IBERIAN BROWN TROUT THREATENED BY CLIMATE CHANGE

BEN TYSER

Although brown trout in Europe are not, as a whole, classified as threatened or endangered, the status of certain populations and sub-species is arguably more precarious, for example the Ohrid trout of Albania and marble trout of the Balkans.

Brown trout on the Iberian peninsula occupy the periphery of the brown trout's natural range, the high average temperature of the Mediterranean region being the chief barrier. Brown trout cannot withstand high temperatures, their upper limit being water temperatures in the low 20s Celsius.

Many people will not recognise Spain as country that supports brown trout. Despite its regionally warm temperatures, there are localized populations of wild brown trout, chiefly in the cooler mountainous regions such as the Pyrenees and Cantabrian mountains where altitudes can reach 2,500-3,000m. Ernest Hemingway used to fish the Irati River in the Pyrenees quite regularly and trout fishing in the Navarre region featured in his novel *The Sun also Rises*. The Iberian region is very important for the genetic diversity of the species as a whole; it was one of the refuges for brown trout when they were forced out of other parts of Europe during the ice age(s) and represents a stronghold for the Mediterranean lineage of brown trout, a recognized unit of brown trout diversity.

Climate change predictions are varied but all predict global temperature rises under all scenarios. A recent study (Almodóvar et al., 2012) paints a worrying picture of the future persistence of trout in the Iberian Peninsula. The study, on the Aragon river in the Pyrenees, considered trout abundance and catches from 1993–2004 while analysing local water and air temperatures from 1974–2008. An abrupt rise in temperatures was observed in 1986 and worryingly, the warming was associated with a significant decline in trout abundance in the lower reaches of the river and tributaries. The warming trend is in effect pushing trout up into the cooler, upper reaches of the rivers where, for now, it seems that stocks were unaffected. This corresponded with a significant decline in catch rates for the rod fishery. On top of this, it appeared that trout are being replaced in the lower reaches by warmer water loving cyprinid species. The best result for brown trout under all predicted climate change scenarios is that they will retain barely 3.5 per cent of their current range by 2085.

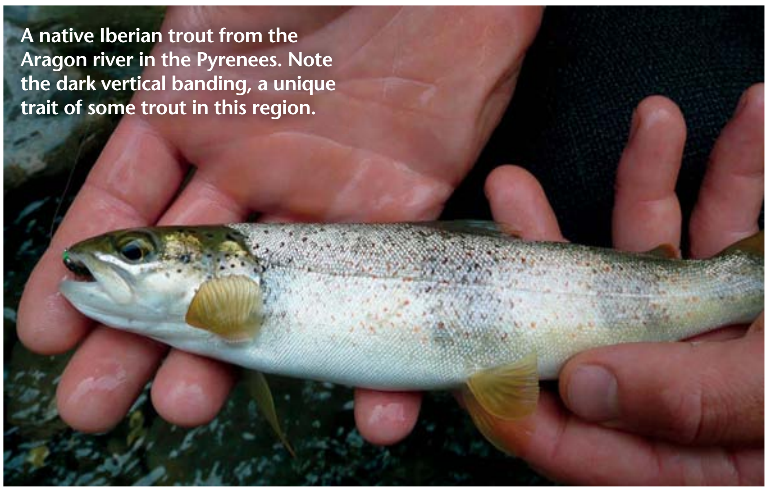
The extinction of brown trout in the Iberian Peninsula would be very damaging; the Mediterranean lineage represents a sizeable chunk of brown trout genetic diversity, due in no small part to its isolation. It is this isolation that further dampens the outlook for brown trout in this region, which cannot undertake seaward migrations as other populations are able to do. Trout populations in the Pyrenees have been subjected to a number of other human pressures including over fishing by anglers, stocking and the construction of impoundments. While overfishing problems have largely been overcome, the authors highlighted the presence of impassable dams preventing downstream dwelling populations of fish from accessing thermal refuges in the colder, upstream parts of the river. These refuges are very important to trout in times of high temperature stress.

While the study area was not stocked, other Spanish rivers are, sometimes heavily. Climate change is a pressing problem and the impacts of stocking and migration barriers are exacerbating the situation. This highlights the paramount importance of habitat connectivity and preserving the genetic integrity and diversity of current populations if we are to preserve wild brown trout populations across their native range under future warming scenarios.

WHAT DOES THE FUTURE HOLD FOR BROWN TROUT IN IBERIA?

This study and the evidence surrounding global warming are far from promising about this and other peripheral regions' prospects. However, there is work and research being conducted into creating thermal refuges for trout and creating shaded refuges by strategic tree planting. There is evidence to suggest that these measures can create localized cold spots that remain cooler than other parts of the river. Only time will tell whether this will actually work in the face of global warming.

Almodóvar, A. et al., 2012. Global warming threatens the persistence of Mediterranean brown trout. Global Change Biology, 18(5), pp.1549–1560.



A native Iberian trout from the Aragon river in the Pyrenees. Note the dark vertical banding, a unique trait of some trout in this region.

Image credit: Marcus Janssen

THE MAYFLY CLIMATE PHENOLOGY PROJECT

Dr. Nick Everall of the MCPP provides an update

Ephemera danica nymph © Dr. Cyril Bennett

The Mayfly Climate Phenology Project is a collaborative project between Aquascience, Loughborough University, National Riverfly Partnership, Wild Trout Trust, Beresford Fishery, Trent Rivers Trust, Derbyshire County Angling Club, Environment Agency, Staffordshire Wildlife Trust and Peak District National Park Authority on the phenology of the Mayfly (*Ephemera danica* Muller, 1764) in the River Dove in Staffordshire. Phenology is the study of periodic life cycle events in living things and how these are influenced by variations in the seasons and climate.

E. danica is one of the largest mayflies found in the British Isles with some females reaching over 30mm in length. It is a widespread species found in rivers, streams and lakes throughout Europe. The larvae are burrowing animals and often found where silt accumulates in watercourses.

SAMPLING IN THE RIVER DOVE

The project relies upon seasonal sampling of mayfly nymph populations, continuous river temperature logging and subsequent sample data analysis from Beresford Dale and Dovedale in the River Dove in Staffordshire. Approximately 200-300 *E. danica* nymphs have been sampled from the study sites, followed by sexing and sizing of these animals, each year from 2007 to date by Dr. Nick Everall of Aquascience. Contemporary daily recordings of river temperature have been historically collected by the Environment Agency and with continuous loggers since 2010 by Loughborough University at the mayfly study sites.

FINDINGS IN THE RIVER DOVE TO DATE

Initial studies at Beresford Dale and other sites in the dale in 2007 revealed a typical size distribution of *E. danica* (Bennett, 2007) as shown in Figure 1; there are two distinct groupings, one representing two-year-old nymphs about to emerge from the river (with a difference in size distribution according to sex) and the other, one-year-old, immature, smaller nymphs (sex not recorded).

From 2010, all the Beresford Dale study sites revealed a potential change in the phenology of *E. danica* populations, with only one generation of a smaller size range of male and female mayfly evident just before the main emergence period (Figure 2). In Figure 2 the small peaks in body length >22mm may or may not be the remnants of second year females.

The one-year life cycle pattern has continued in the River Dove in Beresford Dale up to the main emergence period in June 2012 and has been strongly associated with river temperatures during this time (Figures 3a and 3b), whereas the populations of *E. danica* in the cooler (by about 2°C), spring-fed waters in the river in Dovedale remained in a two-year cycle in 2012 (Figure 3c).

Interpretation of the field data from the mayfly phenology and temperature study sites in the River Dove from 2000–2012 suggested that consistent summer average temperatures above 14 °C and maximum temperatures in the range 15–18 °C associated with *E. danica* moving to a one-year generation population and reduced size in emergent females in this watercourse. These results were consistent with temperature thresholds observed for identical changes in the phenology of *E. danica* in both field and laboratory studies by Bennett (2007). In contrast, the cooler thermal regimes of the River Dove in Dovedale over the last 12 years appeared to associate with an *E. danica* phenology characterised by a two-year life cycle.

Figure 1: Size and sex distribution of ***E. danica*** nymphs in Beresford Dale in the River Dove in April 2007.

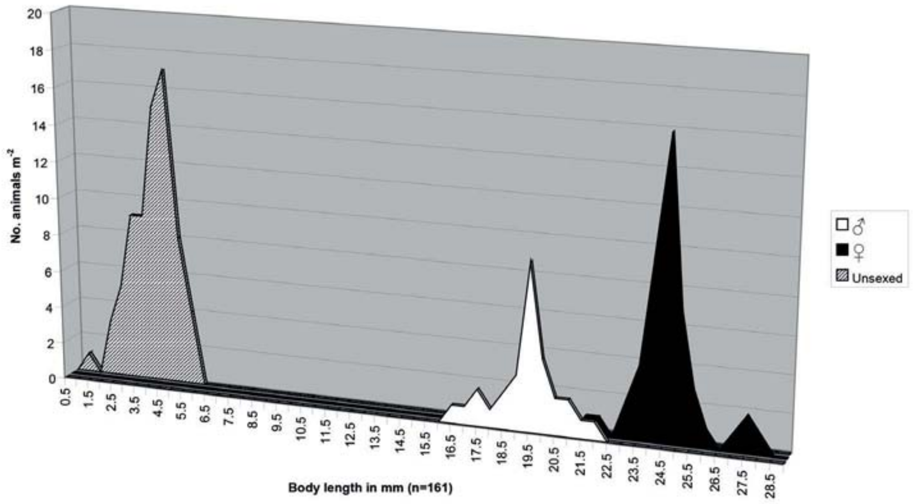


Figure 2: Size and sex distribution of ***E. danica*** nymphs in Beresford Dale in the River Dove in April 2010.

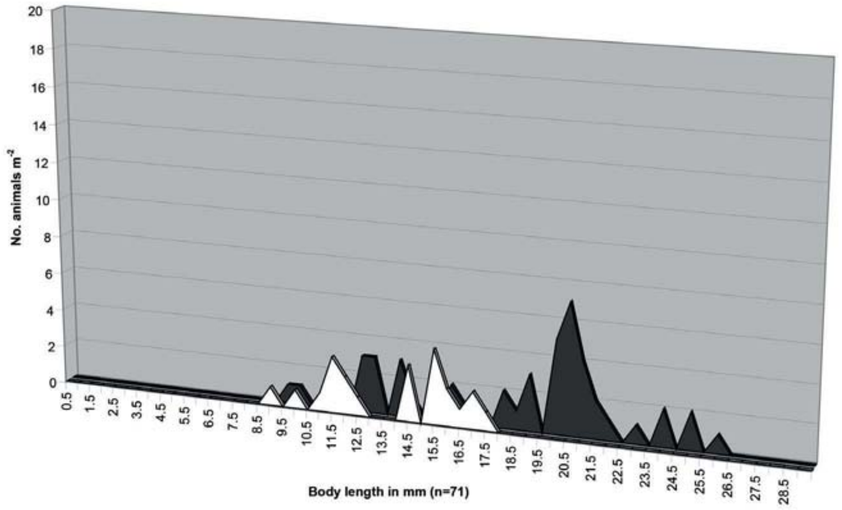
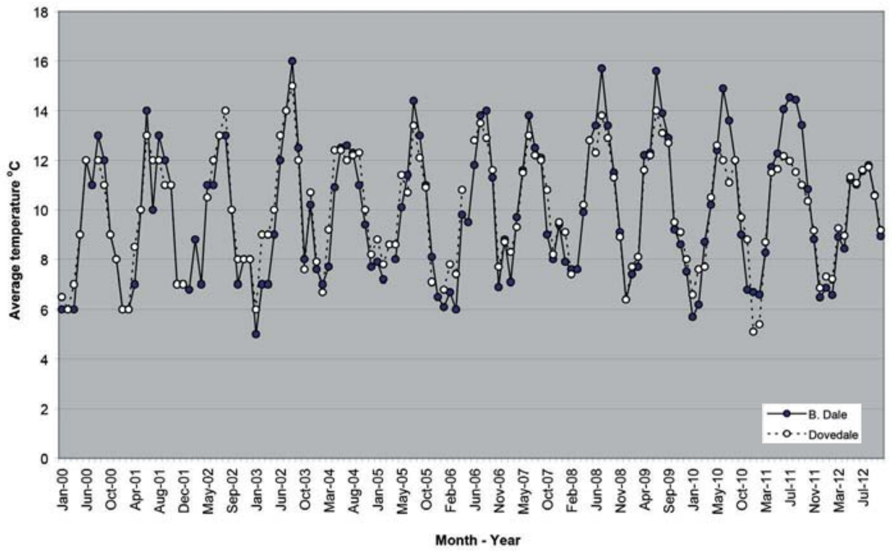


Figure 3a: Differing temperature regimes in River Dove in Beresford Dale and Dovedale 2000-2012



Not surprisingly, the size of adult mayfly emerging in the River Dove in Beresford Dale in 2009, 2010 and 2011 were reported to be markedly smaller than those in 2007, particularly females which tended to merge into the smaller size ranges of males (N. Everall, A. Bridgett and A. Heath pers. obs., 2009-2011). Such a phenology change could have serious consequences for *E. danica*; Owen (2011) points out that a period of bad weather during the relatively short main emergence period, when most of the mayfly population are adults, could severely reduce or even wipe out a population. Similarly, it has been shown that the emergence of smaller female *E. danica* results in the production of fewer eggs, from around 6,000 in a 24mm female compared with 3,000 in an 18mm female (Bennett, 1996).

It was also clear from the longer-term river temperature data in upper Beresford Dale that average water temperatures in the spring-fed River Dove during the wettest spring-summer recorded in 100 years in 2012 were cooler than at any time recorded over the previous 11 years. If the cooler waters recorded in Beresford Dale during 2012 lead to a reversion in mayfly phenology to a two-year life cycle, this would not fully manifest itself until the following years and so the findings from the River Dove study sites in 2013 will be most interesting. Such results may also help us to understand more about how to ameliorate, at least in the short-term, the impacts of rising river temperatures upon the ecology of rivers, based upon our growing knowledge of techniques to produce in-stream cooling (Everall et. al., 2012).

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Figure 3b: Size and sex of E.danica nymphs in River Dove in Beresford Dale at Site A on 30th April 2012

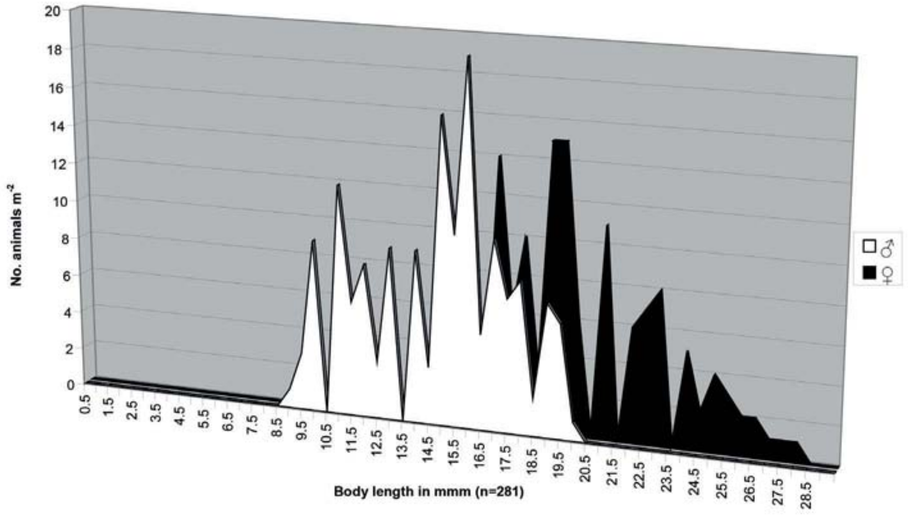
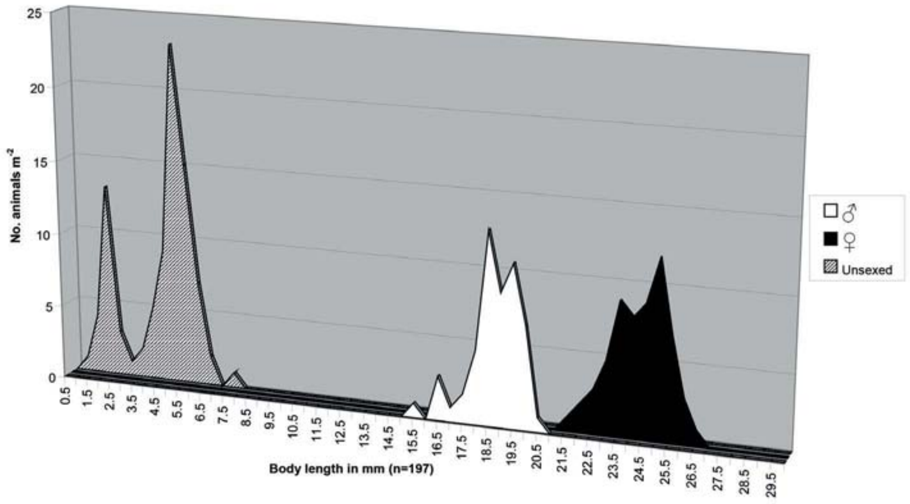


Figure 3c: Size and sex of E.danica nymphs in River Dove in Dovedale at Site C on 30th April 2012



SPECIES RESILIENCE

Ben Tyser looks at Pacific salmon and how diversity is the key to survival.

There are five species of Pacific salmon: pink, chum, coho, sockeye and Chinook. They are members of the genus *Oncorhynchus* (meaning hooked snout) and native to Northwest North America. Also within this genus are species of trout such as rainbows and cutthroats with a range of sea-going and landlocked forms. These species evolved into their current forms about 6 million years ago.

This 6-million-year period has been one of recurring environmental change including repeated glaciation and gigantic 'superfloods'. The dynamism and diversity of the Pacific Northwest's coastline is thought to be why there are five species of Pacific salmon, while the relatively mild and benign conditions of Europe have just produced one. Even in relatively stable periods (the last 5,000 years), populations have been subject to other pressures like wildfires, landslides and volcanoes. Pacific salmon have therefore had ample time for evolution and within-species diversification.

To cope with dramatic environmental changes during their evolutionary history, these species have shown remarkable resilience, largely due to their extensive genetic 'tool kit'. *Oncorhynchus* species display a rich variety of life history traits, both within and among populations. Sockeye salmon and rainbow trout have completely landlocked forms. In other cases, diverse life histories allow Pacific salmon to take advantage of habitats that cannot support a population through all its freshwater life stages. For example coho salmon 'nomads' are fry that spend their first summer in estuaries, migrating into tributaries to overwinter, thus allowing smolts to be produced from streams that may not otherwise be able to support them. Evidence is accumulating that Pacific salmon are capable of rapid evolution and that 'Evolutionary significant units' (ESUs = groups within the same species that share common traits and are significantly different from other groups) are capable of evolving in short periods of time (about 100 years).

The concept of diversity within a single species is an important one. The idea of biodiversity being important to mankind by providing stable ecosystems (and 'ecosystem services') is becoming more widely accepted. However, it is the diversity in the number of species that has received most attention, rather than the diversity of groups or 'ESUs' within a species. Recently, five decades of data from the sockeye salmon (*Oncorhyncus nerka*) marine fishery in Bristol Bay, Alaska, were analysed (Schindler et al., 2010). Variability in annual Bristol Bay sockeye catches is 2.2 times lower than it would be if the system consisted of a single homogenous population rather than the several hundred discrete populations it currently consists of. Furthermore, if it were a single homogeneous population, such increased variability would lead to ten times more frequent fisheries closures. Maintaining that diversity within a single species is important socially and economically.

Natural forces and disasters impact on salmon populations differently to those created by man. In the last 200 years, the Pacific Northwest has seen dramatic changes to its river systems: dam building, draining marshlands, and canalizing rivers are just some factors that have obvious impacts on population viability. Some estimates point to 30 per cent of salmon populations being lost – a sizeable chunk of those 6 million years of evolution gone forever. But Pacific salmon are highly resilient; shouldn't they be able to cope having survived glaciers and superfloods?

It is the way in which these human changes alter the evolutionary 'template' or the circumstances in which evolution has taken place that are so serious for the resilience and viability of Pacific salmon. Their evolution has been dictated by the frequency of large and local scale disturbances; human induced changes like flood control schemes reduce or increase the frequency of these events beyond natural parameters. Anthropogenic changes also reduce the diversity of the landscape and habitats that have influenced evolution, translating to reduced life history diversity.

The variety of life histories has equipped Pacific salmon to deal with change. But this diversity, in turn tied up with habitat diversity, is being lost and the resilience of the genus is being compromised. The same goes for increased frequencies of extreme events, for example floods brought on by global warming or deforestation. These frequencies are greater than those with which salmon have adapted to cope. Locally, such changes may lie within the capabilities of Pacific salmon to adapt, but when replicated across heavily modified human landscapes (e.g. multiple road culverts on tributary) and resilience is again compromised.

Conservation efforts in the USA have, as in the UK, focussed on restoring natural disturbance regimes (e.g. flood cycles, sediment supply in rivers), habitat restoration and removing barriers to migration. The situation facing Pacific salmon stocks has many parallels with brown trout and Atlantic salmon in the UK and Europe. While many populations of Pacific salmon have disappeared and much diversity is lost, a considerable amount still remains. In the same way, despite years of harmful stocking practices and habitat destruction, much of the brown trout diversity of the British Isles remains. Because of the narrow temperature tolerances of brown trout and the increasing threat of climate change, protecting the resilience of the species becomes ever more important. Habitat restoration is key to restoring the viability of trout populations and restoring migration pathways and connectivity is crucial to facilitate the all-important natural flow of genes between and within populations. If we can provide conditions that allow essential evolutionary processes to continue, brown trout should be well equipped to deal with future challenges, just as they have throughout their evolutionary history. The issue of population resilience also puts the stocking of fertile, hatchery-bred fish into sharp perspective; as a measure that compromises the genetic vigour of wild populations, it has no place in wild fisheries.

Further reading

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