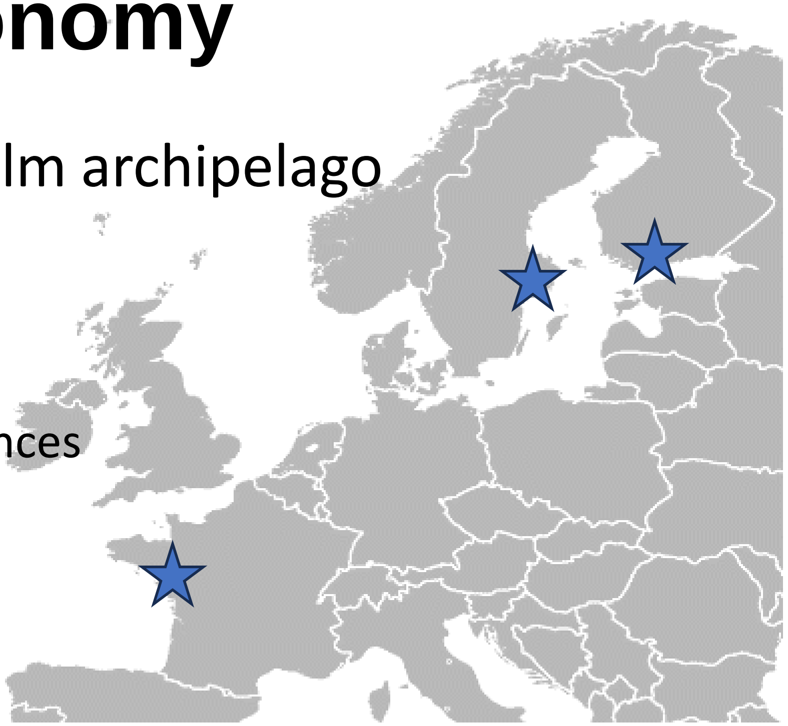
BOxHy – Baltic Sea Oxygenation and the Super-Green Hydrogen Economy

Potential pilot experimental areas in the Stockholm archipelago



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SKVVF kontaktombudsmöte 2023-12-05

Flexens
FLEXIBLE ENERGY SOLUTIONS

Lhyfe

Stockholm University

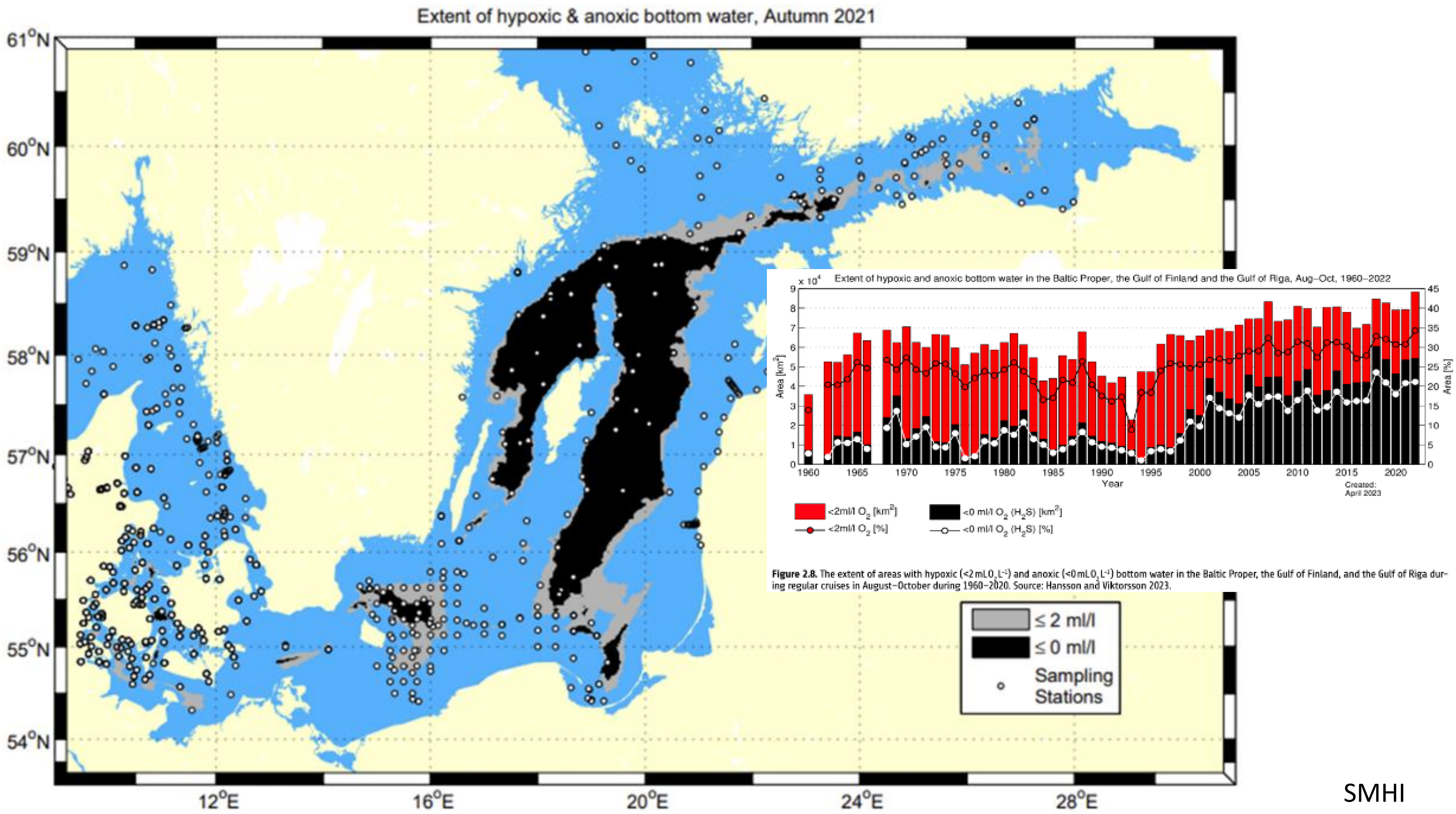
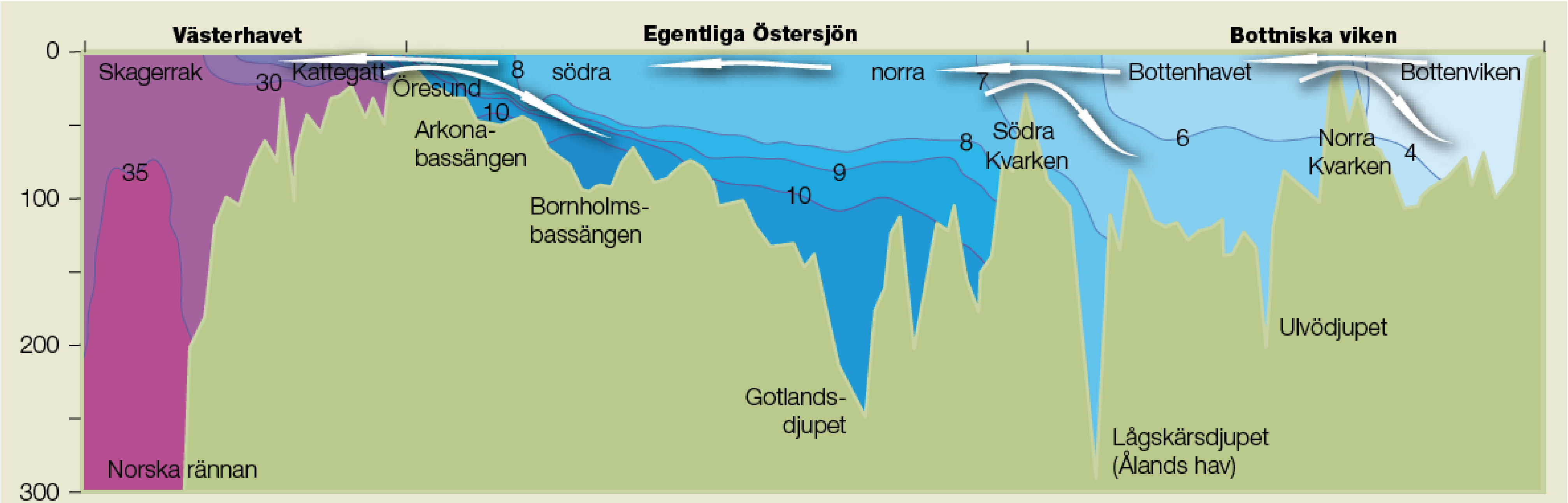


Figure 2.8. The extent of areas with hypoxic (<2 mL O_2 L^{-1}) and anoxic (<0 mL O_2 L^{-1}) bottom water in the Baltic Proper, the Gulf of Finland, and the Gulf of Riga during regular cruises in August–October during 1960–2020. Source: Hansson and Viktorsson 2023.

SMHI

Why do we have an Oxygen problem?

- Permanent salinity stratification (=halocline), restricts vertical water exchange.
- Inputs of new oxygen occur irregularly with major deep water inflows. There are long periods of stagnant deep water.
- Nutrient loading has increased production of plankton and thus the amounts of sinking organic matter that consume organic matter when it is degraded.



Från Bernes, "Förändringar under ytan" (Monitor 19). Data från Winsor et al. (2001) och Fonselius (1996).

If we could improve the oxygen conditions...

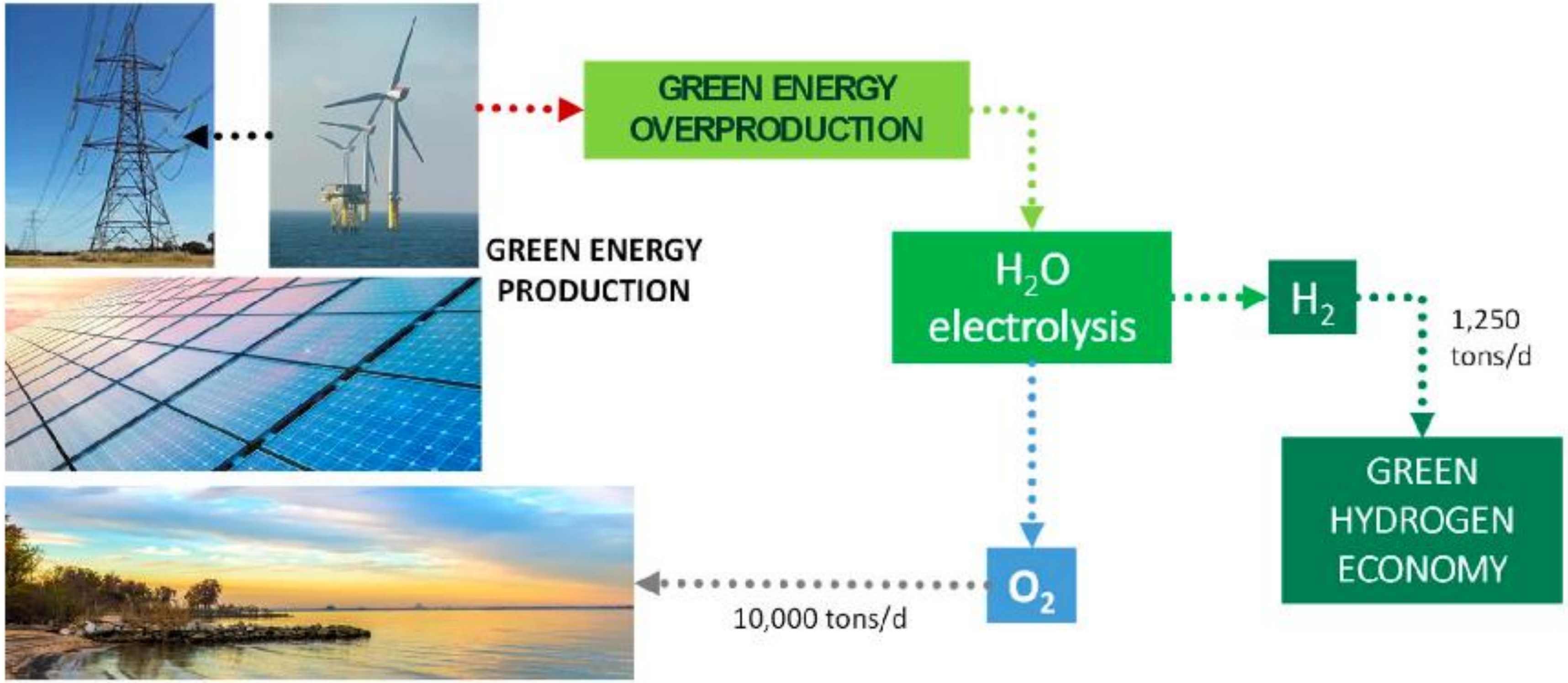
- More phosphorus will be bound in sediments and concentrations in the water lowered
- → Less cyanobacterial blooms
- Better survival of cod eggs and larvae
- More benthic animals
- More deepwater zooplankton
- → More food for herring and cod, larger and more healthy cod stock

Do we have to wait for a 100 years of slow recovery?

Project background and idea

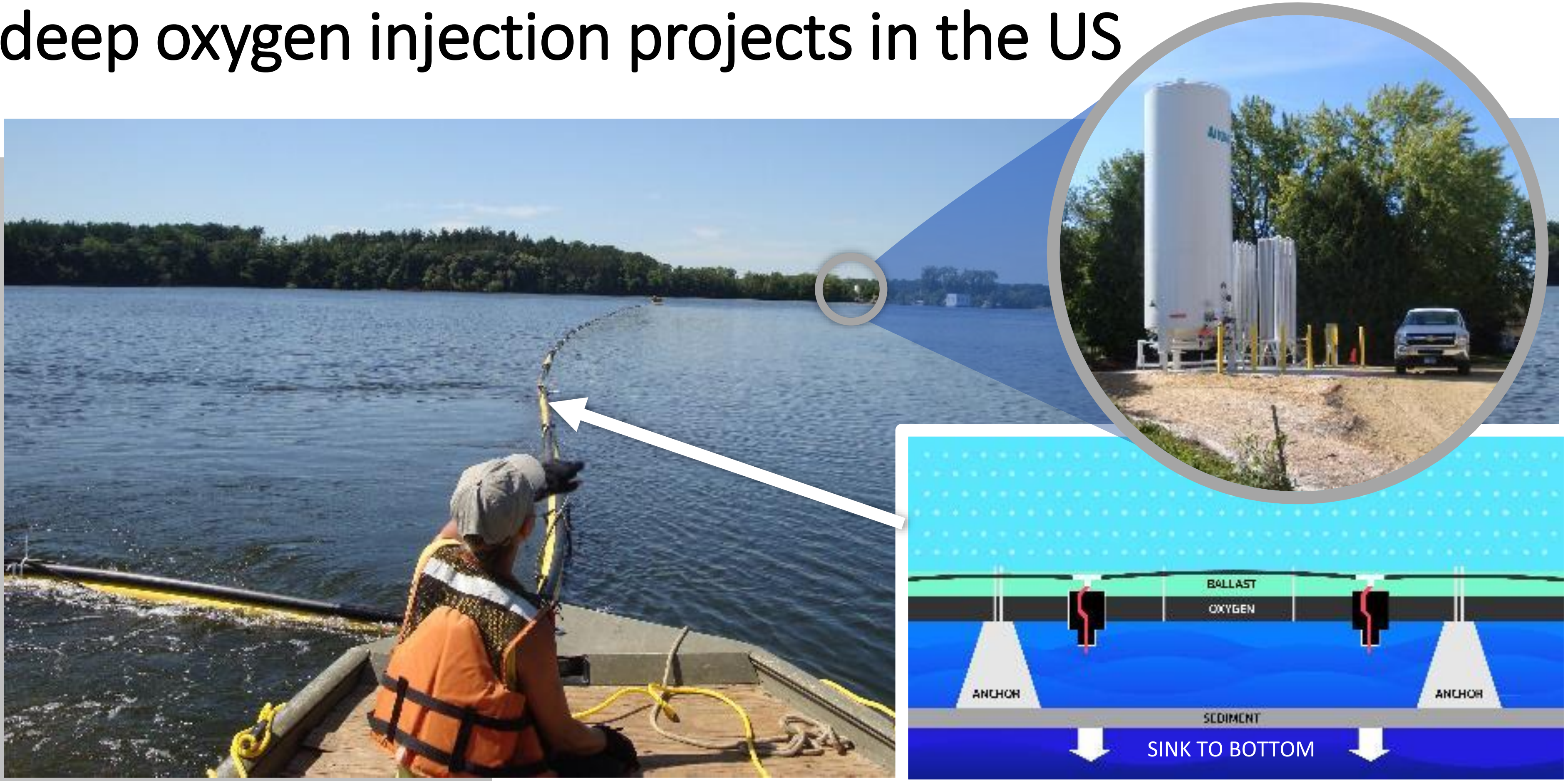
BOxHy is a follow up
Project of the 2021- 2022
Prefeasability study

„COMBINING GREEN
HYDROGEN
PRODUCTION AND DEEP
INJECTION OF
PURE OXYGEN GAS TO
RECOVER THE
BALTIC SEA“



VAHANEN Jacobs

Several deep oxygen injection projects in the US



O_2 demand scale comparison (tonnes/d):	
Largest reservoir:	350
Baltic Sea:	~10,000-15,000
Chesapeake Bay :	~2,000

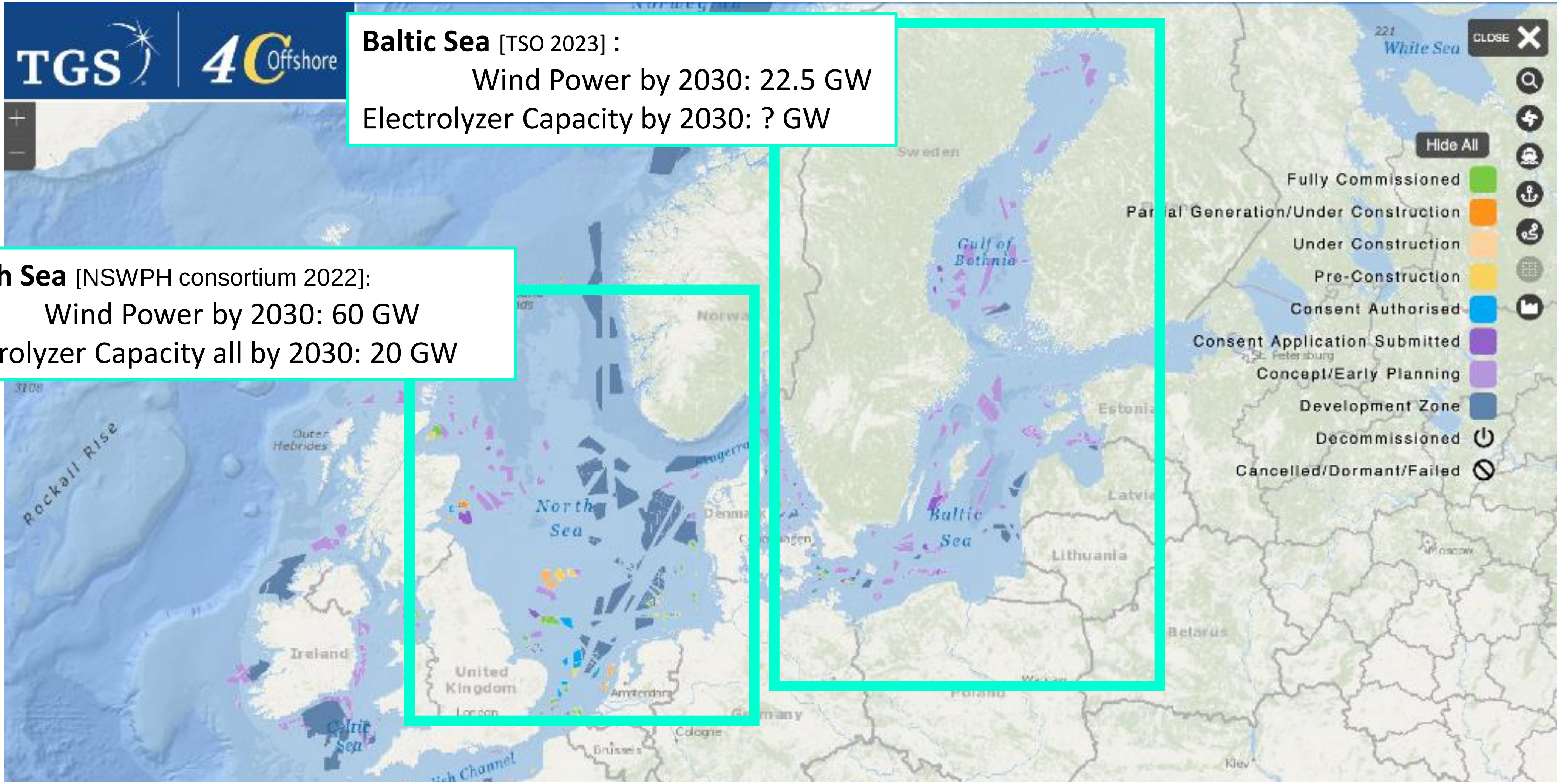
From: David Austin

Jacobs

Green Energy Potentials

Baltic Sea [TSO 2023] :
Wind Power by 2030: 22.5 GW
Electrolyzer Capacity by 2030: ? GW

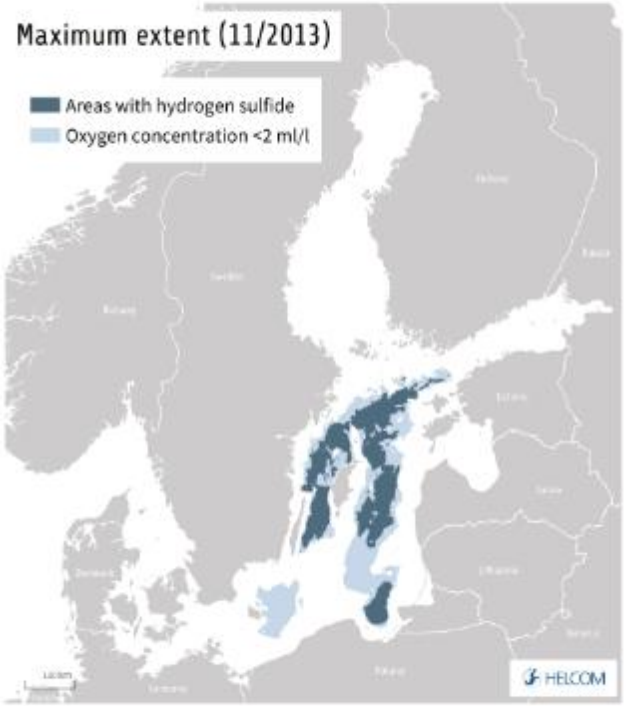
North Sea [NSWPH consortium 2022]:
Wind Power by 2030: 60 GW
Electrolyzer Capacity all by 2030: 20 GW



Marine Spatial Plan for Offshore Wind Parks

[https://map.4coffshore.com/offshorewind/ access 07.06.2023]

Deoxygenation Mitigation – Baltic Sea



[HELCOM HOLAS II, Fig 1.10]

How could reoxygenation be included as a seabased measure in existing eutrophication abatement Strategies ?

The Baltic Sea could be suitable …

Theoretically:

- **O_2** demand **10.000 – 15.000 t/day** (2 – 6 Mt/year) [Conley et al. 2009, Stigebrandt and Gustafsson 2007]
- **500 MW** Platform **– ~1500 O_2 t/d**
- **9-10** such platforms or 4.5 - 5 GW installed would **produce** the **O_2** needed

Practically – Transdisciplinary:

How do we oxygenate – with which technique ?
Where do we oxygenate ? (strategically)
} Engineering

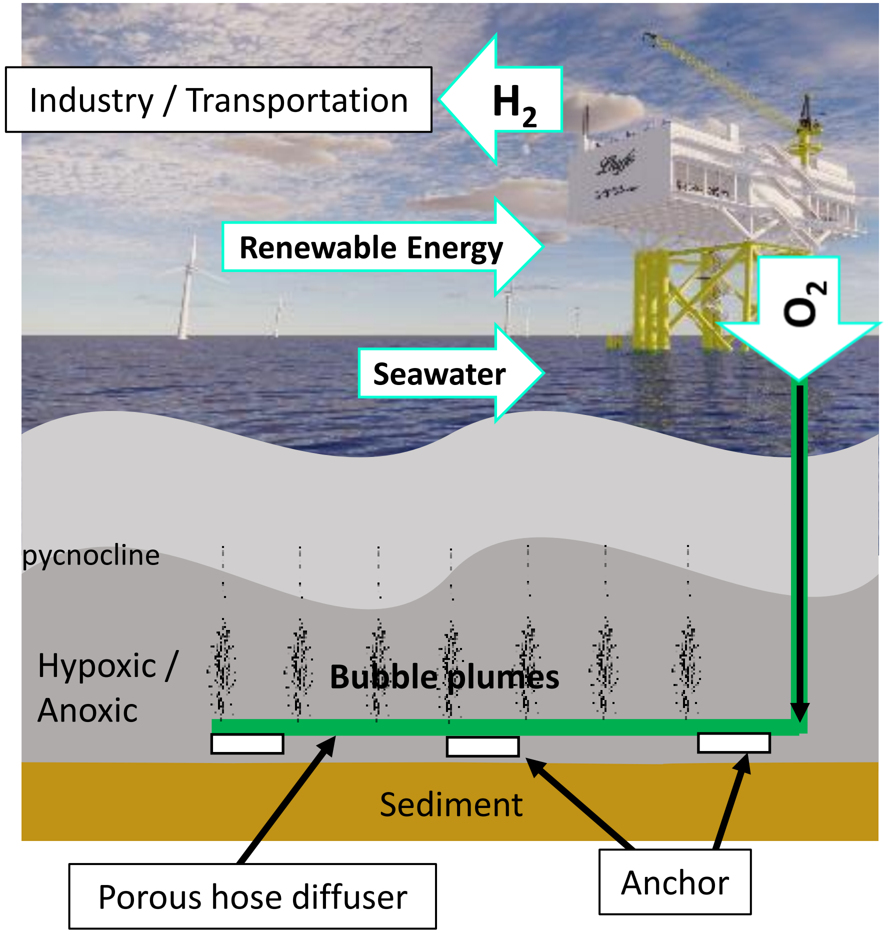
What are possible risks ?
What happens if O_2 input not steady ? (Ecosystem Response)
What are short term and long term effects ?
How much O_2 is enough?
} Scientific:
- Physical
- Biogeochemical
- Ecological

Who is monitoring ?
Who is paying for reoxygenation ?
Legislation for territorial waters?
}
- Political
- Legal
- Societal

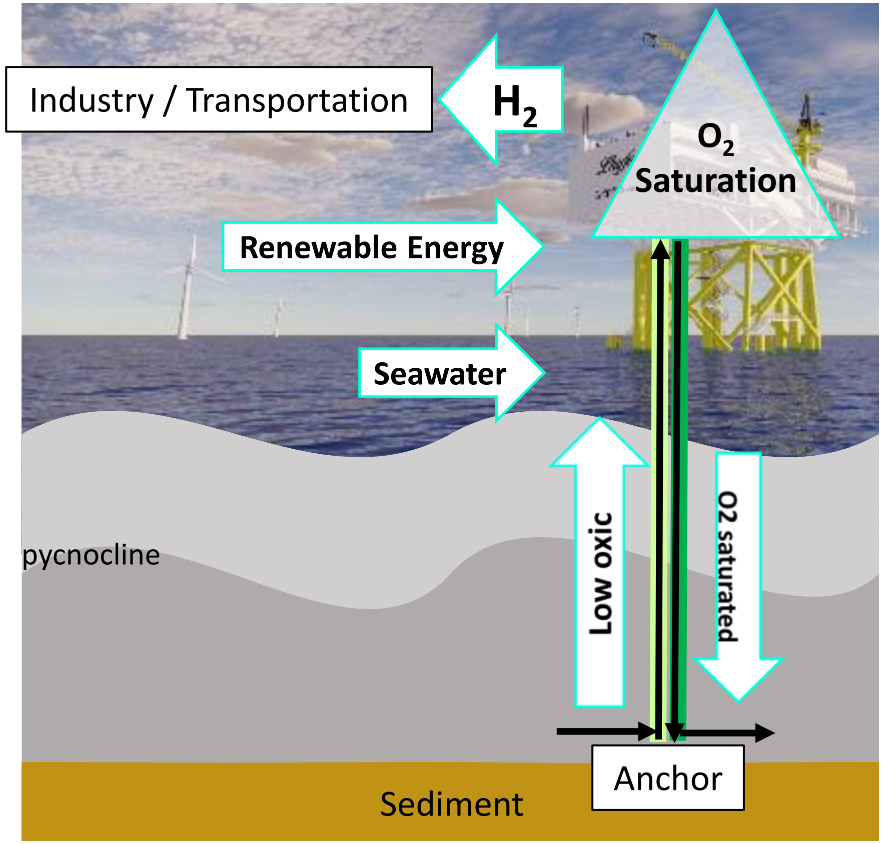
… and many more …

Subsea architecture – two possibilities

- How much energy needed in comparison ?



Bubble plume Diffuser

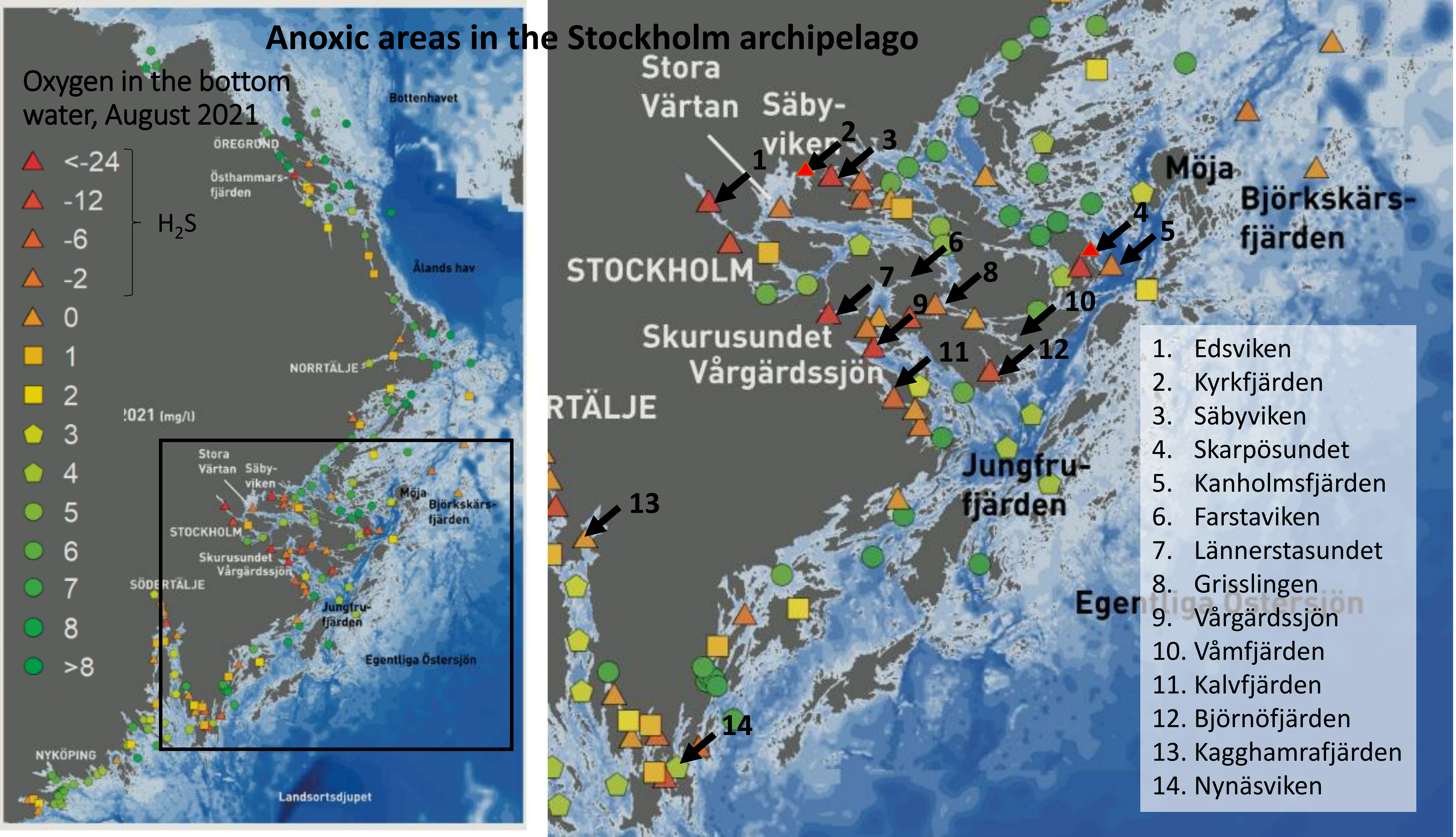


Deep water oxygenation – Full lift systems

Project Scope

- **BOxHy Project Oct 2023 – Oct 2024**:
  - **Identify sites** for proving Dissolved Oxygen Injection (DOI) in a marine environment
    - Initiate the **pilot site preparation** for testing oxygen injection in the Baltic Sea
  - Investigate the **upscaling** of the super-green hydrogen economy
  - **Engage with stakeholders** to discuss financing and political, regulatory, and social approvals for this kind of project
  - Identify **overlapping areas of interest** between DOI and large-scale hydrogen production
  - Define the **technical design of a large-scale DOI** incorporated with offshore H2 production
  - **Disseminate knowledge** gained during the project to relevant stakeholders

Anoxic areas in the Stockholm archipelago



Pilot Site criteria

- to be updated

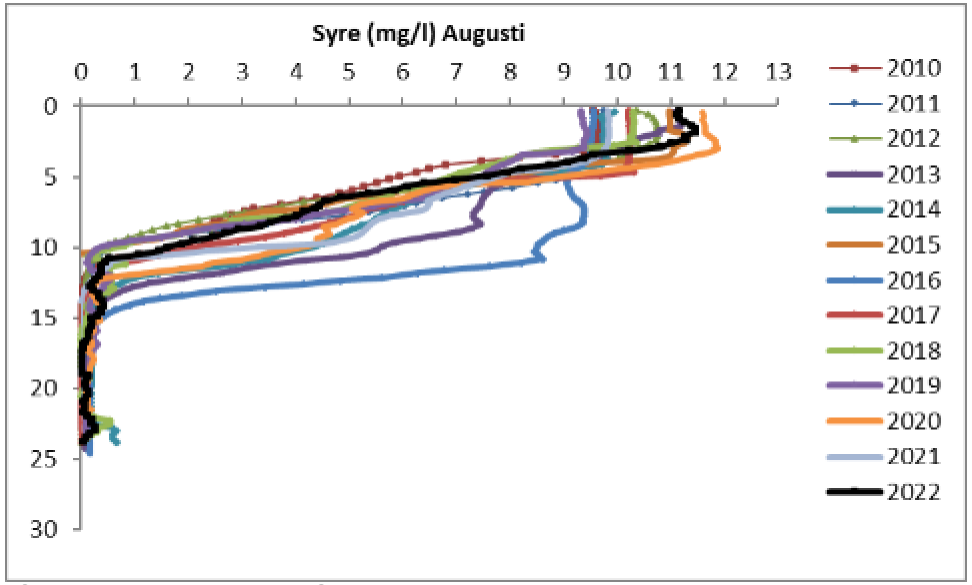
Technical/scientific criteria	
Current, detailed bathymetric survey	
Bathymetrically confined anoxic subbasin	
Persistent anoxia below halocline (strongly preferred over summer-only anoxia)	Depth, anoxia
Summer anoxia below thermocline (second best to long-term anoxia)	
Oxygen demand below halocline near or less than 10 tonnes O_2 per day	
Site available close to shore for oxygen storage or generation	
Pipe access to water from oxygen source	
Underwater oxygen supply pipe access to deep water	
Location on water body to construct diffusers and supply pipe	Access
Marine contractor available to position and hold diffusers and supply pipes while ballast pipe is flooded	
If LOX supply, access for large oxygen delivery truck (about 20 tonne capacity or greater)	
If site oxygen generation by electrolyser:	
• Electrical supply to site per electrolyser demand	
• Hydrogen facility per designated use	
Baseline data available	
Academic monitoring research programme engaged and funded	Monitoring
Continuous monitoring system installed prior to oxygenation (temperature, salinity, pH, DO)	

Pilot Site criteria

- to be updated

Social criteria
Local government support for project
Local stakeholder support for project
Public engagement plan developed in consultation with stakeholders
Location convenient for public to see installation
Operational criteria
Site security to protect oxygen supply and in-water monitoring probes
Unrestricted operational access to oxygen supply
Regulatory criteria
Well-defined permitting and oversight authority
• HELCOM

Lännerstasundet/Skurusundet

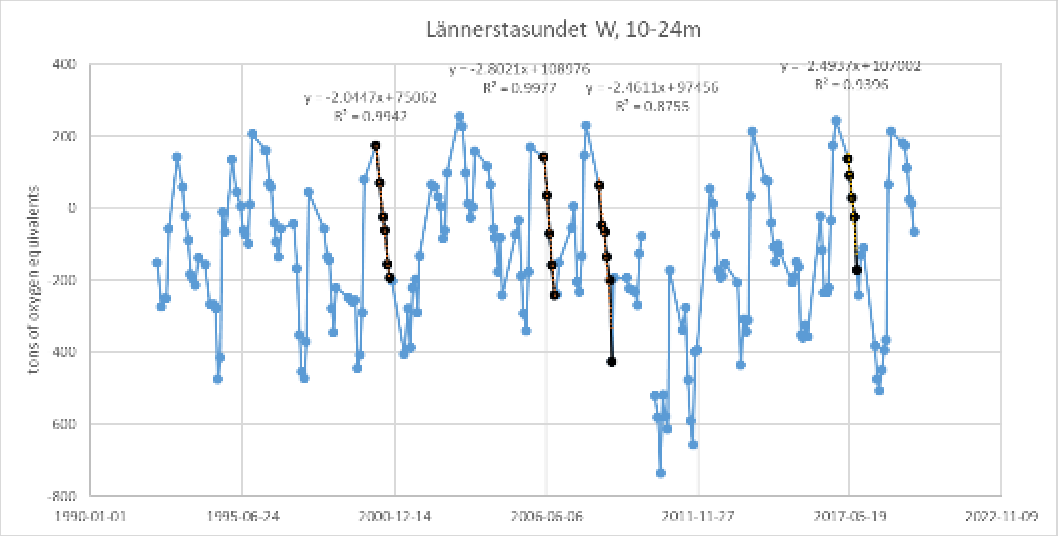


Hypoxisk area (<2mg O_2/l) (>10m) 0.59 km^2, 4.5 Mm^3

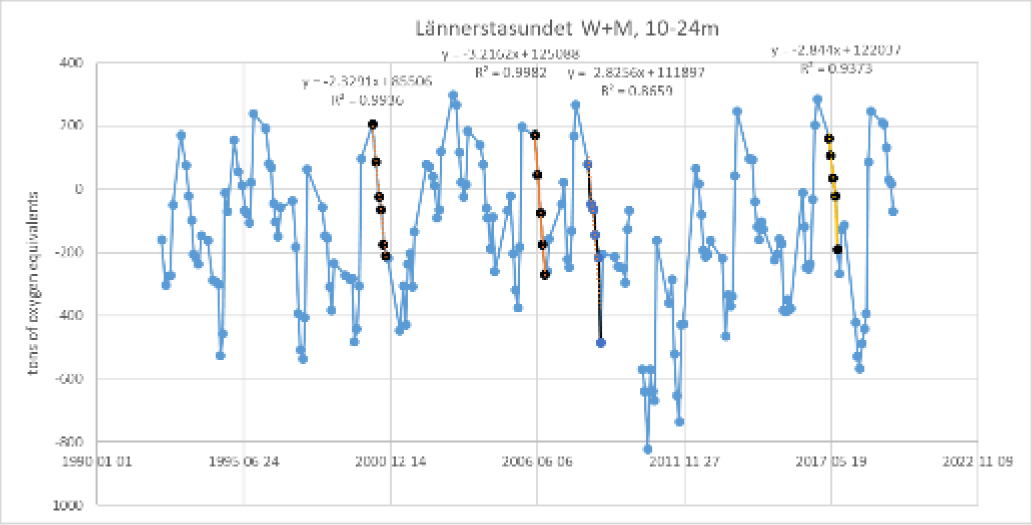
45 ton syre för att gå från 0 till 10 mg/l

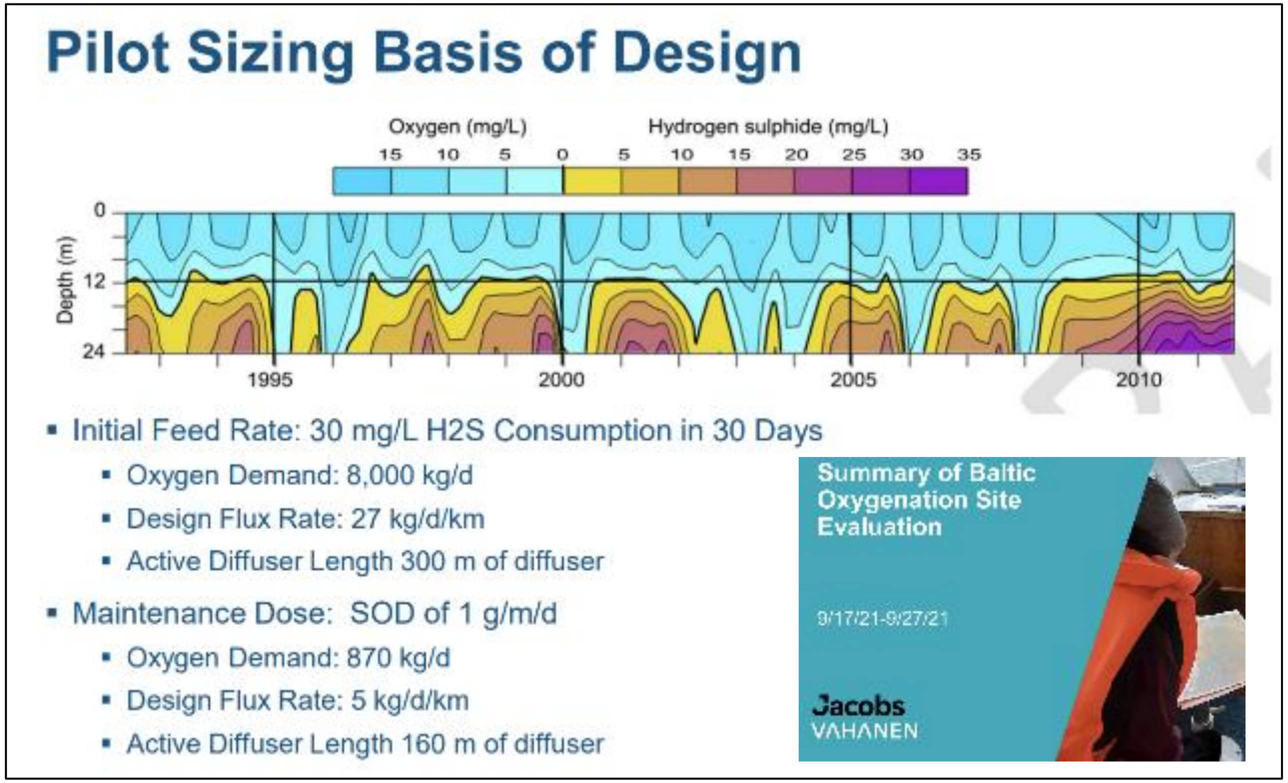
135 ton syre för att gå från 10 mg/l svavelväte till 10 mg/l syre

Oxygen consumption in Lännerstasundet

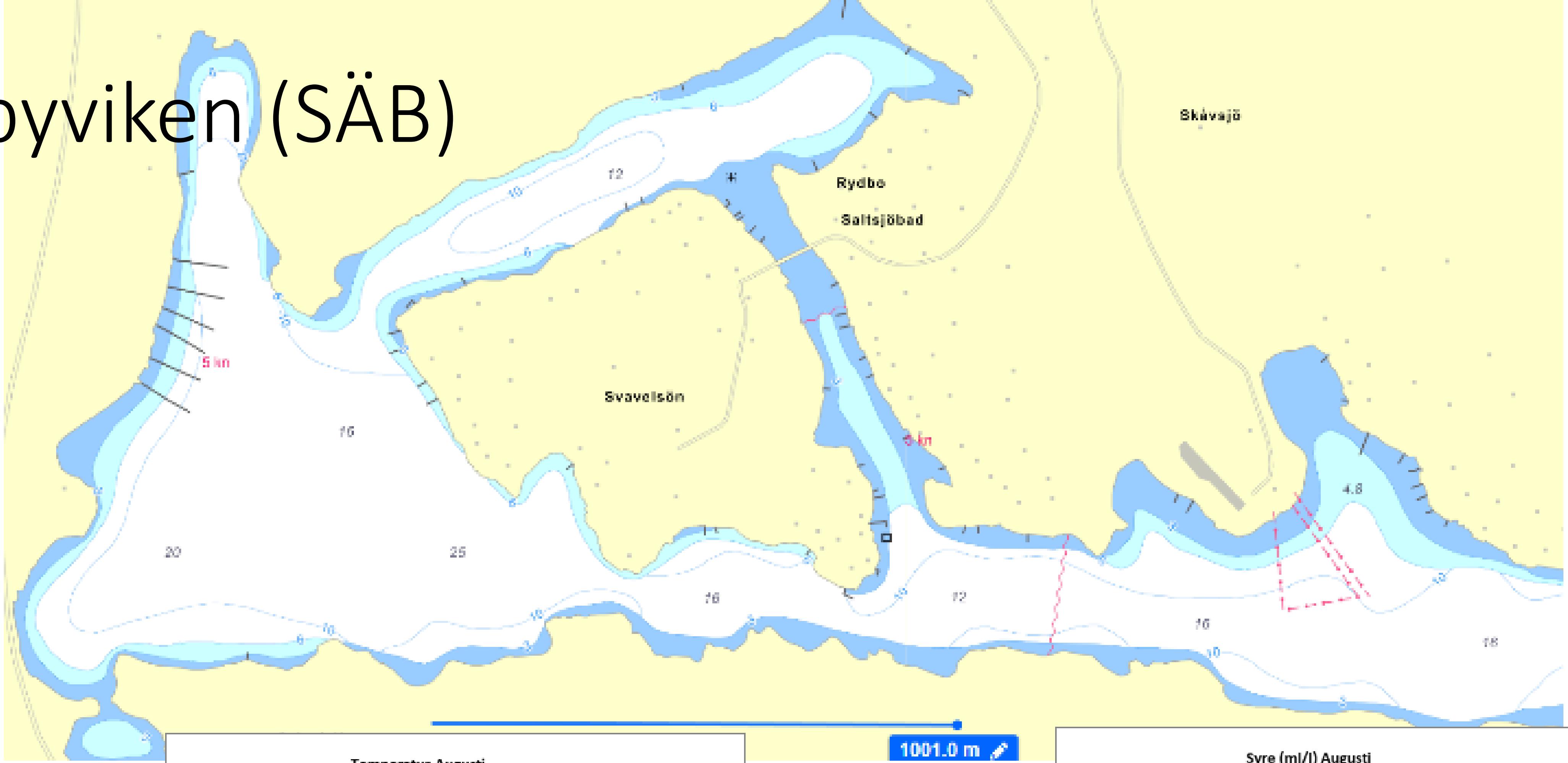


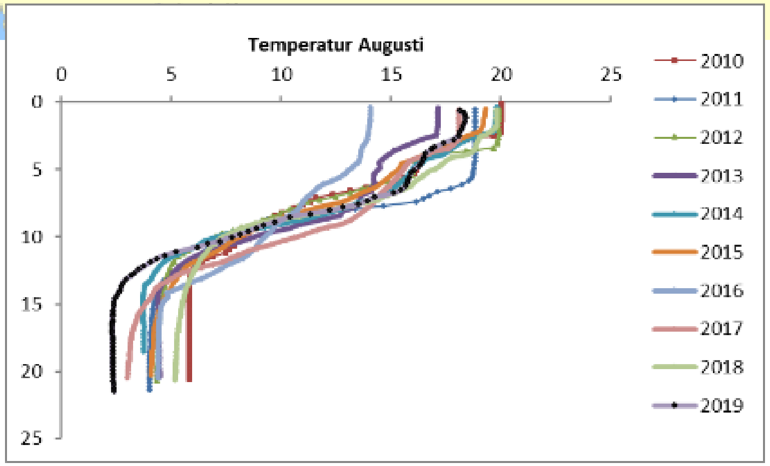
Consumption rate 2-3 tons O2 per day
(based on basin volumes and depth interpolated O2 and H2S data, for each 1m depth layer, summed for 10-24m)

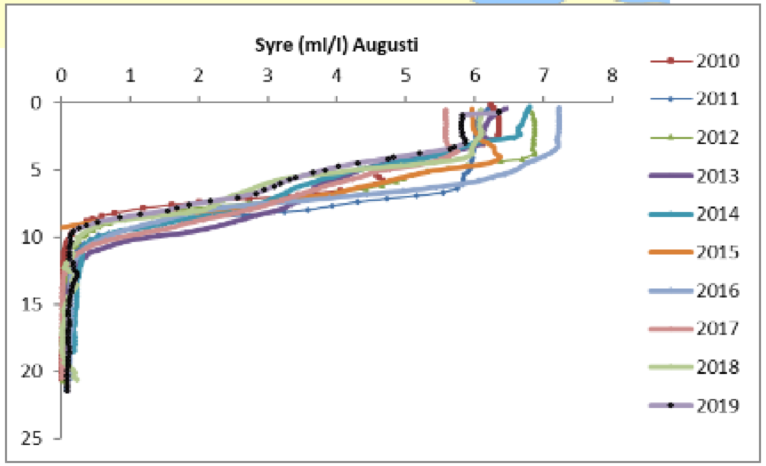




Säbyviken (SÄB)







Tack för att ni lyssnat!

- Workshop/seminar late winter 2024