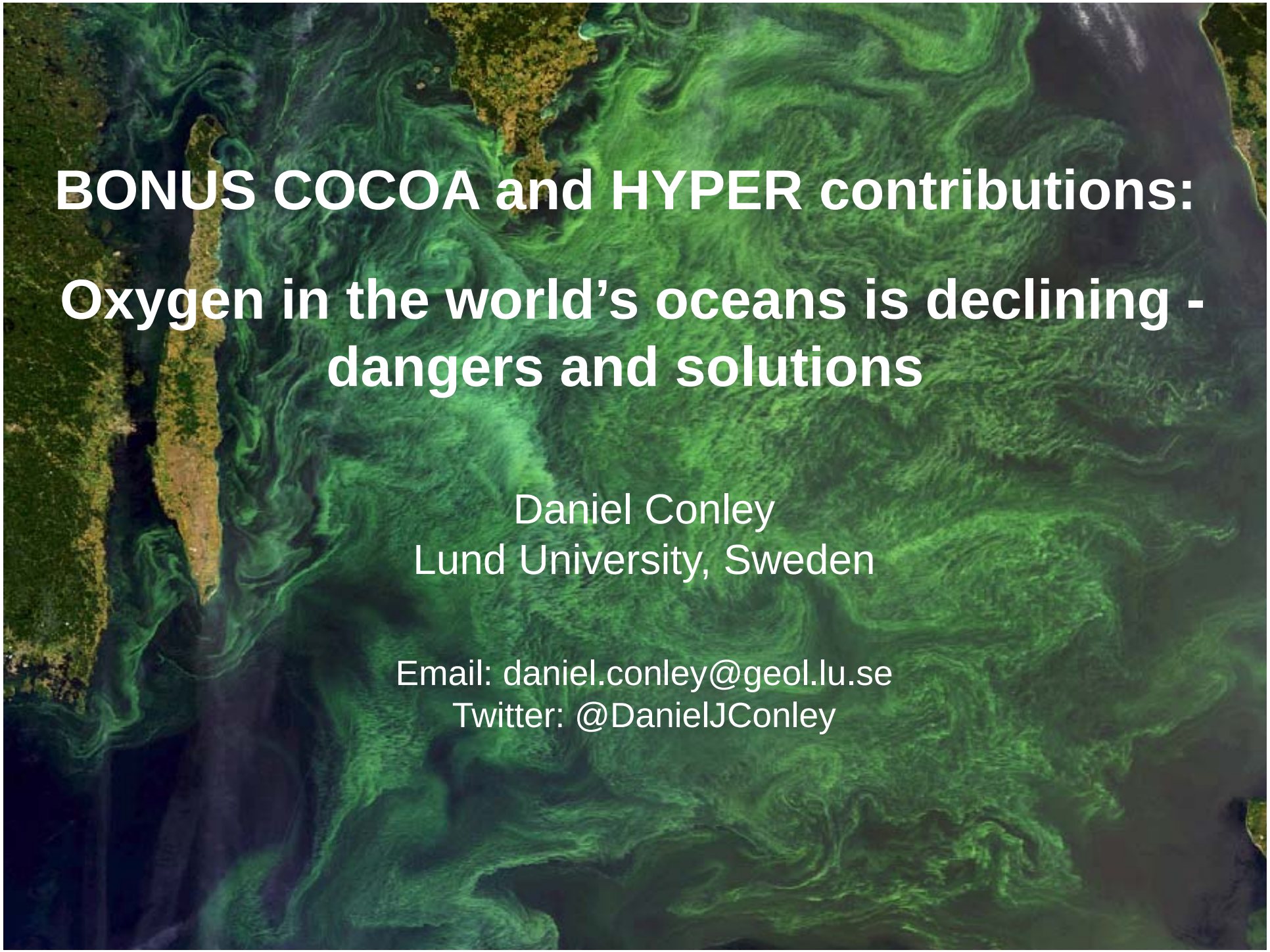

BONUS COCOA and HYPER contributions:

Oxygen in the world's oceans is declining - dangers and solutions

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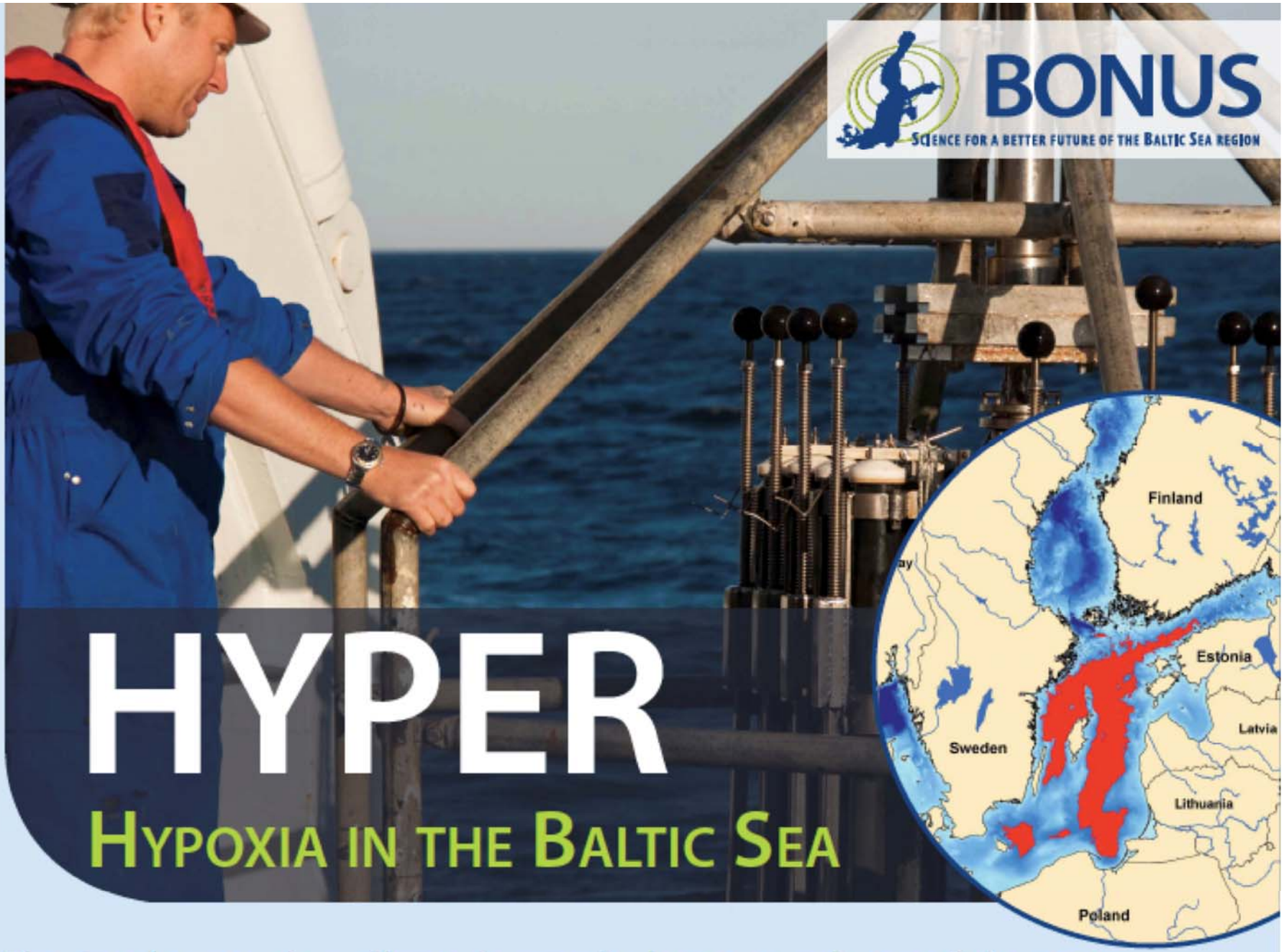


The drastic expansion of hypoxia over the last century is one of the most profound effects of eutrophication in the Baltic Sea.

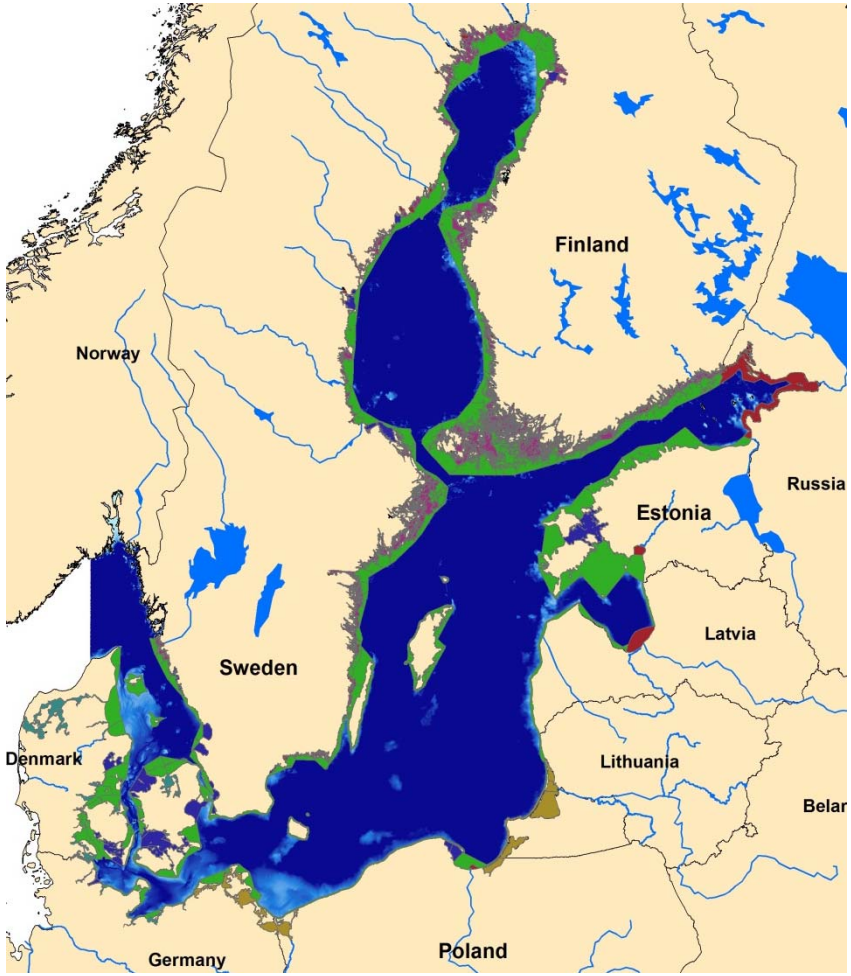
cocoa

Nutrient cocktails in the coastal zone of the Baltic Sea

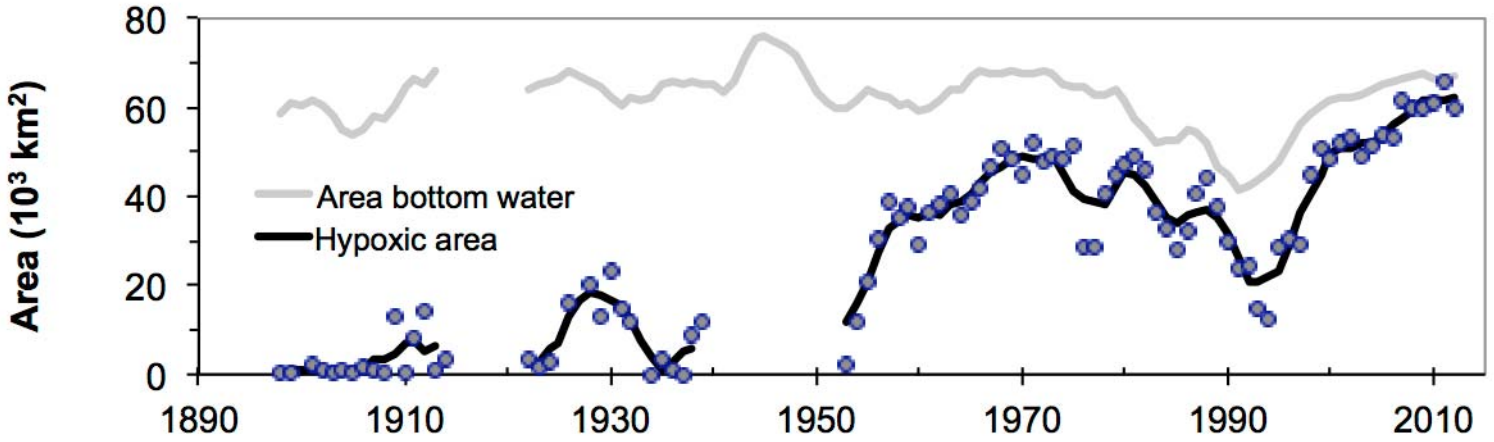
BONUS

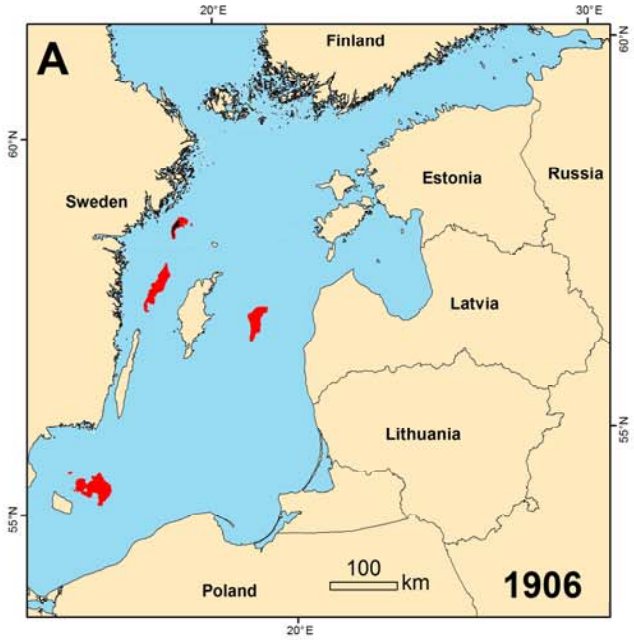
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

How effective is the coastal zone for removing nutrients?

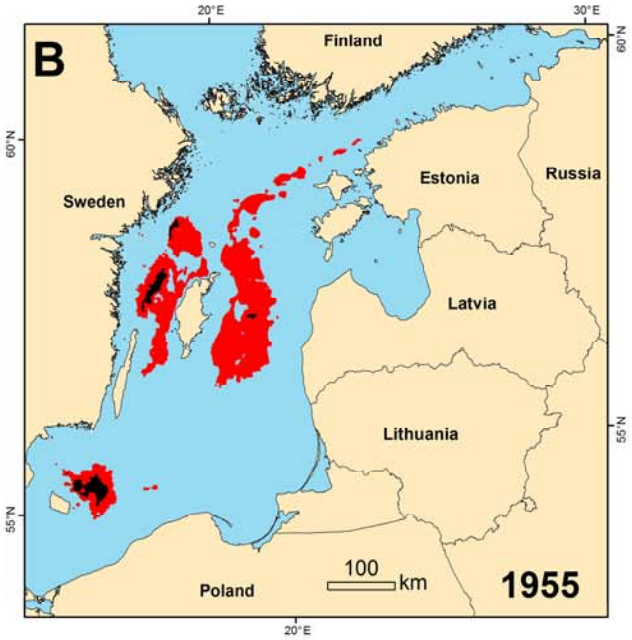


Development of hypoxic area (<2 mg/L) through time

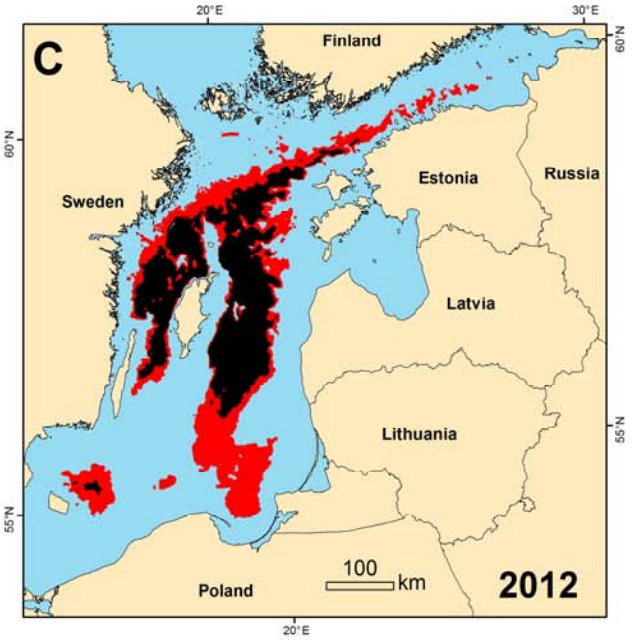




1,500 km^2

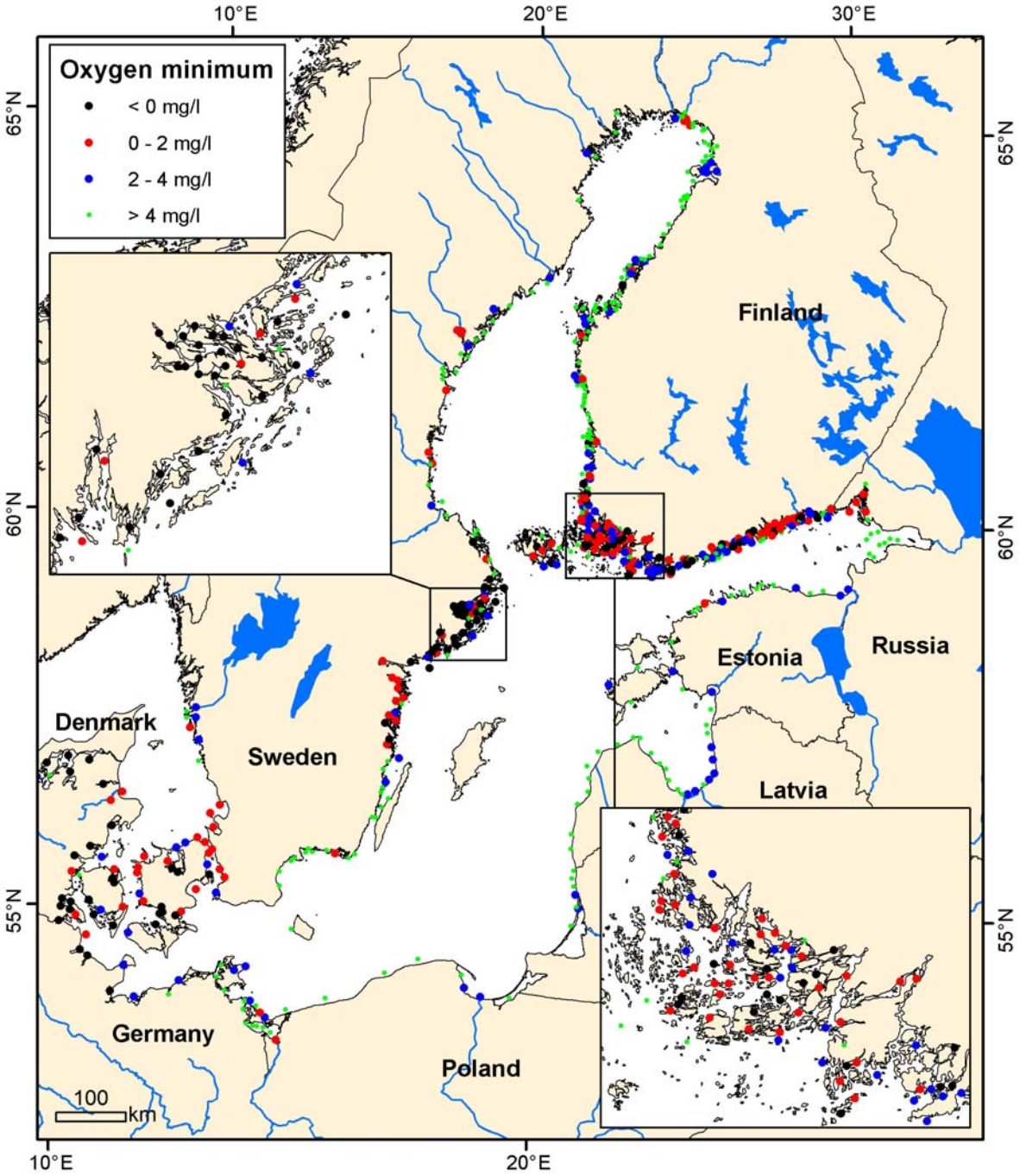


25,000 km^2



65,000 km^2

Carstensen et al. (2014)



Mininum oxygen concentrations (1955-2009)

215 sites out of 613 coastal units have experienced hypoxia

Conley et al. 2011

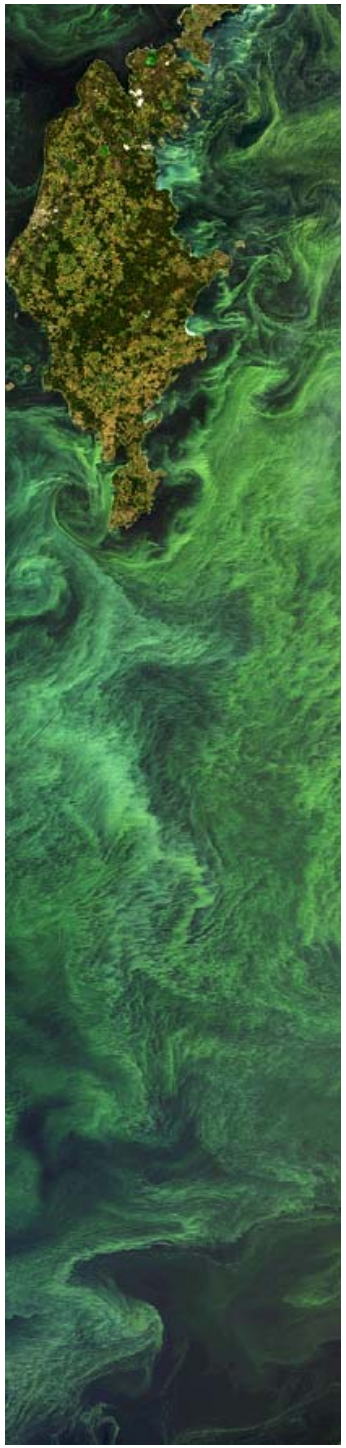
HYPER and COCOA BONUS Projects have advanced our scientific understanding of processes in the Baltic Sea.

WHO NEEDS THE INFORMATION???

Our results have:

Helped with the Baltic Sea Action Plan process.

Provided important information to stakeholders including environmental ministries, HELCOM, the European Union, NGOs, local and regional authorities and the public.



Geoengineering, but why?

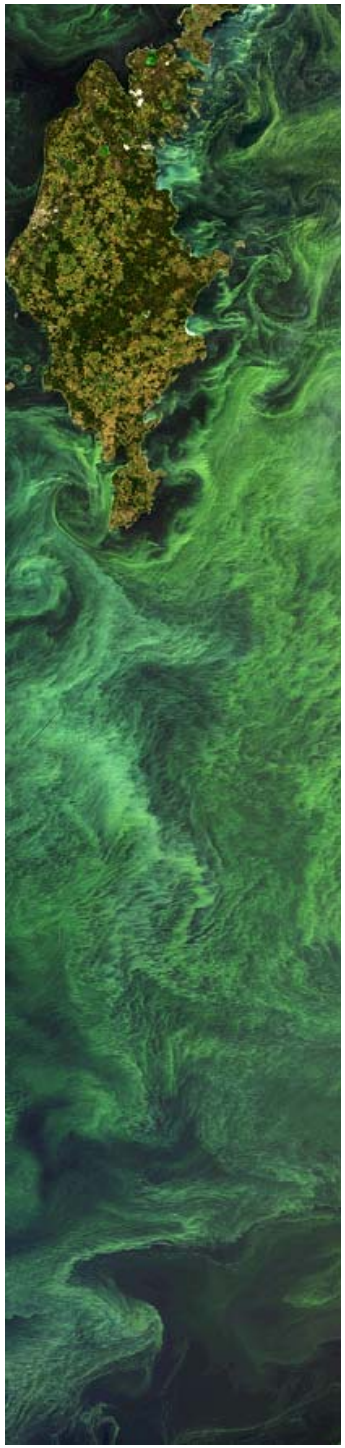
Time scale of improvement is long (decades)

- Geoengineering provides rapid improvements

Costs of nutrient reductions to society are enormous

- Geoengineering is a cheaper alternative

Popular in the media and politically attractive



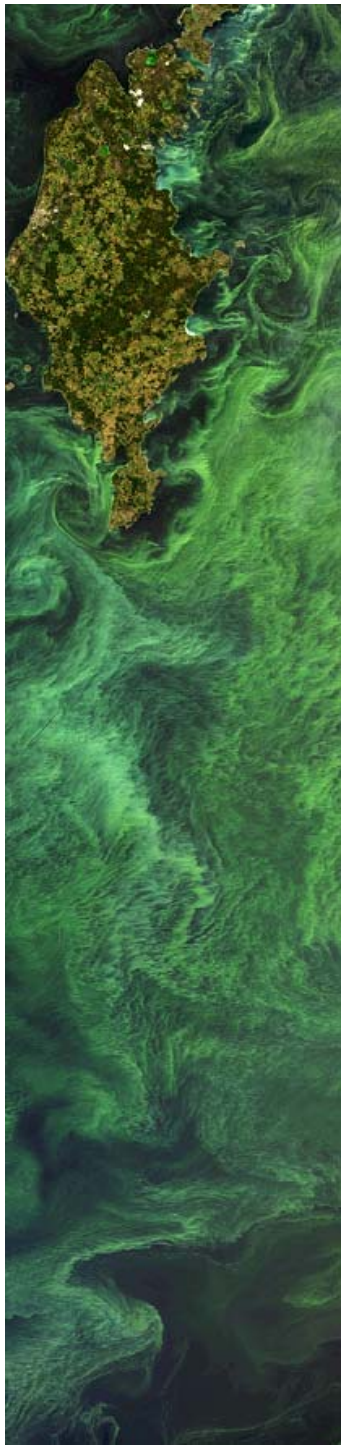
Can we add oxygen to the Baltic?

(Conley et al. 2009, *ES&T*)

The hypoxic area (oxygen < 2 mg/l) averages 49,000 km^2

Would require 2-6 million tons oxygen to be added each year

20,000-60,000 railway cars of liquid oxygen each year to keep bottom waters oxic



Different geoengineering options

(Conley et al. 2009, *ES&T*)

1) Turn the Baltic Sea into lake

2) Increase saltwater inputs into the Baltic
   Strengthens permanent stratification, increases hypoxia

3) Halocline ventilation by mid-water mixing
   Potentially serious ecological effects, unsure it will work
   Scientific, legal, consumer and management questions

4) Phosphorus sequestration
   Costs, London Convention

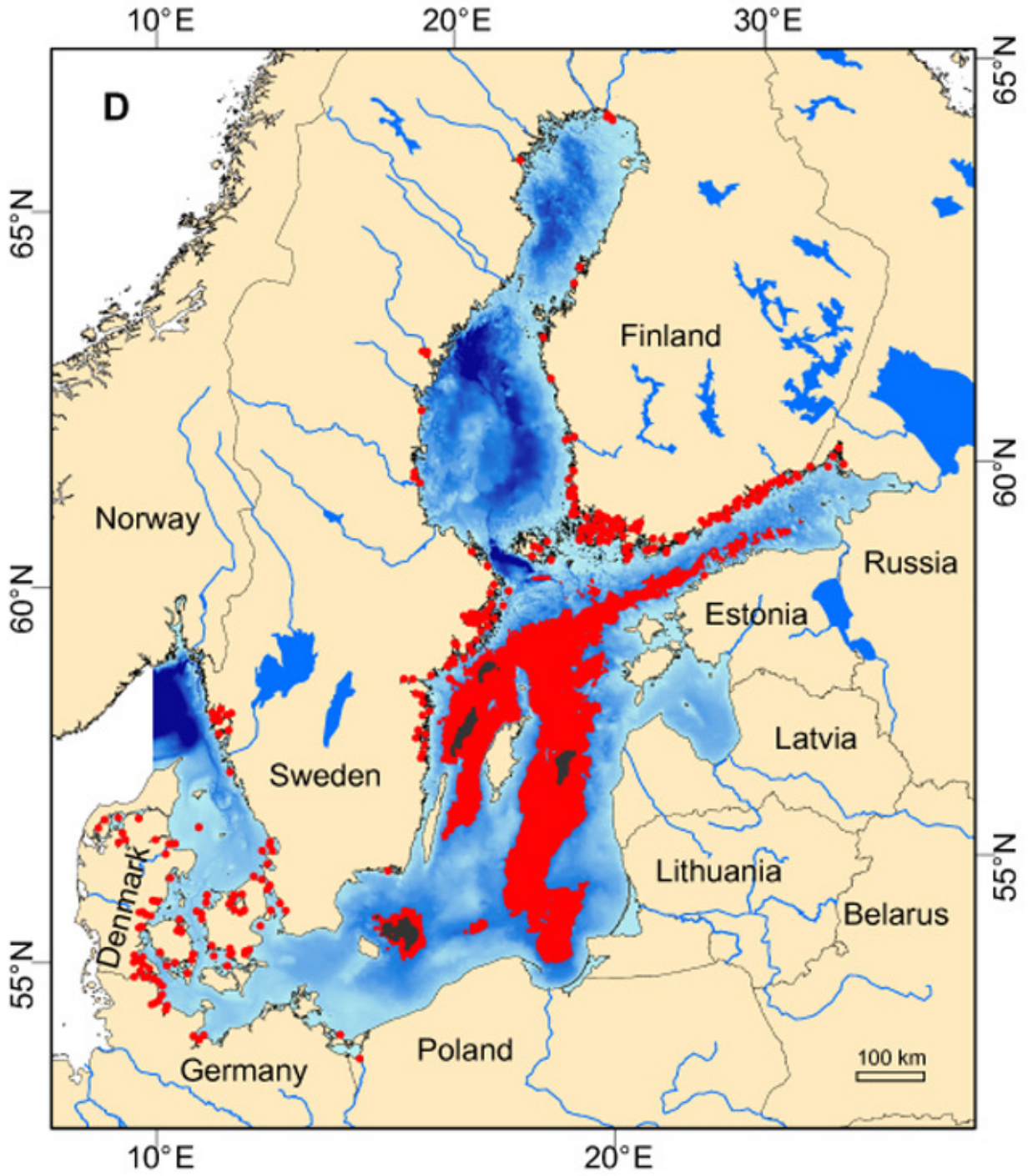
5) Nutrient removal by biological means
   Mussels, sea squirts, macroalgae

6) Dredge out the sediments in the Baltic Sea and recover the phosphorus and metals

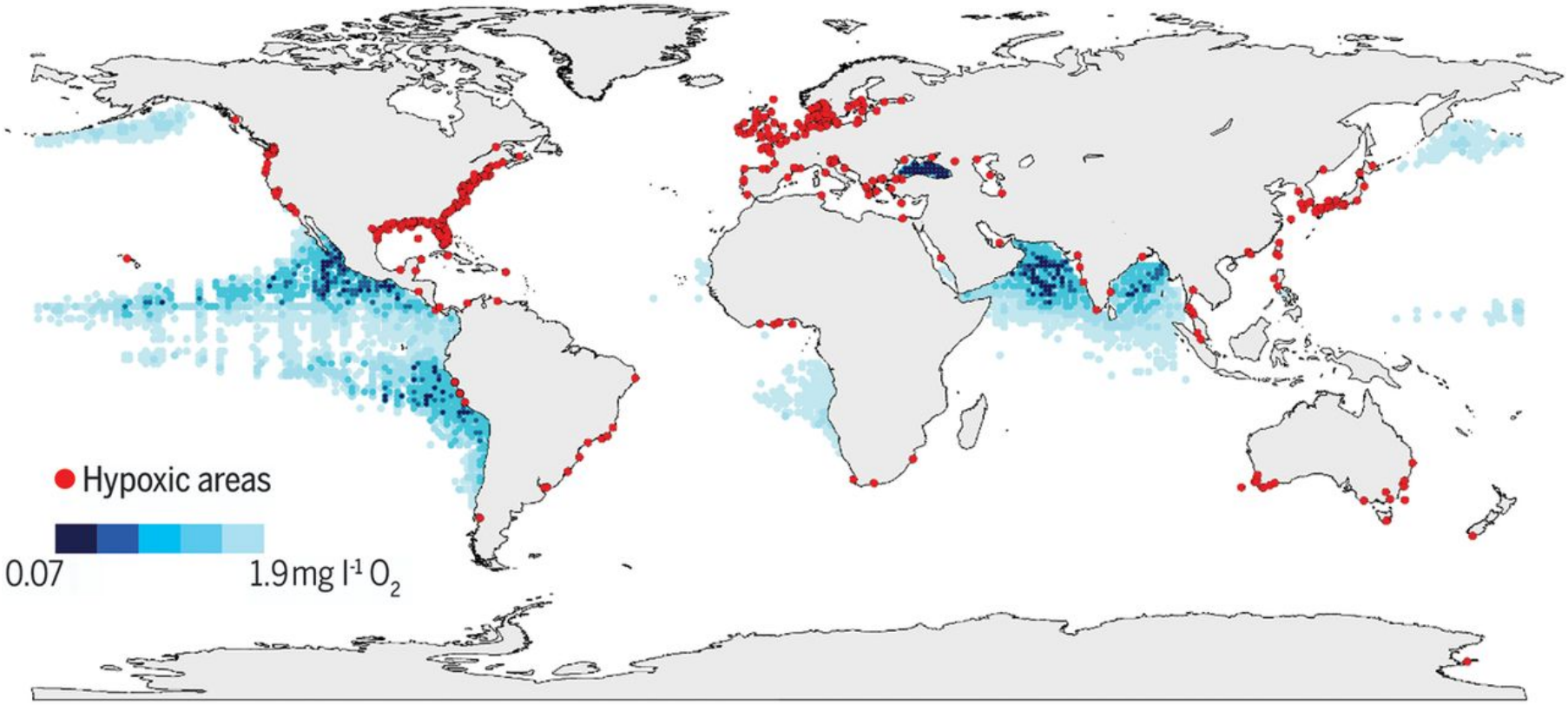
Pathway to a healthier marine ecosystem based on

- Basic knowledge
- Monitoring & Assessment
- Governance & Management
- Action
- Need to speed up implementation of BSAP

How do our results compare internationally?



Sharp increases in both deoxygenation and ocean heat content beginning in the mid 1980s



Breitburg et al. (2018) *Science*

Low declining oxygen levels affect processes ranging from biogeochemistry to food security.

We recommend that the issue be addressed from three angles:

- Address the causes: nutrient pollution and climate change. While neither issue is simple or easy, the steps needed to win can benefit people as well as the environment.

- Protect vulnerable marine life. Some low oxygen areas are unavoidable, however, it is crucial to protect at-risk fisheries from further stress.

- Improve low-oxygen tracking worldwide. Enhanced monitoring together with numerical models will help pinpoint which places are most at risk and determine the most effective solutions.

Thanks for listening!

QUESTIONS???