Figure 1 | The stonefly *Dinocras cephalotes*.

Ecology

River recovery might have run out of steam in Europe

Ian P. Vaughan

How has river quality in Europe changed over time? A detailed analysis of invertebrate data provides a picture of biological recovery from past problems, but also points to remaining challenges. **See p.582**

Rivers and other freshwater environments support a disproportionately high level of biodiversity, given that they cover less than 1% of Earth's surface[1]. There is evidence that they are among the world's most threatened ecosystems, with some of the largest reported declines in biodiversity[2], linked to a combination of factors, such as intense exploitation by humans, pollution and the changing climate. However, a few studies have found evidence of increasing invertebrate biodiversity[3]. Fortunately, rivers are some of the most widely monitored ecosystems, and the invertebrate community that lives on the bed of rivers is often used as an easily sampled, sensitive indicator of river quality. On page 582, Haase *et al.*[4] draw together invertebrate data from across Europe to provide a view of how river quality has changed across the continent in past decades, and the result is a mixed picture. Although the authors find evidence of rivers recovering biologically from historical impairment, this recovery seems to have run out of steam, with many rivers still in a relatively poor condition.

Similar to other global- and continental-scale biodiversity studies of freshwater and terrestrial environments, Haase and colleagues combined data from a diverse array of sources. Their impressive data set included evidence from more than 1,800 locations and from 22 countries, with samples collected over more than 50 years, albeit with the vast majority from after 1990 and from a subset of those countries.

The authors examined the number of individuals and taxa (the 'richness' of species or other taxonomic groups such as families) of invertebrates present in a typical sample. Haase and colleagues also assessed the diversity of ecological traits such as body size, diet and dispersal strategies, because a lower diversity of some traits in invertebrates might impair ecological processes such as decomposition of organic matter and can be a sensitive indicator of environmental impacts[5]. Haase *et al.* examined how the assessed diversity changed over time and whether the rates of change were affected by factors such as agricultural or urban land use in a river's catchment, the presence of dams, average climate or the magnitude of climatic changes during the study period.

The results highlight large cumulative changes in European invertebrate communities, with an increase of individuals and diversity (both taxa and ecological traits) at rates sometimes greater than 1% per year across the decades. The abundance results correspond closely to those of a global insect-focused meta-analysis study[3], whereas the diversity increases are consistent with changes seen from studies undertaken on smaller scales[6]. The increases are interpreted as biological recovery from poor water quality in particular, driven mainly by improvements to wastewater treatment (for example, following the European Union's 1991 Urban Waste Water Treatment Directive), and the decline or offshoring of polluting industries, as well as the outcome of habitat-restoration efforts. Haase *et al.* report that some of the largest increases in abundance were observed in pollution-sensitive taxa such as mayflies (Ephemeroptera) and stoneflies (*Dinocras cephalotes*; Fig. 1), supporting this general conclusion, although future analyses looking in more detail at changes in the constituent taxa could strengthen the case.

This picture of Europe is a more optimistic finding than a similarly large-scale assessment across the United States[7], which showed declining invertebrate abundance while richness increased. Beyond rivers, such analysis also enriches the wider narrative around global insect and invertebrate declines, although the devil might be in the detail. For instance, in the United States, insects fared worse than other invertebrates, with a loss of richness and steeper declines in abundance[7], whereas in Europe, Haase and colleagues report that insects showed larger abundance gains but smaller increases in diversity than did the invertebrate community as a whole. There is unquestionably more work to do.

Although Haase *et al.* carefully filtered and analysed the data, adjusting for a range of environmental variables, the precise magnitudes of estimated changes need to be treated with caution because of the uneven spatial and temporal coverage, and the variability of invertebrate data from many sources. Fortunately, the authors' sensitivity analyses suggest that the broad picture is robust in relation to several of these possible issues. Change estimated at the continental-scale will inevitably disguise underlying geographic variation. The authors found that richness declined at approximately 30% of locations and abundance at 40%, and it would be interesting to understand more about whether these declines were concentrated in particular river types or regions.

The overall percentage changes presented by Haase and colleagues are important results, confirming and extending earlier work[3]. However, the really striking finding is in how biodiversity gains have slowed in the past 20 years, with little or no net change among many measures in the last 5–10 years. Smaller-scale studies have hinted at these results[6,8], but Haase *et al.* present a compelling picture of a slowdown across Europe. Attributing a cause is a formidable challenge in this context, with rivers exposed to a complex and ever-changing mix of stressors that probably vary across the continent.

One possible explanation for the slowdown is simply that biological recovery is near-complete, but this is quickly undermined by the extent to which rivers across Europe still fail to reach 'good ecological status' as defined by the EU's 2000 Water Framework Directive. A more plausible explanation is that recovery is running out of steam because the benefits derived from past interventions have been exhausted, or because new stressors are emerging or existing ones are intensifying (for example, new types of pollutant or the effect of a changing climate). Such factors might slow and potentially reverse biodiversity gains. Consistent with this hypothesis, Haase *et al.* demonstrate that increases in abundance and diversity were often smaller and less frequent in rivers with a more rapidly warming climate, in those that drain urban and agricultural areas and in those downstream of dams. However further work will be needed to determine the causes.

Assuming that the biological recovery of Europe's rivers is stalling, the obvious question is how to revive and extend recovery. The challenges facing freshwater ecosystems are manifold and the required interventions are similarly multifaceted, involving some blend of legislation, technological development (for example, in wastewater treatment), changes to land-use practice and reduced exploitation, among others[9]. Further work to understand the causes of the deceleration would help to guide these actions.

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Atmospheric science

Clues to rain formation found in droplet images

Thomas Leisner

X-ray and optical imaging have revealed the intricate process through which droplets freeze during the formation of rain. The results could help to explain how clouds are able to produce enough ice particles to make rain. **See p.557**

The first few drips of a rain shower are usually a sign that 'supercooled' droplets in the cloud above have started to freeze. Supercooled water exists as a liquid below the normal freezing point of water, and the freezing of these droplets has a key role in the process of rain formation. Writing on page 557, Kalita *et al.*[1] have imaged this process with exquisite time resolution, enabling them to analyse the evolving crystalline structure of the ice in real time. Their observations provide a way of calibrating and improving models that help to explain the physics of clouds.

At temperatures below freezing, but above −36 °C, liquid water freezes only in the presence of tiny 'ice-nucleating' particles, which initiate the formation of ice in the supercooled cloud droplets. Ice has a lower vapour pressure than does supercooled liquid water, so it grows rapidly by sucking up water vapour from the surroundings at the expense of the liquid droplets. As the ice particles grow, they start to fall and collide with the cloud droplets to form larger particles called graupels. These graupels then melt as they fall to lower altitudes, contributing to the eventual formation of rain.

Each ice-nucleating particle can freeze only a single cloud droplet, so the number of ice