The way to fish evolution is through the stomach

Trout that live in stable ecosystems divide the prey spectrum among themselves and develop into specialists. In streams with instable food supply, however, the trout become generalists. Sticklebacks from different evolutionary lineages alter their environment by their feeding habits. This is deleterious to their descendants except they are hybrids. Understanding the interaction between species and environment is important for the effective protection of biodiversity. *By Sibylle Hunziker*

Petra Nobs, Eawag

Fig. 1: Scientists use electro-fishing to catch trout for their experiments.

Trout populations are under pressure in many Swiss streams. They suffer as a result of streams being over-engineered and other interventions in their environment. The effect of various stress factors from human and natural sources is being investigated by Jakob Brodersen's research team at Eawag, studying trout in various habitats and lifecycle phases. "What is already well researched is the migration between the streams in which the trout hatch from eggs and mature, and the lakes in which some of these brook trout become large lake trout," he says. This scientific knowledge is encapsulated in the Federal Act on the Protection of Waters, which stipulates the removal of obstacles to migration. "We know only very little, on

the other hand, about the relationship between migration and adaptation to changing habitats," says Brodersen. The fish ecologist and his team are studying fish ecology in lake Lucerne and its inflowing rivers in order to learn how trout populations adapt to conditions in their various original streams.

Generalist or specialist – according to habitat

Doctoral student Philip Dermond has investigated whether a stable food supply allows the trout to divide up the food spectrum among themselves. For the specialised animals, this would have the advantage that they could hunt more efficiently. In an unstable habitat with rapidly changing availability of food, on the other hand, it is assumed that the animals have to eat whatever happens to be there. Dermond chose ten streams altogether. Five are fed by ground water and therefore have a relatively stable water level. The other five are surface-water fed with sharply alternating flow rates. During flooding in these streams, insect larvae and other important foodstuffs for the trout are washed away. In order to determine whether these variations have an effect on nutrition, 20 trout from each stream were investigated by the researcher. He compared detailed snapshots of the stomach contents with the analysis of nitrogen and carbon isotopes in muscle tissue that allow conclusions to be drawn about long-term feeding habits. (Fig. 2).

The results were clear. To be sure, all the trout populations made use of a comparative food supply. But while in the streams with sharp water-level variations all the animals made use of the whole supply, those in the stable streams limited themselves to only about one half. The choice varied among the individuals: they had specialised strongly where feeding was concerned. "The results provided good arguments for the assumption that the development of generalists and specialists depends on adaptations to the ecological conditions," says Brodersen. "But further investigations are needed." In one of these his team investigated 150 streams all over Switzerland. The scientists also tested how brook trout react to bank construction and other stress factors caused by humans – and also which protective measures best serve the trout population.

Philip Dermond, Eawag

Fig. 2: The stomach contents provide conclusions about the feeding habits of trout.

Aldo Todaro, Eawag

Fig. 3: Blake Matthews and Rebecca Best duplicate the habitat of a lake in mesocosms and investigate how sticklebacks alter this habitat.

Artificial habitats for invasive fish

While many fish in Switzerland belong to threatened species, invasive sticklebacks feel all too comfortable in Lake Constance. The non-demanding little fish with the striking spines on their backs were introduced in the late 19th century by East Europeans to Lake Constance and by way of the Rhone to Lake Geneva. In Lake Constance they have recently increased so massively that they are a hindrance to net fishing. Moreover, hybrids of the Geneva and Constance lineages can now be found in many bodies of water between the two lakes. An Eawag research team led by the aquatic ecologist Blake Matthews and the evolution biologist Ole Seehausen are investigating how sticklebacks and their habitats influence each other and how ecological changes encourage or hinder large increases in stickleback populations.

For her study, the postdoc Rebecca Best conducted a controlled experiment. She used 50 identical mesocosms: tubs filled with 1000 litres of water, to all of which were added the same amounts of sand, stones, algae, zooplankton, mussels, snails and insect larvae (Figure 3). As the first step, this researcher populated each of these standardised habitats with varying numbers of sticklebacks from Lake Constance or Lake Geneva. Five weeks later she removed the fish from the mesocosms and documented the changes in algae and invertebrates. Then she placed 99 juvenile sticklebacks, 33 each from Lake Constance, Lake Geneva and from mixed origin, in each mesocosm.

Hybrids master change better

The results clearly showed that adult sticklebacks alter their habitat in a way that benefits the survival and fitness of juvenile fish. Depending on their genes, juvenile fish can cope with these changes to a greater or lesser extent. The most successful in adapting to the new conditions were the hybrids. Their advantage over the pure Constance and Geneva sticklebacks was especially great where food was in short supply. No one particular characteristic was the best survival aid, but rather the fact that the hybrids differed from the previous generation and possessed as broad a spectrum as possible of different genes with correspondingly great potential for useful characteristics.

Hardest hit by the selection were the juvenile fish with the ecological inheritance of the Geneva sticklebacks. In contrast to the Constance sticklebacks, those from Lake Geneva had greatly reduced the optimal food spectrum in their mesocosms. All the juvenile fish suffered from this situation, but those most affected were the ones originating from the same lineage. The juvenile Geneva sticklebacks also found alternative prey; however, because they were not of optimal size, they probably took longer to snatch and swallow such snacks and thus ran a higher risk that a rival would snap them up faster.

Invasion because of hybridisation?

Just what is the significance of these results for research on sticklebacks in Swiss lakes? "If we want to understand natural processes, we have to see that fish and their environment influence each other constantly – and note when decisive changes happen," says Best. "Experiments like ours make it possible to note single factors in these complex processes separately, and to formulate and test clear hypotheses." The researchers will thus also investigate the mesocosms to determine whether the sticklebacks adapted quickly to the new living conditions in Lake Constance owing to their hybridisation.

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