



Water Quality in Salmon Spawning Gravels



Hyporheic water sampling in a groundwater dominated spawning reach of the Gironck Burn, Aberdeenshire.

Introduction

In early winter, salmon (*Salmo salar*) and sea trout (*Salmo trutta*) lay their eggs in depressions that they excavate in streambed gravels. These nests are typically between 10 and 30 centimetres deep. Burial in gravel protects the eggs from disturbance or predation during incubation. Eggs depend on a supply of well-oxygenated water for survival and development. However, the water found beneath the streambed often contains low oxygen concentrations and in some cases eggs die as a result.

What factors determine streambed water quality?

A typical stream catchment in Scotland contains in excess of a year's annual precipitation due to storage below the surface of the landscape. This so-called groundwater drains through soils and rocks towards streams. Transit times, for rainfall falling on the catchment to leaving as stream flow, range from near instantaneous during heavy rainfall events, to years or even decades for long-residence groundwater.

After prolonged contact with soils and rocks, groundwater becomes chemically different from stream water. It contains more dissolved minerals (indicated by high alkalinity) and less oxygen than surface water. In general terms, groundwater is detrimental to fish embryo survival. Groundwater and surface water mix beneath the streambed in the *hyporheic zone*. Hyporheic water is made up of complex mixtures of groundwater and surface water

that are of similarly variable quality. Because the hyporheic zone is where salmonids make their nests, and hyporheic water bathes the developing eggs, it is important that scientists are able to understand the processes governing groundwater intrusion. This way it will be possible to identify locations affected by groundwater that are likely to be unfavourable for egg development.

Variability in hyporheic water quality

As part of a collaborative research project with the University of Aberdeen, Fisheries Research Services (FRS) has monitored water quality and salmon embryo survival at a set of sites in the Gironck Burn, Aberdeenshire (Fig. 1). Salmon previously used each of the sites for spawning. At five sites, stream and hyporheic water quality were found to be rather similar, indicating surface water dominance of the hyporheic zone (Fig. 2). At two sites, hyporheic water was consistently high in alkalinity (characteristic of longer residence water) and low in oxygen, indicating a strong influence of groundwater. The remaining sites showed intermediate characteristics, indicating a range of mixing conditions.

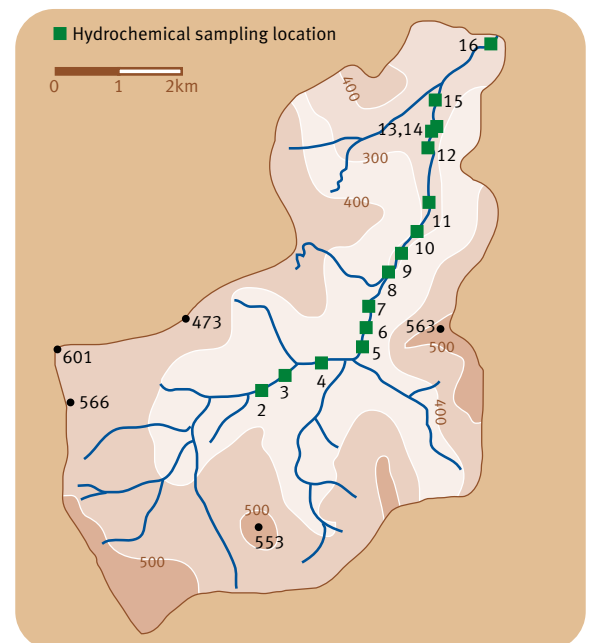


Figure 1. Map of the Gironck Burn, Aberdeenshire showing monitoring locations.

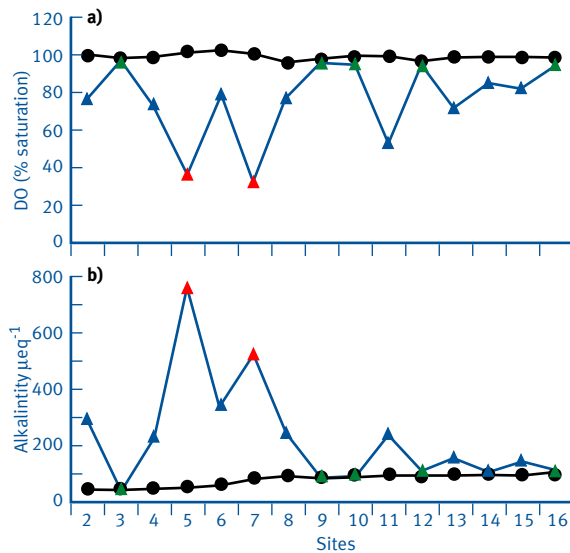


Figure 2. Spatial variability of stream (●) and hyporheic (▲) water quality in the Gironck Burn, Aberdeenshire showing (a) DO and (b) alkalinity. Red sites are groundwater dominated and green sites surface water dominated.

What causes groundwater upwelling?

The two sites showing strong groundwater upwelling were located immediately upstream of valley constrictions caused by ancient deposits of glacial debris. These impede groundwater flowing down the valley, forcing it laterally towards the stream channel where it upwells into the hyporheic zone.

How does variable water quality affect salmon embryos?

At sites where there was a strong influence of groundwater, salmon egg survival was low. At sites dominated by surface water, or at sites with intermediate characteristics, egg survival was generally good. Even here, however, a range



Plate 1. These alevins are the same age and share the same parents. The pair on the right developed in hyporheic water of low oxygen content. Those on the left developed in surface water of good quality.

of sub-lethal effects was observed. These included delayed hatching and reduced body size (Plate 1). The severity of these effects was related to hyporheic oxygen concentrations.

What are the implications for salmon management?

In the Gironck Burn the barriers that caused groundwater upwelling also reduced stream gradient causing spawning gravels to accumulate. Thus, the two short reaches of stream that were strongly affected by groundwater attracted about 40% of all the spawning that occurred in the Gironck Burn. Therefore, despite its limited spatial extent, groundwater upwelling has a disproportionate effect on salmon spawning success in the stream as a whole.

Where low DO groundwater has sufficient impact on egg survival to reduce fry recruitment, surface water incubators could be used to rear eggs and mitigate against the effects of low hyporheic oxygen.

Summary

- Hyporheic water quality varied across a set of 15 sites investigated in the Gironck Burn, Aberdeenshire;
- Hyporheic conditions varied according to the relative influence of groundwater and surface water;
- Valley constriction caused by post-glacial features favoured both groundwater upwelling and salmon spawning due to the accumulation of suitable spawning gravel;
- Because of this dual effect, the impact of groundwater upwelling on salmon embryo survival in the stream as a whole was disproportionately large.

For further information see:

I.A. Malcolm, C. Soulsby, A.F. Youngson and D.M. Hannah (in press) Catchment scale controls on groundwater – surface water interactions in the hyporheic zone: implications for salmon embryo survival. *River Research and Applications*.

Youngson, A.F. Malcolm, I.A. Thorley, J.L. Bacon, P.J. and Soulsby C. (in press) Long-residence groundwater effects on incubating salmonid eggs: low hyporheic oxygen impairs embryo development and causes mortality. *Canadian Journal of Fisheries and Aquatic Sciences*.