Scottish Natural Heritage

TREND NOTE

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Climate change and rivers

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Falls of Acharn, ©Lorne Gill

Introduction

Running waters in Scotland vary from small trickles and seepages in headwaters to large rivers such as the Tay which has the greatest mean annual flow of all British rivers (Scottish Natural Heritage, 2002). There are striking differences between rivers flowing to the north and west and those to the south and east as a result of climatic and topographic differences (Werritty, 2002). The timing of peak flows consequently varies geographically in response to rainfall patterns and to waterlogging of the soil. In some years, rivers draining from the Cairngorms experience Alpine characteristics with high spring flows due to snowmelt (Smith & Lyle, 1994) but these patterns are changing.

Apart from the broad-scale indirect effects of climate change on catchment land cover, especially in riparian areas, rivers are directly affected by impacts on water temperature and flow. Even relatively small increases in temperature can disrupt life-cycles of fish and aquatic insects and change community composition. Changes in the amount and timing of rainfall can alter river hydrographs – the volume and seasonal pattern of river flow and surface flow velocity. These characteristics are closely associated with changes to river habitats and the organisms they support. Hydrological changes also affect the frequency and degree of floodplain inundation, and may have consequences on the extent to which pollutants are diluted.

River Dee, ©SNH Images

River Tay, ©Lorne Gill/SNH Images

Key Points

- Changes to temperature and rainfall in Scotland are having significant effects on rivers and streams.
- Winter precipitation has shown an increase of almost 70% in North Scotland, between1961 and 2004.
- Between 1961 and 2004 river flows have shown no significant change in the summer flows but substantial increases in winter flows (Dee, 38%; Kelvin, 69%; Teith, 91%).
- Mean spring, summer and winter air temperatures have risen by more than 1°C since 1961.

Past changes in precipitation and river flow

Various scenarios of climate change have been developed and regularly updated over the past decade. However, in addition to predictions about the future there is already evidence to show that changes to temperature and rainfall in Scotland are already having significant effects on rivers and streams. Table 1 summarises the change in precipitation from 1961 to 2004, averaged within each of the four seasons for north, east and west Scotland.

Table 1: Percentage change in precipitation in Scotland from 1961 to 2004 (Barnett et al., 2006)

	North Scotland	East Scotland	West Scotland	Scotland
Spring	16.2	9.4	17.3	14.8
Summer	-7.0	0.2	7.3	-0.6
Autumn	5.3	22.2	5.9	9.1
Winter	68.9	36.5	61.3	58.3
Annual	21.0	18.4	23.3	21.1

Flood waters of River Tay, ©Lorne Gill

These data show an upward trend in winter precipitation since 1961, with an increase of almost 70% in North Scotland. For the same period, the data show that Scotland, as a whole, has become 20% wetter. In contrast, northern areas of Scotland have become drier in summer since 1961.

Analysis of river flows in Scotland for the period 1961 to 2004 show no significant change in summer flows but substantial increases in winter flows – e.g. 38% in the Dee, 69% in the Kelvin, and 91% in the Teith (Scottish Environment Protection Agency, 2006).

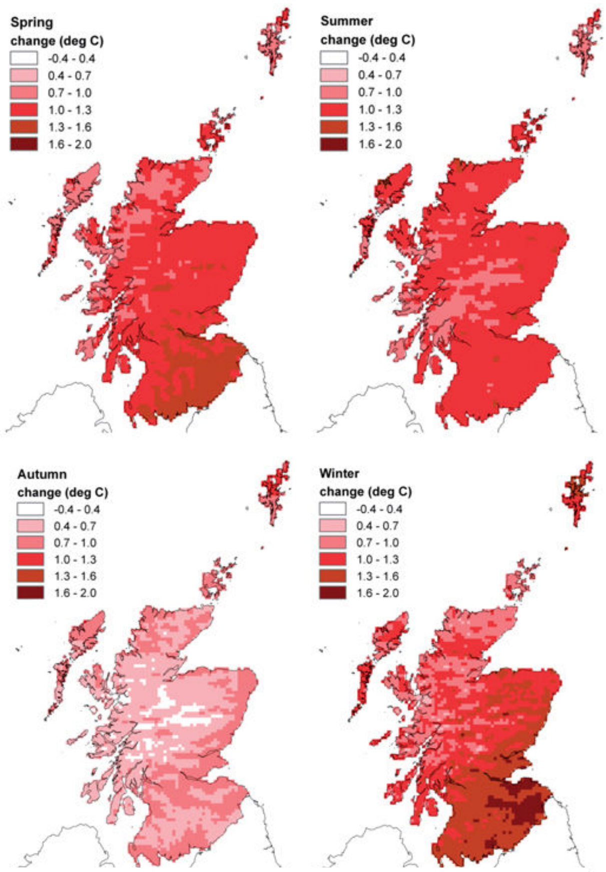

Figure 1: Change in mean air temperature (°C) 1961 to 2004. Source: Barnett et al., 2006.

Past changes in air temperature

Scotland's temperature records show that average spring, summer and winter temperatures have risen by more than 1°C since 1961 (Figure 1). The greatest warming trends are in south-eastern Scotland during the winter (December to February) (Scottish Environment Protection Agency, 2006).

It is not possible to relate these changes in air temperature with corresponding changes in the temperature of rivers because data on river water temperature in Scotland are not routinely collected. Instead, the information that is available usually comes either from specific research projects (e.g. Langan *et al*., 2001) or from monitoring results from industries that discharge heated effluents (e.g. Baum *et al*., 2005).

River Nethy,
©P&A Macdonald/SNH Images

Although some species are likely to respond directly to changes in water flow and temperature induced by climate change, the greatest impacts on biodiversity will result from a combination of climate change with other pressures such as nutrient enrichment, water abstraction and habitat modification (Clarke, 2009). Modelling the predicted effects of climate change on fresh waters in England and Wales has led to the conclusion that there are likely to be various detrimental impacts on freshwater invertebrates in rivers (Conlan et al., 2007). Increasing temperatures, rather than flow-related changes, are the principal factors involved, with average water temperatures raised by 2 to 3oC leading to a reduction in abundance and species richness. Higher temperatures affect invertebrates in different ways, such as increased predation by fish (Kishi et al., 2005) and the faster breakdown of organic matter resulting in less food being available (Lepori et al., 2005).

In general these patterns are likely to apply to Scottish streams and rivers as well, although the detail will differ as a result of geographical differences in climate and in the species composition and abundance of invertebrates compared with southern Britain.

This work, based on studies of the River Wharfe in Yorkshire and the River Tyfi in mid-Wales, also predicted significant effects on salmonid habitat as a result of climate change. Simulations to the 2050s from a baseline period of 1961 to 1990 suggest a sharp reduction in nursery habitat for Atlantic salmon *Salmo salar* and smaller reductions for spawning and rearing habitats (Figure 2a), caused by alterations in flow, velocity and depth. In contrast, predictions for brown trout *Salmo trutta* suggest little change (Figure 2b), perhaps because of a greater tolerance to the reductions in low flows and their associated habitat changes (Conlan *et al*., 2007).

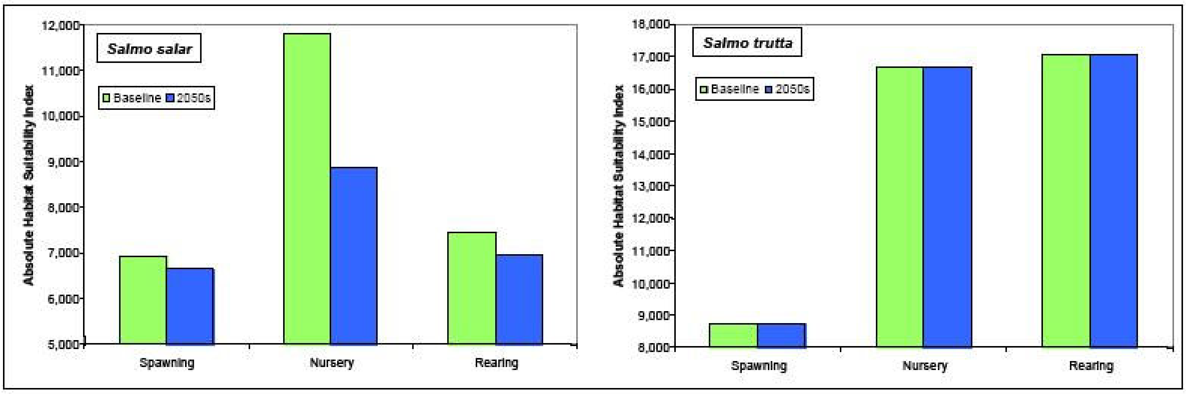

Figure 2a & 2b: Illustrative changes in absolute habitat suitability index from baseline to the 2050s for Salmo salar *and* Salmo trutta *from Conlan* et al.*, 2007* (reproduced with prior permission of the Environment Agency). Baseline = 1961-1990

The impact of climate change on riverine species considered important for conservation is a matter of particular concern. For example, freshwater pearl mussel *Margaritifera margaritifera*, protected nationally under the Wildlife and Countryside Act 1981 and listed in Annex II of the EC Habitats Directive, may be particularly at risk. The size and frequency of floods are likely to have a detrimental effect by removing the gravel substrates in which pearl mussels bury themselves; expected increases in maximum temperatures and the frequency and duration of flooding may also be damaging (Hastie *et al*., 2003).

The bigger picture

A report published by the European Environment Agency, the Joint Research Centre of the European Commission, and the World Health Organization (EEA, 2008) used a range of environmental indicators to present new information on past and projected climate change and its impacts. Three aspects of water quantity, river floods and droughts, and four aspects of freshwater quality and biodiversity were examined across northern, temperate and southern regions of Europe (Table 2).

River Feshie, ©Lorne Gill/SNH Images

Table 2: Observed and projected trends in freshwater quantity, quality and biodiversity for northern, temperate and southern regions of Europe (EEA, 2008)

	Northern		Temperate				Southern	
Indicator	**Arctic and boreal**		**Maritime climate**		**Central/ Eastern**		**Mediterranean**	
	Obs	Proj	Obs	Proj	Obs	Proj	Obs	Proj
Water quantity, river floods and droughts								
River flow	+	+	o	+	o	+	-	-
River floods (number of events)	o	-	+	+	+	+	o	+
Drought	o	-	o	+	o	-	o	+
Freshwater quality and biodiversity								
Water temperature	+	+	+	+	+	+	+	+
Lake and river ice cover	-	-	-	-	-	-	-	-
Northward and upward shift of species	+	+	+	+	+	+	+	+
Water quality	n.a.	-	n.a.	-	n.a.	-	n.a.	-

The report concludes that climate change is intensifying hydrological cycles throughout Europe, although other factors such as land-use changes and water abstraction have made it difficult to separate out the trends that are due solely to climate change. In general, observed increases in annual river flows in northern regions and decreases in southern regions are predicted to intensify. However, this pattern will be overlain by strong changes in seasonality, with lower flows in summer and higher flows in winter. Surface water temperatures in lakes and rivers have increased by 1 to 3^{o}C during the 20th century, partly as a result of global warming, and are projected to increase further. This is likely to have impacts on water quality and on species distributions and life-cycle patterns.

A report on climate change and water by the Intergovernmental Panel on Climate Change (Bates *et al.*, 2008) reached similar conclusions, adding that, as a result of climate change, by the 2050s, the area of land subject to increasing water stress is projected to be more than double that with decreasing water stress. In the face of changes of this magnitude it will be critical to ensure that biodiversity conservation is not neglected in future decision-making on water resource management (Clarke, 2009).

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