

Evolution & Behavior

Salmon are shrinking and you can see it in their genes

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This Break was edited by Max Caine, *Editor in chief* - TheScienceBreaker

ABSTRACT

Atlantic salmon age at maturity has globally declined over the last four decades. This trait is strongly associated to survival and reproductive success. By monitoring temporal changes in the gene (vgll3) controlling age at maturity, we showed that Atlantic salmon have quickly evolved to mature earlier, at a smaller size, in the Teno river.



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The environment in which we and other living beings reside has been quickly modified over the last decades due to climate change and the expansion of human activities. This can result in characteristics of individuals (for example, size at reproduction) that previously gave them the best chance to survive and reproduce no longer being optimal in the changed environment, leading for instance to higher mortality rates or lower reproductive success. To cope with such environmental changes, living beings may acclimate by changing their strategies during their lifetime and/or evolve over several generations through natural (or human induced) selection.

Evolution is often seen as a slow process taking thousands, or even millions, of years to lead to the

creation of new species, but it can, and often does, also occur in a few generations and modify populations characteristics. Why is it important to study cases of rapid evolution? Because it helps to understand the kinds of circumstances under which some species may be able to keep up with adjusting (via evolution) to human-induced changes. However, it is not so straightforward for scientists to demonstrate that evolution has actually occurred. First, we need to demonstrate that the variations in individual characteristics result in differences in survival and reproductive success. Then, those characteristics also need to be controlled at the genetic level, as genes allow the transmission of the variation from generation to generation. When these requirements are met (along with a few others we'll

skip over here), individuals with the more optimal set of characteristics have higher ‘reproductive success’ - they produce more offspring and thus the genetic variants generating the more optimal characteristics to the next generation.

Atlantic salmon abundance has declined worldwide due to a number of human-induced changes including over-fishing, hydro-electric dams, climate change and pollution. The size at which salmon reproduce has also dramatically decreased due to the fact they have reduced the length of their marine feeding period (known as their ‘sea age at maturity’). Late maturing individuals have generally higher reproductive success (for instance, a female can produce 3000 eggs after spending one year growing at sea but 15 000 after 3 years) but there is a trade-off, as they also run a higher risk of mortality previous to reproduction, particularly if conditions are not favorable. We previously found that a gene called *vgll3* seemed to control age at maturity, but in a different manner in males and females. One version of the gene confers early maturation (E) whereas the other is associated with late maturation (L). In far north Finland and Norway, salmon populations of the [Teno river](#) have been monitored over the last 45 years and scales samples from about 150 000 individuals have been collected by local fishers (see <https://go.nature.com/2NTcH1w> for more details about citizen science). Those samples are a rich source of information as age at maturity can be retrieved from growth rings in a similar way than with trees and also provide DNA. Thus, we had all the ingredients needed to test whether rapid

evolution had occurred in this population during a 42 year period as we could monitor the character (age at maturity) as well as the gene controlling it (*vgll3*).

To do this, we obtained DNA sequences of the *vgll3* gene and from other genes probably not evolving in the same manner from 1330 individuals, caught in the river from 1972 to 2014. We indeed found that the largest change in gene variants amongst all the genes we studied was for the *vgll3* gene, whereby the late maturation version declined by 18%. Thus, it seems that salmon are becoming smaller via rapid evolution. It suggests that staying for a long time at sea and thus growing large for reproduction is less advantageous than it used to be 40 years ago. Individuals became genetically prone to return to the river earlier, to the great displeasure of fishers. Interestingly, males and females didn’t respond in the same way to the changes in *vgll3* frequency. Although male age at maturity declined by about half a year over 42 years, we didn’t detect any trend in female age at maturity that could be attributed to genetics. This is likely to arise because of the sex-specific genetic basis of age at maturity in salmon.

Although these results likely indicate degradation of marine conditions and a decrease in survival, it also provides a piece of evidence for the Atlantic salmon ability to adapt quickly and “durably” to environmental changes. The potential reasons behind this evolution of age at maturity are numerous (selective fishing, sea temperature, preys abundance) and need to be further investigated.