Geophysical Research Abstracts
Vol. 17, EGU2015-6372, 2015
EGU General Assembly 2015

Phenology changes in the mayfly *Ephemera danica* in response to water temperature variations in the River Dove, UK

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Water temperature in rivers is critical to aquatic life. Climate and environmental change can elevate river temperatures to levels that stress fish, but impacts on other aquatic organisms are not well understood. In particular, rising temperatures are expected to alter the phenology of aquatic insects at levels substantially below those required to stress fish species.

The phenology of the mayfly *Ephemera danica*, a large burrowing species that is widespread throughout Europe, is known to be sensitive to temperature change. 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. Variations in Growing Degree Days (GDDs) were modelled for an upstream site with an annual temperature range in excess of 15 ˚C (Beresford Dale) and a downstream site, dominated by near constant discharges of cool groundwater with an annual range less than 8 ˚C (Dovedale).

The emergence 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. 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.

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. Therefore, new monitoring strategies are required in order to identify important changes in aquatic populations in response to rising temperatures.