science summary

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The thermal biology of brown trout and Atlantic salmon

Science Summary

Previous studies have looked at manmade influences on river water temperature, and the possible effects of such temperature changes on salmon at different stages of their life cycle. However, a lack of information on the thermal biology of salmon has made such studies difficult. A new report by the Environment Agency attempts to bridge this gap, particularly in light of concerns over the effects of climate change on rivers. The report summarises our current knowledge on the thermal biology of salmon and brown trout.

Fish have little control over their body temperature. If the temperature of their environment is uncomfortable or unsuitable, they may migrate or seek thermal refuges locally. Water temperature has a major impact on the distribution, migration, survival, physiology, feeding, growth, reproduction and behaviour of all fish species.

This report summarises what is already known about the effect of temperature on salmonids native to the streams and rivers of England and Wales. The report covers Atlantic salmon (Salmo salar) and the brown and sea trout (Salmo trutta) at various stages of their life history. Reference is also made to related species from North America and elsewhere, where appropriate.

The majority of observations on the effect of temperature on salmonids come from laboratory or hatchery experiments. These are valuable observations on the singular effect of temperature and are reviewed here. However, in practice and especially at high temperatures, other associated factors may have a major effect, such as lowered dissolved oxygen, reduced steamflow or interactions with a predator or pathogen. Some field observations do exist and these are considered within this report, to see what they can add to the laboratory results. Wherever possible, field observations are discussed in the context of associated conditions that the fish are likely to be encountering.

The report draws the following conclusions.

The incubation period (fertilization to hatching) depends upon water temperature. The incubation period for both species is 100 days at 5°C, and 50 days at 10°C. The range of temperatures in which eggs survive is around 0-13°C for brown trout and 0-16°C for Atlantic salmon. However, mortality and deformity rates increase markedly in salmon eggs above 12°C.

The period between hatching and first feeding, when the fish subsist on their yolk sacs, is also influenced by temperature; it is around 38 days at 7.5°C. Alevins can survive in a wider range of temperatures than can eggs; Atlantic salmon alevins develop normally up to 22°C.

The report provides temperature polygons for trout and salmon showing the effect of acclimation temperature on lethal temperatures and the range of temperatures at which feeding occurs. Upper lethal temperatures depend upon acclimation temperature and the length of time that the fish are subjected to them. With acclimation to warm water the 1000-minute upper lethal temperature is 27°C for brown trout and 29.5°C for Atlantic salmon parr. The seven-day upper lethal temperature is 25°C for trout and 28°C for salmon parr. Brown trout (presumably also salmon) may survive short-term high temperatures by seeking cooler refuges in pools and deeper water.

For brown trout, growth can occur between 3.5°C and 19.5°C, with maximum growth at 13°C. For Atlantic salmon, growth can occur between 6°C and 22.5°C, with maximum growth at 16°C.

Where a choice is available, salmonids appear to avoid areas with temperatures outside their growth range. The zone between the growth range and lethal temperatures is called the critical range, over which increasing stress and disturbance to normal behaviour is apparent.

Increasing temperature increases the effect of pollutants and the susceptibility of fish to many pathogens.

Smolt age depends on growth, which in turn depends on a number of factors including the temperature regime. A decrease in mean smolt age has been recorded in many populations of sea trout and salmon. The development of smolt characteristics is temperature dependent, as is the rate of loss of smolt characteristics (including the ability to make the transition to salt water) if migration is delayed or prevented. The timing of smolt migration is influenced by a number of factors including temperature. Early migration of salmon smolts in warm seasons may have consequences for marine survival.

Conditions in the sea, including sea surface temperature (SST), clearly have a major effect on the survival, condition and growth of salmon, but the situation is complex. Major shifts in the balance of sea-age at return appear to be linked to SST. The marine survival of Atlantic salmon from two European stocks has been negatively correlated with the extent and location of sea surface temperatures between 5 and 7°C, and positively correlated with the extent and location of SST of 8-10°C in May during the year of smolt migration. There is evidence from the River Bush (Ireland) and the Girnock Burn (Scotland) that a lower survival is associated with early salmon smolt migration in warm years. There has been a decline in marine survival and the condition of salmon in recent years (culminating in the widespread occurrence of “thin grilse” in 2006) which is correlated with an increase in winter SST.

Survival in, and passage through, the estuary by returning adult salmon is influenced by temperature, especially where other water quality parameters are critical. The lethal level of dissolved oxygen is around 3 mg/l at 15°C, and 7 mg/l at 25°C.

Temperatures exceeding about 16°C may be associated with reduced migration in estuaries and rivers, with very little migration above about 20-23°C, but varying between rivers. Atlantic salmon delayed in estuaries in hot, dry summers may suffer significant mortality.

Swimming ability (burst speed) is limited by low temperatures, resulting in reduced migration under cold conditions.

The temperature experienced by adult female salmon in the months before spawning can affect gamete quality. Eggs produced by females kept at 22°C were smaller, less fertile and less viable than those produced by fish held at 18°C or below. Ovulation falters or fails in fish maintained at an elevated temperature, for example 4°C above ambient temperatures in one experiment.

Spawning appears to be timed so that the resulting fry start to feed at the optimum time in the spring. As the rate of egg development is temperature-dependent there is a wide variation in spawning time, presumably under genetic control. Spawning only occurs within a limited temperature range, below 11.5°C for Atlantic salmon in France. Recent climatic warming has reduced the time available for successful spawning in this case.

The presence of viable populations of brown trout and salmon appears to be limited by temperatures well below those considered to be directly lethal. Critical temperatures for Atlantic salmon appear to be about 2°C higher than equivalent figures for brown trout, suggesting that trout would probably suffer sooner from environmental warming. However, it is the salmon that appear to have declined to the greater extent, especially in the southern part of their range.

Overall, it appears that the occurrence of temperatures within the upper critical temperature range (above 19.5°C for brown trout and 22.5°C for Atlantic salmon) represents a stress that may affect the long-term well-being of the population. In addition, there may be effects on life-history aspects at temperatures below this level.

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