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Assessing the stability of stonefly (Plecoptera) biodiversity in the Swiss National Park

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An inventory of stonefly species in the alpine Swiss National Park was conducted during 2011 and 2012 over 33 sites in various stream types, from springs and brooklets to larger rivers. 34 species were identified, representing 60% of the central eastern Alps fauna. Most species were widespread alpine species, 5 were alpine endemics and 3 species were threatened in Switzerland. Cold stenotherm and rheophilic species dominated, but eurytherm and limnophilic species appeared in streams with high habitat diversity. Historical stonefly data, collected between 1934 and 1964, enabled a long-term comparison. The stability of the stonefly fauna over more than half a century is remarkable. The low impacted stream morphology and flow regime, as well as diversity of stream types and substrate are important biodiversity drivers. In the present study one species was missing, but has always been rare in the Park. Three species are new for the Park. One species expands to higher locations and this could be related to climate changes. The present species data basis is particularly valuable for assessment of further impacts, as some changes are only perceptible at the species level.

Keywords: Plecoptera, freshwater ecology, alpine streams, biodiversity, species, protected area

INTRODUCTION

The Swiss National Park (SNP) includes a complex hydrological network in a multitude of small catchment areas including springs, brooklets, brooks, torrents, rivers, ponds and lakes. These aquatic environments shelter a characteristic fauna including the insect order Plecoptera (Stoneflies). Aquatic insects in this region have been studied by Adolf Nadig between 1934 and 1942 (Nadig 1942), and by Jacques Aubert from 1949 to 1964 (Aubert 1965). Nadig specialized in spring fauna, whereas Aubert concentrated on the insect order Plecoptera. He collected in the SNP as well as in the neighbouring regions, and also studied the specimens collected by Nadig. The results were presented in a volume of the series dedicated to the research activities in the SNP (Aubert 1965). Stoneflies in the SNP were poorly studied during the following decades (less than 10 new records in the national database CSCF, as of October 2013). Nevertheless, macroinvertebrates were still collected during long term monitoring programs and stonefly records have recently been added to the national database. A second inventory of the stonefly species was conducted in 2011 and 2012, in order to assess today's species composition and distribution. Comparison with historical data is therefore possible and sets the basis for a long term monitoring.

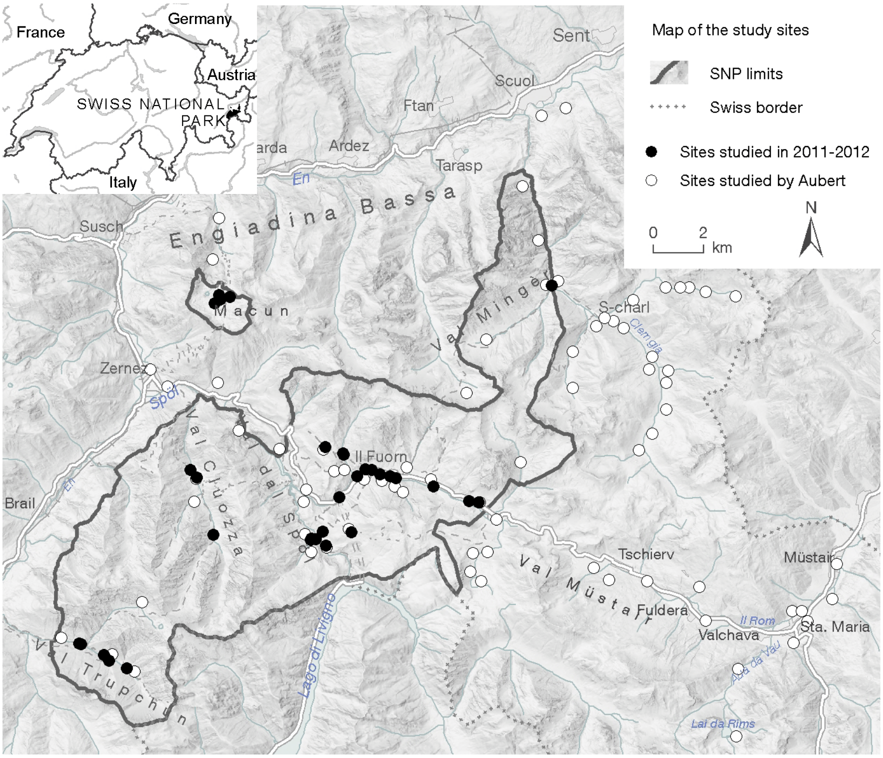

Fig. 1: Map of sites studied in 2011-2012 (○) and by Aubert (1965) (●).

MATERIAL & METHODS

Study area

The SNP is located at the very south-east corner of Switzerland in the canton of Graubünden (Fig. 1). Created in 1914, it is the oldest national park in the Alps and central Europe, classified by IUCN as a category 1 nature reserve. It covers an area of 170 km^2 at a mean altitude of 2320 m asl. 31 % of the SNP is covered by forest, 17 % by grassland, the rest has no vegetation cover and glaciers are absent.

Characteristics of the catchment area

The hydrological network of the SNP belongs to the Inn catchment and therefore its waters drain via the Danube River into the Black Sea. Streams have a natural alpine nival runoff regime, except the River Spöl, which is regulated by the Livigno dam since 1962, and the River Clemgia, which is regulated since 1967. The Ofenpass road crosses the Park and some streams are very locally impacted (bridges). Beyond that the freshwater system is morphologically pristine. Most streams are classified as alpine, situated over 1800 m except the Spöl valley, the

River Clemgia and the lower section of the River Fuorn (beneath Il Fuorn). The maximum elevation of nearly all catchment basins is above 3000 m asl. Water temperatures rarely exceed 10 °C (Eisenhut 2013). The flow regime is very dynamic, with low flow in winter, higher and fluctuating flows during summer, which is influenced by snowmelt and heavy thunderstorms. Rivers have a wide and rocky streambed. Springs are rheocrenes, except one limnocrene, originating from a pool at Il Fuorn. Because of mostly permeable soils, ponds and lakes are the exception, and the Macun-lakes belong to the SNP since 2000.

Tab. 1: Sampling sites and sampling periods.

Stream, location	coord. X	coord. Y	altitude (m)	1-4.6.2011	5-8.9.2011	2-3.4 or 15.5.2012	15-18.6.2012	24-31.7.2012	13-16.9.2012
Ova dal Fuorn, Il Fuorn	811848	171847	1781	x	x	x			
God sur Il Fuorn, brook	811603	171869	1777	x	x	x			
Champlönch, brook	810000	172760	2010	x	x				x
Ova da Val Ftur, Val Ftur	810717	172511	1871	x	x				
Ova da Stabelchod	714425	171525	1916	x	x	x			
Ova da Val Chavagl	812830	171530	1857	x	x				
Ova dals Pluogls	815740	170615	1940	x	x				
Alp La Schera, brook	811028	169370	2087	x	x				
Val Ftur, brook	810740	172470	1888	x	x				
Clemgia, Pradatsch	819055	179221	1666	x	x				
Spring, Spöl right bank	809885	169378	1754				x	x	x
Spring, Plan da l'Acqua Suot	809416	169065	1752				x	x	x
Ova da l'Acqua, Plan da l'Acqua Suot	809450	169115	1745				x	x	x
Spring, Spöl left bank	809619	169070	1712				x	x	x
Ova da Cluozza, Chamanna	804860	171536	1810				x	x	x
Spring near path, Val Cluozza	804604	171842	1820				x	x	x
Spring, opposite to Val dal Fuorn	812581	171598	1841				x	x	x
Spring, God dal Fuorn (GFQ1)	812178	171678	1822				x	x	x
Ova da Trupchun, Alp Trupchun	802059	163915	2024				x	x	x
God Trupchun, brook	801351	164225	1991				x	x	x
Ova da Trupchun, Alp Purcher	800250	164885	1868				x	x	x
Spring, Alp Purcher	800156	164901	1855				x	x	x
Spring Dschembrina, Val Trupchun	801157	164451	1975				x	x	x
Spring, Ova dals Pluogls	816117	170555	1969					x	x
Ova dal Fuorn, under O. Stabelchod	814320	171195	1891			x			
Ova dal Fuorn, Punt La Drossa	810560	170755	1695			x			
Ova da Val Ftur, lower Val Ftur	811271	171607	1764			x			
Macun, Aua da Zeznina	806193	178766	2594					x	
Macun, N Lai Sura	805748	178832	2631					x	
Macun, Lais d'Immez	805805	178661	2623					x	
Ova da Cluozza, Plaun Sassa	805532	169254	1935				x		
Punt Periv, brook	810023	168814	1707				x		
Macun, springbrook	805579	178503	2662					x	

We considered 5 types of freshwater habitats:
- mid-sized streams, flowing on large valley floors: rivers
- lateral 2nd order tributaries with variable flow over the year and steep slope (> 7%): torrents
- small 1st order streams flowing in forested or open areas (former pastures), gentle slope (< 3 %): brooks
- springs and their spring brooklets: spring brooklets
- standing water bodies: ponds and lakes

Sites and sampling methods

In 2011 and 2012, 23 primary sites were sampled two or three times each (Tab. 1) for three groups of aquatic insects, Ephemeroptera, Plecoptera and Trichoptera. These sites are representative of stream types and different valleys in the SNP, and had already been sampled by Aubert or Nadig (Fig. 1). Some secondary sites (Tab. 1) were sampled to look for early emerging species or using the opportunity to access and sample particular systems (e.g. Macun). Sampling methods were combined. Larvae were collected in all aquatic habitats using a kick-net and qualitative sampling by hand. Adults were collected in the riparian vegetation, using a sweep net or a beating sheet. Each site was prospected for 30 to 45 minutes depending on the stream size. Insects were preserved in 80 % ethanol and the probe was labelled with date, name of the site and coordinates (Garmin etrex). Sampling periods were chosen according to the phenology of stonefly species: April-May (remaining snow cover in 2012), June (beginning of vegetation period), end of July, September. Stoneflies were identified to species level (Lubini *et al*. 2012a), the specimens preserved and labelled as recommended (Stucki 2012) and deposited in the collections of the Musée Cantonal de Zoologie in Lausanne (Switzerland). Data are recorded in the national database (CSCF, Neuchâtel).

Other data sources

Stoneflies from two long term monitoring programs focusing on benthic fauna were controlled or identified: monitoring of hydropower effects in the Spöl river basin (Mürle & Ortlepp 2012), biodiversity monitoring in ponds at the Macun Lakes region (Indermühle & Oertli 2007). Data from the national database (CSCF, Neuchâtel) was provided, including historical data from Nadig (1942) and Aubert (1965) who sampled 90 stream sites in the SNP region, 40 of which were located inside the SNP limits.

Data analyses

The species were classified considering their ecological preferences for current and temperature using the system of Moog (1995, 2002) completed by Graf *et al*. (2009). Temperature preference was not documented for *Taeniopteryx kuehtreiberi*, and current preference was not documented for *Leuctra rosinae* and *Protonemura algovia*. For *Rhabdiopteryx harperi* and *Leuctra muranyii*, the preferences of *R. alpina* and *L. braueri*, respectively, were used because the species have ecological similarities concerning zonation and habitat.

Similarity (%) of the species composition between different streams was calculated using Jaccard-index (Jaccard 1908). Values ≥ 64 % are considered as simi-

Tab. 2: Species list: Species in **bold** are new for the SNP; — [A]: Categories as in Red Data List of Switzerland (Lubini *et al*. 2012b); — [B]: Conservation priorities as in the Swiss list of national priority species (OFEV 2011); — [C]: Responsibility as in the Swiss list of national priority species (OFEV 2011); — in grey, species not found since 1951.
Notes from 1 to 11: leg. or det. when not by the authors, and species names before nomenclature changes and corrections vs Aubert (1965); — [1]: syn. *Perlodes intricata* (Pictet 1841); — [2]: first records leg. Ortlepp 2008, syn. *Perla maxima* (Scopoli 1763); — [3]: re-identification of *Chloroperla tripunctata* (Scopoli 1763); — [4]: syn. *Chloroperla montana* (Pictet 1841); — [5]: confused with *Rhabdiopteryx alpina*; — [6]: leg. Ortlepp, det. Mürle; — [7]: re-identification of *Protonemura nimborella* Moselyi 1930; — [8]: leg. Mürle, det. Mürle; — [9]: leg. Ortlepp, det. Knispel; — [10]: re-identification of *Leuctra braueri* Kempny 1898; — [11]: leg. Aubert, det. Aubert.

			Threatening category[A]	Alpine endemite (E)	National priority[B]	National responsibility[C]	Last records in the SNP
Perlodidae	*Dictyogenus alpinum*	(Pictet, 1841)					2012
	Dictyogenus fontium	Ris, 1896	NT				2012
	Isoperla rivulorum	(Pictet, 1841)					2012
	Perlodes intricatus[1]	(Pictet 1841)					2013
Perlidae	***Perla grandis***[2]	Rambur 1842					2012
Chloroperlidae	*Chloroperla susemicheli*[3]	Zwick 1967					2012
	Siphonoperla montana[4]	(Pictet 1841)	NT				2012
Taeniopterygidae	*Rhabdiopteryx alpina*	Kühtreiber, 1934	NT		4	2	2012
	Rhabdiopteryx harperi[5]	Vinçon & Murányi, 2008	VU	E	3	2	2012
	Rhabdiopteryx neglecta	(Albarda, 1889)					2012
	Taeniopteryx kuehtreiberi[6]	Aubert, 1950					2013
Nemouridae	*Amphinemura standfussi*	(Ris, 1902)	NT				2012
	Protonemura algovia[7]	Mendl 1968	VU	E	3	2	2012
	Protonemura brevistyla	(Ris, 1902)					2012
	Protonemura lateralis	(Pictet, 1836)					2012
	Protonemura nimborum	(Ris, 1902)					2012
	Protonemura nitida	(Pictet, 1835)					2012
	Nemoura cinerea	(Retzius, 1783)					2011
	Nemoura mortoni	Ris, 1902					2012
	Nemoura obtusa	Ris, 1902	NT		4	2	2012
	Nemoura sinuata	Ris, 1902	NT		4	2	2012
	Nemoura undulata	Ris, 1902	CR	E	1	2	2012
	Nemurella pictetii	Klapalek, 1900					2013
Capniidae	*Capnia nigra*	(Pictet, 1833)					2012
	Capnia vidua	Klapalek, 1904	NT				2012
Leuctridae	*Leuctra alpina*	Kühtreiber, 1934					2012
	Leuctra armata	Kempny, 1899	NT		4	2	2012
	Leuctra helvetica[8]	Aubert, 1956	EN	E	2	2	2014
	Leuctra inermis	Kempny, 1899					2012
	Leuctra major	Brinck, 1949					2012
	Leuctra moselyi[9]	Morton, 1929					2012
	Leuctra muranyii[10]	Vinçon & Graf 2011		E			2012
	Leuctra rauscheri	Aubert, 1957	NT				2012
	Leuctra rosinae	Kempny, 1900					2012
	Leuctra teriolensis[11]	Kempny, 1900					1951

Tab. 3: Species composition and abundances in the SNP streams studied since 2011. Presence of adult stages (A), larval stages (L) including exuviae. — *sampled by Mürle & Orlepp (2012) during the ongoing Spöl basin monitoring; — **species sampled in a stream type where it can obviously not originate from; not taken into account in the Jaccard index and the stream type diversity.

	Sites	Spöl*	Clemgia, Pradatsch	Ova dal Fuorn	Ova Cluozza	Ova Trupchun	Ova Ftur	Ova da Val Chavagl	Ova da l'Acqua, Plan da l'Acqua Suot	Ova da Stabelchod	God Trupchun, brook
	Freshwater habitat type (number of sites when grouped)	*river (4)*	*river*	*river (4)*	*river (2)*	*river (2)*	*torrent (2)*	*torrent*	*torrent*	*torrent*	*torrent*
Perlodidae	*Dictyogenus alpinum*		5L	1A 8L	10L	3L	2L	8L	6L	1L	1L
	Dictyogenus fontium			1A**							
	Isoperla rivulorum	2L	8A	10L	2L	1L		1L	1A 2L		
	Perlodes intricatus			9L	2A 1L			1L	1L	2L	
Perlidae	*Perla grandis*			2L							
Chloroperlidae	*Chloroperla susemicheli*	1A 1L	1L		1L				1A 19L		
	Siphonoperla montana		3L	3L	2A 7L	1L		10L	2L	1L	
Taeniopterygidae	*Rhabdiopteryx alpina*				1A						
	Rhabdiopteryx harperi			12L			6A 14L			8A 13L	
	Rhabdiopteryx neglecta			2A 10L			8L				1A
	Taeniopteryx kuehtreiberi	1L*		2L *							
Nemouridae	*Amphinemura standfussi*										
	Protonemura algovia			1L	1L						
	Protonemura brevistyla			1A 2L	20L	8L		1L	19L	11L	8L
	Protonemura lateralis		2L	2L					2L		1A 1L
	Protonemura nimborum			15L			2L			1A	2A
	Protonemura nitida	4A	1A 5L	3L							
	Nemoura cinerea										
	Nemoura mortoni		9L	7L	14L			1L	3L	5L	5L
	Nemoura obtusa										
	Nemoura sinuata										
	Nemoura undulata									1L	
	Nemurella pictetii		1A**						12L		
Capniidae	*Capnia nigra*	3A 3L	1A								
	Capnia vidua			14A 2L							
Leuctridae	*Leuctra alpina*		1A								
	Leuctra armata										
	Leuctra inermis	101 A	4A	5A	2A			1A	1A	2L	
	Leuctra helvetica			6A *							
	Leuctra major	4A			9A				1A		
	Leuctra moselyi	6A									
	Leuctra muranyii			1A**							
	Leuctra rauscheri	2A	2A	7A		1A	1A				
	Leuctra rosinae	16A	2A	4A	14A 15L	2A		2A	1A	4A 1L	1A

lar, and values between 50 and 63% as a weak similarity (Smukalla & Friedrich 1994). Similarity was calculated for streams sampled with comparable effort (3 sampling periods). For streams sampled at different sites, a species list for the whole stream is given in Tab. 3 (e.g. Ova dal Fuorn, Ova da Val Ftur). Species in the adult stage were sometimes sampled in a stream type where they can obviously not originate from. These occurrences were pointed out in Tab. 3 and not taken into account in stream type diversity (Tab. 4) and Jaccard-index (Tab. 5).

RESULTS

Biodiversity and stream type

Today the SNP shelters 34 stonefly species (Tab. 2), which represent nearly 60 % of all 57 species listed in the "central eastern Alps" biogeographic zone (Lubini *et*

God sur Il Fuorn, brook	Val Ftur, brook	Ova dals Pluogls	Champlönch, brook	Alp La Schera, brook	Spring near path, Val Cluozza	Spring, God dal Fuorn (GFQ1)	Spring, Alp Purcher	Spring, Plan da l'Acqua Suot	Spring, Spöl right bank	Spring, Spöl left bank	Spring Dschembrina, Val Trupchun	Spring, Ova dals Pluogls	Spring, opposite to Val dal Fuorn	Macun
brook	*brook*	*brook*	*brook*	*brook*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*spring brooklet*	*lake*
							1L			1L				
4L	2L		1L	1A 3L	4A 5L								3L	
12L	1L	1A 13L	5L	2L		1A	10L					12A 5L		
1A		3L					2L						3L	
								1A 4L						
													2A	
														1A**
						1A**								
1A	4A		15A 3L	2A		2A								
1L		8A 9L			8A 5L							1A	1L	
1A 3L	1L	6A 6L	3L	1A 5L	1L	2A	4A 9L		2L	1A 7L		6A 9L	1A 16L	
1L														10A 11L
6L					1A									
			2L											
1A 7L	4L	3A 18L	5L	3A 2L			1A 3L					1L	2L	
4L	1L										1A 6L		1L	
1A	1L			2A 10L	1A 1L	1L		5L	1A	2A 1L			8A 5L	
					1A									
1A		4L				5A 27L	12A 19L	9L				15A 14L		
									4A					
	1L	3A	14A	60A 2L					6A	1A		2A	1A	
1A				2A				2A**	3A**	15A**				
													2A**	
4L	1A 8L		1L	20A 4L		10A 22L			5A 2L	21A 9L				
9L		24A					47A							
1A		4A 4L		1A	32L		2A				1A		11A	

al. 2012a, Gonseth *et al*. 2001). The fauna is composed mainly of widespread and characteristic alpine species, with additional presence of five endemic alpine species. *Nemoura undulata*, found in a spring brooklet and in the Ova Stabelchod (torrent), is a species limited to the central Alps, known from the Engadin (Inn valley), as well as *Leuctra muranyii*, *Protonemura algovia* and *Rhabdiopteryx harperi*. The geographic distribution of *Protonemura algovia* covers the entire Swiss Alps and was found in the SNP in the rivers Fuorn and Cluozza. *Leuctra muranyii*, previously confused with *L. braueri*, is a crenophilic species collected in several springs and spring brooklets in the SNP. In Europe its distribution is limited to the south-eastern Alps, from Italy to the Austrian upper Inn valley (Vinçon & Graf 2011) and, in Switzerland, is limited to the SNP, to the Val Müstair, lower Engadin and Puschlav valleys. *Leuctra helvetica* is an extensive alpine and epirhithral species, originally described from the Engadin (Val Sesvenna). In Switzerland it is limited to the

Tab. 4: Species diversity in different stream types as the sum of all observations since 2011.

	Rivers (N=5)	Spring brooklets (N=9)	Brooks (N=5)	Torrents (N=5)	Lakes (N= 2)
Total species	25	20	18	17	1
Arithmet. mean	12 ± 5	6 ± 2	10 ± 3	8 ± 3	
Maxima/Minima	19/6	10/2	16/8	12/5	

Engadin (Inn valley) and the Val Colla on the southern slope of the Alps. Detailed species composition and their abundances in the streams are given in Tab. 3. One third of the species are threatened or nearly threatened in Switzerland (Lubini *et al.* 2012b). *Nemoura undulata* is critically endangered (category CR), *Leuctra helvetica* is endangered (category EN), *Protonemura algovia* and *Rhabdiopteryx harperi* vulnerable (category VU). *Nemoura undulata* has a very high national priority (OFEV 2011).

The highest species diversity is found in rivers (Tab. 4) with some characteristic species: *Capnia nigra*, *C. vidua*, *Perla grandis*, *Protonemura algovia* (Tab. 3). Few species live in torrents where waterflow is reduced after the snowmelt and which even dry out in summer, like some of the streams at Alp Trupchun. Torrents and rivers have species in common, which were not found in other stream types in larval stages: *Rhabdiopteryx harperi*, *R. neglecta* and *Siphonoperla montana*. *Chloroperla susemicheli* and *Dictyogenus alpinum* were rare in brooklets. Lakes only shelter larvae of *Nemurella pictetii*. Numerous species live in springs and brooks.

Comparing communities between stream types shows that very few streams have a similar species composition, which might be related to distinct ecological characteristics, although stream physiography might be similar. Highest similarity was shown for a small group of brooks (Tab. 5). The brook at Alp La Schera had a similar stonefly fauna to that at Champlönch and the forested brook in Val Ftur (≥ 64 % of similarity) because the species composition included strongly creno-

Tab. 5: Similarity (%) of the species composition between different rivers, torrents and brooks (Jaccard 1908), 2011-2012 observations. Values ≥ 64 % (in bold) are considered as similar (Smukalla & Friedrich, 1994).

		rivers				torrents				brooks				
		Clemgia	Ova dal Fuorn	Ova Cluozza	Ova Trupchun	Ova Ftur	Ova da Val Chavagl	Ova da l'Acqua	Ova da Stabelchod	God Trupchun	God sur il Fuorn	Val Ftur	Ova dals Pluogls	Champlönch
rivers	Ova dal Fuorn	45												
	Ova Cluozza	41	41											
	Ova Trupchun	38	29	38										
torrents	Ova Ftur	7	21	7	11									
	Ova da Val Chavagl	43	42	**67**	56	9								
	Ova da l'Acqua	50	41	**71**	38	7	**67**							
	Ov da Stabelchod	29	45	47	33	27	**64**	47						
brooks	God Trupchun	27	37	40	30	38	36	36	42					
	God sur il Fuorn	33	40	27	22	5	33	40	30	28				
	Val Ftur	17	12	17	7	0	13	17	6	14	47			
	Ova dals Pluogls	31	33	31	36	0	42	50	27	33	47	29		
	Champlönch	18	13	11	8	0	14	18	6	15	33	**70**	31	
	Alp La Schera	29	21	22	14	0	29	29	24	21	53	**73**	36	**70**

Tab. 6: Similarity (%) of the species composition between different spring brooklets (Jaccard 1908), 2011-2012 observations. Values ≥ 64 % (in bold) are considered as similar (Smukalla & Friedrich, 1994).

		spring brooklets							
		Val Cluozza	God dal Fuorn	Pluogls	Val dal Fuorn	Alp Purcher	Dschembrina	Spöl rhight bank	Spöl left bank
spring brooklets	God dal Fuorn	18							
	Ova dals Pluogls	18	33						
	Val dal Fuorn	45	14	33					
	Alp Purcher	15	30	40	29				
	Dschembrina	13	0	0	20	11			
	Spöl right bank	20	38	22	25	8	0		
	Spöl left bank	20	38	20	21	18	0	**67**	
	Plan dal Acqua Suot	10	29	13	8	10	0	14	14

philic species such as *Amphinemura standfussi*, *Leuctra muranyii*, *L. armata*, *N. sinuata* and *Dictyogenus fontium*, beside species with larger ecological preferences. Within the group of torrents, only Ova da Val Chavagl, Ova da l'Acqua and Ova Stabelchod had a species composition considered as similar (Tab. 5). Ova Cluozza had also a similar composition to two of these torrents. No similarity between the species composition has been demonstrated for rivers, nor for spring brooklets with the exception of two in the Val Spöl (Tab. 6).

Ecological traits of the stonefly fauna

Most species are considered as being stenoecious, particularly regarding temperature tolerance, and most are cold stenotherm (Fig. 2). Cold and very cold stenotherm species were found in all stream types, as for example larvae of *Perlodes intricatus* (Tab. 3). However, five species, *Nemoura cinerea*, *Protonemura nitida*, *Nemurella pictetii*, *Leuctra inermis* and *Leuctra major* are eurytherm. The larvae of these species develop in habitats with wider temperature ranges (Tab. 3), such as lower Spöl, Clemgia and Ova dal Fuorn up to Il Fuorn as well as some tributaries (*Protonemura nitida*, *Leuctra inermis*), brooks with high amount of particulate organic matter (Champlönch, *Nemoura cinerea*) or deep in the sediment pores of rivers (*Leuctra major*). *Nemurella pictetii* has been found in some springs as well as in the lakes of Macun. These species occur all over Switzerland down to low altitudes.

The high amount of rheophilic species (Fig. 2) has to be related with the prevalence of steep streams and fluctuating discharge during summer. Species with no current preference (e.g. *Amphinemura standfussi*, *Protonemura nitida*) or limnophilic species (e.g. *Nemoura cinerea*, *Nemurella pictetii*) occur mainly in lakes, spring brooklets, but also in streams with slight slopes and calm, shallow riverbanks (e.g. transition to fens/marshland).

Temperature and current preferences of occurring species were not very different between stream types (Fig. 3). Rivers and torrents have a very low amount of limnophilic or current indifferent species. Cold stenotherm species were frequent

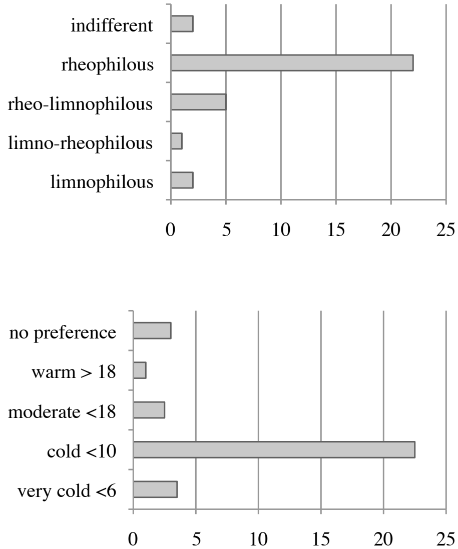

Fig. 2: Number of stonefly species in the SNP with distinct current (upper; n = 32) and temperature (lower; n = 33) preferences.

in springs and brooks, and their abundance was higher than in larger streams. The situation is opposite for warm tolerant species or temperature indifferent species.

Temporal development of the stonefly fauna

Aubert (1965) recorded 38 stonefly species. Four of them had been located outside the SNP in the neighbouring regions: *Amphinemura sulcicollis*, *Perla grandis* (syn. *Perla maxima*), *Leuctra mortoni*, *Leuctra moselyi*. A control of the «catalogue des espèces» in Aubert (1965) and the location of sampling sites gave evidence for two further species sampled outside of the SNP limits: *Leuctra sesvenna* and *Leuctra handlirschi*. *L. sesvenna* is mentioned in Aubert (1965) from the Aua da Sesvenna, Marangun, between 2300 and 2500 m asl. This location is situated outside the SNP, just east of Val Nüglia and Val Foraz. *L. handlirschi* is mentioned in Aubert (1965) only from the Aua da Zeznina, at Val Zeznina at 1930 m asl, located outside the SNP, just north of the Macun lakes. Aubert (1965) thus finally recorded 32 stonefly species for the SNP. Descriptions of new species have been published since then. Material of the concerned species, collected before 1965 by Nadig or Aubert (today in museum collections in Lausanne or Chur), has been revised during the Red List Project (Lubini *et al.* 2012b) or the present work and recorded in the national database. Unverified data was put aside (e.g. *Leuctra* spp. larvae, or specimens cited in publications, but not found in the corresponding museum collections). Corrections and nomenclature changes have been mentioned in Tab. 2.

The current stonefly inventory of 34 species includes two more than nearly 60 years ago. Examining changes in composition and distribution provided evidence that one species, *Leuctra teriolensis*, has not been collected in the SNP again. In fact, the only verified record before 1965 in the SNP is from the river Ova Spin at

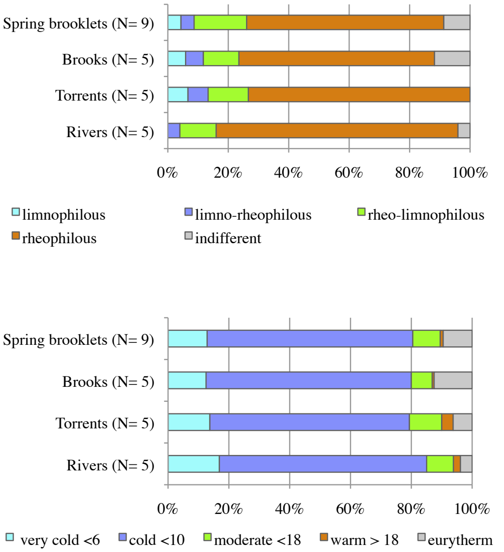

Fig. 3: Average composition of species (%) relative to their current (upper; n =32) and temperature (lower; n =33) preferences in different stream types.

Ova Spin. It means that the species was rare and could not be confirmed until now in the SNP. It was recently collected near the SNP, at Tschierv (Val Müstair) and at Susch (Inn Valley) (CSCF, Neuchâtel). The species is, however, common in the Alps. Three species collected in 2011 and 2012 were new for the SNP: *Leuctra moselyi*, *Perla grandis* and *Rhabdiopteryx harperi*. *R. harperi* was recently taken out from the *R. alpina*-species complex and described as new by Vinçon & Murányi (2009). Due to the lack of adult male specimens in Aubert's material, its presence in the SNP before 1965 cannot be confirmed or invalidated. Concerning *Perla grandis* and *Leuctra moselyi*, both species are widespread in Switzerland, mainly in streams below 1400 m as shown from *P. grandis* larvae records (Fig. 4). Both species were collected recently in the SNP with altitudinal limits of 1960 m asl (Ova dal Fuorn) and 1510 m asl (lower Spöl), respectively.

DISCUSSION

The results of the present study emphasized the stability of the stonefly fauna in the SNP over more than half a century. With one exception, all species, including endemic and rare species, were still sheltered in the protected area. Except for the River Spöl, this could be attributed to low impact on streambed morphology and the pristine runoff regimes, which are, in addition to high permeability of the riverbank substrate, important biodiversity drivers (Oswald 1990; Burgherr *et al*. 2003). Refuge habitats were provided by high streambed structure diversity combined with different stream types, which enhance ecosystem stability.

With 34 Plecoptera species, the present diversity reached the expected level, taking into account the harshness of the environmental conditions induced by nival flow regimes, dynamic stream morphology, low water temperatures, biogeographic region of the central Alps; all are important drivers of the stonefly species composition. Biodiversity of the three aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera in Switzerland is the highest between 700 and 1300 m asl (Altermatt *et al.* 2013) and then decreases with increasing altitude. These results were supported by different studies, like the pre-alpine Sense catchment study between 577 and 1400 m asl that registered 52 stonefly species (Zurwerra *et al.* 2000). Similar situations were observed in the Italian western Alps (Malicky *et al.* 2007) and the Isar catchment in Germany (Hering 1995).

Similarity of total Plecoptera species composition between streams was very low, except for a few streams of various types. Presence of some species seemed highly influenced by typology, like e.g. several crenophilic species present in a small group of similar brooks. Other factors may be important, like stream morphology or distance between sites. The three torrents with similar species composition had large gravel beds and catchment areas limited to a few km^2, but differed in their exposition (Haller 2013). The only similar spring brooklets in the Val Spöl had similar morphology and were situated very close. Springs in the SNP are of various types due to very different chemical and physical characteristics (Schlüchter *et al.* 2013). An extensive study of 20 springs and their direct surroundings in the Park, taking into account the entire macroinvertebrate fauna, was conducted recently (Felder 2013). Neighbouring springs were shown to have similar faunistical assemblage in contrast to springs situated farther away.

The recently confirmed presence of *Perla grandis* in the SNP needs a focus on its altitudinal distribution in Switzerland. First evidence of its presence in the larval stage above 1800 m asl was provided in the 1990s (national database, CSCF, Neuchâtel). Proportionally, *P. grandis* has been found more often at altitudes ≥ 1400 m asl after 1990 than before. The development of *P. grandis* larvae takes up to 3 years until emergence in spring, preferring streams with water temperatures from 8

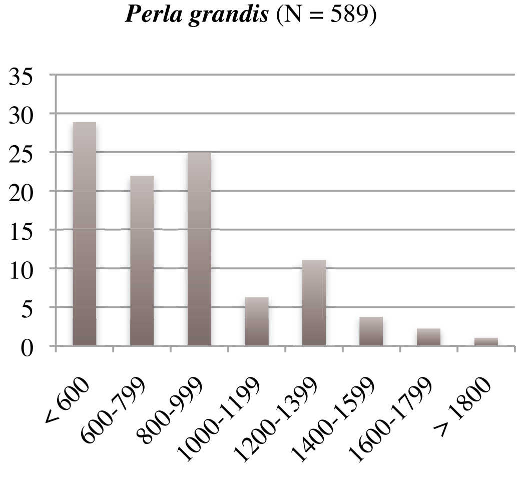

Fig. 4: Distribution (%) of *Perla grandis* records at the larval stage clustered by altitudinal classes (m asl) (national database, CSCF, Neuchâtel, October 2013).

to 20 °C, while maximum growth occurs during the warm season (Frutiger & Imhof 1997). As the species was not found before 2008 in the SNP despite the important collecting effort (Aubert 1965) and as grown larvae were found in 2012, we conclude that *P. grandis* colonized the Ova dal Fuorn. As water temperature has major influence on egg development duration and larval growth (Lillehammer *et al.* 1989), influence of temperature increase has to be considered. There is clear evidence for warming in the SNP since 1917, with a raise of annual air temperature of 1.6 °C per 100 years and a more pronounced seasonal air temperature increase of 1.7 to 5 °C (Bundesamt für Meteorologie und Klimatologie Meteoschweiz, 2013). Warming is higher in spring, during increase of larval growth that follows winter growth slowdown. As water temperature is related to air temperature (e.g. Mohseni & Stefan 1999), stream temperatures increased from 0.8 to 1 °C in lowland rivers (Hari *et al.* 2006). In small mountain streams, in absence of glacier melt-water as in the SNP, warming is also visible and mainly due to solar and long wave radiation, heat exchange with the sediment and dissipation of kinetic energy (Meier *et al.* 2003). Increase of water temperature in the SNP streams due to climate change is therefore highly probable and the possible impact on the freshwater fauna has to be documented further. Issues are for example the ability of species to maintain viable populations in the SNP and the consequences on cold stenotherm species living at high altitudes, which are expected to come under increasing physiological stress because they will not be able to migrate to higher elevations. The immigration of species from lower locations is expected to be a major driver of the freshwater biodiversity in the Alps (Burgherr *et al.* 2003; Robinson & Oertli 2009). Migration of eurytherm species to higher locations has already been observed as illustrated by the following examples. The eurytherm mayfly *Habrophlebia eldae*, has immigrated from Italy to the canton of Ticino (CH) (Wagner *et al.* 2007). North of the Alps, in the catchment area of the River Rhine, the stonefly *Leuctra geniculata* recently spread to higher locations (Vittoz *et al.* 2013).

The importance of long-term monitoring in freshwater systems, especially in protected areas, has been recently emphasized (Robinson *et al.* 2011). Biodiversity monitoring in Switzerland already includes Plecoptera species diversity on a systematic sampling grid covering the whole country (Altermatt *et al.* 2013). As some changes are only perceptible at the species level, the present SNP stonefly species data is of unique value since it allows long term comparisons with a historical data set over more than half a century time span. A SNP Plecoptera monitoring program would therefore benefit from both Swiss large scale program and the detailed SNP database (box 13.1 in Scheurer *et al.* 2014). Such a data base is also valuable for the assessment of climate change effects, the control monitoring after rehabilitation measures (Mürle & Ortlepp 2012) and other possible impacts. Alpine streams in Switzerland are particularly threatened by the country's much higher hydroelectric power production density (kWh/year and km^2) than in other neighbouring countries (Kissling *et al.* 2007) and in fact they are coming under increasing pressure through the planned energy transition from nuclear to non-fossil. The actual data base on the SNP is an important basis for a future reference system for the Swiss freshwater typology (Schaffner *et al.* 2013).

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Brochard C. & van der Ploeg E. 2014: Fotogids Larven van Libellen.

240 Seiten, über 650 Fotos, 17 x 24 cm, gebunden. KNNV Uitgeverij, Zeist (NL). ISBN: 9789050114868.
Preis: € 47.95, ohne Versand. Bezug:
http://www.knnvuitgeverij.nl/EN/webwinkel/insects/0/49807

Unter den Insekten gehören die Libellen (Odonata) zu den relativ gut erforschten Ordnungen. Nach wie vor ist jedoch nur wenig über ihr unscheinbares Leben als Larve unter Wasser bekannt. Es ist daher nicht erstaunlich, dass sich die vorhandene Bestimmungsliteratur grösstenteils auf das prominente Imaginalstadium der Libellen konzentriert.

Mit Erscheinen dieses neuen Exuvien-Fotoführers ist die Bestimmung der Larven und Larvenhäute (Exuvien) um einiges leichter und attraktiver geworden. Das ist der erste umfassende Foto-Larvenführer für alle in Nordwest-Europa vorkommenden Libellenarten. Im Mittelpunkt des Buches stehen die hervorragenden Fotos lebender Larven im letzten Stadium mit Habitusbildern und Detailansichten von verschiedenen Seiten. Zudem bekommt der Leser Informationen zur allgemeinen und artspezifischen Ökologie von Libellenlarven. Für die Artbestimmung mit Schlüssel wird auf den Exuvienführer* verwiesen, da sich das Exuvienbuch genauso für Larven im letzten Stadium eignet.

Die ersten Kapitel des Buches beinhalten eine Übersicht der bestehenden Bestimmungsliteratur europäischer Libellenlarven und -exuvien, eine kurze allgemeine Einführung zu Libellen, sowie eine Beschreibung ihres Lebenszyklus' mit interessanten Details. Für Einsteiger besonders wertvoll ist das Kapitel zur Anatomie der Libellenlarven. Anhand qualitativ hochwertiger Detailfotos wird dem Leser der äussere Körperbau der perfekt an das Unterwasserleben angepassten Larven nähergebracht. So können die verwendeten Fachbegriffe leicht verstanden und jederzeit nachgeschlagen werden.

Die folgenden Kapitel behandeln Lebensräume, Verhalten sowie Nahrungssuche, Prädation und Parasiten der Larven, ergänzt mit eigenen Beobachtungen der Autoren. So ist beispielsweise eine Libellenlarve abgebildet, die aus dem Wasser steigt, um eine frisch geschlüpfte Grosslibelle zu ergreifen. Im Kapitel «Libellenlarven züchten» erfährt der Leser wie und wo Larven am besten gefangen, wie sie transportiert und aufgezogen werden. Fotografen finden wertvolle Angaben zur technischen Installation für die Fotografie von Libellenlarven.

Das Kernstück des Buches besteht aus den reich bebilderten Portraits der über 80 behandelten Arten. Die artspezifischen Merkmale werden sowohl im Text beschrieben als auch mit detaillierten, hochwertigen Fotos dokumentiert. Pfeile weisen auf die wichtigen artspezifischen Merkmale hin. Zudem erfährt man, zu welcher Jahreszeit voll ausgewachsene Larven gefunden werden, mit welchen ähnlichen Libellen die beschriebenen Arten verwechselt werden können und wo sie vorkommen. Für den Bestimmungsschlüssel und die Beschreibung der Exuvien wird bei jeder Art auf die entsprechenden Seitenzahlen im Exuvienführer* verwiesen.

Einziger kleiner Nachteil für die deutschsprachige Leserschaft dieses Buches ist die holländische Sprache. Da das Holländische aber recht nahe mit dem Deutschen verwandt ist, ist der Text relativ leicht verständlich. Ausserdem sind die bezeichneten Fotos meist selbsterklärend.

Insgesamt ist «Fotogids Larven van Libellen» die ideale Ergänzung zum erwähnten Exuvienführer*. Das Werk ist sowohl für Experten als auch für interessierte Einsteiger sehr empfehlenswert. Für Spezialisten ist es ein ausgezeichnetes Nachschlagewerk. Besonders wertvoll sind die detaillierten Bilder jeder Art, die verschiedenen Farbvarianten und Zeichnungsmuster sowie die Hinweise zu Verwechslungsmöglichkeiten. Insektenliebhaber werden von den erstklassigen Fotos der lebendigen Larven begeistert sein und mit dem Buch einen Einblick in das erstaunliche und wenig bekannte Leben von Libellenlarven erhalten.

Daniela Keller

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* Brochard C., Groenendijk D., van der Ploeg E. & Termaat T. 2012. Fotogids Larvenhuidjes van Libellen, KNNV Uiteverij, Zeist (NL), 320 pp.