Lake Brienz: should it be "fixed"?

To boost fish yields, some members of the fishing community would like to see phosphorus levels artificially increased in Lake Brienz. However, Eawag research on water fleas and whitefish shows that the species composition of a lake is irreversibly altered by higher nutrient levels.

Thanks to local wastewater treatment, the water in Lake Brienz is once again nutrient-poor, as phosphorus inputs have been reduced to a fraction of the levels seen in the past. While in the early 1980s a litre of lake water contained around 20 micrograms of phosphorus, concentrations today are below 1 microgram per litre. For some fishermen, however, these water pollution control measures have gone too far: they claim that the lack of nutrients is responsible for a decline in catches. Today – as in the 1950s – the annual whitefish yield is 2 kilograms per hectare of lake surface, while yields of 15 kilograms were recorded during the years of increased phosphorus inputs. Accordingly, they argue that phosphorus elimination at wastewater treatment plants should be reduced: higher nutrient inputs would promote algal growth and thus support the water flea populations – a food source for fish.

However, as the proposed reduction in phosphate precipitation would contravene water pollution control regulations, motions have been tabled in both houses of parliament calling on the government to approve a pilot project. Similar plans are under consideration for Lake Lucerne. Scientists at Eawag take a highly critical view of such experiments. Their position is supported by recent studies which demonstrate the extent to which species and communities are affected by eutrophication.

Ole Seehausen

Eawag scientists investigating biodiversity in Lake Brienz as part of "Projet Lac" found a number of endemic whitefish species.

One water flea species displaced by another

A study by Piet Spaak and co-workers from the Aquatic Ecology department focused on water fleas *(Daphnia)*, which are zooplanktonic organisms. With the aid of genetic analyses of resting eggs retrieved from lake sediments, the researchers showed that – before Swiss waterbodies were exposed to pollution – *Daphnia longispina* was the predominant water flea species in all the lakes studied.

During the period of eutrophication, the invasive species *Daphnia galeata* became established at the expense of the native species in heavily polluted lakes. In most cases, the two species formed hybrids. Where *Daphnia longispina* was displaced altogether – e.g. in Lakes Constance and Greifen – the change has proved irreversible. Spaak comments: "Today, *Daphnia galeata* and the hybrid forms are the only *Daphnia* species occurring in these and other lakes, even where the nutrient status has returned to normal." In oligotrophic waterbodies such as Lake Brienz, which were never as polluted as the lakes of the Central Plateau, the native water flea species tended to survive. Although it sometimes also hybridized with *Daphnia galeata*, it became predominant again as the waters became cleaner.

In laboratory experiments involving clones of the two *Daphnia* species, the researchers demonstrated the importance of different types of food supply: *Daphnia longispina* fared better when reared under oligotrophic conditions, while *Daphnia galeata* performed better with a eutrophic food supply. Accordingly, few or no resting stages of *Daphnia galeata* were found in sediments from lakes minimally affected by eutrophication. In earlier times, Lake Brienz was too nutrient-poor to support even the native water flea. As Spaak points out, "It's been shown that there were no permanent populations of *Daphnia* in this lake before 1950."

Disappearance of specialist whitefish

Eutrophication not only alters the composition of water flea species in lakes – it also has adverse effects on whitefish, as shown by researchers from Eawag and Bern University. Using a survey carried out 60 years ago, the scientists compared historical and current whitefish populations in 17 lakes. They found that the number of endemic whitefish species has decreased by 38 per cent since 1950. Ole Seehausen of the Fish Ecology and Evolution department, who led the study, says: "The higher the maximum phosphorus concentrations

recorded in a lake, the greater the loss of species." In seven lakes, the original whitefish populations are now extinct, and they have been replaced by hatchery stocks.

Most whitefish species found in Switzerland are endemic – i.e. they occur exclusively in the lake in question. But, says Seehausen, "Around a third of these species have already become extinct as a result of eutrophication." In the case of highly eutrophic lakes, all the whitefish species have disappeared. In lakes less severely affected by eutrophication, species adapted to life in the bottom and deep waters have been lost: as these waters became oxygen-depleted owing to phosphorus inputs and the accumulation of dead algal matter, the specialists were deprived of their ecological niches. They thus died out or moved to shallower waters. Here, they interbred with other whitefish species and, as a result, lost their genetic and functional distinctiveness within a few generations. In all the formerly polluted lakes, genetic differentiation has therefore declined among the surviving populations – a development which also affects ecological behaviour. Populations are therefore now much less specialized in terms of appearance, type of feeding and spawning time. Seehausen comments: "This loss of variation amounts to a reversal of speciation."

Lower yields, but greater diversity

Although whitefish are also believed to have hybridized in Lake Brienz, it seems that none of the original species disappeared completely. Further information will be provided by the systematic survey of fish biodiversity in pre-alpine lakes which is being carried out as part of "Projet Lac". This project, launched by Eawag and various partners in 2011, is recording the occurrence of fish at all depths and in all types of habitat. Endemic species and naturally spawning populations of whitefish were detected even in the depths of Lake Brienz. In addition, numerous whitefish were netted. The researchers concluded that, while there is no scarcity of fish, they are smaller than those found in other lakes, which helps to explain the relatively low yields.

The fact that Lake Brienz now harbours smaller whitefish and fewer water fleas means that it has been restored to a more natural condition. As Seehausen emphasizes, "Switzerland has a number of highly productive, nutrient-rich lakes, and so the few naturally oligotrophic waters – with their unique biodiversity – should be preserved." In his view, Switzerland also has a responsibility to the international community, since the endemic species are included in the Red List. And the evolutionary biologist also has an eye to future developments: "Oligotrophic waters such as Lake Brienz represent a unique reservoir of genetic diversity where new species can evolve through specialization."

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The case for phosphorus elimination

Experts at Eawag take a critical view of proposals to restrict phosphorus removal at WWTPs:

- Lake Brienz is a naturally oligotrophic waterbody. After years of excessive phosphorus loads, it has been successfully restored to its natural condition – in accordance with the goals of Swiss environmental policy – and this should not be jeopardized.
- Only a few large oligotrophic lakes exist in Switzerland. They harbour unique, diverse communities of species, some of which only occur in one lake. These distinctive species and ecosystems should be preserved.
- Even a slight rise in nutrient levels affects biodiversity.
- Available data strongly suggest that community composition can be permanently altered by an increase in phosphorus inputs: endemic species adapted to oligotrophic waters are irretrievably lost.

www.eawag.ch/fb-brienzersee
(factsheets in French and German)