Oxygen trends in Norwegian waters

Case study Sognefjord

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Vannforeningen
André Staalstrøm

Problem: Are there trends in oxygen conditions in Norwegian waters?
Can these trends be linked to climate change?
Can these trends be linked to discharge?

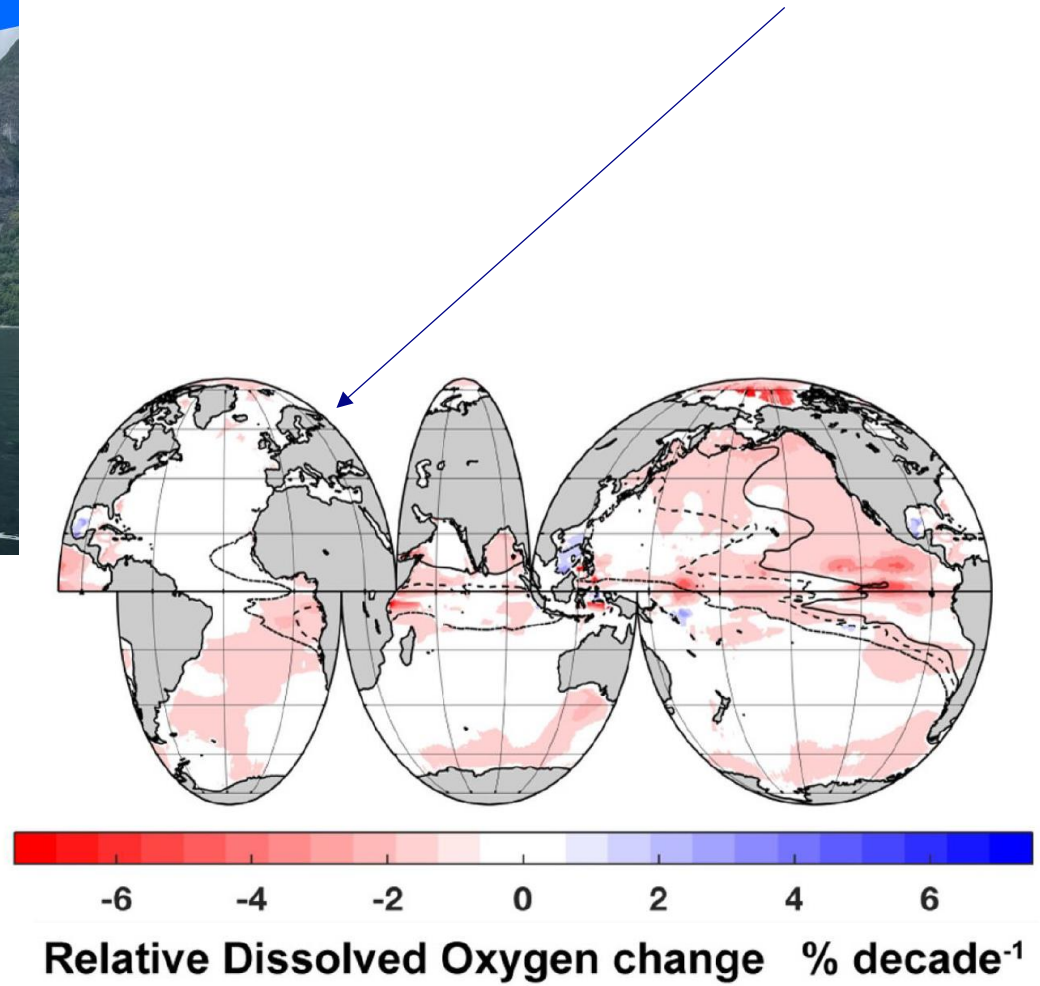
Here we will describe the conditions in the Sognefjord, which is an area where a negative trend in oxygen conditions has been demonstrated, negative changes are linked to both climate change and a steady increase in discharge of nutrients.

Miljø-direktoratet

NIVA

https://hdl.handle.net/11250/3171753

Global trends



Figur 9: Global trend i oksygenkonsentrasjon i havet hvor enheten er prosentvis endring per tiår i perioden 1960-2010. Figuren er hentet fra Garcia-Soto et al. (2010) som har basert dette på data fra Schmidtko et al. (2017).

Garcia-Soto et al. (2021) provides an overview of global oxygen trends. There is a significant decline in many places in the world, especially in the area around the equator. But less than half a percent change in the ocean area outside Norway.

First question: Are there trends in oxygen conditions in Norwegian waters?

The next question was whether any trends can be linked to climate change.

The third question was whether any trends can be linked to the supply of nutrients and organic matter.

For the last question, it was chosen to focus on the area around the Sognefjord.

Summary of the report

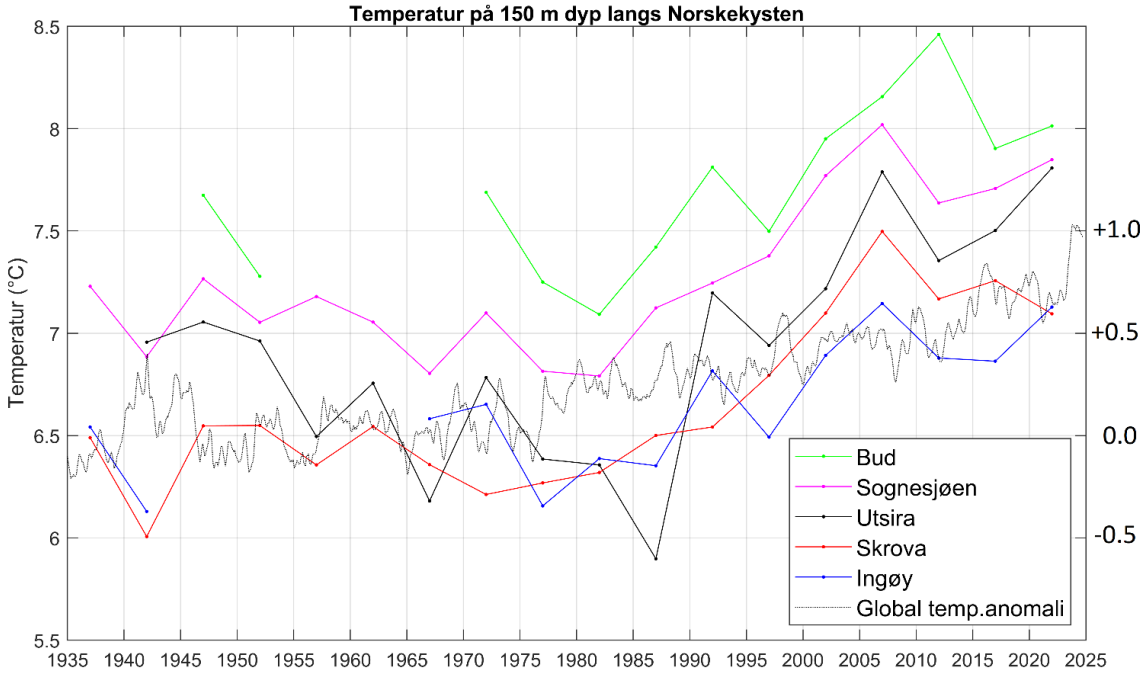
All along the coast it has been 0.6-0.7° warmer, and most of the increase has been the last 35-40 years. This coincide with global trends.

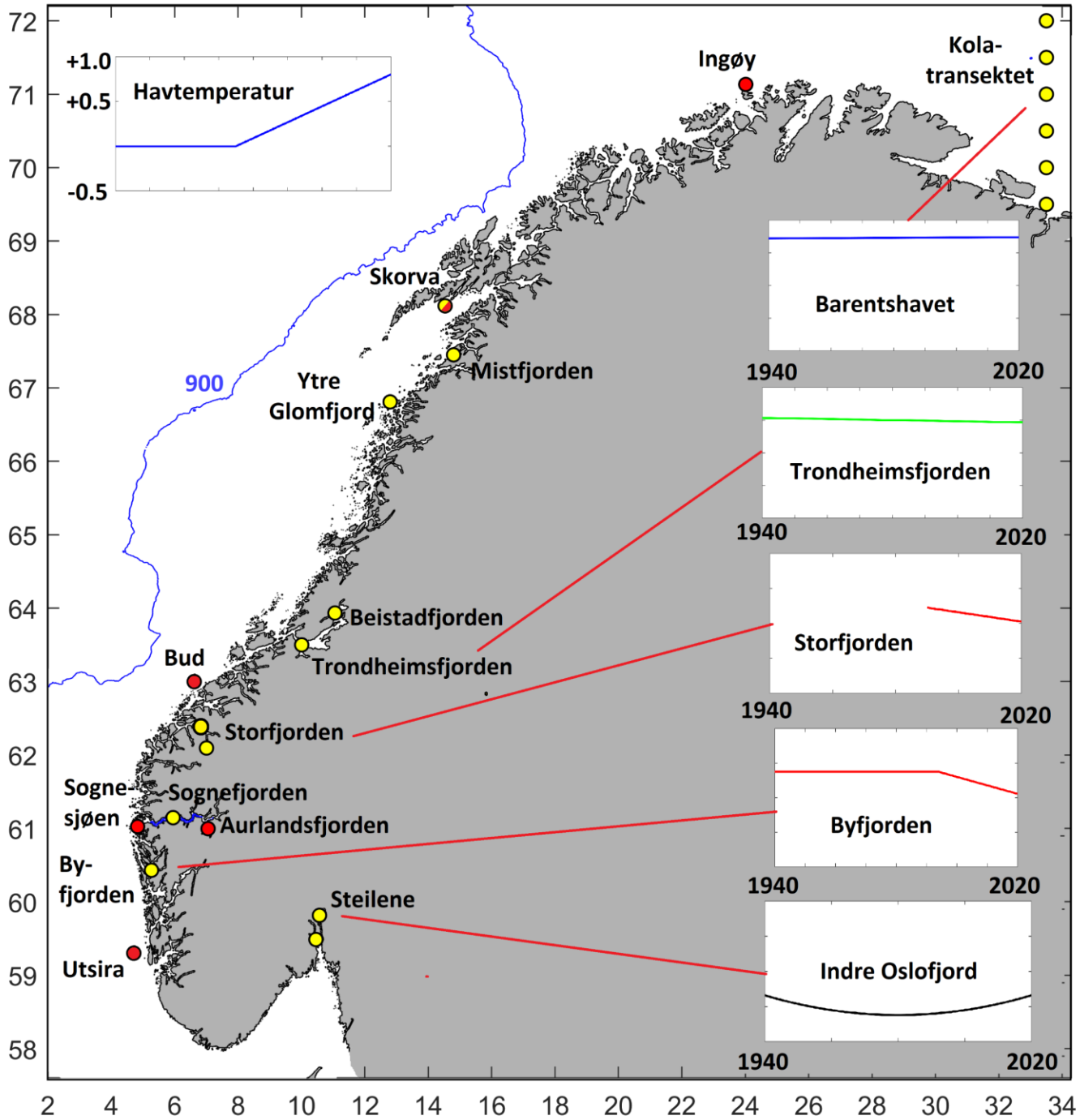
In the inner parts of Storfjorden within Ålesund, oxygen concentrations have decreased by 0.5-1.0 ml/L in the period 1991-2023.

The time series from Byfjorden outside Bergen starts in 1912, and shows a stable situation until around 1990, followed by a decrees.

The Sognefjord has a few observations from around 1970 that can be compared with modern observations.

The Inner Oslofjord had the worst oxygen conditions around 1970-1980.



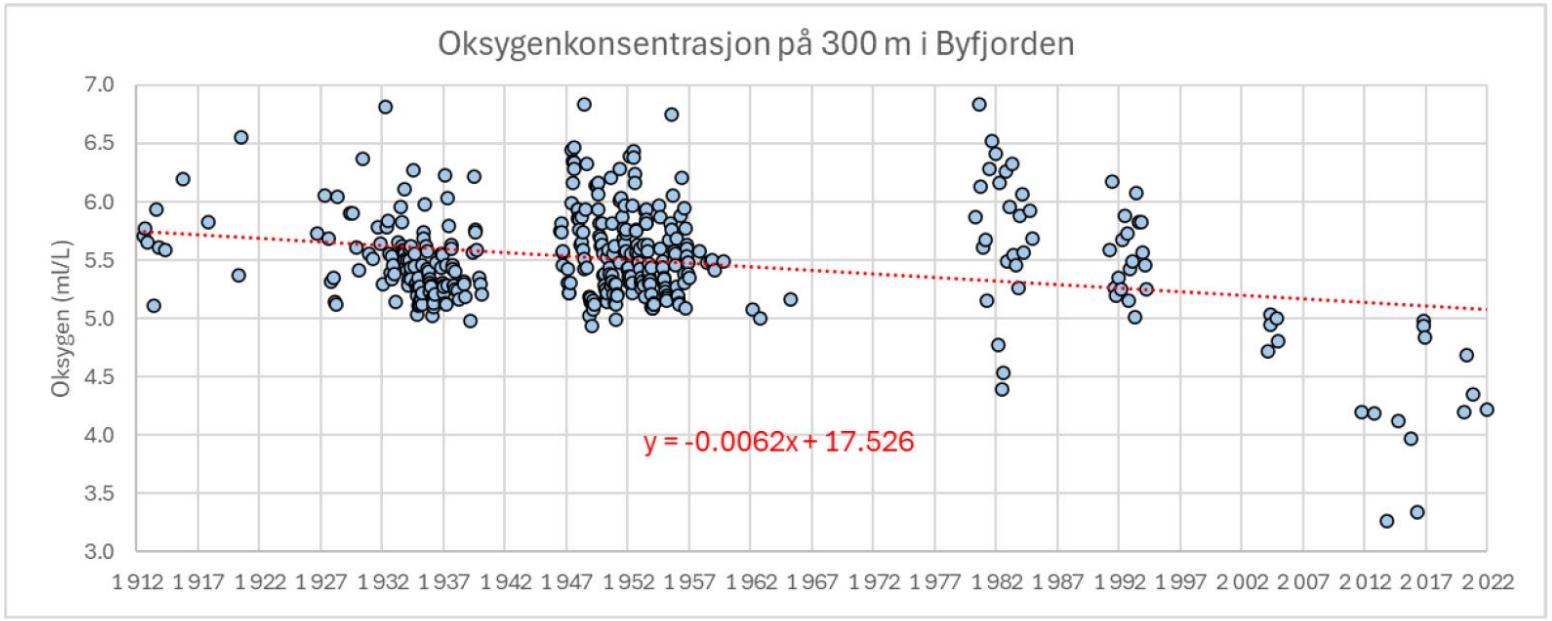


Byfjorden outside Bergen

Gaarder (1916) presented the first oxygen measurements from Norwegian fjords.

Before 2010, oxygen was classified as “very good” status.

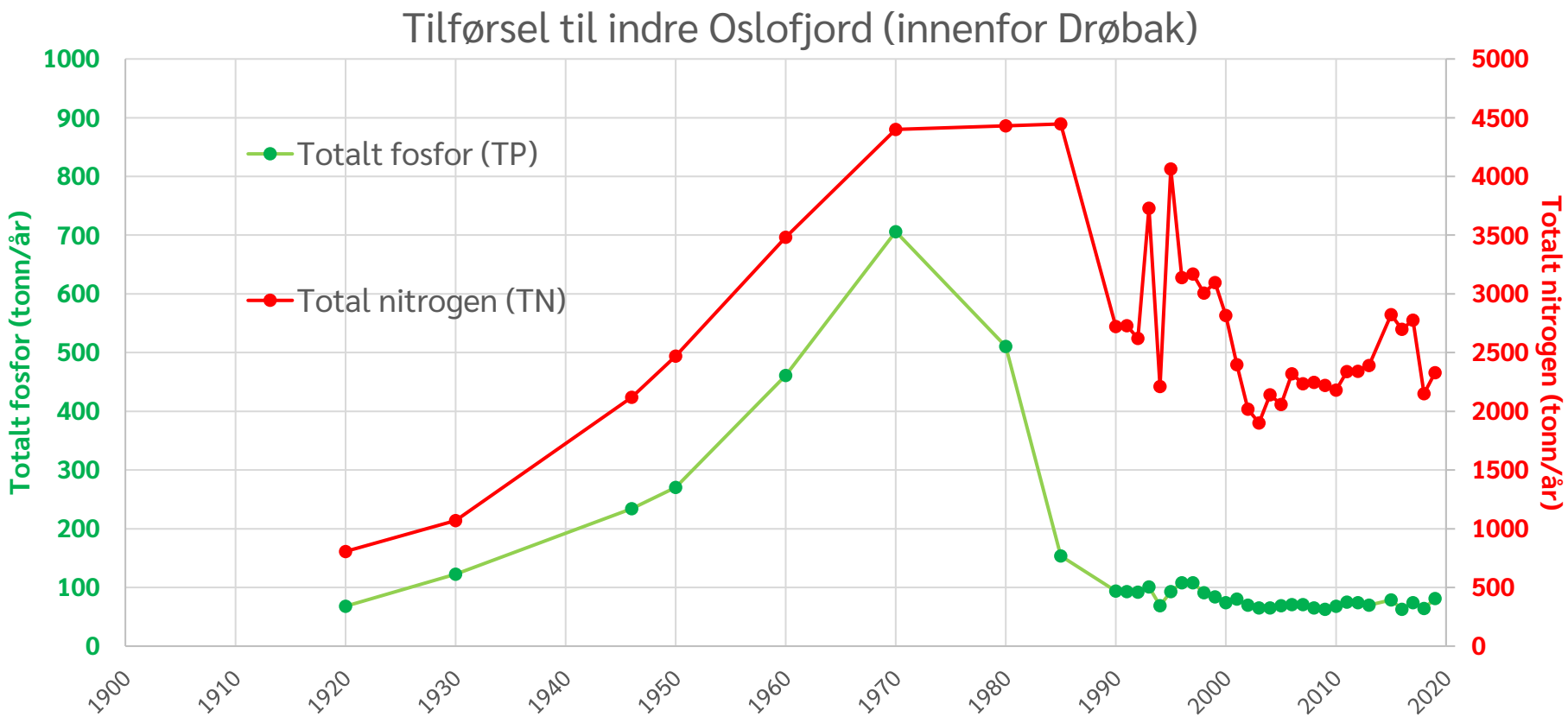
After this, there is a sharp decline in the oxygen status, with the status class "good".

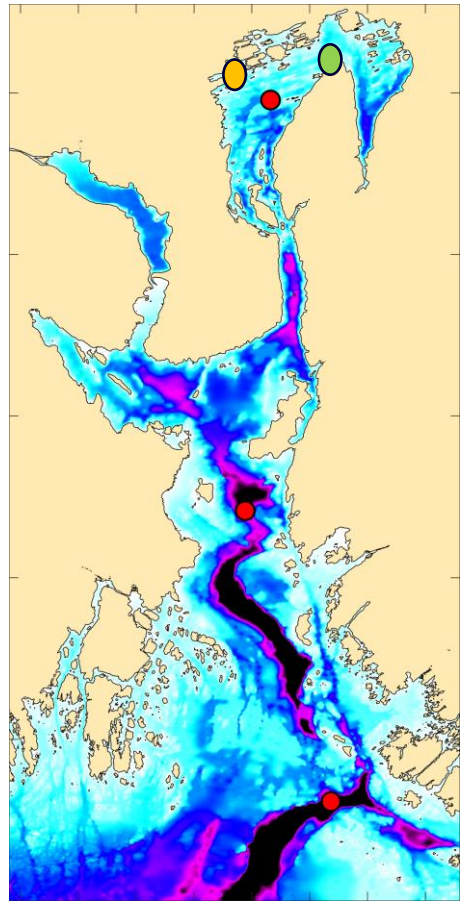


Figur 22: Målt oksygenkonsentrasjon på 300 m fra stasjon 4 i Byfjorden (60.43°N, 5.27°E).

Inner Oslofjord

Discharge to the inner Oslofjord.

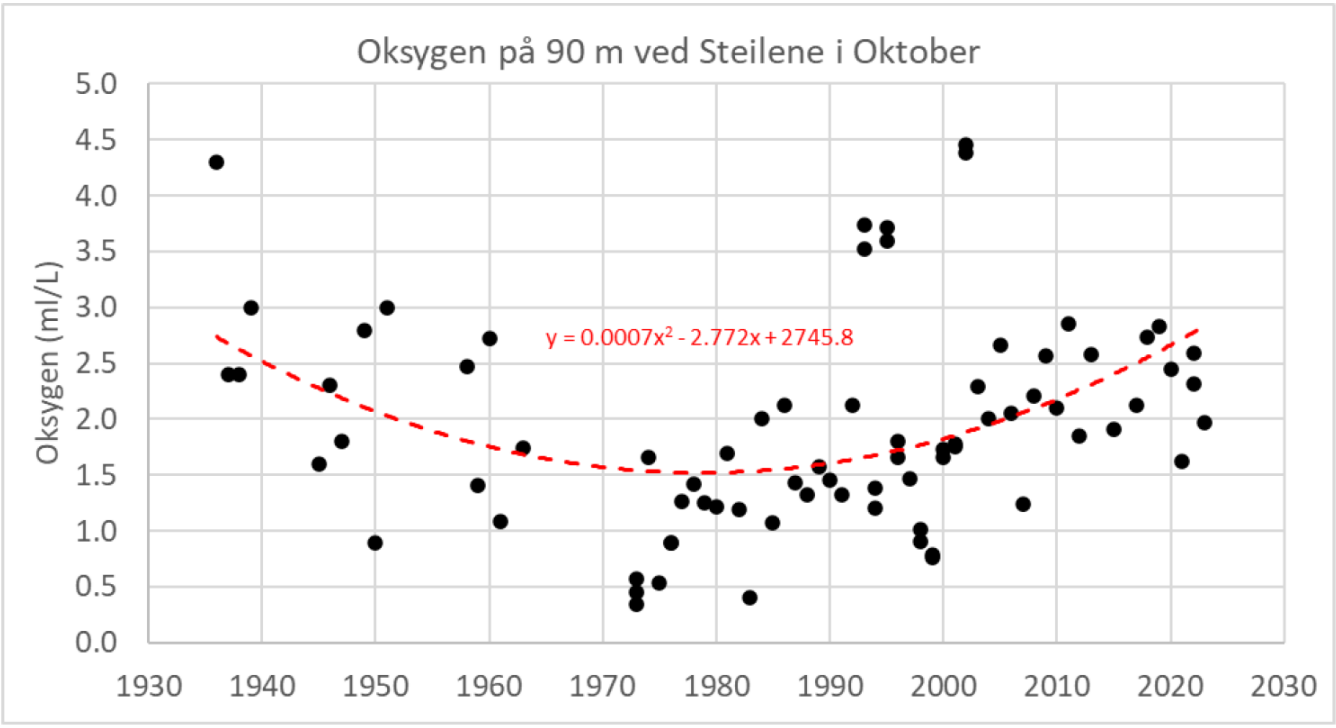


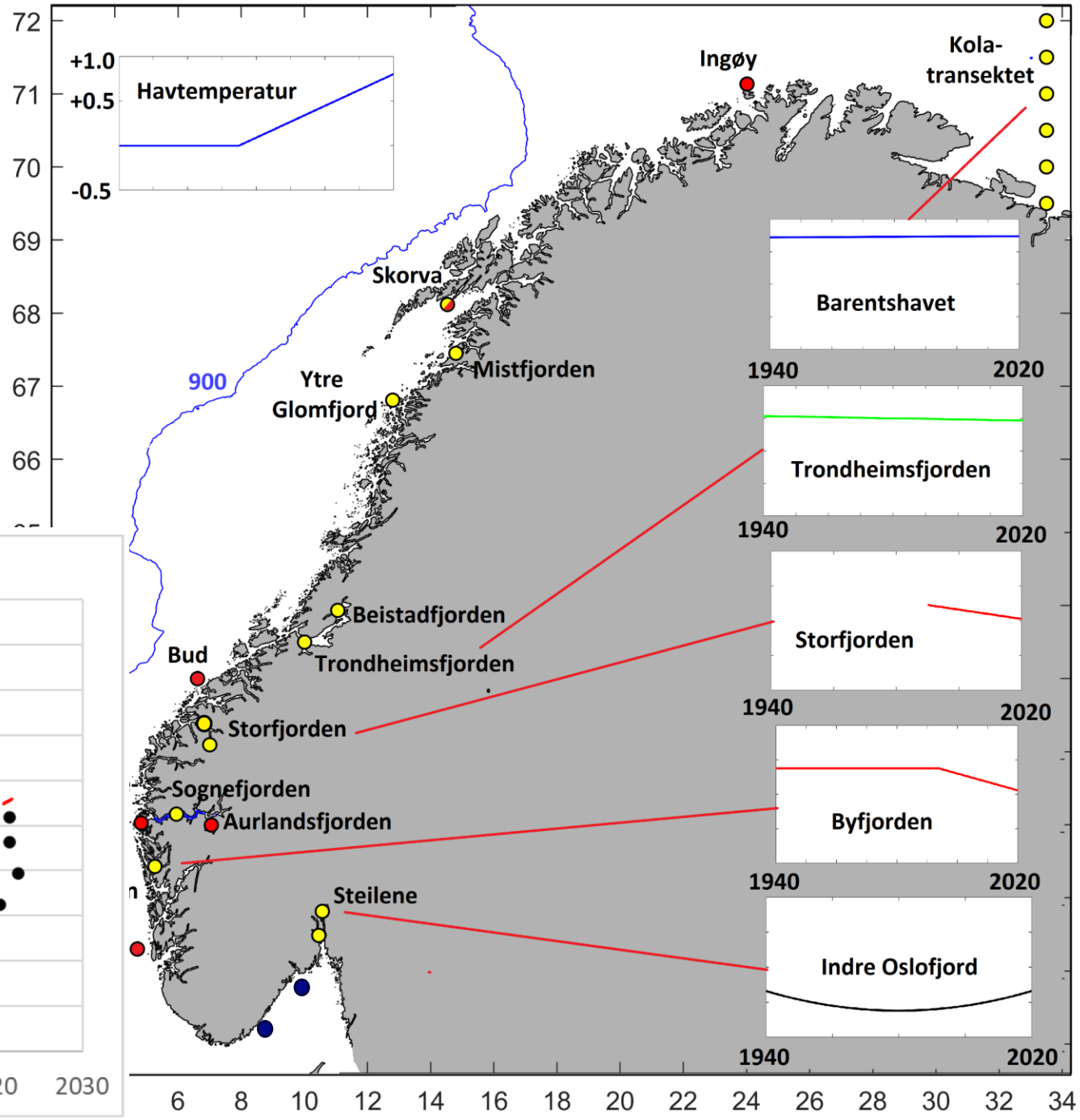


Inner Oslofjord

The oxygen conditions had a minimum during 1970ties.

The shrimps disappeared - but came back.





Modeling the Sognefjord

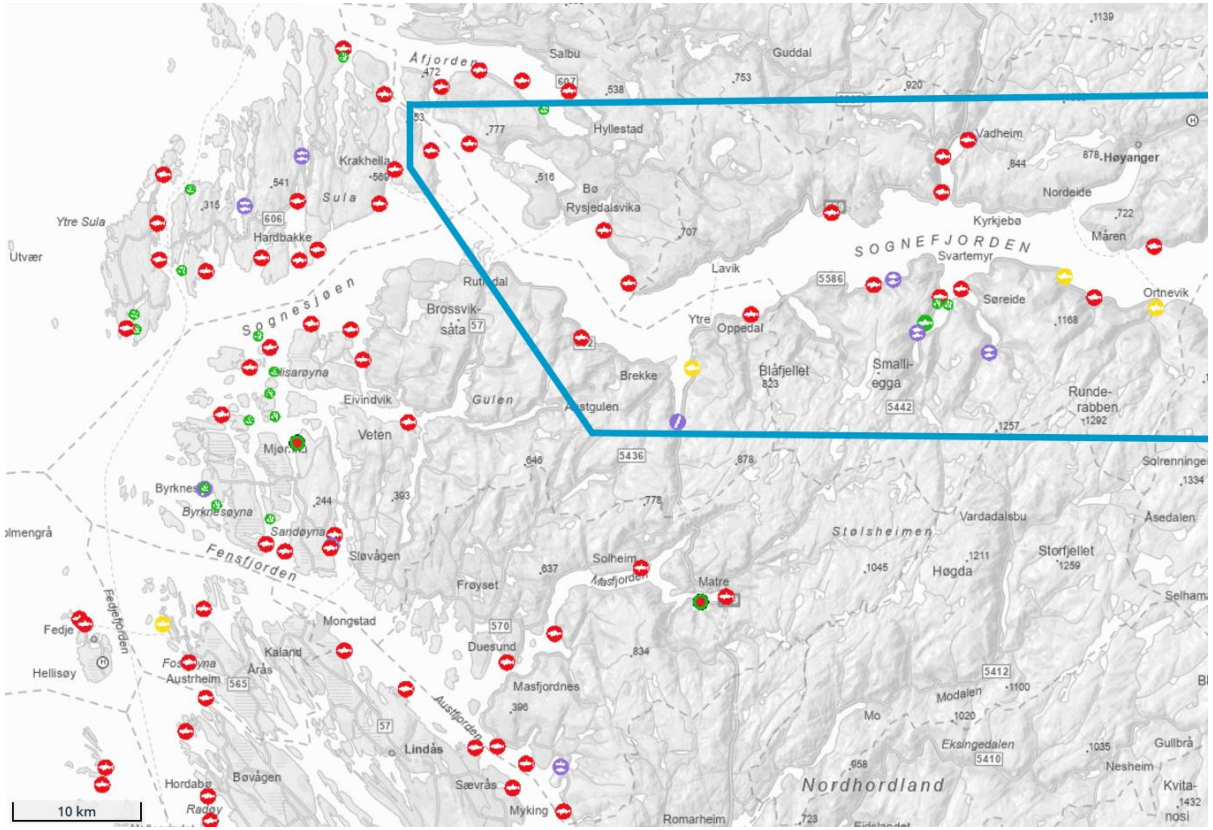
On the left we see a map of the outer part of the Sognefjord, where the location of fish farms is marked.

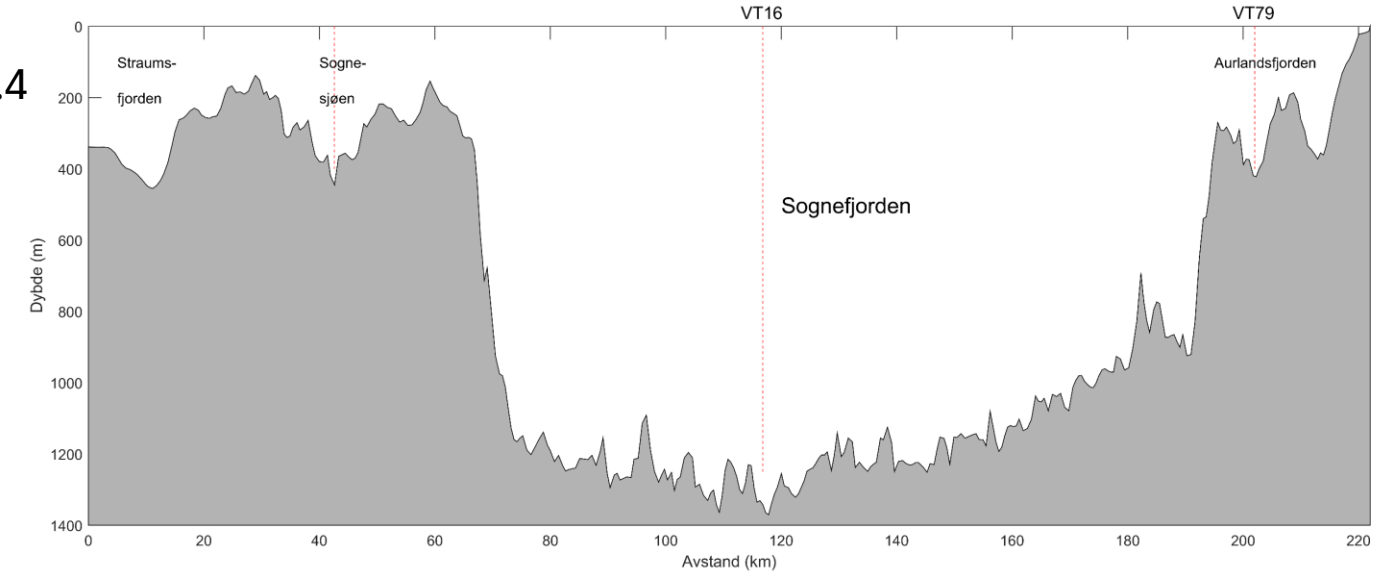
There are many fish farms in the area, but not so many in the Sognefjord itself.

Nevertheless, we see a large increase in input to the Sognefjord. The input is calculated only for the area within the blue polygon.

Since the 1990s:

- The input of nitrogen has increased by a factor of 1.5
- The input of phosphorus has increased by a factor of 3.4



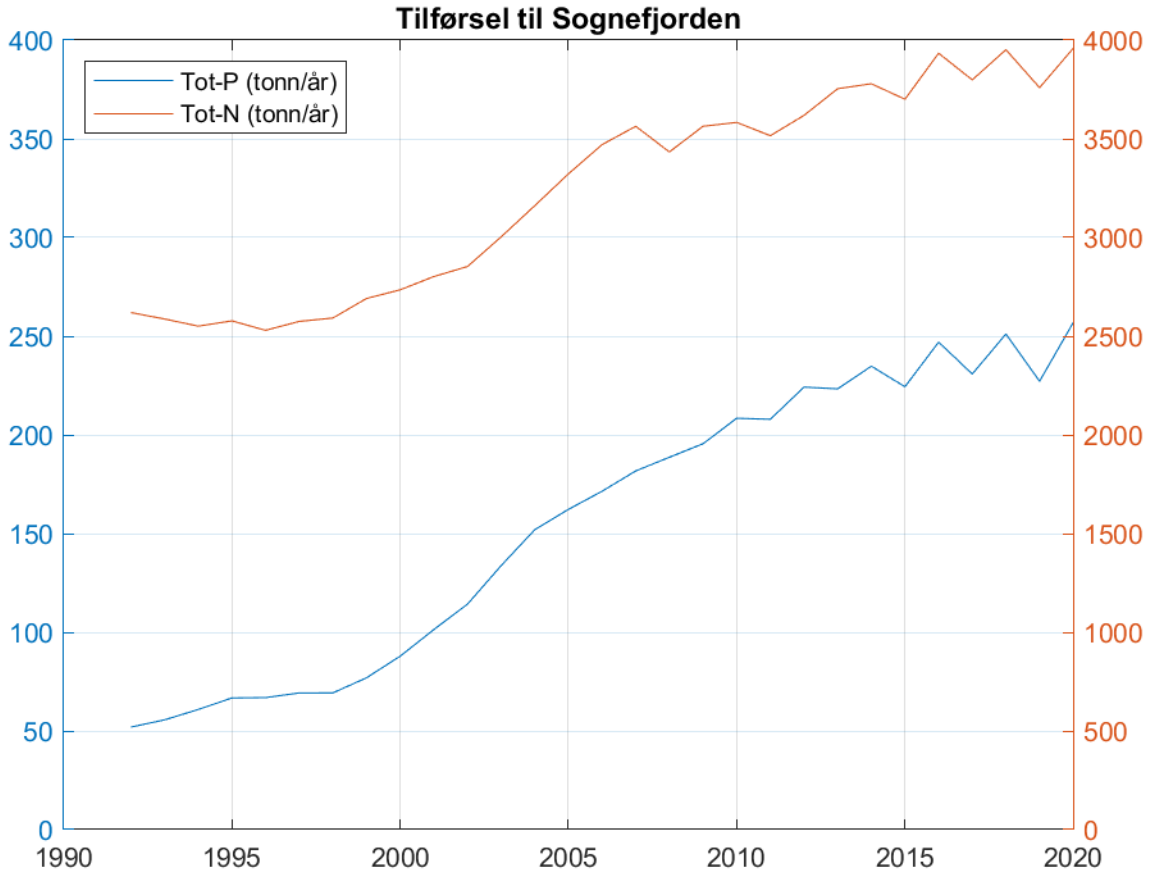


Discharge

Here we have used TEOTIL2.

Nitrogen supply has increased by a factor of 1.5.

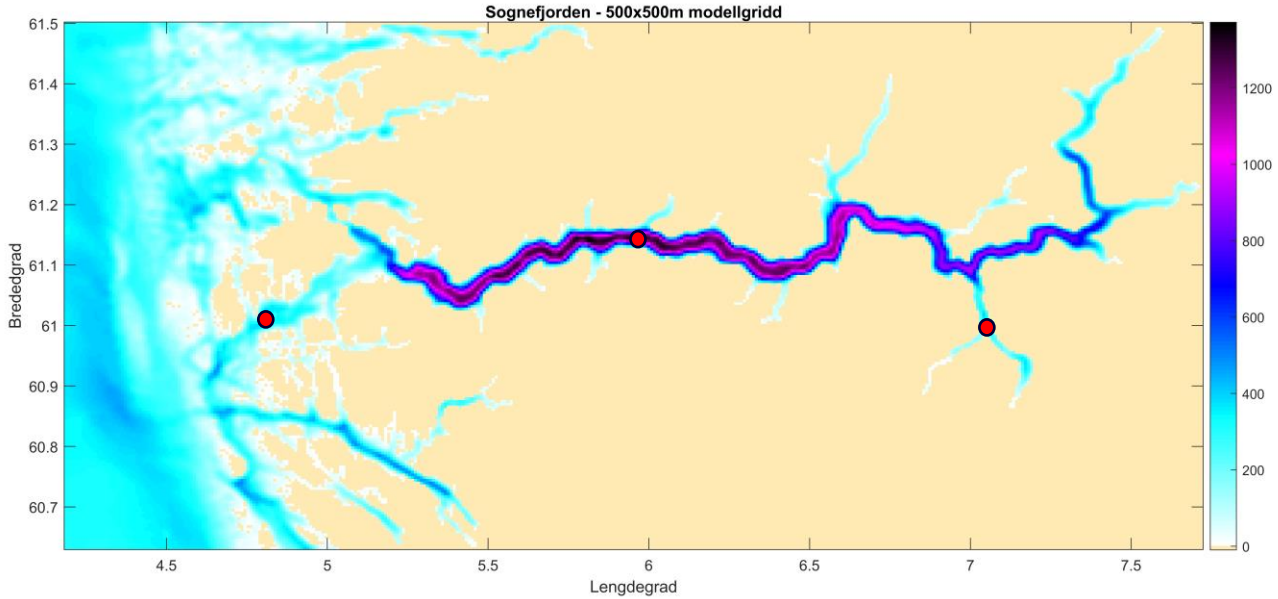
Phosphorus supply has increased by a factor of 3.4

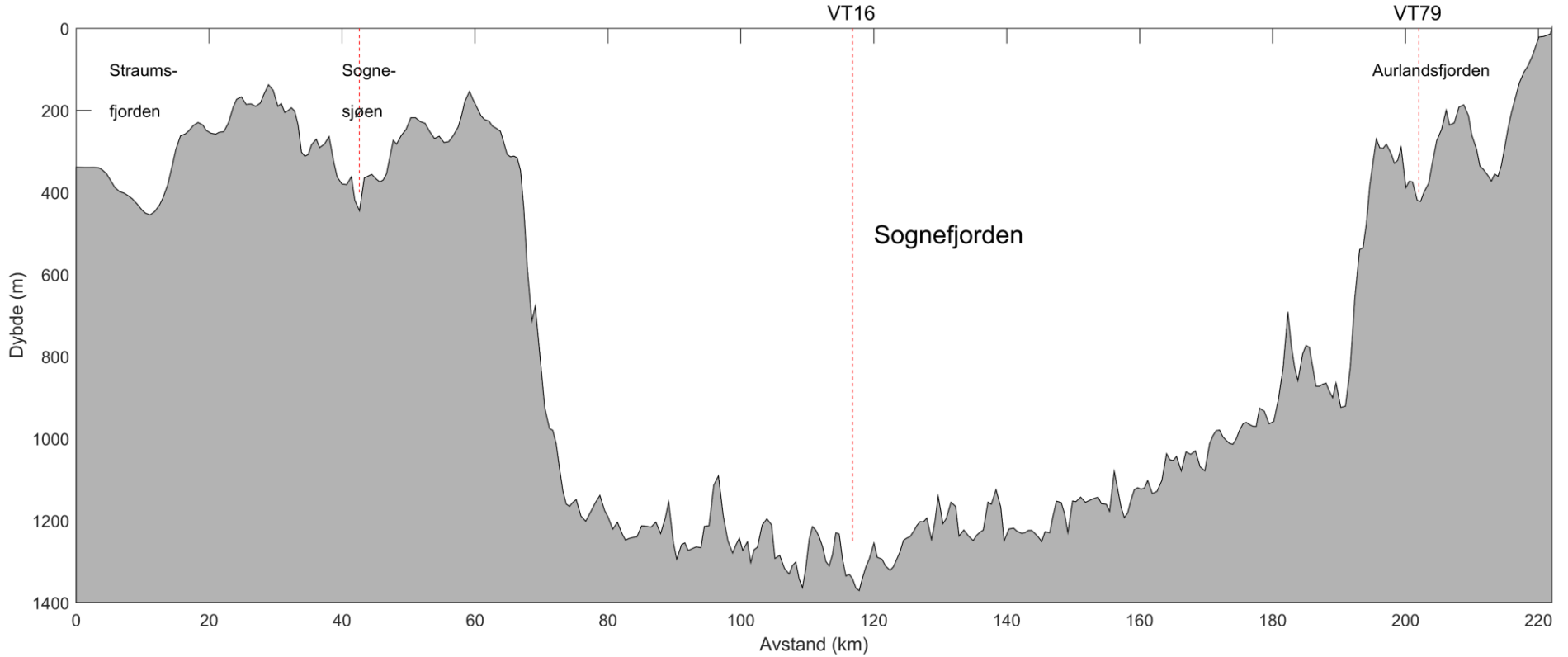


The Sognefjord

One of the largest sill fjords in the world.
A very large volume of water.

We lack continuous data, but there was a study in 1970.





Oxygen conditions in 1970

In April 1970, before the deep-water renewal, the oxygen concentration was 5.5 ml/L in the deep water.

In December 1970, after the deep-water renewal, the oxygen concentration was 6.0 ml/L in the deep water.

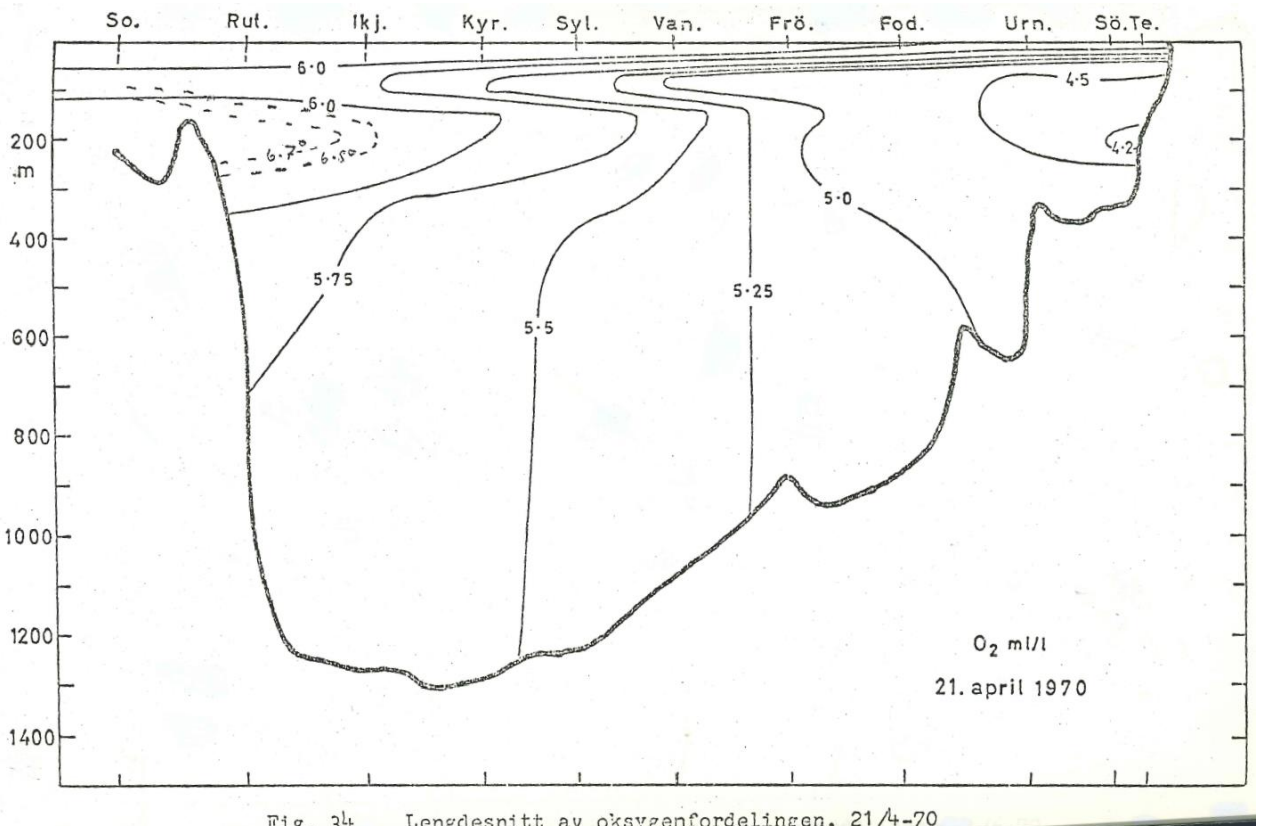


Fig. 34. Lengdesnitt av oksygenfordelingen, 21/4-70

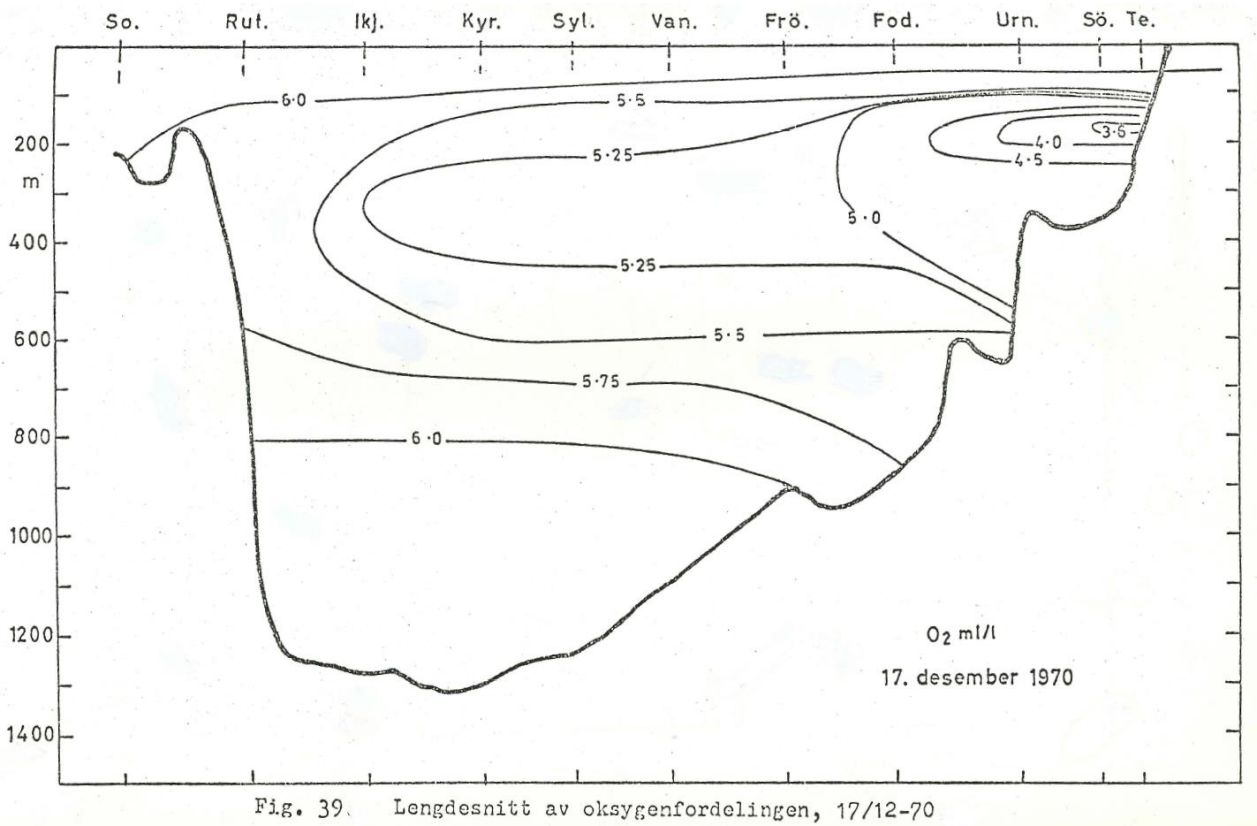


Fig. 39. Lengdesnitt av oksygenfordelingen, 17/12-70

Oksygenforholdene

In April 1970, before the deep-water renewal, the oxygen concentration was 5.5 ml/L in the deep water.

In December 1970, after the deep-water renewal, the oxygen concentration was 6.0 ml/L in the deep water.

In 2017 the oxygen concentration was below 4.8 ml/L. A reduction of 0.7-1.1 ml/L.

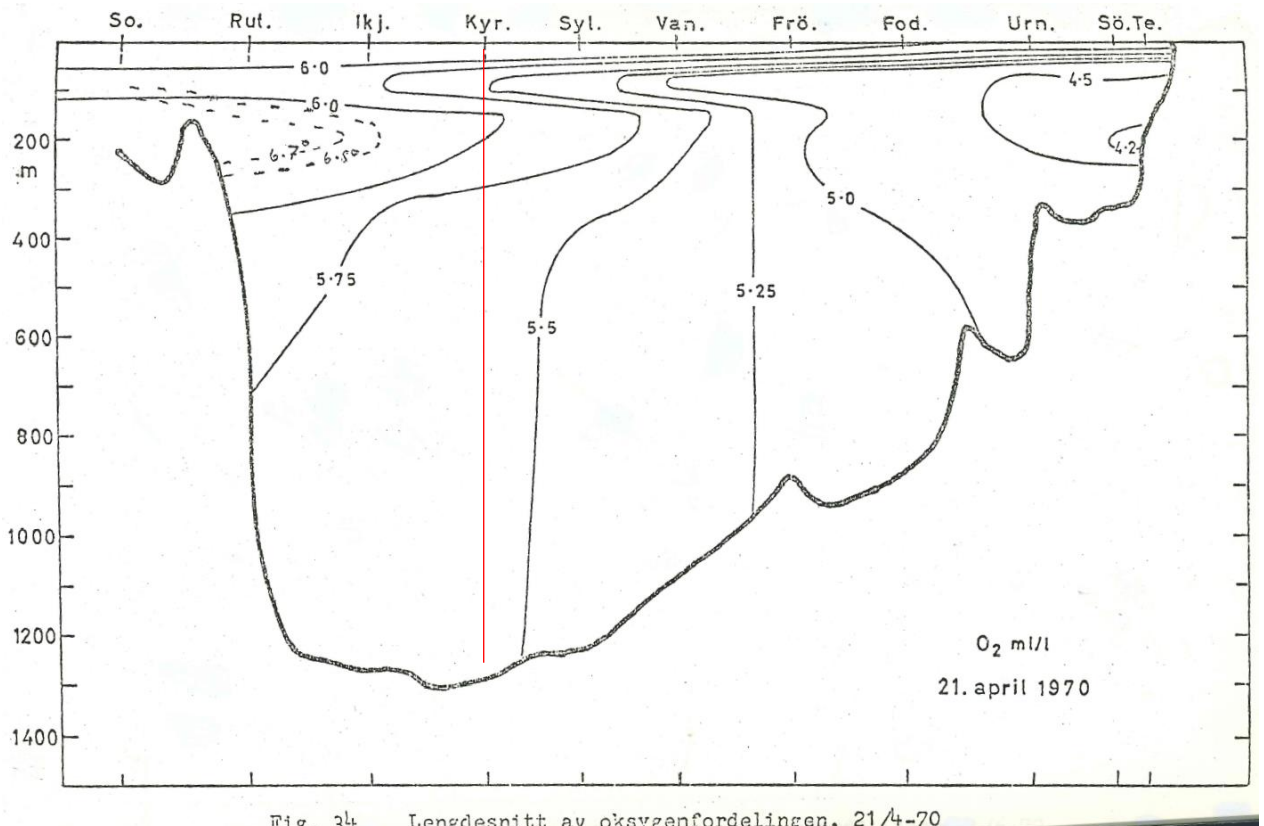
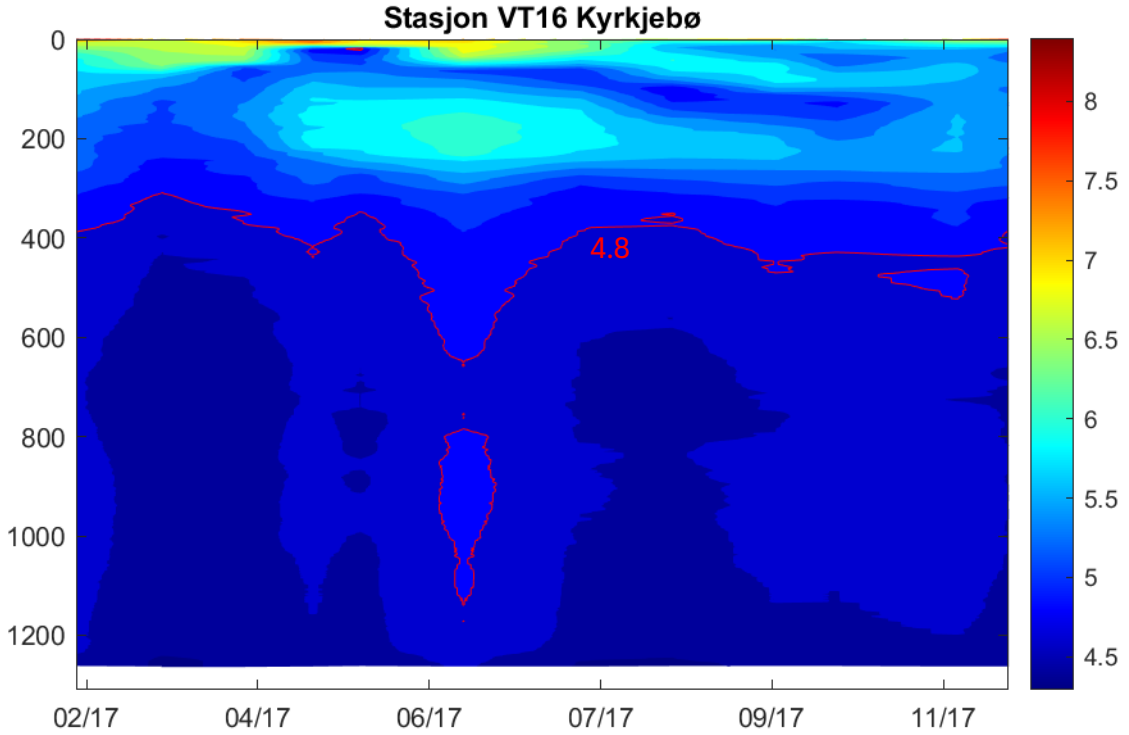


Fig. 34. Lengdesnitt av oksygenfordelingen, 21/4-70



Modeling the Sognefjord

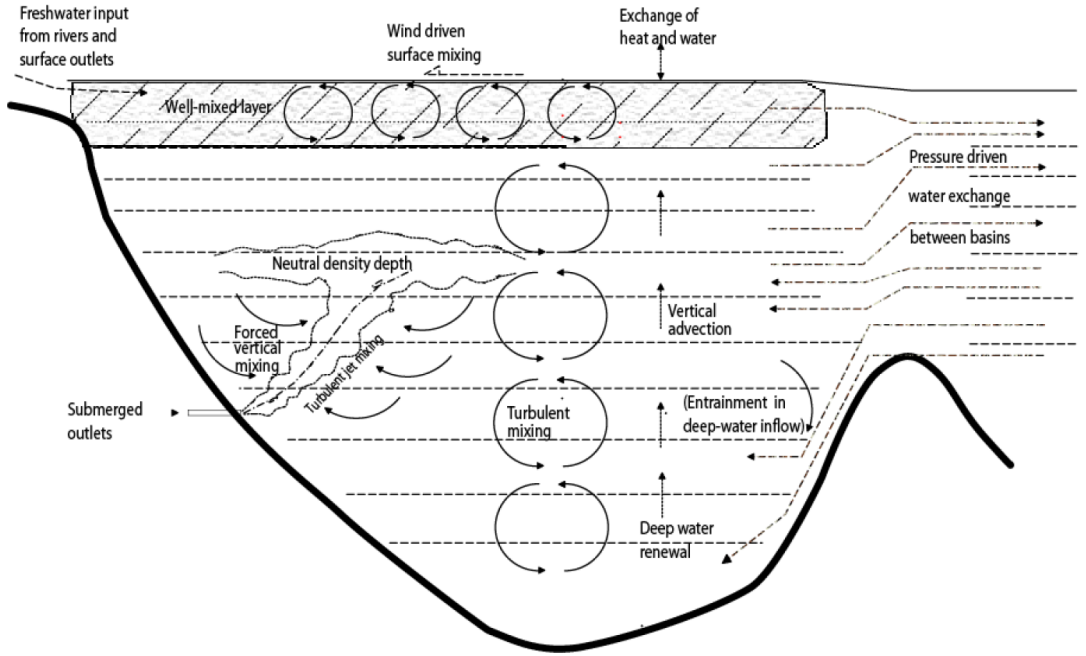
We use the NIVA Fjord Model to model the Sognefjord. The model can be called a box model and is built up so that it consists of one or more basins connected to an outer basin. In each basin, variation with depth is described with high resolution, as illustrated in Figure 35.

The length, width and depth of the connections between the basins in the fjord are specified in the model setup.

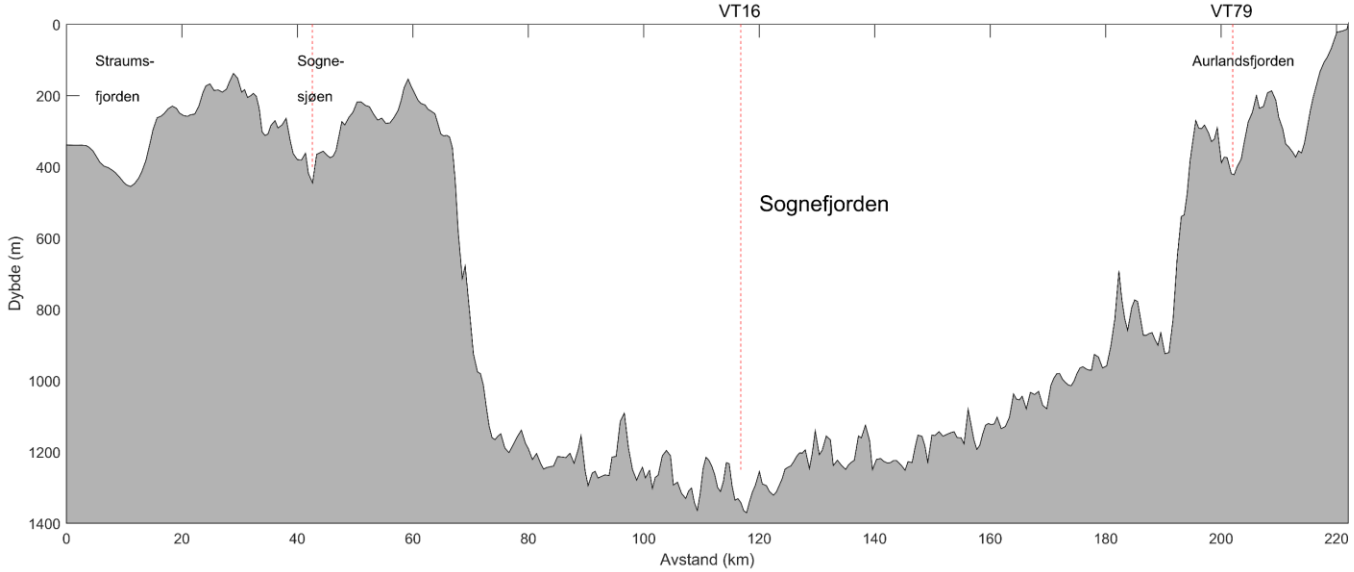
In the setup for the Sognefjord, only one basin has been included that describes the entire Sognefjord, and this basin is connected to the open sea (Sognesjøen).

The model describes separately the budget for the different nutrients as well as carbon and oxygen.

A central part of the model consists of calculating oxygen consumption when organic matter is decomposed.



Figur 35: Illustrasjon av de forskjellige fysiske prosessene som er inkludert i NIVA Fjordmodell. Legg merke til at det i modellen blir simulert hvordan de vertikale blandingsforholdene endrer seg hvis man legger inn et dykket utslipp i bassenget.



Modeling the Sognefjord

Four model scenarios have been run. In the first model run, conditions in the Sognefjord are described as they were in the 1970s. This model scenario is called the "baseline". This model scenario is compared with three others.

In what is called the "dagens tilstand", warmer water in the open sea and higher input have been included. Then we see a decrease in the oxygen level in the deep water of 0.6 ml/L. This is slightly less than the observed decrease in oxygen of around 0.7-1.1 ml/L, but is of the same order of magnitude.

Scenarios have also been run where there is only warmer water in Lake Sognefjord (the "warm" scenario), and only higher input (the "nutrient-rich" scenario). The results from the model scenarios are shown in Table 2.

Of the total decrease in oxygen between the baseline and the current situation, one third of the decrease can be attributed to climate change and two thirds to increased input. With increased discharge, we see that a higher concentration of nutrients builds up in the depths. There is no data on the development of nutrients in the depths, but oxygen has been monitored thoroughly in recent years.

Decrease in oxygen is caused by a combination of climate change and increased discharge.

Tabell 2: Resultater fra modellscenarier beregnet med NIVA Fjordmodell. Oksygen, fosfat og nitrat på 1200m dyp er vist.

Senario	Beskrivelse	Oksygen på 1200 m	PO_4 på 1200 m	NO_3 på 1200 m
Baseline	Temperatur og tilførsel som 1970	6.35 ml/L	41.1 µg P/L	257 µg N/L
Varm	Temperatur som i dag og tilførsel som 1970	6.15 ml/L	43.2 µg P/L	266 µg N/L
Næringsrik	Temperatur som 1970 og tilførsel som i dag	5.95 ml/L	50.0 µg p/L	292 mg N/L
Dagens tilstand	Temperatur og tilførsel som i dag	5.75 ml/L	52.5 µg P/L	302 mg N/L