GLACier-fed rivers, HYDRoECOlogy and climate change; NETwork of monitoring sites (GLAC-HYDRECO-NET).

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Abstract

Most glaciers worldwide are shrinking thereby reducing meltwater runoff volume and shifting peak flow timing. This alters the dynamics of these systems as water from other sources (snowmelt, rainfall and groundwater) is also changing in terms of quantity and timing. High climatic sensitivity and low human perturbation make glacial-fed river basins early indicator systems for identifying hydrological and ecological responses to climate change/variability. Our understanding of these sensitive systems in Arctic and alpine areas and their response is limited, particularly in terms of regional and global inter-comparisons. We are proposing a worldwide network of monitoring sites be established using similar protocols to evaluate change more consistently and robustly than hitherto achieved. While this network does not just focus on Arctic rivers, the common focus is glacial systems and their sensitivity to climate change and the network would allow comparisons across different glacier types within different climatic zones and ecoregions. This would allow the glacier-fed rivers of the Arctic to be placed in context of other glacial systems worldwide.

Context

Glaciers store about 75% of the world's freshwater, contribute significantly to river flow and water resources at high altitude and latitude (Fleming and Clarke, 2005), and maintain stream flow during the summer dry season when rivers in non-glacierized basins display low flow (Hannah *et al.*, 2005). Rivers with glacier meltwater inputs sustain important downstream ecosystems with significant influence on lakes, wetlands and meadows, irrigation and hydroelectric power (Buytaert *et* al. 2011), and meltwaters provide habitat for fisheries (Milner *et al*. 2009; Stahl *et al*., 2008) and a number of rare and endemic macroinvertebrate taxa (Snook & Milner, 2001; Brown *et al.*, 2007). Glacial rivers are also important for ecosystem services like hydroelectric power and irrigation for agriculture, particularly in the European Alps and South America. Glacierized environments are demonstrably one of the most vulnerable systems to climate change due to connections between atmospheric forcing, snowpacks/ glacier mass-balance, stream flow, water quality and hydrogeomorphology (physico-chemical habitat), and river ecology (Smith *et al.*, 2001).

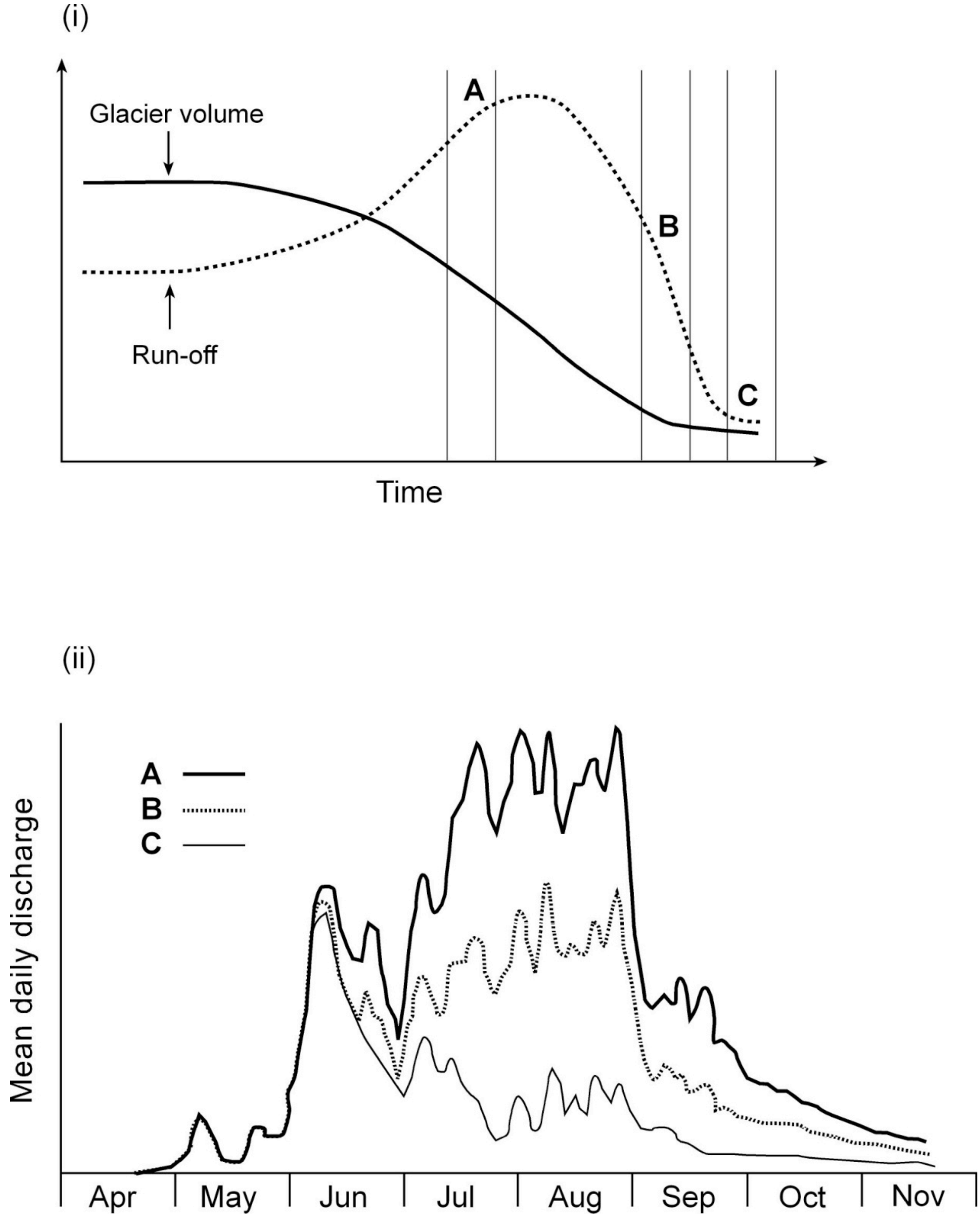

Figure 1 (i) Changes in runoff with glacial volume and (ii) how this will influence discharges as glacial volume decreases at three points A, B and C (adapted from Milner et al. 2009).

In the current phase of global climate warming, many glaciers are shrinking (Barry, 2006). Loss of snow and ice-masses will alter spatial and temporal dynamics in runoff with important changes in the relative contributions of snowmelt, glacier melt and groundwater to stream flow (Milner *et al.*, 2009). Overall runoff from glacial sources will decrease, particularly during the summer period (see Figure 1) The projected reduction in sediment load, warmer water temperature and increased channel stability will drive significant shifts in the floral and faunal composition of glacier-fed rivers (Brown *et al.* 2007). Reduced glacial influence will potentially increase species (alpha) diversity at the reach scale but some cold stenothermic taxa will be vulnerable to extinction and thus reduce regional (gamma) diversity (Jacobsen *et al*., 2012). These sensitive macroinvertebrate taxa may be important biological indicators of environmental change in glacierized river basins (Brown *et al*. 2007). Moreover, high climatic sensitivity and low human perturbation make glacially influenced river basins early indicator systems for identifying hydrological and ecological responses to climate change/ variability (Hannah *et al.*, 2007).

Innovation and Application

Glaciers behave differently across different climatic zones, hence glacier-fed stream habitats and ecology also differ (Jacobsen *et al*., 2010). Even within the same climatic zone, glaciers differ with respect to their distribution, size, slope, and geology and we expect this to have profound effects on the biodiversity and function of downstream ecosystems. A major ***goal of the proposed network is to obtain a broader understanding of glacier-fed freshwater ecosystems across a wider spatial and temporal scale and to improve our understanding of these systems as sentinels for climate change.*** In addition, much of the focus of the ecological response in glacier-fed rivers has been on macroinvertebrate communities, but we will explore in this network the response of microbes, algae, macrophytes, fish, and the coupling to downstream ecosystems fed by glacial runoff such as lakes and wetlands. We will be particularly focused on endemism in glacier-fed systems, and the biodiversity that we are at risk of losing in connection with the loss of glacial runoff.

Recent research has highlighted methods to quantify runoff contributions from different water sources (e.g. Brown *et al.*, 2006), which is critical in studies of these environments to accurately characterise physico-chemical habitat and to evaluate the biotic response. These cutting edge methodologies will be a major goal of the network, so that a fuller understanding of their potential will be ascertained and inform an evaluation of which approaches should be incorporated into future research protocols.

Anticipated Outcomes of the Network

A principal outcome of this network will be a significant increase in our understanding of these sensitive ecosystems on a wider spatial scale than has ever previously been achieved.

A worldwide monitoring network of glacier-fed systems will be established where investigators follow the same protocols in both physicochemical and biological investigations using the cutting edge methodologies that have recently been developed. Although some sites are already well established, others would have to be initiated. Regions would include: Arctic; Lappland, Svalbard, Greenland, Alaska; Subarctic; Alaska, Iceland, Norway; Temperate; Switzerland, Austria, Italy, Pyrenees, New Zealand; Subtropical; China, Tibet, Nepal; Tropical; Bolivia, and Equatorial; Ecuador. By following similar protocols, data collected from sites in glacier-fed watersheds would be comparable and driving variables and underlying trends would be easier to distinguish across a range of glacier types and geographical regions.

Future research and breakthroughs

The network would provide future international collaboration between the research groups that would significantly advance the field and our understanding of these sensitive systems to climate change due to identifying clear research priorities and to collect comparable data for synthesis and integration. It would represent a major breakthrough for the investigators to all be directing their research towards a common goal and allow comparisons that would otherwise be impossible due to disparate approaches and consequently incomparable data for regional to global analysis of patterns of change. It is only by having these comparisons that we will fully understand how these systems function worldwide and be able to develop adaptive strategies to conserve biodiversity and protect ecosystem services.

A key feature of the proposed network is knowledge transfer and mechanisms would be in place to inform stakeholders and interested parties of the knowledge to date and of future investigations, in addition to the standard use of journal articles and presentations at scientific meetings. We would establish a database where data from the network sites is stored and available to the network group. We would establish a website for GLAC-HYDRECO-NET where we would highlight the scope of the project and post syntheses of the results as they are analysed available to interested parties. We would plan to have teleconnections to sites so live data could be streamed and potentially include webcams to document runoff during the meltwater season so as to engage the broader public.

Interested contributors to the network please contact Alexander Milner (a.m.milner@bham.ac.uk).

References

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