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Detecting phenology change in the mayfly *Ephemera danica* in response to water temperature variations

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Water temperature is critical to aquatic life. Rising river temperatures under climate change are expected to affect the phenology (i.e. timing of life events) of aquatic insects, including *Ephemera danica* which is a large burrowing mayfly that is widespread throughout Europe.

To assess the temporal and spatial variability in mayfly emergence, *E. danica* were monitored at two reaches in the River Dove, English Peak District over the period 2007 to 2013. Inter-annual variations in Growing Degree Days (GDDs) were modelled for an upstream site with intermittent spring flows supplementing main channel flow (Beresford Dale) and a downstream site dominated by near constant discharges of cool groundwater (Dovedale).

The emergence cycle of *E. danica* was strongly related to GDDs at each site. *E. danica* usually remains in an aquatic larval stage for two years before emerging in its adult, terrestrial form. However, after particularly warm summers in Beresford Dale, *E. danica* was recorded to emerge after only one year in its aquatic form. Following the particularly wet/cold year of 2012, *E. danica* began to revert back to a bi-annual cycle. In Dovedale, an average of 374 fewer GDDs were accumulated in comparison to Beresford Dale. As a result, *E. danica* maintained a two-year growth cycle throughout the monitoring period despite the phenology changes observed 8 km upstream at Beresford.

Changes to insect phenology are significant because populations with a one-year cycle are potentially more vulnerable to adverse weather when the majority of the population is in terrestrial form. Also, altering the growth, development and size of insects affects reproductive success with implications for population dynamics.

Conventional monitoring of both water temperature and invertebrates as used by regulatory authorities in the UK, did not identify the changes in insect phenology or the association between phenology and water temperature. Data from the present study suggest that habitats near cool groundwater may provide important refugia for populations of insects, potentially delaying permanent shifts in phenology under climate change. However, the ability to detect changes in thermal triggers and phenological response may be hindered by conventional spot sampling protocols.