The effects of drying on aquatic macroinvertebrate communities in the temporary headwaters of the River Thames

A report produced by Nottingham Trent University for the Environment Agency

Written by Avreen Roque, Kieran Gething and Rachel Stubbington*
School of Science & Technology, Nottingham Trent University, Nottingham NG11 8NS UK
***** rachel.stubbington@ntu.ac.uk

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Executive summary

We analysed the aquatic macroinvertebrate communities at two sites with contrasting temporary flow regimes in the River Thames headwaters: Ewen, which typically dries for six months each year, and Somerford Keynes, which stops flowing in late summer and dries only for a few weeks. The dataset spanned 2018, a typical hydrological year, and 2019, in which a wetter summer maintained flow. We characterized spatial and temporal variability in the communities and species, to inform effective biomonitoring in temporary streams.

Main findings

- Despite their proximity and similar instream habitats, the two sites supported **distinct macroinvertebrate communities**, reflecting their site-specific temporary flow regimes.
- Overall **taxa richness was comparable** at the two sites, but whereas Somerford Keynes supported higher EPT richness, Ewen was home to more beetles and snails.
- The Community Conservation Index (CCI) was comparable at the two sites, both of which supported shared and site-specific **nationally notable species**.
- *Nemoura* and *Paraleptophlebia* were restricted to, or more abundant at, Ewen. Their species-level identification may reveal **specialist species of conservation interest**.
- The invasive snail *Potamopyrgus antipodarum* did not occur at Ewen, suggesting that drying may **limit the distribution of** this **invasive species** in temporary streams.
- **Biomonitoring indices** including the WHPT ASPT and NTAXA had **naturally lower scores** at Ewen, due to less high-scoring EPT taxa occurring at this drier site.
- Surprisingly, **DELHI index scores were lower in the wetter year**, which may reflect the availability of ponded and damp habitats for low-scoring taxa at temporary sites.

Recommendations

1. Community composition should be interpreted in light of data describing antecedent instream conditions—but where these are unavailable, the DEHLI index may be used to indicate when communities have recovered from recent dry phases.
2. The values of indices such as WHPT ASPT decline and become more variable as flow permanence decreases. A major research priority is thus to determine the index values indicative of unimpacted conditions in different temporary river types.
3. Sites with temporary flow are likely to be dry in autumn, and spring sampling is thus recommended to align with Environment Agency field seasons. Targeted supplementary surveys may be needed to identify specialist species of conservation interest.
4. Summer sampling may complement spring sampling and may better characterize aquatic communities, including taxa that use ponded and pool habitats in late summer.
5. Characterizing the communities at sites with contrasting flow permanence regimes will reveal the contribution that temporary sites make to catchment-wide aquatic biodiversity.

Contents

1.1 An introduction to temporary streams

Temporary streams are those in which water sometimes stops flowing, and many lose most or all surface water. These drying streams are surprisingly common in countries with temperate climates, such as the UK, where they occur primarily in the headwaters. Even major watercourses such as the River Thames have headwater reaches with a range of temporary flow regimes. Further upstream, some sites typically dry for several months in summer and autumn. With progression downstream, flow permanence increases and some near-perennial sites dry only during drought years.

The aquatic macroinvertebrate communities that inhabit temporary streams can have lower site-specific taxonomic richness than those with perennial flow, but temporary sites can support specialist species, including some rarities of national conservation concern. In addition, the communities at temporary sites can be highly variable, meaning that they collectively make a considerable contribution to catchment biodiversity. As such, effective biomonitoring methods are needed to assess the ecological health of temporary river fauna.

1.2 Aim and objectives

Our aim was to characterize and compare aquatic macroinvertebrate communities sampled at monthly intervals at two sites in the River Thames headwaters, Ewen and Somerford Keynes, in 2018 and 2019 (Appendix 1). Both sites have temporary flow, but whereas Ewen dries for 5–6 months between July and December in most years, Somerford Keynes typically retains water in ponded reaches into late summer, and dries for shorter periods in autumn. During the study period, 2018 was a fairly typical hydrological year, whereas a wet summer maintained flows throughout 2019 (Fig. 1).

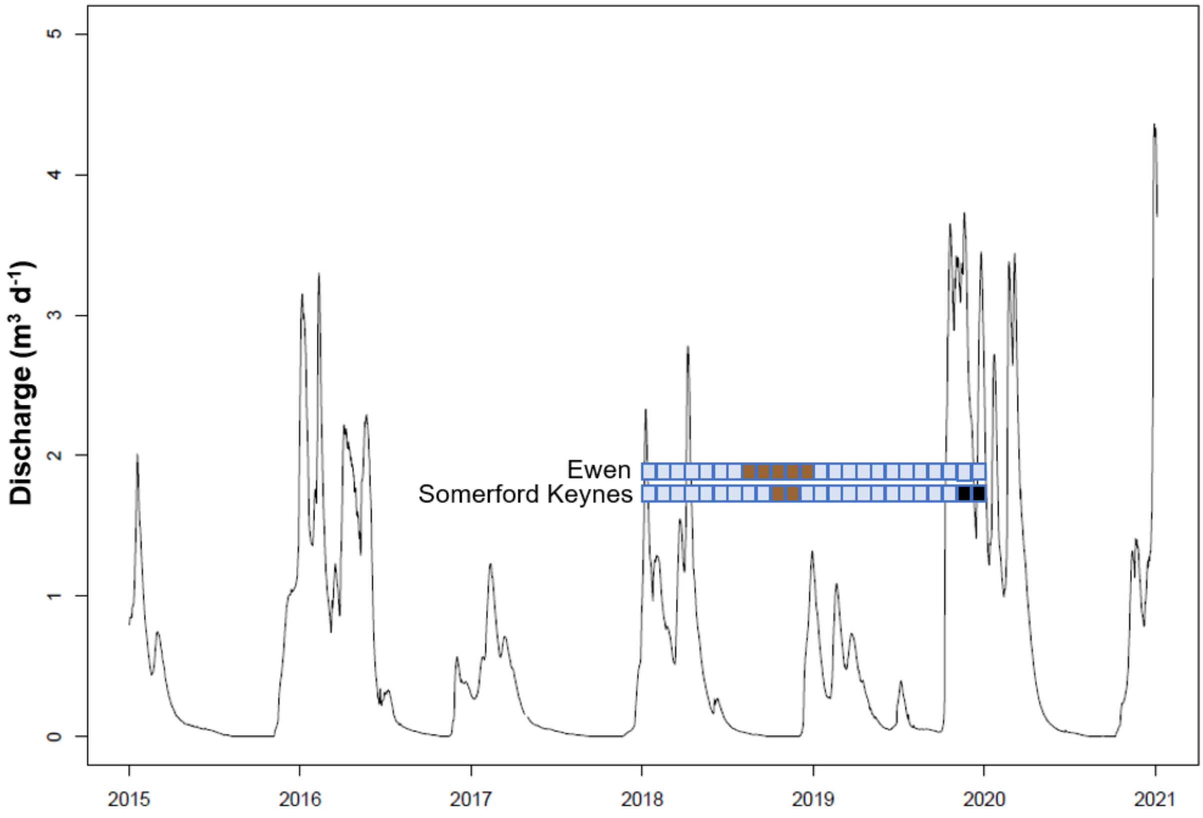

Figure 1. Discharge at Ewen gauging station (150 m downstream of the Ewen sampling site). Coloured bars indicate months in which samples were collected (light blue) and not collected because the site was dry (brown) or for logistic reasons (black) at Ewen and Somerford Keynes

Our specific objectives (O) were:

O1. to characterize and compare aquatic macroinvertebrate community composition at the two sites;
O2. to identify species (or higher taxa) common to both sites and those restricted to one site, including species of conservation interest;
O3. to characterize and compare temporal variability in metrics summarizing community composition (e.g. richness, WHPT ASPT, DELHI, CCI) and taxon-specific abundance at the two sites;
O4. to recommend the months in which temporary sites should be sampled to characterize communities effectively.

For O1–3, we related community differences to site-specific flow permanence regimes.

2. Methods

2.1 Dataset

The dataset reports the abundance of taxa in kick samples collected at monthly intervals from Somerford Keynes in January 2018 to October 2019 excluding October–November 2018 (n = 20), when sites were dry, and from Ewen in January 2018 to December 2019 excluding August–December 2018 (n = 19), again when sites were dry. Taxa were identified to the lowest practical level, in many cases species, but genus, family or major group for some early instars and taxonomically challenging taxa. Supplementary data report physical habitat characteristics including discharge (Fig. 1) wetted width, water depth, flow rate (high, normal, low, dry), instream habitats (pool, run, glide, slack, marginal deadwater, unvegetated sidebar), sediment types, and macrophyte and algal cover, and state additional comments.

2.2 Data harmonization

We removed all taxa other than macroinvertebrates, i.e. fish and meiofauna. We retained semi-aquatic taxa such as Succineidae and *Zonitoides*, which are important contributors to the temporary stream fauna. We classified all individuals identified as the glossosomatid caddisfly genus *Agapetus* (recorded only in 2018) as *Synagapetus dubitans* (recorded only in 2019), reflecting the likelihood that *Agapetus* were misidentified prior to the introduction of new national identification guidance. We classified all Oligochaeta as such and classified all chironomid tribes, genera and species to subfamily, due to their inconsistent identification to a lower taxonomic level. We removed redundant taxa, for example we classified Rhyacophilidae as *Rhyacophila*, which is the sole UK genus within the family. However, we retained many taxa (e.g. limnephilid caddisflies) at family, genus and species levels, due to the occurrence of multiple representatives within each lower level, and also to indicate the months in which specimens can be identified to the lowest taxonomic resolution. We also created a separate dataset in which we assigned individuals of taxa identified to multiple taxonomic levels (e.g. Limnephilidae, *Limnephilus* and *L. lunatus*) to the single most likely taxon, to calculate uninflated estimates of taxonomic richness.

2.3 Calculation of community metrics

Community metrics provided in the dataset included the WHPT index average score per taxon (ASPT) and number of scoring taxa (NTAXA; Paisley et al. 2004); the Community Conservation Index (CCI; Chadd et al. 2004); and the Drought Effect of Habitat Loss on Invertebrates (DEHLI) index and its NTAXA (Chadd et al. 2017). We also calculated total taxonomic richness, order-level taxonomic richness for orders with a mean of at least two representatives per sample (i.e. Coleoptera, Diptera, Gastropoda and Trichoptera), total abundance, and the abundance of selected taxa. In calculating total and Diptera richness, we included *Simulium* (Simuliidae) and *Pericoma* (Psychodidae) at the genus level, to ensure that richness estimates were comparable for samples in which specimens were identified to genus and to species level.

2.4 Data analysis

O1. Characterization of community composition. To visualize community composition at each site in each month and in each year, we created a non-metric multidimensional scaling (NMDS) plot.

O2. Identification of characteristic taxa. We listed and noted the abundance of taxa common to both sites and taxa restricted to one site and explored these lists in the context of previous research, to identify potential temporary stream specialists. We used CCI taxon scores to identify species of conservation interest.

O3. Characterization of variability in community metrics and population abundance. We plotted line graphs to visualize how the abundance of all taxa and of selected taxa (i.e. *Isoperla grammatica*, *Nemoura*, *Serratella ignita*, *S. dubitans*) and each community metric (i.e. taxa richness; order-level taxa richness for the Coleoptera, Diptera, Gastropoda and Trichoptera; WHPT ASPT and NTAXA; DEHLI and its NTAXA; CCI) varied over time at the two sites. These analyses informed recommendations for future biomonitoring of temporary streams (**O4**).

3. Results and Discussion

3.1 Characterization of community composition: differences between sites

A total of 17,652 invertebrates from 97 taxa were identified at Ewen and 12,145 invertebrates from 101 taxa at Somerford Keynes. The most dominant taxa at Ewen were the true fly family Chironomidae (15.7% of all invertebrates), followed by the caddisfly *S. dubitans* (15.4%) and the isopod *Asellus aquaticus* (12.1%). In contrast, the most abundant taxa at Somerford Keynes were the amphipod *Gammarus pulex/fossarum* (16.0%), the stonefly *I. grammatica* (15.8%), the mayfly *S. ignita* (13.4%) and the Oligochaeta (11.6%). These compositional differences are apparent on the NMDS plot (Fig. 2), which shows complete distinction between communities at the two sites along NMDS1.

3.2 Characterization of community composition: changes over time, within and between years

The distribution of NMDS points indicates that the extent of seasonal variability in community composition was similar at the two sites, contrasting with previous research suggesting that communities at drier sites can be more variable. The two sites experienced comparable temporal changes within years: summer communities (shown in 'warmer' colours) tended to plot towards the top of the plot, then composition gradually shifted in autumn (greys) and winter (blues), the latter communities plotting near the bottom of NMDS2 in both years (Fig. 2). Spring communities (yellow) were most variable between sites, remaining within the winter cluster at Ewen but resembling summer communities at Somerford Keynes, which could reflect earlier flow resumption and thus community development at the latter site. The two sites differed in their interannual variability: whereas 2018 samples mainly plotted within the 2019 cluster at Somerford Keynes, at Ewen, 2018 and 2019 communities overlapped little and distances between month pairs (e.g. Jan 2018 and Jan 2019) were generally greater. This aligns with previous research showing that drier sites experience considerable interannual variability.

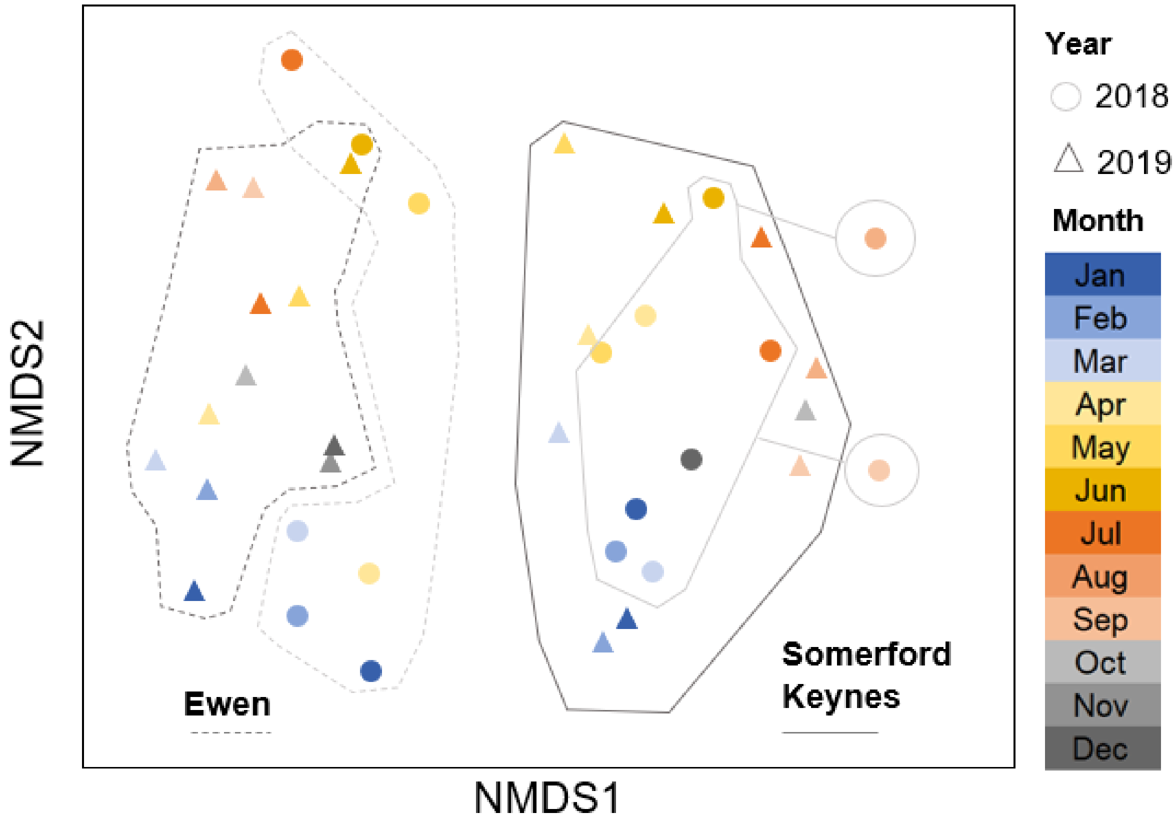

Figure 2. Non-metric multidimensional scaling (NMDS) plot of macroinvertebrate community composition at Ewen and Somerford Keynes in 2018 and 2019. Each coloured point represents the community sampled in one month. Samples were not collected from Ewen in August–December 2018, or from Somerford Keynes in October–November 2018 and November–December 2019.

3.3 *Identification of characteristic taxa*

Seventy taxa occurred at both Ewen and Somerford Keynes (Appendix 2), although in some cases abundance was very different at the two sites. Taxa that were at least 10× more abundant at Ewen comprised the amphibious leech *Trocheta subviridis*, flatworms of the genus *Polycelis*, the snail *Ampullaceana balthica* (Maitland name *Lymnaea peregra*), *A. aquaticus*, the beetle genus *Dryops*, larvae of the beetle family Dytiscidae, adults of the beetle genus *Haliplus*, the true fly subfamily Chironominae and genera *Simulium* and *Oxycera*, *S. dubitans*, and the limnephilid caddisfly *Micropterna sequax*. Stoneflies of the genus *Nemoura* were also far more abundant at Ewen, where this genus may well be represented by the winterbourne specialist *N. lacustris* (see Macadam 2015). Fewer taxa were approx. ≥10× more abundant at Somerford Keynes, namely the true fly family Ceratopogonidae, the true fly genus *Dicranota*, the true fly species *Simulium latipes*, the riffle beetle *Elmis aenea* and the caddisfly *Limnephilus marmoratus*. Note that this list includes taxa which Armitage & Bass (2013) noted as both restricted to perennial reaches (i.e. *E. aenea*) and winterbourne reaches (i.e. *S. latipes*).

Other taxa were restricted to one site: 46 taxa at Ewen and 52 at Somerford Keynes, highlighting the collective contribution that sites with contrasting temporary flow regimes make to catchment-wide biodiversity. Those recorded only at Ewen comprised two leeches, four flatworms, eight snails, ten beetles, nine true flies, the mayfly genus *Paraleptophlebia*, a dragonfly and seven caddisflies (Appendix 2). The species of *Paraleptophlebia* may well be

P. werneri, a winterbourne specialist and a nationally scarce species (Macadam 2016). The beetles also include species associated with temporary waterbodies, such as *Hydroporus palustris*. The Somerford Keynes-only taxa comprised one leech, four snails, seven beetles, 13 true flies, six mayflies, *Sialis lutaria*, two leuctrid stoneflies and 15 caddisflies (Appendix 2). Considerable variability between sites also occurred within orders. For example, dytiscid and elmid beetles characterized Ewen and Somerford Keynes, respectively. Similarly, within the caddisfly genus *Limnephilus*, four species occurred only at Ewen, one at Somerford Keynes, and two were recorded at both sites.

Collectively, these observations show that whereas many EPT taxa were restricted to Somerford Keynes, flatworm, snail, beetle and dragonfly taxa all made unique contributions to the Ewen fauna. In addition, one of the snails restricted to Somerford Keynes was *Potamopyrgus antipodarum* (Maitland name *P. jenkinsi*), suggesting that drying can limit the distribution of this invasive species in temporary streams.

3.4 Variability in community metrics between sites, years and months

3.4.1 Total invertebrate abundance

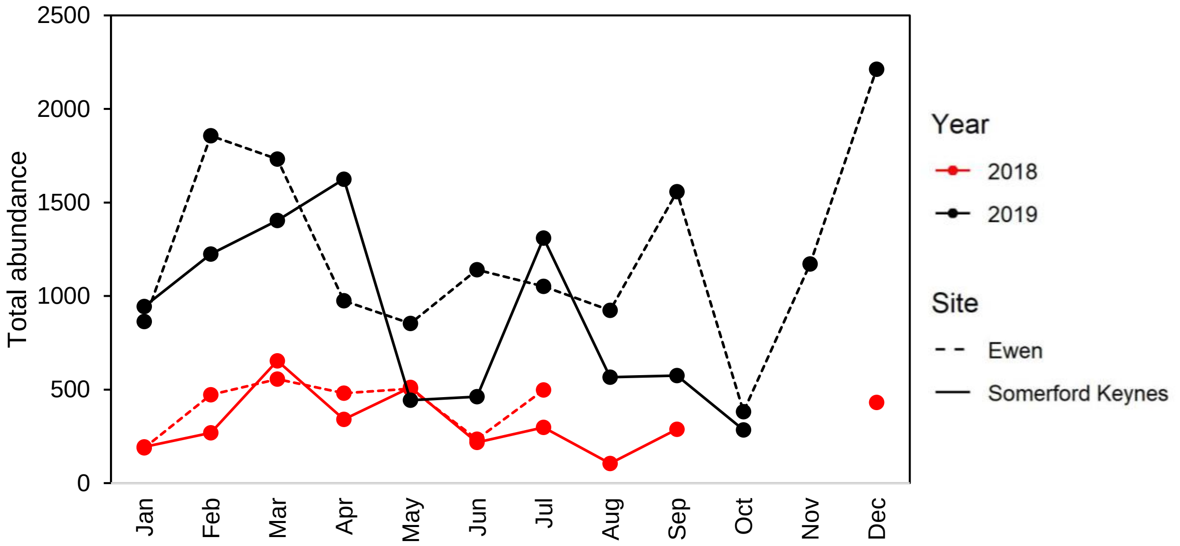

Figure 3. Total abundance of macroinvertebrate taxa in kick samples collected at monthly intervals from Ewen (dashed lines) and Somerford Keynes (SK; solid lines) in 2018 (red) and 2019 (black). Gaps reflect months in which samples were not collected. The December 2018 sample is from SK.

Abundance was higher at Ewen (mean ± SE 929 ± 132; min.–max. 188–2212 individuals per sample) than at Somerford Keynes (607 ± 100; 105–1625 individuals per sample; Fig. 3). This difference may be skewed by collection of three samples from Somerford Keynes but not Ewen in August–December 2018, when abundance was low, and collection of two samples from Ewen but not Somerford Keynes in November–December 2019, when abundance was high. Equally, Ewen samples collected in the same month as Somerford Keynes samples often contained more individuals, notably in September 2019 (Fig. 3), when low wetted width and water depth (Fig. 4) may have forced mobile invertebrates to move into a contracting area of slack water.

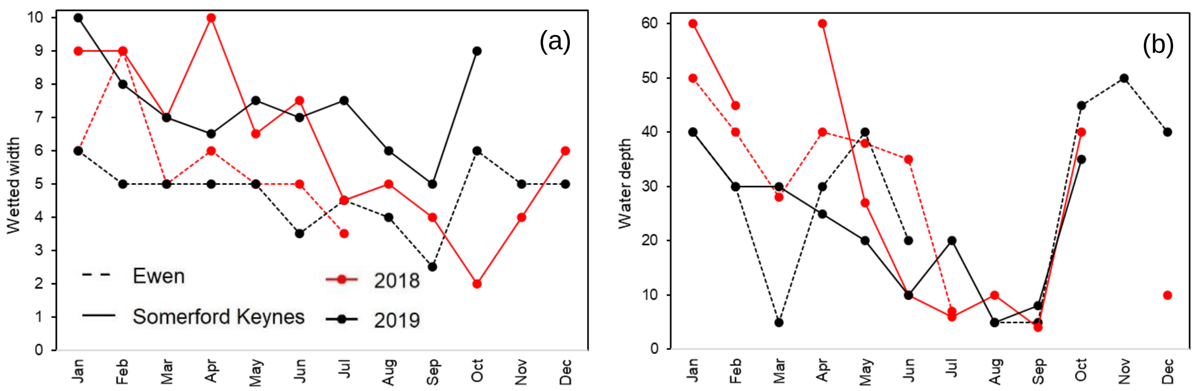

Figure 4. (a) Wetted width and (b) water depth at Ewen and Somerford Keynes in 2018 and 2019; for further details, see the Figure 3 legend.

Considering change over time, abundance was low, stable and comparable at both sites in January to July/September 2018 (Fig. 3). Abundance was then higher after the 2–to–5-month dry phases that affected both sites, reaching almost 1000 individuals per sample in January 2019. Abundance was then varied considerably at both sites throughout 2019.

Some fluctuations do *not* appear to have been driven by increasing densities within contracting wetted habitats (Fig. 4); for example, wetted width and water depth were stable at Ewen between October and December 2019, while abundance rose sharply.

No one taxon was responsible for peak abundances, for example *G. pulex/fossarum*, *A. aquaticus*, *S. dubitans*, Oligochaeta and the *Simulium ornatum* species complex each accounted for 9–17% of all invertebrates sampled from Ewen in 2019.

3.4.2 Abundance of selected species

The abundance of selected species (*S. ignita*, *I. grammatica*, *Nemoura* including *N. cinerea*, and *S. dubitans*) is shown in Figs. S1–S4 (Appendix 3). The abundance of each species has a distinct seasonal peak—as early as February, for *Nemoura*, and usually as late as May, for *S. ignita*. Each species had very high abundance in the wetter 2019, at either Ewen (*Nemoura*, *S. dubitans*) or Somerford Keynes (*I. grammatica*, *S. ignita*).

3.4.3 Total taxonomic richness

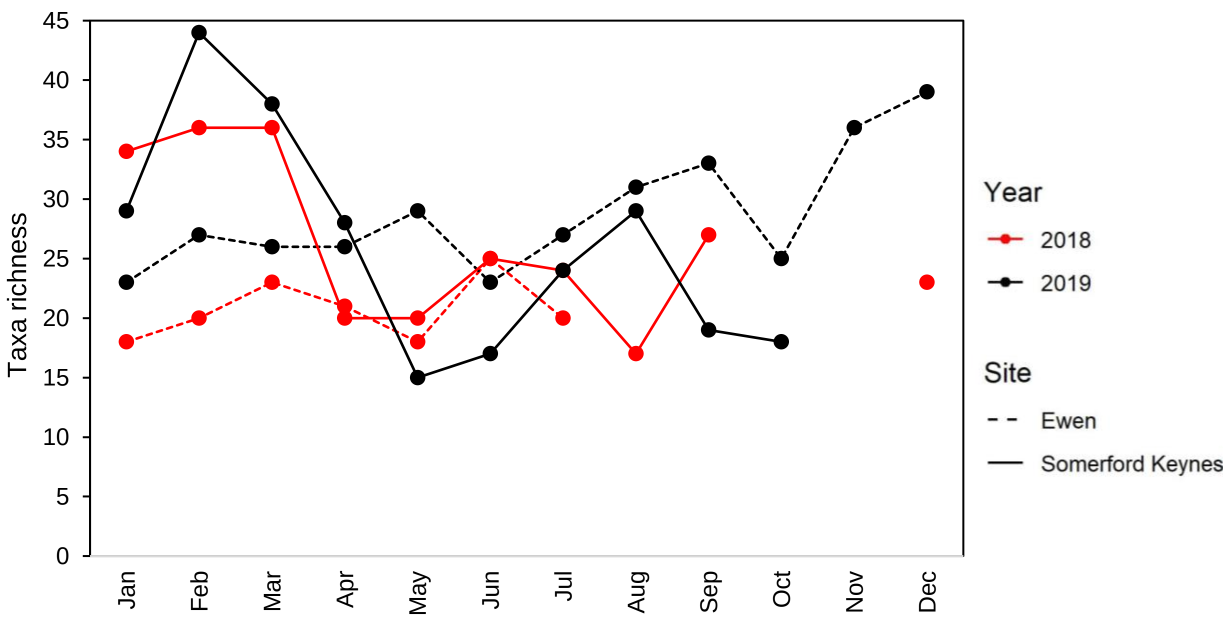

Figure 5. Total richness of all macroinvertebrate taxa; for further details, see the Figure 3 legend.

Overall, total taxa richness was entirely comparable at Ewen (26.63 ± 0.27 taxa per sample) and Somerford Keynes (26.65 ± 0.36), and was higher in 2019 (28.72 ± 1.91) than 2018 (23.94 ± 1.48) at both sites (Fig. 5).

Temporal changes differed between the two sites. At Somerford Keynes, richness peaked in February and March of both years, reaching 48 taxa in February 2019, including 17 true fly and 12 caddisfly taxa, as described in more detail below. At Ewen, richness was stable throughout the 2018 months in which samples were taken (i.e. January to July), despite considerable changes in instream conditions, including low flow, width, depth and increased plant cover in July. Compared to July 2018, richness was slightly higher when sampling recommenced in January 2019—within 1 month of flow resumption after the 5-month dry phase. Ewen richness then increased to a peak of 40–41 taxa per sample in November–December 2019, with no single taxonomic order contributing >10 taxa to this peak in either month.

3.4.4 Order-level taxonomic richness

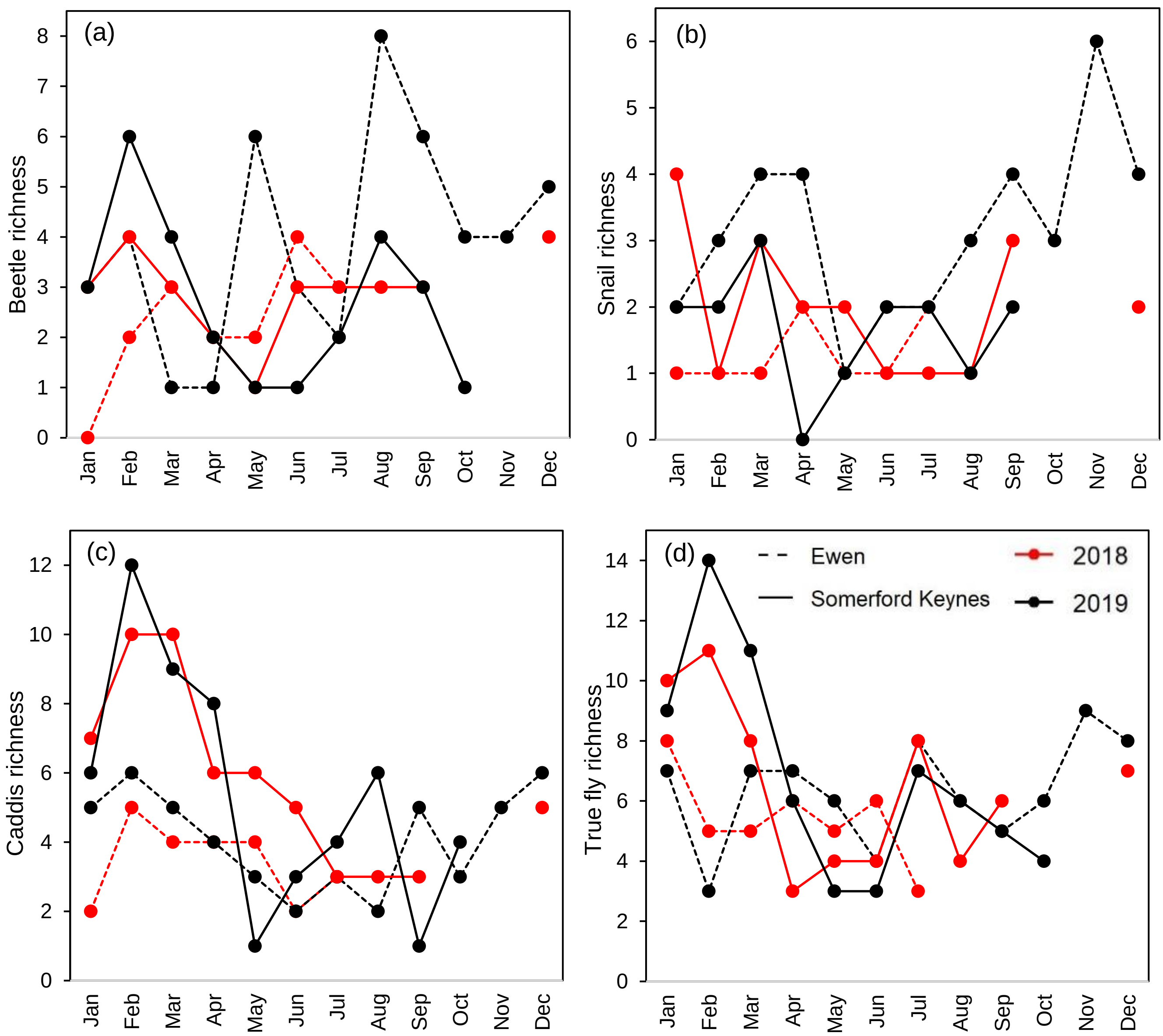

Figure 6. Taxonomic richness in the orders (a) Coleoptera; (b) Gastropoda; (c) Trichoptera; and (d) Diptera. A key is provided on pane (d); for further details, see the Figure 3 legend.

Of the four orders with sufficient taxa to warrant plotting, the mean richness of beetles (Fig. 6a) was higher at Ewen (3.3 ± 0.1 taxa per sample) than Somerford Keynes (2.8 ± 0.1), as was snail richness (2.5 ± 0.1 cf. 1.9 ± 0.1; Fig. 6b). Richness of both these orders was particularly high and variable at Ewen in 2019. Although not plotted, flatworm richness was also higher at Ewen: four species from three families were present, whereas only *Polycelis* was recorded at Somerford Keynes.

In contrast, caddisfly mean richness was higher at Somerford Keynes (5.6 ± 0.2 taxa per sample) than Ewen (3.8 ± 0.1; Fig. 6c). Both sites supported Goeridae, Glossosomatidae, Leptoceridae and Limnephilidae; Beraeidae, Polycentropodidae, Rhyacophilidae and Sericostomatidae also occurred at Somerford Keynes, and Apataniidae and Hydroptilidae at Ewen. True fly richness was similar at Ewen (6.0 ± 0.1 taxa per sample) and Somerford Keynes (6.7 ± 0.1; Fig. 6d) and generally declined between January–February and May–July. The particularly high richness at Somerford Keynes in February 2019 included representatives of the Ceratopogonidae, Empididae, Limoniidae, Pediciidae, Psychodidae, Rhagionidae, Simuliidae, Stratiomyidae, Tabanidae, Tipulidae and three chironomid subfamilies.

3.4.5 WHPT metrics: ASPT and NTAXA

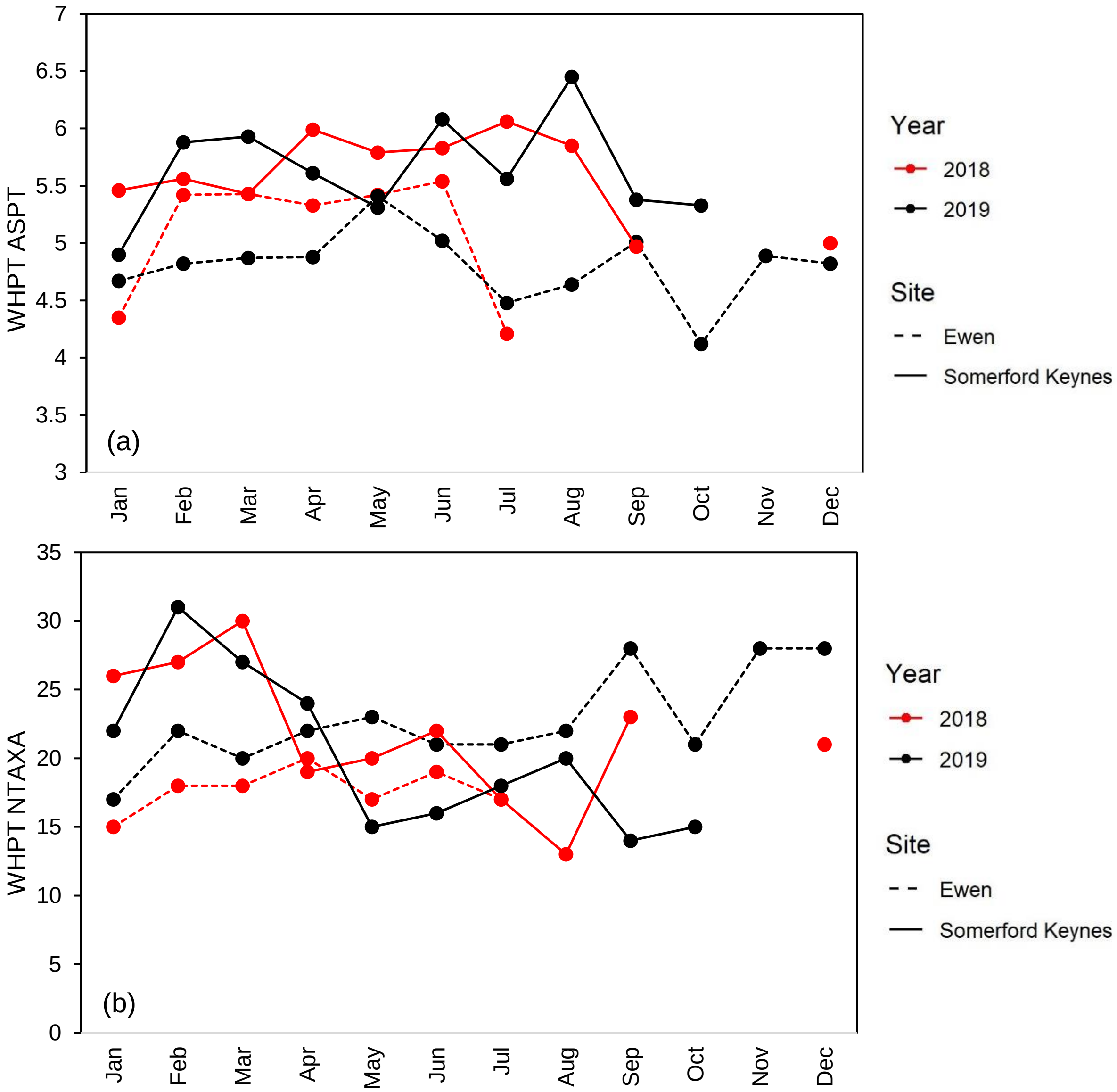

Figure 7. WHPT (a) ASPT and (b) NTAXA; for further details, see the Figure 3 legend.

The WHPT ASPT was consistently higher at Somerford Keynes (5.6 ± 0.02) compared to Ewen (4.9 ± 0.02; Fig. 7a), reflecting the lower occurrence of high-scoring EPT taxa at the latter site. Scores were comparable over time at Somerford Keynes, with a notable peak (6.5) in August 2019, when high-scoring families included Goeridae, Leuctridae, Perlodidae, Rhyacophilidae and Sericostomatidae. At Ewen, ASPT scores declined from June in both years, likely due to the loss of habitats suitable for flow-loving taxa as discharge declined. Overall, ASPT scores were most consistent between sites in May, but were sufficiently stable between February and June to enable interpretation of index values.

The number of taxa contributing to the ASPT (i.e. NTAXA) varied between 13 (at Somerford Keynes in August 2018) and 31 (at the same site in February 2019; Fig. 7b). Values were relatively stable at Ewen and between April and July. In contrast, at Somerford Keynes, the ASPT was particularly high in January to March, then much lower from April onwards. Overall, scores were most consistent between sites and years in April.

3.4.6 DEHLI metrics: DEHLI and NTAXA

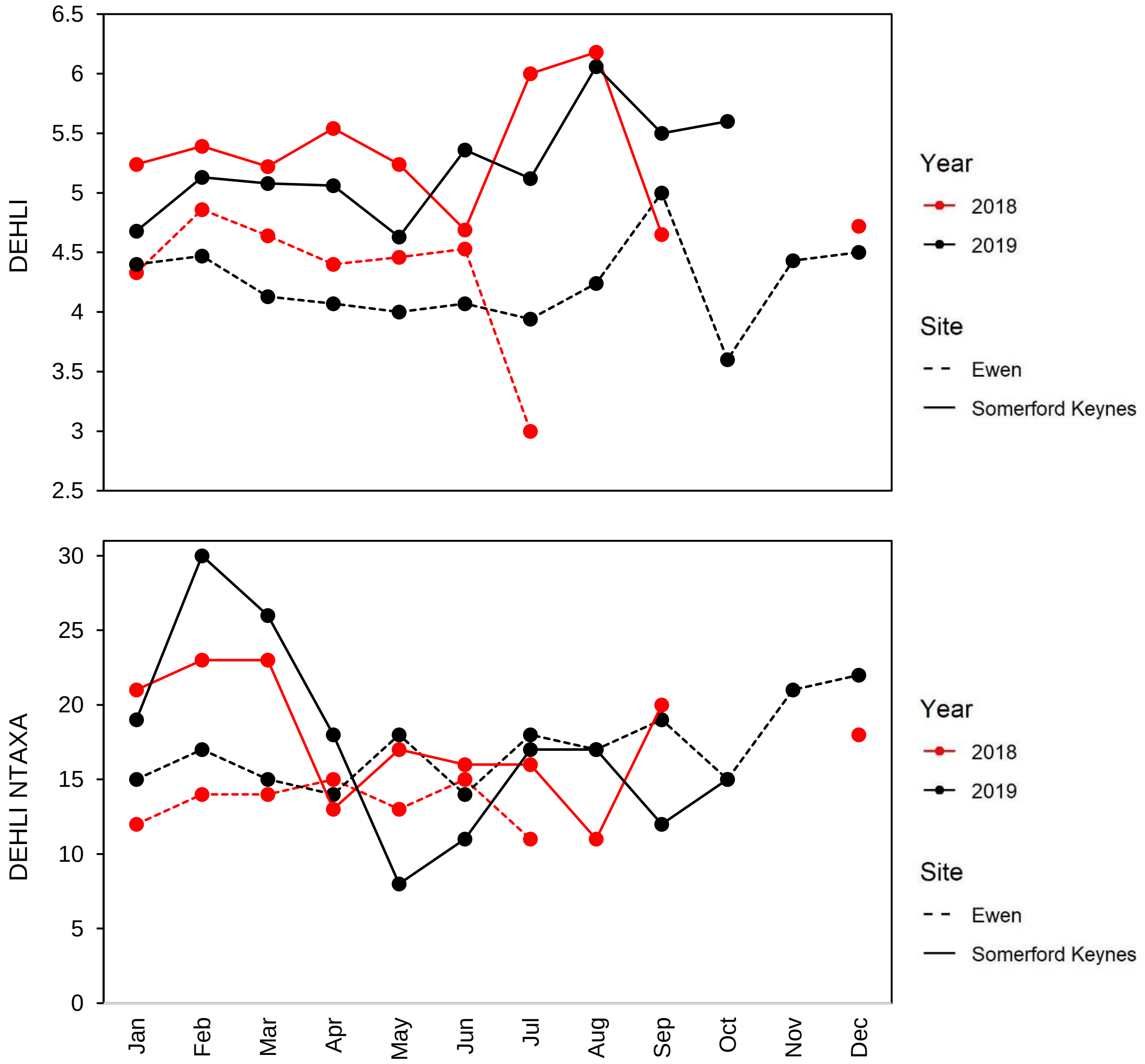

Figure 8. Drought Effect of Habitat Loss on Invertebrates (DEHLI) metrics: (a) the DEHLI score, i.e. the average Drought Intolerance Score per taxon; (b) the number of scoring taxa; see Fig. 3 for more details.

The DEHLI index was designed to quantify invertebrate community responses to changes in habitat conditions associated with severe supra-seasonal droughts in near-perennial rivers, but also responds to seasonal intermittence in temporary streams (Chadd et al. 2017). As such, DEHLI scores were consistently higher at Somerford Keynes (5.3 ± 0.02) compared to Ewen (4.3 ± 0.02; Fig. 8a), reflecting Ewen's reduced occurrence: of drought-intolerant EPT taxa such as Rhyacophilidae due to lower flows; and of taxa that live in marginal habitats and are thus affected by the loss of lateral connectivity, such as Bithyniidae.

At both sites, DEHLI scores were consistently higher in 2018 than 2019 in February–May, despite 2019 being a wetter year (Fig. 8a). Ewen and Somerford Keynes both typically dry, and these counterintuitive higher scores may thus reflect the greater availability of slow-flowing, ponded, macrophyte-rich and damp habitats for low-scoring lentic taxa in 2019. For example, at Ewen, 10 taxa with Drought Intolerance Scores of 2–7 were recorded only in 2019, including a true bug, a dragonfly, two beetles, two snails and two true fly larvae. These results suggest that temporal changes in DEHLI in intermittent streams may differ from those observed in the perennial and near-perennial systems for which the index was developed.

3.4.7 Community Conservation Index

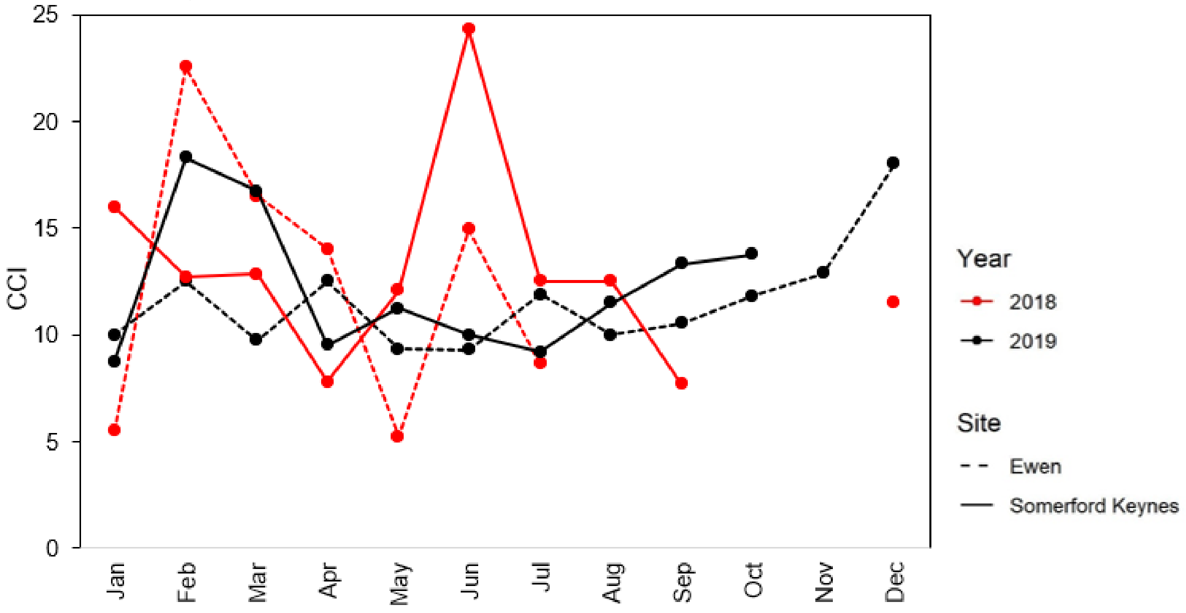

Figure 9. The Community Conservation Index (CCI); for further details, see the Figure 3 legend.

Community Conservation Index (CCI) values were similar at Somerford Keynes (11.9 ± 0.17) and Ewen (12.6 ± 0.15) but varied over time at both sites, especially in 2018. No Red Data Book (RDB) species (CCI scores 8–10) were recorded at either site, but five nationally notable (score 7) and two regionally notable (score 6) taxa were recorded. Of these seven taxa, *Agabus biguttatus* (7) occurred only at Ewen; *Nebioporus depressus* (7), *Riolus subviolaceus* (7), *Hydraena rufipes* (7) and *Procloeon bifidum* (6) only at Somerford Keynes; and *Oxycera morrisii* (7) and *Simulium latipes* (6) inhabited both sites.

The genus *Paraleptophlebia* occurred at Ewen, which—considering the long dry phases that characterize this site—is likely to be the CCI 8-scoring, nationally scare species *P. werneri* (Macadam 2016; Fig. 10a). Similarly, *N. cinerea* occurred at both sites but was more abundant at Ewen. This stonefly is morphologically superficially similar to the winterbourne specialist *N. lacustris*, which was first discovered in the UK in 2012 and is nationally rare (Macadam 2015; Fig. 10b; CCI score 7, R. Chadd, pers. comm.). In addition, *S. dubitans* occurred at both sites, being 10× more abundant at Ewen (Fig. 10c); 'local' (score 5) in the CCI (R. Chadd, pers. comm.), *S. dubitans*' designation as nationally rare by Wallace (2016) may reflect the few records we have of a species first recorded in the UK in 2011.

Many species—notably the true flies—have not been assigned CCI scores. Determining their conservation status (for example of *Pericoma* species, many of which have few records on the NBN Atlas) could enhance recognition of the biodiversity value of temporary sites.

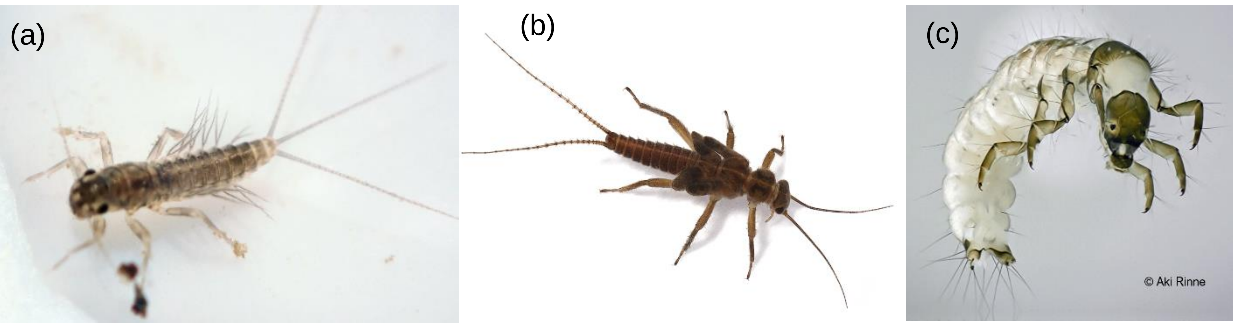

Figure 10. Temporary stream species of conservation interest: (a) *Paraleptophlebia werneri* © Cyril Bennett; (b) *Nemoura lacustris* © Cyril Bennett; and (c) *Synagapetus dubitans* © Aki Rinne.

4. Recommendations for future monitoring

Interpret community composition in light of environmental data

As observed herein, the composition of aquatic macroinvertebrate communities in temporary rivers varies both within and between years, making a two-year time series (comprising one typical and one wetter year) sufficient to draw only preliminary conclusions regarding the 'best' time to take samples. This characteristic variability also means that community data should be interpreted in light of abiotic data, ideally gauged flow data or on-site observations of instream conditions that indicate the duration and timing of recent dry phases. However, where such data are unavailable, DEHLI index values may be used to indicate whether community composition is influenced by a recent drying event (Chadd et al. 2017).

Alter your expectations

Compared to perennial sites, BMWP-type biomonitoring indices including WHPT naturally have lower values at temporary sites, and their values decrease further as dry phase durations increase, and are more variable over time both within and between years (Wilding et al. 2018; White et al. 2019). A major, national (and indeed global) research priority is thus to determine the index values indicative of unimpacted reference conditions and varying severity of human impacts—at sites representing the full range of different temporary river types (Stubbington et al. 2018).

Sample in spring… and summer?

The likelihood of sites being dry from late summer to early winter, and low ASPT scores in late winter, leave spring and early summer as the only reliable options for planned sampling campaigns. Abundance and richness both increased quickly after flow returned and ASPT values were relatively stable from March to June, suggesting that spring sampling is appropriate—which would also fit in with routine Environment Agency biomonitoring programmes. In addition, ASPT scores peaked at Somerford Keynes in August in both years; beetle richness was highest at Ewen in August; true fly richness peaked at Ewen in July; and mayfly richness was highest at Somerford Keynes in August—such results indicate the value of second, summer sampling campaign, to increase biodiversity estimates.

Conduct targeted sampling campaigns to identify rare specialists

Nemoura and *N. cinerea* were found at both sites but were far more abundant at Ewen, and *Paraleptophlebia* was found only at Ewen. Species-level identification is recommended to determine if *P. werneri*—a nationally scarce species—occurs at Ewen. Nemourids should also be identified to species level in light of the 2012 discovery of the morphologically similar, nationally rare winterbourne specialist *N. lacustris* in England (Hammett, 2012). Both species could contribute to the biodiversity value of temporary reaches of the Thames headwaters.

Based on this study's single record of eight *Paraleptophlebia* in May 2019 as well as observations made by the authors in chalk winterbournes, mid-May may be the best time to collect late-instar *P. werneri* with clear species-level identification features. In contrast, based on *Nemoura* and *N. cinerea* abundance in this study and the authors' previous observations, sampling in March may be necessary to capture late-instar nemourids.

Sample enough sites to characterize a range of temporary flow regimes

Communities at temporary sites are known to differ from those at equivalent perennial sites. This study demonstrated that there are also considerable differences between communities at temporary sites with contrasting flow regimes. Therefore, to characterize catchment-wide biodiversity, communities should be sampled from sufficient sites to represent a breadth of temporary flow regimes.

5. Recommended reading

A small-scale study that shows clear differences between perennial and winterbourne sites and identifies species associated with the latter:

Armitage, P.D. and Bass, J., 2013. Long-term resilience and shortterm vulnerability of South Winterbourne macroinvertebrates. Proceedings of the Dorset Natural History and Archaeological Society 134, 43–55. Available on ResearchGate.

A review paper that recognizes the diversity of temporary streams in cool, wet countries such as the UK:

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Appendices

Appendix 1. Photographs of the study sites during flowing, ponded and dry phases: Ewen with slow flows in May 2019 (a) and during a dry phase in September 2018(b), and downstream of Somerford Keynes during a low-flow phase in August 2018 (c) and with normal flows in March 2019 (d).

Appendix 2. Taxa common to Ewen and Somerford Keynes and taxa found at only one of these sites. Numbers indicate the taxon's total abundance in all samples. Taxa identified to a coarser taxonomic level (i.e. family/genus) are not listed as site-specific if identified to a lower taxonomic level (i.e. genus/species) at both sites; abundance of such taxa has been added to the most likely taxon. Taxa are listed alphabetically within families within orders.

Order	Family	Common taxa		Site-specific taxa	
		Somerford Keynes	**Ewen**	**Somerford Keynes only**	**Ewen only**
Hirudinea	Erpobdellidae	Erpobdellidae 1	Erpobdellidae 9		
		Erpobdella octoculata 4	*Erpobdella octoculata* 1		
					Erpobdella testacea 13
		Trocheta subviridis 1	*Trocheta subviridis* 14		
	Glossiphoniidae	*Glossiphonia complanata* 16	*Glossiphonia complanata* 8		
		Helobdella stagnalis 5	*Helobdella stagnalis* 1		
				Hemiclepsis marginata 2	
					Theromyzon tessulatum 1
Oligochaeta	-	Oligochaeta 1404	Oligochaeta 1091		
Tricladida	Planariidae	*Polycelis* 7	*Polycelis* 75		
					Polycelis felina 5
					Polycelis nigra or *tenuis* 927
	Dendrocoelidae				*Dendrocoelum lacteum* 29
	Dugesiidae				*Dugesia lugubris* or *polychroa* 32
Bivalvia	Sphaeriidae	*Pisidium* 150	*Pisidium* 25		
Gastropoda	Bithyniidae			*Bithynia tentaculata* 3	
	Lymnaeidae	Lymnaeidae 3	Lymnaeidae 14		
		Ampullaceana balthica 17	*Ampullaceana balthica* 171		
		Galba truncatula 2	*Galba truncatula* 1		
				Lymnaea stagnalis 1	
					Stagnicola palustris 60
	Physidae				*Aplexa hypnorum* 1
					Physella acuta 1
	Planorbidae			*Ancylus fluviatilis* 5	
					Planorbis 4
		Anisus vortex 1	*Anisus vortex* 1		
					Anisus leucostoma 40
	Succineidae				Succineidae 2
	Tateidae			*Potamopyrgus antipodarum* 150	
	Valvatidae	*Valvata cristata* 3	*Valvata cristata* 3		
					Valvata piscinalis 1
	Zonitoidae				*Zonitoides* 2
Isopoda	Asellidae	*Asellus aquaticus* 24	*Asellus aquaticus* 2137		
		Proasellus meridianus 7	*Proasellus meridianus* 44		
Amphipoda	Crangonyctidae	*Crangonyx pseudogracilis/ floridanus* 27	*Crangonyx pseudogracilis/ floridanus* 156		
	Gammaridae	*Gammarus pulex/fossarum* agg. 1941	*Gammarus pulex/fossarum* agg. 919		
	Dryopidae	*Dryops* 1	*Dryops* 14		

Coleoptera	Dytiscidae	Dytiscidae (larvae) 5	Dytiscidae (larvae) 94		
				Agabus guttatus 1	
					Agabus biguttatus 8
					Agabus didymus 8
					Dytiscus semisulcatus 1
					Hydroporus discretus 2
					Hydroporus palustris 2
					Ilybius fuliginosus 2
				Nebrioporus depressus 2	
	Elmidae	*Elmis aenea* 217	*Elmis aenea* 26		
				Esolus parallelepipedus 1	
		Oulimnius 29	*Oulimnius* 18		
				Oulimnius tuberculatus 23	
				Riolus subviolaceus 24	
	Haliplidae				*Brychius elevatus* 1
		Haliplus 1	*Haliplus* 32		
					Haliplus lineatocollis 11
	Hydraenidae	*Hydraena* 2	*Hydraena* 1		
				Hydraena riparia 2	
				Hydraena rufipes 1	
	Hydraenidae	*Helophorus* 1	*Helophorus* 1		
					Helophorus brevipalpis 10
					Hydrobius fuscipes 1
Diptera	Ceratopogonidae	Ceratopogonidae 266	Ceratopogonidae 25		
				Atrichopogon 1	
	Chironomidae	Chironomidae 103	Chironomidae 38		
		Chironominae 306	Chironominae 1781		
		Orthocladiinae 164	Orthocladiinae 309		
					Podonominae 20
		Prodiamesinae 14	Prodiamesinae 2		
		Tanypodinae 90	Tanypodinae 613		
	Dixidae				*Dixa* 105
	Empididae	Empididae 10	Empididae 17		
	Limoniidae	Limoniidae 2	Limoniidae 5		
				Pilaria 1	
				Phylidorea 1	
	Muscidae	*Limnophora riparia* 12	*Limnophora riparia* 6		
	Pediciidae	*Dicranota* 81	*Dicranota* 1		
					Austrolimnophila ochracea 1
					Gonomyia 1
					Molophilus 4
	Psychodidae	*Pericoma* 19	*Pericoma* 104		
				Pericoma blandula 1	
				Pericoma fallax 23	
				Pericoma trivialis 213	

					Psychoda cinerea 3
				Psychoda gemina 1	
				Tonnoiriella pulchra 1	
	Ptychopteridae			*Ptychoptera* 1	
	Rhagionidae			*Chrysopilus cristatus* 2	
	Simuliidae	Simuliidae 26	Simuliidae 149		
		Simulium 1	*Simulium* 720		
		Simulium (*Eusimulium*) 20	*Simulium* (*Eusimulium*) 7		
		Simulium (*Nevermannia*) 10	*Simulium* (*Nevermannia*) 88		
		Simulium angustipes/velutinum 4	*Simulium angustipes/velutinum* 28		
					Simulium armoricanum 21
					Simulium aureum 64
		Simulium latipes 20	*Simulium latipes* 1		
		Simulium lundstromi 2	*Simulium lundstromi* 1		
		Simulium ornatum/ intermedium/trifasciatum 14	*Simulium ornatum/ intermedium/trifasciatum* 203		
		Simulium vernum 42	*Simulium vernum* 215		
	Stratiomyidae				*Beris* 1
		Oxycera 9	*Oxycera* 93		
		Oxycera morrisii 29	*Oxycera morrisii* 15		
				Oxycera nigricornis 3	
				Oxycera rara 1	
	Tabanidae			Tabanidae 2	
		Chrysops 1	*Chrysops* 1		
	Tipulidae	*Tipula* 11	*Tipula* 27		
		Tipula maxima 7	*Tipula maxima* 2		
		Tipula montium 6	*Tipula montium* 4		
Ephemeroptera	Baetidae	*Baetis* 52	*Baetis* 3		
				Baetis muticus 1	
		Baetis rhodani/atlanticus 235	*Baetis rhodani/atlanticus* 47		
		Baetis scambus/fuscatus 4	*Baetis scambus/fuscatus* 3		
				Baetis vernus 17	
				Centroptilum luteolum 4	
				Procloeon bifidum 2	
		Procloeon pennulatum 43	*Procloeon pennulatum* 131		
	Caenidae			*Caenis horaria* 1	
				Caenis luctuosa/macrura 6	
	Ephemerellidae	*Serratella ignita* 1629	*Serratella ignita* 628		
	Leptophlebiidae				*Paraleptophlebia* 6
Hemiptera	Corixidae	*Sigara* 1	*Sigara* 3		
				Micronecta 1	
	Notonectidae			*Notonecta glauca* 3	
	Vellidae				*Velia* 2
Megaloptera	Sialidae			*Sialis lutaria* 4	

Odonata	Libellulidae				*Libellula quadrimaculata* 1
Plecoptera	Leuctridae	*Leuctra fusca* 54	*Leuctra fusca* 4		
				Leuctra geniculata 8	
				Leuctra nigra 2	
	Nemouridae	*Nemoura* 73	*Nemoura* 230		
		Nemoura cinerea 29	*Nemoura cinerea* 167		
	Perlodidae	*Isoperla grammatica* 1915	*Isoperla grammatica* 1217		
Trichoptera	Apataniidae				*Apatania muliebris* 11
	Beraeidae			*Beraeodes minutus* 56	
	Glossosomatidae	Glossosomatidae 28	Glossosomatidae 176		
				Agapetus ochripes 10	
		Synagapetus dubitans 241	*Synagapetus dubitans* 2713		
	Goeridae	*Silo nigricornis* 466	*Silo nigricornis* 58		
				Silo pallipes 2	
	Hydroptilidae				*Agraylea* 1
	Leptoceridae			*Athripsodes* 19	
				Athripsodes cinereus 4	
		Mystacides 19	*Mystacides* 2		
				Mystacides azurea 3	
				Mystacides longicornis 3	
	Limnephilidae	Limnephilidae 639	Limnephilidae 746		
				Anabolia nervosa 112	
				Chaetopteryx villosa 1	
				Glyphotaelius pellucidus 170	
				Halesus radiatus 2	
		Limnephilus 124	*Limnephilus* 81		
					Limnephilus bipunctatus 3
					Limnephilus centralis 2
				Limnephilus flavicornis 61	
		Limnephilus lunatus 261	*Limnephilus lunatus* 220		
		Limnephilus marmoratus 69	*Limnephilus marmoratus* 2		
					Limnephilus rhombicus 3
					Limnephilus sparsus 12
		Micropterna sequax 10	*Micropterna sequax* 406		
					Potamophylax latipennis 1
		Stenophylax permistus 23	*Stenophylax permistus* 86		
	Polycentropodidae			*Plectrocnemia conspersa* 6	
				Polycentropodidae 1	
	Psychomyiidae			*Lype* 2	
	Rhyacophilidae			*Rhyacophila* 14	
				Rhyacophila dorsalis/fasciata 49	
	Sericostomatidae			*Sericostoma personatum* 71	

Appendix 3. Change over time in the abundance of selected species.

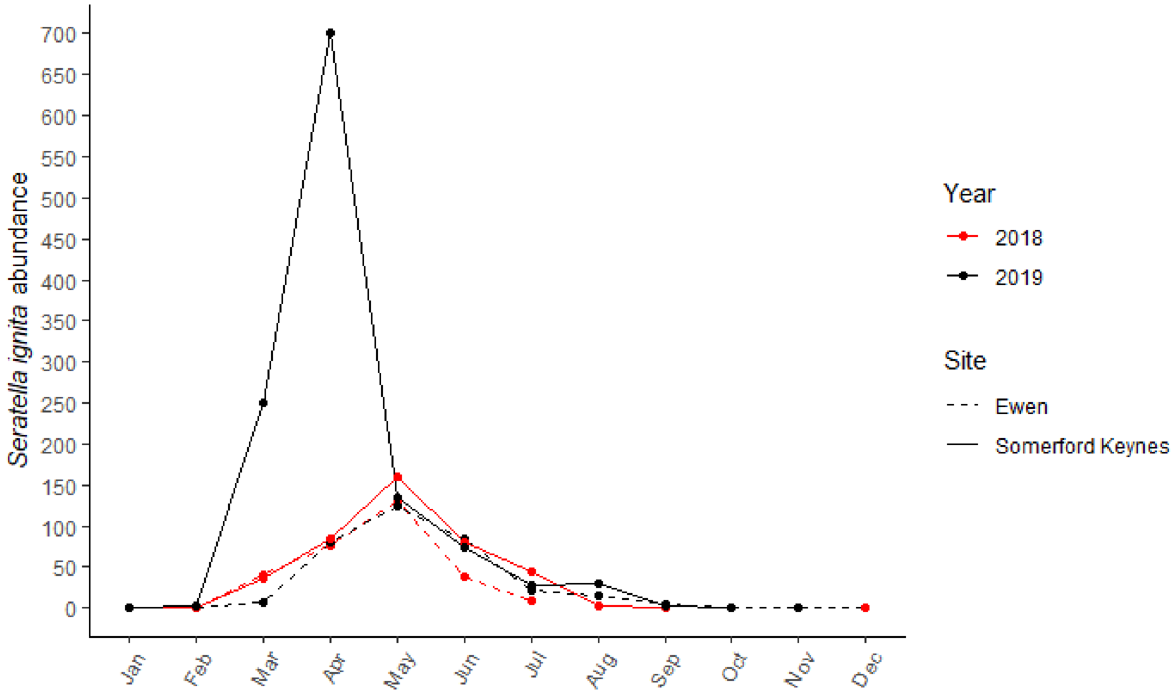

Figure S1. The abundance of *Serratella ignita* in monthly kick samples collected from Ewen (dashed lines) and Somerford Keynes (SK; solid lines) in 2018 (red) and 2019 (black). Gaps reflect months in which samples were not collected. The December 2018 sample is from SK.

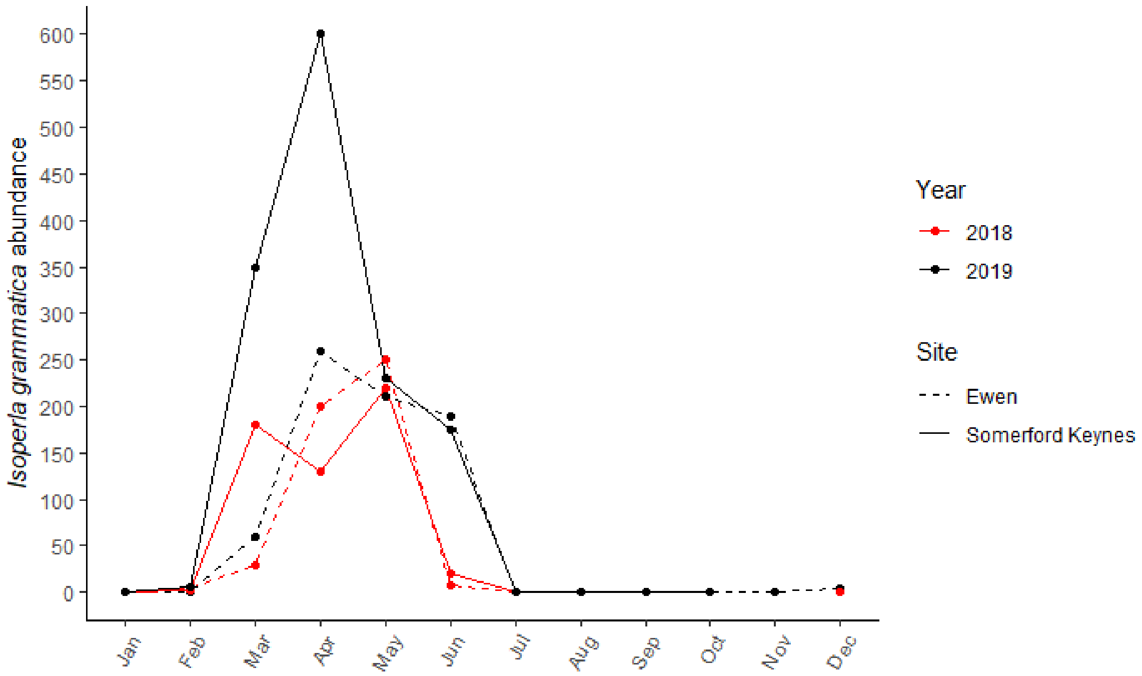

Figure S2. The abundance of *Isoperla grammatica*. For further details, see the Fig. S1 legend.

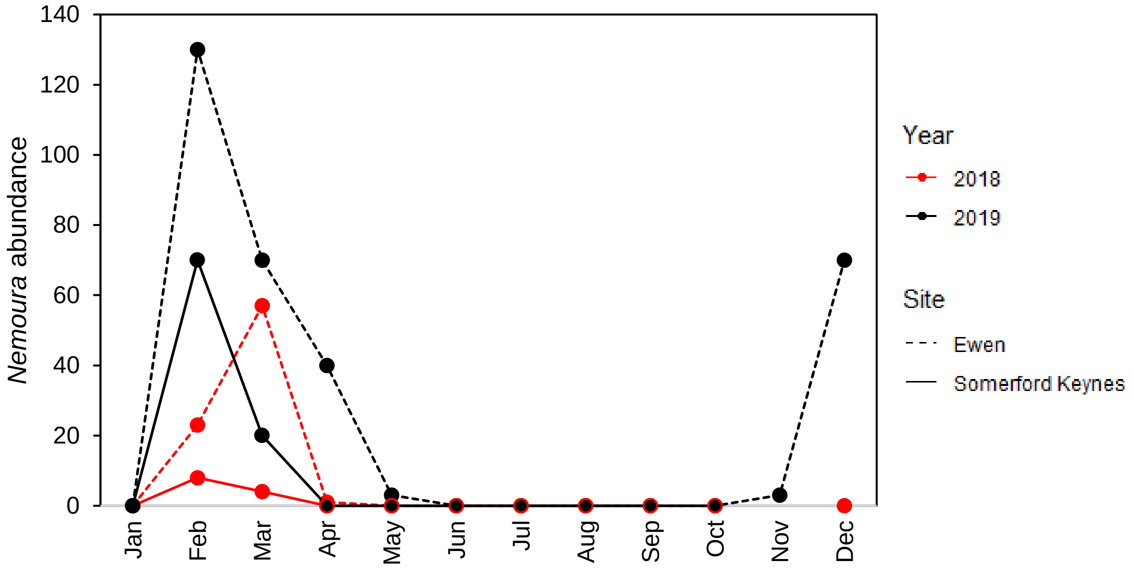

Figure S3. The abundance of all nemourids i.e. the genus *Nemoura* and the species *N. cinerea*. For further details, see the Fig. S1 legend.

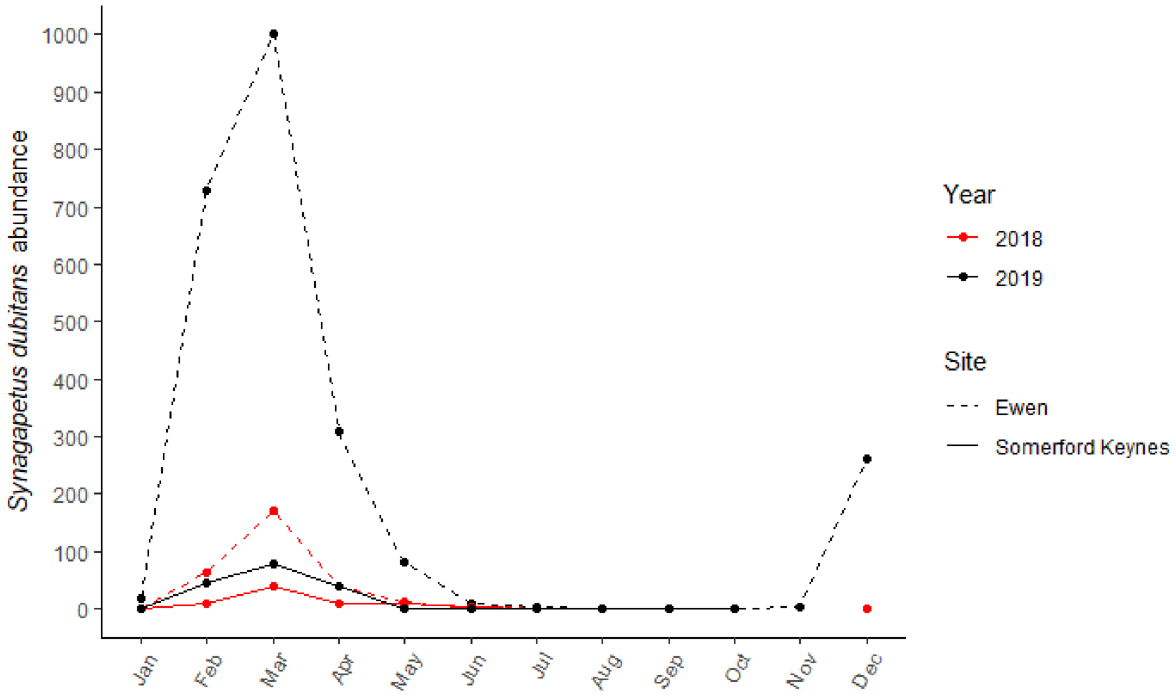

Figure S4. The abundance of *Synagapetus dubitans*. For further details, see the Fig. S1 legend.