The impact of climate change on FRESHWATER INVERTEBRATES

1 Freshwater invertebrates are at the bottom of the food chain and are the staple diet for many other important aquatic organisms, such as salmon and trout.

2 Increased water temperature, which is likely caused by climate change, has resulted in a marked retreat of cold water adapted invertebrates to higher-up, colder water rivers and streams.

3 High altitude rivers and head-waters will be, under further climate change, an increasingly important refuge to support downstream restoration and recovery. There is an opportunity for business to help protect and enhance this valuable resource.

4 There is an increasing risk that life-cycle timings in the aquatic environment are disrupted under climate change and this could impact on the highly protected freshwater pearl mussels.

What is an invertebrate?

Invertebrates are simply animals without backbones.

Macro-invertebrates are larger invertebrates that can be easily seen with the naked eye. Groups present in freshwaters include molluscs (snails, limpets etc), crustaceans (shrimps and slaters), insects (flies, beetles and bugs), leeches, worms and flatworms.

Why are invertebrates used in biomonitoring?

Invertebrates are widely used in the monitoring of freshwaters as there is high quality evidence that links their species make-up and density to the quality of the environment.

They spend a large part of their life cycles in prolonged contact with the water and thus can be reflective of environmental conditions over a long period of time.

They are also easy to sample and identify, as well as being widespread and diverse.

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Why are invertebrates important for Scotland?

Freshwater invertebrates are at the bottom of the food chain and are the staple diet for many other important aquatic organisms, such as salmon and trout.

They play an important role in Scottish river ecosystems, and can act as an early warning of many kinds of environmental disturbance.

Several Scottish freshwater invertebrates are of high conservation value (such as freshwater pearl mussel *(Margaritifera margaritifera)* and upland summer mayfly *(Ameletus inopinatus)*.

Scotland is a haven for the freshwater pearl mussel *(Margaritifera margaritifera)*. The mussels are attached to the river bed as an adult, but lives as a parasitic larvae in salmonid fish during its early development (larval) stages.

Adult mussel populations have been declining and we have seen low numbers of young mussels (Skinner *et al* (2003)). Some authors have suggested that higher water temperature affect the development of the larva-stage of the mussels through a disruption of life-cycle timing between the larva and its fish (salmonid) host and a failure to settle. This however needs further investigation.

Upland summer mayfly (Ameletus inopinatus) is one of the high biodiversity species and *Taubmann et al (2010)* predicted that that the higher altitude rivers in Scotland will be an increasingly important refuge for this species under further climate change.

Figure 1. Freshwater pearl mussel in a Scottish river.

Why do we focus on freshwater invertebrates and water temperature in this analysis?

A number of effects have been proposed for climate change on the aquatic environment. These include:

- increased temperature;
- raised CO_2 levels;
- altered river regimes.

Of these, the easiest to measure and predict is temperature – the records are easily available and interpretable. Rivers and streams, while not directly mirroring air temperatures, are small volumes of water that will change temperature in proportion to air temperature.

We decided to look at the effects of changing water temperature on invertebrates because:

- the pathway is clear (increased air temperature raises water temperature, raised water temperature then affects invertebrates which can be used as indicators);
- the thermal tolerances of invertebrates are well known and understood;
- invertebrates are widespread and relatively easy to identify;
- we hold a good invertebrate dataset
- Invertebrates are good indicators of water quality and we use this in our freshwater quality assessment.

How do we link invertebrates to water temperature?

Invertebrates (and indeed most organisms) can be split into three broad temperature groups:

- cold specialists (cold stenotherms);
- warm specialists (warm stenotherms);
- generalists (Eurytherms).

In the case of this study, temperature preference group was derived from the freshwaterecology.info database (Schmidt-Kloiber, A. & Hering D. (2015)) with some additional references from the literature for exceptions not covered by the data from this source.

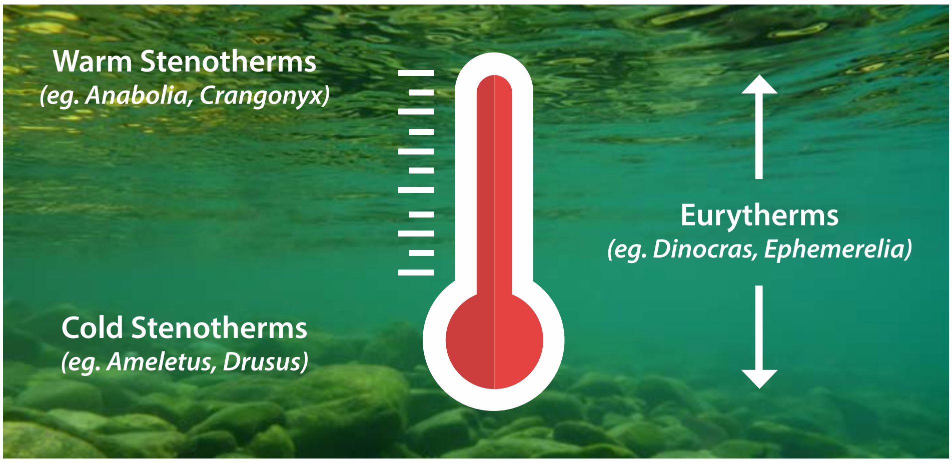


Figure 2. Diagram showing the temperature preference of invertebrate groups

The relative proportion and abundance of each of these groups in a sample can therefore act as an indicator of prevailing water temperatures that communities have been exposed to.

Note that we are uncertain whether this is a shift in timing of growth and reproduction effect (samples are taken at the same time every year) or whether it is due to extinction at a particular site.

Several warm stenotherms are non-native/invasive species, suggesting that climate change may exacerbate other environmental issues.

We analysed our data from across Scotland, based on five years data. This showed a strong relationship between the ratio of cold specialists to generalists and altitude, whereby cold specialists were more abundant in samples from rivers and streams higher up the slope (above 250m altitude) than generalists.

We predict that, as climate change progresses and water temperature rise, the decline of the proportion of cold water stenotherms will rise up the slope.

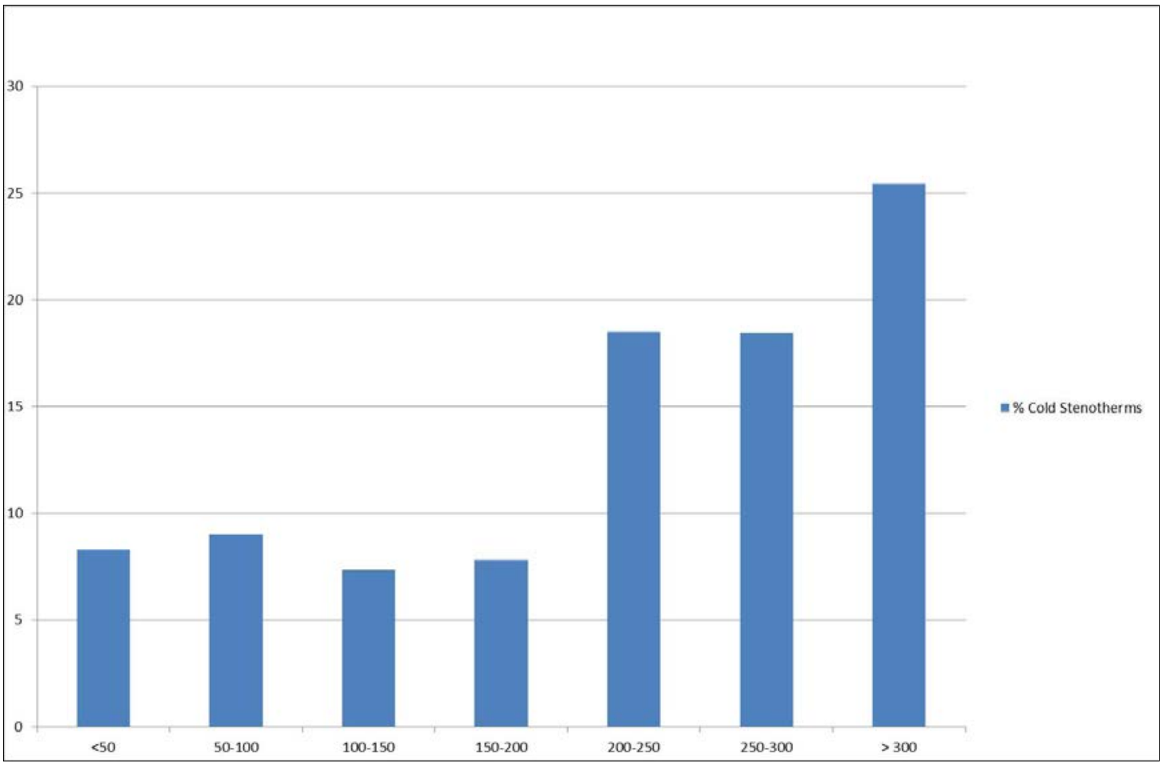


Figure 3. The percentage of cold-water specialist invertebrates in samples taken in rivers across Scotland at different altitudes.

Why did we choose the Spey catchment?

The Spey catchment has several advantages when it comes to monitoring the effects of climate change. Firstly, there are relatively few issues with water quality compared to other rivers, which means that the observed relationships are more likely caused by other environmental changes, such as temperature.

Secondly there are a good range of sample locations with long-term data going from sea level to 300m.

And finally, we have good (air) long-term temperature data from the nearby Braemar weather station, with records going back to the 1960's.

What does the Spey data tell us?

Figure 4 shows a long-term (1982 to 2009) increase in late summer air temperature at Braemar and concurrent clear decrease in percentage of cold water specialist invertebrates at Spey river invertebrate sample locations (near Garva). Both air temperature sampling location and river sampling location are at similar altitudes (ca 300m) and in close proximity. We used air temperature as a proxy for water temperature as the air temperature records are available and water temperature of shallow rivers closely follows air temperature. We used the air temperature at the end of the summer/autumn (September PY) in the previous year as this is an ecological important time in the life cycle of freshwater invertebrates when eggs are deposited in the river bed that will form next years generation

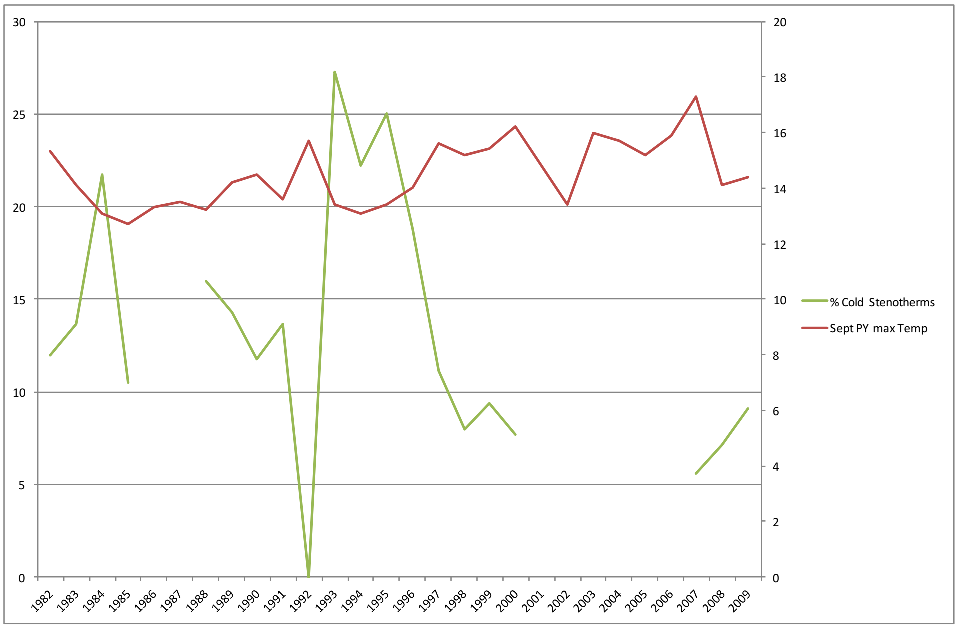


Figure 4. September maximum air temperature (at Braemar) and percentage of cold-water specialist invertebrates in samples taken from the Spey (upstream from Garva) from 1982 to 2009.

The graph in figure 5 shows a clear inverse relationship of air temperature and percentage of cold-water specialist invertebrates over 29 years. The fitted log-curve was highly significant (P<0.001) with and R2 of 0.56.

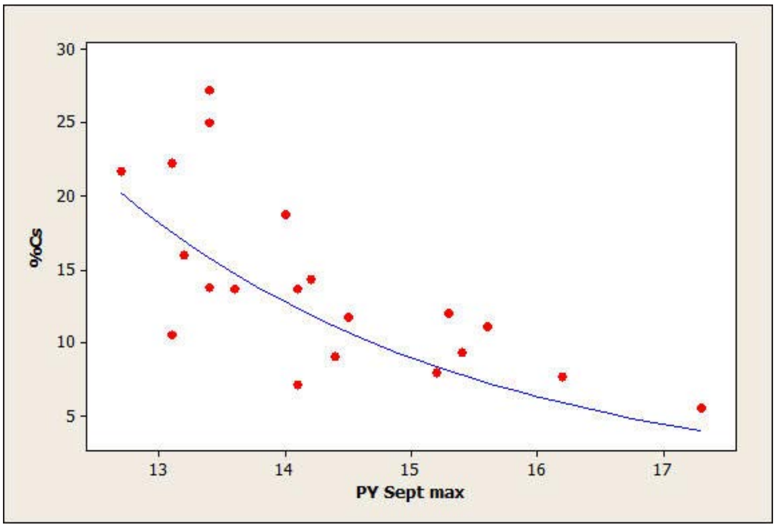


Figure 5. The percentage of cold water specialist invertebrates at the Spey (near Garva) as a function of the air temperature at Braemar in previous September.

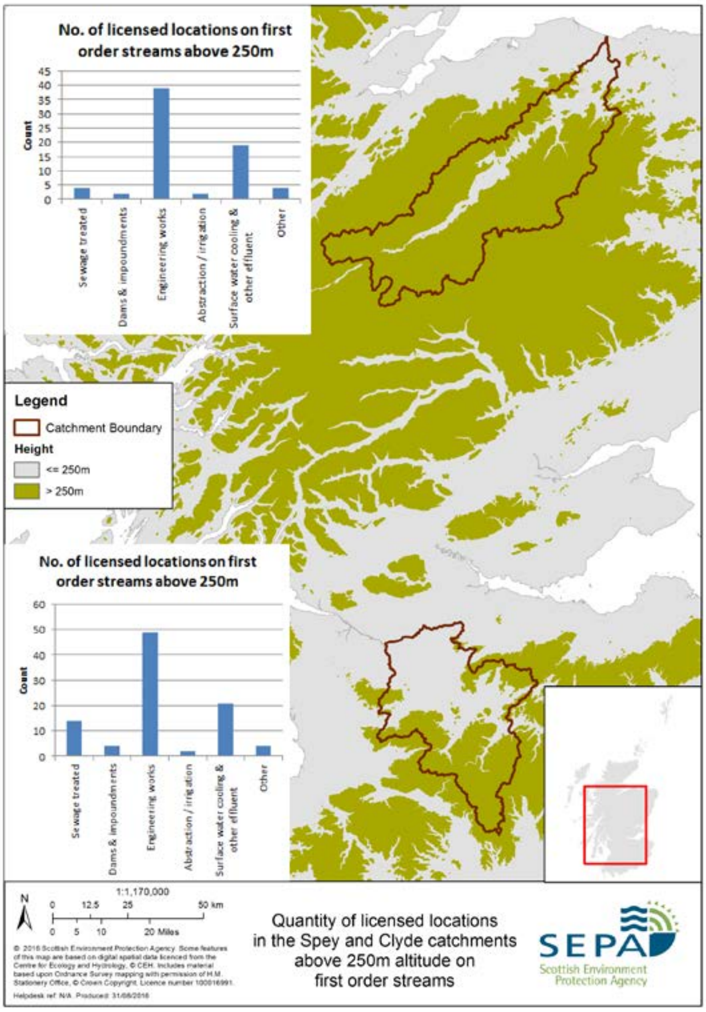
What does this mean for Scotland?

Scotland will, under further climate change, be an increasingly important European refuge for these biodiversity species, such as freshwater pearl mussel and Upland Mayfly. We will need to evaluate this increasing responsibility against other potential societal uses of this water.

There is an increasing risk that essential relative life-cycle timings in the aquatic environment are disrupted under climate change, and this could impact on the value of this environment to support business and recreation (such as angling).

There is no clear evidence at this moment in time that the changing invertebrate population at higher temperature is more or less sensitive to environmental pressures as nutrient enrichment. However, it is clear that thermal discharges (such as those coming from cooling water and sewage treatment plants) will change the invertebrate species make up at higher altitude rivers.

Our high altitude streams are also often the top-end of catchments (first order streams) and provide essential sources of invertebrates to recolonise the downstream river after a pollution has impacted the invertebrate population or the river recovers from restoration works. It is thus important that our management of pressures on the river in these potential 'seed-sources' takes account of this. The figure on the right shows the extent of the top-end of the catchment from two of Scotland's main rivers (Spey and Clyde) and the amount of human activity that could impact on the invertebrate population. There are opportunities for business within these areas to go 'beyond compliance' and work with us to protect and enhance this valuable resource.



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