

## Faunistic Characterization of Alpine springs in the Swiss National Park

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Keywords: Alpine springs, Swiss National Park, macroinvertebrates, endangered species

### Abstract

Springs are unique habitats for highly adapted organisms that are endangered by anthropogenic impacts. The springs in the Swiss National Park (SNP) have remained largely free of direct anthropogenic impacts since the foundation of the park. Monitoring of these unaffected Alpine springs is therefore of special interest. In this project 19 springs in the SNP and the adjacent Val Müstair Biosphere Reserve were investigated. In early summer and autumn 2012, the springs were mapped and physiochemical parameters were measured. The macroinvertebrates were sampled quantitatively with a surber sampler and qualitatively by hand-picking. Results show that Diptera, Trichoptera and Plecoptera are the most diverse orders. Within these orders, cold-stenothermal species with alpine altitudinal preferences and endemic species were found. They are partly endangered or at least vulnerable in Switzerland. The macroinvertebrate species assemblages of the springs show a high degree of individuality. However, looking at the species assemblages, springs at different sites or valleys differ significantly from each other. This underlines the importance of protected areas as sanctuaries for threatened species living in endangered habitats such as springs. Moreover, a protection of the springs outside of the SNP would be desirable.

### Profile

Protected area

Swiss National Park & Val Müstair

Biosphere Reserve

Mountain range

Alps

Country

Switzerland

### Introduction

Springs are multiple ecotones between the ground-water and the surface water and provide a habitat for specialized organisms (Cantonati et al. 2006). Perennial springs exhibit reduced variability of environmental conditions (van der Kamp 1995; Cantonati et al. 2012). Alpine springs are even more special as species have to adapt to lower temperatures and a short growth season during summer. Environmental changes and anthropogenic impacts have severely endangered these springs. In the Swiss Jura mountains and in the Central Plateau, few springs remain in a natural condition (Zollhöfer 1997). Alpine springs are also threatened, for instance, by cattle grazing and trampling (Wigger & von Fumetti 2013). They are sensitive habitats, usually of a small spatial extent (Cantonati & Ortler 1998) and fed by small catchment areas (Cantonati et al. 2006). Recent studies on Alpine springs in Switzerland were conducted e.g. by Weber 2004, Robinson et al. 2008 and Wigger & von Fumetti 2013.

Springs in protected Alpine areas have been intensively monitored in Berchtesgaden National Park in Germany (Gerecke & Franz 2006), where over 330 springs have been investigated. In Austria, the Kalkalpen and Gesäuse National Parks were intensively monitored in the past ten years (e.g. Weigand 1998; Weigand & Graf 2004; Gerecke et al. 2012). In the Swiss National Park (SNP) research is one of the main aims, therefore the fauna and flora is well investigated. However, scientific research on springs in the SNP has been mostly limited to chemical and physi-



Figure 1 – A typical spring in the Swiss National Park. © S. Felder

cal parameters (Nold & Schmassmann 1955; Döring 2002) and to certain taxa, such as water mites (Bader 1975) and stoneflies (Aubert 1965). There is one study from Nadig (1942), who closely investigated five springs around Il Fuorn. With its long-standing protection since 1914, the SNP is still a very remote and natural area with over 200 natural springs recorded in the areas Val dal Spöl, Il Fuorn and the valleys around Il Fuorn (Steiner 2005).

In this study, 19 springs were investigated of which 14 are situated within the borders of the SNP and five

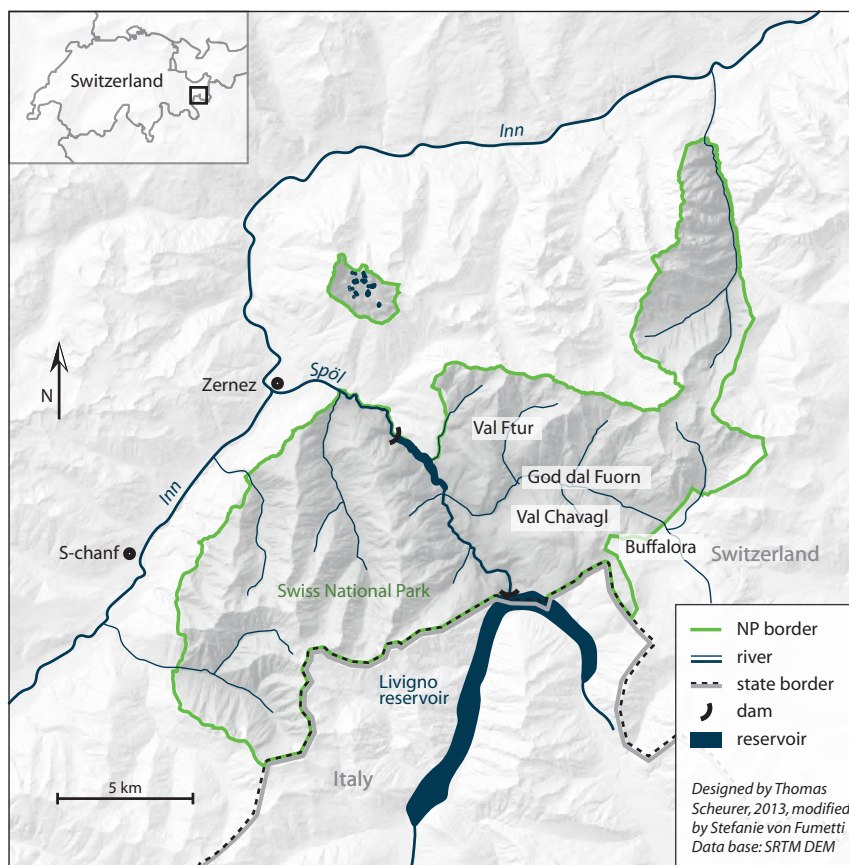


Figure 2 – Locations of the springs within the SNP in the side valleys Val Ftur and Val Chavagl and around God dal Fuorn. Five springs are located in the region Buffalora in Val Müstair BR.

in the area of Buffalora in Val Müstair Biosphere Reserve (BR). The aims of the study were (a) to determine the main abiotic factors influencing the macro-invertebrate assemblages of the springs within and outside the SNP and (b) to assess the function of the SNP as a sanctuary for endangered species. This study gives a first comprehensive insight into the fauna of the springs around Il Fuorn in the SNP and the Alp Buffalora in Val Müstair BR.

## Methods

### Study site

The SNP was founded in 1914 and has been subject to total nature protection since then. Fourteen of the investigated springs are situated within the SNP around the hotel Il Fuorn in the side valleys Val Ftur and Val Chavagl and around God dal Fuorn. Five springs are located in the region Buffalora in Val Müstair BR (Table 1 & Figure 2). All springs are geologically located in the Engadine Dolomites (Trümpy 1997). The altitudinal range of the springs varies from 1770 m to 2255 m. This alpine to subalpine area is covered by snow for up to nine months a year. The mean precipitation at Buffalora is 793 mm/a (1968 m; MeteoSchweiz 2013). The average annual air temperature reaches 0.7 °C; temperatures vary between –9.2 °C during winter and 10.3 °C during summer. Increasing temperatures have been measured since 1990 (Ketterer & Haller 2009). The studied springs all flow into the Ova dal Fuorn that feeds the river Spöl. Most

investigated springs are rheocrenes. The springs Q4, GF1 and BUF5 were characterized as helocrenes and BUF1, FiW and LIM as limnocrenes. The springs in the Buffalora region in Val Müstair BR are moderately influenced by extensive cattle grazing. Despite the total nature protection, few springs within the park are used for drinking water supply.

### Faunistic and abiotic sampling

All springs were sampled twice, in early June and late September 2012. Of each spring four quantitative samples were taken with a small surber sampler (10 cm x 10 cm; 500 µm mesh) after von Fumetti et al. (2006). Additionally the springs were sampled by hand-picking. All samples were preserved in 80% ethanol and sorted afterwards in the laboratory. Specimens were identified to species level whenever possible. Demanding taxa, such as Chironomids were identified to sub-family level or grouped into morphospecies. Water temperature, pH, oxygen content and saturation, and electrical conductivity were measured using portable meters (WTW, Weilheim, Germany). The discharge was measured using a plastic bag and a graduated cylinder after Zollhöfer et al. (2000). The springs were mapped geomorphologically based on the manual by Lubini et al. (2009).

### Statistical analysis

All statistical analyses were calculated using PRIMER 6.0 (Clarke & Gorley 2006). The statistical analysis of the faunistic data was performed with the data

of the quantitative sampling. For the faunistic data, the Bray-Curtis similarity and a fourth root-transformation were used. Abiotic data were normalized and the Euclidian distance was used as similarity measure. Ordination of the springs was conducted using non-metric multidimensional scaling (nMDS). The analysis of similarities procedure (ANOSIM), which is analogous to an ANOVA but relies on a similarity matrix and makes few assumptions about the data, was used for testing the grouping of the springs. Additionally a principal components analysis (PCA) and a BEST-analysis (Biota and Environmental Matching) were performed. In the BEST analysis, the Spearman rank correlation is used for correlating faunistic and abiotic data. The combination of abiotic variables with the highest  $\rho$  value best describes the faunistic distribution ( $\rho$  between 1 and  $-1$ ).

## Results

The water temperature in the springs varied from 3.0 °C (BUF3) to 7.0 °C (LIM) during the summer sampling (mean: 5.1 °C). The temperature amplitude was between 0.1 (GF3, LIM) and 4.7 (BUF4). The pH ranged from 7.2 (Q2) to 8.9 (VCh2) and the electrical conductivity from 107  $\mu\text{S}/\text{cm}$  (BUF3) to 575  $\mu\text{S}/\text{cm}$  (GF1). The limnocrone LIM had a very high electrical conductivity (1511  $\mu\text{S}/\text{cm}$ ). The oxygen concentration varied from 4.6 mg/l (GF2) to 10.0 mg/l (OFb2) and the saturation from 47% to 98%. The limnocrone LIM had very low values, with an oxygen concentration of 0.3 mg/l (3%). Discharge varied from 2 L/min (Buf2) to 144 L/min in VCh3 (Table 1). Several springs had a much lower discharge in autumn (VCh2, GF1-GF3, BUF1), and the spring BUF5 did not show any surface flow in autumn.

In the springs a total of 63 species and higher taxa were recorded. The number of taxa in any spring was between 4 (BUF3) and 24 (BUF2). Fifty percent of the taxa only occurred in one or two springs, one third of the taxa only occurred in one single spring. The most diverse order were Diptera (19 taxa), Trichoptera (17 taxa), and Plecoptera (12 taxa) (Table 3). Among the Trichoptera and Plecoptera, 15 of 26 species are listed on the Swiss Red List (Lubini et al. 2012). The stonefly *Nemoura undulata*, a highly isolated species threatened with extinction, was found in the spring at the highest location within the study area on the Alp Buffalora, BUF3. *Acrophylax zerberus*, a near-endemic species (Oertli et al. 2008), *Drusus melanchaetes*, *Drusus nigrescens* and *Rhyacophila bonaparti* are vulnerable Trichoptera. Also the molluscs *Quickella arenaria* and *Vertigo genesii* show a restricted distribution.

For the PCA conducted with the abiotic data, the limnocrone LIM was excluded because of its extremely different physico-chemistry. The PC axes one and two of the PCA explained 35% and 21% of the variance, respectively. The first three PC axes together explained 71% of the variance. Component one is

Table 1 – Site description

Site	Area	Altitude [m]	Swiss coordinates	Spring type
Q1	Val Ffur	1832	811'545/171'995	Rheocrone
Q2		1920	810'945/172'490	Rheocrone
Q3		1960	810'875/172'555	Rheocrone
Q4		1900	810'740/172'600	Helocrone
Q5		1780	811'720/171'870	Rheocrone
Q6	Val Chavagl	1975	813'160/170'910	Rheocrone
Q7		1965	813'100/170'920	Rheocrone
Q8		1845	812'575/171'605	Rheocrone
GF1	God dal Fuorn	1800	811'875/171'680	Helocrone
GF2		1802	811'725/171'645	Rheocrone
GF3		1805	811'760/171'620	Rheocrone
Lim		1822	812'185/171'675	Limnocrone
FiW		1770	811'630/171'845	Limnocrone
Buf1	Buffalora	2177	816'280/168'880	Limnocrone
Buf2		2176	816'260/168'830	Rheocrone
Buf3		2255	815'560/169'100	Rheocrone
Buf4		2163	816'365/169'025	Rheocrone
Buf5		1980	816'360/169'900	Helocrone
OFb2		1960	816'120/170'560	Rheocrone

Table 2 – Abiotic characteristics of the investigated springs. Electrical conductivity and oxygen content and saturation are given as means of two measurements. \* the physico-chemistry of Buf5 was monitored once; the pH is therefore a single measurement

Site	pH [median]	conductivity [ $\mu\text{S}/\text{cm}$ ; 25°C]	O <sub>2</sub> [mg/l]	O <sub>2</sub> [%]	discharge [l/min]	temperature [°C; summer]	temperature [°C; autumn]
Q1	7.9	273	8.1	96	9.6	5.0	5.3
Q2	7.4	328	7.5	93	3.6	5.7	6.7
Q3	7.8	286	8.1	96	6.0	4.5	4.8
Q4	8.2	275	7.7	93	9.6	5.2	5.4
Q5	8.0	275	9.6	95	36.0	5.2	5.7
Q6	8.3	240	9.5	93	24.0	3.0	4.8
Q7	8.5	266	8.9	87	9.6	4.0	4.7
Q8	8.1	276	9.6	94	144.0	3.0	5.2
GF1	8.3	575	6.6	68	3.6	5.2	7.0
GF2	8.2	324	4.6	47	4.2	3.8	6.5
GF3	8.0	226	8.0	79	4.2	5.9	6.0
Lim	7.5	1511	0.3	3	16.8	7.0	6.9
FiW	7.6	319	6.9	84	3.6	4.4	6.7
Buf1	7.6	161	7.7	79	14.4	4.9	5.2
Buf2	7.7	213	8.4	91	1.8	4.4	7.4
Buf3	8.3	107	9.5	93	16.8	2.8	3.0
Buf4	7.9	259	6.8	73	5.4	2.7	7.4
Buf5	7.9*	–	–	–	6.0	4.4	–
OFb2	8.1	185	10.0	98	78.0	4.4	4.6

dominated by the oxygen concentration (eigenvector=0.505) on the positive axis and by the electrical conductivity (eigenvector=-0.517) on the negative axis. GF1 and GF2 show a high load on the negative axis of PC1. Component two is dominated by the altitude (eigenvector=0.611) on the positive axis separating BUF1-BUF4 from the other springs and by the pH (eigenvector=-0.408) and the discharge (eigenvector=-0.408) on the negative axis.

In the nMDS analysis, the springs in the different areas were plotted together. Only the springs of the



Table 3 – List of presence (+) and absence (–) of the 63 taxa at each investigated site.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	GF1	GF2	GF3	LIM	FIW	BUF1	BUF2	BUF3	BUF4	BUF5	OFb2
<b>Turbellaria</b>																			
<i>Crenobia alpina</i> (Dana, 1766)	+	+	+	+	+	+	+	+	+	+	+	–	+	+	+	+	+	+	+
<b>Oligochaeta</b>																			
<i>Galba truncatula</i> (Müller, 1774)	–	+	–	–	–	–	–	–	+	+	–	+	+	–	+	–	+	+	–
<i>Quickella</i> cf. <i>arenaria</i> (Bouchard-Chanteraux, 1837)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Columella</i> cf. <i>edentula</i> (Draparnaud, 1805)	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
<i>Vertigo genesii</i> (Gredler, 1856)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<b>Bivalvia</b>																			
<i>Pisidium</i> cf. <i>personatum</i> (Malm, 1855)	–	–	–	–	–	–	–	–	–	+	+	+	+	+	–	–	+	+	–
<b>Acari</b>																			
<i>Ostracoda</i>	–	–	–	+	–	–	–	–	+	+	+	+	+	+	+	–	+	–	–
<b>Ephemeroptera</b>																			
<i>Baetis alpinus</i> (Pictet, 1843)	+	–	–	–	–	–	–	+	–	–	–	+	–	–	+	–	–	–	+
<i>Rhithrogena loyolae</i> (Navas, 1922)	–	+	–	–	+	–	–	+	–	–	–	–	+	–	–	–	–	–	–
<b>Plecoptera</b>																			
<i>Leuctra armata</i> (Kempny, 1899)	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
<i>Leuctra</i> gr. <i>braueri-murayii</i>	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
<i>Leuctra</i> cf. <i>rosinae</i> (Kempny, 1900)	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	+	–	–
<i>Amphinemura</i> sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
<i>Nemoura cinerea</i> (Retzius, 1783)	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
<i>Nemoura mortoni</i> (Ris, 1902)	–	–	–	+	–	–	–	–	–	–	–	–	–	+	+	–	+	+	+
<i>Nemoura</i> cf. <i>sinuata</i> (Ris, 1902)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
<i>Nemoura undulata</i> (Ris, 1902)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
<i>Nemurella pictetii</i> (Klapalek, 1900)	+	–	–	–	–	–	–	–	+	+	+	–	+	+	+	–	+	+	–
<i>Protonemura</i> cf. <i>lateralis</i> (Ris, 1902)	+	–	–	+	+	–	+	+	–	–	–	–	+	+	+	–	–	–	+
<i>Dictyogenus alpinum</i> (Pictet, 1841)	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–
<i>Isoperla rivulorum</i> (Pictet, 1841)	–	–	–	–	+	–	–	+	–	–	–	–	+	–	+	–	–	–	+
<b>Coleoptera</b>																			
<i>Agabus bipustulatus</i> (Linnaeus, 1767)	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
<i>Hydroporus</i> sp.	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Halipplus lineatocollis</i> (Marsham, 1802)	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
<i>Limnebius</i> sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
<b>Trichoptera</b>																			
<i>Beraea pullata</i> (Curtis, 1834)	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–
<i>Lithax niger</i> (Hage, 1859)	–	+	+	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	+
<i>Acrophylax zerberus</i> (Brauer, 1867)	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Chaetopterygini/Stenophylacini	–	–	+	+	–	–	+	–	–	–	–	+	–	–	+	–	–	–	+
<i>Consorophylax consors</i> (McLachlan 1880)	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Drusus biguttatus</i> (Stephens, 1837)	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Drusus chrysotus</i> (Rambur, 1842)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Drusus discolor</i> (Rambur, 1842)	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Drusus melanchaetes</i> (McLachlan, 1876)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
<i>Drusus monticola</i> (McLachlan, 1876)	+	–	–	–	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–
<i>Drusus nigrescens</i> (Meyer-Dür, 1875)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Limnephilus coenosus</i> (Curtis, 1834)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
<i>Parachiana picicornis</i> (Pictet, 1834)	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–	–
<i>Plectrocnemia conspersa</i> (McLachlan, 1871)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Rhyacophila bonaparti</i> (Schmid, 1947)	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Rhyacophila glareosa</i> (McLachlan, 1867)	–	–	+	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
<i>Rhyacophila sensu stricto</i>	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<b>Diptera</b>																			
Ceratopogoninae	–	+	–	+	–	–	–	–	+	+	–	+	+	+	+	–	+	–	+
Chironomidae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Prodiamesa olivaceae</i> (Meigen, 1818)	–	–	–	–	–	–	–	–	–	+	–	+	+	+	–	–	+	–	–
Tanypodinae	–	–	+	+	+	–	–	–	–	+	+	–	+	–	+	–	+	–	–
Chironomini	–	–	–	+	–	–	–	–	–	+	+	+	+	–	+	–	–	+	–
Tanytarsini	+	+	+	+	–	+	+	–	+	+	+	+	+	+	+	–	+	–	+
Culicidae	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
<i>Dixa</i> sp.	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<b>Diptera (cont.)</b>																			
Dolichopodidae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Clinocerinae	–	–	+	–	+	–	–	+	–	–	–	–	–	–	–	+	–	–	–
Limoniinae	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Dicranota</i> sp.	–	–	+	+	–	–	–	+	–	+	–	–	–	–	+	+	–	–	–
<i>Eleophila</i> sp.	+	–	–	–	–	–	–	–	–	+	–	+	–	+	+	–	–	–	–
Psychodidae	–	–	+	+	–	–	–	–	–	+	–	–	–	–	–	+	–	+	–
<i>Oxycera</i> cf. <i>pardalina</i> (Meigen, 1822)	+	–	+	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–	–
<i>Oxycera</i> cf. <i>pseudoamoena</i> (Dusek & Rozkosny, 1974)	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–
<i>Oxycera rara</i> (Scopoli, 1783)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>Thaumalea</i> sp.	–	+	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
<i>Tipula</i> sp.	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Number of Species	14	17	21	18	14	5	9	12	14	16	15	10	20	20	24	4	17	10	14

Alp Buffalora were scattered all over the ordination (Figure 3). The limnocene LIM and the highest spring BUF3 differed the most. The ANOSIM confirmed overall significant differences between the sampling areas ( $R = 0.352$ ,  $p = 0.001$ ). The differences between the springs in the Val Chavagl and around God dal Fuorn were greatest ( $R = 0.744$ ,  $p = 0.018$ ), whereas the springs of the Alp Buffalora were not significantly separate from the springs in the other sampling areas. A grouping of the springs according to their electrical conductivity and their oxygen content revealed a significant separation ( $R = 0.423$ ,  $p = 0.003$  and  $R = 0.328$ ,  $p = 0.006$ , respectively). The BEST analysis also revealed that the electrical conductivity and the oxygen content influenced the composition of the macrozoobenthic assemblages most ( $q = 0.390$ ), although the correlation is not high. Other abiotic factors did not have a significant influence on the composition of the macrozoobenthic assemblages in the springs. The location of the springs in a particular valley is most important.

## Discussion

Electrical conductivity and oxygen saturation were identified as the main environmental factors differentiating the springs and their macrozoobenthic assemblages. The springs at the Alp Buffalora had the lowest electrical conductivity. This is most likely due to their location above the tree line with a naturally shorter retention time of the groundwater in the aquifer (Cantonati et al. 2006). Overall we consider the differences of the abiotic parameters between the springs as moderate. The study area provides similar environmental conditions for the macroinvertebrates as all springs are situated on the same geological layer. The altitudinal difference between the lowest and highest spring was less than 500 m, an altitudinal gradient of the macroinvertebrate assemblages was therefore not evident. However, all springs in the area of the Alp Buffalora outside of the SNP are above the tree line, thus minimizing the input of leaf-litter as an important food-source. Even springs above the tree line seem to be heterotrophic systems with simple food webs and mostly omnivore invertebrates (Robinson et al. 2008). The limnocene spring LIM, which was also investigated by Nadig (1942), differs morphologically from the other springs due to its large size (62 m<sup>2</sup>) and the depth of the pond (2.1 m). The very high electrical conductivity, which was also reported by Döring (2002) and Nadig (1942), is caused by a high sulphate concentration (Döring 2002). The extremely low oxygen concentrations emphasize the special and even hostile character of this spring.

Comparisons with the Red List of molluscs (Rüetschi et al. 2012) and of the Ephemeroptera, Plecoptera and Trichoptera (Lubini et al. 2012) showed that the SNP is an important nature protection zone. The two endangered mollusc species found are both associated with wet conditions occurring on wet

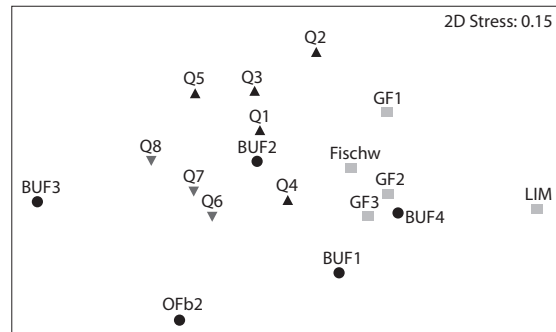


Figure 3 – Non-metric multidimensional scaling (nMDS) of the investigated springs based on the average of the quantitative faunistic sampling; similarity index: Bray-Curtis, transformation: fourth root; factor: area; ▼ = Val Chavagl; ■ = God dal Fuorn; ▲ = Val Ftur; ● = Buffalora; Analysis of Similarities (ANOSIM) with area as discriminating factor:  $R = 0.352$ ,  $p = 0.001$ .

meadows and also next to intact natural spring habitats (Boschi 2011), which still exist in the SNP. *Quickella arenaria* is vulnerable because of its fragmented habitat in the Alps. With climate change, this species might be replaced by more common species such as *Succinella oblonga* (Turner et al. 1998). *Vertigo genesii* has its main distribution in the canton Grisons. *V. genesii* is an endemic species for Switzerland (Turner et al. 1998) and highly endangered (Boschi 2011). According to Waringer & Graf (2011), *Drusus melanchaetes* and *Drusus nigrescens* are endemic Trichoptera for the Western Alps, with *D. melanchaetes* restricted to an altitudinal distribution between 1960 m and 2560 m (Malicky 2004). In the SNP they probably reach the eastern border of their distribution area, they do not, for example, occur in Gesäuse National Park (Gerecke 2012). The species of the Drusinae are generally often restricted to small distribution areas and are typical cold-stenothermic species, which only occur in water bodies of high water quality and constant low water temperatures. They are therefore valuable bioindicators (Graf et al. 2002; Waringer & Graf 2011). Overall, six different species of the genus *Drusus* were found in this study, most of them in the small Val Ftur. Many spring specialists are found among the Trichoptera listed as vulnerable (Lubini et al. 2012). The four vulnerable Trichoptera found in this study are still common in Switzerland. Their habitat, Alpine springs, is however severely endangered (Lubini et al. 2012). The highly endangered Plecoptera *Nemoura undulata* is an endemic species of the Central Alps above 1800 m and was only detected in Switzerland on the Furkapass and in the SNP (Lubini et al. 2012). Two specimens of *N. undulata* were also found in Berchtesgaden National Park in Germany (Gerecke & Franz 2006) but not in Gesäuse National Park in the eastern part of Austria (Gerecke et al. 2012). In this study *N. undulata* was only found in the spring BUF3 outside the SNP on the Alp Buffalora. This spring is situated above the tree line and is composed of few inorganic substrates. Investigating

more springs above the tree line within the SNP and Val Müstair BR would therefore be most desirable.

On the one hand, similar species assemblages were detected in the investigated springs due to similar environmental prerequisites. On the other hand, we found large small-scale differences between the species assemblages of the springs as one third of the taxa only occurred in one single spring. Many of the endangered or vulnerable species in particular only occurred in one spring. This underlines the high degree of individuality of the spring fauna (Bonettini & Cantonati 1996; Weigand 1998; Lencioni et al. 2011). Moreover, the study revealed a grouping of the springs according to the valley or area they are situated in. This higher similarity of the macroinvertebrate assemblages of neighbouring springs points to the restricted dispersal abilities of spring species. This is especially true of the Drusinae, which almost exclusively occurred in the Val Ftur. It is therefore likely for species to become extinct if springs get damaged or polluted.

The springs at Alp Buffalora in Val Müstair BR outside of the SNP are not as strictly protected as the springs within the park borders. They are at least potentially threatened by anthropogenic impacts. Steiner (2005) mentioned fencing in BUF3 to prevent cattle entering the springhead. This was not evident in 2012. Despite the anthropogenic impact and despite their higher location, the spring fauna did not significantly differ from the spring fauna within the SNP. The species richness was similar to the species richness within the park and endangered or at least vulnerable Plecoptera species occurred as well. However, Drusinae were completely absent. Expanding the area of the SNP would be helpful in order to protect sensitive habitats such as springs. In a first step, fencing springs can be helpful to prevent damages to the springs and their surroundings. Monitoring of the springs in the SNP is being continued in 2013. However, a comprehensive monitoring campaign, such as the ones undertaken in Berchtesgaden and Gesäuse National Parks would be desirable to understand similarities and differences between protected areas. Moreover, long-term studies are necessary to understand the consequences of global climate change on spring ecosystems and for the protection of springs (Gerecke et al. 2011). The study stresses the importance of protected areas as sanctuaries for endangered species living in unique habitats such as springs.

## Conclusion

In the high-altitude springs in the SNP and also in Val Müstair BR, macrozoobenthic assemblages of a high degree of individuality were found despite similar environmental prerequisites. Rare and endemic species occur in low abundances and at isolated patches. They are in danger of extinction if springs get disturbed. Considering global climate change and anthropogenic impacts, the SNP provides a valuable sanctuary for the

cold-stenothermal fauna in Alpine springs. Moreover, protection of the springs outside of the park, especially in Val Müstair BR, would be desirable as they are also inhabited by endangered species. A comprehensive monitoring of the springs in this area would help to further assess the value of the SNP as a sanctuary for endangered and endemic spring species.

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