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Trichoptera diversity in Icelandic springs

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Abstract

The aim of this study was to characterize the Trichoptera fauna of freshwater springs in Iceland and to relate distribution of caddis larvae to environmental properties of the springs. Out of a total of 48 springs sampled, Trichoptera larvae were found in only eleven. Larval densities were low, as was species diversity. Only three of the 12 species known to occur in Iceland were found: *Apatania zonella*, *Limnephilus griseus*, and *Limnephilus affinis*. The occurrence of *A. zonella* in springs in North-Iceland may suggest that springs might play a role as refugia for this species that is otherwise excluded from the area by larvae of the predatory caddis species *Potamophylax cingulatus*, which seems to be absent from spring habitats. Caddis larval abundance was higher in rheocrene springs and in springs with sandy substrate, and decreased with increasing water temperature. Presence or absence of Trichoptera larvae, on the other hand, was not associated with any of the environmental variables measured.

Keywords: Caddis larvae, *Apatania zonella*, *Limnephilus griseus, Limnephilus affinis*, temperature

Introduction

Iceland is probably the country with the highest number of freshwater springs relative to its area. Eight of the ten largest springs in the world are found in Iceland (Óskarsdóttir 2011). Many of the numerous smaller springs emerge from the edge of porous lava fields and are highly variable in appearance as well as physical and chemical properties. One evident feature is the variability in hydraulic conditions, reflected in different spring types, i.e. limnocrene (pool-forming) and rheocrene (stream-forming) springs. Another peculiarity of Icelandic springs is their extreme range in temperature, from as cold as 2°C to geothermally heated hot springs. The benthic substrate in the immediate vicinity of the spring sources is often comprised of bare lava rock, and sometimes sand or gravel. Allochthonous input into the spring from surrounding terrestrial vegetation is usually low, as the majority of Iceland is not forested.

The aquatic insect fauna of Iceland is species-poor (Gíslason 2005; Hrafnsdottir 2005). Odonata are absent, and Plecoptera and Ephemeroptera are each represented by only one species (Tuxen 1938; Lillehammer *et al.* 1986). Chironomidae (Diptera) is by far the most abundant taxon in Icelandic freshwaters, as well as being the most species-rich taxon (Hrafnsdottir 2005). Trichoptera are represented by twelve species, belonging to the families Apataniidae (1), Limnephilidae (10), and Phryganeidae (1) (Ólafsson & Gíslason 2010). Distribution and habitat preferences of Icelandic Trichoptera have been studied for a wide range of freshwater habitats including spring-fed rivers and pond/pool habitats (Gíslason 1981a) but spring sources themselves had not been sampled in a systematic manner.

The invertebrate community in springs is influenced by a number of ecological factors, such as water temperature (Myers & Resh 2002), spring type (Govoni *et al.* 2018), and the type of benthic substrate (Ilmonen & Paasivirta 2005; von Fumetti *et al.* 2006). For case-bearing Trichoptera larvae, substrate type is especially important as a source of case-building material (Hanna 1961). Likewise, the amount of plant detritus falling into the spring from the surrounding vegetation (allochthonous material) might be a limiting factor not only as case-building material but also as food source for detritus-feeding species.

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The objectives of this study were 1) to assess the Trichoptera fauna of springs in Iceland, and 2) to determine if habitat characteristics could explain the distribution of caddis larvae in springs. We hypothesized that a) Trichoptera presence and b) abundance in springs is controlled by spring type, water temperature, predominant substrate, and availability of allochthonous plant material.

Methods

Samples were collected at 48 spring sites around Iceland in the summer months (June to August) of 2015 and 2016. One sample per site was collected from the benthic substrate of the spring, approximately 2 meters downstream of the spring source, using a 0.093 m^2 Surber sampler with 63 µm mesh. In the laboratory, Trichoptera larvae were identified from the samples under a Leica MZ12.5 dissecting stereomicroscope (80–100x magnification) using a key by Gíslason (1979).

The sites were classified according to spring type (limnocrene or rheocrene), predominant substrate (lava rock or sand/organic matter), and potential amount of allochthonous input into the water body based on surrounding vegetation (high or low). The 48 sampled springs were distributed among those categories as follows: 30 rheocrenes and 18 limnocrenes, 19 with mainly lava rock and 29 with mainly sandy substrate, and 14 with high and 34 with low amounts of surrounding vegetation. The water temperature of the springs was measured with a multi-probe sonde (HYDROLAB DS5) at the time of sampling, revealing that temperatures ranged from 2.4 to 43°C among sites.

All statistical analyses were conducted in the software R (R Core Team 2016, version 3.4.1). To test whether environmental characteristics of springs differed between sites in which Trichoptera larvae were present and sites in which they were absent, we developed a generalized linear model with binomial distribution, using the function *glm* in the R package *stats*. To relate Trichoptera abundance to environmental variables, we developed a generalized linear model with poisson distribution, in which we included only sites where caddis larvae were present. Larvae of all species were pooled, because the small sample sizes did not allow for statistical analysis at the species level.

Results

Trichoptera larvae were found in 11 of the 48 spring sites sampled (Fig. 1). They occurred in low numbers, ranging from one to 20 individuals per site, resulting in densities between 10 and 215 individuals/m^2. Only three of the 12 Trichoptera species recorded from Iceland were found in the sampled springs: *Apatania zonella* (Zetterstedt 1840), *Limnephilus affinis* Curtis 1834, and *Limnephilus griseus* (L. 1758). The first of these species has a Holarctic distribution, the latter two Palaearctic distributions. *Limnephilus griseus* was the most common species, with a total of 28 individuals found at eight sites (Fig. 1). *Apatania zonella* was found at six sites, with a total of 20 individuals (Fig. 1). At only one site, Staðarhraun in Western-Iceland, 12 larvae of *L. affinis* were found (Fig. 1). The spring Staðarhraun was also the only site in the study where all three Trichoptera species occurred together. *Apatania zonella* and *L. griseus* co-occurred at three sites and *A. zonella* and *L. affinis* co-occurred at one site out of 48. In most cases, only a single species was found: in two sites there was only *A. zonella*, and in four sites only *L. griseus*.

Trichoptera larvae occurred exclusively in the colder springs studied, ranging in water temperatures from 2.4 to 7.2°C. However, presence or absence could not be linked to any of the measured habitat properties of the site (Table 1).

Abundance of caddis larvae, on the other hand, was associated with water temperature, predominant substrate, and plant input (Table 1). Trichoptera abundances were higher on sandy substrate (6.7 ± 6.67; average number of individual per sample ± standard deviation) than on lava rock (3.5 ± 2.69) (Fig. 2b) and in springs with potentially high plant input (7.7 ± 6.70) rather than low input (3.0 ± 2.76) (Fig. 2c). Abundance decreased with increasing water temperature (Table 1).

Although spring type was not statistically significant in explaining either Trichoptera presence/absence or abundance (Table 1), caddis larvae were more often found in rheocrene (7) than in limnocrene (4) springs, and were also more abundant in rheocrenes (Fig. 2a), with on average 7.7 ± 6.21 individuals per Surber sample in rheocrenes compared to 1.8 ± 1.30 in limnocrenes.

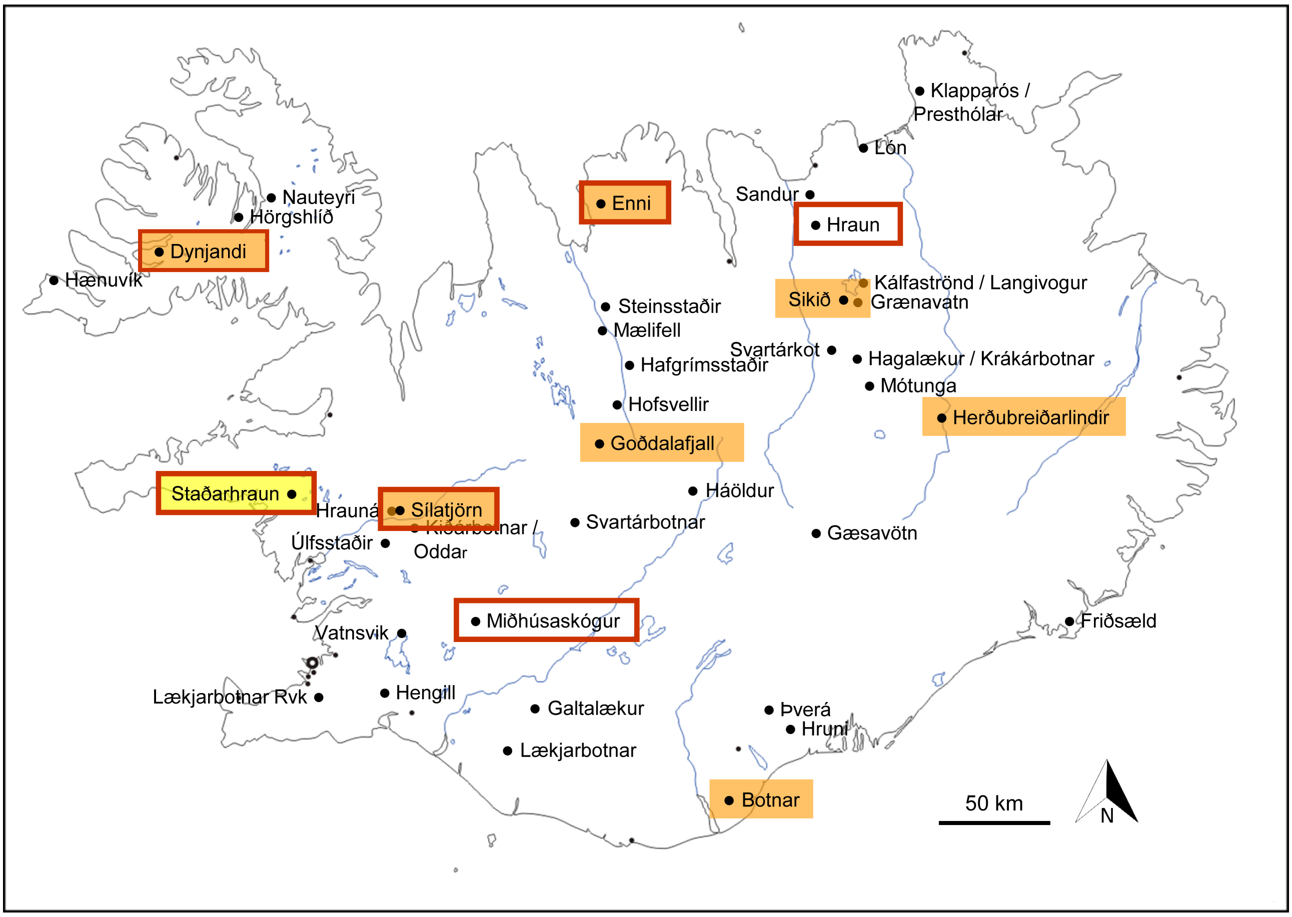

FIGURE 1. Map of sampling sites in springs in Iceland. Springs where Trichoptera were found in this study are highlighted. Orange fill indicates occurrence of *L. griseus*, yellow fill occurrence of both *L. griseus* and *L. affinis*, and red outline indicates occurrence of *A. zonella*.

TABLE 1 Relationship between presence/absence and abundance of Trichoptera larvae from Icelandic springs and environmental properties of the spring. Generalized linear models with binomial distribution were used for presence/absence, and with poisson distribution for abundance (see text). The slope b of the regression, standard error, z-values and p-values are shown. Asterisks (*) behind p-values indicate level of significance, where * > 0.01%, and ** > 0.001%.

Variable	b (slope)	Std. Error	z	p
Presence/absence:				
Spring type	-0.036	0.8226	-0.044	0.965
Temperature	-0.312	0.3031	-1.030	0.303
Substrate	-0.869	0.8460	-1.027	0.304
Plant input	1.373	0.7785	1.764	0.078
Abundance:				
Spring type	-0.658	0.4422	-1.488	0.137
Temperature	-0.732	0.3037	-2.412	0.016 *
Substrate	-1.107	0.3914	-2.828	0.005 **
Plant input	1.824	0.6293	2.899	0.004 **

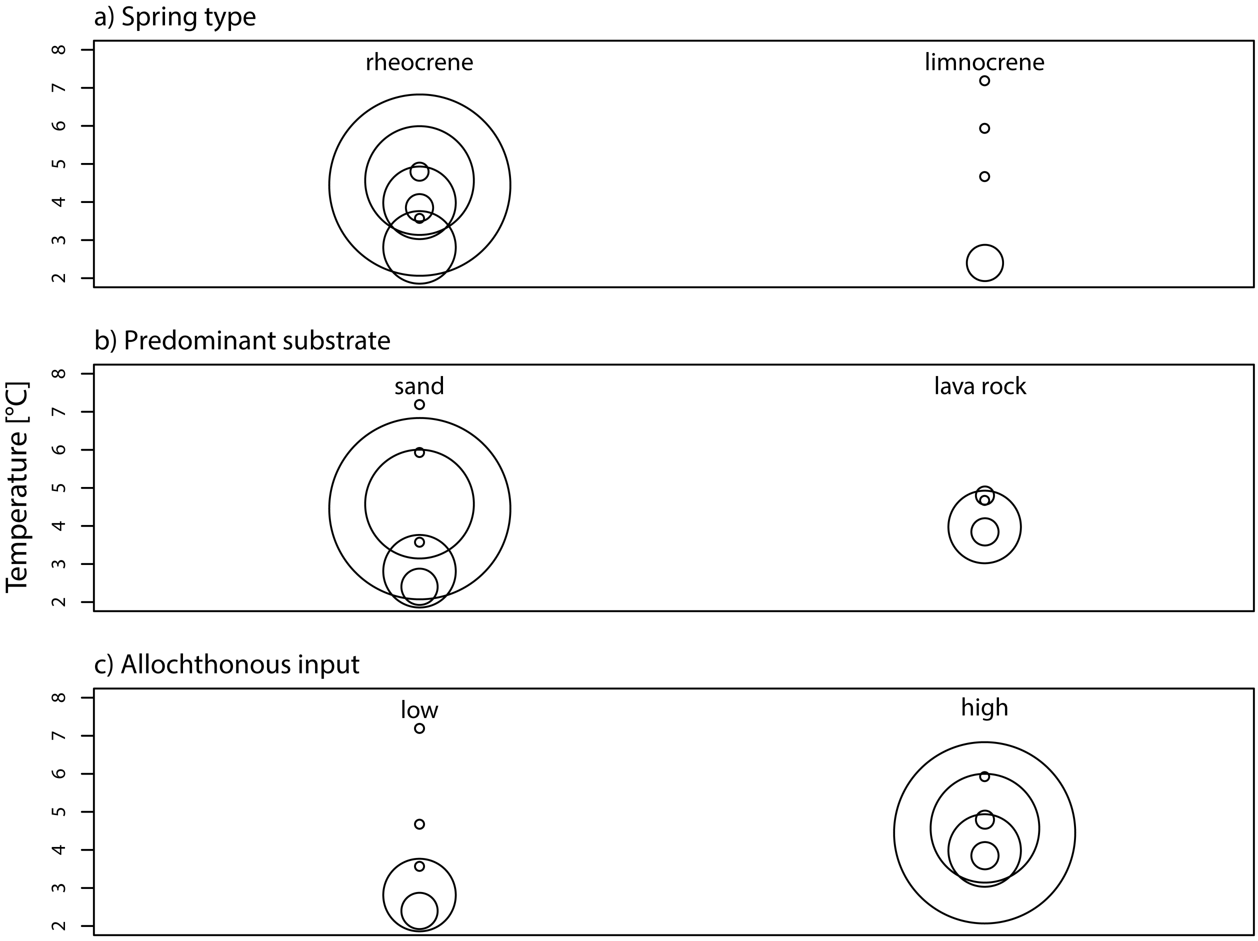

FIGURE 2. Abundance of Trichoptera larvae in springs of different water temperatures depending on (a) spring type, (b) predominant substrate and (c) amount of allochthonous plant material at the site. Water temperatures of the springs plotted on the y-axis. Circles are proportional to the number of Trichoptera larvae in the samples.

Discussion

All three Trichoptera species found in springs in this study were previously recorded for spring-fed rivers in Iceland (Gíslason 1981a). In a study in Þjórsárver in the Central Highlands of Iceland (Gíslason *et al.* 1990), *A. zonella, L. affinis*, and *L. griseus* were the only caddis larvae found in rheocrene springs and their effluent streams with temperatures around 5°C. The most common Trichoptera species, *L. griseus*, is known to inhabit a wide range of habitats in Iceland. It occurs mainly in lakes and rivers but also in ponds and marshes (Gíslason 1981a), and feeds on plant material and detritus. The second limnephilid species, *L. affinis,* has likewise a wide choice of habitats in Iceland and has been recorded from springs especially at freshwater springs with influence from the sea (Gíslason 1978). The main food item of the latter species is plant material and detritus. The third species found in springs, *A. zonella*, is very frequent in Icelandic running waters (Gíslason 1981a), feeding mainly on diatoms (Gíslason & Sigfússon 1987).

The occurrence of *A. zonella* in springs in North-Iceland is presumably associated with the fact that the omnivorous limnephilid *Potamophylax cingulatus* (Stephens 1837) does not occur in springs. Predation pressure from *P. cingulatus* may exclude *A. zonella* from rivers and streams in large parts of Iceland (Gíslason 1981b). *Potamophylax cingulatus* was first found in East-Iceland in 1959 and has spread from there, expanding its distribution over East- and Northeast-Iceland in the 1970s and by 2008 occurred all over the country with the exception of the Central Highlands (Gíslason *et al.* 2015). Although it is now common in spring-fed streams in Iceland, *P. cingulatus* has not been found there in springs. This could be due to limited food availability in springs. In Iceland, *P. cingulatus* preys on Chironomidae larvae and larvae of *A. zonella*, likely causing the exclusion of this species in streams formerly inhabited by it (Gíslason 1981b). Icelandic springs are oligotrophic, especially close to the source, with generally low primary production. Chironomidae larvae are present and abundant, mostly in early instars (Kreiling, personal observation), but might not be sufficient as a food source for *P. cingulatus*, for which the larva is now Iceland's largest stream-dwelling caddis. For the diatom-feeding larvae of *A. zonella*, springs could act as refugia from predation by *P. cingulatus* in areas where *A. zonella* has been otherwise displaced.

On the global scale, Trichoptera are one of the most species-rich groups of aquatic insects found in springs (Erman & Erman 1995; Myers & Resh 2002; Maiolini *et al.* 2011). The low Trichoptera diversity found in Icelandic springs in this study can partly be explained by the low regional species pool. In general, Trichoptera diversity on islands in the North Atlantic decreases with latitude and with distance to the mainland (Gíslason 2005): One caddis species is reported from Svalbard, 12 from Iceland, 20 from the Faroes, 37 from the Shetlands, compared to 193 species known from Norway. Furthermore, one has to bear in mind that the three species found in springs in Iceland represent 25% of the country's Trichoptera fauna.

Whether Trichoptera larvae were present or absent in a spring was not associated with the measured habitat properties (Table 1). However, the presence of caddis larvae in springs was clearly limited by water temperature. No Trichoptera were found at temperatures above 7.2°C, whereas other aquatic insects such as Chironomidae larvae are common and abundant in Icelandic springs even at temperatures as high as 40°C (Kreiling *et al.* 2018).

Although this study was limited to the low number of springs in which caddis larvae were found, the abundance of Trichoptera larvae could be linked to certain habitat properties. Abundance was higher in colder springs and decreased with increasing temperature (Table 1).

Trichoptera were more abundant in springs with sandy bottom compared to springs with lava rock as the predominant substrate (Fig. 2b, Table 1). In Iceland, all three species found in this study are quite opportunistic in their choice of case building material, especially in the early instars, and sand grains are commonly used (Gíslason, personal communication). Appropriate case building material is thus literally everywhere in springs with predominantly sandy substrate but rare on bare lava rock. Substrate composition, including amount of leaf litter, has been shown to influence the macrofauna diversity in springs (von Fumetti *et al.* 2006). Larval abundance was also related to the amount of potential allochthonous material entering the springs, with more caddis larvae in springs with high plant input (Fig. 2c, Table 1). However, the classification of springs into sites with low and high allochthonous input, respectively, was based only on estimation of vegetation density around the spring and allochthonous material in the spring itself was not directly measured in this study. Although Trichoptera abundance was not statistically associated with either of the spring types (Table 1), it was clearly higher in rheocrene than in limnocrene springs (Fig. 2a). Invertebrate abundances are often reported to be higher in rheocrene than in limnocrene springs (Maiolini *et al.* 2011), and rheocrene springs hold higher species richness compared to limnocrene springs, which is the case for both aquatic invertebrates in general (e.g., Ilmonen & Paasivirta 2005; Maiolini *et al.* 2011) and Trichoptera in particular (Cianficconi *et al.* 1998).

In this study, we found a very simple Trichoptera community in springs in Iceland, and were able to link caddis larvae abundance to some habitat properties. However, we were restricted to very few environmental variables, and did not measure other potentially important factors such as flow velocity, algal production, or isolation from other water bodies. It could be worth studying this extremely simple faunistic system in more detail, to shed light on the mechanisms structuring species distribution in freshwater springs.

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