EU Strategy for the Baltic Sea Region
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BASROD: Studies of BAltic Sea Restoration by Oxygenation of the Deepwater

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What is the problem?

Eutrophication due to too large supply of phosphorus from the internal source. Anoxic bottoms deliver about 100 000 tonnes P/year (about ten times more than reductions required by BSAP)

Solution?

Switching off the internal source from anoxic bottoms by oxidation of the deepwater. This will **decrease the loading by 100 000 tonnes P/year.**

Cant this restore the Baltic Proper?

Yes, if all anoxic bottoms are oxygenated during 10 years the Baltic Proper will be restored to a state similar to that in the 1940s.

Before restoration can be undertaken all effects of it must be known.

To meet this need, **BASROD will produce a complete manual for restoration of the Baltic Proper** describing the science including biogeochemistry and ecology, technological methods, costs, socioeconomic effects, risks and law issues.

Eutrophication problem – Spreading of anoxic and hypoxic bottoms in Baltic Proper
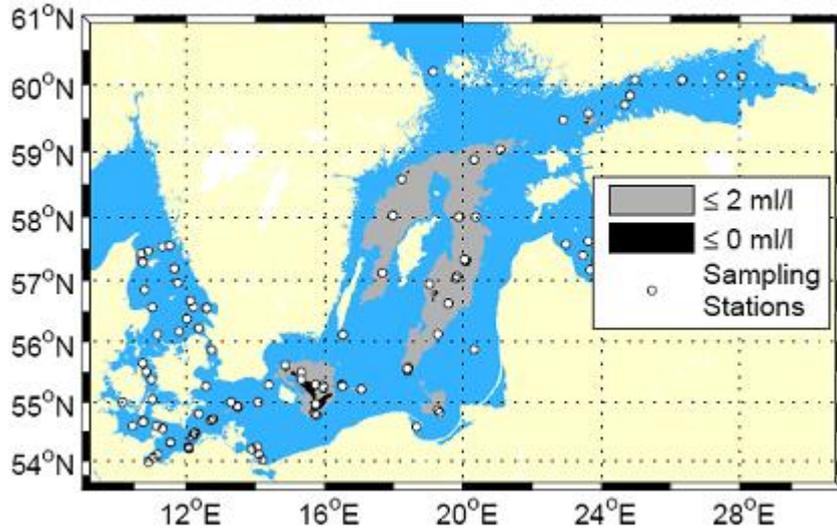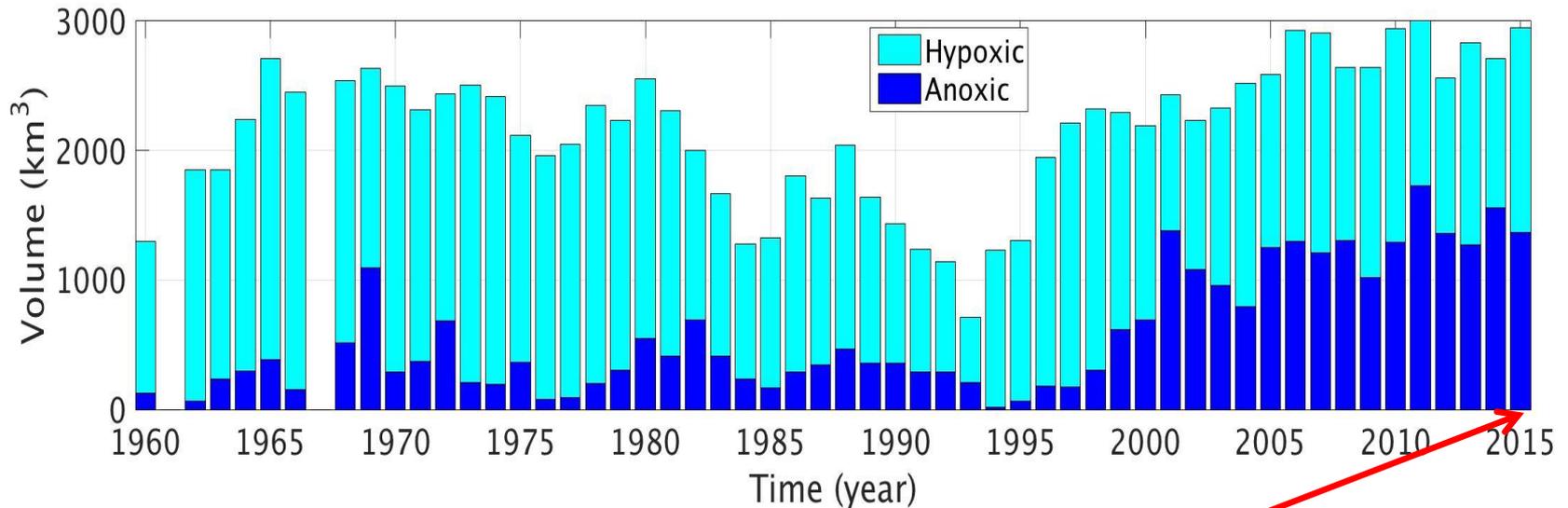

Autumn 1995

(best since 1960)
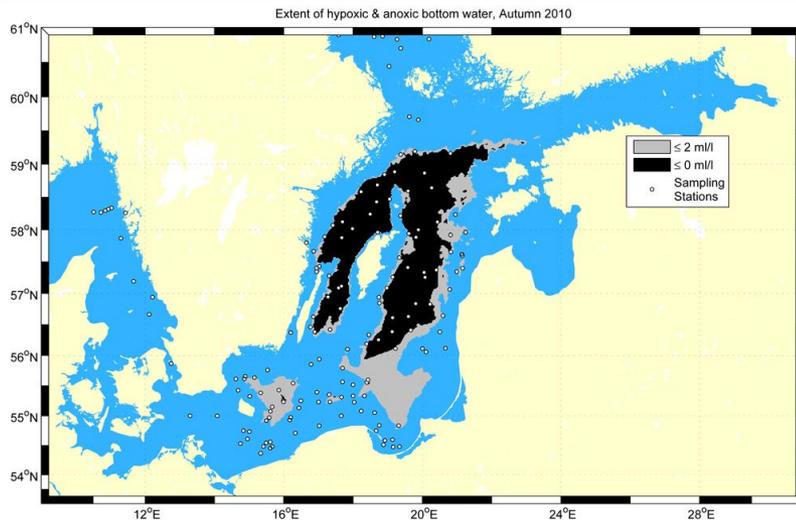
Autumn 2010

(among the worst since 1960)

From www.SMHI.se

Volumes of hypoxic and anoxic water in the Baltic Proper (from observations obtained in the period August - October)

The large inflows of new deepwater in December 2014 and January 2015 were not able to even reduce the "oxygen debt"
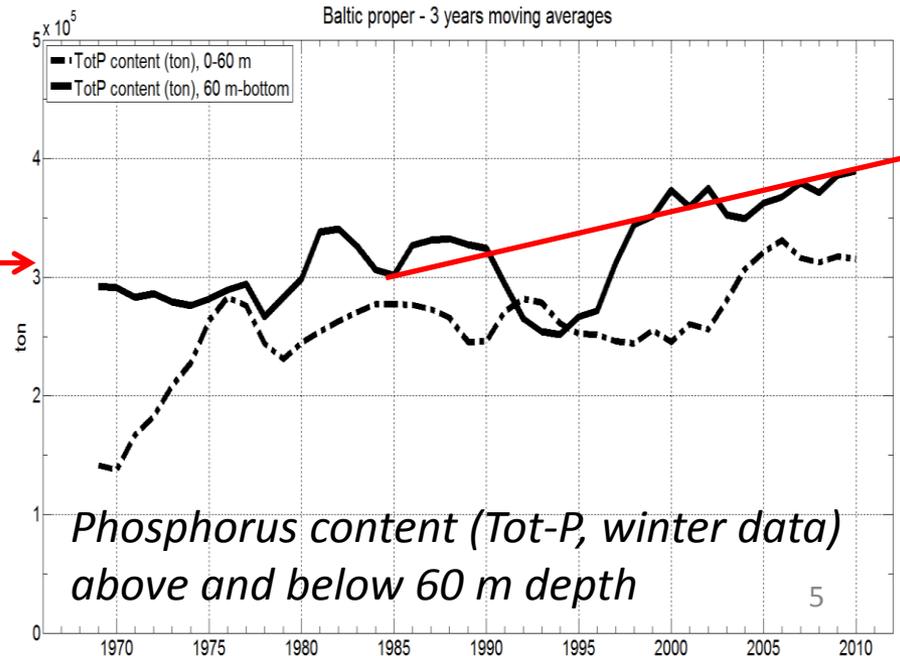
From www.SMHI.se

Baltic proper – External supply of P

The annual external supply of phosphorus (P) to the Baltic Proper is halved since 1985!
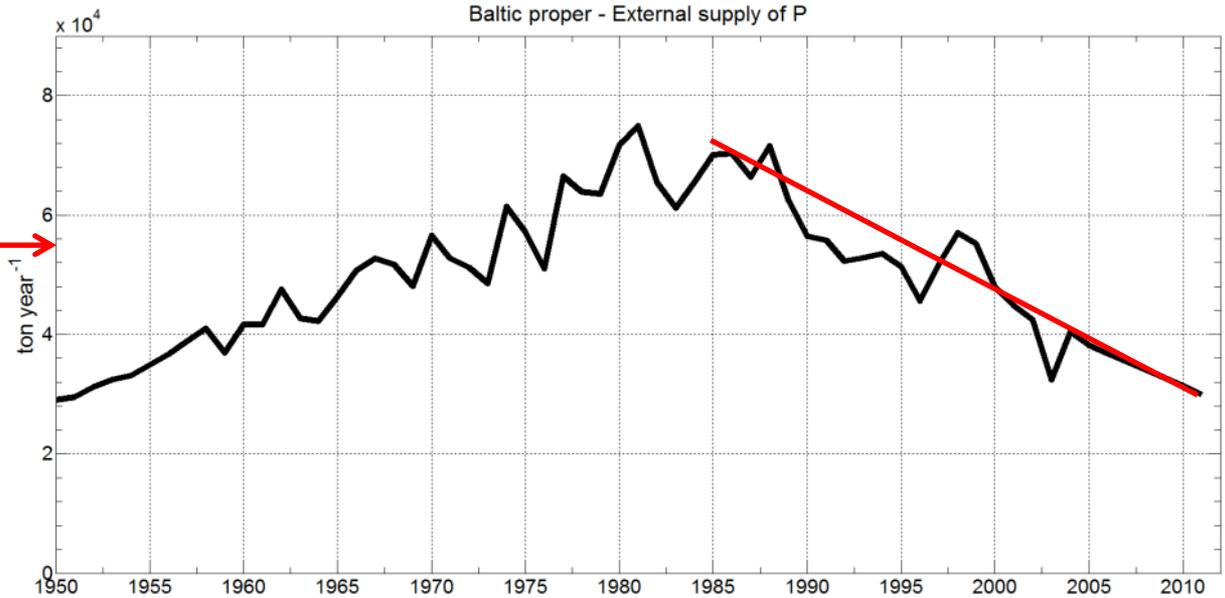
(After Gustafsson et al., 2012, Ambio), Data after 2006 are extrapolated.

But the contents of P in the water column increases after 1985! Explanation?

From Stigebrandt et al. "A new phosphorus paradigm for the Baltic proper" Ambio (2014)

Baltic proper – 3 years moving averages

Legend:
- TotP content (ton), 0-60 m
- TotP content (ton), 60 m-bottom

Phosphorus content (Tot-P, winter data) above and below 60 m depth

5

Tot P below 60 m depth (- - -) and Area of anoxic bottoms in Baltic Proper (———) from 1968 to 2010. (from Hansson et al. 2011).
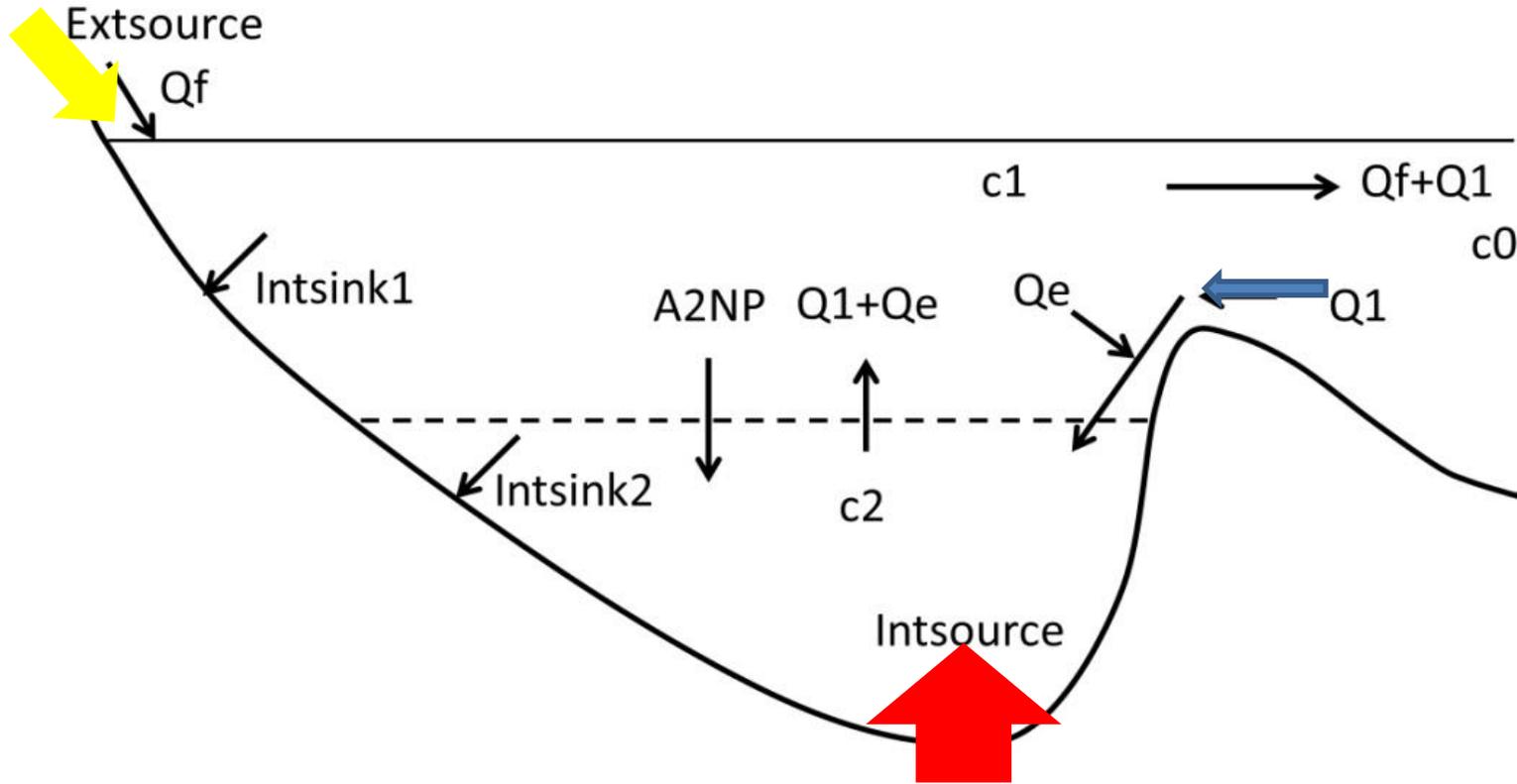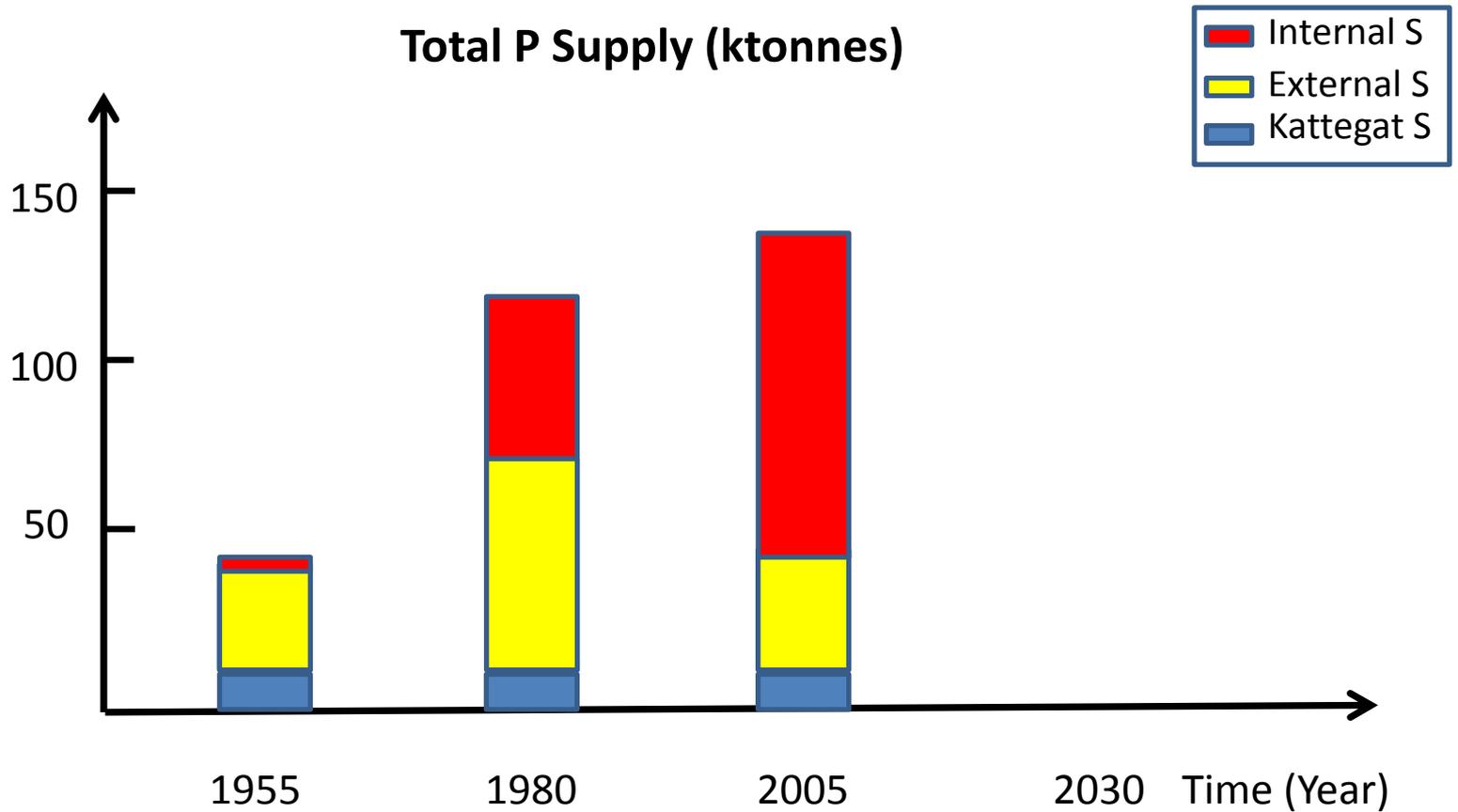

Baltic proper
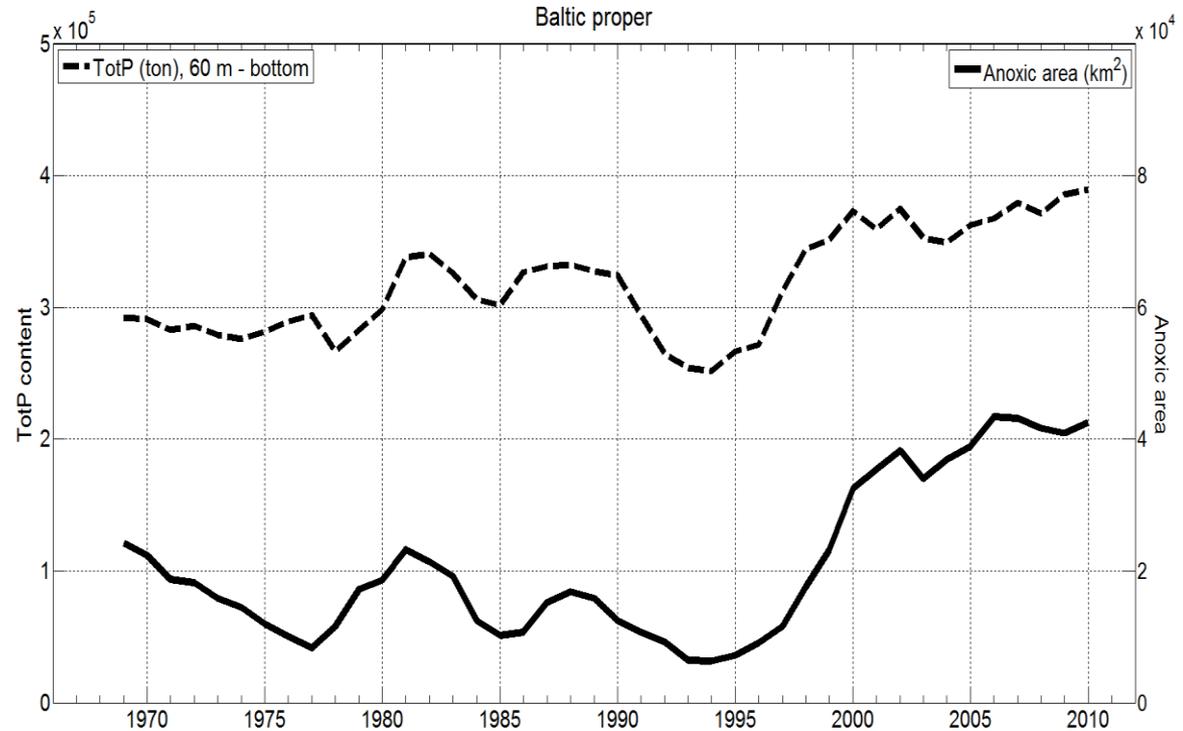
Explanation:
Anoxic bottoms are P sources!
Implies that oxygenation of anoxic bottoms turns off the internal P source!

From Stigebrandt et al. Ambio (2014)

Phosphorus model of a two-layered Baltic Sea

Phosphorus model of a two-layered Baltic Sea. Phosphorus sources are shown by colored arrows. Sinks are proportional to c1. The internal source is computed using the model. From Stigebrandt et al. Ambio, (2014)

Total P Supply (ktonnes)

Legend: Internal S, External S, Kattegat S

Y-axis: 150, 100, 50

X-axis (Time (Year)): 1955, 1980, 2005, 2030

NB! The internal source comes from anoxic bottoms. It can be shut of by oxygenation of the deepwater.

How to do the oxygenation?

The HOLD method
About 10 000 m^3 s^{-1}
needed pumping rate
for the whole Baltic
Proper

HOLD
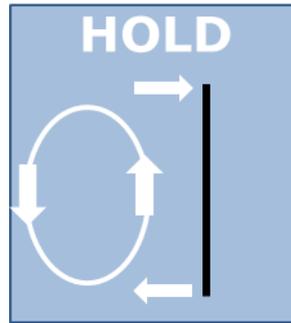
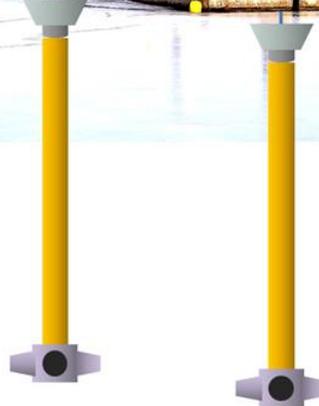Pumping water of
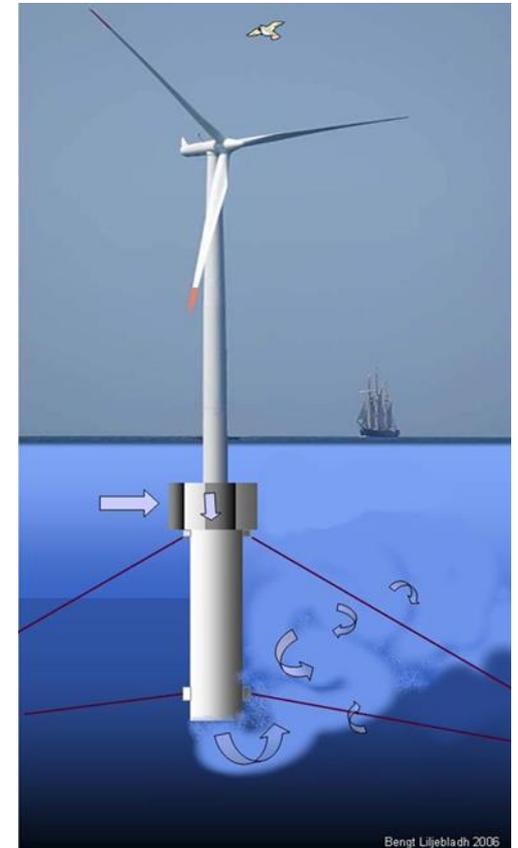**High Oxygen
Low Density**

Floating wind power
station with pump

Pump arrangement
used in the By Fjord

The pumping may be
powered by wind,
waves or the electrical
grid (like in the By
Fjord).

Bengt Liljebladh 2006

Total P Source (ktonnes)

Legend:
- Internal S (red)
- External S (yellow)
- Kattegat S (blue)

Removal by oxygenation

Restoration

1955   1980   2005   2030   Time (Year)

C_1 (mmol m^{-3})

1

2005
2030
1980
1955
2030
Rest

100 000   200 000

Total P supply (tonnes yr^{-1})

(From Stigebrandt 2016 ; submitted to *Ocean Science*)

How long time will it take to restore the Baltic Proper?

Restoration of the Baltic Proper will take about 10 years to perform . After the restoration the trophic level of the Baltic Proper will be in balance with the external supply of phosphorus! Winter surface concentration will be about 0.25 mmol P m^{-3}.

NB! Pumps may be removed after 10 years when restoration completed! The natural circulation should then support enough of oxygen to the deepwater.

However, extremely large and salt inflows may trigger a new period of anoxia and eutrophication. But it is the easy to destroy the stratification by pumping

Anoxia occurs when there is an imbalance between the supplies of oxygen and oxygen demand for oxidation of reduced matter.

Very saline inflows prolong the residence time of bottom water and hampers the deepwater oxygen supply, cf the development after the inflow in 1951.
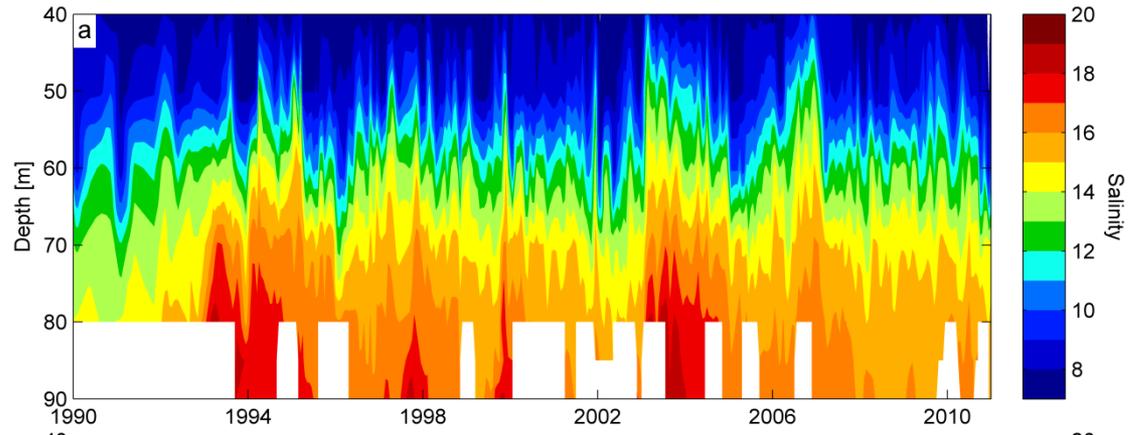
Eutrophication increases the rate of oxygen consumption.
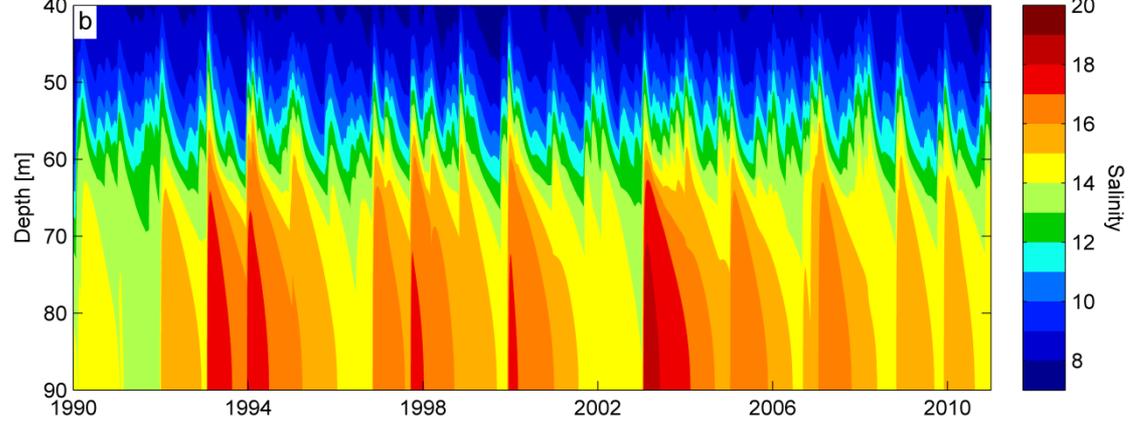
Density and oxygen in East Gotland Basin (BY15)
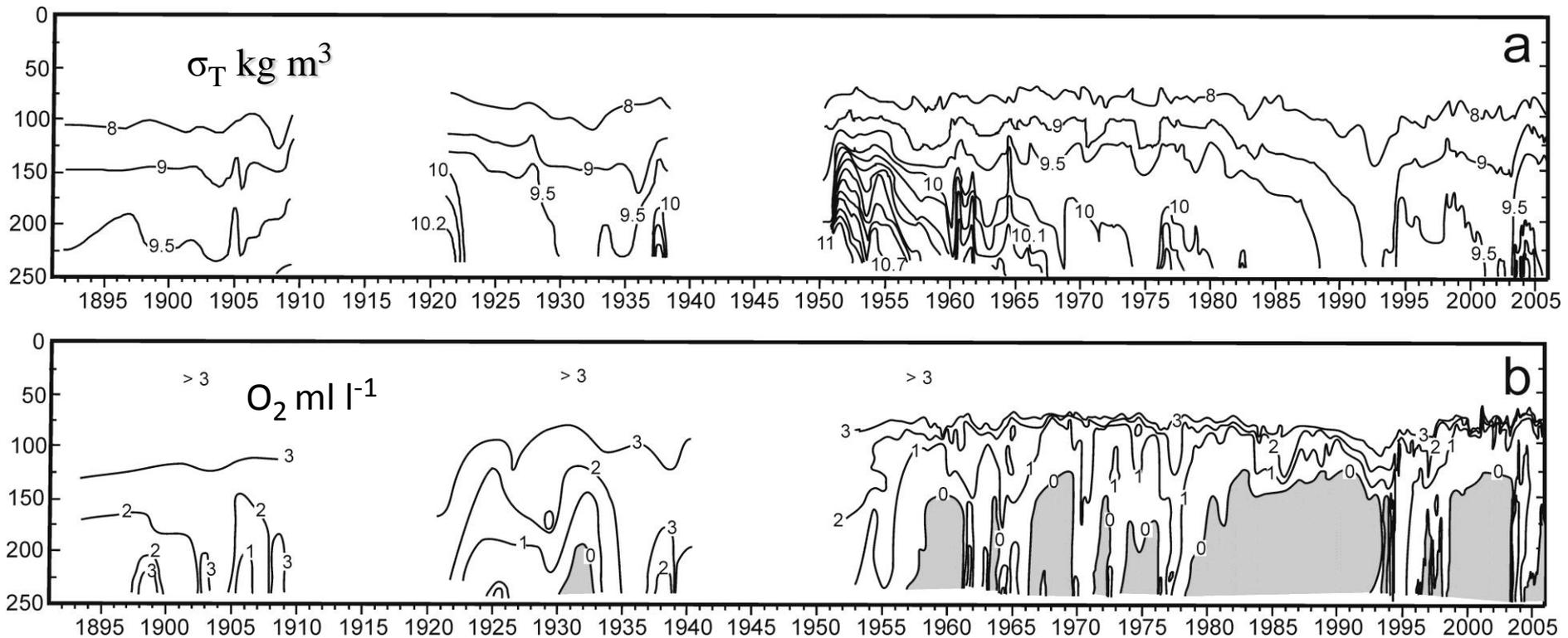
Salinity Bornholm Basin

Observations

Model simulation

Model prediction when pumping 1000 m ^{3} s^{-1}

From Stigebrandt et al., Ocean Science, 11, 93-110, 2015
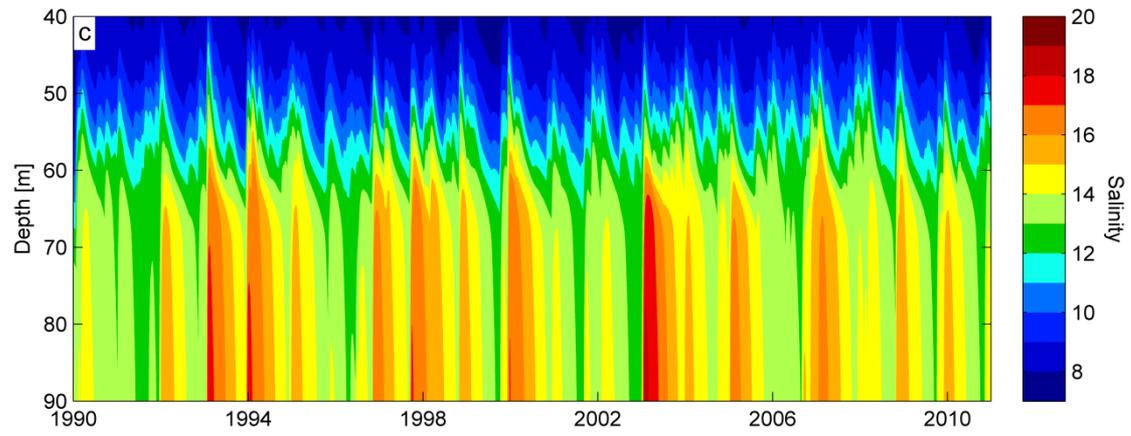
Oxygen Bornholm Basin

Observations

Model simulation

Model prediction when pumping 1000 m ^{3} s^{-1}

From Stigebrandt et al., Ocean Science, 11, 93-110, 2015
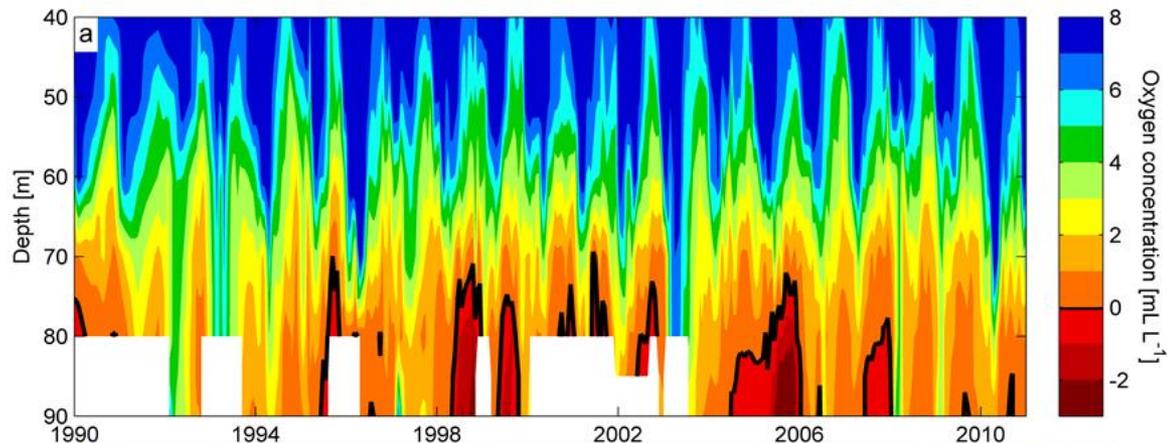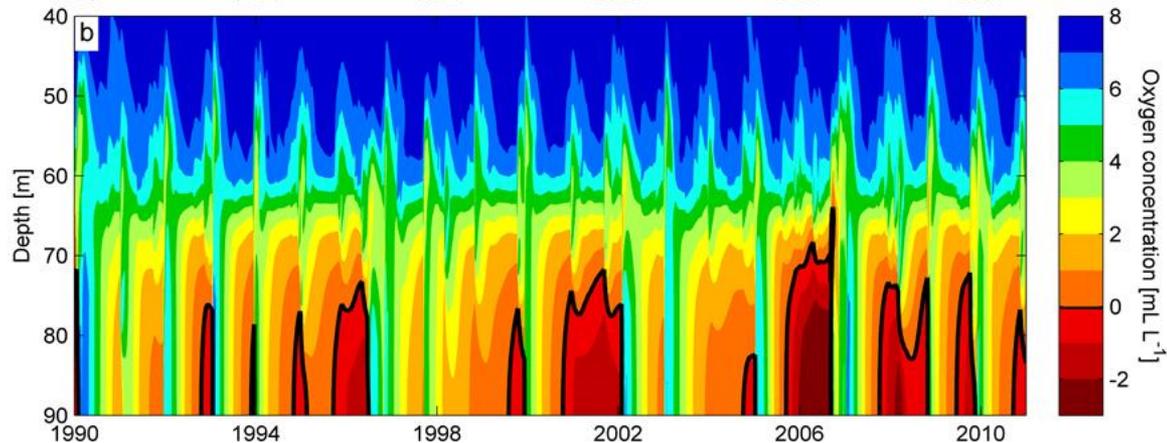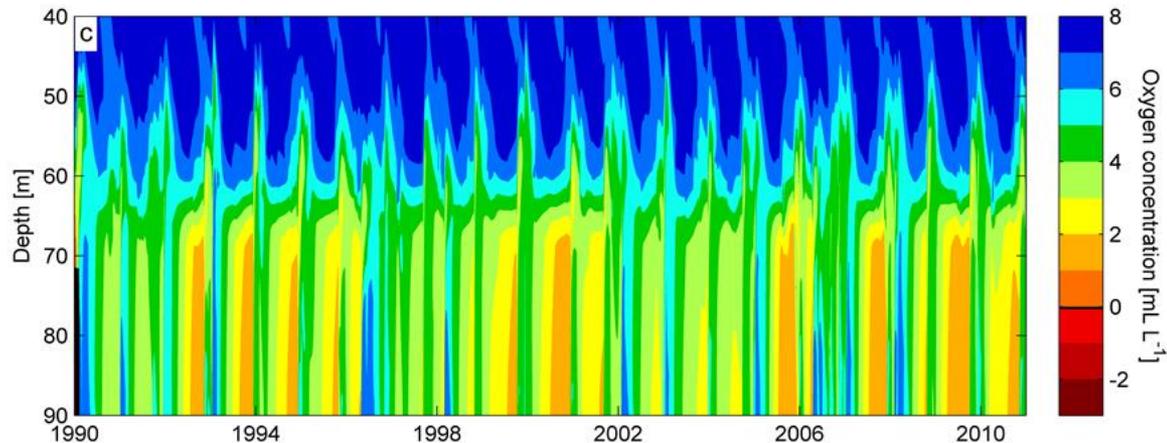
Sediment profile images from 19 m depth in the By Fjord – colors are digitally revised

Azoic sediment
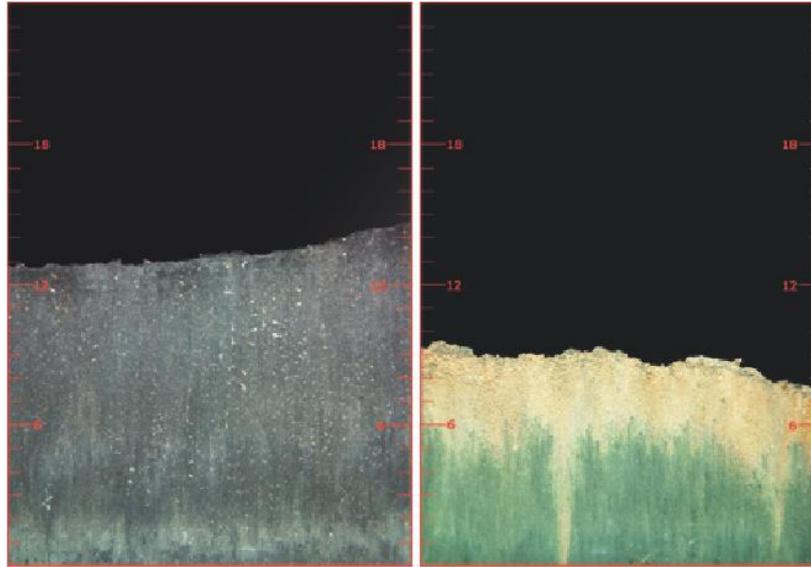
Oxidized surface layer

Digging macroscopic animals in the sediment. NB deep burrows.

2009

March 2012

16 months after oxygenation of the deepwater.

From Stigebrandt et al., 2015, Ambio

A complete Environmental Impact Analysis (EIA) is needed

After restoration, the surface water will be in equilibrium with the external P supply which will about the same as in the 1940s. The sight depth will be larger than today and the sea beds in the deepwater will be colonized. The ecology of the Baltic be similar to that in the 1940s.

What happens during the restoration period? We already know quite much about environmental effects of oxygenation through the experiment by the Box project in the By Fjord and from studies of basins that are switching between oxic and anoxic states, e.g. the Bornholm Basin. Theoretical investigations show that oxygenation of the Bornholm Basin would improve the conditions for cod recruitment and lead to colonization of now dead bottoms in the Bornholm Basin.

BASROD will be led by a Steering Group and by Anders Stigebrandt, University of Gothenburg Sweden.

The work is organized into seven Work Packages:

WP A: Ecological effects and risks of oxygenation.
WP B: Modeling of the restoration process. Prediction of ecological changes and various environmental effects. Finding the best solution with regard to the pumped volume flow of oxygen saturated water in different basins in the Baltic Proper.
WP C: Specification of technical performance required by a system capable of oxygenating the Baltic Proper deep water under the solution produced by WP B.
WP D: Development of a best practice monitoring strategy to be applied during and after the restoration process.
WP E: Preparation of an environmental impact assessment (EIA) for the entire period of the restoration and beyond, based on work done in the other WP's.
WP F: Production of estimates of the economic benefits of a complete restoration according to the description developed in WP B. This WP will also draw up proposals for funding of the restoration. Furthermore, international legal aspects are investigated and solutions of identified possible legal problems are developed.
WP G: Investigation of alternative/complementary methods.

End Product

A book with tentative title

"The complete guide to Baltic Sea Restoration in ten years"

describing all aspects of restoration using oxygenation of the deepwater. The book may serve as a manual when politicians have decided to restore the Baltic Proper.

Co-workers (the list is not complete)

Docent Sven Blomqvist, Stockholm University, Sweden
Dr Andy Dale, Geomar, Kiel, Germany
Docent Karl-Johan Lehtinen, Åbo Akademi, Finland
Professor Rutger Rosenberg, University of Gothenburg, Sweden
Dr Stefan Sommer, Geomar, Germany

Several other persons will be engaged if BASROD attains PA Nutri Flagship Status

Financing plan: Swedish Agency for Marine and Water Management (HaV) has supported the initial phase. When BASROD attains flagship status applications will be sent to BSAP (through the Nordic Investment Bank) and many other national and international funding agencies including BONUS and national research councils for specific parts of the project..

Thank you for your attention!