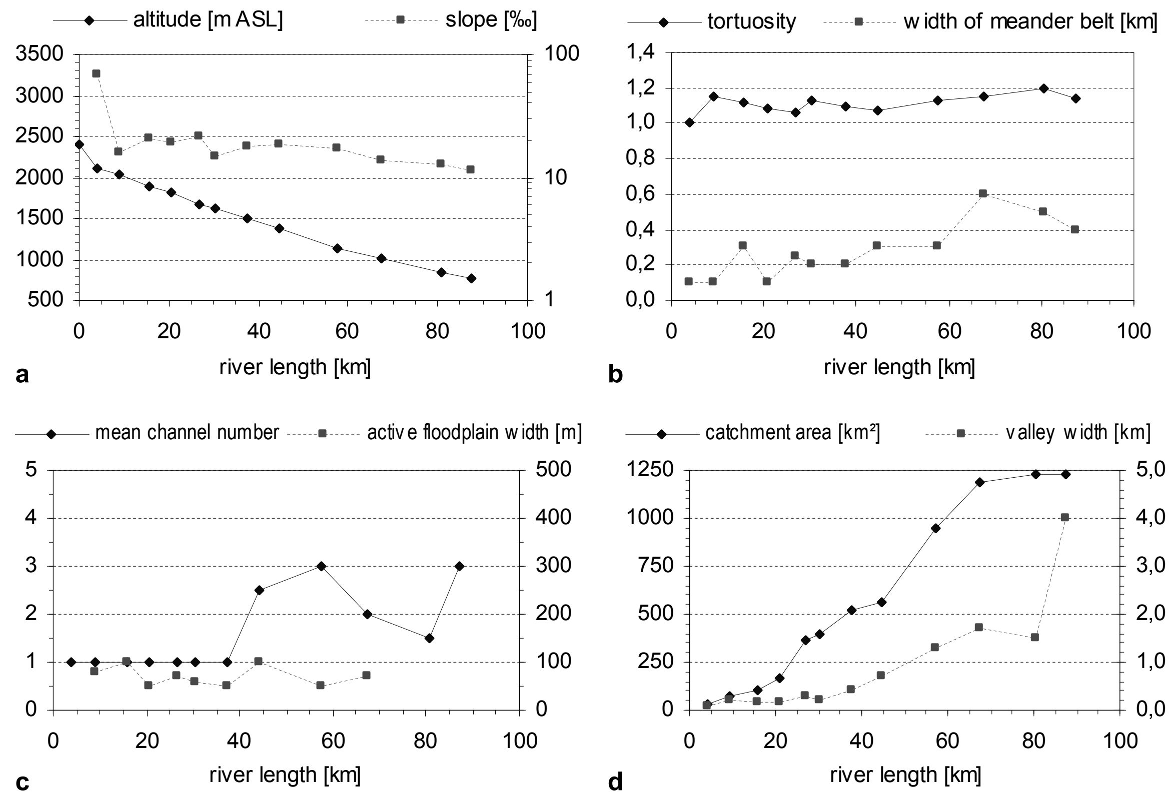


Fig. 77a-d Morphological longitudinal profile of Torkhilog Gol.

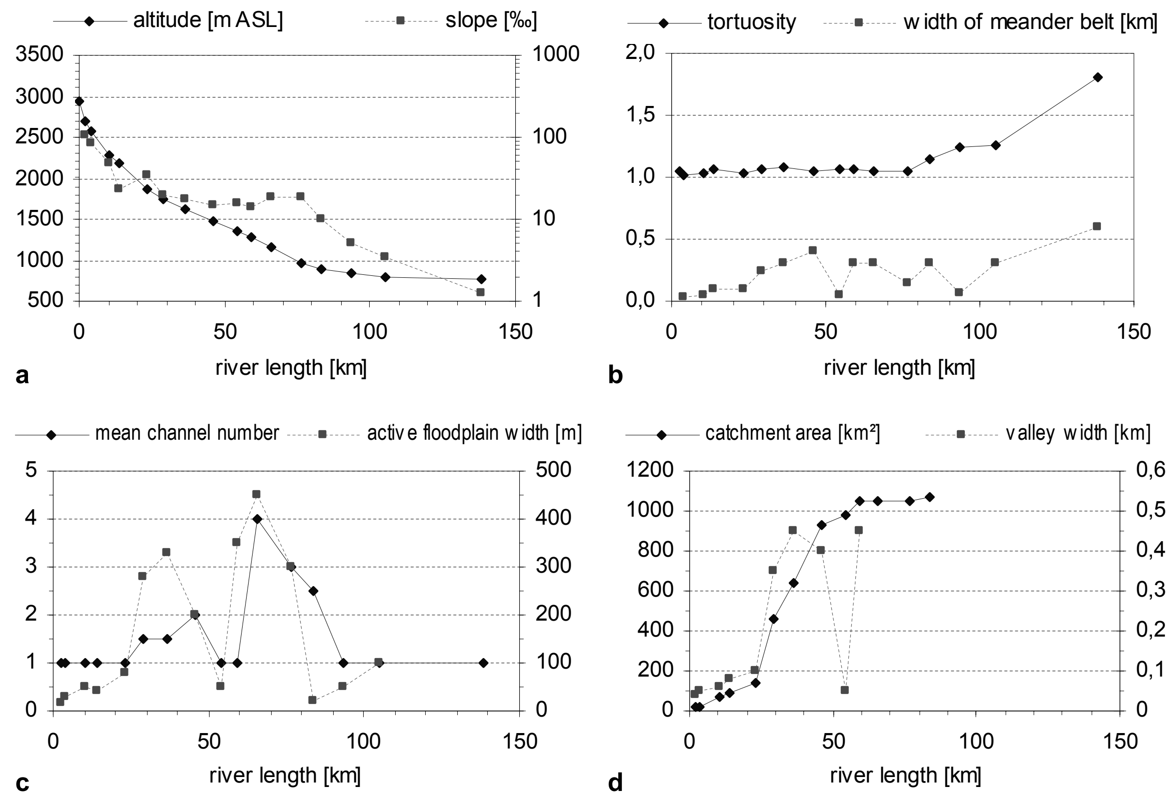
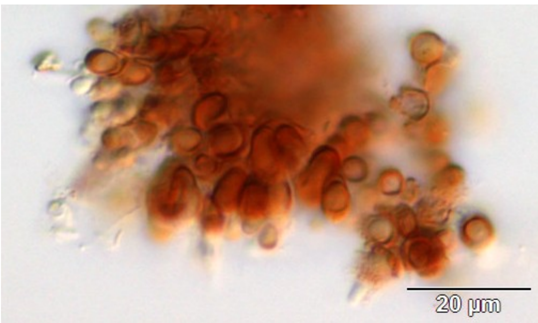


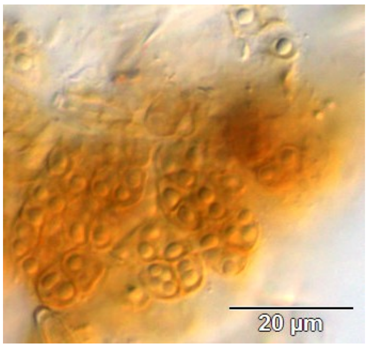
Fig. 78a-d Morphological longitudinal profile of Turgen Gol.

6.3 Microscopic images of algal species

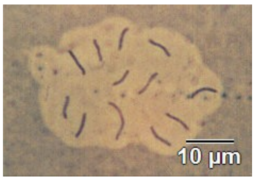


Chamaesiphon polonicus (from Dshibertu Gol-0): common in the alpine streams Dshibertu and Tsunkheg, associated with H. janthina, forming reddish crusts on stones.

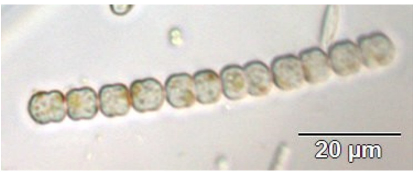
Clastidium setigerum (from Turgen Gol-1): associated with C. polonicus, only few-celled, inconspicuous cell clusters.



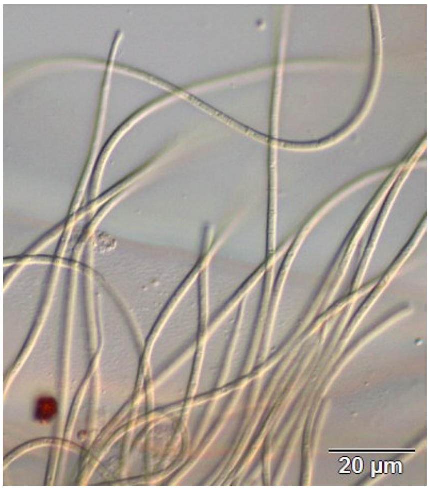
Gloeocapsa sp. (from Dshibertu Gol-1): associated with *C. polonicus* crusts.



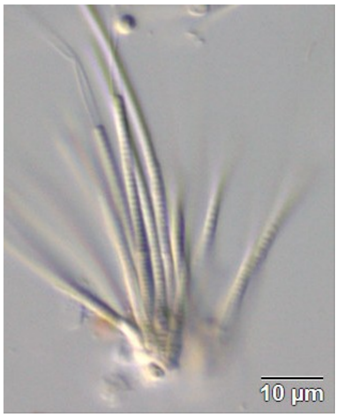
Rhabdoderma cf. *tenuissimum* (from Baga Nuur): mucilage made visible with indian ink. This species was only found in the plankton of Baga Nuur where it was dominant.



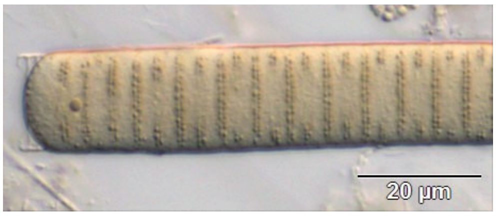
Komvophoron schmidlei (from Khustay Gol-lower reach) – a typical epipsammic species.



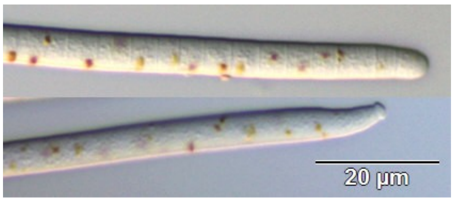
Geitlerinema splendidum (from Khoyd Gol): growing on sponge; typical species of slow flowing lowland streams.



Homoeothrix janthina (from Dshibertu Gol-4): tapering trichome ends in most cases truncated; associated with *H. varians* and *C. polonicus*.

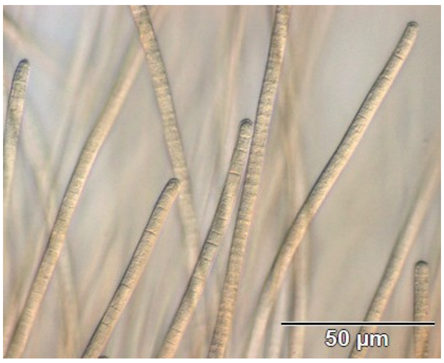


Oscillatoria cf. *curviceps* (from oxbow pond Tesiyn Gol-5.5)



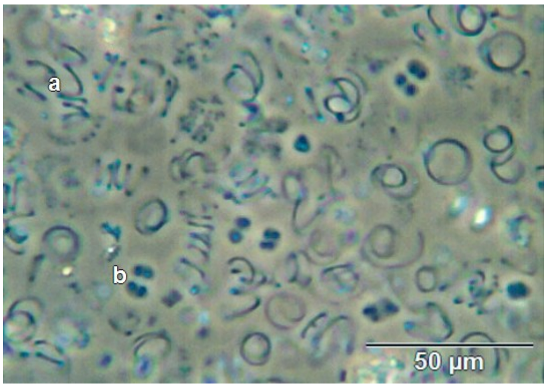
Phormidium cf. *calcareum* (from Turgen Gol-3): forming calcareous crusts on stones; terminal cell with calyptra.

Phormidium caucasicum (from spring at Torkhilog Gol): forms spirally twisted plaits of some centimeters length.



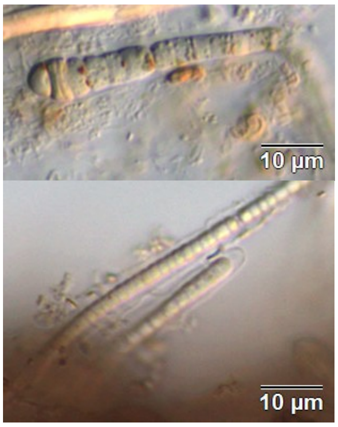
P. caucasicum (detail): terminal cells with calyptra.

Phormidium autumnale (from Borshoo Gol-2): characteristic leathery thalli on stones.

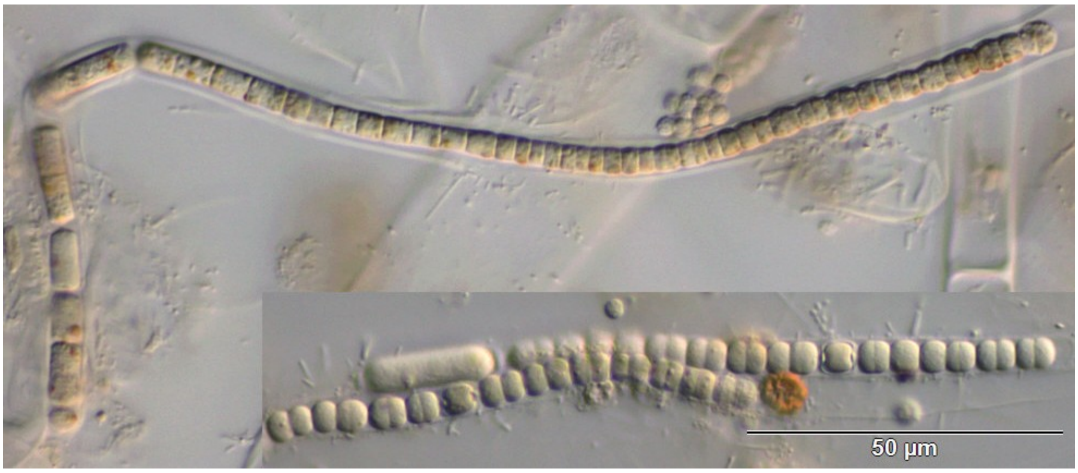


Planktolyngbya contorta (a) and *Coccopedia limnetica* (b) from Uvs Nuur-NW: the dominating phytoplankton species of Uvs Nuur.

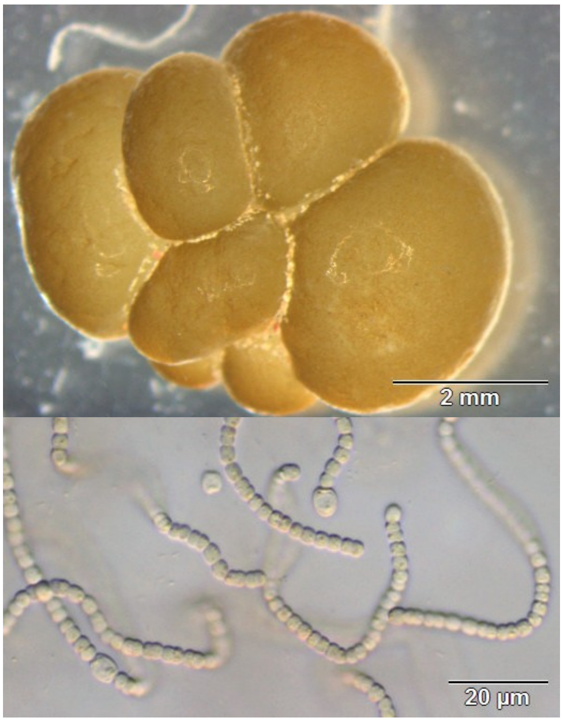
Trichocoleus tenerrimus (from Uvs Nuur-NW): benthic species with several trichomes in one sheath.



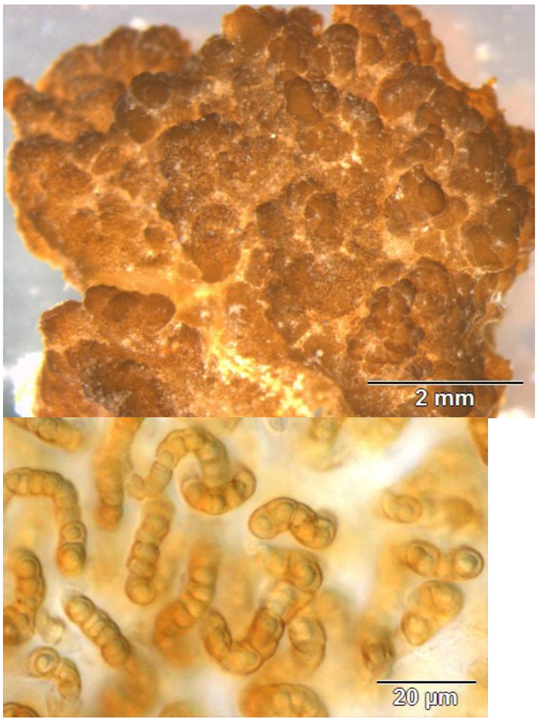
Calothrix cf. *kossinskajae* (from oxbow pond Tesiyn Gol-5.5): trichome with basal heterocyte growing on filamentous algae; tapering trichome ends with closed sheaths.



Microchaete tenera (from oxbow pond Tesiyn Gol-5.5): large image shows basal heterocyte and beginning akinete formation; trichome creeping on Mougeotia, then free. Trichome cells show strong heteromorphism. Small image: akinete and intercalary heterocytes.

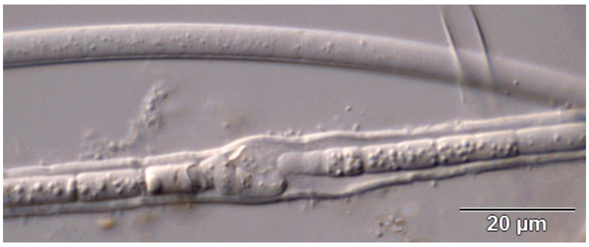


Nostoc sphaericum (from Borshoo Gol-0): upper image thallus, lower image trichomes with heterocytes.



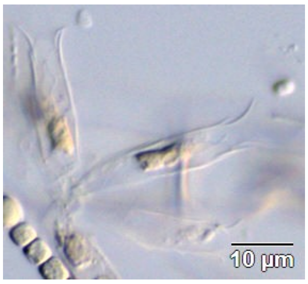
Nostoc verrucosum (from Tesiyn Gol-2): upper image thallus, lower image ensheathed trichomes; heterocytes not observed.

Chroodactylon ramosum growing on *Cladophora* (from Döröö Nuur)

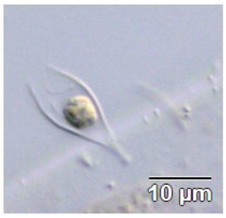


Tolypothrix cf. *tenuis*, young (upper) and old, pseudobranching trichome (from Döröö Nuur)

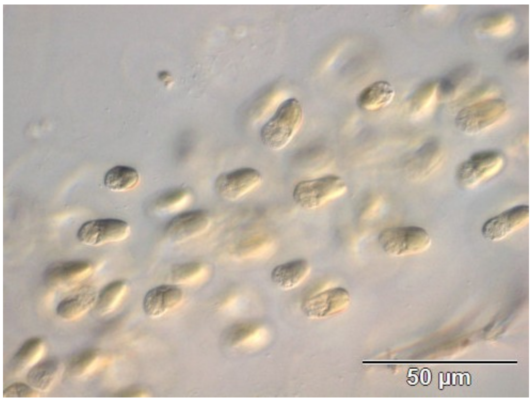
Batrachospermum sp. (from spring at Torkhilog Gol). Note the confluent whorls and the carposporophytes outside the whorls.



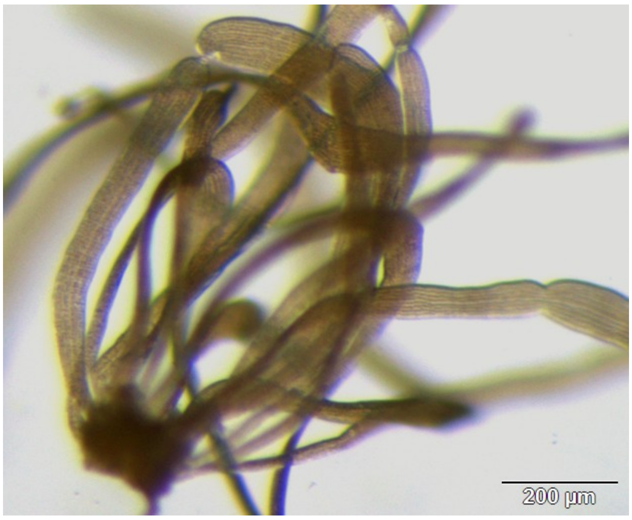
Epipyxis cf. *borgei* (from oxbow pond Tesiyn Gol-5.5)



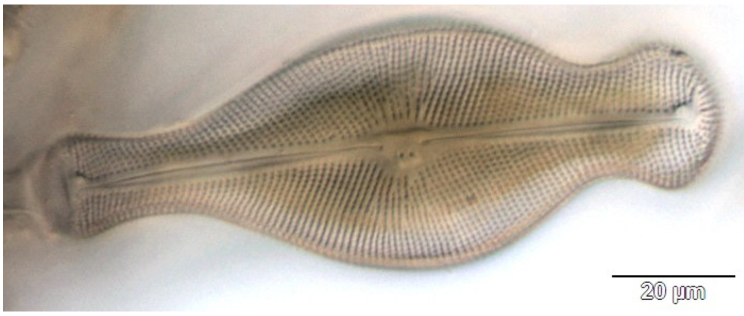
Epipyxis marchica (from oxbow pond Tesiyn Gol-5.5)



Hydrurus foetidus (from Tsunkheg Gol-3)

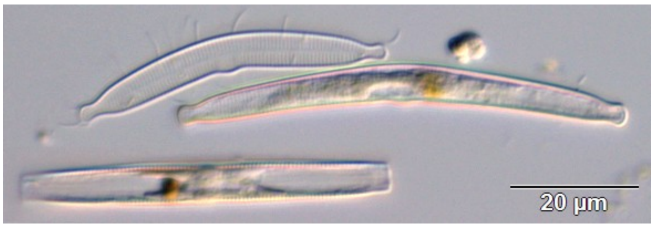


Prasiola fluviatilis (from Turgen Gol-0.1) – thallus originally light green.



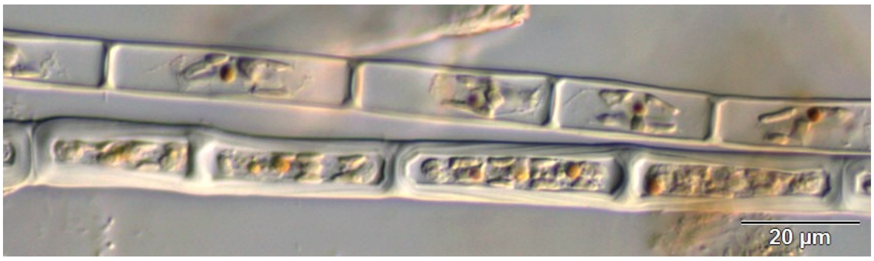
Didymosphenia geminata (from Borshoo Gol-2).

Aphanochaete repens (from oxbow pond Tesiyn Gol-5.5) on Mougeotia trichome. Terminal hairs up to 110 µm long.

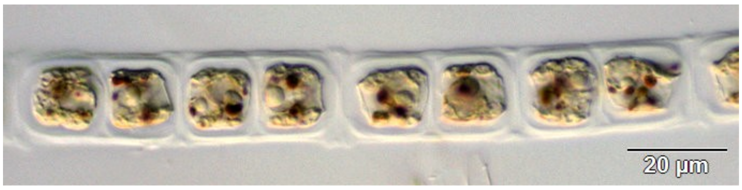


Hannaea arcus (from Tsunkheg Gol-3) forming gelatinous masses on stones.

Pseudoteraedriella camillae (from Bayan Nuur), a planktic Eustigmatophycean also known from European lakes.

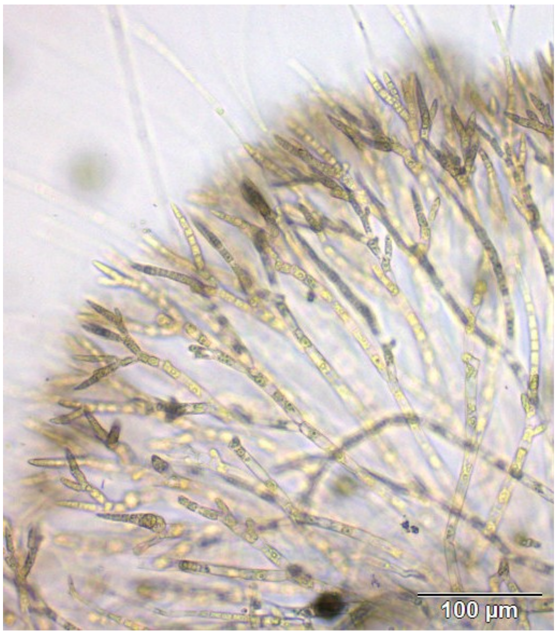


Microspora stagnorum (upper) and *Microspora amoena* (lower trichome) from oxbow pond Tesiyn Gol-5.5.



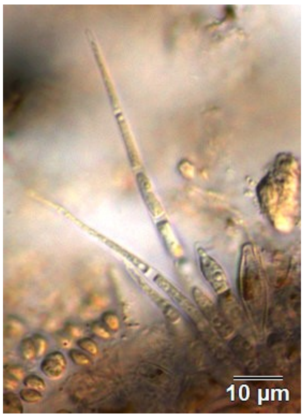
Ulothrix aequalis (from Tsunkheg Gol-3). Note the distinct division pattern of two- and four-cell clusters.

Closterium littorale var. *crassum* (from Borshoo Gol-2)



Stigeoclonium sp. (from Borshoo Gol-0).

Cladophora fracta (from Khoyd Gol) with side trichomes branching in a wide angle.



Pseudochaete crassiseta (from Tesiyn Gol-1) growing on *Cladophora.*

6.4 Satellite images

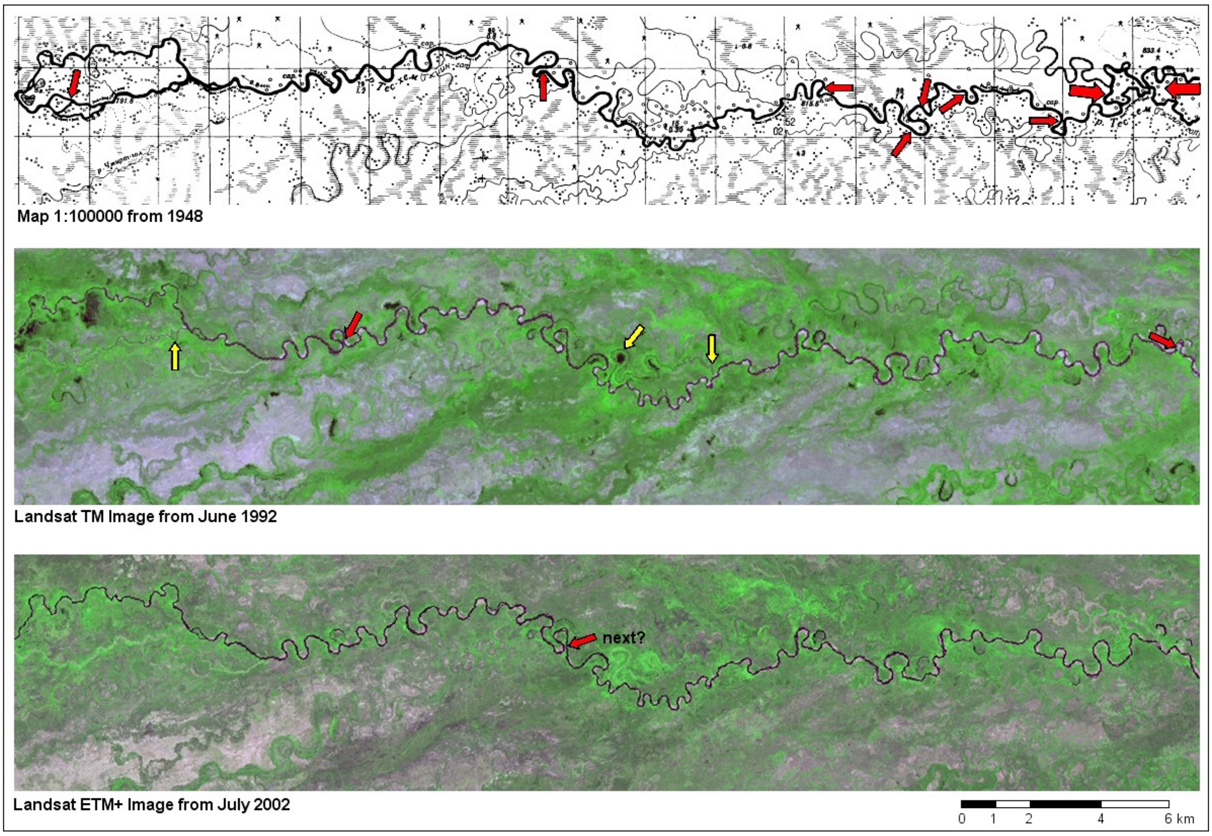


Fig. 79 Large scale morphological changes of the downstream reaches of Tesiyn Gol (around sampling place Tesiyn Gol-5, center at 93°40' E, 50°34' N) during a period of 54 years. Red arrows show meander bows that are cut off in the next image; yellow arrows show channels (temporarily?) drying out. False color images using channels 7, 4 and 2.

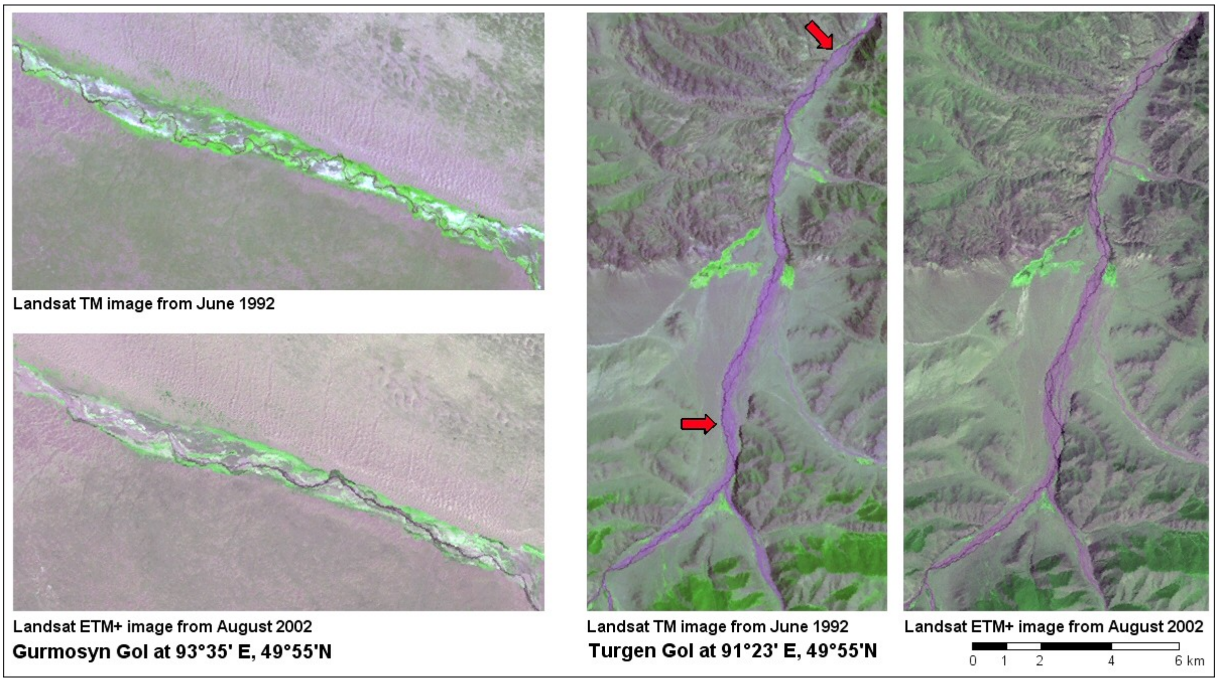


Fig. 80 Large scale morphological changes of the downstream reaches of Baruunturuun Gol (called Gurmosyn Gol) and the mountain reaches of Turgen Gol (around the Gauging station Delgermörön) during a period of 10 years. Red arrows show river reaches that are abandoned in the next image. Note the completely changed, less meandering course of Gurmosyn Gol in 2002. False color images using Landsat channels 7, 4 and 2.

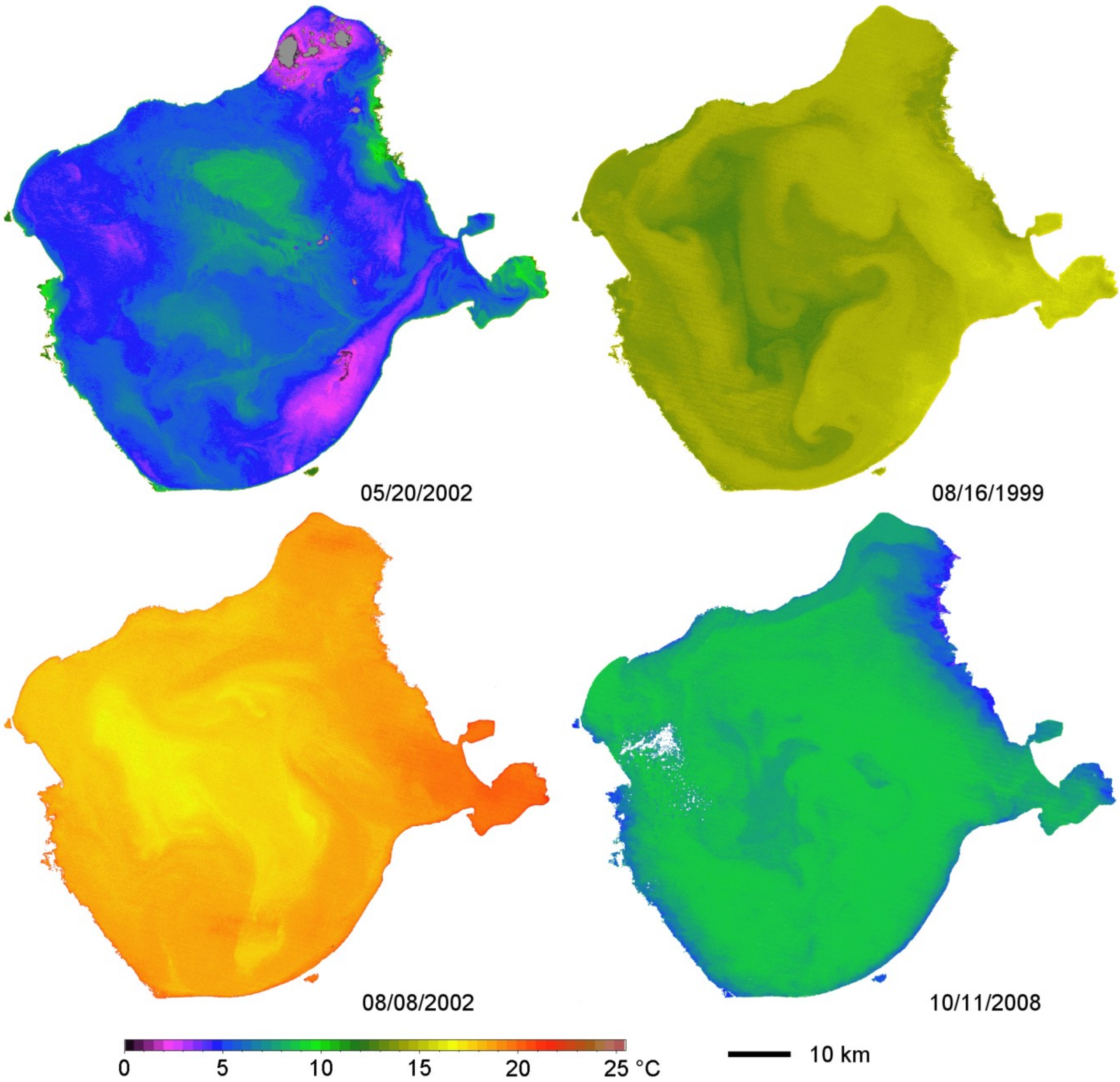


Fig. 81 Surface temperature of Uvs Nuur, Baga Nuur and Southern Baga Nuur, calculated from channel 6 of Landsat ETM+ images. Gray areas are ice floes, white spots are clouds. Note the faster warming and cooling of Baga Nuur and Southern Baga Nuur indicated by temperatures in the May 2002 image being some 5 degrees higher than in Uvs Nuur and 5 degrees lower in the October 2008 image.

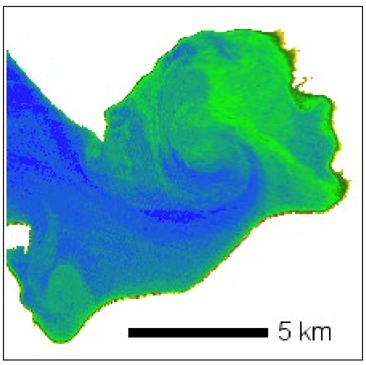


Fig. 82 Detail of the surface temperature in the E bay from the May 2002 image, showing a well developed counter-clockwise eddy with temperature differences of up to 5 degrees.

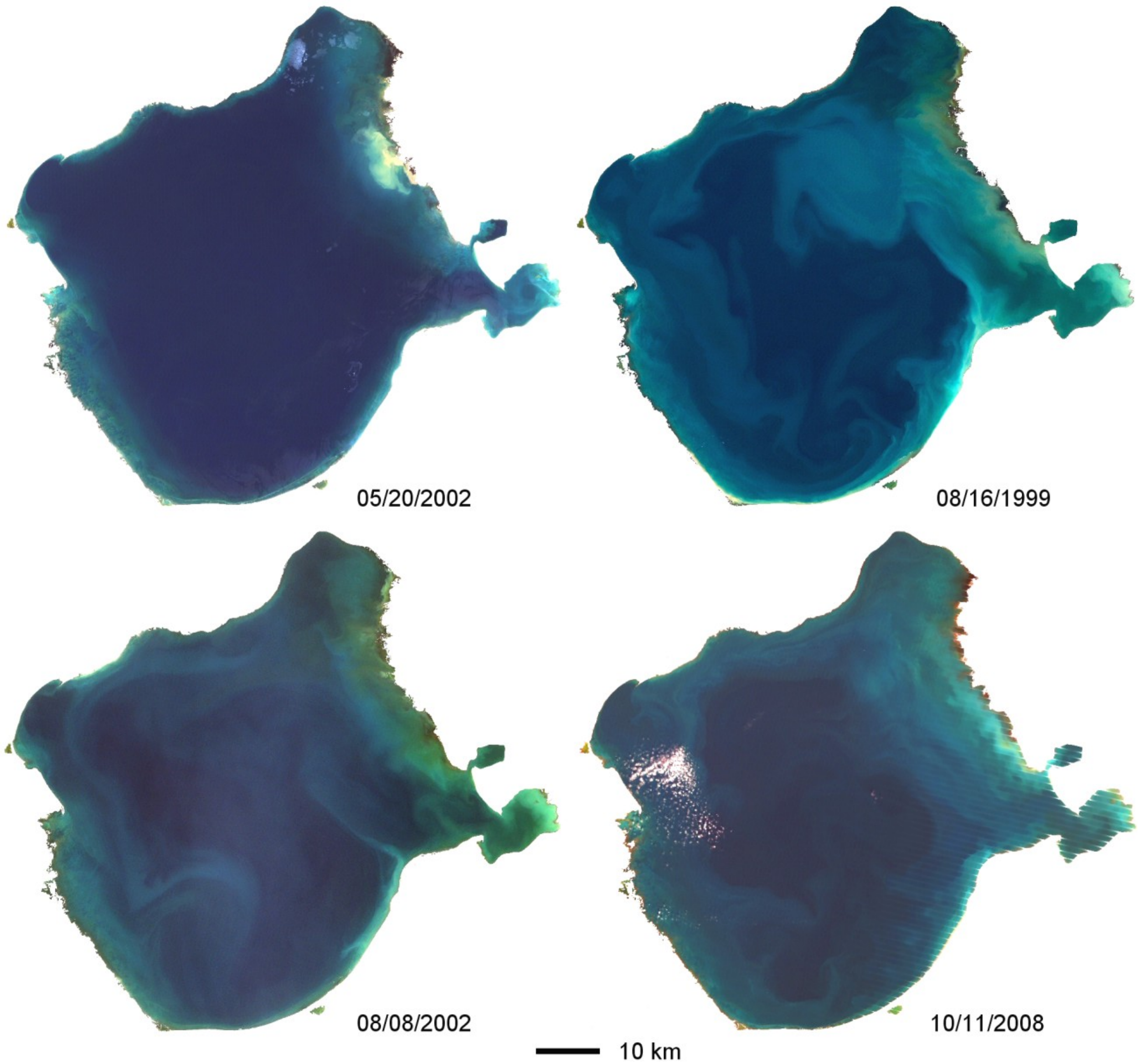


Fig. 83 Distribution of suspended particulate matter (sediment and phytoplankton) in Uvs Nuur, Baga Nuur and Southern Baga Nuur. Qualitative depiction based on visual spectral channels 1, 2 and 3 of Landsat ETM+ (contrast and saturation enhanced images). Stripes in the 2008 image are artifacts due to sensor malfunction. Note the clear visibility of littoral bottom features in the May 2002 image where turbidity is low because of calm weather. Interpretation of colors:

- dark blue = clear water with a depth greater than ≈ 7 m
- light blue = turbid water of any depth, but also sandy lake bottom shining through (mainly on the SE, SW and NW shores)
- blue-green = water of higher Chlorophyll content
- olive = turbid water with higher chlorophyll content
- light ochre (May 2002 image) = extremely turbid plume at the mouth of Tesiyn Gol
- brownish = organic lake sediment or stands of macroalgae and macrophytes shining through (mainly on the NE shore)
- white spots in the October 2002 image = clouds.

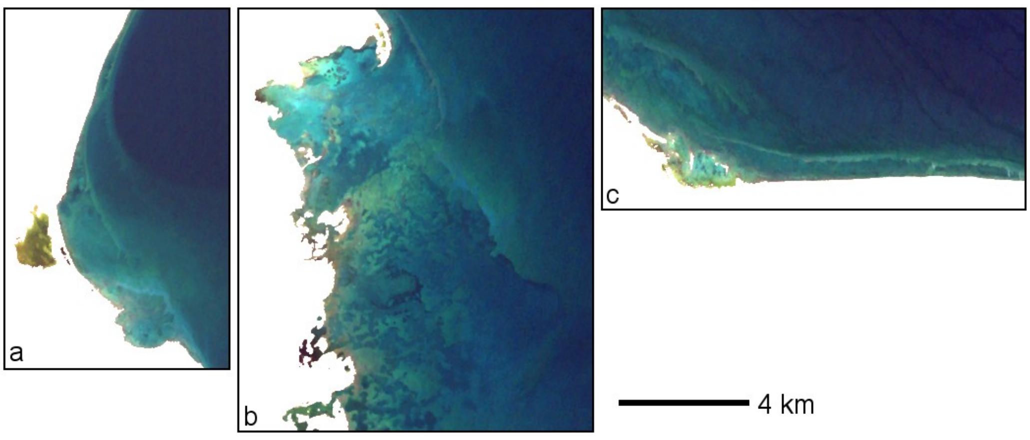


Fig. 84 Details of the May 2002 image showing submerged geomorphological structures.
a NW bay with gravel bars/spits.
b W shore with spit and small-scale thermokarst hollows.
c S shore with spit and gravel bar; these were islands in 1950 – see Fig. 32.

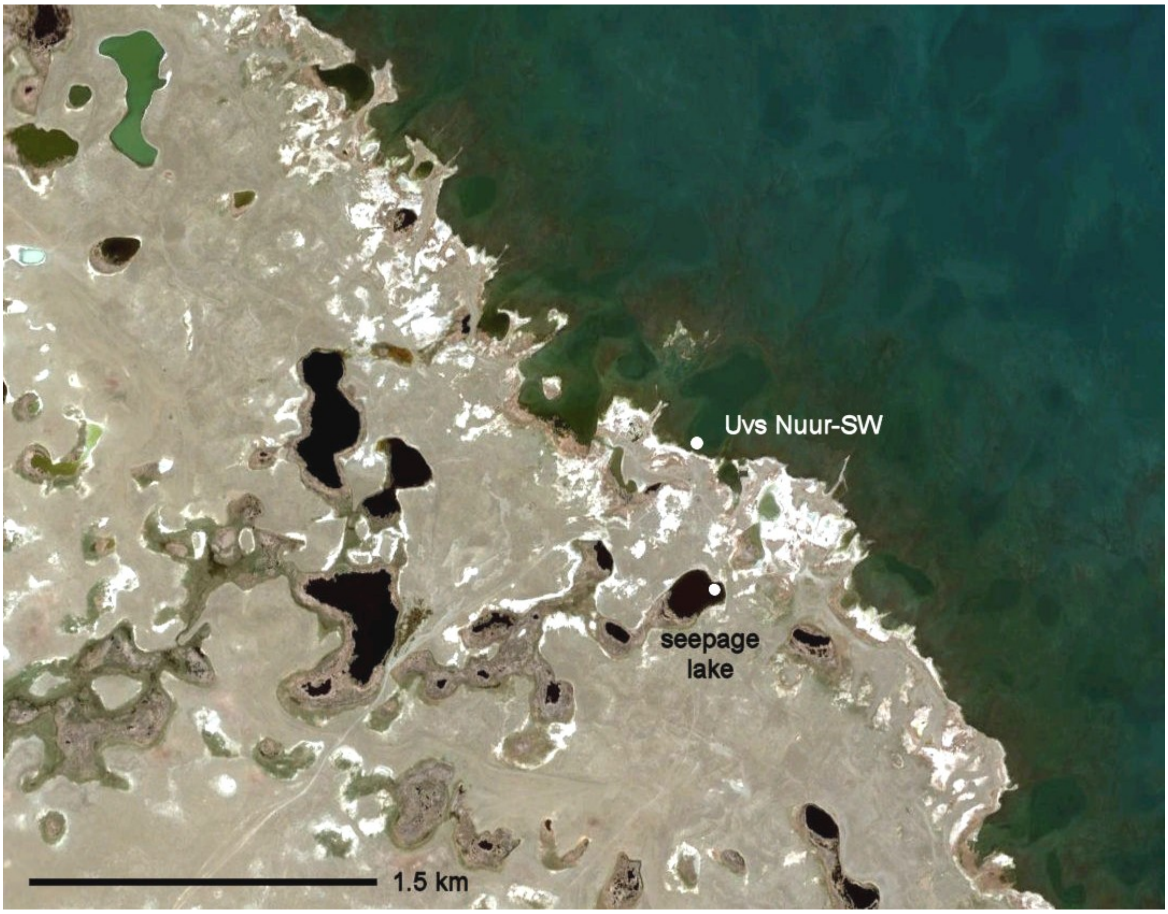


Fig. 85 Satellite image of the area around sampling places Uvs Nuur-SW and Seepage Lake, showing numerous small thermokarst lakes, connected by reed covered wetlands. Note the eutrophic lakes in the northwest corner and "blackwater" lakes rich in humic substances in the center of the image. The inundated hollows near the coastline are thermokarst lakes flooded after 1970. Image taken on 06/22/2005, copyright by Google Earth ™.

6.5 Photographs of sampled waters

Fig. 86 The spring area of Turgen Gol which is fed by the left glacier. The peak Tsagaan Degli (right) is 3965 m high.

Fig. 87 Turgen Gol and Endert Gol (small stream in the foreground) at sampling point Turgen Gol-2. The active floodplain is 280 m wide.

Fig. 88 Borshoo Gol in its middle reaches at sampling point Borshoo Gol-0. Some kilometers downstream, willows and poplars cover the whole floodplain.

Fig. 89 Spring pond of Burat Usu Bulag near the NW shore of Uvs Nuur. The bottom is covered with filamentous algae, at light spots loose sand is stirred up by upwelling groundwater.

Fig. 90 View from the NW shore of Uvs Nuur to the Turgen-Kharkhiraa Mountains. The plain near the shore is a gravelly dry steppe with bushes of Caragana. The distance of the glaciated peaks is about 100 km; the mountains of the delimiting range in the middle are 60 km away (contrast of the mountains enhanced).

Fig. 91 The southeastern shore of Uvs Nuur, surrounded by semidesert. Note the high grazing pressure by cashmere goats. The character of the amphibious zone of salt marshes and inundated dune valleys at the shore is highly variable in space and time due to lake level fluctuations.

Fig. 92 The western part of Döröö Nuur in the dune field Böörög Deliyn Els, near the sampling place. The reed belt is up to 50 m wide.

Fig. 93 Middle reaches of Khustay Gol in the Böörög Deliyn Els dune field. Note the erosion of mobile sand in the meander bow.

Fig. 94 Floodplain of Tesiyn Gol in its middle reaches near sampling point Tesiyn Gol-3. Note the big flock of sheep in the middle.

Physical map of the Uvs Nuur Basin (NW Mongolia). Detail area: Turgen Mountains.

The words "Gol" for river and "Nuur" for lake in the labels of sampling places were omitted for clarity.
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