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# Impacts of drainage and climate change on keystone insects and upland breeding birds

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Craneflies (Diptera: Tipulidae) are key invertebrates in UK blanket bog ecosystems, with both the adults and the larvae providing a major food resource for upland breeding bird species such as European Golden Plover *Pluvialis apricaria* (Buchanan *et al.*, 2006; Pearce-Higgins, 2010). Cranefly larvae experience high mortality under drought conditions (Coulson, 1962; Milne *et al.*, 1965), meaning that any process leading to peatlands becoming drier could drive declines in this key prey item. Therefore, extensive drainage ditch networks dug into British blanket bogs during the 20th century (see, e.g., Holden *et al.*, 2004) and the risk of warmer, drier conditions under climate change could threaten both cranefly and breeding bird populations (Pearce-Higgins *et al.*, 2010). However, ongoing programmes of drain blocking for peatland restoration could provide an opportunity to reduce drainage impacts and, potentially, ameliorate future climate change impacts.

The influence of moisture variation and artificial drainage on cranefly populations was explored using a large-scale experiment in three British blanket bogs (Carroll *et al.*, 2011). As expected, cranefly abundance was positively and significantly related to soil moisture, but with a 'wedge-shaped' relationship; in wetter areas, both high and low abundances could occur; in dry areas, abundances were always low. Therefore, any process that reduces soil moisture could be expected to decrease cranefly abundance. Further, cranefly abundance was significantly lower in areas around active, open drainage ditches than in areas around blocked drains. This suggests that although drains lower water tables and reduce cranefly abundance, drain blocking, currently being undertaken for peatland restoration, could also benefit moisture-dependent peatland invertebrates.

Large-scale spatial and temporal variation in cranefly abundance was explored by combining field-derived empirical relationships with a model of peatland hydrology. The MILLENNIA peatland cohort model (Heinemeyer *et al.*, 2010), which includes a dynamic water table depth sub-model driven by simple topographic and climatic inputs, was found to reasonably predict observed water table fluctuations and mean water table depth (Carroll, 2012). Modelled water table depths were significantly related to observed moisture, which was in turn significantly related to observed cranefly abundance, allowing estimates of cranefly abundance to be generated from modelled water table depths (Carroll, 2012).

When the model was driven by climate change projection data, falling summer water tables were projected to drive declines in cranefly abundance over the 21st century in three focal blanket bogs, with the scale of declines greater when drains remained open (Carroll, 2012). When the model was driven by observed climate data, modelled cranefly abundance was found to be significantly and positively related to observed abundances of Golden Plover, Dunlin *Calidris alpina* and Red Grouse *Lagopus lagopus* in the South Pennines (Carroll, 2012); these species are known to prey heavily upon craneflies during the breeding season (Pearce-Higgins, 2010). Further, Golden Plover population trends appeared to be influenced by cranefly abundance, with higher estimated cranefly abundances related to increased Golden Plover population stability (Carroll, 2012).

We suggest that both climate change and drainage could drive declines in blanket bog cranefly populations, and that in turn, this could impact both the abundance and the stability of upland breeding bird populations. Finding ways to maintain high moisture levels and high abundances of peatland craneflies could therefore be a key consideration in helping more southerly populations of upland breeding birds adapt to climate change.

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