Baltic Earth/BEAM Summer School
Askö 2015-08-28

Stockholm University

The Baltic Proper Ecosystem & Climate Change

Ragnar Elmgren
Dept. Ecology, Environment & Plant Sciences
Stockholm University

Take home message:

We are still extremely uncertain how climate change will affect the Baltic ecosystem.

Why?

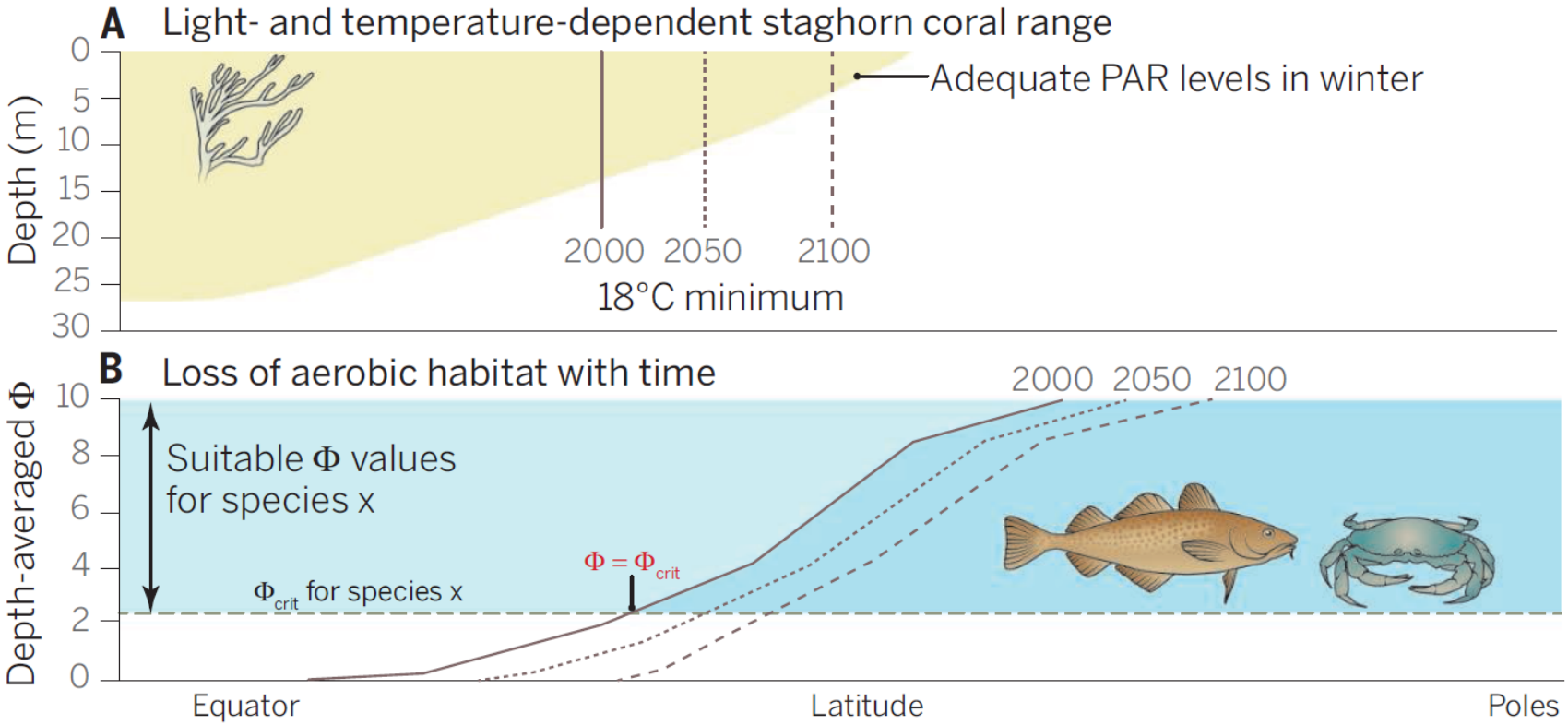
- Ecological predictions require climate predictions, down-scaled
- Climate predictions require
  - Climat models, ensembles of
  - Emission assumptions
  - Assumptions on land-use
  - Ecological feed-back
- Downscaling not trivial

Why?

Ecological predictions also

- Require a tested mechanism and/or empirical relation
- Normally use models, which are neccessarily gross simplifications
- Seldom include effects of potential invasive spp.
- Need to take other anthropogenic changes into account (nutrients, overfishing, hydrology changes, contaminants)

Not only temperature matters, but also light, oxygen and, for the Baltic in particular, salinity



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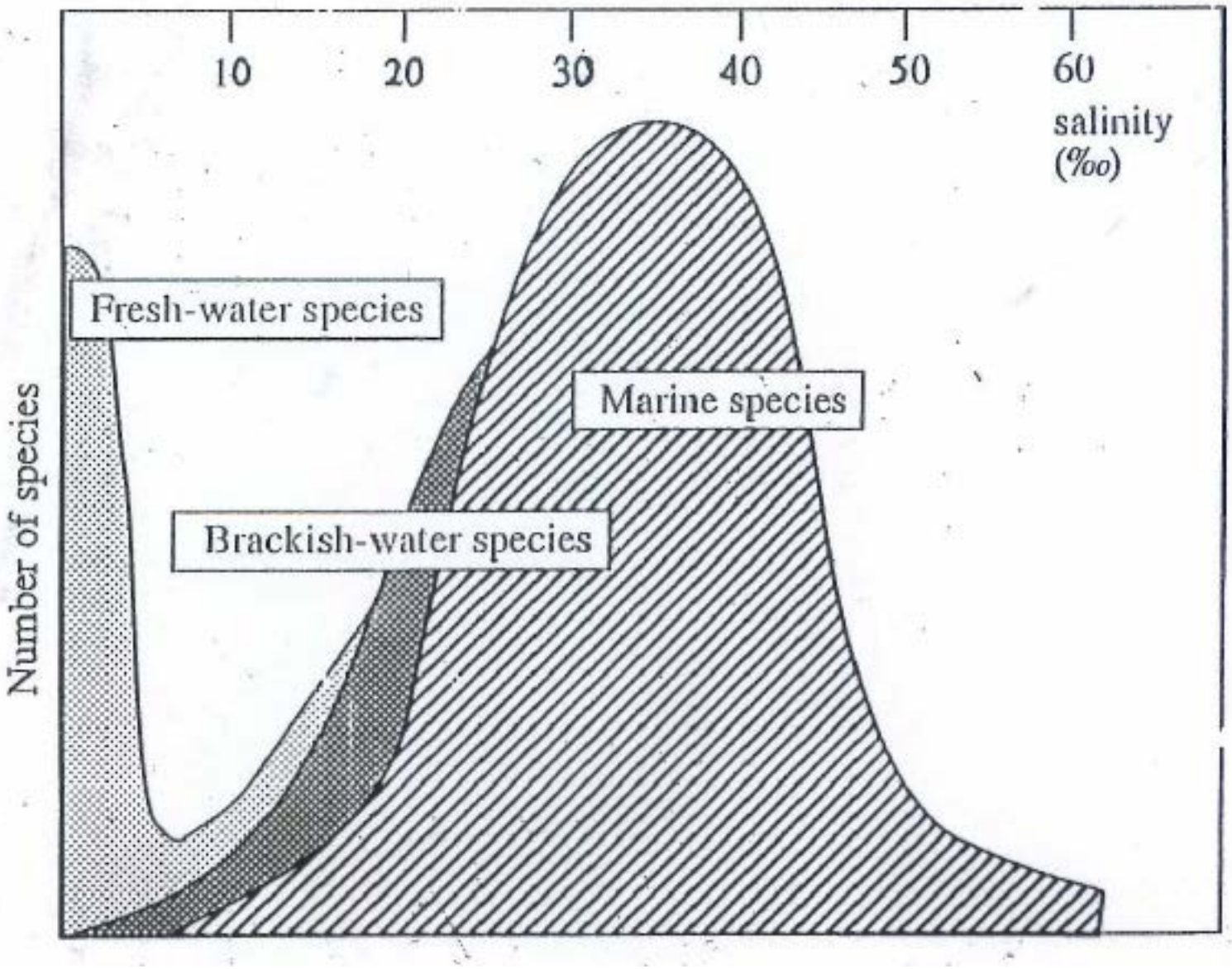
Source: Klepas, J. 2015. Science 348: 1086-1087


10
20
30
40
50
60
salinity
(‰)
Number of species
Fresh-water species
Marine species
Brackish-water species

Therefore:

To predict with any confidence we need

- **Model prediction(s)**
- **A proven ecological mechanism**
- **Data showing effect in nature**

I will explore some effects and mechanisms relating to Baltic plankton

Still,

This does not rule out surprises due to

- **Non-linear effects**
- **Regime shifts**
- **Invasive species**

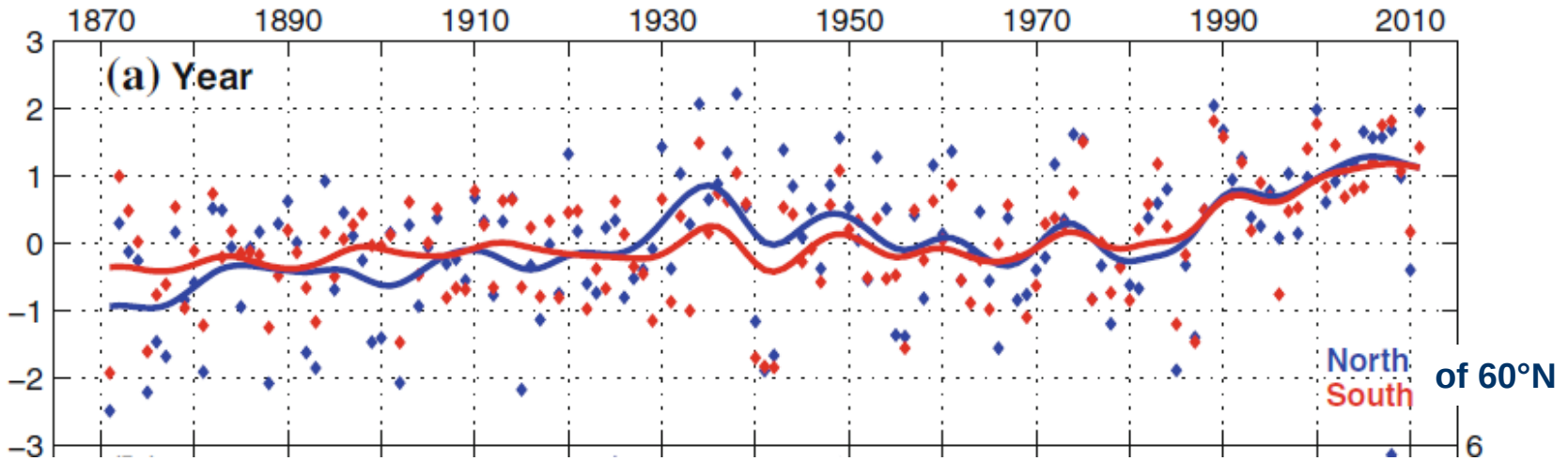
”Can *Cylindrospermopsis raciborskii* invade the Baltic Sea?” Engström-Öst et al. 2015.

We have near-agreement that in the Baltic area

- CO_2 concentrations will increase
- Temperature will increase
- There will be less winter ice
- Absolute sea level will rise

Baltic Sea Basin air temperature

1871-2011, relative to 1960-1991



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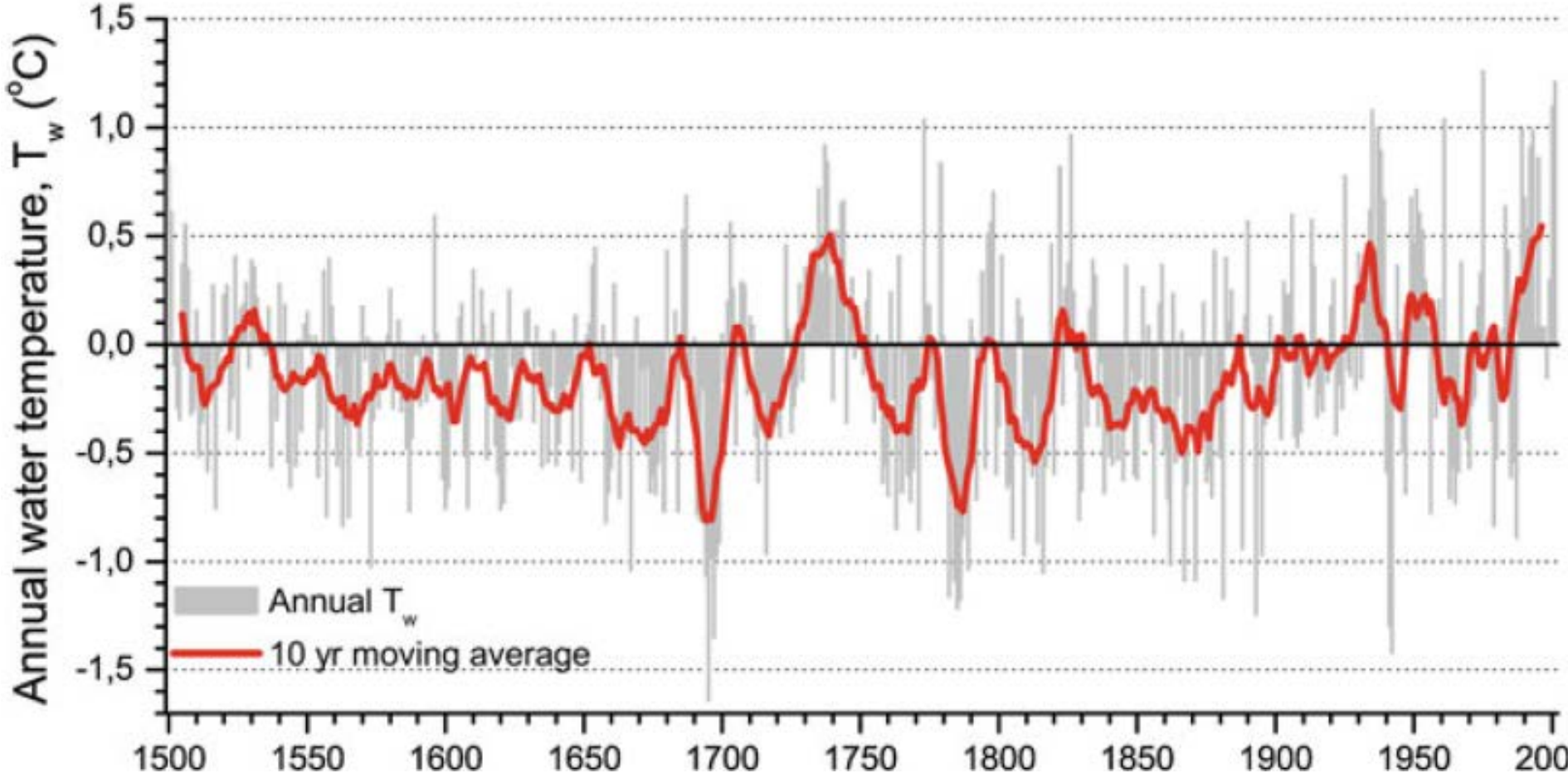
Source: BACC II Book 2015

Baltic Sea mean water temperature

1500-2001, modelled, relative to 1900-1999



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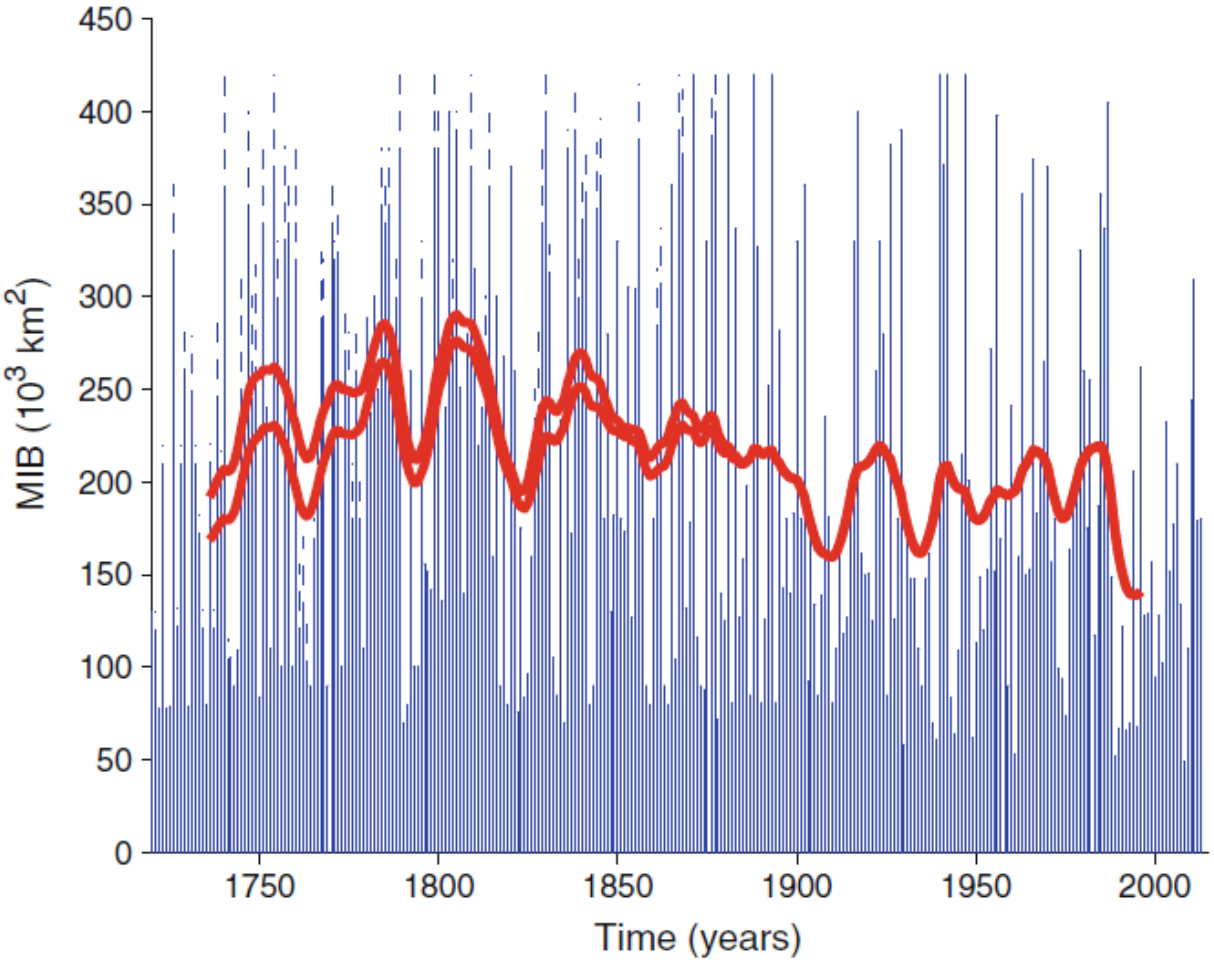
Source: Hansson and Omstedt 2008

Baltic Sea maximum ice cover

1720-2012, 30-year moving average in red



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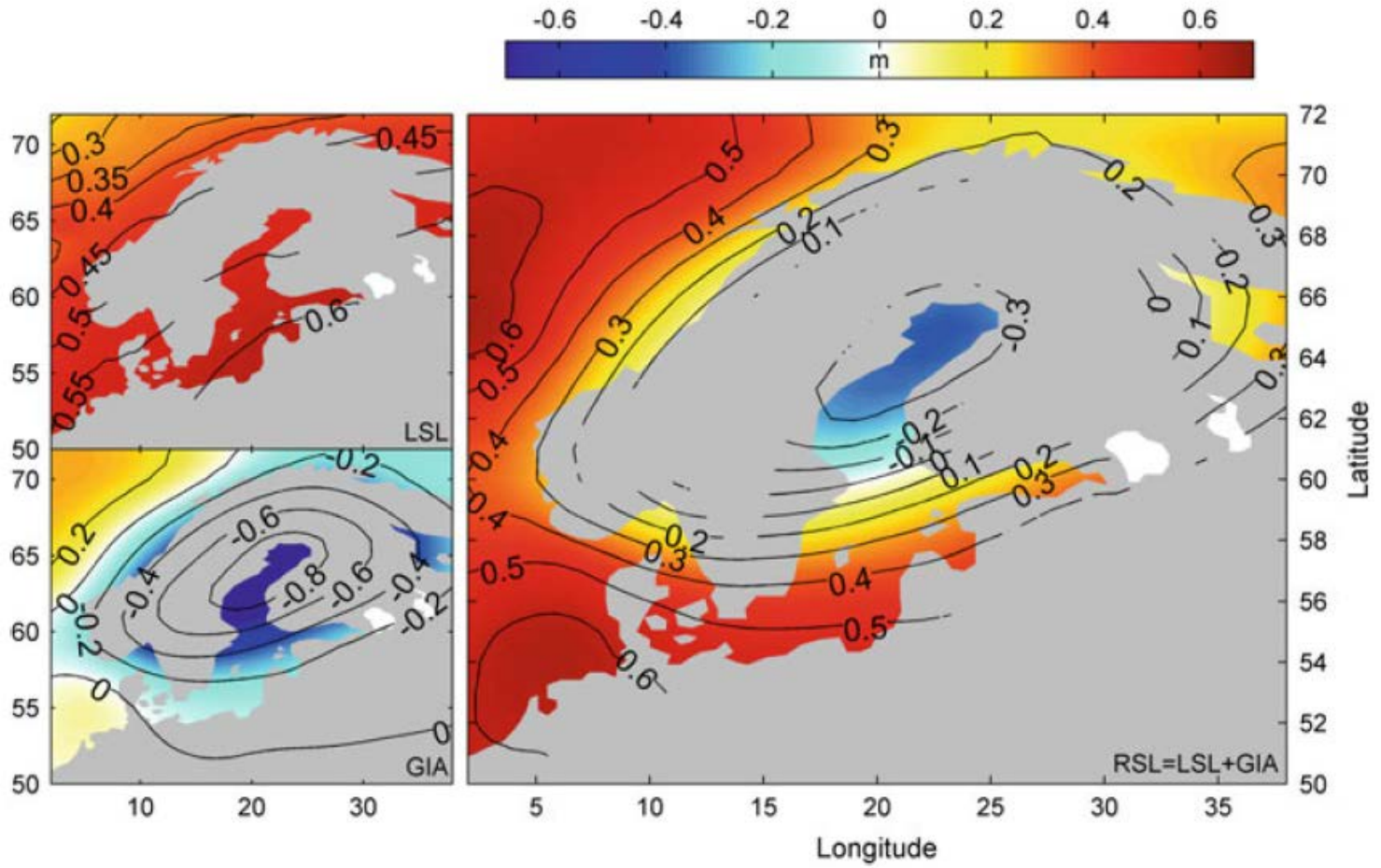
Source: BACC II Book 2015

Baltic Sea relative sea level,

projected for 2090-2099, relative to 1990-1999



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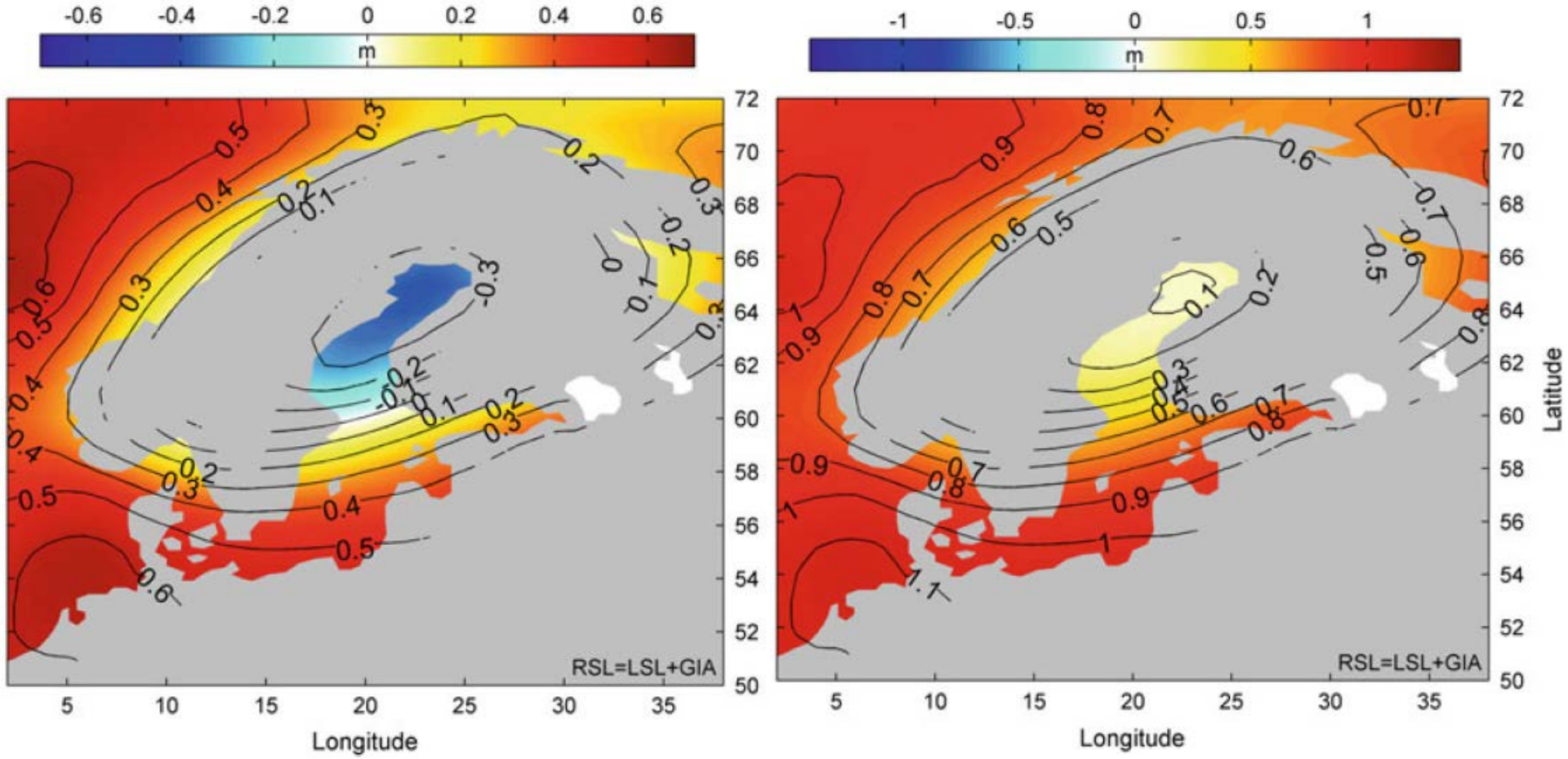
Source: BACC II Book 2015

Baltic Sea relative sea level,

projected for 2090-2099, relative to 1990-1999, high-end case at left



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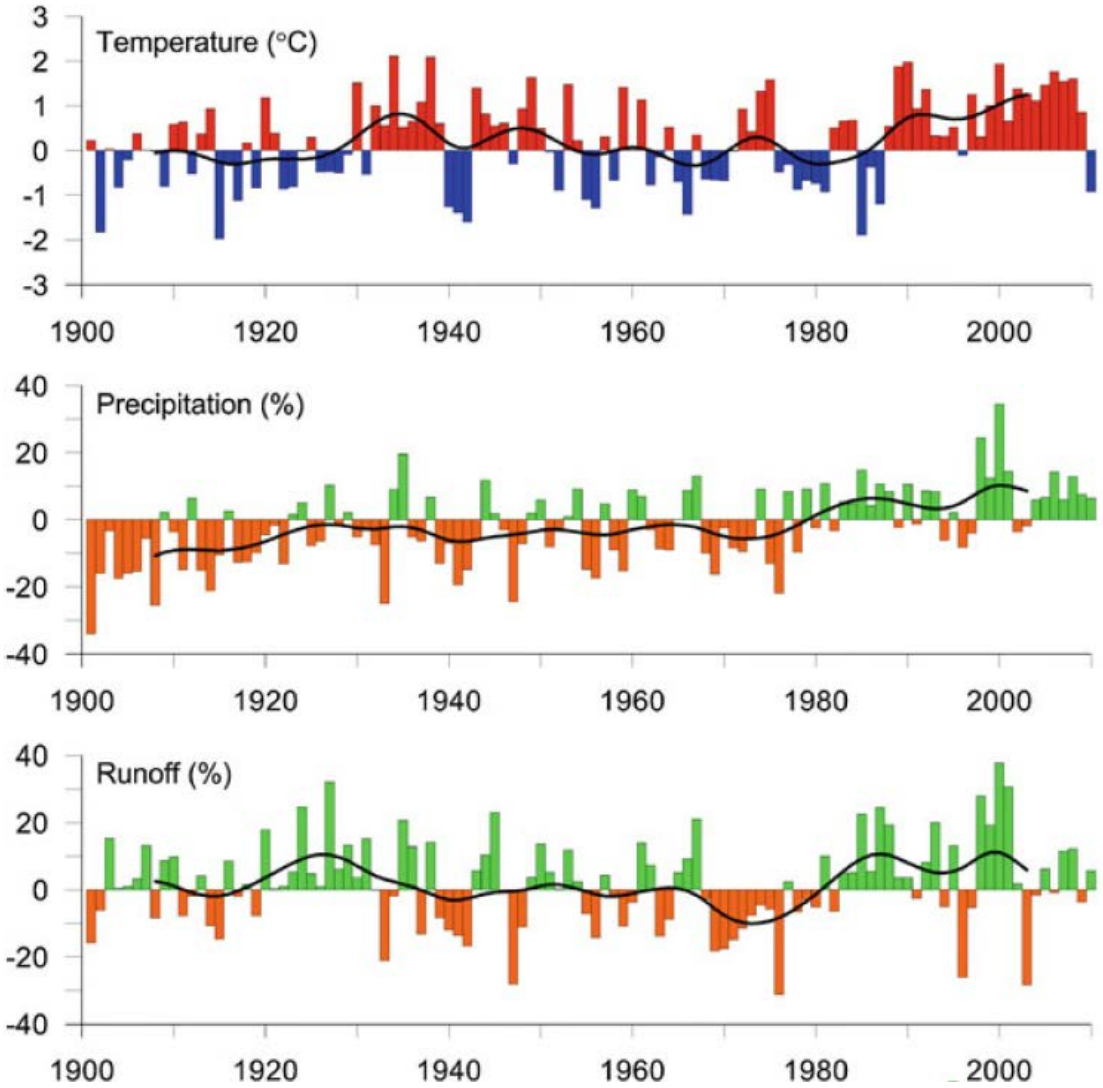
Source: Hill et al. 2010

It also seems highly likely that

- Baltic water pH will decrease
- Precipitation & runoff will increase
- Coastal erosion will increase

Climate anomalies for Sweden

1901-2010, relative to 1960-1990



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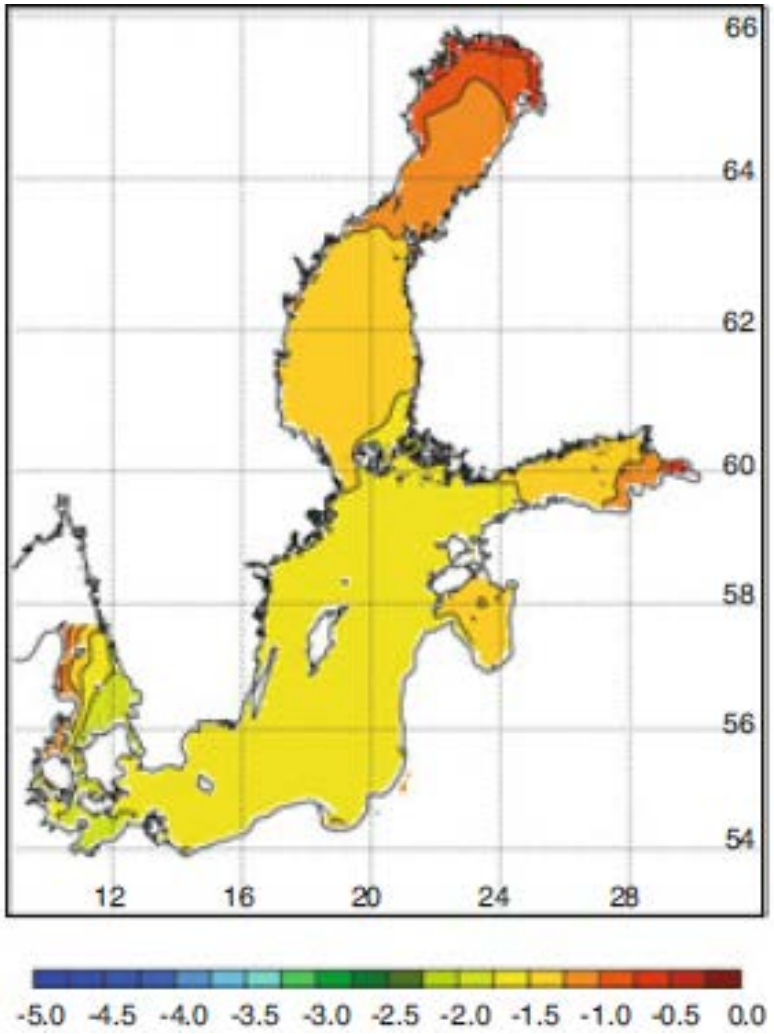
Source: Hellström and Lindström 2008

We don’t know about

- Winds and storms
- Time and place of precipitation
- Major Baltic inflows
- Salinity effect of changes
- Clouds
- Immigration & invasion of species
- Many ecological interactions

Baltic Sea salinity projected for 2068-2098,
relative to 1978-2007



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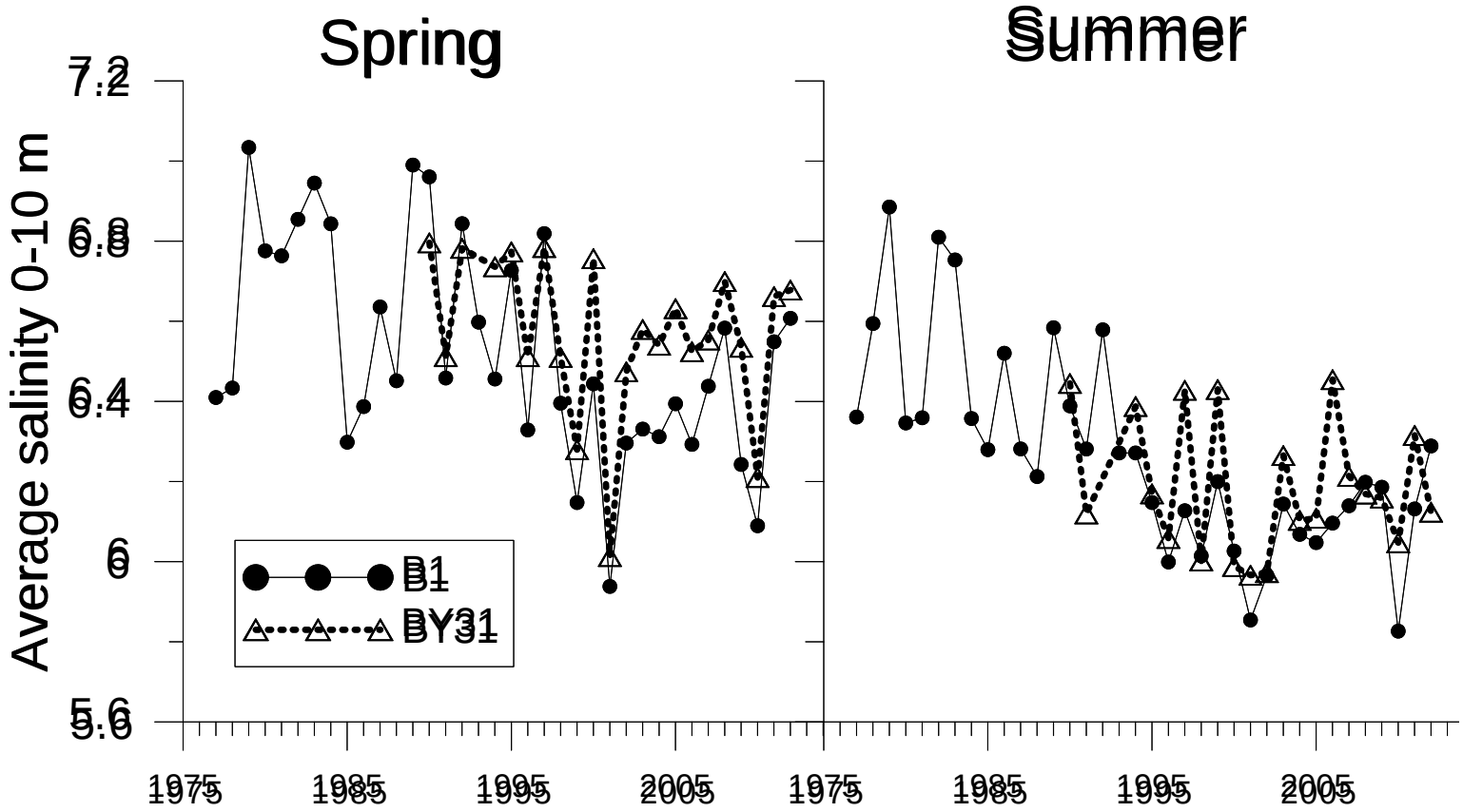
Source: Meier et al.2012

Salinity near Askö, 0–10m, 1977-2012



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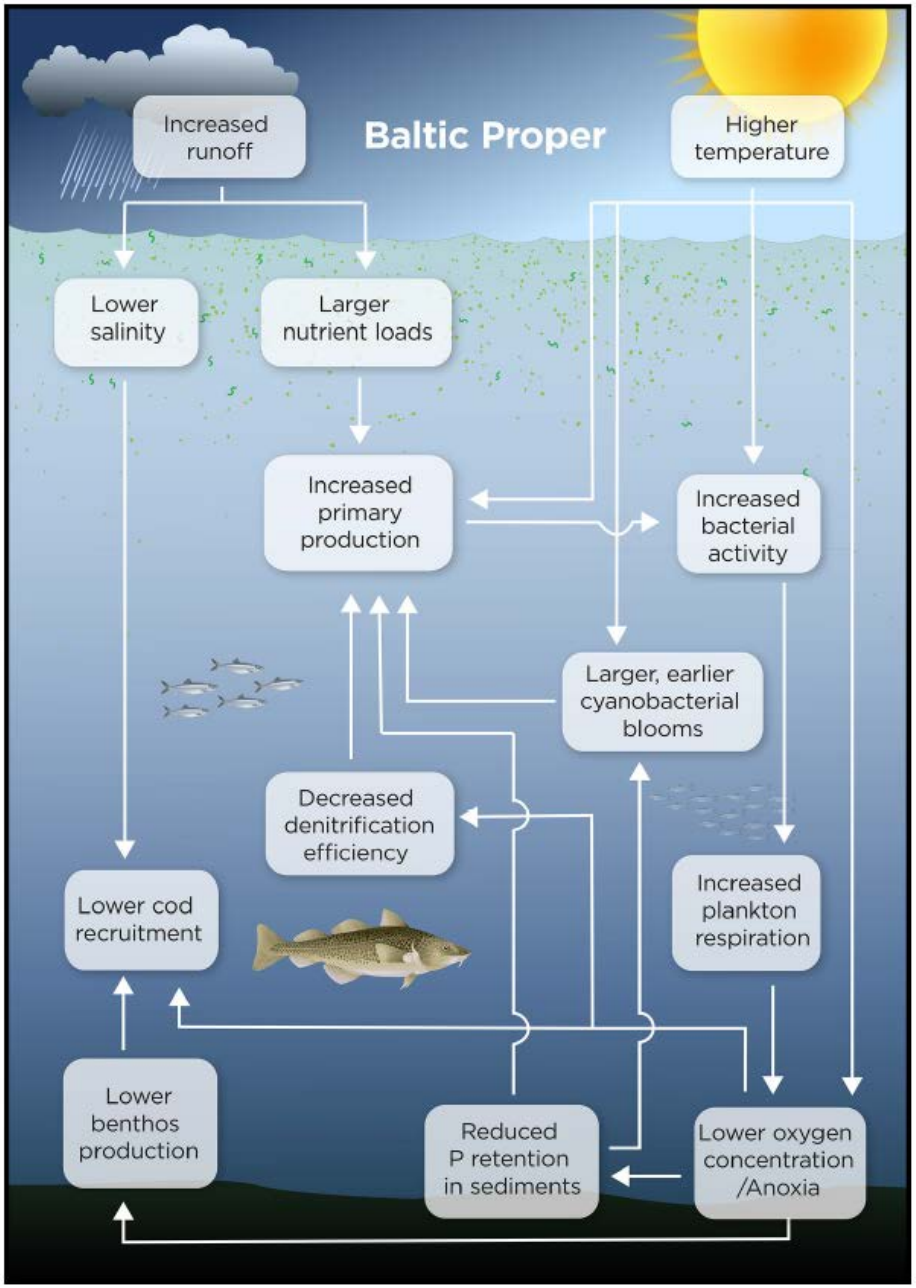
Source: Larsson, U. et al.
***In prep.* 2015**



Baltic Sea proper, conceptual model of likely climate-induced changes to 2100

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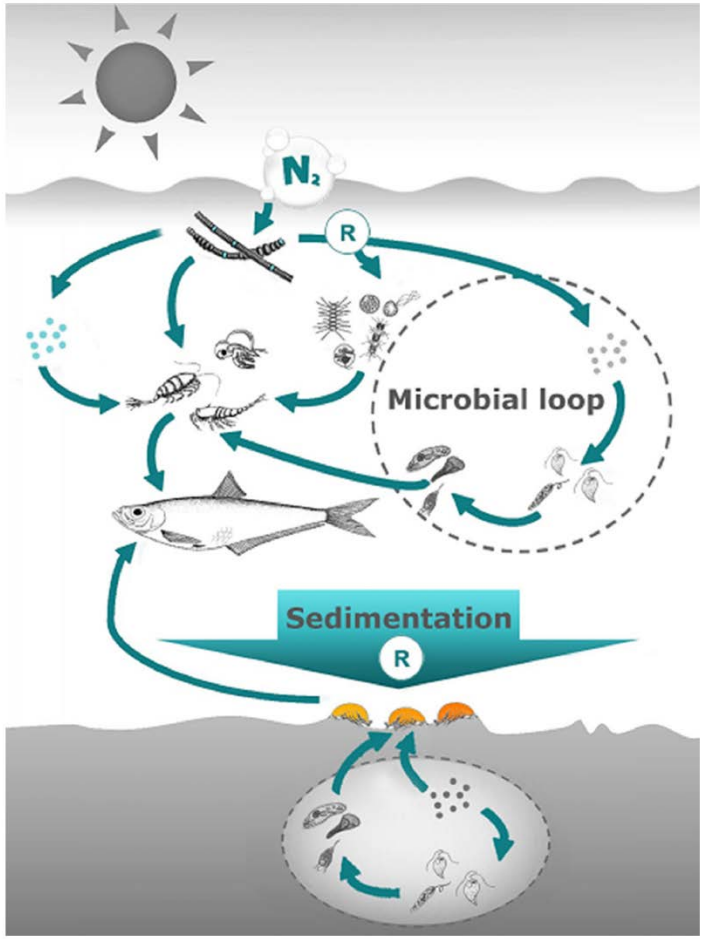
Source: Andersson et al. 2015

How bloom-forming cyanobacteria stimulate secondary production



N_2 = molecular nitrogen
R = reactive, bioavailable nitrogen

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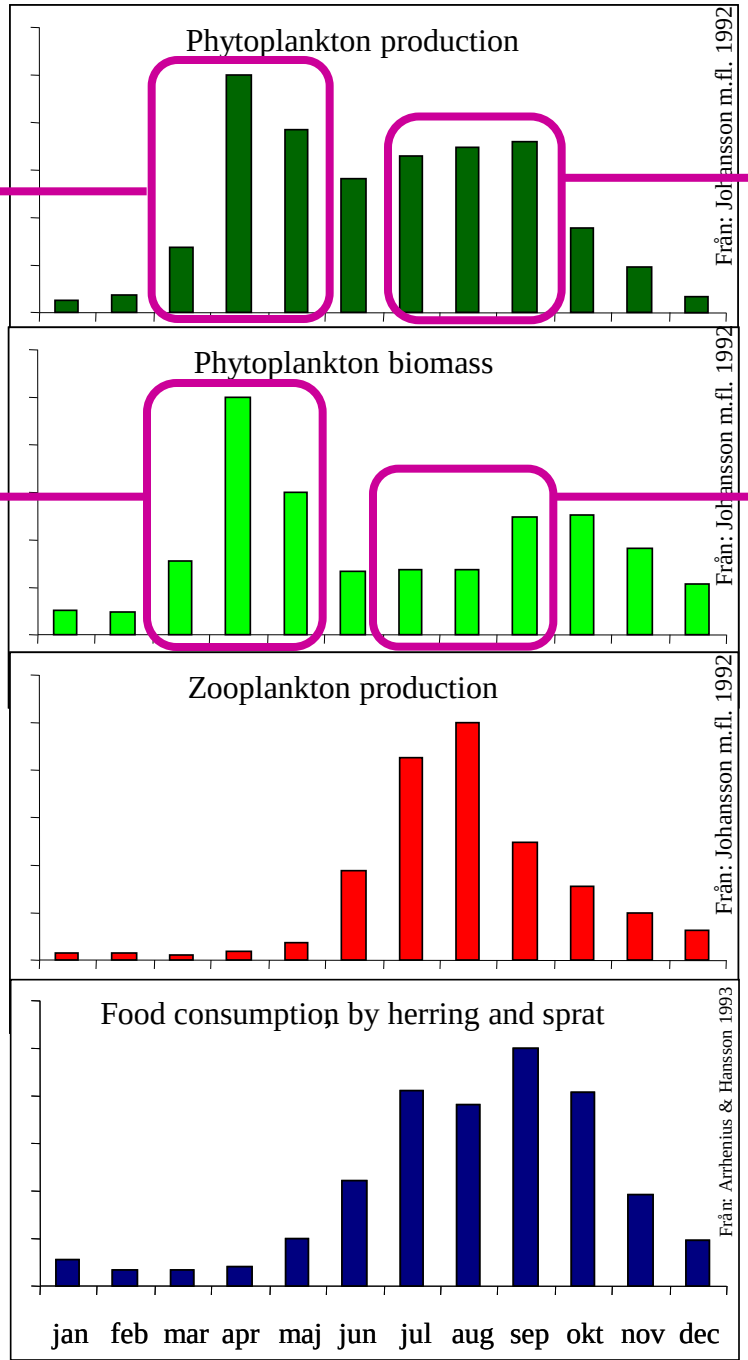
Source: Karlson et al. 2015

The Baltic proper production cycle

Production nitrogen-limited

Much sinks out



Cyanobacterial bloom provides nitrogen

Grazed by zooplankton, the main basis of Baltic fish production

Sources:
Johansson et al. 1992.
Arrhenius, Hansson 1993

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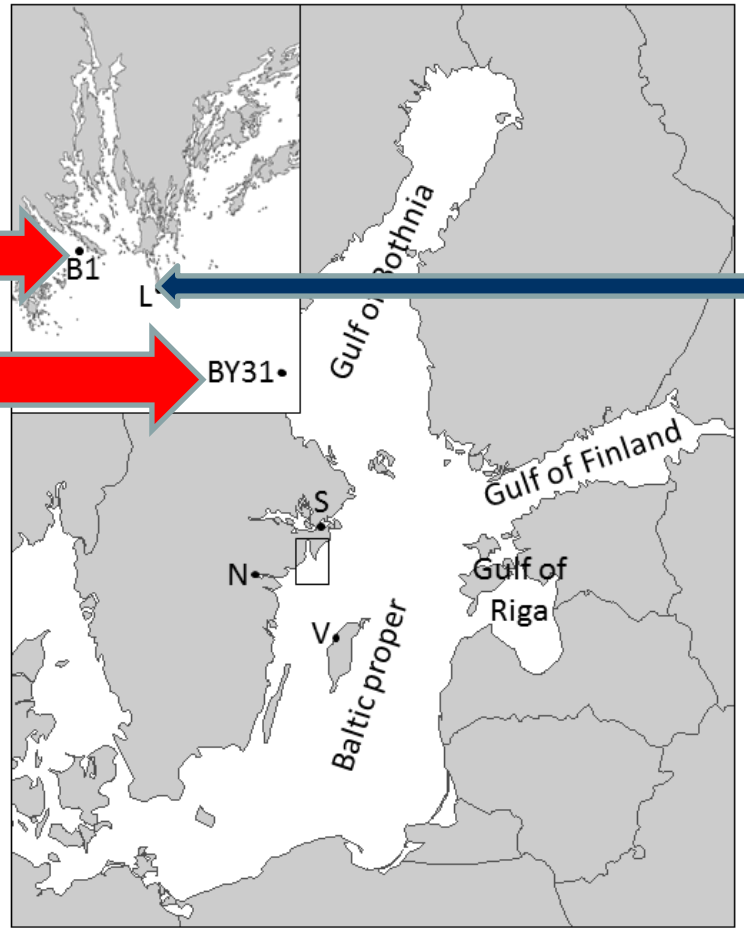
Study area



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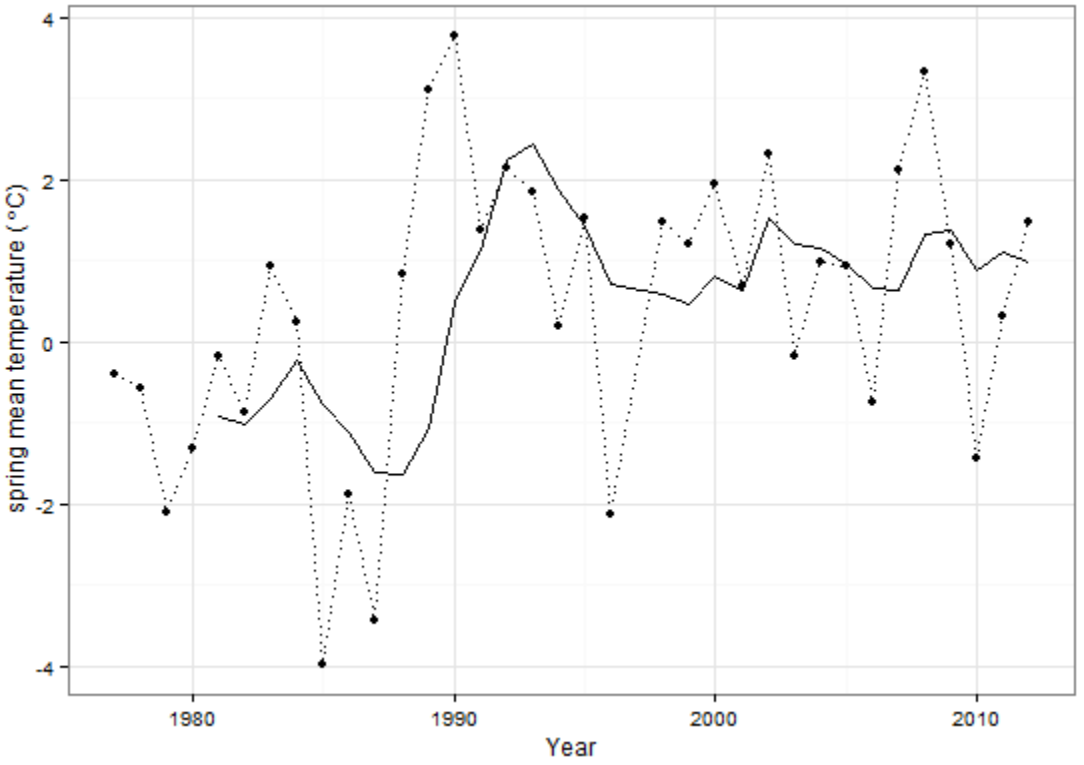
Map source: Hjerne, O. et al., submitted

Winter-spring (JFMA) air temperature at Landsort 1977-2012



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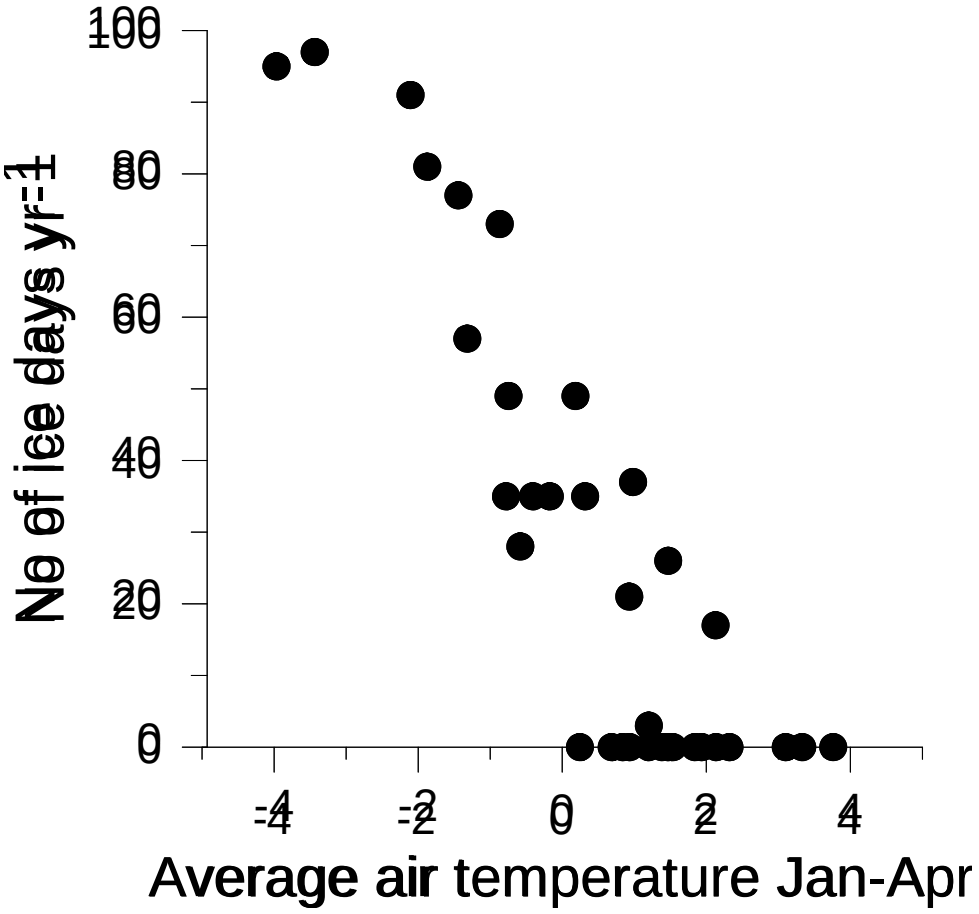
Source: Larsson, U. et al.
***In prep.* 2015**

Ice cover near Askö vs. air temperature in winter-spring (JFMA), 1977-2012



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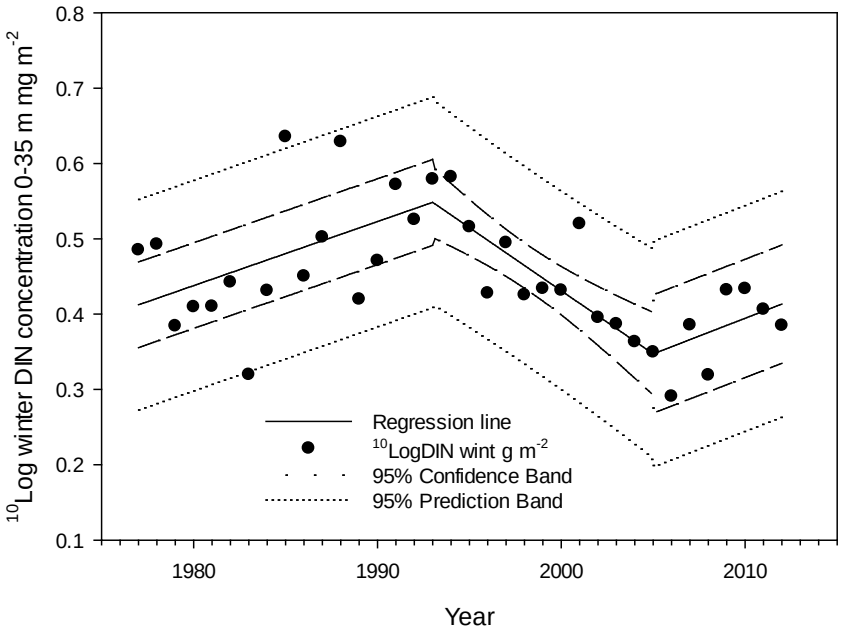
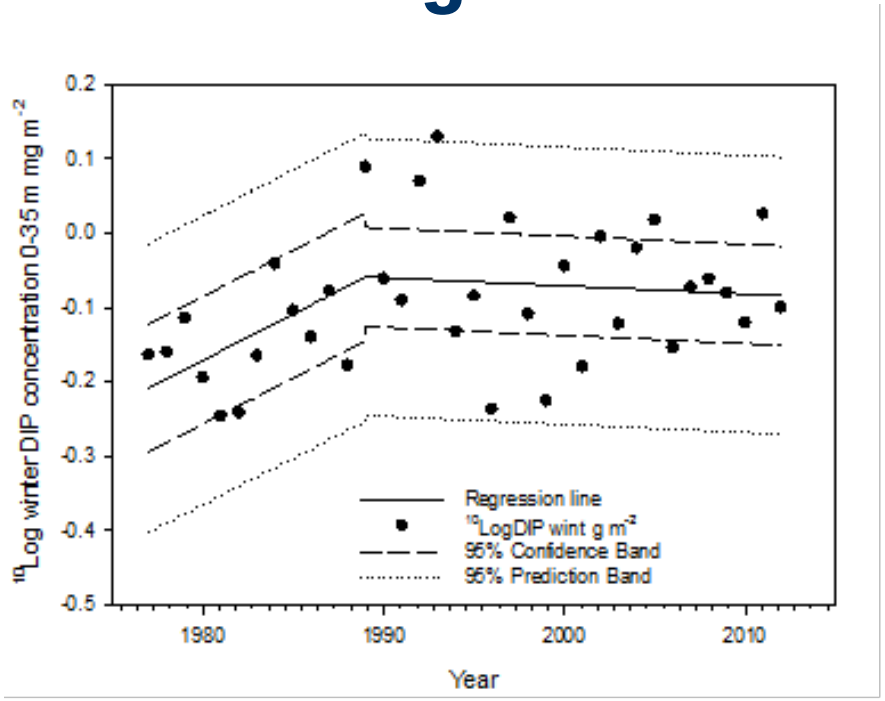
Source: Larsson, U. et al.
***In prep.* 2015**

Askö coastal inorganic nutrient winter (JF) concentrations (0-35m), 1977-2012

^{10}Log DIN



^{10}Log DIP



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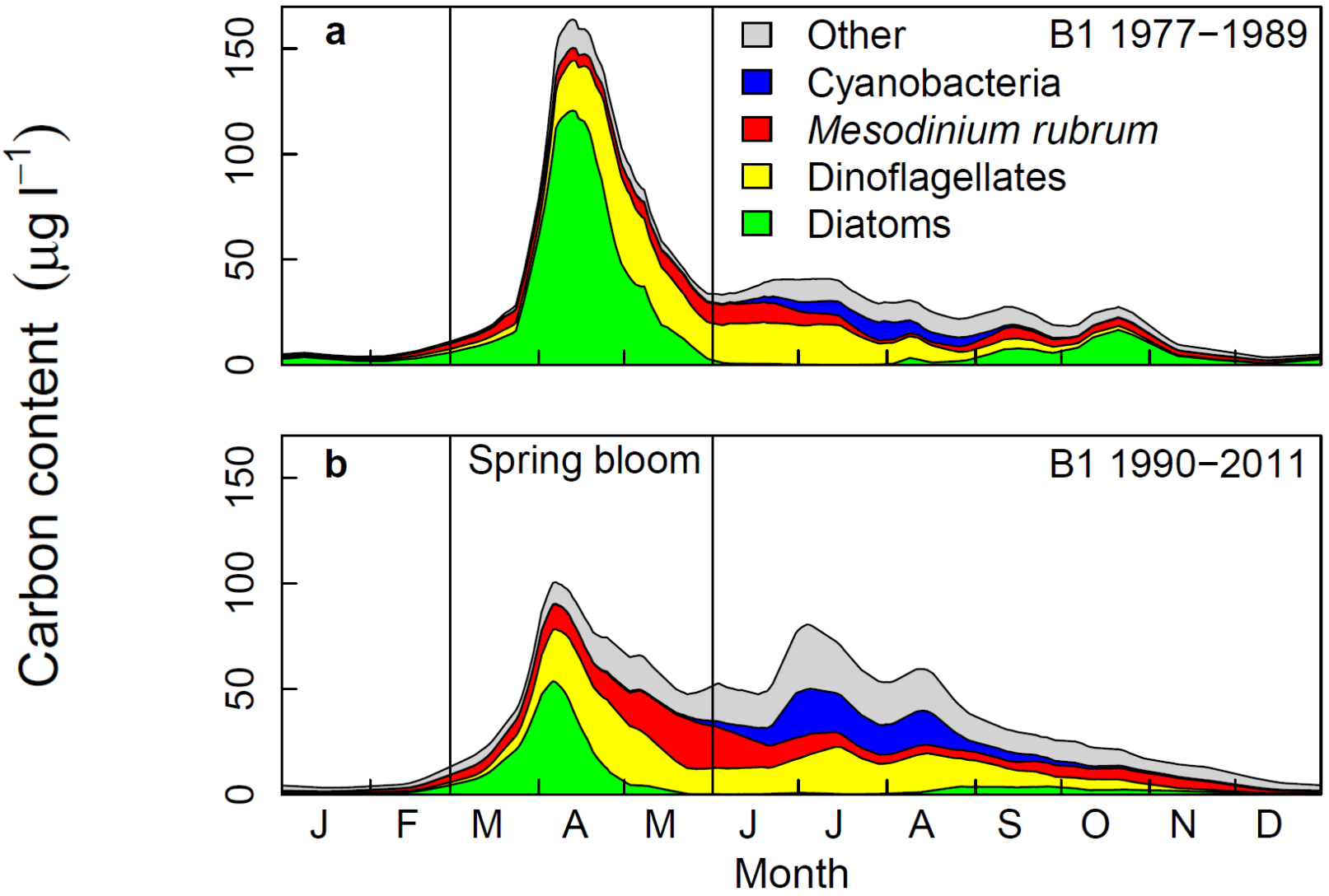
Source: Larsson, U. et al.
***In prep.* 2015**

Coastal phytoplankton annual dynamics



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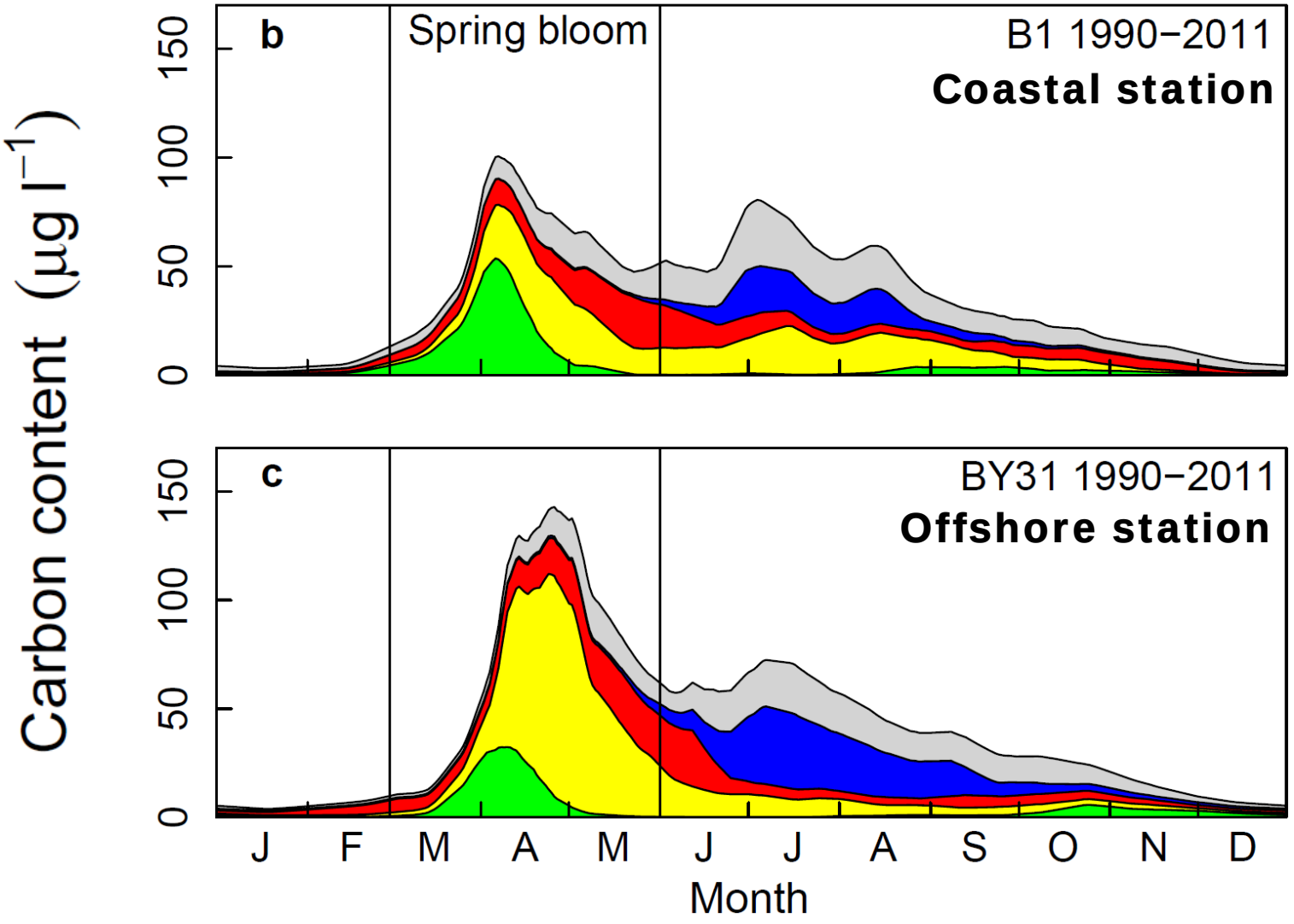
Source: Hjerne, O. et al., submitted

Baltic proper phytoplankton annual dynamics



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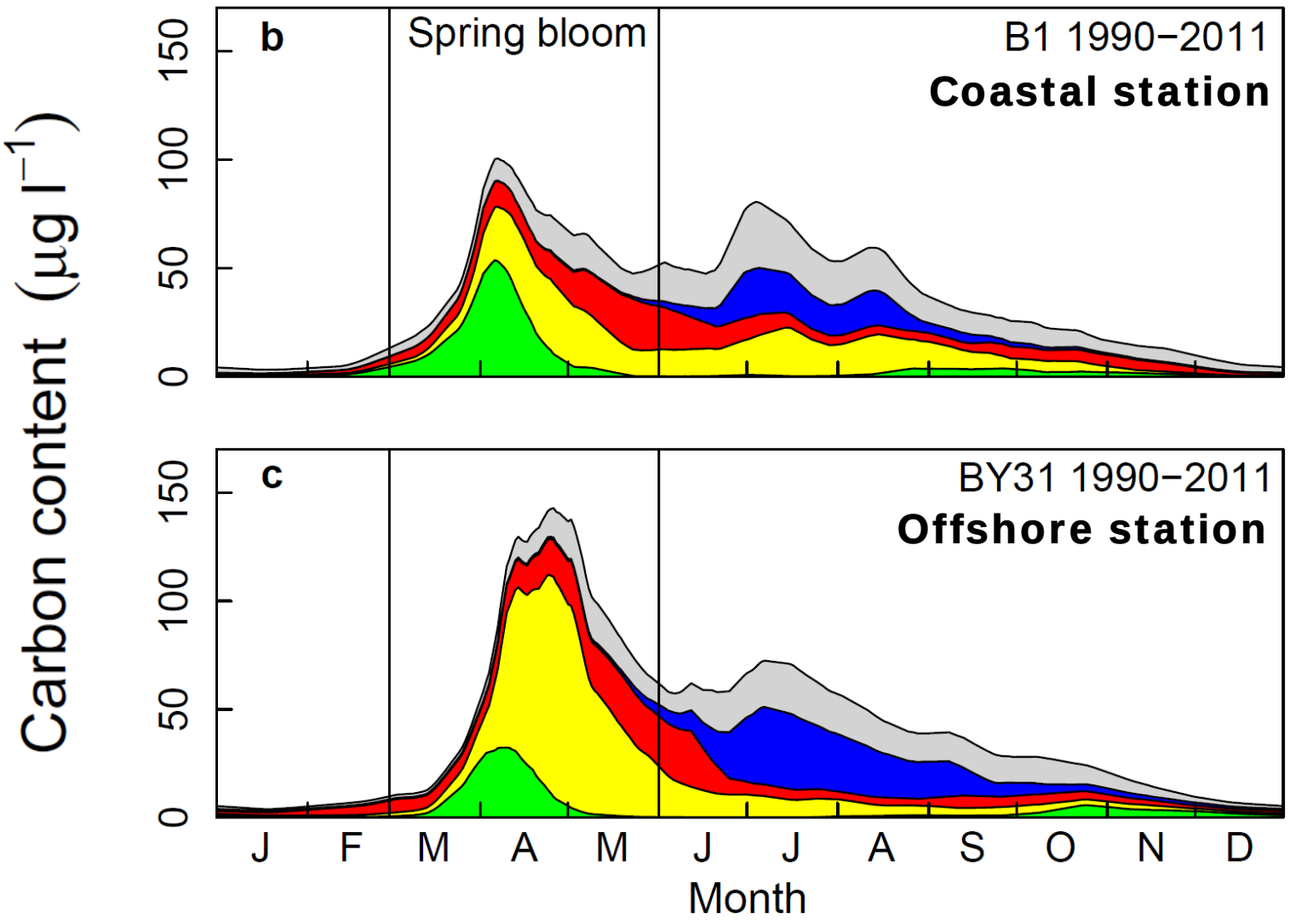
Source: Hjerne, O. et al., submitted

Baltic proper phytoplankton annual dynamics



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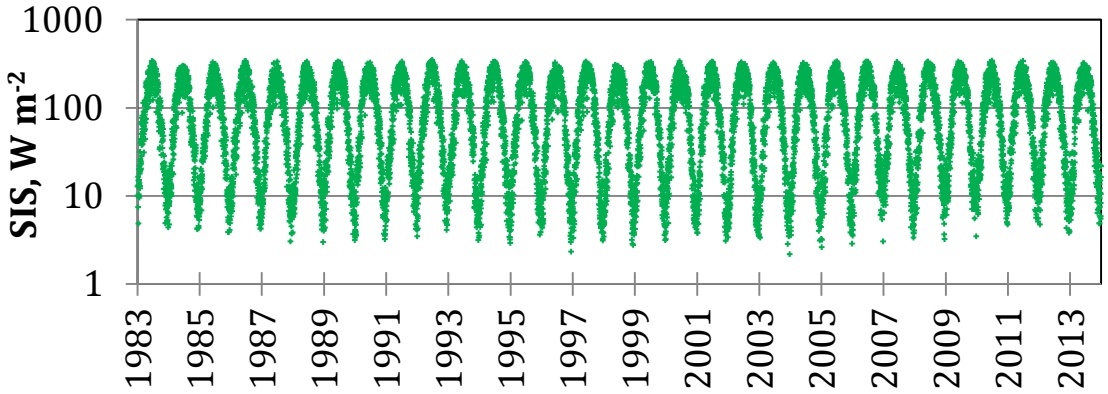
Stockholm University

Source: Hjerne, O. et al., submitted

Surface incoming shortwave irradiance (SIS),
from Meteosat sensors, averaged over the Baltic Sea.



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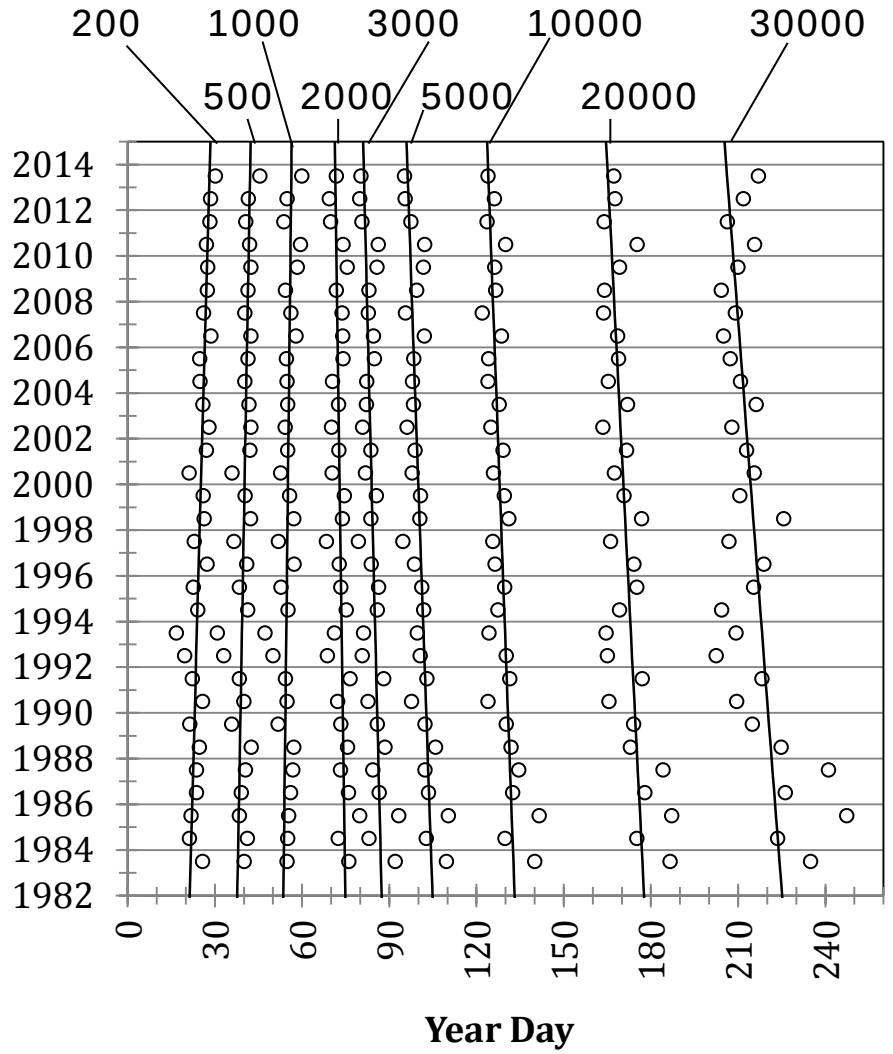
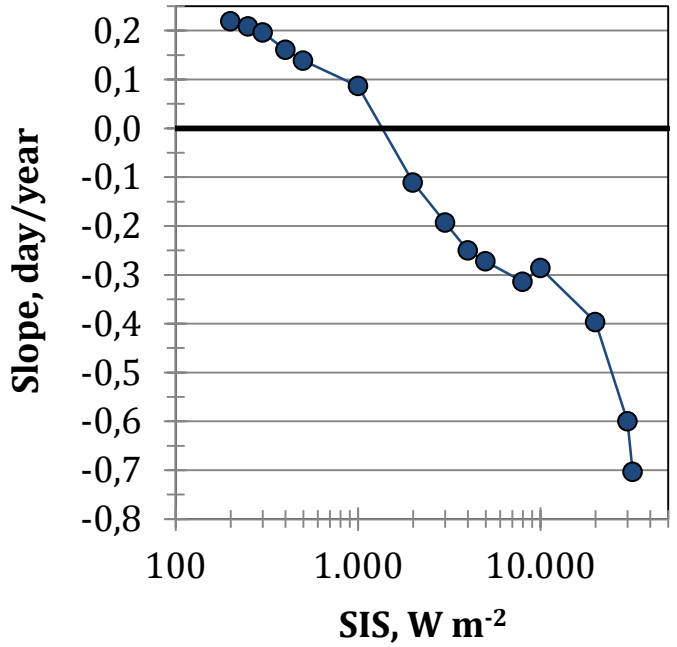
Source: Kahru, Elmgren, Savchuk, in prep.

Change in Baltic Sea cumulative surface incoming shortwave irradiance, Wm^{-2}.





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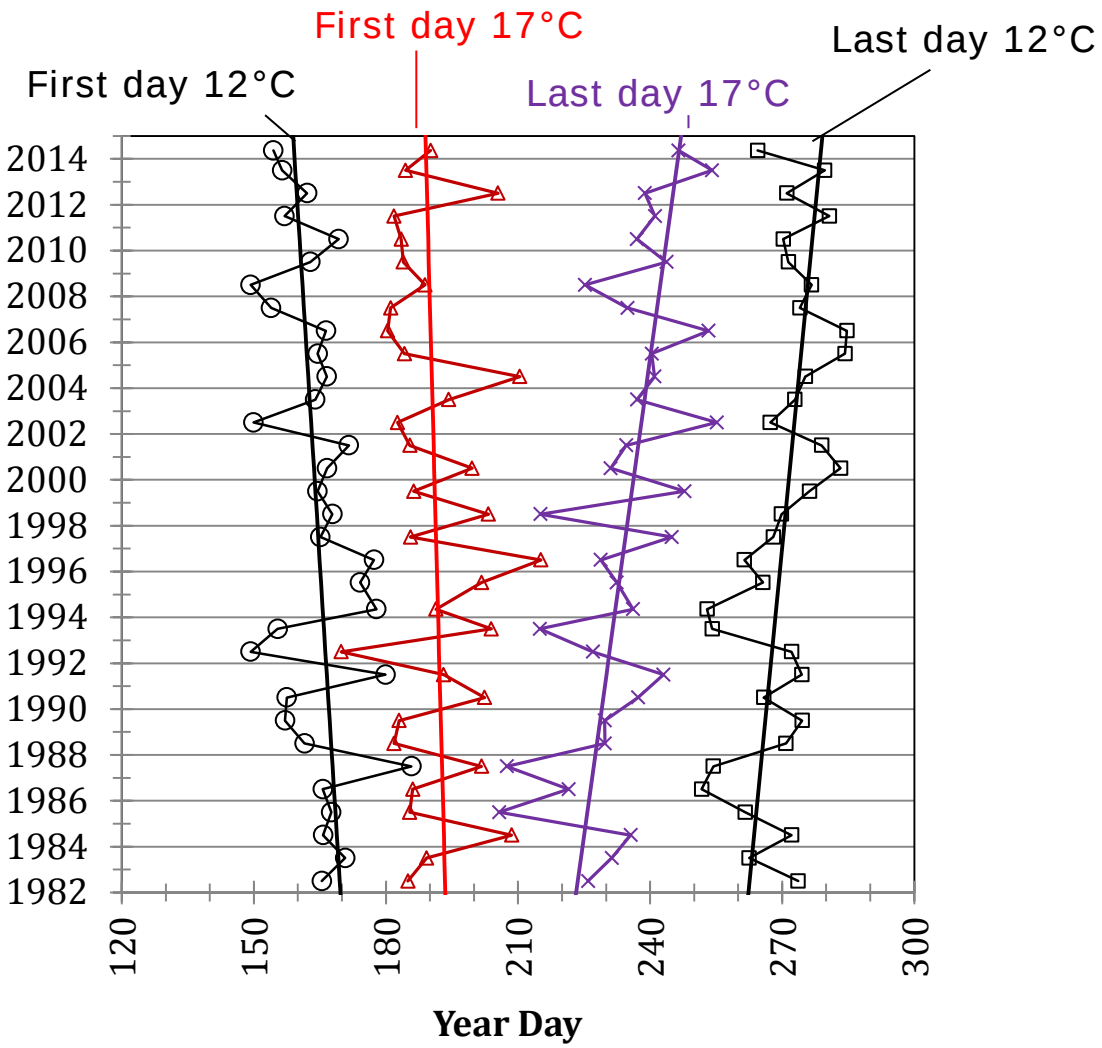
Source: Kahru, Elmgren, Savchuk, in prep.

Sea surface temperature(SST) phenology,
from satellites, averaged over the Baltic Sea.



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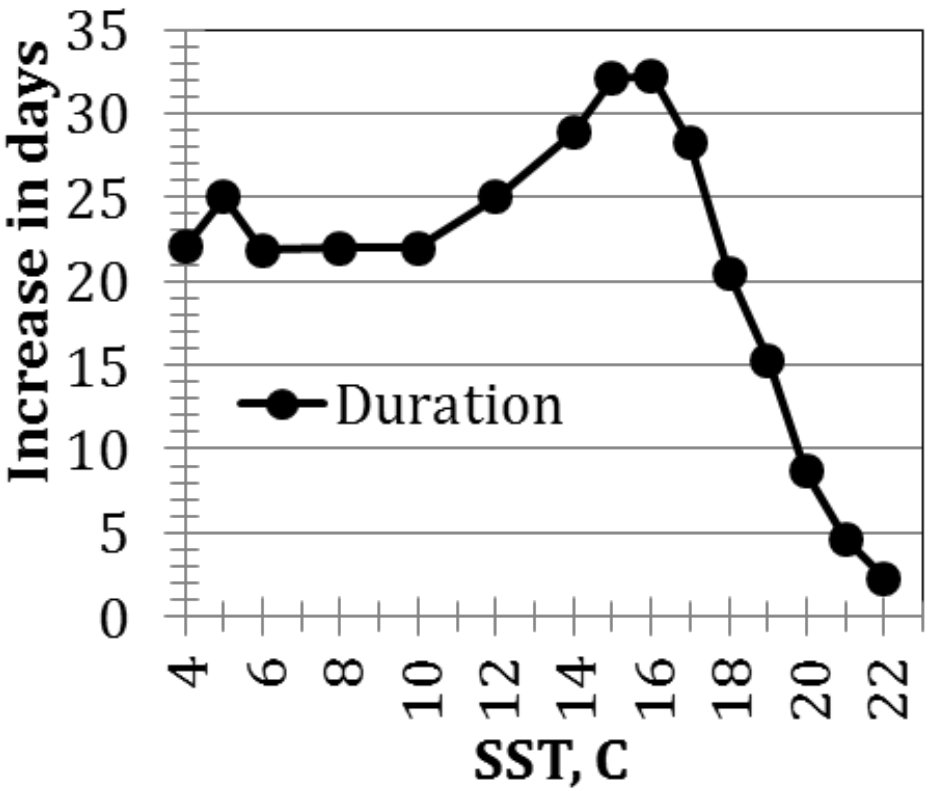
Source: Kahru, Elmgren, Savchuk, in prep.

Changed duration of the period with SST above a certain level, 1982 to 2014



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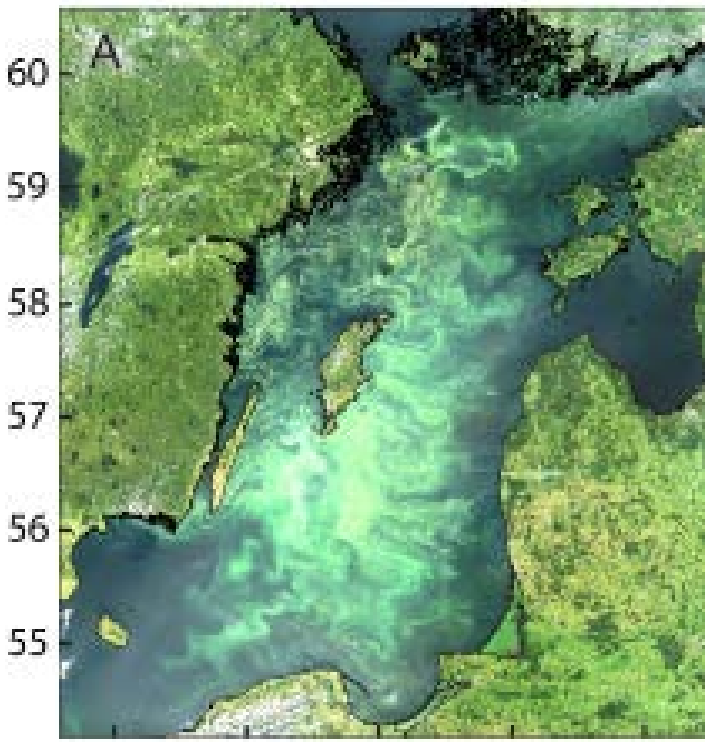
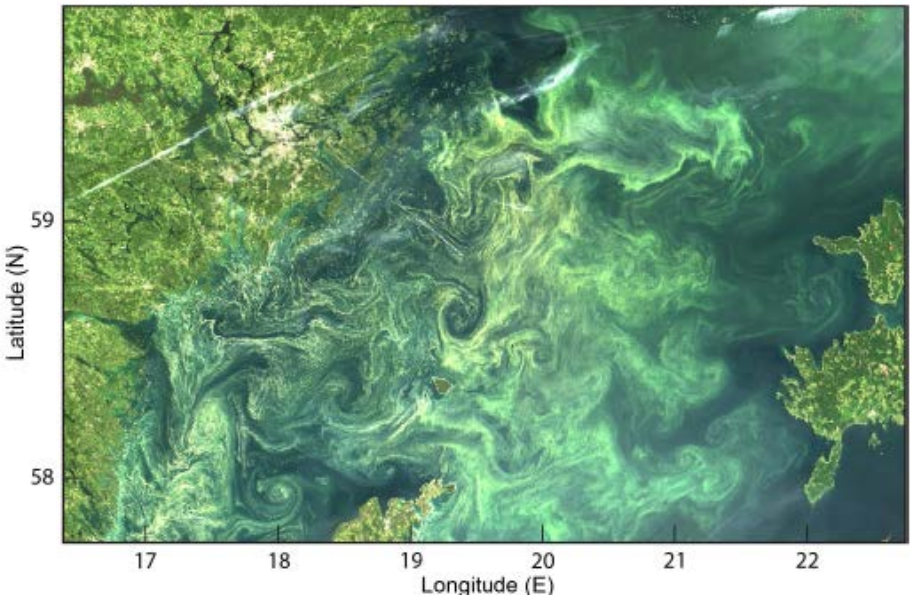
Source: Kahru, Elmgren, Savchuk, in prep.

Surface accumulations of Cyanobacteria can be recorded from space.





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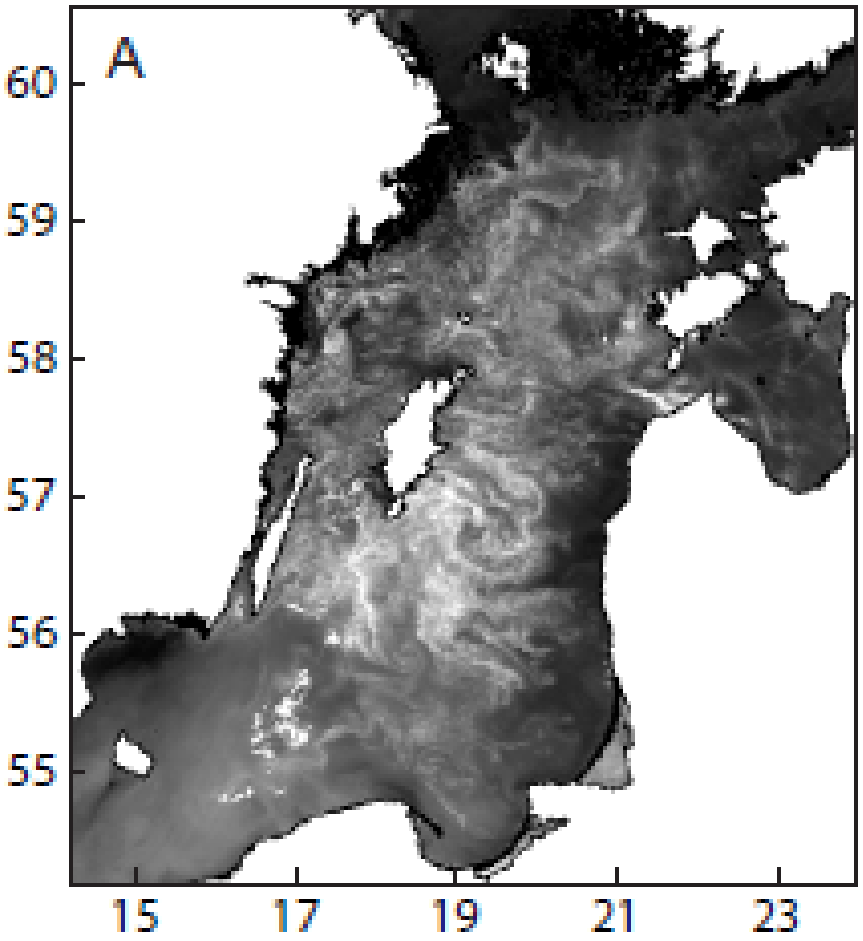
Source: Kahru, Elmgren, 2014

Observations started in the 1970s



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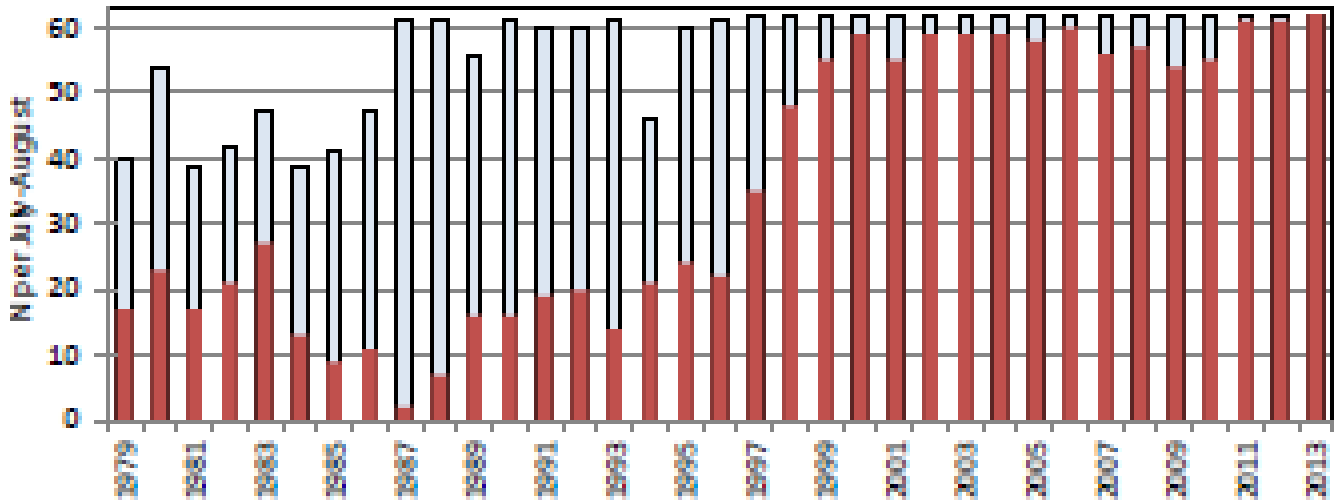
Source: Kahru, Elmgren, 2014

But later satellites use more wavelengths and give more frequent observations



Column height = No of usable daily data sets, Jul-Aug 1979-2014
Red fill = data sets with detected surface accumulations

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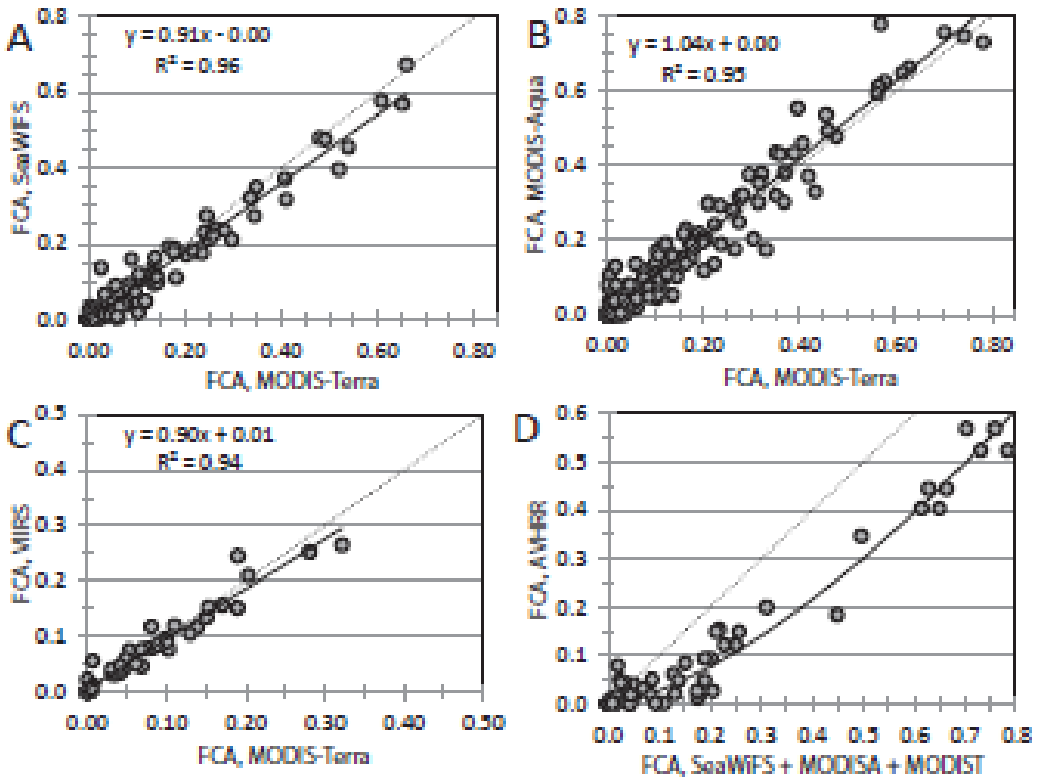
Source: Kahru, Elmgren, 2014

Creating a usable time-series requires calibrating between satellites



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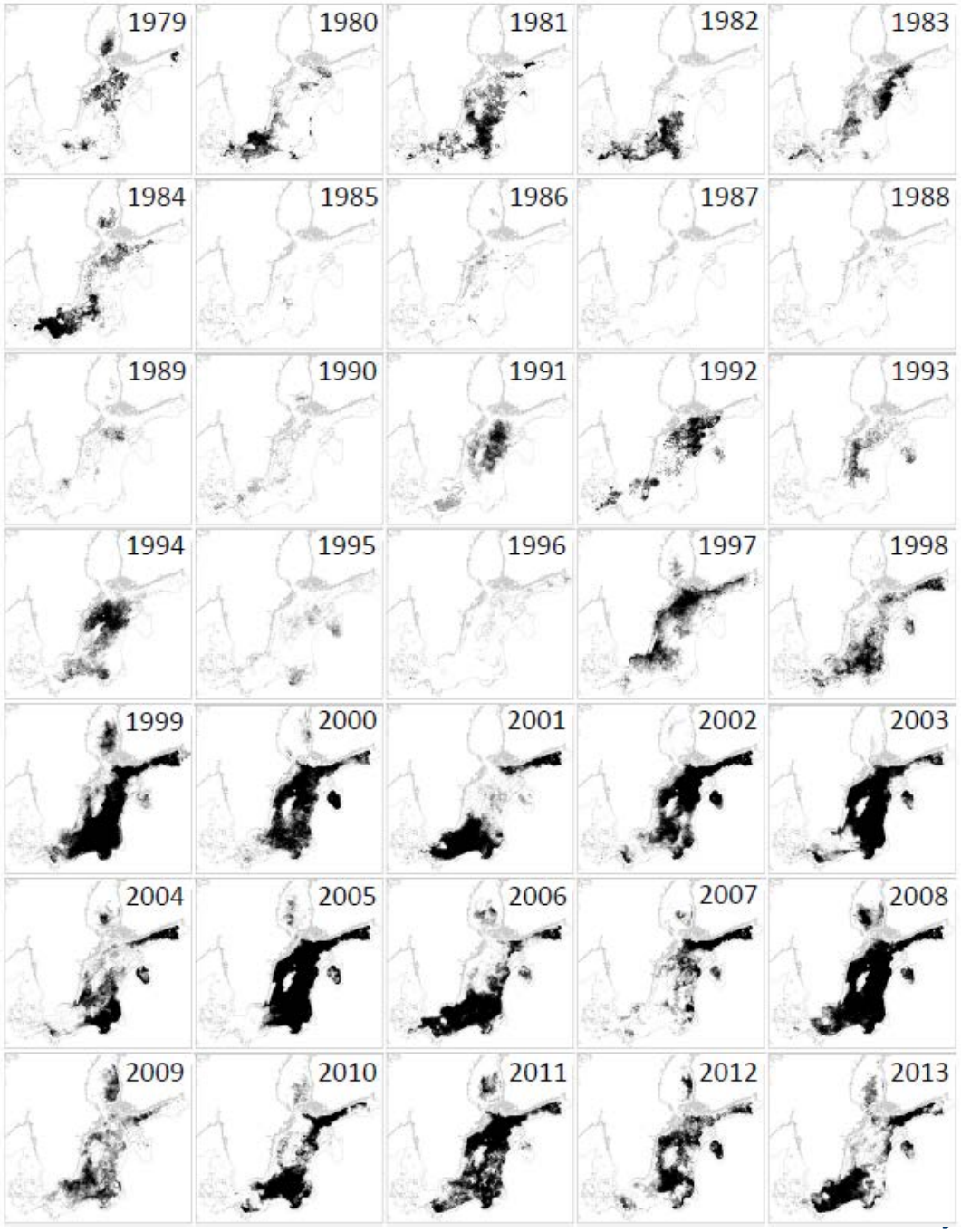
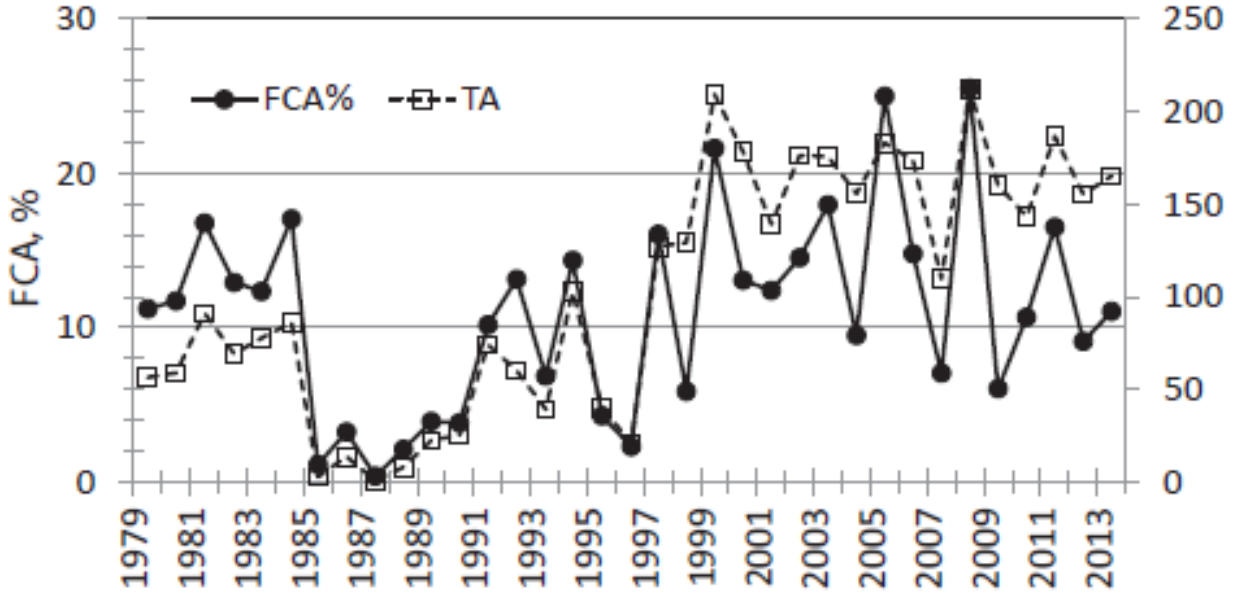
Source: Kahru, Elmgren, 2014



Cyanobacteria surface accumulations registered by satellites, 1979-2013

Source: Kahru, Elmgren, 2014

In July and August an average of up to 25% of the Baltic can be covered (FCA%), and the cumulative area (TA) can exceed 200 000 km²



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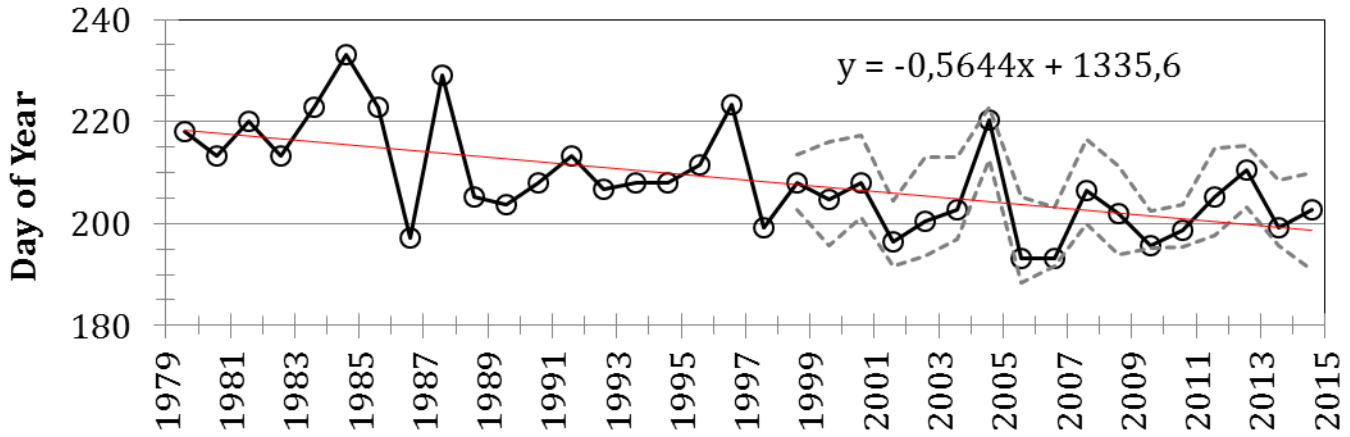
Source: Kahru, Elmgren, 2014

Center of time appearance of Baltic Cyanobacterial surface accumulations, 1979-2014



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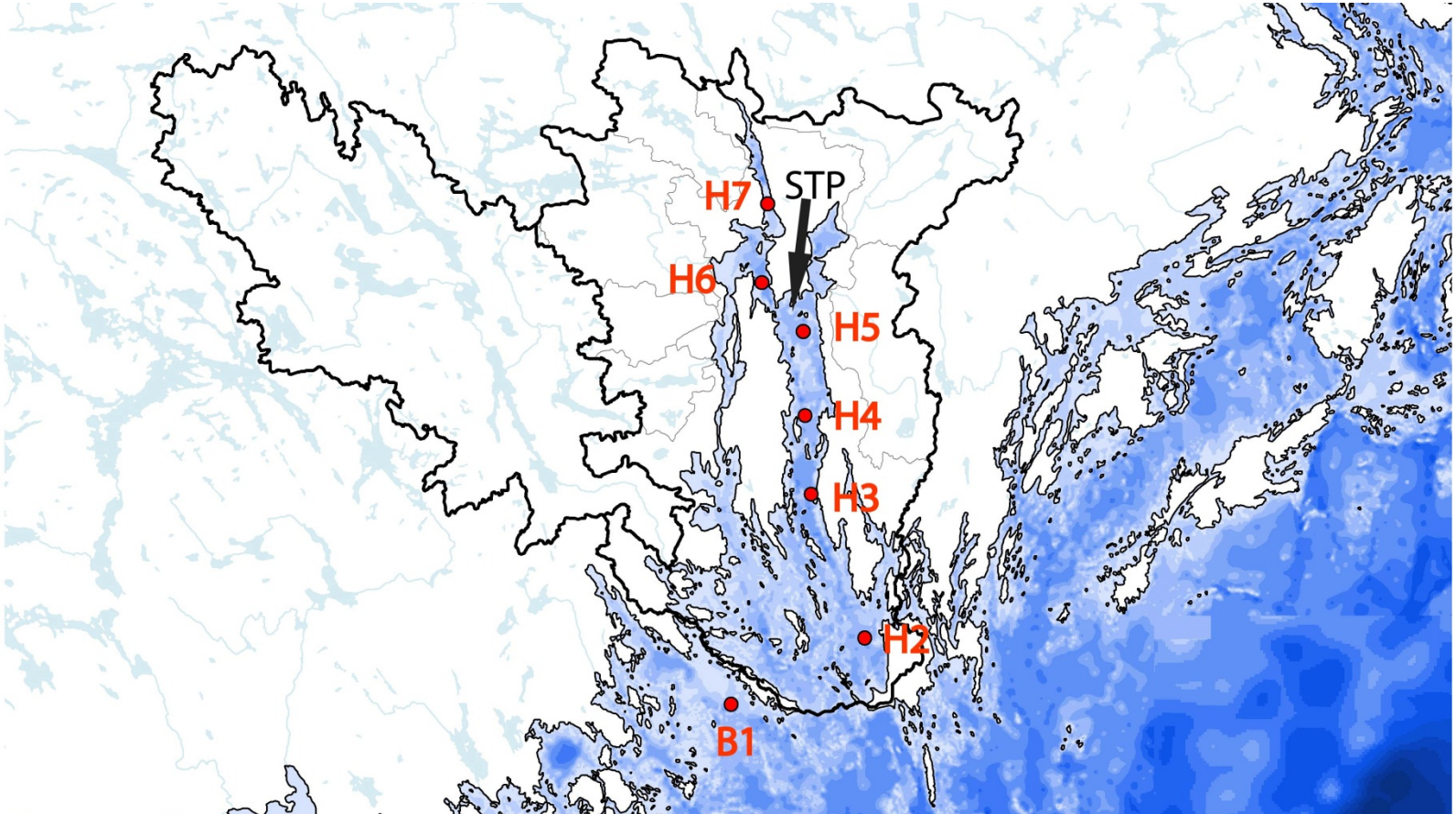
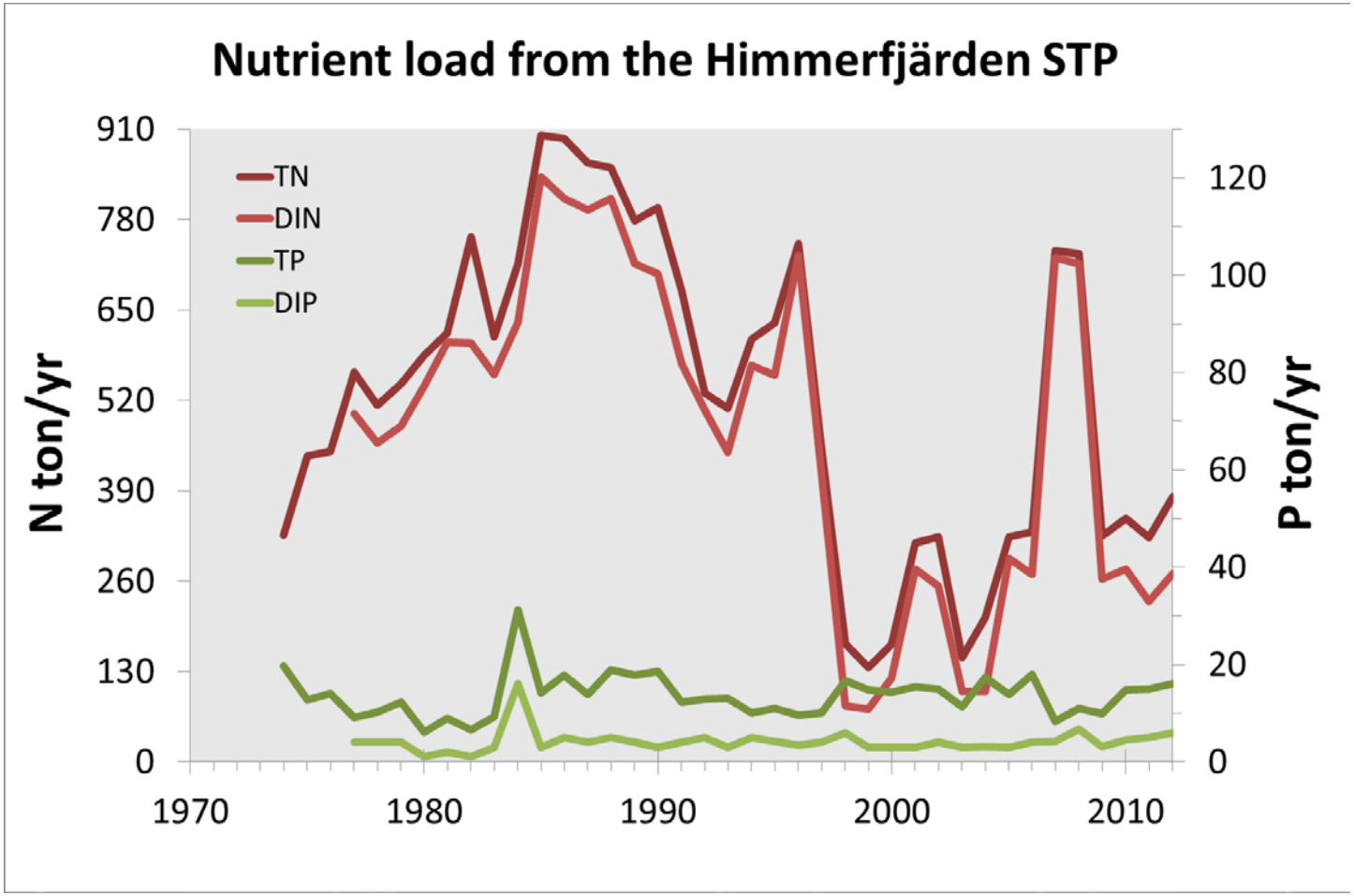
Source: Kahru, Elmgren, Savchuk, in prep.

- **HIMMERFJÄRDEN STUDY**





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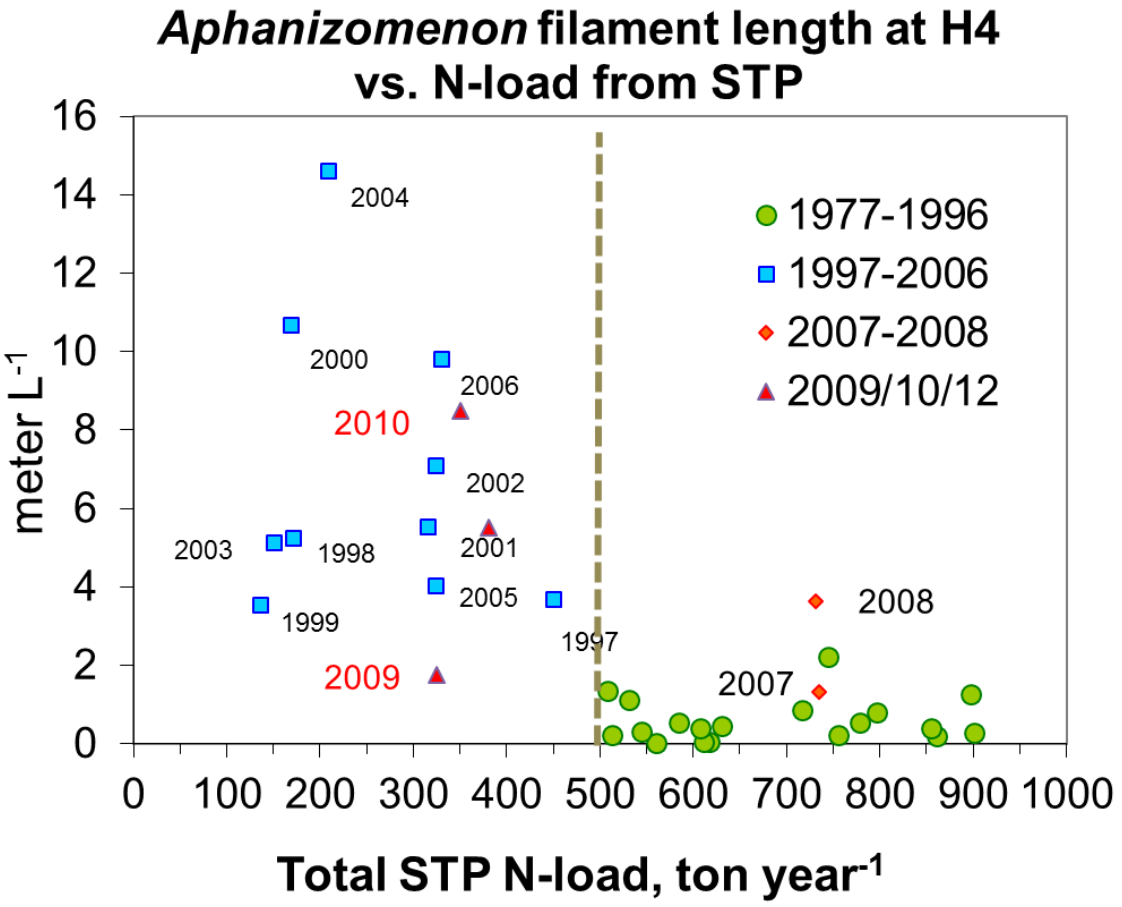

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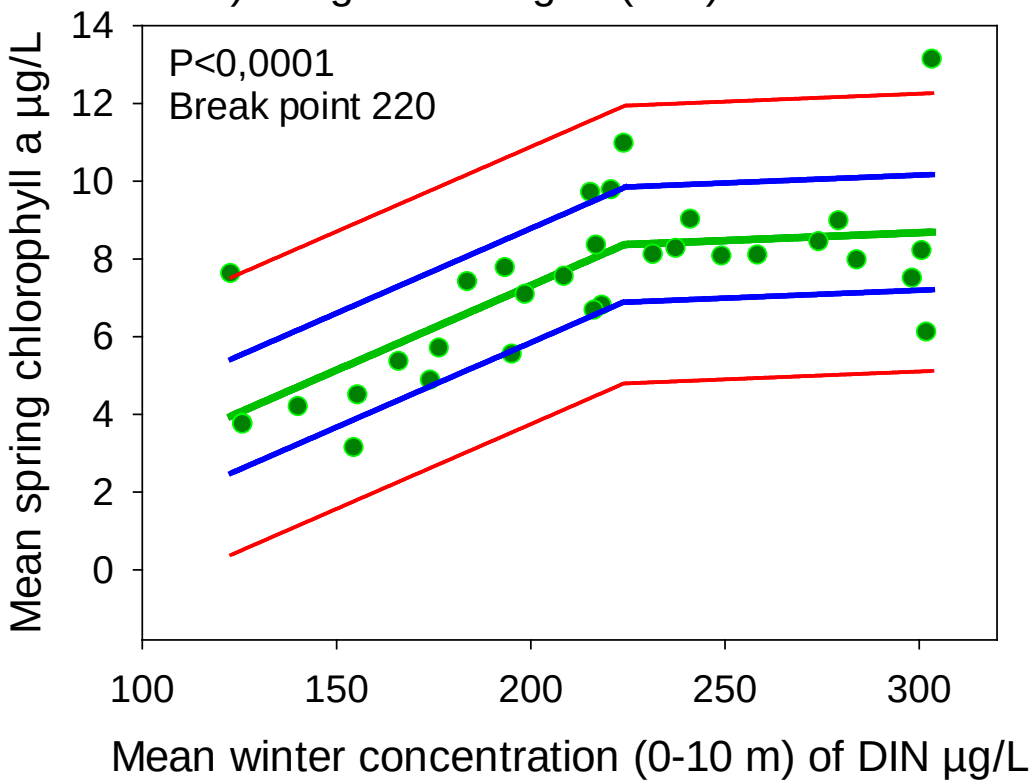
Spring mean chlorophyll a vs winter (Jan-Feb) inorganic nitrogen (DIN) concentration



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Do I think modelling is a wasted effort?

- No, we need to explore the range of possibilities, using both historcial, geological and modelling results
- Models test if our ideas are consistent
- But we should be sceptical and keep measuring in nature, and adjust our efforts at mitigation and adaptation to reality, as it unfolds

Thank you for listening!