

# Restoration of Lake Furesø

## An EU's LIFE-Nature Project

Fishing of non-predatory fish and oxidation of the bottom water

Project period:  
2003 – 2006



## Once upon a Time ...

At the beginning of the 20<sup>th</sup> century Lake Furesø was known as one of the cleanest lakes of Northern Europe. Natural scientists started out from a small laboratory located at the bank of the lake close to the town of Virum and examined the water quality, flora and fauna of the lake.

„ ... at the part of the lake which is named Store Kalv, you find at a depth of 3 to 4 meters the large, submarine plain of the bay; during summer this plain is covered by a large almost continuous layer of plants. On an autumn day after a long period of silence a boat trip across the bay is a real pleasure for everybody who loves nature, but most of all for Botanists. Not only is the vegetation at this place exceptionally rich, the individual plants are very sturdy and beautifully developed“.

Citation: J. Boye Petersen, 1911

The water was so clear at the time that from the boat, pike and perch could be observed swimming 10 meters below the keel of the boat.

Thanks to these very thorough examinations of Lake Furesø we know today exactly how the environment of Lake Furesø should be when the lake is no longer under influence of wastewater. This is not the case for most other Danish lakes. The examinations carried out a long time ago at the same time marked the start of Danish research within the field of freshwater ecology.

Pike



Perch

Predatory fish such as pike and perch use their eyes for hunting. They are therefore dependent on clear water.

Stonewort



Pondweed  
(*Potamogeton Lucens*)

A big variation and growth of sessile bottom fauna only occurs in clean and clear lakes.

The above map from 1911 shows the vegetation in the entire Store Kalv down to a depth of 8 meters in the main basin.

At the time, 33 species of submarine plants were registered in the lake, including 18 species of phanerogams and 10 species of stonewort.



Pondweed  
(*Potamogeton Perfoliatus*)

## And the city became larger and larger ...

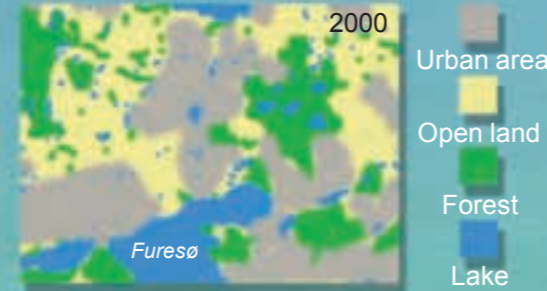
At the beginning of the 20<sup>th</sup> century Lake Furesø was a true paradise in the countryside, surrounded by small towns, forest and agriculture. The impacts of the surroundings on Lake Furesø were limited and did not go beyond what was good for the lake.

During the years 1900 to 1975 Copenhagen expanded. This meant a huge increase in the volume of wastewater, and in conformity with normal thinking at the time: „*What we can not see is of no harm!*“ Therefore, sewer pipes were laid down in order to lead the wastewater away from the city .... for discharge into Lake Furesø without further treatment.

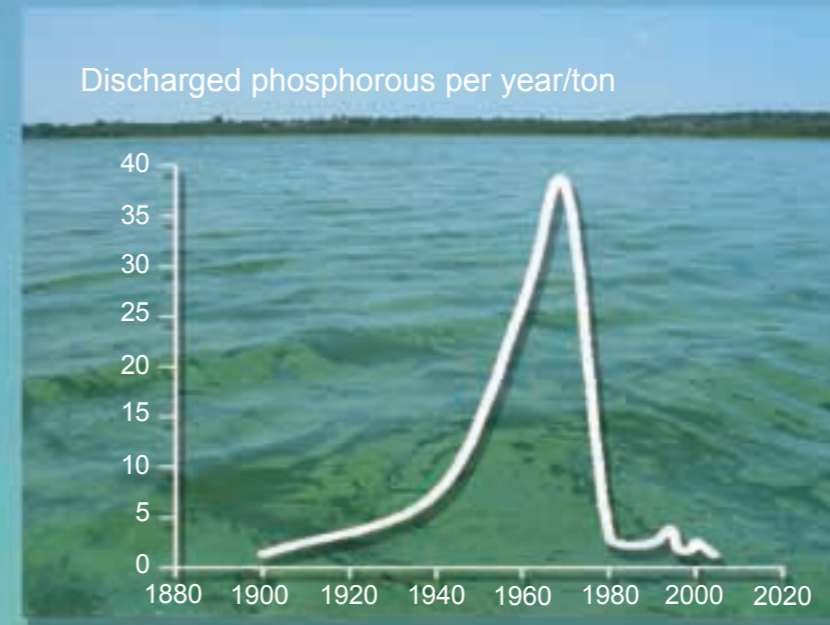
But the discharge of wastewater did harm! With increasing welfare came the installation of washing machines in almost every home. Followed by phosphorous in the detergent in order to avoid lime deposits in the washing machines. The phosphorous later ended up in Lake Furesø, where it served as nourishment for the algae, which then grew energetically each summer.

The algae did not only cause problems for Lake Furesø's role as a popular recreational area for the inhabitants of the City of Copenhagen, they also caused trouble for the flora and fauna of the lake.

The unclear water shaded the bottom vegetation and the predatory fish could no longer see their prey.



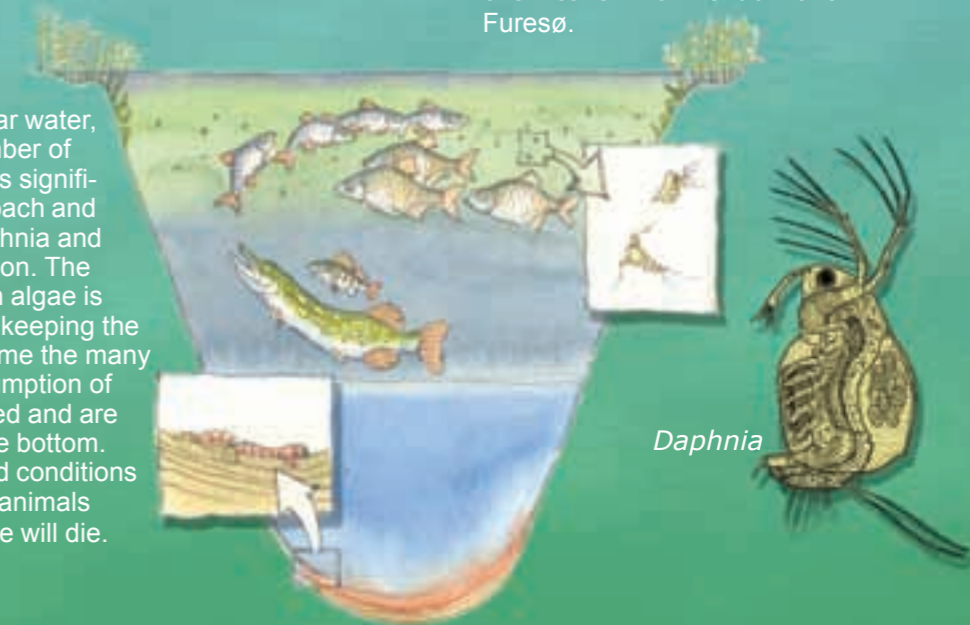
The first established wastewater treatment plants only removed physical objects. It was not until the 1970'ies, when the connection between discharge of wastewater and the environmental problems became really evident, that the treatment plants were developed to also remove solutes, including phosphorous.



Most of the huge discharge of phosphorous into Lake Furesø took place between 1950 and 1970. Although the wastewater treatment plants had by then been extended so that they were able to remove nutrient from the wastewater, the damage had already happened. A huge quantity of phosphorous was left on the bottom of the lake.

As long as there is oxygen in the bottom water, phosphorous is bound chemically to iron minerals. However, in deep lakes like Lake Furesø there will naturally be some periods during summer which are poor in oxygen. This situation liberates phosphorous, which again is the reason for a continuous growth of algae. The growth of algae has impact both on the biological and the chemical environment of Lake Furesø.

The predatory fish can not see their prey in the unclear water, which means that the number of nonpredatory fish becomes significantly higher, especially roach and beam, which live from daphnia and other species of zooplankton. The grazing of zoo-plankton on algae is therefore not sufficient for keeping the water clear. At the same time the many algae cause a huge consumption of oxygen once they have died and are digested by bacteria on the bottom. Not only will the deoxidized conditions liberate phosphorous, but animals which are unable to escape will die.



## Targeted Fishing

Not unexpectedly, examinations had demonstrated a huge number of non-predatory fish in the lake. Fish which to a great extent live from the zooplankton which could otherwise contribute to the reduction of algae. Therefore part of the restoration project was to fish up around 80% of the roach and beam in the lake and hope that predatory fish would in the future be able to keep the number of these fish at a low level.

Since Lake Furesø consists of two parts, one very deep and the other one very low, two different types of fishing equipment have been used. In the lower part, Store Kalv, fishing has taken place by pound net along the shore, supplemented by seine on the open sea. The main basin has very steep slopes and a depth of 38 m, therefore only pound nets have been used here.

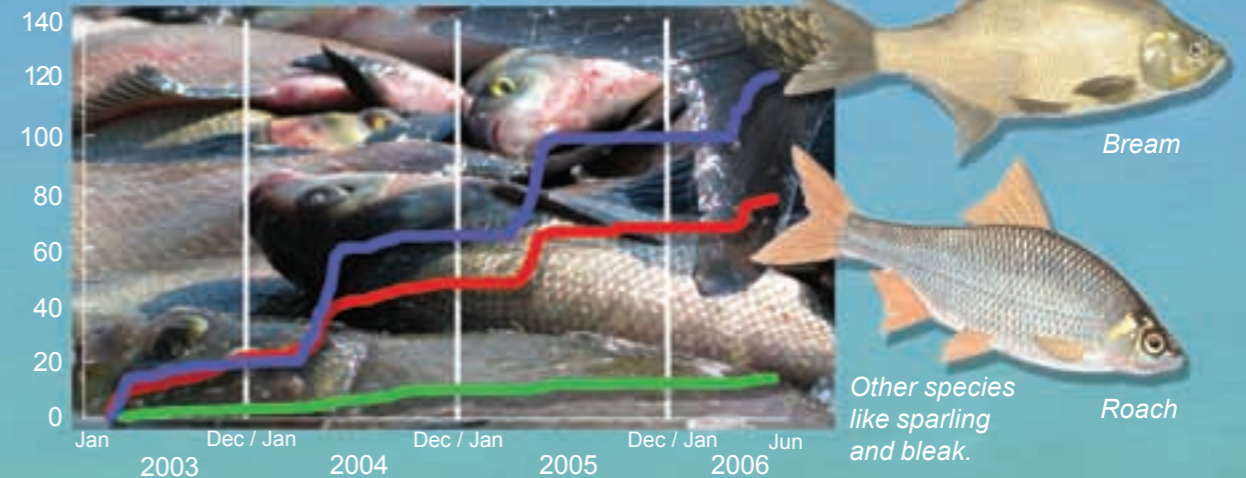
The fishing has mainly taken place from April to July when the fish go on low water in order to spawn.

Due to the fishing equipment selected it has been difficult to avoid getting some predatory fish in the nets as well. To the extent they had not suffered damage they were separated and let out into the lake again.



Up to 42 pound nets have every year been placed along the shores of Lake Furesø. At the lower end of the lake fishing also took place by a 1 km seine which was capable of fishing in the entire water column.

Summarized Catch in Tons distributed on Species



212.5 tons of fish have been caught during the project period. These are distributed on 77 tons of roach, 121 tons of bream, and 14 tons of other species. Around 140 tons have been fished by pound net and 72 tons by seine.

The fishing in Lake Furesø has been carried out according to plan. We will see during the years to come whether the fishing up of more than 200 tons of roach and bream has been sufficient for the predatory fish of the lake to keep the number at a stable level. An important precondition for a successful project is that the water at the same time becomes clearer, i.e., that the huge and long-lasting growths of algae are avoided.

A potential decision about repeating the fishing will have to be made by the surrounding municipalities and the Danish State. The Municipality of Furesø will take over the running of the oxidation plants, so far up till 2012, after the Danish counties have been closed by the end of 2006.



## Oxygen for the Bottom Water

Like all other plants, algae need nutrients in order to grow. In Lake Furesø primarily the phosphorous has a limiting impact on the growth of the algae. Nowadays only little phosphorous is left in the wastewater which is discharged into the lake, whereas formerly around 70 tons were found on the bottom originating from the discharges back in the 1960'ies and 1970'ies.

If there is oxygen in the bottom water, phosphorous enters into a chemical compound and is therefore not available for the algae. However, in deep lakes like Furesø deoxidized periods will naturally arise during the calm and warm summer periods during which there is no mixing of surface water and bottom water. This situation is worsened by the increased oxygen consumption in connection with the bacteriological decomposition of the huge amount of dead algae that sink to the bottom.

In order to ensure that there is sufficient oxygen in the bottom water for maintaining the chemical bond of phosphorous the restoration project has set up a system which adds oxygen to the bottom water every year during the entire critical period of the year, which lasts from June to November depending on the weather.



On land the oxygen system consists of a tank in which the oxygen is kept under liquid form under high pressure and at a temperature of minus 170°C. Three pipes go from the tank into the deepest places of the lake. The huge ice formations on the tank are due to the fact that the oxygen must be transformed into air before being led through the pipes.

In order to better adjust the discharge, pure oxygen is used instead of atmospheric air, which only contains 21% oxygen.

On this model of Lake Furesø you see the difference between Store Kalv and the deep Main Basin.

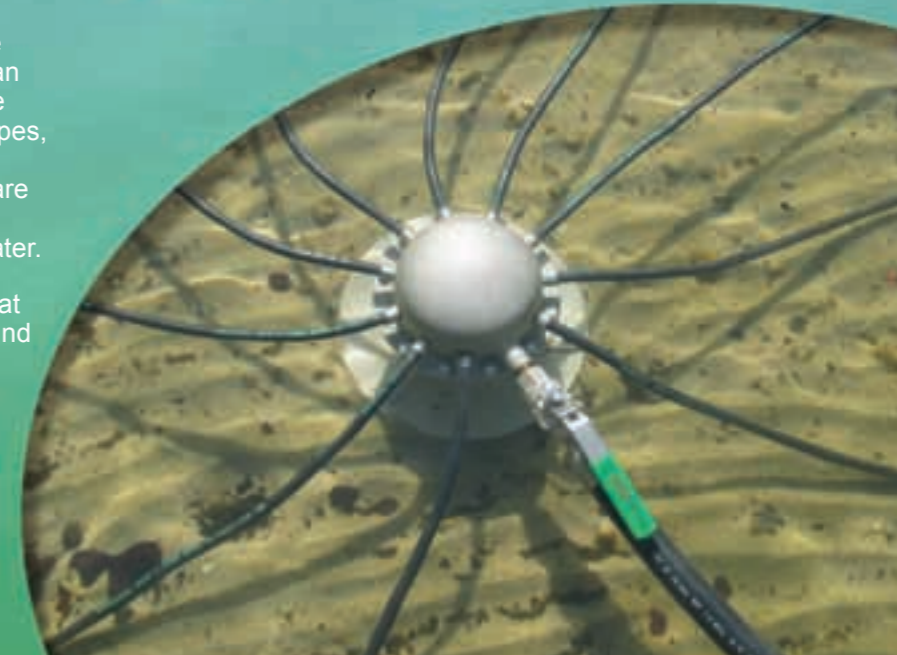


The plant on land is connected to three oxygen diffusers, which are placed at the deepest places in Lake Furesø, more than 30 meters below the surface. Each of the diffusers is equipped with a number of pipes, each of a length of 100 meters and perforated by thousands of holes which are so small that the oxygen bubbles are immediately dissolved into the bottom water.

The discharge is currently adjusted so that the desired oxygen concentration of around 4 mg oxygen / liter in the bottom water is maintained. From 2003 to 2006 the daily discharge of oxygen has been reduced from approx. 5 tons to around 2 tons.



During winter when no oxygen is led out, sludge is caught in the diffusers and the pipes. Therefore they are taken up to the surface every spring for cleaning.



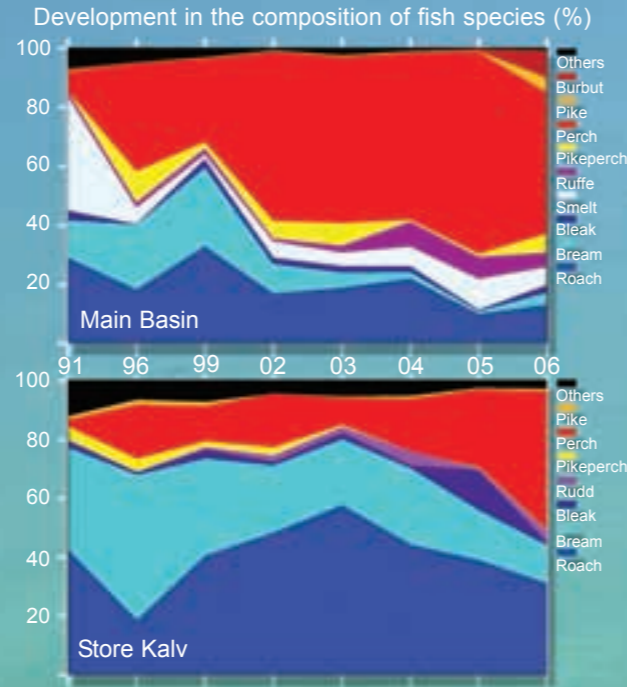
# Nytter det noget ?

Taking into consideration that more than 200 tons of fish have been removed from Lake Furesø, and considering the considerable reduction of the quantity of phosphorous liberated from the bottom of the lake every year, the restoration project does help. But flora and fauna are not machines, and it is therefore not possible to foresee precise results, nor when the objective will actually be met.

The water chemical situation of the lake, with water rich in oxygen and low in phosphorous, has been considerably improved from 2003 to 2006. It is too early, however, to tell anything about its effect on the growth of algae. Heat, wind, rain and other matters beyond our control also have an impact.

Predatory fish as pike and especially perch have become more dominating and thanks to the oxidation the fauna has returned at the bottom of the lake.

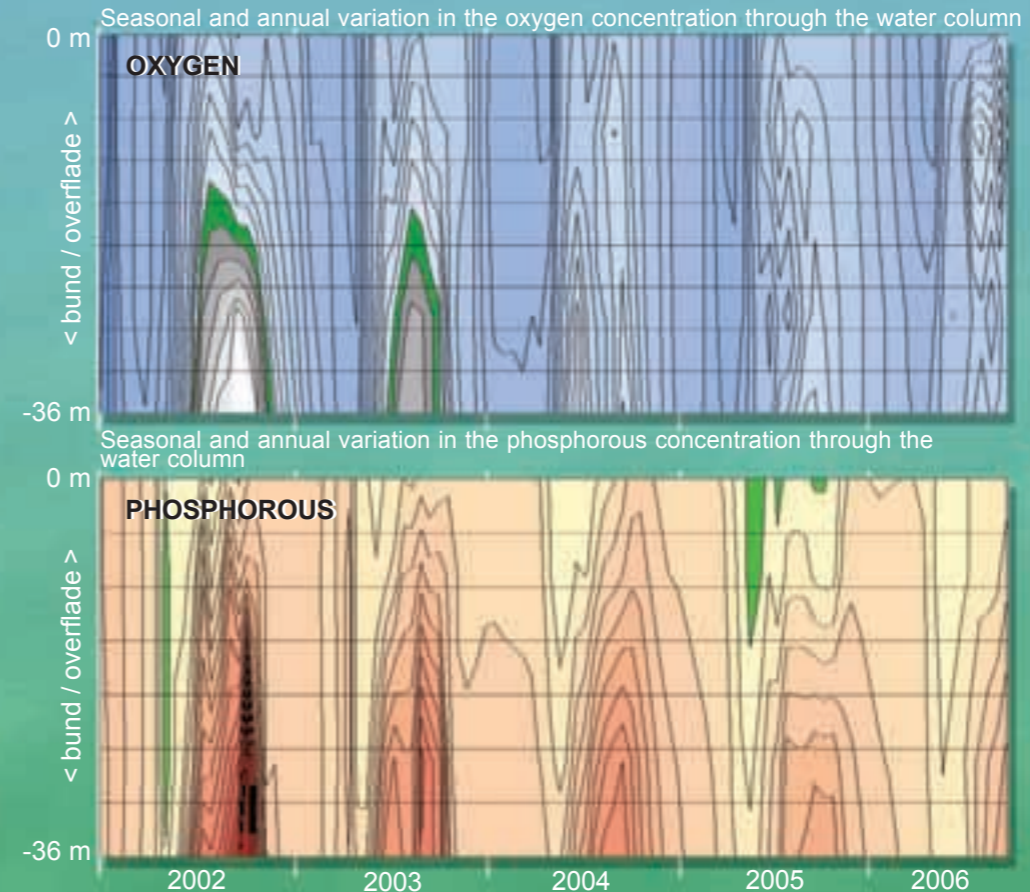
The clarity of the water may vary a lot over the year. On the average, the clarity of the water has not improved during the project period, although bottom flora is now noticed at still deeper water.



The composition of fish species in Lake Furesø has been followed continuously both before and after the project start-up in 2003.

The last survey carried out in 2006 shows that the fishing-up carried out during the project has had some impact, since the number of perch has increased significantly in Store Kalv. Although perch is the most important predatory fish in Lake Furesø, also the increased number of pike in the Main Basin is important. At the same time the number of the unwanted bream and roach has decreased. For bream this is especially the case in Store Kalv.

Thanks to continuous measurements carried out in Lake Furesø, it is possible to make the below graphical presentations, which show a clear connection between the concentrations of oxygen and phosphorous in the bottom water. The white and grey colours in the first presentation show that during the summer periods before the project started in 2003 there was almost no oxygen deeper than 15 meters below the water surface. The deep red colours in the lower presentation show that during the same period huge quantities of phosphorous were liberated from the bottom of the lake. 2003 was the year the oxidation plant was commissioned, therefore the impact of the oxidation on the liberation of phosphorous has only really been observed from 2004.



A small species of crayfish lives in Lake Furesø: *Mysis relicta*. In Denmark this species of crayfish is only found in this one place. It normally lives in colder places, but in the deep Lake Furesø it has managed to survive ever since the last ice age around 15,000 years ago. A successful restoration project will also help ensuring this crayfish optimal living conditions.

Lake Furesø was once one of the cleanest lakes in Northern Europe, and one of the richest in species. Sturdy recurrent growths of algae due to discharge of untreated wastewater in the middle of the 20<sup>th</sup> century destroyed the environment of the lake. This had a negative impact not only on flora and fauna, but also on the many recreational interests of the lake. Supported by the EU LIFE-Nature Programme the County of Frederiksborg and the Municipality of Farum initiated a restoration project, the purpose of which is to bring back a clean lake rich in species. The idea of the project is to try and solve the problem by fishing up roach and bream, combined with discharge of pure oxygen into the bottom water.



One of the most important ways to meet the EU's overall objective of stopping the degradation of biodiversity no later than year 2010 is the NATURA 2000

Directive. This directive is used for protecting and conserving nature as well as species of flora and fauna.



It has been possible through the EU LIFE-Nature Programme to ask for co-financing of nature projects, which met the objective of the NATURA 2000 Directive.

The LIFE-Nature Programme is finalized by the end of 2006.



The County of Frederiksborg and the Municipality of Farum have been responsible for the project until the end of 2006

when the counties are closed down. During the remaining project period up to the year 2012 the Municipality of Furesø will be responsible.



Furesø is located north of Copenhagen. Along with the surrounding forests the area is used for a lot recreational activities through the year.



Produced by Landscape Department of County of Frederiksborg in November 2006. Photos: County of Frederiksborg. Aquarelles: Carsten Groth-Pedersen. For further information about the project, see the web-site of the Municipality of Furesø: [www.furesoe.dk](http://www.furesoe.dk)