Freshwater Science

The invertebrate biodiversity in the hidden headwater springs and streams of the southern Chalk

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Giulio Biondi is a freshwater scientists at APEM Ltd. In 2021, Giulio contributed to a collaborative research project between Nottingham Trent University and the Environment Agency. The team headed deep into remotest south England, to characterise the aquatic invertebrates within the headwater springs and streams along the South Downs scarp slope.

Introduction

Chalk rock dominates the landscape of the South Downs, which stretch across East Hampshire and West and East Sussex, and the steep, north-facing scarp slope is particularly striking. Relatively impermeable geologies lay beneath the chalk, which forces its groundwater to emerge at the foot of the scarp slope, creating springs that flow into headwater streams dotted along a spring line (Jones & Robins, 1999). The late Nigel Holmes highlighted the conservation value of this diverse network of springs over a decade ago (Holmes, 2010), with his characterisation of their biota focusing on the plant communities—whereas their invertebrate biodiversity has remained unknown. Holmes (2010) also observed the considerable variability in habitat conditions among springs and headwater streams, with some sustaining perennial flow whilst—as is characteristic of many chalk stream headwaters—others have 'winterbourne' flow and are typically dry in summer.

Freshwater springs and headwater streams can have high habitat diversity due to structural elements such as rocks, plant roots, woody material and encroaching vegetation, which—in groundwater-fed systems with relatively low and stable flows—are not easily transported downstream. In turn, this habitat heterogeneity and their spatial isolation allows springs and headwater streams to support high biodiversity of groups including aquatic macroinvertebrates (Finn et al. 2011). The biodiversity of winterbourne springs and headwater streams can be further enhanced by populations of specialist species that are largely excluded from nearby perennial reaches (Macadam et al. 2021). In addition, their stable thermal regimes and cool summer temperatures enable springs to support cold-loving invertebrate species (Durance & Ormerod, 2010).

We characterised the aquatic macroinvertebrate biodiversity of a network of springs and headwater streams located along the South Downs scarp slope, and investigated the differences between habitats with winterbourne and perennial flow.

Methods

We selected 42 sites in southern England within an area spanning approx. 75 km from west to east and encompassing Hampshire and West Sussex (Figures 1–2). The sites are distributed across five river catchments: the Adur (4 sites), Arun (7), Meon (1), Rother (27), and Wey (3). The primary land uses immediately surrounding the sites included broadleaf woodland at 24 sites and agriculture, private gardens, rank grassland and suburban areas at 2–7 sites, with a few sites having >1 primary land use. Secondary land uses included agriculture, broadleaf woodland, conifer plantations, private gardens, suburban areas and rank grassland. Some springs were remote and hidden within wooded ravines, whereas others were accessible, even occurring next to a road. We asked landowners, estate managers or other local people about 'their' site's flow regime, and in particular, if the site sometimes dried. Our field campaign was in October–November 2021. To sample benthic macroinvertebrates, we collected a 1-minute kick

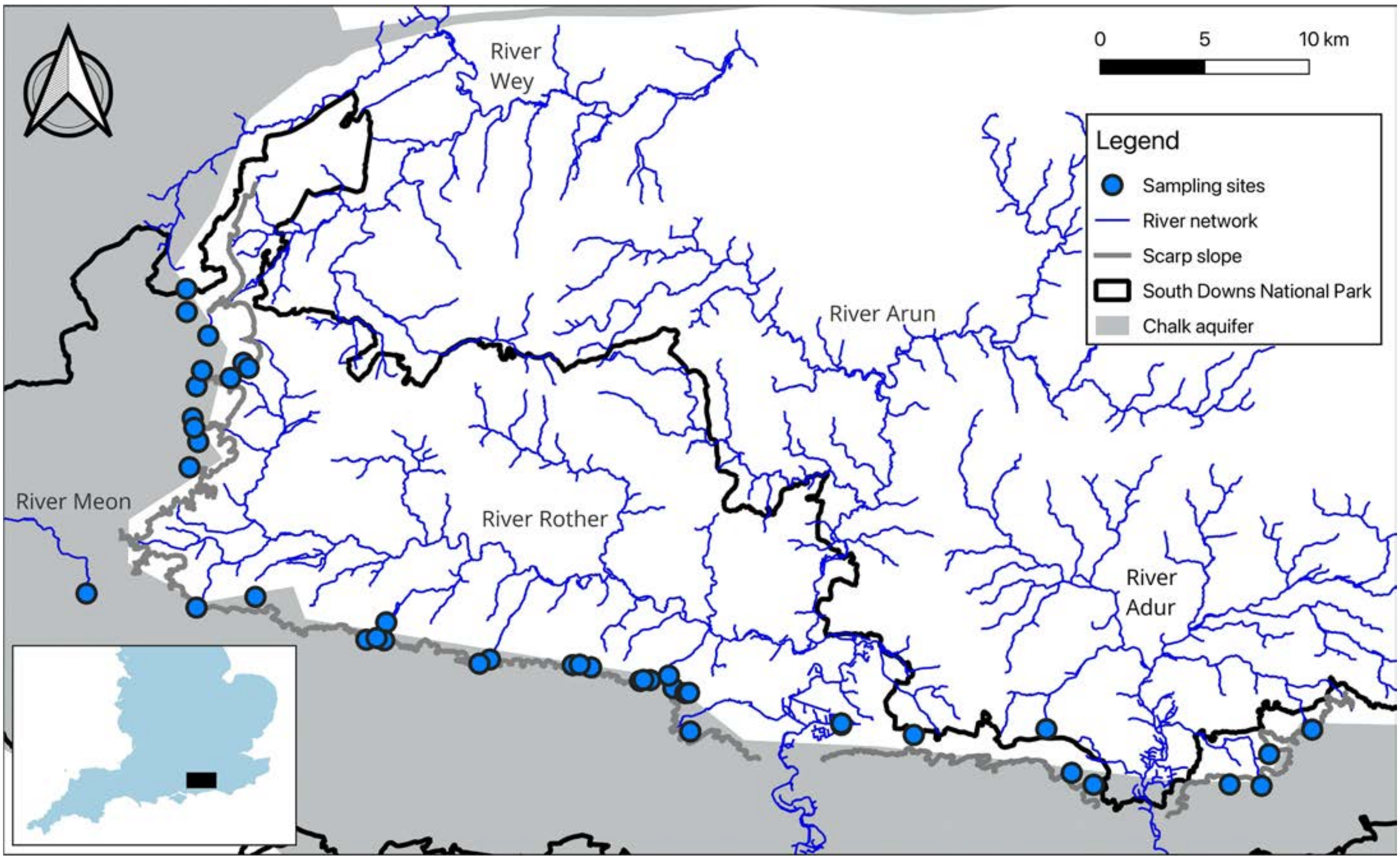

Figure 1. Map of the study area, showing the 42 sites sampled along the northern scarp slope of the South Downs National Park, and the study area location within England.

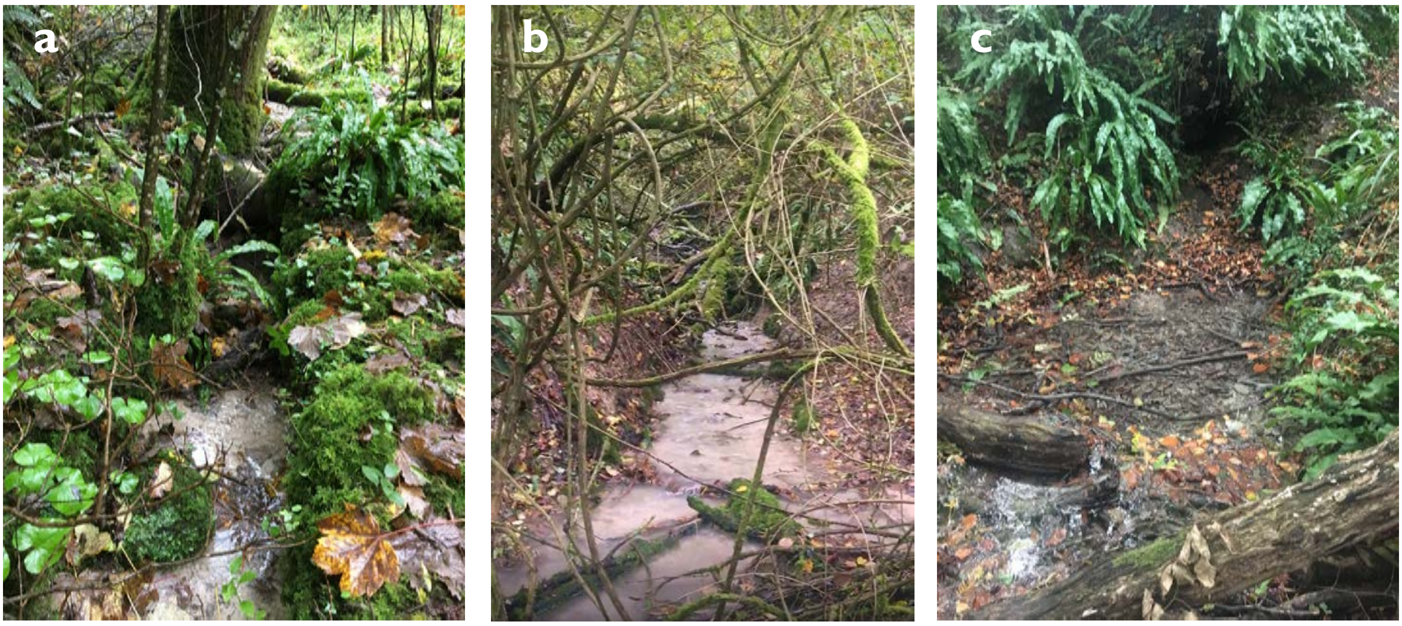

Figure 2. Examples of sampling sites in the South Downs: (a–b) perennial springs in the Rother catchment; (c) a temporary spring in the Adur catchment. We recorded *Crenobia alpina* at site a and both *Niphargus fontanus* and *Simulium costatum* at site b. Photo credits: Giulio Biondi.

sample from each site using a 500-µm pond net, representing each instream habitat type in proportion to its occurrence. At each site, we also measured variables including water temperature, water width and depth, and we visually assessed sediment composition.

In the laboratory, we identified taxa to the lowest practical resolution, mostly to species or a species aggregate, with the following exceptions: Bivalvia, most Coleoptera larvae, and most Diptera were identified to family; Ceratopogonidae were identified to subfamily, and Ptychopteridae and Fanniidae were identified to genus; and Oligochaeta and Hydrachnidia were identified as such. Some early instar insects and damaged specimens were also identified to a higher level. Simuliidae were identified to species by Jon Bass.

Results and Discussion

Springs and streams varied in size, some being trickles about 20 cm wide and 5 cm deep, whereas others were larger, exceeding 5 m in width and reaching 60 cm in depth. Sediment composition also varied widely, from soft, clay-dominated beds to gravel-dominated, stable channels. Most sites had mixed sediments, with clay, gravel and silt dominating at 22, 12, and 8 sites, respectively.

We recorded 12,273 specimens, ranging from 14 to 1427 (mean ± SE: 292 ± 48) individuals per sample, with most samples containing < 160 invertebrates. We recorded at least 75 taxa, ranging from 2 to 23 (11.2 ± 0.8) taxa per sample. The most diverse orders were the Diptera, Trichoptera and Coleoptera, which were represented by 14, 12 and 11 families, respectively. The most widespread and abundant taxon was the amphipod shrimp *Gammarus pulex/fossarum*, which occurred at 38 sites and accounted for approx. 62% of all individuals.

Reflecting variation in instream conditions among sites, we found species with diverse habitat preferences, including some indicative of perennial flow, a winterbourne specialist, cold-loving spring specialists and several groundwater species. Many of these species are of conservation interest, as indicated by their Community Conservation Index (CCI) scores, with scores of 5, 6 and 7 indicating species of local, regional and national note, respectively (Chadd & Extence, 2004).

The winterbourne stonefly *Nemoura lacustris* (Nemouridae; CCI score 7; Figure 3a) is a temporary stream specialist which, in England, occurs almost exclusively in winterbournes on the southern Chalk (Tapia et al. 2018; Gething et al. 2021; Macadam et al. 2021), and is Nationally Rare (Macadam, 2015). We found 12 *N. lacustris* individuals across two sites with different habitat characteristics, one being a gravel-dominated riffle and the other a silt-dominated, slow-flowing spring just metres from the source. Similarly, Gething et al. (2021) recorded *N. lacustris* in both gravelly and silty winterbourne streams and comparable nearby agricultural ditches, indicating the species' diverse habitat preferences beyond one core requirement: shifts between wet and dry instream conditions. It is uncertain whether *N. lacustris* requires such wet–dry shifts to complete its lifecycle, or whether drying supports this rare species by reducing densities of its competitors (Tapia et al. 2018; Aspin & House 2022).

Larvae of the blackfly *Simulium costatum* (Simuliidae; CCI score 5) are restricted to the uppermost headwaters of perennial calcareous spring-fed streams (J. Bass, pers. comm.). We found *S. costatum* at two sites, both < 200 m from the spring source, shallow, dominated by fine sediments, and with at least moderate flow velocities. Its presence enabled inference of perennial flow at these sites, highlighting the value of such 'bioindicator' species in characterisation of flow permanence, in particular at remote sites, for which other sources of such information may be lacking.

The common flatworm *Crenobia alpina* (Planariidae; CCI score 2) is a cold-loving glacial relict found almost exclusively in springs and headwater streams (C. Macadam, pers. comm.). *Crenobia alpina* prefers temperatures ≤ 15°C (Reynoldson, 1953), which agrees with spot measurements (10.5–12.3°C) from the eight sites at which we recorded the species. We also found a second cold stenotherm, the frequent crenobiont (i.e. spring specialist) caddisfly *Crunoecia irrorata* (Lepidostomatidae; CCI 3), at eight sites.

Groundwater specialists of conservation interest were particularly diverse in our samples: we recorded *Niphargus aquilex* (CCI score 6) at three sites, and found one specimen of *Niphargus kochianus* (7), *Niphargus fontanus* (7) and *Crangonyx subterraneus* (7; Figure 3b) at three different sites. These species have been sampled from chalk boreholes in southern England (Maurice et al. 2015), and our results demonstrate that springs and headwater streams can support low densities of groundwater fauna.

Towards a more comprehensive characterisation of headwater biodiversity

Our study demonstrates that networks of sites with diverse habitat characteristics—including those with both perennial and winterbourne flow—collectively support high aquatic invertebrate biodiversity, including many species of conservation interest. These preliminary findings highlight the need for

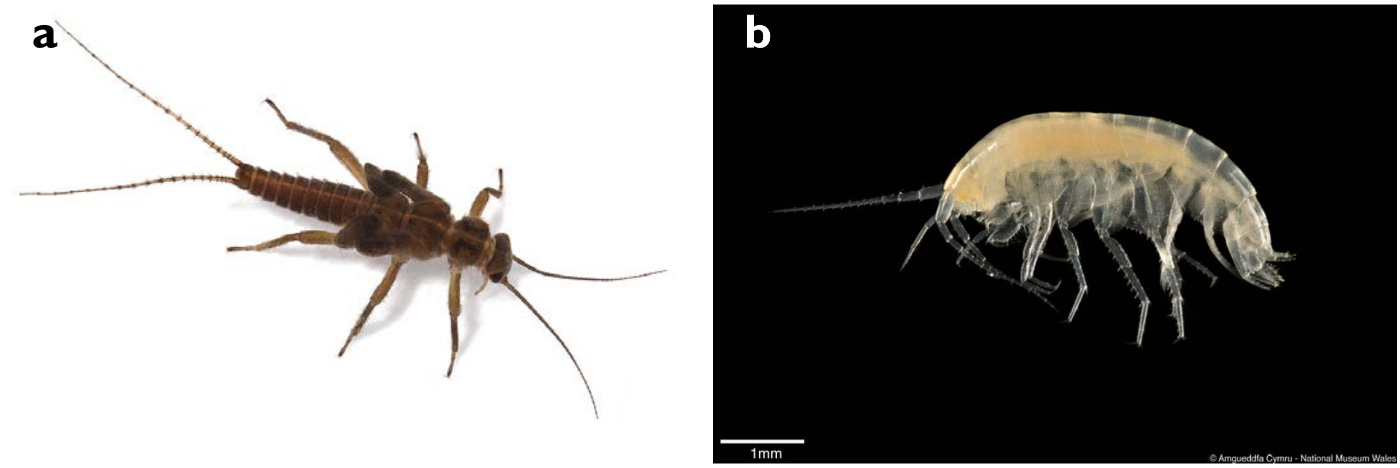

Figure 3. Notable species found in springs and headwater streams of the southern Chalk: (a) the winterbourne stonefly *Nemoura lacustris* and (b) the groundwater amphipod *Crangonyx subterraneus*. Photo credits: (a) Cyril Bennett; (b) Julian Carter.

further investigation to characterise the biodiversity within these headwater springs and streams. First, for logistic reasons, our sampling campaign was in autumn, and sampling of spring-season communities is likely to increase our estimates of taxonomic diversity. Second, our observation of several groundwater species suggests that sampling the subsurface sediments of the hyporheic zone could enhance biodiversity estimates (although our attempts at 'Bou-Rouch pumping' were hampered by clay-dominated sediments at some sites). Third, at sites with temporary flow, sampling the terrestrial species that colonise during dry phases would enable estimation of aquatic–terrestrial invertebrate biodiversity.

We are currently analysing our data to quantify biodiversity in relation to habitat variability and thus to identify the characteristics of sites of high conservation value. Our ultimate goal is to enrich understanding of the biodiversity of the springs and headwater streams of the southern Chalk, thus motivating network-scale management actions that protect their biodiversity.

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