Supplementary Material

S.1. Profiles of Stream Types in Kharaa River Basin (KRB) and Corresponding German Stream Types (LAWA River Types)

KRB River Type	**Small Siliceous Highland Rivers Dominated by Coarse Substrate (LAWA River Type 5)**
Ecoregion	Western slopes of the Khentii Mountains
Water Body Group	Kh:Trib_2 (Sugnugr, Tunkhelin; Bayangol I and Ulgiin Gol) and Kh_Trib_4 (Boroo Gol, upstream part)
River Type (LAWA Type 5, [1,2]	Small coarse substrate dominated siliceous highland rivers
Picture 1: Churcheree Gol, broad valley with coarse material, view east to the summit of Khentii Mts. (2788 m a.s.l.) **Date:** 6 September 2012 **Photo:** Martin Oczipka **Device:** Octocopter flying **Altitude:** 120 m above ground; **Location:** see Picture 2 **Panorama view**: see page S3 [1)]	
Picture 2: Vertical aerial photo of Churcheree Gol, river width *ca*. 10 m **Date** 6 September 2012 **Device:** Octocopter **Flying altitude:** 100 m above ground **Location:** 48.44818° N 107.19004° E **Ground level:** 1478 m **(Photo**: Martin Oczipka**)**	

KRB River Type	**Small Siliceous Highland Rivers Dominated by Coarse Substrate (LAWA River Type 5)**
Picture 3: Churcheree Gol, a tributary of Sugnugr Gol, broad valley section with small river islands, view west in downstream direction **Date:** 5 September 2012 **Photo:** Jürgen Hofmann **Location:** see Picture 2 **Thermal IR panorama view**: see page S3 [2]	
Picture 4: Churcheree Gol, narrow valley section with large boulders; view west in downstream direction **Date:** 5 September 2012 **Photo:** Jürgen Hofmann **Location:** 48.465° N 107.14° E 1406 m a.s.l.	
General description	Rhitral tributaries of the Kharaa River that originate from the Khentii Mountains; coarse material rich in low mountain creeks (elevation: >1100 to 2800 m a.s.l.); northerly exposed slopes covered with dense taiga forest (*Pinus sibirica*, *Larix sibirica*, *Betula platyphylla*) and a thick organic layer of mosses and small shrubs (predominantly *Ledum palustre*, *Vaccinium vitis-idaea*), southerly exposed slopes with steppe vegetation of herb-rich grasslands, valley floors dominated by deciduous shrubbery, consisting mainly of *Betula fusca* and *Dasiphora fruticosa*, occasionally accompanied by *Salix rhamnifolia* and *Salix pseudopentandra*.
River bed substrate	Granite and gneiss, crystalline, granular rocks of quartz, feldspar crystals and glimmer.

KRB River Type	**Small Siliceous Highland Rivers Dominated by Coarse Substrate (LAWA River Type 5)**
Morphological and hydrological characteristics	Glacially and periglacially formed mountain section (>1100 to 2799 m a.s.l.). Different kinds of valleys (depending on the distance to the source; v-shaped, troughs or u-shaped); depending on the form of the valley, the river course features many secondary channels and can be straight, sinuous or weakly meandering. **River banks:** steep, slip-off slope and eroded banks (bank cliffs) are highly distinct **Floodplains:** often marshy; mostly sand and fine gravel, less fine material **River bed:** stones and gravel with local occurrence of rock and boulders; in pools with low current finer substrate can be found. **Current:** turbulent fast flowing waters; characteristic sequences of fast flowing plain and deep calmer sections.
Abiotic profile	Size class: 10–800 km^2 catchment area; slope of the valley floor: 10‰–50‰
Physico-chemical water conditions	Siliceous, conductivity (µS/cm): 50–80, pH-value: 7.0–8.0, water temperature (June to September) 7–8 °C Turbidity [Nephelometric Turbidity Unit NTU] 6–7 (Table 9)
Flow regime	High fluctuations in discharge over the year with pronounced discharge peaks in spring after snow melt and in late summer, ice cover from October until April/May
Diatom assemblage	Dominant species *Hannae arcus, Ulnaria ulna*
Short description of the macroinvertebrate community	Very species rich, dominated by sensitive species in terms of water temperature, current and oxygen concentration; species that colonize the gravel-rich river bed are prevailing; main feeding types: mostly grazers and passive filterers, only a few shredders; longitudinal zonation: species of the epi- and metarhithral dominate.
Characterization of the fish fauna	Epi-, meta- and Hyporhithral: dominated by rheophilic species. Beside the Baikal grayling (*Thymallus baicalensis*) and lenok (*Brachymystax lenok*) the fish community is also characterized by stone loaches (Genus: *Barbatula* spp.) or common minnows (*Phoxinus phoxinus*) as well as other cyprinide species.
Comparative literature Panorama view [1,2)]	Spherical panoramas [3,4] have been created by stitching overlapping photos with the software PTGui Pro [5]. The result is a panorama where the user can see the full environment of the octocopter-mounted camera. The integrated Flash Viewer enables the user to move the panorama in any direction and to zoom in. **[1)]** The spherical panorama view [5] of Picture 1 (6 September 2012) is available online [6] **[2)]** A spherical thermal IR panorama view [5] of Picture 3 was terrestrially collected using an Infratec Variocam hr camera (spectral range 7.5–14 µm, temperature sensitivity < 0.08 K) on 6 September 2012, 8:30 p.m. local time, two hours after sunset. The thermal IR view is available online [7]

KRB River Type	**Small Siliceous Highland Rivers Dominated by Fine Substrate (LAWA River Type 5.1)**
Ecoregion	Western slopes of the Khentii Mountains
Water Body Group	Mandalin, Zagdalin, Shivertin and Boroo Gol (WB: Kh_Trib_1; Kh_Trib_3; Kh_Trib_4; Kh_Trib_5)
River Type (LAWA Type 5.1) [1,2]	Small fine substrate dominated siliceous highland rivers
Picture 1 Upper reaches of Zagdalin Gol *ca*. 12 km south of Jargalant, view upstream **Date:** 26 August 2008 **Photo:** Jürgen Hofmann **Location:** 48.4132° N, 105.91777° E, 1100 m a.s.l	
Picture 2 Lower reaches of Zagdalin Gol with intense degradation of grassland and high fluvial loads of suspended fine sediment **Date:** 17 May 2011 **Photo:** Jürgen Hofmann **Location:** 48.86692° N, 106.06457° E, 796 m a.s.l. Zagdalin_Gol_Bridge_WQM_Logger Sel_Kh07_002, Table 1	

KRB River Type	**Small Siliceous Highland Rivers Dominated by Fine Substrate (LAWA River Type 5.1)**
Picture 3 Lower reaches of Boroo Gol *ca*. 5 km upstream of the confluence with Kharaa Gol **Date:** 26 August 2007 **Photo:** Jürgen Hofmann **Location:** 48.83203° N, 106.2775° E, 836 m a.s.l.	
General description	Rhitral tributaries of the Kharaa River that originate from the Khentii Mountains. Fine material dominate these low mountain creeks (elevation: >900 m a.s.l.). Northerly exposed slopes covered with dense taiga forest (*Pinus sibirica*, *Larix sibirica*, *Betula platyphylla*) and a thick organic layer of mosses and small shrubs (predominantly *Ledum palustre*, *Vaccinium vitis-idaea*), southerly exposed slopes with steppe vegetation of herb-rich grasslands, valley floors are dominated with deciduous shrubbery, consisting mainly of *Betula fusca* and *Dasiphora fruticosa*, occasionally accompanied by *Salix rhamnifolia* and *Salix pseudopentandra*.
River bed substrate	Granite and gneiss, crystalline, granular rocks of quartz, feldspar crystals and glimmer.
Morphological and hydrological characteristics	Glacially and periglacially formed mountain section. Different kinds of v-shaped valleys, depending on the distance to the source and the form of the valley, the river course features many secondary channels and can be straight, sinuous or weakly meandering. River banks: steep, slip-off slopes and eroded banks (bank cliffs) are highly distinct. Floodplains: often marshy; mostly sandy or with fine gravel, less fine material. River bed: high variance in depth and width; in general flat channel profile with locally occurring marginal sand or gravel bars. Current: slow flowing water that is locally fast or turbulent.
Abiotic profile	Size class: 10–100 km^2 catchment area; Slope of the valley floor: 4‰–50‰

KRB River Type	**Small Siliceous Highland Rivers Dominated by Fine Substrate (LAWA River Type 5.1)**
Physico-chemical water conditions	Siliceous, Conductivity (μS/cm): 300–550, pH-value: 8.0–9.0
Flow regime	High fluctuations in discharge over the year with pronounced discharge peaks in spring after snow melt and in late summer, ice cover from October until April/May.
Diatom assemblage	Dominant species *Nitzschia palea*, *N. pura*, *Navicula riparia* and *Cocconeis placentula lineata*.
Short description of the macroinvertebrate community	Relatively poor in species richness compared to other low mountain creeks; rheophilic species dominate the flowing water sections, while cold stenothermic species that are adapted to the current dominate the stable sand deposits, in slow flowing areas with phytal habitats limnophilous taxa (e.g., swimming beetles or damselflies (Zygoptera) are common; main feeding types: collectors and shredders.
Characterization of the fish fauna	Relatively poor in species richness; nearly the entire population is represented by Siberian dace (*Leuciscus baicalensis*), Baikal grayling (*T. baicalensis*), lenok (*B. lenok*) and common minnows (*P. phoxinus*), stone loaches (*Barbatula* spp.) occur in suitable habitats.

KRB River Type	**Large gravel rich highland rivers (LAWA River Type 9.2)**
Ecoregion	Western slopes of the Khentii Mountains
Water Body Group	Middle and upstream Kharaa (WB: Kh_Main_1; Kh_Main_2)
River Type (LAWA Type 9.2) [1,2]	Large highland rivers
Picture 1) Widening of the Kharaa River valley with a broad floodplain after the passage of the mountainous relief; view downstream to Zuunkharaa city **Date:** 8 September 2012 **Photo:** Martin Oczipka **Device:** Octocopter **Flying altitude:** 130 m above ground **Location:** 48,82947° N, 106,65775° E, 920 m a.s.l.	

KRB River Type	Large gravel rich highland rivers (LAWA River Type 9.2)
Picture 2 Kharaa River with steep valley flanks cut into bedrock, view upstream to Mandal village **Date:** 8 September 2012 **Photo:** Martin Oczipka **Device:** Octocopter **Flying altitude:** 130 m above ground **Location:** 48.82947° N, 106.65775° E, 920 m a.s.l.	
Picture 3 Riparian zone with relict trees and bushes on the river floodplain **Date:** 14 September 2011 **Photo:** Melanie Hartwig **Location:** 48.80335° N, 106.6922° E, 915 m a.s.l. Kh8	
Picture 4 Typical eroded river bank **Date:** 28 May 2009 **Photo:** Melanie Hartwig **Location:** 48.8346° N, 106.50909° E, 865 m a.s.l.	

KRB River Type	Large gravel rich highland rivers (LAWA River Type 9.2)
Picture 5 The river bank in the lower reaches with severe degradation of vegetation coverage and high levels of erosion downstream of Baruunkharaa city, view upstream. **Date:** 17.09.2011 **Photo:** Melanie Hartwig **Location:** 48.91589° N, 106.06043° E, 787 m **Panorama view**: see page S12 [3)]	
General description	Hyporhithral, rubble and gravel dominates low mountain range rivers (elevation: 900 to 1100 m a.s.l.). Daurian forest steppe with typical forest types (Siberian larch forest; mixed forests of birch-pine and birch-larch trees; shrub forests), and extended steppe vegetation in the southern reaches that are represented by grass associations such as *Carex-Poaceae* meadow steppe, *Compositae-Gramineae*-herbs steppe and sandy versions of saltmarsh-tussock steppe.
River bed substrate	Paleozoic graywacke with intrusions of granite.
Morphological and hydrological characteristics	Transverse valleys with narrow sections in the low mountains, U-shaped valleys. Depending on the slope, dominated by meandering sections of narrow valleys or complex braided river sections with extensive floodplains. Very dynamic river course development. **River bed:** Stones and gravel with large low-current sections dominated by fine material deposits. **Current:** Mostly fast flowing, with longer stream sections.
Abiotic profile	Size class: 10–10,000 km^2 catchment area; Slope of the valley floor: 1‰–4‰
Physico-chemical water conditions	Conductivity (µS/cm): 150–450, pH-value: 7.5–9.0
Flow regime	Medium fluctuations in discharge over the year with pronounced discharge peaks in spring after the snow (May) melt and in late summer (August), ice coverage from October until April.
Diatom assemblage	Dominant species *Navicula capitatoradiata, Diatoma vulgaris, Encyonema silesiaceae*
Short description of the macroinvertebrate community	Species rich biocoenosis due to the high habitat diversity; Rhithral species (rheophilous) are dominating but are supplemented by potamal (limnophilous) species in depositional areas; Some species are eurytherm.

KRB River Type	**Large gravel rich highland rivers (LAWA River Type 9.2)**
Characterization of the fish fauna	Species rich biocoenosis due to the high habitat diversity; Depending on local conditions dominated by hyporhithral or metapotamal species; the fish community is dominated by rheophilous species such as *T. baicalensis*, *B. lenok*, *Barbatula* spp., *Phoxinus phoxinus* and *L. baicalensis*. Suitable habitats also exist for the endangered taimen (*Hucho taimen*). Depositional sections are regularly colonized by spined loaches (*Cobitis melanoleuca*), burbot (*Lota lota*) and catfish (*Parasilurus asotus*).
Panorama View 3)	3) The spherical panorama view [5] of Picture 5 (12 September 2012, 17:30 local time) is available online [8]

KRB River Type	**Small Lowland Rivers Dominated by Sand (LAWA River Type 14)**
Ecoregion	Eastern foothills of the Selenge-Orkhon highlands
Water Body Group	Bayangol (WB:Kh_Trib_7)
River Type (LAWA Type 14) [1,2]	Small sand-dominated lowland rivers
Picture 1: Lower reaches of Bayan Gol at the bridge (road Darkhan-Baruunkharaa), under wet conditions, view upstream **Date:** 18 September 2010 **Photo:** Jürgen Hofmann **Location:** 49.02805° N, 106.044138° E, 801 m a.s.l.	
General description	Hyporhitrhal to epipotamal, sand and gravel dominated river.
River bed substrate	Holocene/Quaternary sediments above palaeocoic metamorphic rocks and sandstone.
Morphological and hydrological Characteristics	Highly meandering river course, passing broad u-shaped valleys with both vertical and horizontal erosion. The profile is generally plain, but deep side channels are also possible. **River banks**: Slip-off slopes and stable bank cliffs are common, eroding bank cliffs and slightly undercut banks also occur. **River bed**: Dominated by different sand fractions, often mixed with fine and coarse gravel, clay and marl, locally small but well-established gravel bars, secondary habitat structures include coarse woody debris, roots, macrophytes and fallen leaves. **Current**: Long slow flowing sections alternate with short fast/turbulent flowing sections around wood and root barriers.

KRB River Type	**Small Lowland Rivers Dominated by Sand (LAWA River Type 14)**
Abiotic profile	Size class: 10–100 km^2 catchment area; slope of the valley floor: 2‰–7‰
Physico-chemical water conditions	Siliceous, conductivity (µS/cm): 150–250, pH-value: 7.5–8.8, high turbidity due to high sediment loads.
Flow regime	Medium to high fluctuations in discharge over the year.
Diatom assemblage	No data
Short description of the macroinvertebrate community	No data
Characterization of the fish fauna	No data
KRB River Type	**Mid-Sized and Large Lowland Rivers Dominated by Sand and Loam (LAWA River Type 15)**
Ecoregion	Eastern foothills of the Selenge-Orkhon highlands.
Water Body Group	Middle and downstream Kharaa (WB: Kh_Main_3; Kh_Main_4)
River Type (LAWA Type 15) [1,2]	Mid-sized and large sand and loam-dominated lowland rivers
Picture 1: Lower reaches of the Kharaa River ca. 7 km upstream of the confluence with the Orkhon River **Date:** 9 June 2009 **Photo:** Melanie Harwig **Location:** Gauge station Buren Tolgoi of IMHE (Sel_Kh10_001 in Table 2) view upstream.	
Picture 2: Confluence of the Kharaa River (right corner) and Orkhon River (large stream in center). The sediment load of the Kharaa River, with its dark brown color, is clearly visible. Patches of riparian forest in the river floodplain are the remnants of the formerly dense meadow forest. **Date:** 11 September 2012 **Photo:** Martin Oczipka **Location:** see Picture 3 **Panorama view**: see page S12 [4)]	

<table>
<tr><th>KRB River Type</th><th>Mid-Sized and Large Lowland Rivers Dominated by Sand and Loam (LAWA River Type 15)</th></tr>
<tr><td>Picture 3:
Aerial photo of the confluence of the Kharaa River (left) and the Orkhon River (right), view upstream
Date: 11 September 2012
Photo: Martin Oczipka
Device: Octocopter
Flying altitude: 120 m above ground
Location: 49.63162° N, 105.83357° E, 657 m a.s.l.
Panorama view: see page S12 4)</td><td></td></tr>
<tr><td>Picture 4: Aerial photo of detached side arms (right) of the Kharaa River at Deed Guur, view upstream.
Date: 12 September 2012
Photo: Martin Oczipka
Device: Octocopter
Flying altitude: 110 m above ground
Location: 49,3899° N, 105,8971833° E, 703 m</td><td></td></tr>
<tr><td>Picture 5: Aerial photo of the river meadow plain at Deed Guur bridge, monitoring site of IMHE, view downstream to the city of Darkhan
Date: 12.09.2012
Photo: Martin Oczipka
Device: Octocopter
Flying altitude: 110 m above ground
Location: 49,3899° N, 105,8971833° E, 703 m Sel_Kh10_008 in Table 2</td><td></td></tr>
<tr><td>General description</td><td>Epipotamal, sand and loam-dominated lowland river (elevation: 600 to 900 m a.s.l.). Daurian forest steppe with typical forest types (Siberian larch forest; mixed forests of birch-pine and birch-larch trees; shrub forests), and extended steppe vegetation in the southern reaches that are represented by grass associations such as Carex-Poaceae meadow steppe, Compositae-Gramineae- herbs steppe and sandy versions of saltmarsh-tussock steppe</td></tr>
</table>

KRB River Type	**Mid-Sized and Large Lowland Rivers Dominated by Sand and Loam (LAWA River Type 15)**
River bed substrate	Holocene/Quaternary sediments above palaeocenic sandstone with isolated volcanic rocks
Morphological and hydrological Characteristics	Highly meandering river course, passing broad u-shaped valleys with both, vertical and horizontal erosion. **River banks**: Pronounced slip-offs and stable bank cliffs. **Floodplains**: Extensive (over 300 m wide), outwash plains, sandy deposits, loess regions, ground moraines, also in sandy regions of river terraces; numerous drainage channels, detached side arms and backwaters of varying ages are likely. **River bed**: Dominated by sands of varying grain sizes or loam; often supplemented by gravel, in parts by clay and marl, gravel bars can occur, secondary habitat structures include coarse woody debris, roots, macrophytes and fallen leaves. **Current**: Mainly slow flowing.
Abiotic profile	Size class: 10–1000 km^2 catchment area; slope of the valley floor: 0.8‰–1.1‰
Physico-chemical water conditions	Siliceous, conductivity (µS/cm): 200–450, pH-value: 8–8.5, turbidity 70–80 NTU, mean water temperature (June to September) 14–15 °C
Flow regime	Medium fluctuations in discharge over the year with a pronounced discharge peak in spring after snow (May) melt and a more steady high discharge in late summer (August to the beginning of October), ice cover from October until April/May
Diatom assemblage	Dominant species *Nitzschia agnita*, *N. heufleriana*, *Cocconeis placentula*
Short description of the macroinvertebrate community	Relatively rich in species but mostly euryoecious; benthic habitats are sparsely inhabited by taxa adapted to fine and mobile sediments; littoral regions characterized by submerged riparian vegetation, macrophytes, dead wood or pebble zones are colonization hotspots.
Characterization of the fish fauna	Characterized by epirhithral or metapotamal species, mainly cyprinids; Dominated by rheophilous species preferring sandy and gravelly habitats, *i.e.*, Siberian dace (*L. baicalensis*) and spined loach (*C. melanoleuca*), beside that many euryoecious species e.g., European perch (Perca fluviatilis), roach (*Rutilus rutilus*), Prussian carp (*Carassius gibelio*) or carp (*Cyprinus carpio*) can occur; higher riparian vegetation delivers refuge for larger (predominantly nocturnal) predatory species such as burbot (*L. lota*) and catfish (*P. asotus*).
Panorama view [4)]	[4)] The spherical panorama view [5] of the confluence of the Kharaa River and the Orkhon River (Pictures 2 and 3, 11 Sept. 2012, 1:30 p.m. local time) is available online [9]

S.2. Measurements from the Automated Water Quality Monitoring Stations (Data Loggers, Table 1, Figure 3)

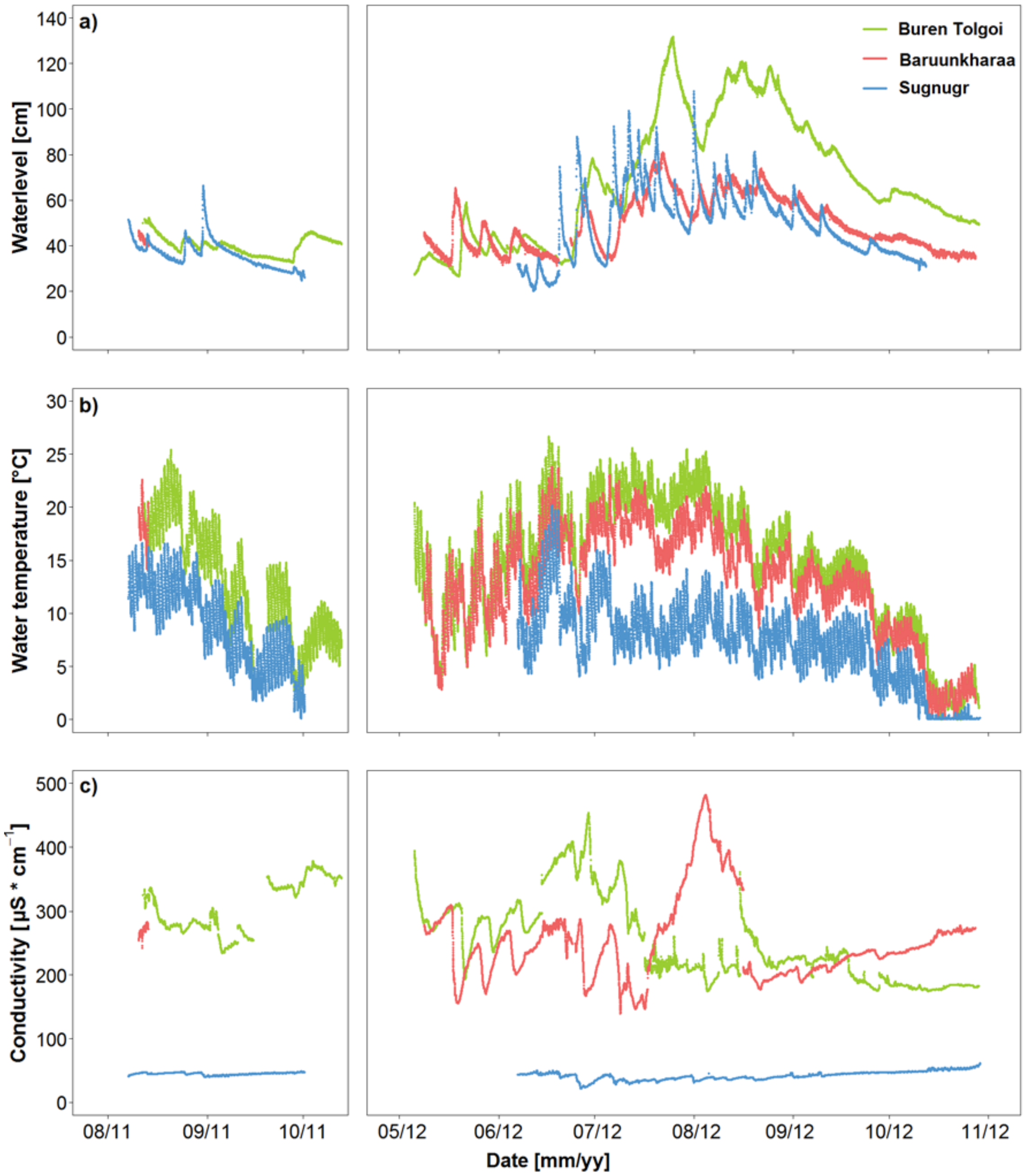

Figure S1. Variations of (**a**) water level; (**b**) water temperature and (**c**) electrical conductivity during the summer periods in 2011–2012 at the automatic water quality monitoring stations Buren Tolgoi, Baruunkharaa and Sugnugr (Sel_Kh10_001, Sel_Kh10_012 and Sel_Kh03_009 in Table 1, Figure 3).

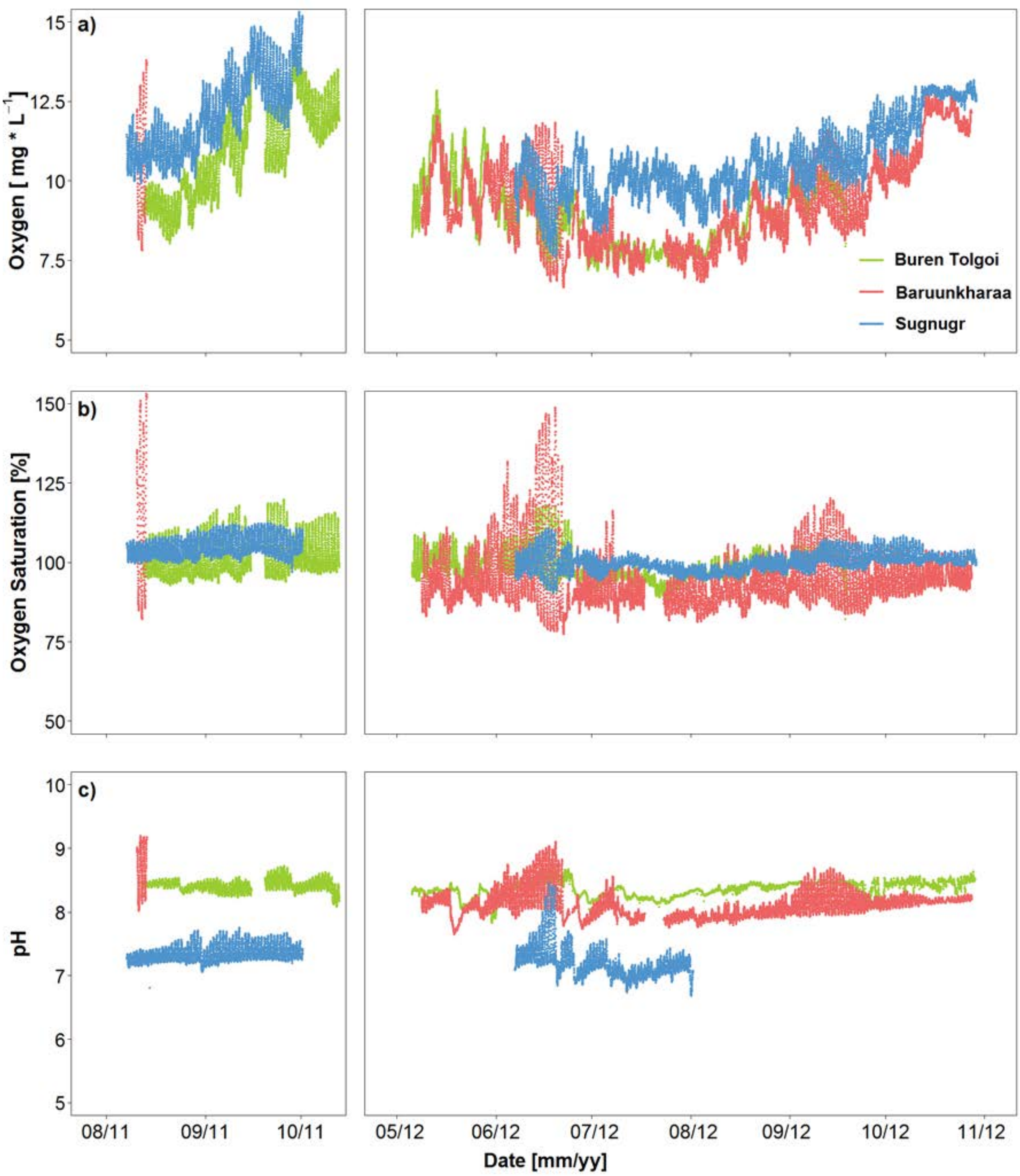

Figure S2. Variations of (**a**) oxygen concentration; (**b**) oxygen saturation and (**c**) pH-value during the summer periods in 2011–2012 at the automatic water quality monitoring stations Buren Tolgoi, Baruunkharaa and Sugnugr (Sel_Kh10_001, Sel_Kh10_012 and Sel_Kh03_009 in Table 1, Figure 3).

S.3. Evaluation Matrix for the Initial Assessment of Individual Water Bodies in the Kharaa River Basin

Table S1. Evaluation matrix of the river water at Kh_Main_1 (Upper Kharaa); Upper Kharaa River basin, downstream of the confluence with Mandalin Gol (*ca*. 7 km N of Batsumber), until upstream of the confluence with the Shivertin Gol (*ca*. 5 km NW of Unikht); *Biocenotic region: Hyporhithral.*

Quality Component	Indicators	Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)	Assessment (*n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)*	Colour	Comment
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "moderate" to "very good"	"not at risk"	green	-
	Fish	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	2	"not at risk"	green	-
Physico-chemical quality	EC (n = 14) Arithm. Mean Chloride (n = 14) Arithm. Mean Bor (n = 4) Arithm. Mean	102–280 µS/cm 175 µS/cm 1.2–3.76 mg/L Cl^- 2.3 mg/L Cl^- 16–30 µg/L B 24 µg/L B	"possibly at risk" *4.0* *2.5* *2.5*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (n = 6) Mean	Arsenic: 0.5–2.5 µg/L 1.83 µg/L	"not at risk" *1.1*	green	-

Table S2. Evaluation matrix of the river water at Kh_Main_2 (Middle Kharaa); Middle Kharaa River basin, downstream of the confluence with Shivertin Gol until upstream of the confluence with Zagdalin Gol.; *Biocenotic Region: Hyporhithral*; *Water quality monitoring Station: Baruunkharaa (ID: Sel_Kh10_012) Table 2.*

Quality Component	Indicators	Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)	Assessment (*n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)*	Colour	Comment
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "unsatisfactory" to "very good"	"possibly at risk"	yellow	-
Biological Quality	Fish	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	3–4	"possibly at risk"	yellow	-
Physico-chemical quality	EC (n = 61) Arithm. Mean Chloride (n = 36) Arithm. Mean Bor (n = 18) Arithm. Mean	120–689 µS/cm 251 µS/cm 1–14.58 mg/L Cl^- 4.31 mg/L Cl^- 5–41 µg/L B 24.24 µg/L B	"possibly at risk" *5.7* *3.3* *2.5*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (n = 21) Arithm. Mean	Arsenic: 0.5–8.5 µg/L 2.11 µg/L	"possibly at risk" *1.2*	yellow	

Table S3. Evaluation matrix of the river water at Kh_Main_3 (Middle/Lower Kharaa); Middle Kharaa basin, downstream of the confluence with the Zagdalin Gol until upstream of the road bridge at Deed Guur; *Biocenotic Region: Epipotamal*.

Quality Component	**Indicators**	**Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)**	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: “moderate”	“possibly at risk”	yellow	-
Biological Quality	Fish	Ecological status based on multimetric assessment: “moderate”	“possibly at risk”	yellow	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	3	“possibly at risk”	yellow	-
Physico-chemical quality	EC (n = 50) Arithm. Mean Chloride (n = 31) Arithm. Mean Bor (n = 21) Arithm. Mean	213–476 µS/cm 324 µS/cm 2.9–93.8 mg/L 10.83 mg/L 5–98 µg/L 33.53 µg/L	“possibly at risk” *7.4* *8.3* *3.5*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (n = 23) Mean	Arsenic 0.5–3.8 µg/L 1.92 µg/L	“not at risk” *1.1*	green	-

Table S4. Evaluation matrix of the river water at Kh_Main_4 (Lower Kharaa); Lower Kharaa River basin, downstream of the road bridge at Deed Guur until the confluence with the Orkhon Gol; *Biocenotic Region: Epipotamal*; *Water quality monitoring station: Buren Tolgoi (Station ID: Sel_Kh10_001) Table 1.*

Quality Component	**Indicators**	**Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)**	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "unsatisfactory" to "very good"	" possibly at risk"	yellow	-
	Fish	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	2–4	"possibly at risk"	yellow	-
Physico-chemical quality	EC (n = 68) Arithm. Mean Chloride (n = 31) Arithm. Mean Bor (n = 22) Arithm. Mean	231–592 µS/cm 359 µS/cm 2.4–14.9 mg/L 9.15 mg/L 13–97 µg/L 38.7 µg/L	"at risk" *8.2* *7.0* *4.1*	red red yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As Arsenic (n = 24) Arithm. Mean	Arsenic: 0.5–9.7 µg/L 2.29 µg/L	"at risk" *3.3*	red	-

Table S5. Evaluation matrix of the river water at Kh_Trib_1 (Mandalin Gol).

Quality Component	Indicators	Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)	Assessment (*n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)*	Colour	Comment
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "moderate"	"possibly at risk"	yellow	-
	Fish	Ecological status based on multimetric assessment: "moderate" to"good"	"possibly at risk"	yellow	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	3	"possibly at risk"	yellow	-
Physico-chemical quality	EC (*n* = 68) Arithm. Mean Chloride (*n* = 31) Arithm. Mean Bor (*n* = 22) Arithm. Mean	113–654 µS/cm 332 µS/cm 1–19.6 mg/L Cl 4.9 mg/L Cl 5–62 µg/L B 24.3 µg/L B	"possibly at risk" *7.5* *3.8* *2.5*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., Arsenic) Arsenic (*n* = 7) Arithm. Mean	Arsenic: 1,6-fold concentration of natural background 1.2–4.6 µg/L 2.81 µg/L	"possibly at risk" *1.6*	yellow	-

Table S6. Evaluation matrix of the river water at Kh_Trib_2 (WK Khentii Reference); Water body (WB)–Group of rhitral tributaries with natural background conditions in the Khentii Mts. (sub-basin 2 to 5, e.g., Bayangol-I, Sugnugr Gol, Tunkhelin, Ulgii Gol) orographically right of the Kharaa River main channel; *Water quality monitoring station: Sugnugr (Station ID: Sel_Kh03_009) Table 1.*

Quality Component	**Indicators**	**Range** ***(incl. Arithm. Mean of Physico-Chemical Quality Parameters)***	**Assessment** ***(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "moderate" to "very good"	"not at risk"	green	-
	Fish	Ecological status based on multimetric assessment: "very good" to "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	1–2	"not at risk"	green	-
Physico-chemical quality	EC (*n* = 45) Arithm. Mean Chloride (*n* = 35) Arithm. Mean Bor (*n* = 16) Arithm. Mean	22–61 µS/cm 44 µS/cm 1–3.54 mg/L Cl 1.30 mg/L Cl 5–33 µg/L B 9.5 µg/L B	"not at risk"	green green green	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (*n* = 15) Mean	0.7–3.2 µg/L 1.72 µg/L	"not at risk"	green	-

Table S7. Evaluation matrix of the river water at Kh_Trib_3 (WK Khentii modified); WB-Group of rhitral, anthropogenic influenced tributaries from the Khentii Mts. orographically left (Gatsuurt Gol, sub-basin 4) and right (Shivertin Gol, sub-basin 8) of Kharaa River main channel.

Quality Component	Indicators	Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)	Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)*	Colour	Comment
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
	Fish	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	2	"not at risk"	green	-
Physico-chemical quality	EC (*n* = 16) Arithm. Mean Chloride (*n* = 12) Arithm. Mean Bor (*n* = 10) Arithm. Mean	137–350 µS/cm 260 µS/cm 1–11.3 mg/L Cl 3.4 mg/L Cl 5–66 µg/L B 20.56 µg/L B	"possibly at risk" *5.9* *2.6* *2.2*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (*n* = 13) Arithm. Mean	Arsenic: Arsenic: 11.2-fold concentration of natural background 9.7–37.8 µg/L 19.23 µg/L	"at risk" *11.2*	red	-

Table S8. Evaluation matrix of the river water at Kh_Trib_4 (Boroo Gol).

Quality Component	**Indicators**	**Range *(incl. Arithm. Mean of Physico-Chemical Quality Parameters)***	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: "moderate"	"possibly at risk"	yellow	-
	Fish	Ecological status based on multimetric assessment: "good"	"not at risk"	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	3	"possibly at risk"	yellow	-
Physico-chemical quality	EC (*n* = 15) Arithm. Mean Chloride (*n* = 13) Arithm. Mean Bor (*n* = 8) Arithm. Mean	271–565 µS/cm 440 µS/cm 9.69–18.4 mg/L 14.2 mg/L 22–110 µg/L 50.1 µg/L	"at risk" *10.0* *10.9* *5.3*	red red red	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (*n* = 12) Arithm. Mean	Arsenic: 3.7-fold concentration of natural background 1.2–10.3 µg/L As 6.34 µg/L As	"at risk" *3.7*	red	-

Table S9. Evaluation matrix of the river water at Kh_Trib_5; (Zagdalin Gol upstream of Zagdalin infiltration).

Quality Component	**Indicators**	**Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)**	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: No data	no data	grey	-
	Fish	Ecological status based on multimetric assessment: No data	no data	grey	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	-	no data	grey	-
Physico-chemical quality	EC (n = 3) Arithm. Mean Chloride (n = 3) Arithm. Mean Bor (n = 2) Arithm. Mean	215–250 µS/cm 230 µS/cm 1.48–4.14 mg/L Cl 2.6 mg/L Cl 25–26 µg/L B 25.5 µg/L B	"not at risk" *5.2* *2.0* *2.7*	green green green	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (n = 2) Arithm. Mean	Arsenic 1.8–2.5 µg/L 2.15 µg/L	"possibly at risk" *1.3*	yellow	-

Table S10. Evaluation matrix of the river water at Kh_Trib_6; (Zagdalin Gol downstream of Zagdalin infiltration).

Quality Component	**Indicators**	**Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameter*)**	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: “moderate” to “unsatisfied”	“at risk”	red	-
	Fish	Ecological status based on multimetric assessment: “good”	“not at risk“	green	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	4	“possibly at risk”	yellow	-
Physico-chemical quality	EC (*n* = 29) Arithm. Mean Chloride (*n* = 14) Arithm. Mean Bor (*n* = 9) Arithm. Mean	186–602 µS/cm 471 µS/cm 4.65–27,4 mg/L Cl 12.5 mg/L Cl 25–128 µg/L B 65.8 µg/L B	“at risk” *10.7* *9.6* *6.9*	red red red	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (*n* = 10) Arithm. Mean	Arsenic: 0.5–4.7 µg/L As 2.71 µg/L As	“possibly at risk” *1.6*	yellow	-

Table S11. Evaluation matrix of the river water at Kh_Trib_7 (Bayangol); Bayangol.

Quality Component	**Indicators**	**Range (*incl. Arithm. Mean of Physico-Chemical Quality Parameters*)**	**Assessment *(n-Fold Exceedance of Natural Background Physico-Chemical Quality Parameters)***	**Colour**	**Comment**
Biological Quality	Macroinvertebrates	Ecological status based on multimetric assessment: No data	no data	grey	-
	Fish	Ecological status based on multimetric assessment: No data	no data	grey	-
Hydromorphology	Morphological structure under consideration of riparian vegetation	No data	no data	grey	-
Physico-chemical quality	EC (*n* = 29) Arithm. Mean Chloride (*n* = 14) Arithm. Mean Bor (*n* = 9) Arithm. Mean	141–293 µS/cm 204 µS/cm 0.89–5.73 mg/L Cl 3.2 mg/L Cl 5–33.2 µg/L B 17.1 µg/L B	"possibly at risk" *4.6* *2.5* *1.8*	yellow yellow yellow	-
Specific non-synthetic priority substances	Heavy metals (e.g., As) Arsenic (*n* = 4) Arithm. Mean	Arsenic: 25-fold concentration of natural background 1.1–150 µg/L 43 µg/L As	"At risk" *25*	red	-

S.4. Nexus of Deficits, Causes, Countermeasures and Stressor Complexes in KRB

Table S12. Nexus of Deficits, Causes and Countermeasures in KRB.

Parameter	Deficit	Cause	Measure
		Hydromorphology	
Hydromorphology	Riverbank instability and river bank erosion [10] Riparian vegetation (decreasing biomass, soil compaction by (livestock) trampling, decline of wooden vegetation *etc*.).	Intensive livestock farming in the floodplain (overgrazing), timber logging.	Floodplain recovery Waste water treatment and recycling systems with combined timber production (e.g., decentralised zero-outflow willow-based wastewater treatment systems [11].
Erosion	Flowing water: decrease in the benthic primary production, permanent function of the hyporheic zone affected, impairments of the hydraulic exchange, loss of habitat function and the self-purification potential concerning nutrient retention and processing (fine-grained sediments may reduce the vertical extend, but also increase reactive surface).	Riverbank erosion generates 74.5% of the suspended sediment load, whereas surface erosion contributes 21.7% and gully erosion only 3.8% [10]. Erosion due to agricultural land use is of minor importance. Fine-grained sediment emission by settlements is likely to occur (e.g., deterioration of water ecology downstream of Zuunkharaa and Baruunkharaa) [12].	Comprehensive grazing management Protective area concepts to support the recolonization of natural river bank vegetation Protection of all river banks of the Kharaa middle reaches.

Table S12. *Cont.*

Parameter	Deficit	Cause	Measure
Water Quality			
Nutrients	Increasing nutrient loads, high relevance of phosphorus Lower relevance of nitrogen, NOTE: no data on primary production was available, up to now only marginal signals for eutrophication (e.g., green growths of phytobenthos, increase of macrophytes, first records of increased benthic algae growth (observed at Kh_5 and Kh_8, Table 1), seasonal biological clogging due to benthic algae is possible (Kh_5, Table 1). Risk of eutrophication in river sections with low slope and low shearing forces: partially low slope due to geomorphological characteristics quite low and fine-grained sediments (possibly enriched with phosphorous) may clog the river bed.	Diffuse emissions of nutrients from rural settlements and ger- districts without waste water treatment. Emission peaks caused by the release of untreated waste water due to a malfunction of the WWTP Darkhan and to a minor extent from the WWTP Baruunkharaa, caused harmful events. Direct nutrient emission due to livestock farming/grazing (increasing also in urban areas) [13].	Construction of a new WWTP in Darkhan with separate treatment of industrial sewage and municipal sewage; Modular Concept for Municipal Water and Waste Management [11] Decentralised waste water treatment in *ger* districts *etc*., Repair of sewers, Implementation of an agricultural nutrient management plan. Recycling concept, reuse of nutrients from urban areas in agriculture [11,14] Implementation of inland watering points for livestock with an appropriate distance to the river.
Heavy metals	Increasing concentrations of As, Al, Pb, Fe, and Mn. Detection of heavy metals (particularly in fish) and concerns of accumulation within the food chain.	Increase of the geogenic basic load in particular due to gold mining and the ash deposit basin of the thermal power plant in Darkhan [13,15]	Self-surveillance, precautionary measures, supplementary sealing of tailing basins (e.g., ash basins from the Thermal Power Plant in Darkhan and tailing pond at Boroo gold mine), installation and operation of safety wells and emergency plans in case of urgent groundwater pollution.

Table S12. *Cont.*

Parameter	Deficit	Cause	Measure
Oxygen as indirect indicator for eutrophication	Increased oxygen saturation in the middle reaches and to a lesser extent at the downstream reaches of the Kharaa River, especially under low flow situations where there is an indication of an increase in photosynthesis and primary production and therefore for enhanced eutrophication risk.	Diffuse emissions of nutrients [13]	Protective area concept coupled with the implementation of inland watering points for livestock with an appropriate distance from the river.
Chloride and Boron as pollution indicator	Significantly increasing concentrations in the middle and downstream reaches with long-term increases also recognisable in the groundwater well gallery of Darkhan [16]	Diffuse emissions of untreated waste water and cleaning agents [17].	Decentralised waste water treatment in *ger* districts *etc.*, Sealing of sewers.
Organic pollution	No monitoring data (No hygienic aspect in MoMo-Monitoring), but reports of the environmental agency Darkhan state that downstream, the population suffers frequently from gastrointestinal illnesses.	Direct emission of faeces from livestock at watering places in the Kharaa River. Inappropriately treated municipal waste water (low safety of wastewater disposal of Darkhan's WWTP).	Implementation of inland watering points for livestock with an appropriate distance from the river. Increasing safety of wastewater disposal by construction of a new WWTP in Darkhan.
Biology			
Diatoms	Significantly increasing abundance and species richness in the muddy habitats and high percentage of motile diatom abundance in the middle and downstream reaches. Highest motile abundance in the Boroo River (personal communication Bukhchuluun & Soninkhishig 2014)	Riverbank erosion and sediment deposition were discussed to be the main causal factor responsible (pers. comm. Bukhchuluun & Soninkhishig 2014)	Riverbank protection along the Kharaa River and its tributaries. Grazing management.

Table S12. *Cont.*

Parameter	Deficit	Cause	Measure
Macroinvertebrates	The loss of macroinvertebrate biodiversity and increased abundance of fine sediment colonizers [13,18,19].	Physical clogging of the hyporheic zone [13,20,21].	Protective area concept coupled with the implementation of inland watering points for livestock at an appropriate distance from the river, grazing management.
Fish	Decrease in biodiversity, Alteration of species composition (e.g., loss of *H. taimen* in the river basin) and age patterns Incorporation of heavy metals incorporation in biota (especially in the middle and lower catchment in the large bodied species).	Unregulated and illegal recreational fishing Habitat loss [22,23]	Control and management of recreational fishing, awareness raising.

Table S13. Identified stressor complexes and related main issues in the KRB.

Stressor Complex	Issues	Affected Water Body
People (urban centres)	Inefficient water supply due to severe leakages in the central water supply system	Kh_Main_4
	Inefficient water treatment due to very poorly maintained treatment facilities	Kh_Main_4 [11,24]
	Extremely high per capita water demand in central urban areas due to a lack of public awareness for water scarce resource, lack of metering and missing incentives to save water (e.g., pricing)	Kh_Main_4 [11]
People (urban *ger* districts)	No connection to the central water supply or waste disposal system of the city centres	Kh_Main_4 [25]
	Socio-economic cut-off due to high distances, lack of infrastructure to the city centre and limited public services, facilities or employment options	Kh_Main_4
	Water supply infrastructure (water kiosks) is not efficient enough to provide all inhabitants with sufficient drinking water to meet basic human needs	Kh_Main_4
	No safe sanitation or waste management	Kh_Main_4
	The proximity of latrines to shallow private wells bear high health risks for inhabitants due to potential microbiological contamination	Kh_Main_4
	No flood protection for areas located in the floodplain	Kh_Main_4

Table S13. *Cont.*

Stressor Complex	Issues	Affected Water Body
People (rural)	Lack of drinking water supply or waste water disposal facilities	Kh_Main_1; Kh_Main_2: Kh_Main_3; Kh_Trib_1; Kh_Trib_4; Kh_Trib_5/6
	No flood protection for areas in the floodplains	Kh_Main_3; Kh_Trib_1; Kh_Trib_4
Water Resources	Hydrological recharge zones in the Khentii Mountains are altered/disturbed by burnt forest cover	Kh_Main_1; Kh_Trib_1; Kh_Trib_2; Kh_Trib_5/6
	Rising nutrient levels and eutrophication risk due to urban waste water discharge and agricultural activities	Kh_Main_4
	Contamination of surface waters and aquatic organisms with heavy metals	Kh_Main_4; Kh_Trib_4
	Extremely high and non-transparent water consumption at mining sites	Kh_Trib_4; Kh_Trib_5/6; Kh_Trib_7
	High contamination risk due to inappropriate processing and storage of waste and waste water from industries and mining	Kh_Main_4; Kh_Trib_4; Kh_Trib_5/6; Kh_Trib_7

Table S13. *Cont.*

Stressor Complex	**Issues**	**Affected Water Body**
Environment	Destruction of riparian vegetation and the river bank due to livestock grazing, which enhances erosion and thus fine-grained sediment and nutrient input to rivers	Kh_Main_2; Kh_Main_3
	High fine-sediment loads are destroying the habitat function of the river bed and thus altering the aquatic community (fish and macroinvertebrates)	Kh_Main_1; Kh_Main_2; Kh_Trib_2; Kh_Trib_5/6
	Decreased biodiversity and number of individual fish due to intensive recreational and illegal fishing activities	Kh_Main_2; Kh_Main_4; Kh_Trib_1
Industries & Mining	Insufficient waste water treatment (mining), high water consumption	Kh_Main_4; Kh_Trib_4 [26,27]
	Uncontrolled discharge of industrial waste water to the CWWTP	Kh_Main_4 [26]
Agriculture	Obsolete, inefficient or total lack of irrigation systems that limit agricultural productivity while utilising lareg volumes of water	Kh_Trib_1
	A absence of inland watering points for livestock farming, which promotes the concentration of animals at small regions and restricts the development of new grazing grounds	Kh_Main_2; Kh_Trib_1; Kh_Trib_5/6; Kh_Trib_7
Water Quality and Quantity Monitoring	The existing monitoring network is not comprehensive enough	Especially Kh_Trib_7
	Equipment used for measuring stations is often insufficient	All Water Bodies
	Current monitoring activities are partly relying on foreign projects with limited project durations (e.g., IWRM MoMo-Project) and thus are not sustainable for future data requirements	All Water Bodies

S.5. Implementation of Management Recommendations

S.5.1. Upper Kharaa (Kh_Main_1)

The development goal for the upper Kharaa River will be to protect the vital forest cover and regenerate the burnt areas to prevent surface erosion and safeguard the soils for further degradation (Table S14).

Table S14. Recommended implementation measures for water body Kh_Main_1.

Upper Kharaa (Kh_Main_1)	
Deficit Parameter	**Planned Measures**
Water Resources	
Forest fires	Establishment of controlled forest protection areas to prevent anthropogenic deforestation for timber production and prevent natural forest fires by early emergency
	Reforestation measures in burnt forest areas
	Forest management in the tributaries
Water and Environment	
Elevated fine grained sediment loads	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
	Forest management and protection against natural and anthropogenic induced forest fires in the upstream region
Fish	Decrease the fine-grained sediment loads due to surface erosion in burnt areas
	Educating the population about the risks of consuming contaminated fish tissues
Water quality parameters	Establishment of a decentralised waste water treatment concept in the upstream settlement of Batsumber (Mandalin Gol)
Heavy metals	Regulations for middle catchment mining site

S.5.2. Middle Kharaa (Kh_Main_2)

In the upper part of this river reach, Tunkhel, has the only significant anthropogenic influence and thus needs a more sophisticated and sustainable urban water management system to minimise its impact and improve the hygienic situation for its inhabitants. Furthermore, it might be possible to reduce the high sediment loads received from upstream, by trapping the transported sand (sand traps: small settlement pools without water current).

Further downstream anthropogenic pressures increase. In order to stop additional destruction of the river bank structure and vegetation by extensive livestock grazing, sustainable grazing strategies, including inland watering points and safe river passes for animals should be implemented. To protect the fish stocks it is necessary to increase awareness by educating recreational fishers and strictly controlling illegal fishing by enforcing Mongolian fishing legislation (see Table S15).

Table S15. Recommended implementation measures for the management unit in the middle Kharaa River basin.

Middle Kharaa (Kh_Main_2)	
Deficit Parameter	**Planned Measures**
Water and People (Urban Center)	
Drinking water supply	Establishment of water resource protection zones surrounding the drinking of well water in Zuunkharaa
	Establishment of a constant drinking water quality monitoring regime to detect possible contaminations as early as possible
Water consumption	Installation of water meters at each household
	Reduction of leakages in the water supply pipelines
Waste water treatment efficiency	Reducing the oxygenation in the sludge activation
	Improvement of the communications among the operators and the cooperation of their activities
Water and People (Urban Ger Districts)	
Hygiene and sanitation	Construction of 86 "Comfort Islands" with an attraction radius of *ca*.250 m and a capacity for 140 inhabitants
	Constant monitoring or restriction of shallow private wells in close proximity to latrines
	Education and capacity building concerning hygiene and water- borne/related diseases
Water and People (rural)	
Lacking supply of safe drinking water	Research on possible drinking water supply sources upstream of Tunkhel
	Establishment of water resource protection zones around the located drinking water sources upstream of Tunkhel
	Installation of sufficient drinking water extraction wells in the protection zone
	Implementation of an adjusted water supply system
Lacking waste water management	Development of a decentralized waste water management solution (willow-based waste water treatment plant to supplement natural timber resources)
	Implementation of a sewer network to connect the households to the waste water treatment plant
Water Resources	
Slightly elevated sediment loads	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
Slightly elevated sediment loads	Forest management and protection against natural and anthropogenic induced forest fires in the upstream region
Water and Environment	
Hydromorphology	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local livestock farmers

Table S15. *Cont.*

Middle Kharaa (Kh_Main_2)	
Deficit Parameter	**Planned Measures**
Macroinvertebrates	Reducing the fine-grained sediment input to prevent habitat destruction by the clogging of the river bed
	Improvement of the hydrological status
Fish	Control recreational fishing activities (*i.e.*, overfishing)
	Raise public awareness and knowledge regarding ecological issues of excess fishing to improve the compliance of fishing regulations
Water quality parameters	Establishment of a decentralised waste water treatment concept in the settlement of Tunkhel
Nutrient levels	Limit livestock entering the river with the construction of special crossing areas
Heavy metals	Regulations for upstream mining site
	Educating the population about the risks of consuming contaminated fish tissues
Water and Agriculture	
Livestock farming	Restricting livestock numbers according to the grazing capacity of the region
	Establishment of an inland network of livestock watering points to increase the steppe's capacity by enable the development of formerly abandoned areas
	Education and build capacity concerning sustainable livestock grazing among herders in order to raise awareness of sustainable practices
Crop farming	Development and establishment of efficient irrigation systems
	Establishment of a sustainable nutrient cycle

S.5.3. Middle /Lower Kharaa (Kh_Main_3)

Development goals for the river stretches at Kh_Main_3 include the protection and restoration of the degraded river banks and their adjoining environment by establishing sustainable livestock farming management strategies that are accepted and implemented by local herders. The fine-grained sediment load needs to be reduced to natural levels by installing sand traps along the river course. The river surface water should be free from specific pollution and the overall water quality should be improved. To do so, it is important to identify the actual entrance pathways and sources with specific monitoring. As the settlement centres are expected to be the most important sources for pollution, the wastewater disposal systems need to be analysed and equipped with appropriate facilities to ensure an efficient and ecologically friendly management (see Table S16).

Table S16. Recommended implementation measures for the management of the Middle/Lower Kharaa River basin.

Middle /Lower Kharaa (Kh_Main_3)	
Deficit Parameter	**Planned Measures**
Water and People (Urban Center)	
Drinking water supply	Establishment of water resource protection zones surrounding the drinking water wells of the **Salhit** and **Baruunkharaa**
	Establishment of constant drinking water quality monitoring in **Salhit** and **Baruunkharaa** to detect possible contaminations as early as possible
Water consumption	Installation of water meters at each household (**Salhit** and **Baruunkharaa**)
	Reduction of leakages in the water supply pipelines (**Salhit** and **Baruunkharaa**)
Waste water treatment efficiency	Replacement of the return sludge pump at the secondary treatment in **Salhit** as a short term measure
	Construction of a willow-based WWTP as a long term measure (**Salhit**)
	Replacement of the old dysfunctional plant in **Baruunkharaa** by an adjusted decentralise solution
Water and People (Urban Ger Districts)	
Hygiene and sanitation	Construction of 7 “Comfort Islands” with an attraction radius of *ca*. 250 m and a capacity for 140 inhabitants in **Salhit** and **Baruunkharaa**
	Constant monitoring or restriction of shallow private wells in close proximity to latrines
	Education and capacity building concerning hygiene and water- borne/related diseases
Water and Environment	
Hydromorphology	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local herders
Macroinvertebrates	Reducing the fine-grained sediment input to prevent habitat destruction by the clogging of the river bed
	Improvement of the hydrological status
Fish	Control recreational fishing activities (*i.e.*, overfishing)
	Raise public awareness and knowledge regarding ecological issues of excess fishing to aid in the compliance of fishing regulations
Water quality parameters	Sealing of sewer pipelines and dump sites for industrial deposits
	Establishment of a sufficient number of ‘Comfort Islands’ especially in the ger areas close to the floodplain
Nutrient levels	Limit livestock entering the river with the construction of special crossing areas
	Sealing of the sewer system
	Decrease of nutrient content of the discharged waste water

Table S16. *Cont.*

Middle /Lower Kharaa (Kh_Main_3)	
Deficit Parameter	**Planned Measures**
Heavy metals	Regulations for upstream mining site ("Bayangol" and "Zagdaling Gol")
	Educating the population about the risks of consuming contaminated fish tissues
	Water and Agriculture
Crop farming	Assessment of nutrient cycling and irrigation efficiency at the rapeseed production sites (15 ha around **Baruunkharaa**)
livestock farming	Limiting of livestock numbers according to the grazing capacity of the region
	Establishment of an inland network of animal watering points to increase the steppe's capacity by enable the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable methods

S.5.1. Lower Kharaa (Kh_Main_4)

The most important development objective for this water body is a detailed monitoring program to eliminate persisting contamination sources in Khongor and all remaining residues in the river. The establishment of a sufficient number of "Comfort Islands" (public sanitation stations) in the ger areas of Khongor and Darkhan are of high importance to secure the provision of safe drinking water and sanitation for all inhabitants. The reduction of grazing pressure, in the surrounding environment and the direct reaches of the river would give the natural vegetation a chance to return. Additionally, smaller numbers of animals that would enter the river would result in a decrease of nutrient emissions. Further, a modernisation concerning the safety of the drinking water supply system and the efficiency of wastewater treatment and disposal in Khongor and Darkhan is important to improve both the hygiene and sanitation conditions for the human population, but also the habitat functions for the local macroinvertebrate and fish communities (see Table S17).

Table S17. Recommended implementation measures for water body Kh_Main_4.

Lower Kharaa (Kh_Main_4)	
Deficit Parameter	**Planned Measures**
	Water and People (Urban Center)
Drinking water supply	Establishment of water resource protection zones surrounding the drinking water wells of **Khongor** & **Darkhan**
	Establishment of a constant drinking water quality monitoring scheme to detect possible contaminations as early as possible
Water consumption	Eventually introducing drinking water purification programs due to the high concentration of specific pollutants contaminating the water resources
	Installation of water meters at each household
	Reduction of leakages in the water supply pipelines

Table S17. *Cont.*

Lower Kharaa (Kh_Main_4)	
Deficit Parameter	**Planned Measures**
Waste water treatment efficiency	Repair of sludge discharge between primary and secondary treatment as a short term measure
	Construction of a willow-based WWTP as a long term measure
Waste water treatment efficiency	Repair of sludge discharge between primary and secondary treatment as a short term measure to ensure waste water treatment in **Darkhan**
	Construction of a willow-based WWTP as a long term measure in **Darkhan City**
Water and People (Urban Ger Districts)	
Hygiene and sanitation	Construction of 13 'Comfort Islands' with an attraction radius of *ca*. 250 m and a capacity for 140 inhabitants in **Khongor** and approximately 256 in **Darkhan City**
	Constant monitoring or restrictions for shallow private wells in close proximity to latrines
	Education and capacity building concerning hygiene and water- borne/related diseases
Water and Environment	
Hydromorphology	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local herders
Macroinvertebrates	Reducing the fine-grained sediment input to prevent habitat destruction by the clogging of the river bed
	Improvement of the hydrological status
Fish	Control recreational fishing activities (*i.e.*, overfishing)
	Raise public awareness and knowledge regarding ecological issues of excess fishing to improve compliance of fishing regulations
Water quality parameters	Sealing of sewer pipelines and dump sites for industrial deposits
	Establishment of a sufficient number of "Comfort Islands" especially in the ger areas close to the floodplain
Nutrient levels	Sealing of the sewer network and dump sites
	Improve agricultural nutrient management
Heavy metals	Sealing and observing the storage sites of all industrial waste especially at the thermal power plant and the local dump site
	Constant monitoring and inspection at contamination sources (illegal mining sites)
	Reduction of the concentrations in industrial waste water
	Educating the population about the risks of consuming contaminated fish tissues
Water and Industry	
Water consumption	Introduction of water pricing strategies to promote incentives for efficient water use
	Development and introduction of waste water reuse concepts for industrial processing
	Allocation of limited water use licenses
Waste water disposal	Incorporation of the polluter-pays principle in the water pricing system
	Establishment of legally prescribed external and internal quality management of the discharged waste water
	Legal prescription to install specific waste water treatment facilities at each industry

Table S17. *Cont.*

Lower Kharaa (Kh_Main_4)	
Deficit Parameter	**Planned Measures**
	Water and Agriculture
Livestock farming	Limitation of livestock numbers according to the grazing capacity of the region
	Establishment of an inland network of animal watering points to increase the steppe's capacity by enable the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable methods

S.5.5. Mandalin Gol (Kh_Trib_1)

The development goals for this upstream water body include the conservation and rehabilitation of the fish stocks by educating the local residents about the consequences of overfishing and simultaneously strictly regulating and controlling illegal recreational fishing gears and activities during protected spawning periods. The surrounding environment can be protected by the prevention of forest fires (observed conservation areas; reforestation) and sustainably managed livestock farming (buffer and watering zones). These measures will also help to reduce the fine-grained sediment and nutrient loads and thus the habitat functions of this river section. Further, the urban water supply and disposal system of Batsumber has to be modified with adopted, decentralised solutions that are able to provide an efficient use of water resources and safe hygienic and sanitary conditions for the inhabitants and similarly release the ecological pressure by reducing the emission of pollutants to the surface and groundwater resources (see Table S18).

Table S18. Recommended implementation measures for the water body Kh_Trib_1.

Mandalin Gol (Kh_Trib_1)	
Deficit Parameter	**Planned Measures**
	Water and People (rural)
Lacking supply of safe drinking water	Research on possible drinking water supply sources upstream of Batsumber
	Establishment of water resource protection zones around the local drinking water sources upstream of Batsumber
	Installation of sufficient drinking water extraction wells in the protection zone
	Implementation of an adjusted water supply system
Lacking waste water management	Development of a decentralised waste water management solution (willow-based waste water treatment plant to supplement natural timber resources)
	Implementation of a sewer network to connect t households to the waste water treatment plant
	Water Resources
Forest fires	Establishment of controlled forest protection areas to prevent anthropogenic deforestation for timber production and prevent natural forest fires via early emergency responses
	Reforestation measures in burnt forest areas

Table S18. *Cont.*

Mandalin Gol (Kh_Trib_1)	
Deficit Parameter	**Planned Measures**
Water and Environment	
Hydromorphology	Re-vegetation of the degraded riparian zone
	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local herders
Macroinvertebrates	Reducing fine-grained sediment input to prevent habitat destruction by clogging of the river bed
	Improvement of the hydrological status
Fish	Control recreational fishing activities (*i.e.*, overfishing)
	Raise public awareness and knowledge regarding ecological issues of excess fishing to improve compliance of fishing regulations
	Improvement of the hydrological status
High sediment loads	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
	Establishment of grazing strategies that consider the steppe's capacity
	Protection and rehabilitation of burnt forest areas
	Development and establishment of crop farming strategies that prevent exposed top soil
Water quality parameters	Sealing of sewer pipelines and dump sites for industrial deposits
	Establishment of a sufficient number of 'Comfort Islands' especially in the ger areas close to the floodplain
Nutrient levels	Limiting livestock from entering the river through the construction of special crossing areas
	Surveillance of the nutrient management in agriculture
Heavy metals	Constant monitoring and inspection of the contamination source (upstream mining sites)
Water and Agriculture	
Livestock farming	Limiting livestock numbers according to the grazing capacity of the region
	Establishment of an inland network of animal watering points to increase the steppe's capacity with the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable farming techniques

S.5.6. Khentii Tributaries with natural background conditions (Kh_Trib_2)

In this tributary forest fires are threatening the natural conditions. Therefore, the establishment of observed conservation areas may help to protect the forest cover and its important ecosystem functions. In addition, development goals for this upstream water body also include the conservation and rehabilitation of the fish stocks by educating the local residents about the consequences of overfishing and simultaneously strictly regulating and controlling illegal recreational fishing gears and activities during protected spawning periods. All measures that are recommended to maintain the overall 'good' ecological status of this management unit and improve the deficits for the fish community status are presented in Table S19.

Table S19. Recommended implementation measures for the water body (Kh_Trib_2).

Khentii Tributaries with natural background conditions (Kh_Trib_2)	
Deficit Parameter	**Planned Measures**
Water Resources	
Forest fires	Establish controlled forest protection areas to prevent anthropogenic deforestation for timber production and prevent natural forest fires by early emergency (**Bayangol1** & **Tunkhelin Gol**)
	Reforestation measures in burnt forest areas (**Bayangol1** & **Tunkhelin Gol**)
Water and Environment	
Fish	Control recreational fishing activities (*i.e.*, overfishing)
	Raise public awareness and knowledge regarding ecological issues of excess fishing to aid in the compliance of fishing regulations

S.5.7. Khentii Tributaries with anthropogenic impacts (Kh_Trib_3)

Both livestock farming and forest fires have currently only minor impacts on the monitored water quality parameters in this tributary. To maintain this situation it is important to prevent an intensification of the influencing pressures. The establishment of observed conservation areas along the river course may help to protect the vegetation cover and its important ecosystem functions. In addition, development goals for this upstream water body include the conservation and rehabilitation of the fish stocks by educating the local residents about the consequences of overfishing and simultaneously strictly regulating and controlling illegal recreational fishing gears and activities during protected spawning periods (see Table S20).

Table S20. Recommended implementation measures for the water body Kh_Trib_3.

Khentii Tributaries with anthropogenic impacts (Kh_Trib_3)	
Deficit Parameter	**Planned Measures**
Water Resources	
Forest fires	Establish controlled forest protection areas to prevent anthropogenic deforestation for timber production and prevent natural forest fires by early emergency
	Reforestation measures in burnt forest areas
Water and Environment	
Fish	Raise public awareness and knowledge regarding ecological issues of excess fishing to aid in the compliance of fishing regulations
	Reducing fine-grained sediment input to prevent spawning habitat destruction by clogging of the river bed
	Improvement of the hydrological status
Water and Agriculture	
Livestock farming	Establishment of an inland network of animal watering points to increase the steppe's capacity with the development of formerly abandoned areas
	Develop and implement sustainable grazing strategies that limit livestock numbers
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable farming techniques

S.5.8. Boroo Gol (Kh_Trib_4)

For the water body Kh_Trib_4 (Boroo Gol) the return of natural water flow regimes, the improvement of river water quality (nutrients, specific pollutants) and normal sediment loads are the main development goals. The most important measure will be a strict regulation of mining activities concerning both water consumption and the disposal of processing waste water. Also sustainable livestock farming strategies, including buffer zones along the river course, will contribute to the reduction of nutrient and sediment emissions (see Table S21).

Table S21. Recommended implementation measures for the management unit encompassing Boroo Gol.

Boroo Gol (Kh_Trib_4)	
Deficit Parameter	**Planned Measures**
	Water and People (rural)
Lacking supply of safe drinking water	Research on possible drinking water supply sources upstream of Bornuur
	Establishment of water resource protection zones around the located drinking water sources upstream of Bornuur
	Installation of sufficient drinking water extraction wells in the protection zone
	Implementation of an adjusted water supply system
Lacking waste water management	Development of a decentralised waste water management solution (willow-based waste water treatment plant to supplement natural timber resources)
	Implementation of a sewer network to connect households to the WWTP
	Water Resources
Fluctuating water levels	Enforcement of regulations concerning the water consumption at mine sites
	Water and Environment
Hydromorphology	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local livestock herders
Macroinvertebrates	Reducing the fine-grained sediment input to prevent habitat destruction with the clogging of the river bed
	Improvement of the hydrological status
High sediment loads	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
	Revegetation of the cleared land remaining post mining operations in order to minimise sediment input via surface erosion
Water quality parameters	Sealing of sewer pipelines and dump sites for industrial deposits
	Establishment of a sufficient number of ‘Comfort Islands’ especially in the ger areas close to the floodplain
Nutrient levels	Limiting livestock from entering the river with the construction of special crossing areas
	Surveillance of nutrient management in agriculture regions
Heavy metals	Constant monitoring and inspection of contamination sources (upstream mining sites)
	Water and Agriculture

Table S21. *Cont.*

Boroo Gol (Kh_Trib_4)	
Deficit Parameter	**Planned Measures**
Livestock farming	Identify limits for livestock numbers according to the grazing capacity of the region
	Establish an inland network of animal watering points to increase the steppe's capacity by enabling the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable farming techniques
Water and Mining	
High water consumption	Allocation of limited water use licenses
	Regulation and control of water consumption and waste water discharge for the Boroo Goldmine and the smaller mining sites upstream
	Introduction of adequate water fees that promote a responsible use for economic reasons
	Development and introduction of waste water reuse strategies at the Boroo Goldmine and the smaller mining sites upstream
Water discharge	Establishment and enforcement of strict regulations concerning the minimum quality of discharged waste water
	Implementation of waste water treatment facilities at the Boroo Goldmine and the upstream mining site centre
	Introduction of filter systems that retain the washed sand
	Constant monitoring of the quality of the discharged water to immediately identify and stop contaminations

S.5.9. Zagdalin Gol (Kh_Trib_5 & Kh_Trib_6)

The most important development goals for Zagdalin Gol include the rehabilitation of the degraded river substrate, to help facilitate a return to natural water flows as well as implement conservation zones that protect the vital forest cover and assist with the reforestation process. The elevated fine-grained sediment loads that are responsible for the habitat alterations are mostly caused by river bank erosion and the discharge of processing water from the local gold mines. Therefore, it will be most important to reduce the grazing pressure and control the water quality of discharged wastewater from the gold mines (see Table S22).

Table S22. Recommended implementation measures for the management unit Zagdalin Gol.

Zagdalin Gol (Kh__Trib_5 & Kh_Trib_6)	
Deficit Parameter	**Planned Measures**
Water and People (rural)	
Lacking supply of safe drinking water	Research on possible drinking water supply sources upstream of Jargalant
	Establishment of water resource protection zones around the located drinking water sources upstream of Jargalant
	Installation of sufficient drinking water extraction wells in the protection zone
	Implementation of an adjusted water supply system

Table S22. *Cont.*

Zagdalin Gol (Kh__Trib_5 & Kh_Trib_6)	
Deficit Parameter	**Planned Measures**
Lacking waste water management	Development of a decentralised waste water management solution (e.g., willow-based waste water treatment plant to supplement natural timber resources)
	Implementation of a sewer network to connect households to the WWTP
Water Resources	
Fluctuating water levels	Enforce the regulations concerning water consumptions on mining sites
Water and Environment	
Hydromorphology	Re-establishing the degraded riparian vegetation
	Establishment of rehabilitation and protection zones for the riparian vegetation in close cooperation with local livestock herders
Macroinvertebrates	Reducing the fine-grained sediment input to prevent habitat destruction through the clogging of the river bed
Fish	Raise public awareness and knowledge regarding ecological issues of excess fishing to aid in the compliance of fishing regulations
	Improvement of the hydrological status
	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
High sediment loads	Re-vegetation of the cleared land remaining post mining operations in order to minimise sediment input via surface erosion
Water quality parameters	Establishment of a sufficient number of ‘Comfort Islands’ especially in ger settlements close to the floodplain
	Limiting livestock from entering the river with the construction of special crossing areas
Nutrient levels	Improved waste water management with a decentralised solutions for Jargalant
	Surveillance of nutrient applications in local agriculture
	Sealing of sewer pipelines
Heavy metals	Constant monitoring and inspection of the contamination sources (upstream mining sites)
Water and Agriculture	
Livestock farming	Placing limitations on livestock numbers according to the grazing capacity of the region
	Establishment of an inland network of animal watering points to increase the steppe’s capacity with the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable farming techniques
Crop farming	Development and establishment of efficient irrigation systems
	Establishment of a sustainable nutrient cycle
Water and Mining	

Table S22. *Cont.*

Zagdalin Gol (Kh__Trib_5 & Kh_Trib_6)	
Deficit Parameter	**Planned Measures**
High water consumption	Allocation of limited water use licenses
	Regulation and control of water consumption and waste water discharge for the small mining sites upstream
	Introduction of adequate water fees that promote responsible use for economic reasons
	Development and introduction of waste water reuse strategies at the small mining sites upstream
	Establishment and enforcement of strict regulations concerning the minimum quality of discharged waste water
Water discharge	Implementation of waste water treatment facilities at upstream mining sites
	Introduction of filter systems that retain the washed sand
	Constant monitoring of the quality of the discharged water to immediately identify and prevent contaminations

S.5.10. Bayangol (Kh_Trib_7)

Missing data is the main issue for this tributary. Incorporating it into the monitoring network is therefore the most important objective. In this way the full impact of the previously identified pressure sources can be assessed in detailed. Overall, mining as well as agricultural-use in this area needs to be regulated to avoid further hydrological degradation (see Table S23).

Table S23. Recommended implementation measures for Bayangol (Kh_Trib_7).

Bayangol (Kh_Trib_7)	
Deficit Parameter	**Planned Measures**
Water resources	
Fluctuating water levels	Enforcement of regulation concerning of the water consumptions at mining sites
Water and Environment	
Hydromorphology	Promoting the rehabilitation and protection zones for the riparian vegetation in close cooperation with local herders
High sediment loads	Installation of sand traps (low current pools) in the river course to settle and extract the surplus of suspended sediments in the water
Water quality parameters	Conduct investigations to determine if there are any additional sources of Boron other than the mining sites responsible for the high river concentration
Heavy metals	Constant monitoring and inspection of the contamination sources (upstream mining sites)
Water and Agriculture	
Livestock farming	Place limitations on the number of animals according to the grazing capacity of the region
	Establishment of an inland network of animal watering points to increase the steppe's capacity with the development of formerly abandoned areas
	Development and implementation of sustainable grazing strategies
	Education and capacity building concerning sustainable livestock farming among the herders in order to raise awareness of sustainable farming techniques

Table S23. *Cont.*

Bayangol (Kh_Trib_7)	
Deficit Parameter	**Planned Measures**
Water and Mining	
High water consumption	Allocation of limited water use licenses
	Regulation and control of water consumption and waste water discharge
	Introduction of adequate water fees that promote the responsible use of water for economic reasons
	Develop and introduce waste water reuse strategies
Water discharge	Establish and enforce stricter regulations concerning the minimum quality of discharged waste water
	Implement treatment facilities at the upstream mining site
	Introduce filter systems that retain the washed sand
	Conduce constant monitoring of the quality of the discharged water to immediately identify and stop contaminations
Water Quality and Quantity Monitoring	
Biological monitoring	Introduction of a comprehensive biological monitoring program of fish and macroinvertebrates to enable a detailed assessment of the ecological status of this management unit
Hydromorphological monitoring	Expand the hydromorphological inventory according to methodology applied in other management units (LaNUV 2012)
Water quality monitoring	Expand the existing monitoring to enable a comprehensive assessment of the nutrient levels within the management unit

S.6.Mongolian Summary

Mongolian Summary

Initial Characterization and Water Quality Assessment of Stream Landscapes in Northern Mongolia

Монгол орны хойд хэсгийн голын ландшафтын анхдагч тодорхойлолт, усны чанарын үнэлгээ

Jürgen Hofmann [1,*], Daniel Karthe [2], Ralf Ibisch [2], Michael Schäffer [2], Saulyegul Avlyush [3], Sonja Heldt [4] and Andrew Kaus [2]

[1] Department Ecohydrology, Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 310, D-12587 Berlin, Germany

[2] Department Aquatic Ecosystems Analysis and Management (ASAM), Helmholtz Centre for Environmental Research (UFZ), Brückstrasse 3a, D-39114 Magdeburg, Germany; E-Mails: daniel.karthe@ufz.de (D.K.); ralf.ibisch@ufz.de (R.I.); michael.schaeffer@ufz.de (M.S.); andrew.kaus@ufz.de (A.K.)

[3] Institute of Geography-Geoecology (Ecological Department), Mongolian Academy of Sciences; Baruun Selbe-15, Chingeltei District, 4th Khoroo, Ulaanbaatar 15170, Mongolia; E-Mail: saulegul_a@daad-alumni.de

[4] Department of Urban Water and Waste Management, University of Duisburg-Essen, Universitätsstr. 15, 45141 Essen, Germany; E-Mail: sonja.heldt@uni-due.de

Abstract/Хураангуй: Монгол орны хойд хэсэг дэх Хараа голын сав газрын ландшафт, байгалийн нөхцлийг гидрологи, гидроморфологи, уур амьсгал, усны физик-химийн шинж чанар, голын хагшаас, ёроолын сээрнуруугүйтэн болон загасны мониторинг судалгаанд үндэслэн анх удаа тодорхойлон гаргасан. Сав газрын хэмжээнд менежментийн арга хэмжээг зохион байгуулах хамгийн бага нэгжүүдийг тодорхойлох үүднээс абиотик, биотик хүчин зүйлүүдийн уялдаа холбоог харгалзан үзэж гадаргын усны “Дэд сангууд”-ын ангилалыг гаргасан. Усан орчны экологийн тааламжтай статуст хүрэх зорилтыг баримталж буй Европын Усны Тогтолцооны Удирдамж (2000.12.22-ны өдрийн 2000/60 тоот удирдамж)-ын дагуу авч үзвэл Хараа голын үндсэн гулдиралын дагуу 4 дэд сан, харин цутгал голуудын 7 дэд санг тодорхойлж болох байна. Усан орчны экосистемийн байгалийн төрхөөрөө байгаа нөхцөл буюу түүний онцлог шинж, тодорхойлолт зэрэгт тулгуурлан орчны үнэлгээ, нөхөн сэргээх стандартуудыг боловсруулах боломжтой болно. Хараа голын сав газрын усны нөөц, чанарыг харгалзан үзвэл Хэнтийн уулархаг мужаас эх авч урсах, голын эх орчимд экологийн статус “тааламжтай” гэж үнэлэгдэж байна. Энэхүү байгалийн төрхөөрөө байгаа нөхцөлтэй харьцуулан үзэж, эрсдлийн анхдагч үнэлгээг хийхэд голын дунд хэсэгт хэд хэдэн, голын адагт түүнээс олон тооны “халуун

цэгүүд”-ийг тодорхойлов. Ийнхүү нөлөөлөлд өртсөн усан сангуудын хувьд гадаргын усны химийн болон экологийн “тааламжтай” гэх статусаас давж хэдийнээ эрсдлийн түвшинд хүрсэн байна. Эдгээр үнэлгээний төгсгөлд нь шалтгаан-хариу үйлчлэлийн харилцан хамаарлын матрикс, нөлөөлөх хүчин зүйлсийг цогцоор нь харууллаа. Сав газрын менежментийн тогтвортой төлөвлөгөөг боловсруулахад дэмжлэг үзүүлэх үүднээс зайлшгүй авч хэрэгжүүлэх менежментийг арга хэмжээнүүдийг тусгасан болно. Байгалийн төрхөөрөө байгаа нөхцөл, түүний онцлог шинжид тулгуурлан үнэлэх арга аргачлал нь хүний үйл ажиллагааны нөлөөллийг үнэлэх шинжлэх ухааны дэвшилтэт үндэслэл болж өгнө.

Figures/Зураг

Зураг 1. Зурагт Сэлэнгийн сав газрын (457,000 км^2 ус хурах талбай бүхий СГСГ) ус зүйн сүлжээ болон Хараа голын сав газрын (14,900 км^2 ус хурах талбай бүхий ХГСГ) байршилыг үзүүлэв.

Зураг 2. Хараа голын сав газар дахь газар ашиглалтыг 2010 оны байдлаар харуулав. Хар өнгийн тоогоор дугаарласан дэд сав газруудад шим тэжээлийн бодисын ялгарлуулалт ба гидрологийн загварчлалыг хийв [13,28]. Газар тариалангийн талбайн ангилалд атаршсан газрын талбайг багтаасан болно. Байгаль нуурт цутгах Сэлэнгэ гол, түүний сав газар (ташуу шугамаар дүрсэлсэн талбай) болон Хараа голын сав газрын (бараан өнгөөр дүрсэлсэн талбай) бүдүүвч зургийг (баруун дээд хэсэгт) үзүүлэв.

Зураг 3. Хараа голын сав газар дахь усны чанарын байнгийн болон байнгийн бус хяналт шинжилгээ. Уул уурхайн болон бохирдолд өртсөн талбай, цэвэрлэх байгууламжийн байршилыг багтаав. Голуудын дэд сав газрыг тоогоор болон текстээр харуулав.

Зураг 4. Хараа голын сав газрыг 10 дэд сав газар (1-10 дугаартай) [13] хуваарилж, тэнд сонгон авсан хяналт шинжилгээний цэгүүдийн байршил, гадаргын усан сангуудын хамт харуулав.

Зураг 5. Хэнтийн уулархаг мужаас (Сөгнөгөр гол, нөлөөлөлд өртөөгүй цэг гэх) эх авч урсан Орхон голд цутгах хүртэлх Хараа голын уртын дагуух хүнцэлийн өөрчлөлт [мкг$^{-1}$ л$^{-1}$]-ийг 2011-2012 оны 05 сараас 09 сард хийсэн нийт 4 удаагийн (2011.05.21, 2011.09.06, 2012.05.18, 2012.09.09) хэмжилтийн үр дүнгээр харуулав. Судалгааны цэгүүдийн байршилыг дэд сангуудын кодоор илэрхийлэв (Хүснэгт 5, Зураг 4). Хүнцэлийн зөвшөөрөгдөх дээд хэмжээг Монгол улсад мөрдөгдөж буй хаягдал усны чанарын стандартад (MNS 4943: 2000, Усны чанар. Хаягдал ус. Техникийн ерөнхий шаардлага) заасан хэмжээгээр хөндлөн шугамаар дүрслэв (MoMo төслийн хяналт шинжилгээний мэдээ).

Зураг 6. Хараа голын Орхон голд цутгах орчим (Бүрэнтолгой, Kh_Main_4, Sel_Kh10_001) дахь хүнд металлын (As, Al, Fe, Mn, Cu, Zn, Cr) зөөвөрлөлтийн хэмжээ [кг$^{-1}$ өдөр$^{-1}$] болон бохирдолын индикаторууд (хлор, бор) -ыг 2011-2012 оны 05 сараас 09 сард хийсэн нийт 4 удаагийн (2011.05.21, 2011.09.06, 2012.05.18, 2012.09.09) хэмжилтийн үр дүнгээр харуулав. Судалгааны цэгийн байршлын дэлгэрэнгүй мэдээллийг Зураг 4, Хүснэгт 1 болон 5-аас харна уу (MoMo төслийн хяналт шинжилгээний мэдээ).

Зураг 7. Хэнтийн уулархаг мужаас (Сөгнөгөр гол, нөлөөлөлд өртөөгүй цэг, Kh_Trib_2) эх авч урсан Орхон голд цутгах хүртэлх (Kh_Main_4) Хараа голын уртын дагуух нийт азот (TN)-ын агууламжийг [мгр$^{-1}$ л$^{-1}$] 2007-2012 онд хийсэн хэмжилтээр харуулав. Судалгааны цэг бүрээс авсан усны дээжний тоог (n) мөн үзүүлэв. Судалгааны цэгийн байршлын дэлгэрэнгүй мэдээллийг Зураг 4, Хүснэгт 1 болон 5-аас харна уу (MoMo төслийн хяналт шинжилгээний мэдээ).

Зураг 8. Хараа голын Орхон голд цутгах орчим (Бүрэнтолгой, Kh_Main_4, Sel_Kh10_001) дахь орто-фосфатын нийлүүлэлт [тонн$^{-1}$ жил$^{-1}$]-ийг 2007-2012 оны хяналт шинжилгээний үр дүнгээр харуулав. Судалгааны цэгийн байршлын дэлгэрэнгүй мэдээллийг Зураг 4, Хүснэгт 1 болон 5-аас харна уу (MoMo төслийн хяналт шинжилгээний мэдээ).

Зураг 9. Хараа голын сав газар, түүний дэд сав газруудын химийн эрсдэлийн анхдагч үнэлгээ. Уг зургийг бусад хэвлэлийн мэдээнд тулгуурлан бэлтгэв [15,27,29–31].

Tables/Хүснэгт

Хүснэгт 1. Гидроморфологи, урсац, физик-химии, цахиурт замаг, макросээрнуруугүйтэн, загасны хэмжилтийн цэгүүд. Цэгүүдийн анхдагч код, ID (зүүн талаас 2 дугаар багана) дугаар нь хэд хэдэн мэдээллийг багтаана. Жишээлбэл: Sel_Kh10_001; Sel = Сэлэнгэ голын сав газар, Kh = Хараа голын сав газар, 10 = Хараа голын сав газарт багтах 10 дугаартай дэд сав газар [13], 001 = усан сан болон ус хэрэглээнээс хамаарах дэд сав газрууд.

Хүснэгт 2. Хараа голын сав газарт тархсан макросээрнуруугүйтэний бүлгэмдэлд тулгуурласан экологийн чанарын үнэлгээний шалгуур босго үзүүлэлтүүд.

Хүснэгт 3. Хараа голын сав газарт тархсан загасны зүйлийн бүрэлдэхүүнд тулгуурласан экологийн үнэлгээ.

Хүснэгт 4. Хараа голын сав газарт багтах голуудын төрөл, тэдгээрийн эко- болон дэд бүсүүдийг ХБНГУ-ын LAWA ангилалын [1,2] дагуу тодорхойлов.

Хүснэгт 5. Хараа голын сав газрын гадаргын усан сангууд, биоценозын бүсчлэл (Зураг 4). Баруун багана дахь “MONERIS дэд сав газрууд”-аар MONERIS загварчлалаар шим тэжээлийн бодисын ялгаруулалтыг тооцоход ашиглагдсан гидрологийн дэд сав газруудыг харуулав [13]. Berner [32]-ийн зохиосон биоценозын бүсчлэл, гидрографын зургийг ашиглав.

Хүснэгт 6. Дэд сав газруудын голын сүлжээний урт

Хүснэгт 7. Байгалийн төрхөөрөө байгаа судалгааны цэгийн (Kh_Trib_2, харьцуулах цэг) физик-химийн хэмжилтийн үр дүнг Монгол улсад мөрдөгдөж буй стандартад (MNS 900:2005, MNS 4586:1998) [33,34] заасан зөвшөөрөгдөх дээд хэмжээтэй харьцуулав.

Хүснэгт 8. Сөгнөгөр гол (Kh_Trib_2, харьцуулах цэг), Хараа голын Баруунхараа (Kh_Main_3, Хараа голын дунд хэсэг) болон Бүрэнтолгой (Kh_Main_4, Хараа голын адаг) орчмын усны чанарын хяналт шинжилгээний автомат станцад 2012 оны ургамалжилтын хугацаанд буюу зуны саруудад (5-аас 10 дугаар сар) хийгдсэн физик-химийн хэмжилтийн мэдээ (дундаж±стандарт хазайлт). Станцын анхдагч код, ID дугаарын хүснэгт 1-ээс харна уу. Зөвхөн ууссан хүчилтөрөгчийн хэмжилтийг 2012 оны 9 дүгээр сарын дунд хүртэл хийв.

Хүснэгт 9. Хараа голд тархсан усны макросээрнуруугүйтэнийг ашиглан усан орчны экологийн үнэлгээг өгөх нь. Экологийн чанарын үнэлгээг 1 "маш сайн" –ээс 5 "маш муу" хүртэл оноогоор үнэлнэ (ЭЧ = Экологийн чанар. E = Ephemeroptera = Өдөрч. P = Plecoptera = Хаварч. T = Trichoptera = Хоовгоно).

Хүснэгт 10. Хараа голд тархсан загасны популяцийг ашиглан усан орчны экологийн үнэлгээг өгөх нь. Экологийн чанарын үнэлгээг 1 "маш сайн" –ээс 5 "маш муу" хүртэл оноогоор үнэлнэ ("зүйл болон амьдрах орчны хоорондын хамаарал" = тухайн зүйлийн амьдрах орчны онцлог. Дагуул зүйл. Нүүдлийн зүйл. Амьдрах орчны хамаарал; "Нөхөн үржихүйн болон идэш тэжээлийн хамаарал" = зонхилогч зүйлийн харьцангуй элбэгшил. Алгана загасны харьцангуй элбэгшил. Амьдрах орчны тархалт; "насны бүтэц" = 0+ настай зүйлийн эзлэх хувь).

4. Conclusions / Дүгнэлт

Энэхүү эрдэм шинжилгээний өгүүлэлд Монгол орны хойд хэсгийн голын ландшафтыг тодорхойлох тухай ойлголт, сав газрын менежментийн төлөвлөгөөг боловсруулахад дэмжлэг болох үүднээс усны менежментийн арга хэмжээнүүдийг авч хэрэгжүүлэх жижиг нэгжүүдийг зохион байгуулах усны дэд сангуудын ангилалыг танилцуулав. ХБНГУ-д ашиглагддаг, сав газрын геологи, геоморфологи, ургамалжилт, уур амьсгалаас хамааруулсан сав газрын экологийн онцлогийг илтгэж чадах голын гулдрилын хэлбэрзүйн хэв шинжийн ангилал, шалгуур үзүүлэлтэд тулгуурлан Хараа гол, түүний цутгал голуудын гулдрилын дараах хэв шинжүүдийг тодорхойлов: (i) ёроолын хагшаас нь хайрга, бул чулуугаар зонхилох уулархаг газрын голууд, (ii) ёроолын хагшаас нь хөнгөн шавранцараар зонхилох уулархаг газрын голууд,

(iii) өндөр уулын гол горхинууд, (iv) ёроолын хагшаас нь элсээр зонхилох хөндийн голууд, (v) ёроолын хагшаас нь элс, шавранцараар зонхилох, хэлбэр, хэмжээний хувьд харилцан адилгүй, хөндийгөөр урсах голууд. Түүнчлэн биоценоз, физик-хими, гидрологийн онцлогийг харгалзан Хараа голын үндсэн гудрилыг 4 дэд санд, түүний цутгал голуудыг 7 дэд санд ангилав. Энэхүү арга аргачлалыг усны нөөцийн үнэлгээ хийх, менежментийн арга хэмжээнд ашиглах бүрэн боломжтой.

Монгол орны зүүн-хойд хэсгийн Хэнтийн уулархаг муж нь сав газрын "Усны цамхаг" болох ба хүний хүчин зүйлийн нөлөөлөлд өртөөгүй, байгалийн унаган төрхөө хадгалан үлдсэн байгаагаас дүгнэхэд энэхүү бүс нутаг нь нөлөөлөлд өртөөгүй усан орчны экосистемийг төлөөлөх боломжтой. Иймд Хараа голын эх гэж үзэх уг газар нутагт тархсан голуудын усан дахь химийн бодис, нэгдлүүдийн бага хэмжээ, ялгаатай биоценозын бүлгэмдлүүд, "маш тааламжтай" экологийн нөхцөл нь Хараа голын сав газарт багтах бусад голуудын усны чанарын статусын үнэлгээг шинжлэх ухааны үндэслэлтэй хийх жишиг нөхцөл, босго үзүүлэлт болж өгч чадна. Хүний хүчин зүйлийн нөлөөллийг сав газрын доторх дэд усан сангуудад үнэлэхдээ дээр дурдсан нөхцлийг суурь материал болгон зөвшөөрөгдөх дээд хэмжээнээс хэдий хэмжээгээр ихэссэн болохыг үнэлж тооцох, нөхөн сэргээх стандартуудыг боловсруулахад ашиглана. Түүнчлэн уг арга аргачлалыг Монгол оронд ашиглагдаж буй стандартуудад дутагдаж байгаа биологийн үнэлгээг оруулах, үнэлгээний аргачлалыг шинээр боловсруулахад хэрэглэж болох юм.

Хараа голын сав газрын гадаргын усны эрсдлийн анхдагч үнэлгээг экологийн болон химийн статусаас хамааруулан үзүүлбэл:

(i) Голын эхэн хэсэг дэх ихэнх усан сангууд нь экологийн болон химийн "тааламжтай" нөхцөлтэй;
(ii) Голын дунд болон адаг хэсгийн голын усны чанар уул уурхай, хотжилт, бэлчээрлэлт, мод огтлол, гал түймэрийн нөлөөллийн улмаас өөрчлөлтөнд орсон;
(iii) Нөлөөлөлд өртсөн голын адаг хэсэгт шим тэжээлийн бодисын хэмжээ голын өөрөө цэвэрших чадамжийн хэмжээнээс хэтэрсэн байгаа нь тэнд байгаль орчныг хамгаалах арга хэмжээг нэн яаралтай авч хэрэгжүүлэхгүй тохиолдолд аюултай түвшинд хүрэхээр байна.

Эцэст нь дүгнэхэд голын сав газрын менежментийн төлөвлөгөөг боловсруулах тасралтгүй үйл явцад дэмжлэг болох сав газрын хэмжээнд усны дэд сангуудыг үндэслэн байгуулахад хүний хүчин зүйлийн ачаалал, экологийн доройтол, шалтгаан, нөхөн сэргээх, хамгаалах арга хэмжээг бүхэлд нь хамаатуулан үнэлэх ёстой. Хараа голын сав газрын жишээгээр харахад хүрээлэн буй орчин, нийгэм-эдийн засгийн хувьд гетероген сав газарт голын сав газрын менежментийн төлөвлөгөө, хэрэгжилтийг дэд сангуудын хэмжээнд авч хэрэгжүүлэх нь илүү үр дүнтэй байна. Европын холбооны Усны Тогтолцооны Удирдамжид (EU-WFD) заагдсан, практикт өргөн ашиглагдаж буй сав газрыг дэд усан сангуудад хуваарилан, тэнд менежментийн арга хэмжээг авч хэрэгжүүлдэг энэхүү арга аргачлалыг Хараа голын сав газарт ашиглах бүрэн боломжтойг харуулав.

References

1. Pottgiesser, T.; Sommerhäuser, M. Die Fließgewässertypologie Deutschlands: System der Gewässertypen und Steckbriefe zu den Referenzbedingungen. In *Handbuch Angewandte Limnologie*; Steinberg, C., Calmano, W., Wilken, R.-D., Klapper, H., Eds.; ecomed Verlagsgesellschaft: Landsberg/Lech, Germany 2004. (In German)
2. Pottgiesser, T.; Sommerhäuser, M. Beschreibung und Bewertung der deutschen Fließgewässertypen—Steckbriefe und Anhang. 2008. Available online: http://www.wasserblick.net/servlet/is/18727/?highlight=steckbriefe (accessed on 8 June 2015).
3. Kopp, B.; Minderlein, S.; Menzel, L. Soil moisture dynamics in a mountainous headwater area in the discontinuous Permafrost Zone of Northern Mongolia. *Arct. Antarct. Alp. Res.* **2014**, *46*, 459–470.
4. Minderlein, S.; Menzel, L. Evapotranspiration and energy balance dynamics of a semi-arid mountainous steppe and shrubland site in Northern Mongolia. *Environ. Earth Sci*. **2014**, doi:10.1007/s12665-014-3335-1.
5. Monitoring from Air. Available online: https://www.htw-dresden.de/?id=20030 (accessed on 22 June 2015).
6. Monitoring from Air. Panorama Churcheree Gol. Available online: https://www.htw-dresden.de/fileadmin/userfiles/geo/Labore/Labor_Photogrammetrie_Fernerkundung/Panorama/BaerentalSuedhang/Baerental_Suedhang_DSC00066_Panorama.htm (accessed on 22 June 2015).
7. Monitoring from Air. Thermal IR view of Churcheree Gol. Available online: https://www.htw-dresden.de/fileadmin/userfiles/geo/Labore/Labor_Photogrammetrie_Fernerkundung/Panorama/BaerentalThermal/06092012_Barerental_Thermal.htm (accessed on 22 June 2015).
8. Monitoring from Air. Panorama at Baruunkharaa. Available online: https://www.htw-dresden.de/fileadmin/userfiles/geo/Labore/Labor_Photogrammetrie_Fernerkundung/Panorama/KharaaBaroun/Pano_1_KharaaBaroun_Hoehe1.htm (accessed on 22 June 2015).
9. Monitoring from Air. Panorama of KRB outlet. Available online: https://www.htw-dresden.de/fileadmin/userfiles/geo/Labore/Labor_Photogrammetrie_Fernerkundung/Panorama/KharaaOrkhonJunction/DSC00074_Panorama_post.htm (accessed on 22 June 2015).
10. Theuring, P.; Rode, M.; Behrens, S.; Kirchner, G.; Jha, A. Identification of fluvial sediment sources in the Kharaa River catchment, Northern Mongolia. *Hydrol. Process*. **2013**, *27*, 845–856.
11. Modular concept for municipal water management in the Kharaa River Basin, Mongolia. In *Integrated Water Resource Management: Concept*, *Research and Implementation*; Ibisch, R., Kirschke, S., Stärz, C., Borchardt, D., Eds.; Helmholtz Centre for Environmental Research: Leipzig, Germany, 2015.
12. Hartwig, M.; Borchardt, D. Alteration of key hyporheic functions through biological and physical clogging along a nutrient and fine-sediment gradient. *Ecohydrology* **2014**, doi:10.1002/eco.1571.
13. Hofmann, J.; Hürdler, J.; Ibisch, R.; Schaeffer, M.; Borchardt, D. Analysis of recent nutrient emission pathways, resulting surface water quality and ecological impacts under extreme continental climate: The Kharaa River Basin (Mongolia). *Int. Rev. Hydrobiol.* **2011**, *96*, 484–519.
14. Hofmann, J.; Tuul, D.; Enkhtuya, B. Agriculture in Mongolia under pressure of agronomic nutrient imbalances and food security demands: A case study of stakeholder participation for

future nutrient and water resource management. In *Integrated Water Resource Management: Concept, Research and Implementation*; Borchardt, D., Bogardi, J., Ibisch, R., Eds.; Springer: Berlin, Germany, 2015, in press.
15. Pfeiffer, M.; Batbayar, G.; Hofmann, J.; Siegfried, K.; Karthe, D.; Hahn-Tomer, J. Investigating arsenic (As) occurrence and sources in ground, surface, waste and drinking water in northern Mongolia. *Environ. Earth Sci.* **2015**, *2*, 649–662.
16. Hofmann, J.; Watson, V.; Scharaw, B. Groundwater quality under stress: Contaminants in the Kharaa River basin (Mongolia). *Environ. Earth Sci*. **2015**, *73*, 629–648.
17. Hofmann, J.; Rode, M.; Theuring, P. Recent developments in river water quality in a typical Mongolian river basin, the Kharaa case study. In *Understanding Freshwater Quality Problems in a Changing World*, Proceedings of IAHS-IAPSO-IASPEI Assembly, Gothenburg, Sweden, 22–26 July 2013; IAHS Red Book Series; IAHS Publication: Wallingford, Germany, 2013; Volume 361, pp. 123–131.
18. Avlyush, S.; Schäffer, M.; Borchardt, D. Life cycles and habitat selection of two sympatric mayflies under extreme continental climate (River Kharaa, Mongolia). *Int. Rev. Hydrobiol.* **2013**, *98*, 141–154.
19. Avlyush, S. *Effects of Urface Gold Mining on Macroinvertebrate Communities: A Case Study in River Systems in the North-East of Mongolia*; Lambert Academic Publishing: Saarbrücken, Germany, 2011; p. 94.
20. Hartwig, M.; Theuring, P.; Rode, M.; Borchardt, D. Suspended sediments in the Kharaa River catchment (Mongolia) and its impact on hyporheic zone functions. *Environ. Earth Sci*. **2012**, *65*, 1535–1546.
21. Hartwig, M.; Borchardt, D. Alteration of key hyporheic functions through biological and physical clogging along a nutrient and fine-sediment gradient. *Ecohydrology* **2014**, doi:10.1002/eco.1571.
22. Krätz, D. Ökologie der Fischbestände in Fließgewässern des Khentii-Gebirges (Mongolei) Bestandsaufbau, Dynamik und Gefährdung durch den Gold-Tagebau. Ph.D. Thesis, Technical University of Dresden, Dresden, Germany, 2009; p. 174.
23. Krätz, D.; Ibisch, R.; Saulyegul, A.; Ganganmurun, E.; Sonikhishig, N.; Borchardt, D. Impacts of open placer gold mining on aquatic communities in Rivers of the Khentii Mountains, North-East Mongolia. *Mongol. J. Biol. Sci.* **2010**, *1*, 41–50.
24. Karthe, D. Needs and perspectives for investigations of water hygiene in the Kharaa River Basin, Mongolia. In *Water and Environment in the Selenga-Baikal Basin: International Research Cooperation for an Ecosystem Ecoregion of Global Relevance*, Proceedings of the Bringing Together Selenga Baikal Research Conference 2014, Leipzig, Germany, 1 October 2014; Karthe, D., Chalov, S., Kasimov, N., Kappas, M., Eds.; 2015.
25. Karthe, D.; Malsy, M.; Kopp, B.; Minderlein, S.; Hülsmann, L. Assessing water availability and its drivers in the context of an integrated water resources management (IWRM): A case study from the Kharaa River Basin, Mongolia. *Geoöko* **2013**, *34*, 5–26.
26. Hofmann, J.; Venohr, M.; Behrendt, H.; Opitz, D. Integrated water resources management in Central Asia: Nutrient and heavy metal emissions and their relevance for the Kharaa River Basin, Mongolia. *Water Sci. Technol.* **2010**, *62*, 353–363.

27. Brumbaugh, W.G.; Tillitt, D.E.; May, T.W.; Javzan, C.; Komov, V.T. Environmental survey in the Tuul and Orkhon River basins of north-central Mongolia, 2010: Metals and other elements in streambed sediment and floodplain soil. *Environ. Monit. Assess.* **2013**, *185*, 8991–9008.
28. Menzel, L.; Hofmann, J.; Ibisch, R. Studies of water and mass fluxes to provide a basis for an Integrated Water Resources Management (IWRM) in the catchment of the River Kharaa in Mongolia. *Hydrol. Wasserbewirtsch.* **2011**, *55*, 88–103.
29. Zandaryaa, S. Water Quality of the Kharaa River Basin, Mongolia: Pollution Threats and Hotspots Assessment. Available online: http://iwlearn.net/iw-projects/4029/reports/water-quality-of-the-kharaa-river-basin-mongolia-pollution-threats-and-hotspots-assessment (accessed on 3 February 2015).
30. Inam, E.; Khantotong, S.; Kim, K.W.; Tumendemberel, B.; Erdenetsetseg, S.; Puntsag, T. Geochemical distribution of trace element concentrations in the vicinity of Boroo gold mine, Selenge Province, Mongolia. *Environ. Geochem. Health* **2011**, *33*, 57–69.
31. *Safety of Environment & Health Protection: Drinking Water Standard*; MNS 900:2005; Mongolian National Center of Standardization & Metrology: Ulaanbaatar, Mongolia, 2005.
32. Berner, S. Hydromorphologische Untersuchungen an einem Fließgewässer im Norden der Mongolei (Kharaa Einzugsgebiet): Grundlagenerarbeitung für die Interpretation biologischer Daten. Master's Thesis, University Kassel, Kassel, Germany, 2007. (In German)
33. *Mongolian National Standard for Water Quality of the Aquatic Environment: General Requirements*; MNS 4586:1998; Mongolian National Center of Standardization & Meterology: Ulaanbaatar, Mongolia, 1998.
34. Davaa, G.; Oyunbaatar, D.; Sugita, M. Surface Water of Mongolia. 2007. Available online: http://raise.suiri.tsukuba.ac.jp/new/press/youshi_sugita8.pdf (accessed on 16 February 2015).