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Limnologica 38 (2008) 105–115
LIMNOLOGICA
www.elsevier.de/limno

Testing unbaited stygofauna traps for sampling performance

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Received 10 July 2007; accepted 25 October 2007

Abstract

Unbaited phreatic traps are a promising new method for sampling subterranean limnofauna. The aim of this study is to evaluate whether such trap systems are suitable to gather representative samples of the physico-chemical parameters and the invertebrate fauna of the aquifer. Fifteen traps, installed in five groundwater bores, and four traps located in the hyporheic zone, were sampled twice monthly over a 1 year period (June 2003–June 2004). Water samples were removed in three separated fractions (hose, trap and aquifer water), analysed for physico-chemical and faunal characteristics and compared with one another. The study was carried out in the Nakdong River floodplain, Korea. Physico-chemical characteristics of trap and aquifer were similar, but differed greatly from the hose samples. Abundances of fauna inside the traps were higher than in the aquifer, whereas there were no differences in taxonomic composition of the trap and aquifer samples. Biases of abundances suspected due to the use of traps were negligible in the groundwater, though it is recommended that comparisons between groundwater and hyporheic abundances ascertained by traps be handled cautiously.
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Keywords: Stygofauna; Groundwater; Unbaited phreatic traps; Sampling method

Introduction

One of the major questions arising with groundwater ecological studies is whether the community composition of the aquifer can be recorded representatively (Hahn, 2005; Hahn and Matzke, 2005). Sampling subterranean fauna in the hyporheic, shallow, and deep groundwater zones, can be done by a broad variety of sampling techniques such as freeze-coring, standpipe-coring, pumping, net sampling, traps or by the filtering of spring water (Bretschko and Klemens, 1986; Cvetkov, 1968; Dumas and Fontanini, 2001; Fraser and Williams, 1997; Hahn, 2002; Malard et al., 1997; Pospisil, 1992), but to date there are no standardised methods for sampling stygofauna taxonomic richness and abundances for ecological purposes (Hahn, 2002, 2005). Although Protocols for the Assessment and Conservation of Aquatic Life in the Subsurface (PASCALIS) (Malard et al., 2001) proposed a variety of sampling techniques for subsurface aquatic invertebrates in several habitats as standard methods, these techniques are suitable for ecological questions but only to a limited extent. This is because the focus of PASCALIS (Malard et al., 2001) was to record and describe biodiversity, but not community structure. Faunal data gathered with these methods are thus comparable with each other on a presence–absence level only.

Variations in methods (e.g. different volumes, pumping frequency) have different efficiencies in sampling (Boulton et al., 2004; Fraser and Williams, 1997; Hunt

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doi:10.1016/j.limno.2007.10.001

and Stanley, 2000), so the perception of the aquatic community may change depending on the method used. A statistical comparison of invertebrate samples obtained by different methods is thus critical. Therefore, an agreed and standardised method is needed to obtain representative and comparable data when sampling subterranean fauna in the hyporheic zone and in groundwater.

Such a method should meet the following criteria (Hahn, 2005):

(1) It should be suitable for spatio-temporal sampling, both with a small time lag and for monitoring over longer timescales.
(2) Neither the sampling site nor the sediment layers sampled should be altered by water extraction.
(3) Samples should be representative of both the aquifer water and fauna.

To meet these requirements, Hahn (2005) developed an unbaited trap system, which seems to be a promising method for sampling stygofauna. In a preliminary study, he found no significant differences between trap and aquifer water. This is in accordance with other studies (Hahn, 2003; Hahn and Matzke, 2005; Schmidt et al., 2004), where physical and chemical characteristics of water samples taken from a trap or inside a bore were similar to the aquifer water. With respect to fauna, Hahn (2005) concluded that traps provide representative results which do indeed reflect the communities around. However, he argues that abundances within the traps might be overestimated compared to the aquifer, if the aquifer is poorly populated by invertebrate fauna (see also Panek, 1994). Because of the small data set used by Hahn (2005), a robust evaluation of the trap technique is still required and the following questions must be clarified:

(1) Do hydro-chemical samples taken from inside the trap reflect the situation of the aquifer?
(2) Are the communities of the aquifer captured representatively by using unbaited phreatic traps?
(3) Is it possible that there is a bias of abundance data, with an underestimation near the surface, and an overestimation in sparsely populated aquifers?

In order to respond the questions above and to test the efficiency of the trap system, we sampled five groundwater monitoring bores (each with three unbaited traps) and four hyporheic bores (each with three unbaited traps) in the Nakdong River watershed (South Korea). Differences between the physical and chemical characteristics of hose water, trap content and aquifer water at each trap were assessed. Differences in the faunal communities of the trap and aquifer were also compared.

Study area

The Nakdong River floodplain is situated 15 km west of the city of Daegu, in the southeast of the Korean peninsula (Fig. 1). The study area at Dasan-Myeon (128°26′E/35°50′N, 19 m a.s.l.) is on the right bank of the Nakdong River and is 500 m long and 500 m wide. The site is divided into two sections by a dam and is bounded southward by a steep channel slope, with runoff water of the acreage behind the dam being drained by a small brook flowing at the southern edge of the floodplain. The porous alluvial sediments are composed of silt, mica, sand and gravel layers, and the mean groundwater table is 5–6 m below the surface.

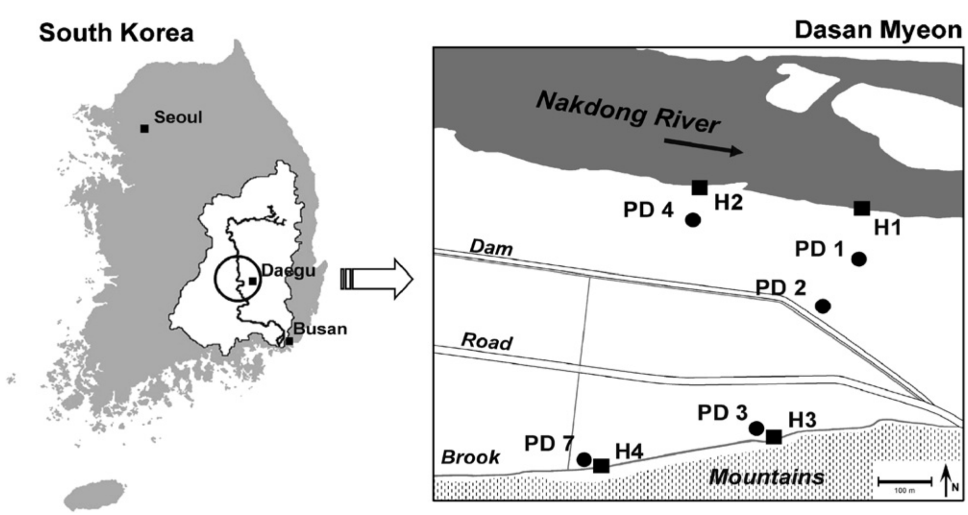

Fig. 1. Map of the Nakdong River watershed and the study area at Dasan-Myeon, Korea (H1–H4 represent the hyporheic sites; PD1–PD7 represent the bore sites).

Table 1. Characteristics of the bores investigated

Bore	Depth Bore (m)	Length of screen (m)	Depth of screen (m)	Range of groundwater table (m)	Depth trap A (m)	Depth trap B (m)	Depth trap C (m)	Latitude (N)	Longitude (E)
PD1	12	10	1–11	2.80–4.48	5.00	6.66	10.00	35°50′45″	128°26′16″
PD2	12	10	1–11	3.07–5.91	5.00	6.66	10.00	35°50′40″	128°26′12″
PD3	12	10	1–11	1.55–6.91	2.00	3.66	10.00	35°50′28″	128°26′05″
PD4	12	9	2–11	3.89–4.07	5.00	6.66	10.00	35°50′48″	128°25′57″
PD7	9	7	2–9	1.76–2.40	3.66	5.32	8.00	35°50′25″	128°25′48″
H1	0.3	0.3	0–0.3	–	0.1	–	–	35°50′48″	128°26′15″
H2	0.3	0.3	0–0.3	–	0.1	–	–	35°50′50″	128°25′58″
H3	0.3	0.3	0–0.3	–	0.1	–	–	35°50′28″	128°26′06″
H4	0.3	0.3	0–0.3	–	0.1	–	–	35°50′25″	128°25′48″

Methods

Trap system

At the sampling site, five monitoring wells were installed in two transects (Fig. 1). The slotted bores (PVC, ∅: 100 mm, slot width: 1.5 mm) were installed, by surrounding them with gravel (∅: 2–3 mm). At the soil surface, they were sealed with concrete. Characteristics of the sampled bores are given in Table 1.

To sample stygofauna, the unbaited trap system previously used by Hahn in 2005 was used (Fig. 2). These trap systems consist of three stratified traps (A–C) and were installed in five bores (PD 1, 2, 3, 4 and 7) for a total of 15 traps installed in the aquifer. The traps were mounted centrally on a threaded rod (Fig. 2), enabling the sampling of a precise horizontal plane. At each bore the uppermost trap (A) was installed near the groundwater table and the second trap (B) 1.5 m beneath it. The third trap (C) was located 1 m above the bottom of each bore.

Each trap consists of a plastic cylinder (∅: 94 mm, height: 150 mm) perforated by rows of entrance holes. In order to prevent hydro-chemical gradients, which could lead fauna out of the trap, the bottom row of the holes is covered by plankton net (74 μm). Fauna enter through the upper holes and are then trapped within the chamber. A hose leads from each trap to the surface to permit discrete sampling of fauna and water from each trap in the series. The system is described in detail by Hahn (2005).

In addition to the 15 traps installed in the aquifer, four bores were installed in the hyporheic zone each with one trap of the same type fixed in a depth of 10 cm below the sediment surface (H1–H4). Details of the hyporheic traps are given in Table 1, and their location is shown in Fig. 1.

Procedure of sampling

Traps were sampled using a suction pump composed of a modified desiccator and a manual camping air pump. Evacuation, ventilation and water flow were regulated by different valves. The hoses of the traps were connected to the desiccator. After evacuation, the valve leading to the trap was opened abruptly, which enhanced the sampling efficiency (Hahn, 2005). Due to the pressure gradient, water flows into a measuring jug (volume = 2 L) situated in the desiccator. A detailed description of the sampling procedure is given by Hahn (2005). In order to compare the water from the hose, trap and aquifer, the water samples were removed in three fractions. Sampling the traps began by removing the hose water then the trap content. At least 2 L of aquifer water were removed. From June 2003 to June 2004, bores were sampled twice a month.

Processing of samples

Temperature (°C), dissolved oxygen (DO), pH-value and specific conductance (EC) were measured immediately using a WTW Multiline 340i probe and sensor (Wissenschaftlich-Technische Werkstätten GmbH, Weilheim). For carbonate hardness ($CaCO_3$) an Aquamerck test kit (Merck KGaA, Darmstadt) was used. Nitrate (NO_3), phosphate (PO_4) and total dissolved iron were measured by Merck-Reflectoquant RQ flex plus (Merck KGaA, Darmstadt).

Fauna samples were sieved on site (mesh size 74 μm) and stored in a cold-box. To separate the fauna from detritus and sand in the laboratory, samples were decanted and passed once more through a sieve (mesh size 74 μm). Animals were then sorted alive using a dissecting microscope (Nikon SMZ 800) at 20× magnification. Samples containing high numbers of animals were preserved using 4% formaldehyde, coloured by Rose Bengal and sorted within a few days. Most taxa were identified to order or family, whereas cyclopoids and bathynellids were identified to species.

Data analysis

All data were checked for normal distribution by a Kolmogorov–Smirnov test and Shapiro–Wilks test at

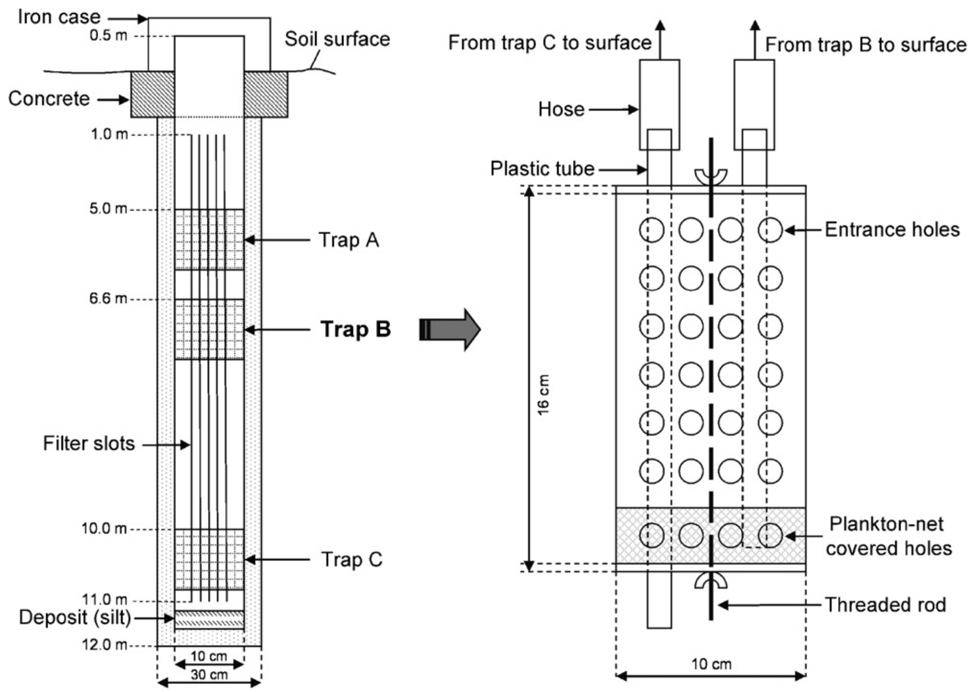

Fig. 2. Sketch of the trap system (S. Bork after Hahn, 2005).

$n < 50$, respectively. Neither physico-chemical nor faunal data were normally distributed, even after $\log(x+1)$ transformation ($p < 0.05$). Accordingly, for statistical analysis only non-parametric tests were performed. Differences between the fraction samples (hose, trap and aquifer) were tested by the Wilcoxon test for paired data. Comparisons of the physico-chemical characteristics and the invertebrate composition of fraction samples were carried out using multidimensional scaling (MDS). For this purpose physico-chemical characteristics were processed using $\log(x+1)$ transformed Euclidean distance, and faunal communities by using the square root transformed Bray–Curtis dissimilarity to fit the data to normal distribution. Mann–Whitney *U*-test was applied to detect differences in abundances between different layers of the aquifer. Data were processed using SPSS 14.0 (SPSS Inc.), PRIMER 5.2.9 (Primer-E Ltd.) and Excel 2000 (Microsoft Corporation).

Results

Water chemistry

In the aquifer, pH values varied between 5.2 and 7.7, while specific conductance ranged from 128 to 589 $\mu S\,cm^{-1}$ (Table 2). Water temperature was high, ranging from 10.9 to 24.4 °C. DO concentrations ranged between 0.0 and 11.2 $mg\,L^{-1}$. Nitrate concentrations varied between 1.0 and 71.0 $mg\,L^{-1}$. Concentrations of phosphate and iron varied between 0.0 and 2.1 $mg\,L^{-1}$ and between 0.0 and 15.1 $mg\,L^{-1}$, respectively, but were mostly lower than measuring range (phosphate: $<0.1\,mg\,L^{-1}$, iron: $<0.5\,mg\,L^{-1}$). Carbonate hardness ranged between 5.4 and 317.7 $mg\,L^{-1}$ (Table 2).

There were significant differences between the hose and both other fractions for most of the physico-chemical parameters (Table 3 and Fig. 3). Exceptions were temperature and phosphate concentrations, which were not different between hose and trap water (Wilcoxon-test: $n = 67$; $p = 0.701$ and $n = 40$; $p = 0.808$, respectively). Also, no differences were found for phosphate between hose and aquifer water (Wilcoxon-test: $n = 40$; $p = 0.439$).

In the hose water, pH (Wilcoxon-test: $n = 69$; $p = 0.001$), iron concentration (Wilcoxon-test: $n = 34$; $p = 0.002$) and carbonate hardness (Wilcoxon-test: $n = 34$; $p < 0.001$) were significantly higher than in the trap water. Compared to the aquifer water, temperature of the hose water was significantly higher (Wilcoxon-test: $n = 67$; $p = 0.004$). EC, DO and nitrate concentrations of the hose water were significantly lower than in the trap and the aquifer water (all $p < 0.05$, Table 3). No significant differences were found for the physico-chemical parameters between trap and aquifer water (Table 3 and Fig. 3).

The MDS (Fig. 4) ordered the fractions of each trap (hose, trap and aquifer samples) by the physico-chemical parameters – mostly close together according to their affiliation to the same trap, indicating their similarity.

Table 2. Physical and chemical characteristics of the different water fractions

Parameters	Fraction								
	Hose			Trap			Aquifer		
	Median	Min.–Max.	*n*	Median	Min.–Max.	*n*	Median	Min.–Max	*n*
pH	6.1	5.6–7.1	70	6.2	5.2–7.1	148	6.2	5.2–7.7	258
EC (μs/cm)	244	155–539	70	270	128–589	148	278	128–589	258
Temperature (°C)	19.4	11.6–26.3	68	17.7	8.8–25.0	148	18.1	10.9–24.4	254
DO (mg/L)	1.4	0.0–4.0	68	1.7	0.0–9.3	148	1.9	0.0–11.2	254
Nitrate (mg/L)	3.0	1.5–119.0	55	13.0	1.5–66.0	131	16.0	1.0–71.0	233
Phosphate (mg/L)	0.0	0.0–0.1	41	0.0	0.0–0.3	117	0.0	0.0–2.1	218
Total dissolved iron (mg/L)	0.25	0.25–1.8	35	0.25	0.25–11.0	111	0.25	0.0–15.1	210
Carbonate hardness $CaCO_3^-$ (mg/L)	92.8	50.0–192.8	35	67.8	32.1–321.3	111	60.7	5.4–317.7	186

Table 3. Results of the Wilcoxon rank-tests: comparison of the fractions "hose" (H), "trap" (T) and "aquifer water" (A)

Parameter	Comparison of fractions					
	H–T		H–A		T–A	
	p	*n*	*p*	*n*	*p*	*n*
pH value	0.001***	69	0.000***	69	0.606	148
EC (μs/cm)	0.000***	69	0.000***	69	0.051	148
Temperature (°C)	0.701	67	0.004**	67	0.499	148
DO (mg/L)	0.000***	67	0.002**	67	0.114	148
Nitrate (mg/L)	0.002**	54	0.002**	54	0.055	131
Phosphate (mg/L)	0.808	40	0.439	40	0.238	117
Total dissolved iron (mg/L)	0.002**	34	0.000***	34	0.073	111
Carbonate hardness $CaCO_3^-$ (mg/L)	0.000***	34	0.000***	34	0.060	111
Number of taxa					0.000***	232
Abundance p. liter					0.000***	232
Abundance p. sample					0.000***	232
Cyclopidae p. liter					0.000***	232
Harpacticoida p. liter					0.000***	232
Nematoda p. liter					0.000***	232
Oligochaeta p. liter					0.000***	232
Insecta p. liter					0.000***	232
Acari p. liter					0.000***	232
Rotatoria p. liter					0.000***	232
Nauplii p. liter					0.000***	232
Cyclopidae (%)					0.088	172
Harpacticoida (%)					0.585	172
Nematoda (%)					0.037*	172
Oligochaeta (%)					0.386	172
Insecta (%)					0.090	172
Acari (%)					0.523	172
Rotatoria (%)					0.671	172
Nauplii (%)					0.673	172
Eucyclops serrulatus p. liter					0.000***	232
Mesocyclops pehpeiensis p. liter					0.000***	232
Mikrocyclops varicans rubellus p. liter					0.000***	232
Eucyclops serrulatus (%)					0.450	172
Mesocyclops pehpeiensis (%)					0.043*	172
Microcyclops varicans rubellus (%)					0.053	172

Significance: $*p<0.05$, $**p<0.01$, $***p<0.001$.

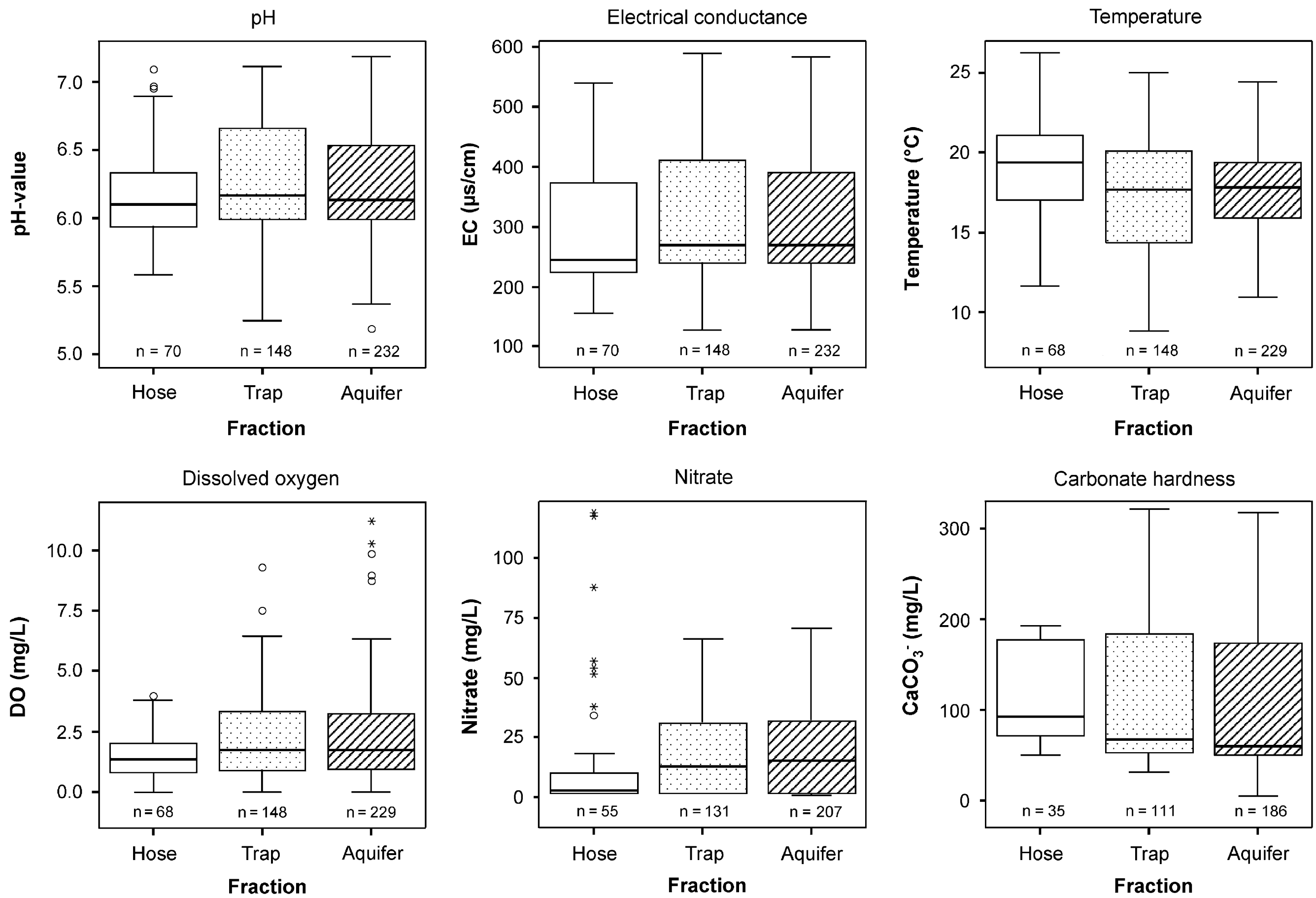

Fig. 3. Boxplots of selected physico-chemical parameters. Comparison of the water fractions "hose", "trap" and "aquifer". Phosphate and iron were not considered since they were mostly lower than the measuring range.

The largest differences between the water fractions of one trap were found in the hyporheic zone near the mountains.

Fauna

Only fauna from the trap and aquifer samples are considered. In total, 232 samples were removed from the traps and the aquifer. From the trap and the aquifer samples, 203 (87.6%) and 182 (78.6%), respectively, were populated by metazoans. A total of 17,849 animals were collected. The most abundant taxa were the cyclopoid copepods (relative abundance: 31.6%) comprising 18 species, the nematods (relative abundance: 22.1%) and the harpacticoids (relative abundance: 12.1%). The Bathynellacea (relative abundance: 0.5%) occurred with one species (*Nakdongbathynella dasani*).

There were significant differences in abundance and taxa richness between the trap and the aquifer samples for the most frequent and abundant taxa and species (Table 3 and Fig. 5). Abundance per sample, abundance per litre, total numbers of taxa, and abundance of single species per litre (*Eucyclops serrulatus*, *Mesocyclops pehpeiensis* and *Microcyclops varicans rubellus*) were all significantly higher in the traps than in the aquifer (Wilcoxon-test: $n = 232$; all $p < 0.001$). The proportions of taxa per sample were similar in the trap water and the aquifer, with the exception of nematodes, whose proportions were significantly higher in the traps than in the aquifer (Wilcoxon-test: $n = 172$; $p = 0.037$) (Table 3).

No differences between trap content and aquifer were found for the proportions of *E. serrulatus* and *M. varicans rubellus* (Wilcoxon-test: $n = 172$; $p = 0.450$, 0.053, respectively), but proportions of *M. pehpeiensis* were significantly higher in the trap water than in the aquifer (Wilcoxon-test: $n = 172$; $p = 0.043$).

The MDS ordered the fractions of each trap (trap and aquifer samples) mostly close together (Fig. 6).

Abundances and taxonomic richness were highest in the hyporheic zone and in the uppermost groundwater traps, and decreased with increasing depth (Table 4 and Fig. 7).

In the groundwater, total abundances per litre of all layers (A–C) were five times higher in the traps compared to the aquifer. In contrast, in the hyporheic

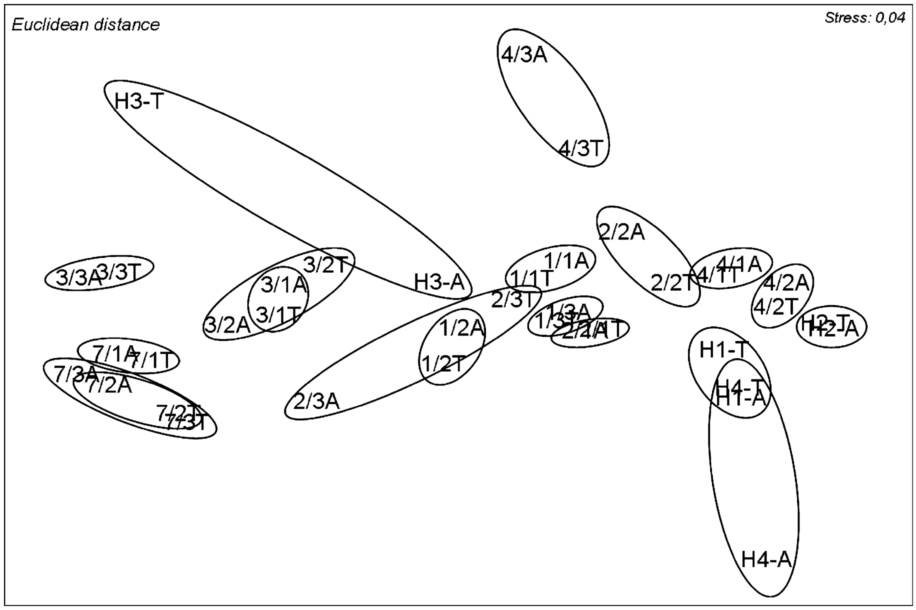

Fig. 4. MDS ordination of the fractions "trap" and "aquifer" by the physico-chemical data. Data were aggregated by medians. Naming of the aggregated samples. the first cipher indicates the number of the bore according to Table 1. A prefixed "H" denotes a hyporheic trap. The cipher behind the slash indicates the layer (1 = A, 2 = B, 3 = C) and the last letter the water fraction (T = trap, A = aquifer).

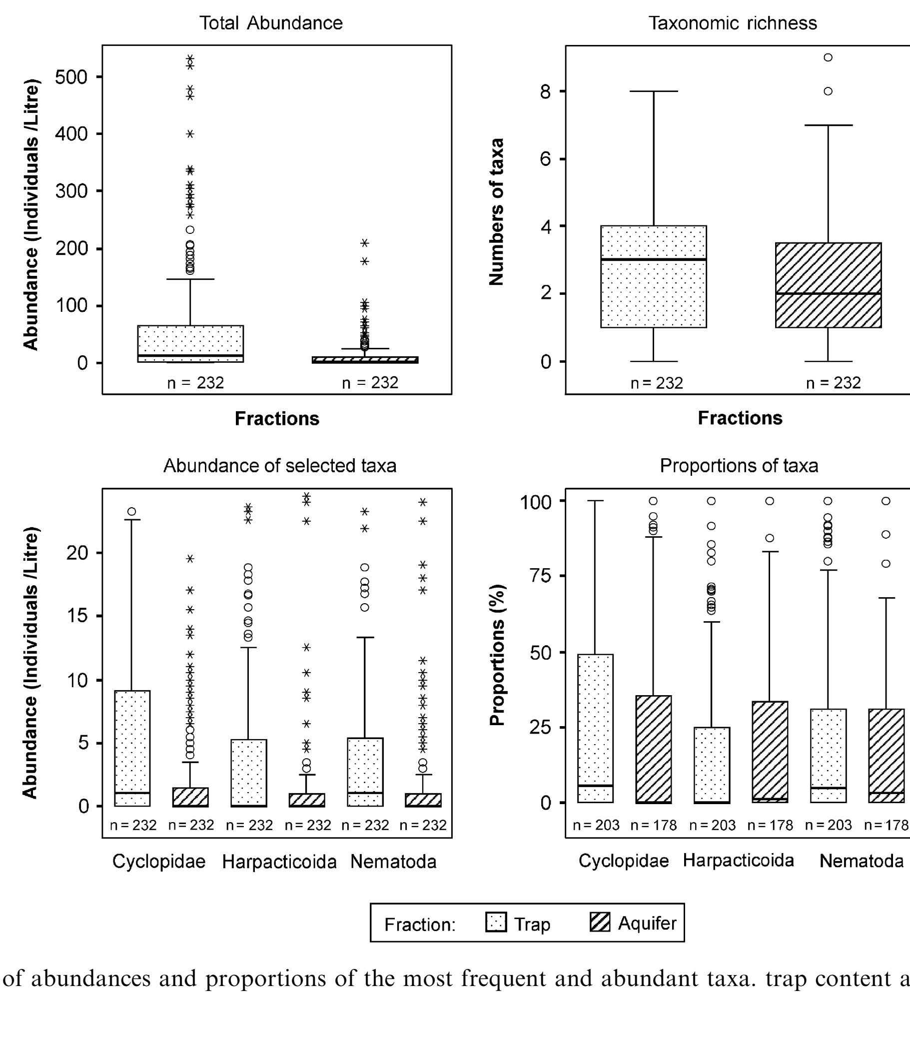

Fig. 5. Boxplots of abundances and proportions of the most frequent and abundant taxa. trap content and aquifer samples.

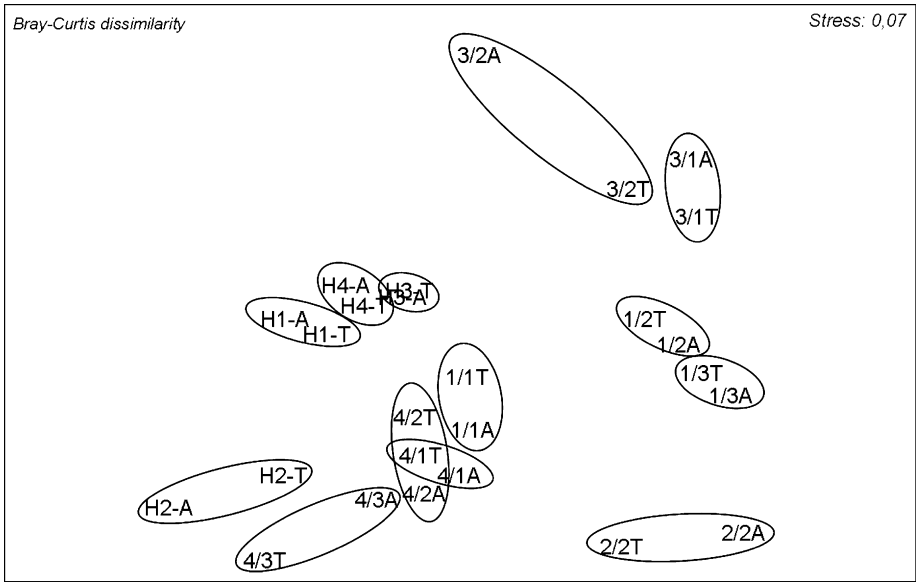

Fig. 6. MDS ordination of the invertebrate communities of the fractions "trap" and "aquifer". Data were processed on species level and aggregated by means. Traps were excluded from the analysis when crustaceans were absent. Naming of the aggregated samples. the first cipher indicates the number of the bore according to Table 1. A prefixed "H" denotes a hyporheic trap. The cipher behind the slash indicates the layer (1 = A, 2 = B, 3 = C) and the last letter the water fraction (T = trap, A = aquifer).

Table 4. Inside–outside ratios of total abundances per litre for different strata (ratios were aggregated by median over each strata)

Layer	Fraction						Ratio trap–aquifer
	Trap			Aquifer			
	Animals/L	n	Median	Animals/L	n	Median	
Hyporheic	4532	23	166.0	1520	23	54.0	3.4:1
A	5294	53	59.8	899	53	9.0	5.4:1
B	2289	71	11.8	340	71	2.5	5.1:1
C	782	85	3.1	139	85	0.5	4.8:1

zone traps, abundances were only three times higher (Table 4 and Fig. 7). There were no significant differences between the groundwater layers A–C (Mann–Whitney U-Test: $p > 0.332$), whereas differences between all groundwater strata and the hyporheic zone were significant (Mann–Whitney U-Test: $p < 0.01$).

Discussion

Water chemistry

Water of groundwater bores may be altered by atmospheric contact or reduction processes within the bore. Consequently, for measuring physico-chemical parameters of the aquifer water, the complete contents of a bore have to be purged twice (DVWK (Deutscher Verband für Wasserwirtschaft und Kulturbau), 1990; Knehr et al., 1996). Hahn (2005) argues that this requirement also applies to the water of the trap hoses, and that hose water must therefore be discarded from analysis. This suggestion is confirmed by the data presented here. The statistical analysis detected highly significant differences for most of the physico-chemical parameters between hose water and both the trap content and the aquifer water. According to Knehr et al. (1996) and DVWK (Deutscher Verband für Wasserwirtschaft und Kulturbau) (1990), the question arises as to whether hydro-chemical samples taken from the trap content accurately reflect the true situation of the aquifer.

Hahn (2003) found differences in pH and DO between trap water and aquifer, which seems to be attributed to air bubbles in the upper part of a trap originating from the installation of the trap system. Furthermore oxygen consumption by decomposition of detritus at the trap bottom should be taken into consideration. In the study presented here, no significant divergences between trap

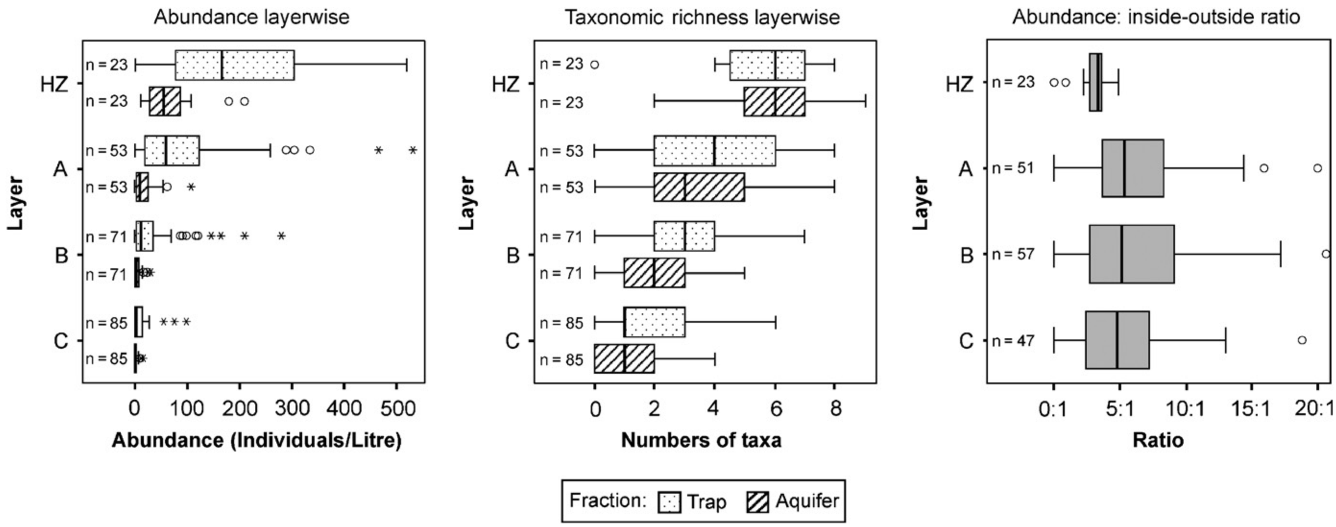

Fig. 7. Boxplots of abundance, taxonomic richness and abundance-based inside–outside ratio. Comparison of the different strata inclusive hyporheic zone (HZ).

and aquifer water were found, although they did occur in some individual cases (e.g. hyporheic traps H3 and H4, see Fig. 4, MDS). This is consistent with the findings of previous studies (Hahn, 2005; Hahn and Matzke, 2005; Schmidt et al., 2004). However, the differences between trap and aquifer water found in the hyporheic zone, might be a result of low hydraulic conductance of the surrounding sediment, which leads to shortcuts with surface water, while pumping. It seems that aquifer conditions are satisfactorily reflected by water samples from unbaited phreatic traps, and that water sampled from traps is representative of the surrounding aquifer.

Fauna

The use of unbaited phreatic traps raises the question of whether invertebrate communities from the aquifer are captured representatively (in terms of abundances and taxonomic composition). The data presented here show significant differences between abundances in the trap and aquifer samples. Densities of invertebrate fauna per litre were considerably higher in the trap water than in the aquifer water. Also, more taxa were sampled from the traps, but percentages of these taxa were comparable between traps and the aquifer. Thus, taxonomic composition of the trap and aquifer samples is similar.

These findings are in accordance with the results of Hahn (2005) and Hahn and Matzke (2005). Unfortunately, the data used by Hahn (2005) was too small for a resilient analysis, and therewith indicated just a trend, while Hahn and Matzke (2005) compared the content of monitoring bores with the surrounding aquifer. However, since bores act like traps (Culver and Sket, 2000; Mathieu et al., 1991; Matzke, 2006; Steenken, 1998), their results should also be valid for traps, and our findings support this, since taxonomic compositions are similar.

On the other hand, it seems that groundwater animals are attracted by traps, which would explain their significantly higher abundances within the traps. The preference to colonise traps or bores probably results from a better food supply due to the enrichment of detritus within the bores and a more spacious habitat in contrast to the surrounding aquifer (Hahn and Matzke, 2005; Steenken, 1998). Many studies indicate the significance of organic matter for hyporheic and groundwater invertebrates (Brunke and Gonser, 1999; Datry et al., 2005; Gibert and Deharveng, 2002), and numbers of taxa and abundances are often found to correlate positively with organic matter (Hahn, 2006; Strayer et al., 1997). Food and oxygen supply decrease with increasing depth as a result of decreasing exchange with surface water, but the strength of decline depends on hydrological characteristics of the aquifer (Brunke and Gonser, 1997). As a result, invertebrate densities and species richness also decrease with increasing depth (Strayer, 1994).

Hahn (2005) assumed an underestimation of abundances of the well-populated near-surface groundwater and an overestimation of the abundances of groundwaters with a poor fauna. This apprehension was derived from an observation made by Panek (1994), who found that the activity rate of hyporheic invertebrate fauna increases with sediment depth. Active trap performance is positively correlated with invertebrate fauna activity rate. Activity rate was found to be much higher when environmental conditions were harsh for fauna and lower when living conditions were better (Panek, 1994). Mösslacher and Creuzé des Châtteliers (1996) found epigean *Asellus aquaticus* characterised by a low activity rate and a high feeding rate. Whereas hypogean *A. aquaticus* showed a high movement activity due to marginal food resources in groundwater habitats and a low feeding rate as a result of a reduced metabolism.

In other words, abundances of traps samples might be overestimated under harsh, and underestimated under good, conditions. With increasing depth, environmental conditions for groundwater fauna degrade as a result of decreasing food and oxygen supply (Brunke and Gonser, 1999; Datry et al., 2005), and invertebrate densities and species richness also decrease with increasing depth (Dôle-Olivier, 1998; Dumas et al., 2001; Hahn, 2005; Strayer, 1994). Hahn (2005) thus suspected an overestimation of abundances particularly in deeper groundwater when compared to near-surface groundwater.

However, the data presented here show that inside–outside ratio of abundances was roughly 5:1 in all layers of the groundwater, and in the hyporheic zone it was significantly lower (3:1). This implies that in groundwater, differences of living conditions and activity rate of the fauna were negligible for all depths investigated – probably the result of the generally bad living conditions in the groundwater (Gibert and Deharveng, 2002). In contrast, in the hyporheic zone, living conditions in terms of food and oxygen supply seem to be significantly better than in the groundwater, which leads to lower activity rates of the fauna and thus to a smaller inside–outside ratio of abundances in the hyporheic traps. Hence, biases of abundances suspected due to the use of traps are considered to be negligible in the groundwater, though comparisons between groundwater and hyporheic abundances ascertained by traps should be regarded carefully.

Conclusion

The scope of this study was to evaluate the sampling efficiency of unbaited phreatic traps. The data presented here imply that samples taken from unbaited traps seem to reflect the physico-chemical conditions of the aquifer satisfactorily, but hose water has to be discarded. The faunal composition of the aquifer is obviously reflected representatively by the traps, in terms of abundance and taxonomic composition. A bias of the abundance data by overestimating groundwater fauna of poorly populated aquifers (compared to abundantly populated ones) was not verified for the groundwater, but might be a problem to some degree when comparing groundwater to hyporheic trap samples. Thus, it is concluded that unbaited phreatic traps are suitable for a wide range of groundwater ecological purposes, but caution should be taken when comparing faunal communities collected from different groundwater habitats with groundwater related ecotones (e.g. hyporheic zone).

Acknowledgements

This study was possible only by the support of Kwaters (former KOWACO, Korean Water Resources Corporation), Daejon, Korea (grant code #3-4-3, 21st Century Frontier Research Program), namely Dr. Hyoung-Soo Kim and Dr. Joo-Lae Cho. We are indebted to Prof. Dr. E. Friedrich and our colleagues from the groundwater ecological working group, University of Koblenz-Landau, for all their advice and numerous helpful discussions. We thank Dr. S.I. Schmidt, GSF, Neuherberg, for helpful discussions and annotations and Noel Morris for vernacular meliorations of the draft report. We are indebted to the unknown reviewers for helpful comments and suggestions.

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