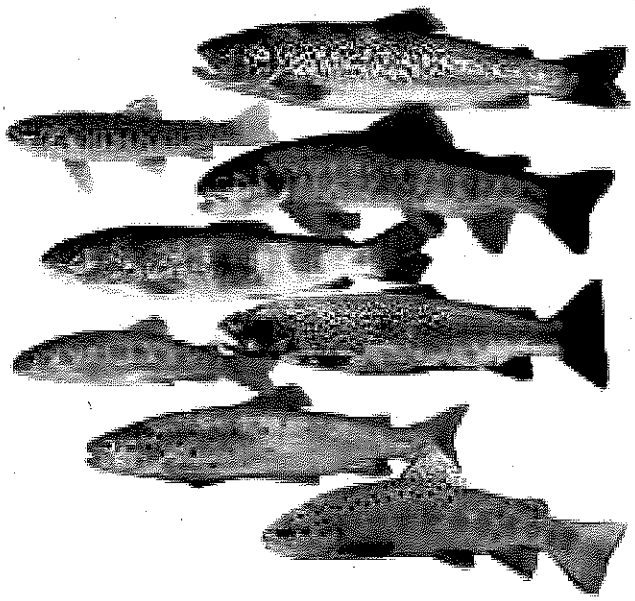
Adaptation in Alpine trout

Intensive stocking of rivers in the Alps led to the mixing of trout species. But genetic differences still exist between the populations of different drainage systems – and there is even evidence of local adaptation to different altitudes.

The four major European rivers rising in the Alps – the Rhine, Rhône, Po and Danube – originally harboured five different species of trout. Representing evolutionarily distinct lineages, these species were well adapted to their respective habitats. However, the isolating effects of geographical barriers were partly offset by fishery management practices: in the last century, in order to increase yields, large numbers of trout of Atlantic origin were translocated from the Rhine to other drainage systems. These stocking measures led to extensive hybridization between native and introduced species. As biologist Irene Keller of the Fish Ecology and Evolution department explains, "If local populations interbreed with non-native individuals, genetic adaptations may be lost and species may merge."

Differentiation maintained

Genetic diversity in Alpine trout was investigated by Keller, together with Master's student Jolanda Schuler and other colleagues, in a three-year project. In particular, the researchers were looking for evidence of genetic divergence among populations – indicating evolutionary adaptations – either between or within river systems. Using tissue samples taken from fins for genetic analysis, Keller and Schuler studied around 400 trout caught by electrofishing at 16 sites in the drainage systems of the Rhône, Rhine and Po.



Irene Keller, Jolanda Schuler, Ole Seehausen

Certain trout populations still differ genetically – and in their appearance.

The investigations confirmed that historical stocking measures led to extensive losses of genetic diversity. Nonetheless, at a number of sites in the various drainage systems trout populations still showed significant levels of genetic differentiation. "Fortunately, the original genotypes of the different forms of trout have not been completely intermixed," says Keller. This suggests that – at least in some habitats – the native fish had certain advantages over the introduced individuals. In addition, the researchers found evidence of "divergent selection" – i. e. selection pressures varied between drainage systems and trout had adapted to the local environmental conditions. "That was to be expected," says Keller, "because geographical isolation prevented genetic exchanges between the populations, so they were able to develop in different ways."

Adaptation to altitude

More striking, however, was the finding that local forms adapted to different altitudes had also developed within the three drainage systems studied. Keller explains: "Within a river system, fish can breed and exchange genes, but we still found clear evidence of genetic differentiation along altitudinal gradients." The researchers conclude that strong selection pressures are at work: increasing altitudes are often associated with dramatic changes in factors such as temperature and the composition of communities of prey and parasites. The differences between the habitats promote altitudinal adaptation in spite of gene flow.

As well as demonstrating the richness of genetic diversity in trout, these findings have important implications for conservation efforts. Keller cautions: "Stocking should only take place within closely circumscribed areas, so that locally adapted forms are preserved."

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