Dry rivers: it's time to recognize their natural value

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Romain is a post-doctoral Research Fellow based at Nottingham Trent University (NTU), and is supervised by Rachel (NTU) and Judy (Environment Agency). Here, Romain provides an insight into temporary streams; in a future issue, he'll continue to explore these dynamic ecosystems, focusing on the work he and others are conducting as part of NTU's expanding temporary streams research group.

The flow of water from upstream to downstream defines lotic ecosystems, but when rivers stop flowing and dry, do they lose their value? Or is it time to view these temporary streams as dynamic ecosystems that support high biodiversity and provide valuable services? Most river networks encompass reaches that naturally dry due to interacting climatic and geological conditions. Dry conditions can last from a moment to years, and this variability creates aquatic-terrestrial ecosystems described as intermittent, temporary or ephemeral; here, we use the term temporary to describe all streams that sometimes stop flowing – with most also experiencing partial or complete surface water loss. Temporary streams can make up 70% of the total river length in Mediterranean and arid climate regions but are also common in places with cooler, wetter climates, including the UK.

Temporary rivers are dynamic ecosystems that support high biodiversity

Our UK temporary streams are diverse and include small upland systems, winterbourne chalk stream reaches and karst limestone rivers, all of which experience natural dry periods (Fig. 1). Many more rivers dry or stop flowing during drought events – even parts of the lower River Thames stopped flowing during the 1976 drought.

Drying creates different in-stream habitat types as flows recede, from slow-flowing waters, to increasingly disconnected stretches of lentic water which become isolated pools, and – following the loss of surface water – sediments that may remain saturated or become desiccated (Fig. 1). Drying represents a strong disturbance for most aquatic organisms, but some adapted species thrive in temporary streams. For example, brown trout spawn in clear and competition-free gravel beds of winterbourne reaches to winter, then adults and new recruits migrate downstream as flows recede in spring (House & Punchard, 2007). In addition, some rare specialists such as the Scarce purple dun *Paraleptophlebia werneri* are found only in temporary streams (Armitage & Bass, 2013).

If isolated pools remain within a drying bed, biodiversity is further enhanced by opportunistic beetles and true bugs that arrive to exploit these habitats (Hill & Milner, 2018), joining birds and amphibians that visit to feast on the 'invertebrate soup' they contain (Boulton & Lake, 2008). Dry channels are also colonised by opportunistic terrestrial species, including plants and carabid beetles. Through habitat 'time-sharing' by aquatic and terrestrial organisms, temporary streams harbour a high biodiversity, with species interacting within communities to perform ecological processes that underpin ecosystem function.

Temporary streams deliver valuable ecosystem services

Temporary streams also provide important cultural, regulating and provisioning ecosystem services, with provision varying between wet and dry phases. For example, temporary streams can support recreational fishing during wet phases but be used as a path by walkers or as foraging areas for livestock during dry phases. Temporary streams could also create opportunities to enhance catchment-wide natural flood management strategies; for example, building leaky dams in headwaters could help regulate the delivery of rainfall to downstream reaches, thus mitigating flooding.

Relatively little attention has been given to temporary river hydrology and ecology in the UK, perhaps because dry channels have, until recently, been perceived as lifeless symbols of human impacts. Although artificial intermittence can result from impacts including over-abstraction, the value of natural temporary rivers – and thus the need to better protect these ecosystems – is increasingly

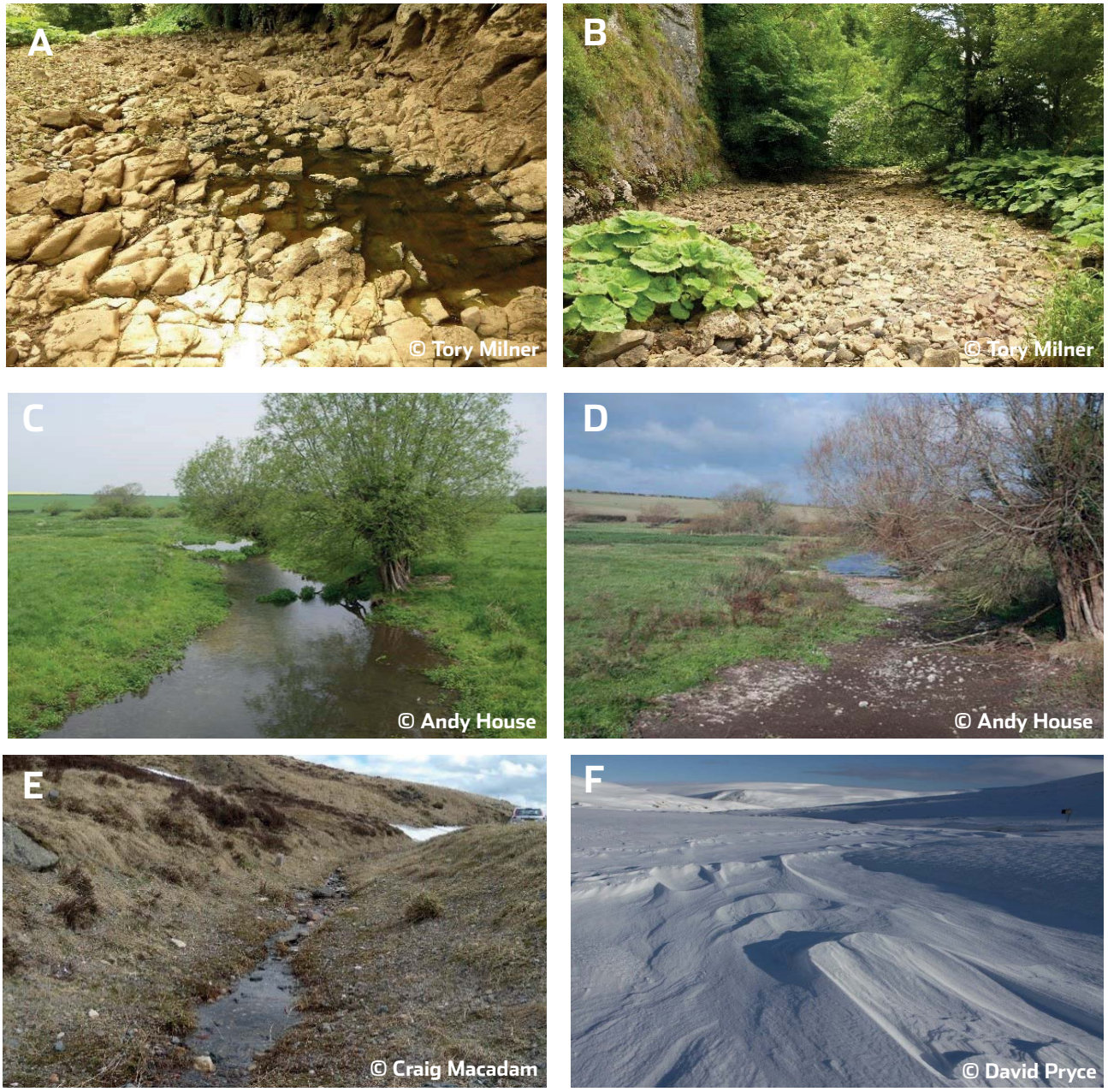

Fig 1: The variety of UK temporary streams: the karst River Manifold (a,b), the chalk stream Till (c,d) and a mountain stream in the Cairngorms (e,f) with different instream conditions: flowing (c), receding water (e), drying pool (a), dry river bed (b,d) and flowing under snow (e).

recognized by both scientists and managers in the UK (Stubbington et al., 2018b), across Europe, and globally. In particular, the COST Action Science and Management of Intermittent Rivers and Ephemeral Streams has united European academic and industry scientists seeking to use our increasing understanding to develop tools for effective temporary stream monitoring, restoration and conservation.

Terrestrial vs. aquatic states: who's where, when, and why?

Characterising the species associated with flowing, ponded and dry phases and how they colonise and survive is key to understanding the mechanisms driving change in community composition as drying progresses. In particular, we know very little about the species colonising disconnected pools or dry riverbeds. There is evidence from international research that

Fig 2. Nottingham Trent University researchers investigating the community composition of temporary streams at different hydrological phases: (a) Romain exploring the invertebrate community composition of a temporary chalk stream reach during its flowing phase; (b) Rachel searching for signs of life in a contracting pool; and (c) collecting drying sediments to explore the survival of desiccation-tolerant aquatic invertebrates.

there could be unique species of dry channel specialists – but opportunistic generalists with strong dispersal and fast colonisation abilities are likely to dominate these communities. UK researchers are among those investigating how temporary river communities change during flowing, ponded and then dry conditions. They also aim at understanding through which pathway organisms colonise from surrounding rivers, ponds and riparian habitats communities or persist in situ as in-stream habitat change (Stubbington et al., 2016; Hill & Milner, 2018; Fig. 2). Such research will help to guide effective management of temporary rivers and the habitats they interact within catchment-wide strategies.

Disentangling the effect of drying, drought and

Fig 3. The changing environment of the River Gade near Great Gaddesdon in Hertfordshire. Photos by Nigel Holmes show the same site (a) before and (b) during the 2005-2007 drought.

human-induced drying

In temporary river networks, drying can be seasonal and predictable in some streams, whereas others dry only during unpredictable drought events. Temporary river communities should be adapted to seasonal drying, but we know little about biotic responses to and recovery from extreme events and how responses differ from those of perennial river communities.

At Nottingham Trent University, we are investigating the effects of drying on aquatic invertebrate communities along a gradient of flow permanence, from sites experiencing drying every year to those drying only during extreme droughts (Fig. 3). We are exploring how communities respond to droughts and the time they take to recover, predicting that temporary river communities can recover more quickly after these unpredictable events end. This research will inform ecosystem management in changing climate, in which more frequent and intense droughts are expected (Ledger & Milner, 2015). An important next step is to disentangle ecological responses to natural intermittence from the effects of drying caused by human activities including water abstraction.

Developing biomonitoring tools to assess ecological quality in temporary rivers

Temporary rivers are rarely represented in regulatory biomonitoring programmes, or are monitored only during their flowing phases and using approaches developed for perennial streams. However, these approaches may not effectively characterise the ecological quality of temporary rivers, because their communities naturally differ from those in perennial rivers (Stubbington et al., 2018a). Tools such as the Drought Effect of Habitat Loss on Invertebrates (DEHLI) index, which assesses the effects of drought on aquatic communities, have recently been developed by UK researchers to better track the effects of drought on aquatic communities (Chadd et al., 2017). However, we still need to characterise communities across the range of aquatic and terrestrial conditions that occur in temporary streams – including responses to natural hydrological variability and to human stressors. Such research will enable the development of effective biomonitoring tools that recognise the dynamism of these ecosystems.

In the context of ongoing global change, European rivers are expected to become increasingly subject to drying in both space and time, due to increasing occurrence of extreme events including heat waves and drought events, and water resource demands (Ledger & Milner, 2015). By improving our understanding of temporary river communities and the functions they perform, recent and ongoing advances in temporary river research can inform the development of biomonitoring strategies that characterize the biodiversity of these aquatic-terrestrial ecosystems, informing actions that enhance and preserve the quality of these unique ecosystems.

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