



Lake (left) and stream (right) ecotypes of threespine stickleback in Lake Constance differ in many phenotypic traits, such as body armor, feeding morphology, coloration of females (top) and nuptial coloration of males (bottom). Photos: David Marques.

Origin of the diversity of sticklebacks in Lake Constance deciphered

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New species can evolve rapidly after adapting to new niches, a process called ecological speciation. But mutations are rare, so how is such rapid ecological speciation possible? Recently evolved lake and stream ecotypes of stickleback from Lake Constance reveal an unexpected answer.

Most recreational fishermen do not take notice of the little threespine stickleback fish – it is too small and spiny to make a good meal. In Lake Constance however, the professional fishermen involuntarily became acquainted with it a few years ago. That's because the stickleback population has exploded in the lake, resulting in half of the fish biomass belonging to this species and them often clogging the fishermen's gill nets. The acquaintance is a rather new one because stickleback have been historically absent from the Lake Constance catchment, but were introduced in the 19th century by humans, at times when the colorful stickleback males, not yet competing with colorful tropical fish for aquarist's likings, were popular pet fish.

Maintaining phenotypic differences

Stickleback have not only reached high numbers in the lake, but they also grow up to 11 cm in length and are heavily armored with thick lateral bony plates on their flanks and long spines on the back and belly. More than a decade ago, Ole Seehausen started investigating these stickleback with Biology

students from the University of Bern in annual practical courses. They immediately noticed a stark contrast between the appearances of stickleback from the lake and stickleback found in streams surrounding the lake. In streams, fish stop growing at a smaller size, have reduced their body armor and have specialized on eating benthic invertebrates rather than plankton. Small stream and large lake ecotypes meet only in lower reaches of streams, where lake fish migrate to in spring to spawn. And surprisingly, despite breeding next to each other, the two maintain phenotypic differences, making them an early case of ecological speciation.

An analysis by Eawag researcher David Marques of genome-wide sequences showed that lake and stream ecotypes were not very strongly differentiated throughout most of the genome, except for some small segments on several chromosomes, suggesting a rather recent origin within Lake Constance. But how did the ecotypes arise in such a short time?

In the recently published study in Nature Communications, a team including Ole Seehausen and David Marques, combines phenotypic, mitochondrial and genomic data from many Lake Constance and surrounding European populations, collected over many years of student courses and field work of the Seehausen lab and by other researchers across Europe. With a demographic modelling approach, the researchers were able to formally compare the fit of different origin scenarios of Lake Constance stickleback to genomic data.

Hybrids between lake and stream

The researchers' analyses uncovered something yet unheard of in stickleback biology: that two freshwater lineages which have colonized different river catchments and evolved independently for thousands of generations, to the extent that taxonomists described them as different species in East and West Europe, suddenly meet in the middle of a continent in secondary contact and form a hybrid zone at the boundary between lake and stream habitats. Importantly however, not all streams are occupied by the same West European lineage: stream stickleback South of Lake Constance, that students of Ole Seehausen have been studying for a decade, are predominantly of the same East European origin as lake stickleback. In those streams, it is introgression of alleles from the West European lineage that caused differentiation in small segments of the genome and thereby facilitated the rapid evolution of a new stream-adapted ecotype within what is otherwise the East European lineage.

The origin story of Lake Constance stickleback ecotypes resembles the recent evolution of a new Darwin's finch species through hybridization and demonstrates, together with many other studies of rapid speciation and adaptive radiations, the potential of admixture derived genetic variation to generate new biodiversity with strong ecological impact.

Do the new findings contribute anything to the question of why the sticklebacks in Lake Constance have become so prevalent? Yes and no, says David Marques. No, because the researchers did not investigate the ecological causes of why stickleback have become so common. However yes, since they identified the East European origin of the most prevalent stickleback. Since they show a marine phenotype - very long spines and a full set of lateral bony plates - it could explain why stickleback were able to colonize the huge pelagic environment of Lake Constance. Whereas in other lakes, where European stickleback are abundant and do not show such phenotypes, they did not manage to colonize the pelagic environment. These are new hypotheses emerging, but they have not been tested yet, Marques emphasizes.



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Original publication

Admixture between old lineages facilitated contemporary ecological speciation in Lake Constance stickleback

Admixture facilitates rapid ecological speciation

(<https://natureecoevocommunity.nature.com/channels/521-behind-the-paper/posts/53740-admixture-facilitates-rapid-ecological-speciation>)

Seewandel

First [Newsletter](#) of the project «Seewandel» published.

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<https://www.eawag.ch/en/info/portal/news/news-archive/archive-detail/origin-of-the-diversity-of-sticklebacks-in-lake-constance-deciphered>