Fry n' eggs: Sockeye salmon in hot water

Pacific salmonid species are important in British Columbia, for reasons ranging from commercial markets, to cultural values, and as a source of ecologically relevant marine derived nutrients. Forest ecosystems rely on the decaying carcasses of anadromous salmon, which have been shown to significantly increase productivity to nearby plants and trees, to the extent that this effect can be seen using dendrochronology and carbon isotope analyses. The commercial fishery based on Pacific salmon, especially for sockeye salmon, is a highly valued aspect of BC's economy. As well, these fish are an integral aspect of First Nations culture as both a food resource and an important cultural connection with the land.

Within UBC Forestry, Scott Hinch's lab group has been studying Pacific salmonids for over 2 decades, with a focus on sockeye salmon as the most commercially important of the 5 Pacific salmon species. Under the guiding hand of Dr Hinch, researchers in the Pacific Salmon Ecology and Conservation Lab, study the migration biology and ecology, reproductive biology, and behavior of these fishes, using a variety of techniques ranging from telemetry to physiology, gene expression to hatchery rearing. They are interested in the effects of recreational angling, commercial fishing, and climate change on the viability and abundance of this important resource.

Charlotte Whitney has focused her research on climate change, aiming to further understand the thermal tolerance limits during early juvenile development of many genetically distinct populations of sockeye salmon. This research builds upon work by Dr Erika Eliason, who was able to show that sockeye salmon populations have developed different thermal tolerance limits as migrating adults based on physiological differences in heart morphology. Using water temperature data gathered over the past decades in the Fraser River, she suggested that differences in overall aerobic swimming ability are related to different environmental conditions among groups, whereby those fish that commonly migrate through highly variable thermal conditions have developed a wider thermal tolerance during this life stage.

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While those results suggest that some populations of sockeye salmon may be more able to tolerate the increasing water temperatures that are predicted with climate change, they were limited in scope to a single aspect of the variable salmon life history. Suggesting thermal tolerance limits for adult salmon does not allow one to extrapolate to how emerging fry will manage changing conditions in rearing lakes, where they spend the first year or two, depending on the species, before out-migrating to the ocean as smolts. In order to understand effects of climate change on the life cycle as a whole, it was necessary to investigate how different populations would respond in other aspects of the life history.

With this in mind, Charlotte and other members of Scott Hinch's group, in collaboration with the Department of Fisheries and Oceans' Environmental Watch group, set out in the fall of 2010 to make fish babies. Lots of fish babies. They collected thousands of eggs from reproductively mature individuals from many populations, all spanning a large geographic range across the province. By crossing egg and sperm from individuals within a population, they created individual families from each group and reared them in a common environment. They compared the response of each population to

3 water temperatures, reflecting ideal incubation conditions, elevated temperatures, and very high water temperatures for the species in this region. Since populations of sockeye salmon migrate to natal spawning streams and reproduce throughout the fall, they had to replicate Charlotte's experiment over 3 months in order to include 9 diverse groups.

Over the next weeks, they used measures of survival, growth rates, and hatching timing to compare population-level thermal tolerance. While previous research has suggested species-level thermal limits, these results are the most comprehensive study to include so many populations at this life stage.

Specifically, they asked whether populations differed in their thermal tolerance during embryonic development, or from fertilization to hatching, and whether that thermal tolerance relates to historical water temperatures of natal streams. Furthermore, they investigated the variation in hatch timing among populations, and whether this was related to survival rates.

And indeed, populations matter. Thermal tolerance varied widely across groups; while the warm-adapted summer spawning populations responded to elevated incubation temperatures with barely reduced survival rates of close to 90%, the late spawning and cool adapted populations experienced mortality of close to 90%. This is hardly a new concept; population differentiation and adaptation to natal environmental norms occurs across species and taxa, especially in species where populations are geographically or temporally segregated across an environmental gradient. This research agreed with this simple conclusion, but Charlotte and her fellow researchers were also able to suggest that these populations of sockeye salmon may be adapted to their historical thermal experience during spawning and early incubation. Additionally, this thermal tolerance at the embryonic life stage does not seem to relate to adult thermal tolerance; indeed, the population with the worst thermal tolerance in Charlotte's study was the same group that displayed the best thermal tolerance at the adult life stage in Erika Eliason's work.

Photo: Matt Casselman

All this goes to show, that climate change will affect species, populations, and life stages differently. We now know that we cannot presume knowledge of a population-wide response by understanding a single aspect of the life history alone. As a jumping off point for future research on population dynamics and evolutionary ecology, Scott Hinch's group can use these data to suggest certain populations to include in studies of the heritability of thermal tolerance. Additionally, they can explore the variability in stress response among populations as a factor of thermal tolerance, and as an influence on reproductive biology. By using these results, they can inform policy decisions on harvest limits and habitat management to mitigate the effects of climate change on sockeye salmon viability in the province.

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