Records from the past century show that Scottish rivers are warming

Why are river temperatures important?

River temperatures significantly affect the distribution, health, and survival of native salmonids. Since salmonids are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse health effects when exposed to temperatures outside their optimal range.

Sustained high temperatures are of concern for our cold water-loving fish communities. For example, Brown trout stop feeding at temperatures above 20°C and water temperatures above 30°C are lethal. With water temperatures of 27°C and 25°C being recorded in Scotland in 2013 and 2014 climate change is a threat to Scottish rivers. With an expected increase in air temperature of 4°C by 2080, there are concerns about the potential impact on fish populations and other species in our hottest rivers. This is a big issue as salmonids are an iconic species to Scotland, and angling contributes £113 million per year to the Scottish Rural economy, with salmon and sea trout anglers accounting for over 65% (£73 million) of this total (Radford, 2004).

This fact sheet is based on a unique analysis of long term temperatures on the River Spey. The research is important to Estate managers, policy makers and regulators as they need to understand not only the root of the problem but management options to enhance the resilience of rivers to change.

How we made the discovery

The Tulchan Estate in Speyside, Moray has a proactive management team, who are keen to learn more about factors that impact on river temperature and level, and measures to make the river more resilient to change in the future.

The Tulchan Estate shared a rare collection of fishing records (including river temperature, river level) with researchers from the James Hutton Institute who performed the analysis.

Data

Since 1912, ghillies working on the estate have measured the river temperature and water level every morning during the fishing season (Feb-Sep) on four fishing beats (A-D). Temperature was monitored with mercury thermometers at the same locations for 104 years. As with all long term records, uncertainties will exist, particularly as records were collected for sporting purposes rather than for scientific interest. Nonetheless, data were subject to rigorous quality control procedures prior to analysis.

Scientists from the James Hutton Institute transcribed the records and integrated them with a wider hydroclimatic dataset to try and identify if the River Spey has warmed over the past century (Table 1).

Table 1: Hydroclimatic data used to understand the trends in water temperature.

	Precipitation & Air temperature	Snow accumulation & melt	Discharge	Water levels	Water temperature
1912-1922	-	-	-	Observed records (Beats A,B,C,D)	Observed records (Beats A,B,C,D)
1922-1936	Reconstruction from weather station records	Simulation (subcatchments)	Simulation		
1936-1953				Observed records (Beats C,D)	Observed records (Beats C,D)
1953-1960			Observed SEPA records (Grantown & Boato'Brig), Simulation (fishing beats)		
1960-1973	MetOffice UKCP09 data for grid cells (25 km^2)	Simulation (MetOffice cells)		Observed records (Beats A,B,C,D)	Observed records (Beats A,B,C,D)
1973-2015					
Temporal resolution	Continuous daily	Continuous daily	Continuous daily	Weekly (fishing season)	Weekly (fishing season)

What we have learnt

Understanding what controls river temperatures is a complex issue. Of course, river temperatures are influenced by flow, and are highest in the summer months when flows are low.

The problem is, over time, the summer river levels are steadily declining and the temperatures are increasing. River temperature was modelled here (Figure 1) as the first step towards assessing how future changes in climate, land-use, management, industry and water use might influence river temperatures.

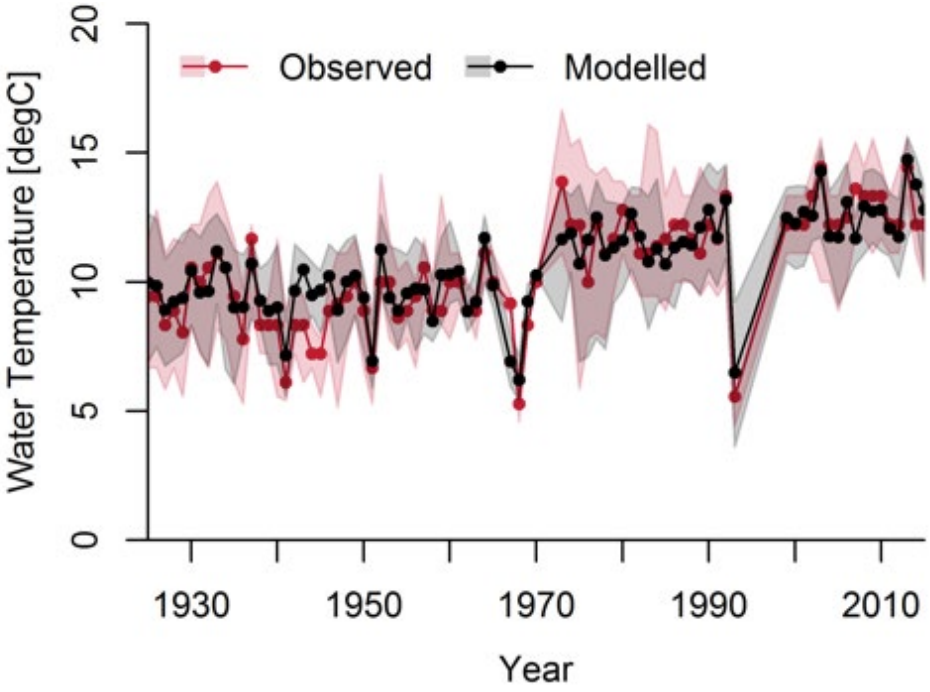

Figure 1: Median annual observed and modelled water temperature from the River Spey (Shaded area: 25%-75% (range) for both the observed and modelled data

What is driving this change?

1. Air temperature has increased significantly during the past decades, especially during spring and autumn.
2. There is no evidence that the amount of rainfall has changed.
3. Accumulations of snow in recent decades are less now compared to the past.
4. Snow melts earlier in the spring (snow-free period starts about two days earlier per decade) and contributes less to summer baseflow (reducing the input of cold water to the river in summer months).
5. Our model shows that declining water levels in the summer months are primarily related to human intervention rather than hydroclimatic changes, however, further work is required to assess the impact of increasing air temperatures and land use change (afforestation) on water loss through evapotranspiration.
6. Declining trends in the observed river level are potentially driven by the increasing demand for water in the Spey catchment reflecting the increase in population, irrigation, industry and hydro-electric generation.

How can we make rivers more resilient to change?

Over the past decade, Marine Scotland Science (MSS) has been undertaking research to understand and predict river temperatures, their sensitivity to climate change and management opportunities (e.g. bankside tree planting). Recent work by MSS, in collaboration with the University of Birmingham, identified clear landscape controls on river temperature using a large scale spatial-temporal analysis of data collected as part of the Scotland River Temperature Monitoring Network. Within river catchments, the hottest temperatures were predicted to occur in rivers where air temperatures and elevation were high and the channels had a north-south orientation. Process-based modelling by Marine Scotland found that woodland planting would be most effective where channel widths are narrow, the gradient low and where the aspect and orientation of the river maximises shading by woodland (Topic sheet 91). Planting trees to shade water is an obvious method of working towards 'future-proofing' such catchment typologies against these climate-change trends.

Recommendations

Measure	Potential water temperature benefit	Other benefits that might come from this action
In-stream measures		
Releasing cold water from upstream impoundments	• Strategically lowers water temperature (scale of impact unknown)	• Creates biotic refugia or habitat • Builds biological communities
River restoration	• Restores connections to floodplains which promotes floodwater infiltration into aquifers (slows the flow and maintains base flows) • Restores natural groundwater exchange • Restores natural river forms including pools that provide shade or deep water that limit direct heating from sunlight	• Restores natural hydrology • Restores natural river geomorphology • Restores biotic refugia and habitat • Slows flow and reduces flooding
Groundwater measures		
Controlling ground water withdrawal	• Maintains groundwater sources that supply base flow to streams and rivers	• Creates habitat and hydrological connectivity • Restores natural hydrology
Land use measures		
Planting riparian woodland	• Shades and reduces heating of riparian land and adjacent rivers • Reduces runoff and promotes ground water infiltration • Provides natural reinforcement of banks preventing channels from becoming wider, shallower and warmer	• Creates habitat and hydrologic connectivity • Rebuilds native vegetation and corridor network • Raises water quality • Restores natural river geomorphology
Keeping livestock out of rivers	• Reduces bank erosion and helps to maintain natural river form and pools that provide temperature refuges	• Restores natural river geomorphology • Raises water quality
Natural Flood Management	• Reduces transit time of water run-off to maintain baseflow levels in rivers • Reduces high peak flows that contribute to erosion and channel changes	• Restores natural hydrology • Restores natural river geomorphology • Raises water quality
Managing water abstraction		
Controlling abstraction from the river	• Reduces abstraction in the summer months to enhance baseflow levels	• Reduces sensitivity in wetted habitats and the biodiversity they support • Improves water quality in the summer

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