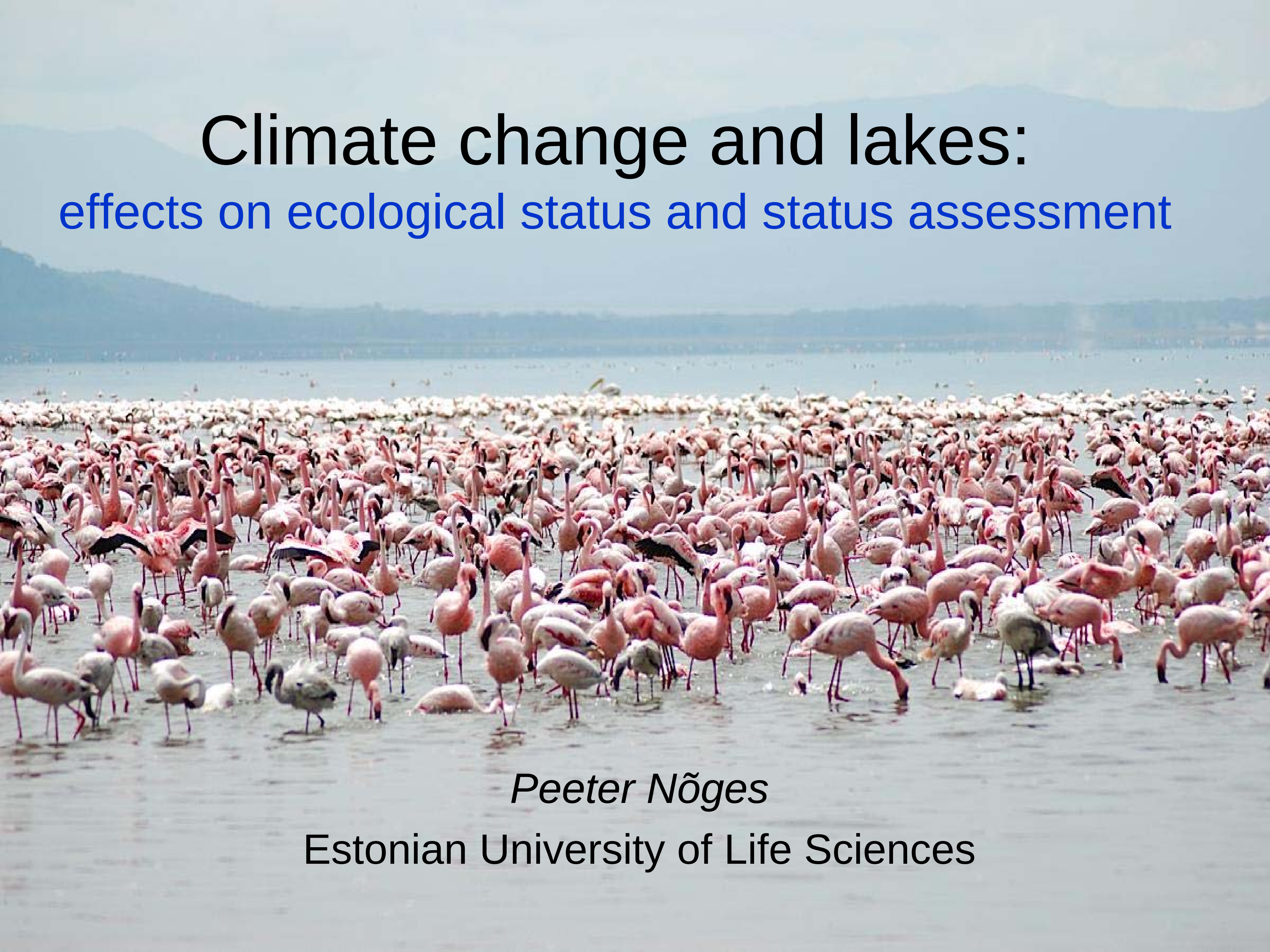

Climate change and lakes:

effects on ecological status and status assessment

Peeter Nõges

Estonian University of Life Sciences

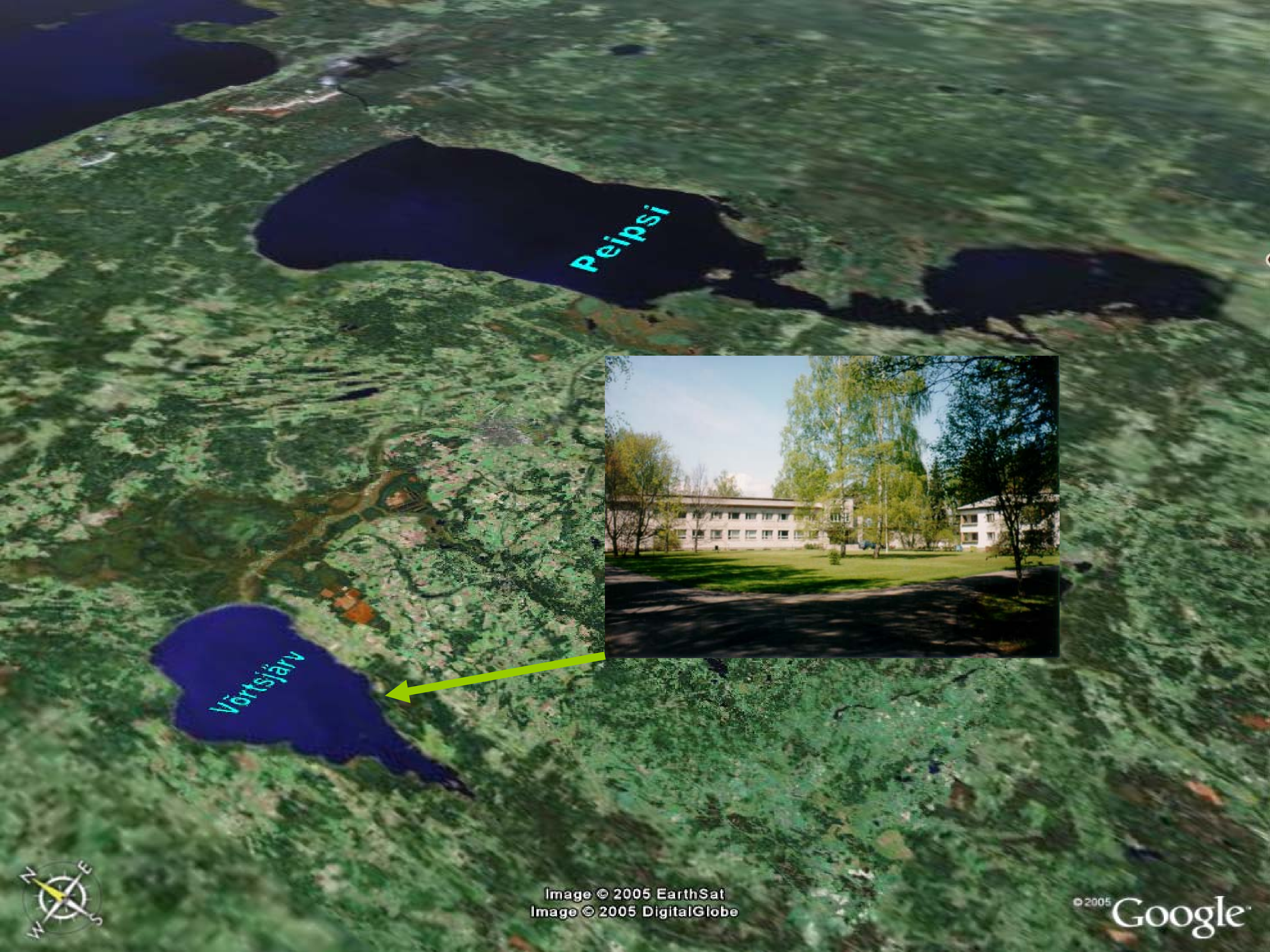
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Image © 2005 EarthSat
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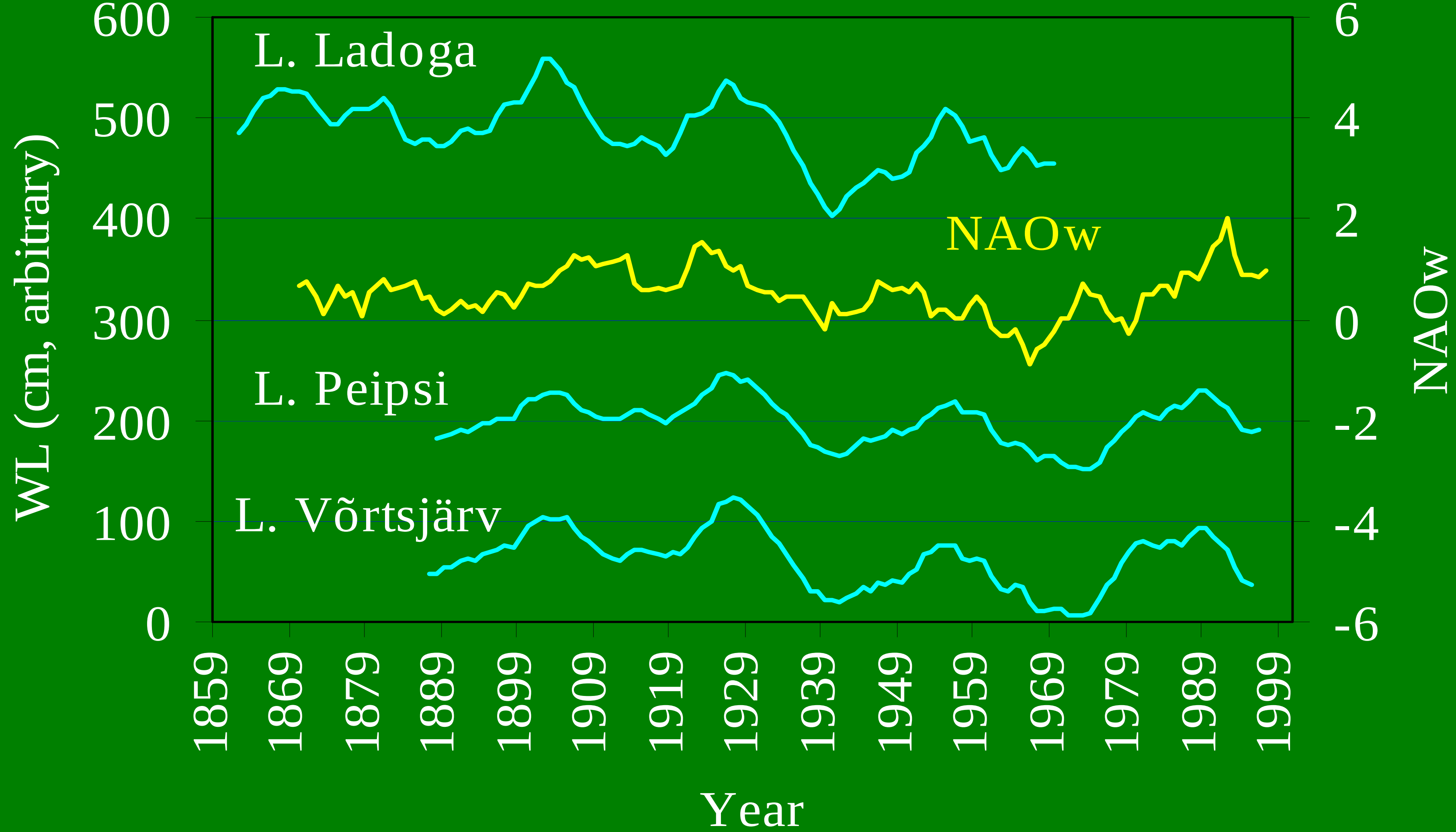
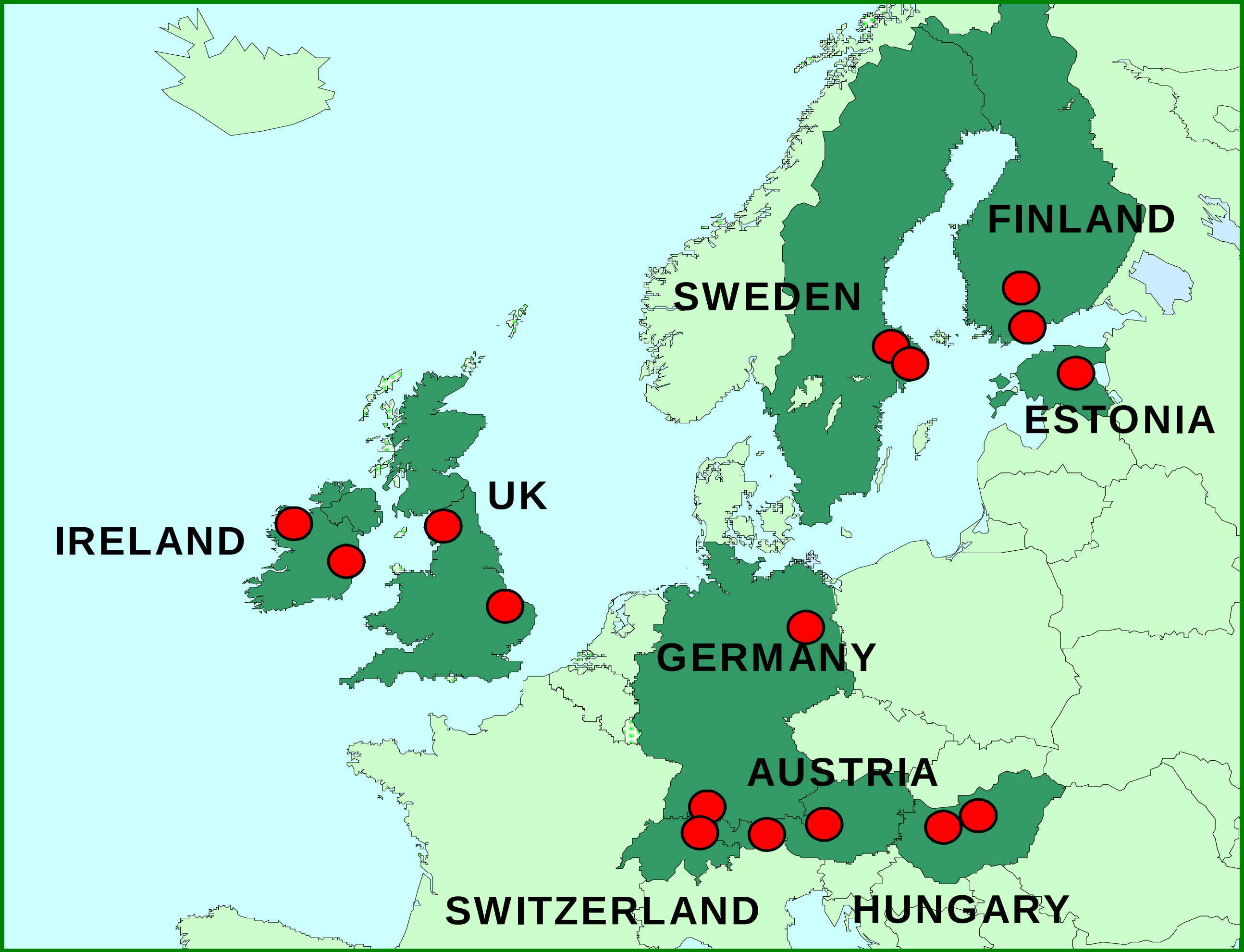
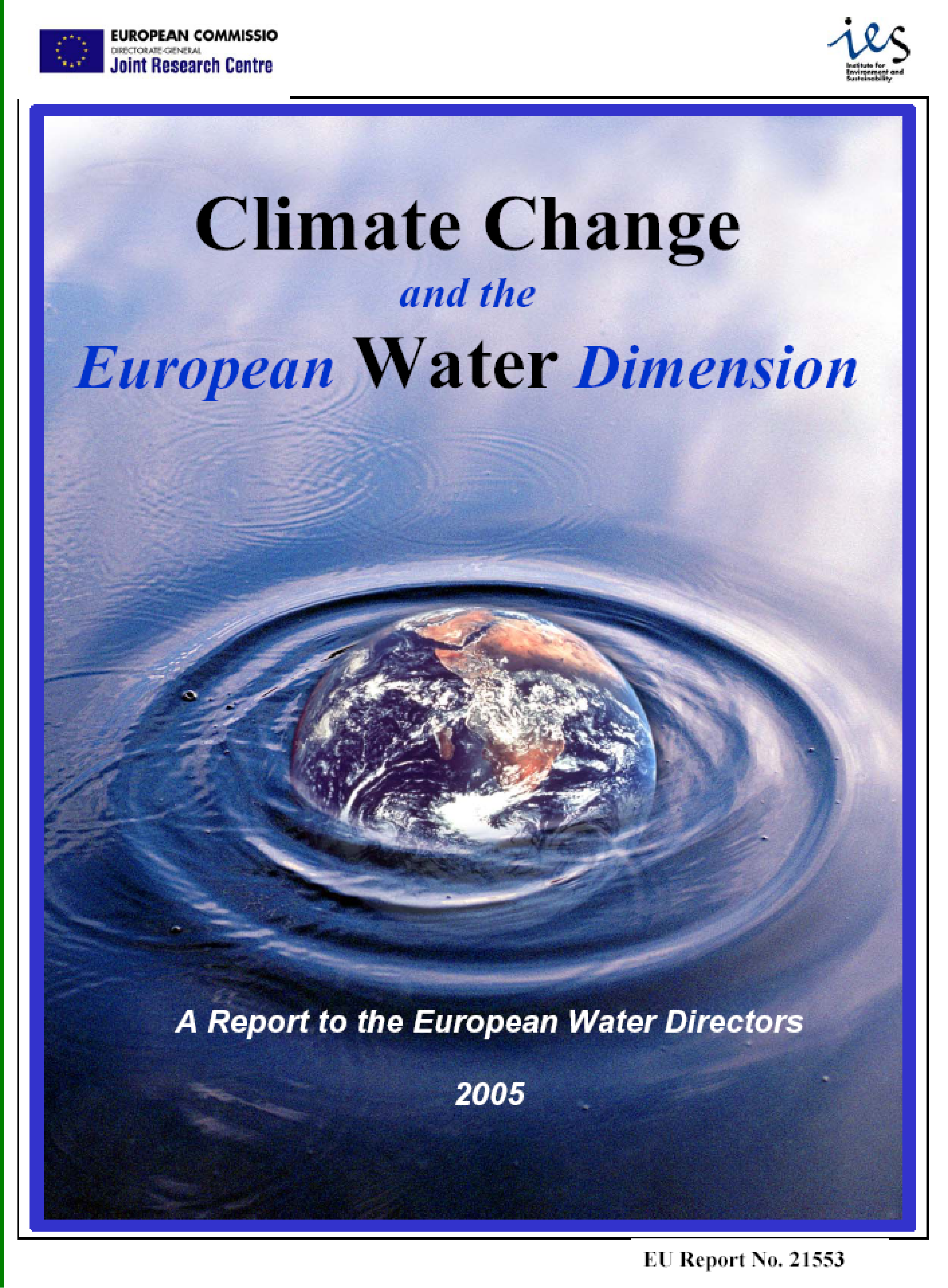
NAO and water level



Climate and Lake Impacts in Europe



CLIME


EUROPEAN COMMISSIO
DIRECTORATE-GENERAL
Joint Research Centre

ies
Institute for Environment and Sustainability

Climate Change
and the
European Water *Dimension*

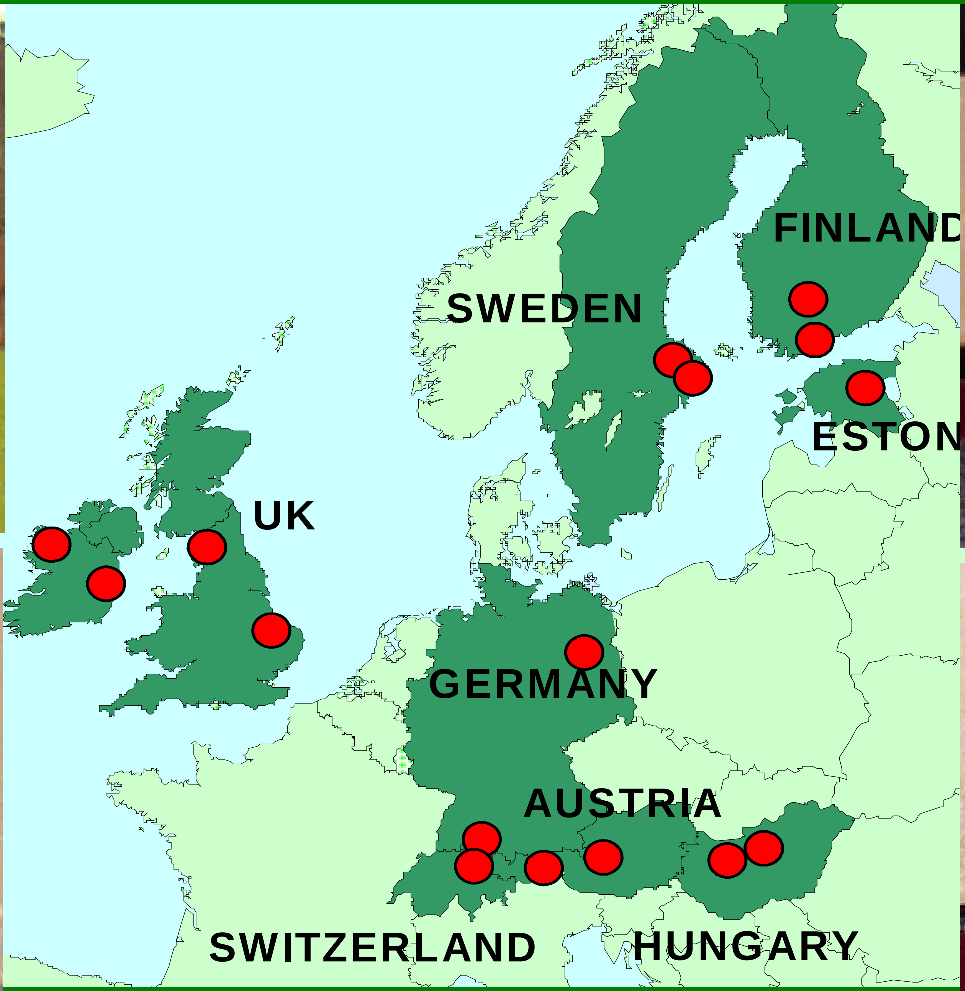
A Report to the European Water Directors

2005

EU Report No. 21553

Eisenreich et al. 2005

Climate and Lake Impacts in Europe



CLIME

Climate impact on Lakes in Europe

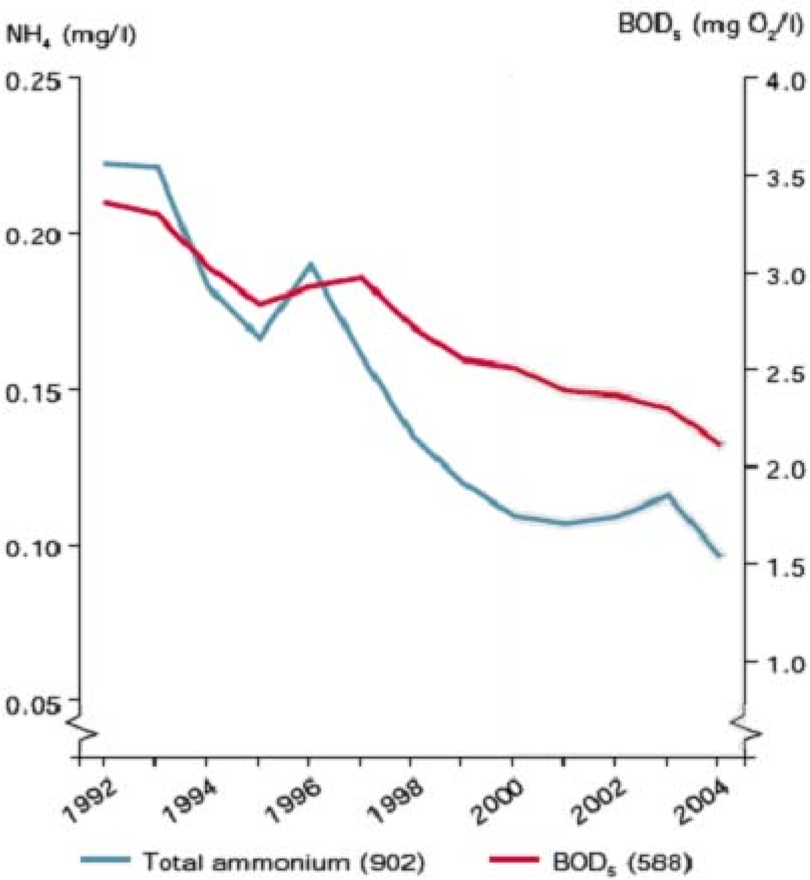
- **Response of lakes to climate forcing is most coherent for physical parameters.**
- **Anticipated changes in the chemical regime of lakes are less coherent and depend strongly on lake type and local conditions.**
- **Because of complex interactions, biological changes induced by climate change are inherently unpredictable.**

Outline

- Present status and trends in surface water quality in Europe
- Direct climatic impact on lakes
- Climatic impact through catchment processes
- Climate change and water policy
- Adaptation and mitigation measures

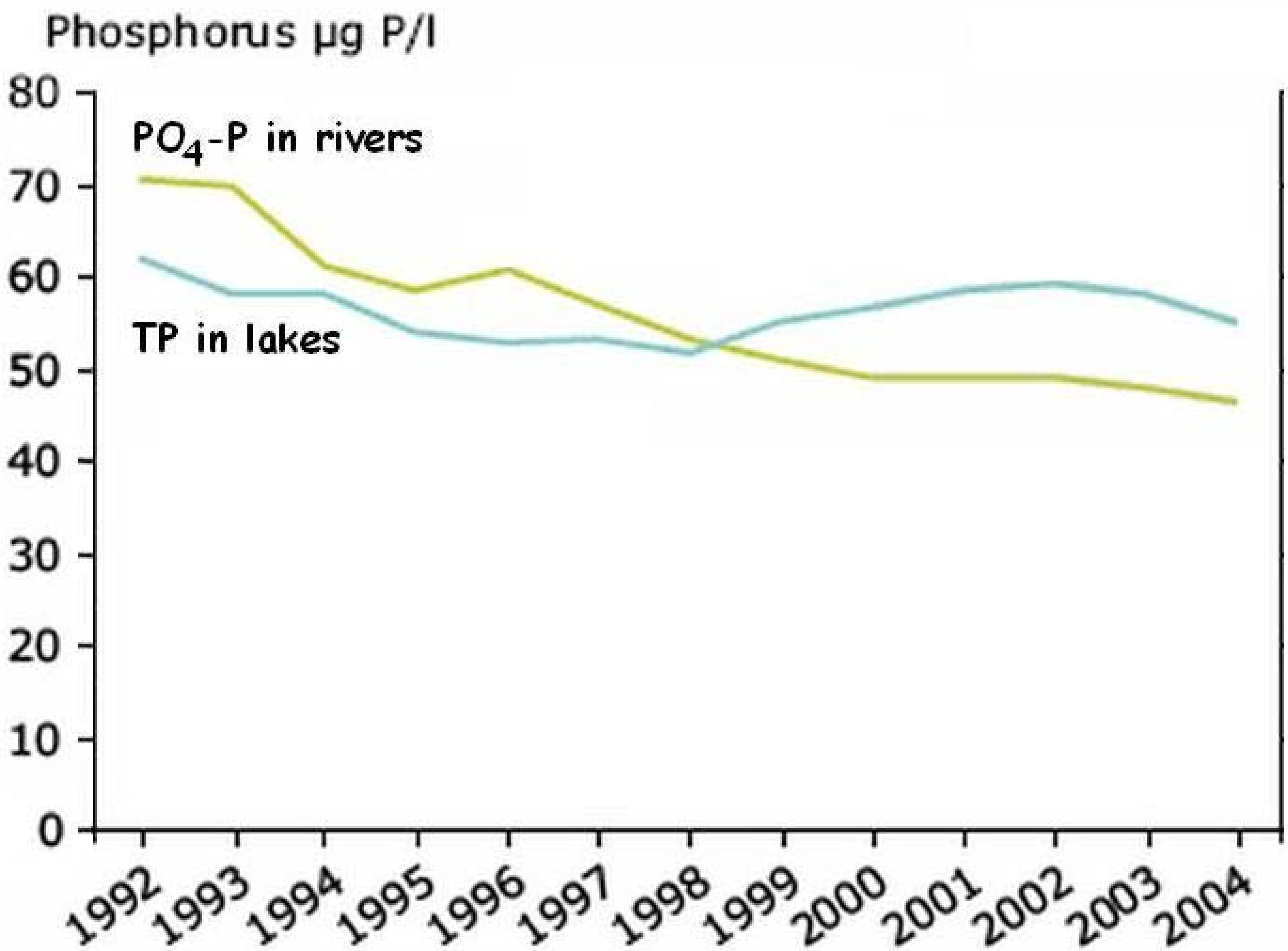
Present status and trends in surface water quality

Trend in total ammonium (NH_4) concentrations and BOD_5 in selected WCE rivers (1992–2004)

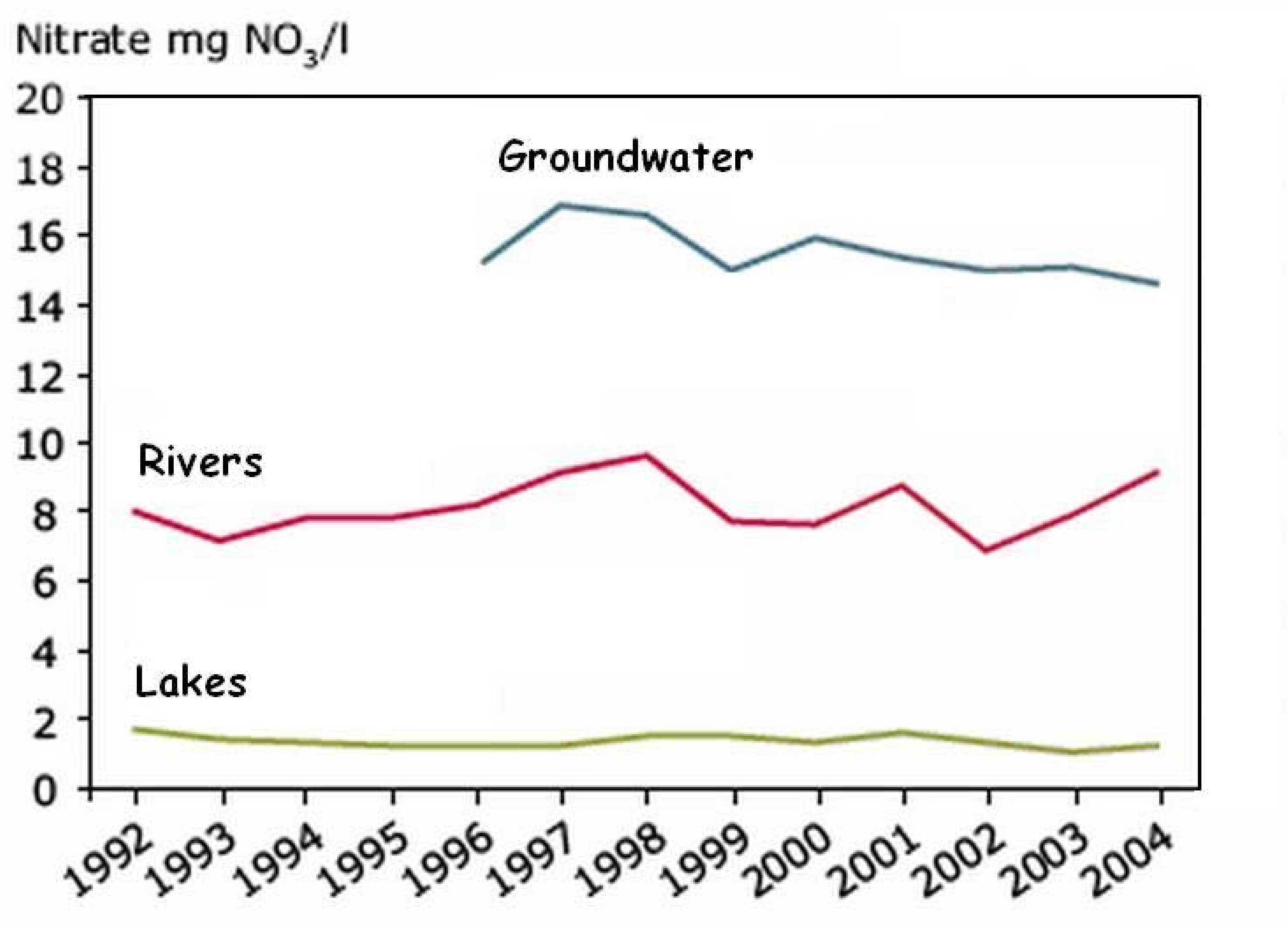


- Concentrations of organic matter (BOD_5) and total ammonium (NH_4) have generally decreased in rivers in the EEA member countries in the period 1992 to 2004, reflecting the general improvement in wastewater treatment over this period.

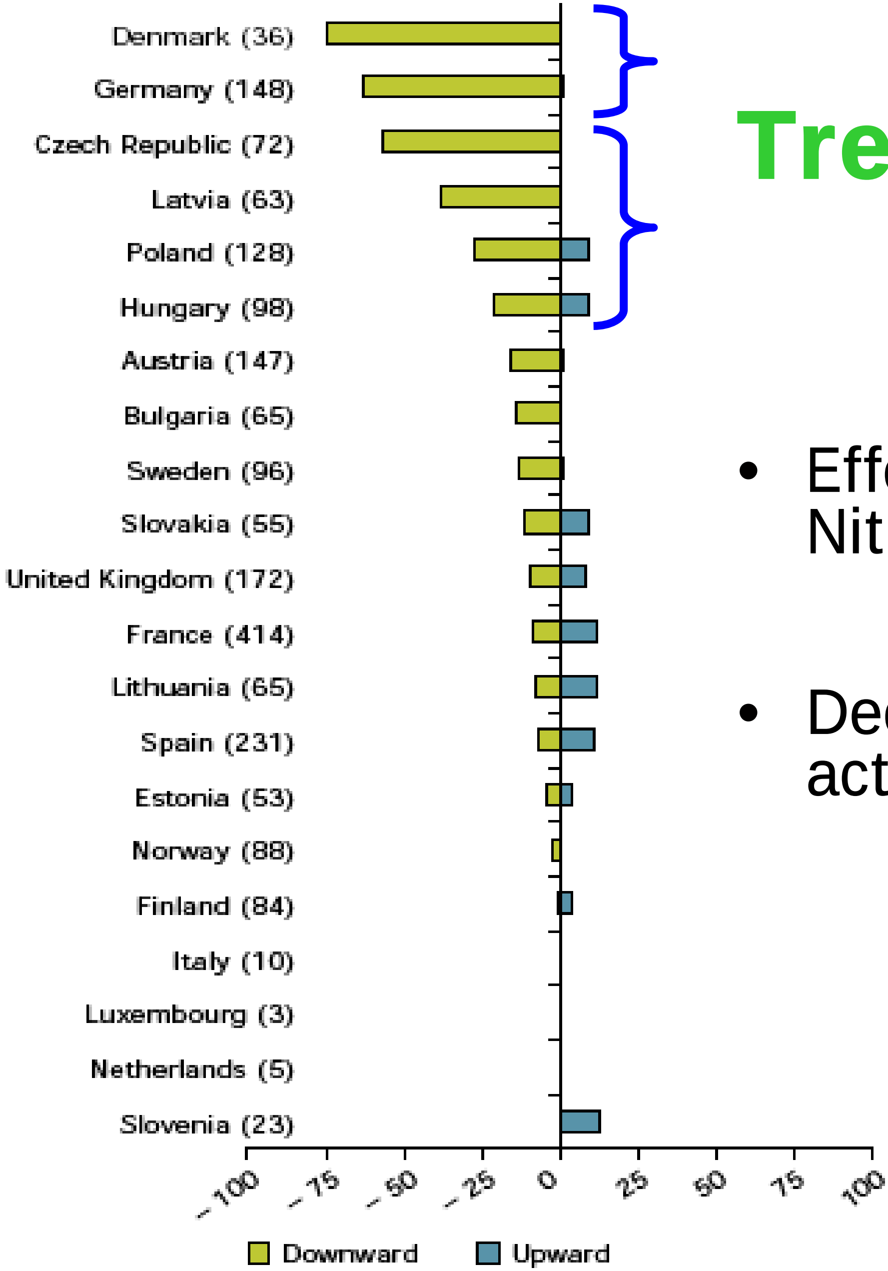
Phosphorus concentrations in selected WCE freshwater bodies (1992–2004)



Nitrate concentrations in selected WCE freshwater bodies (1992–2004)



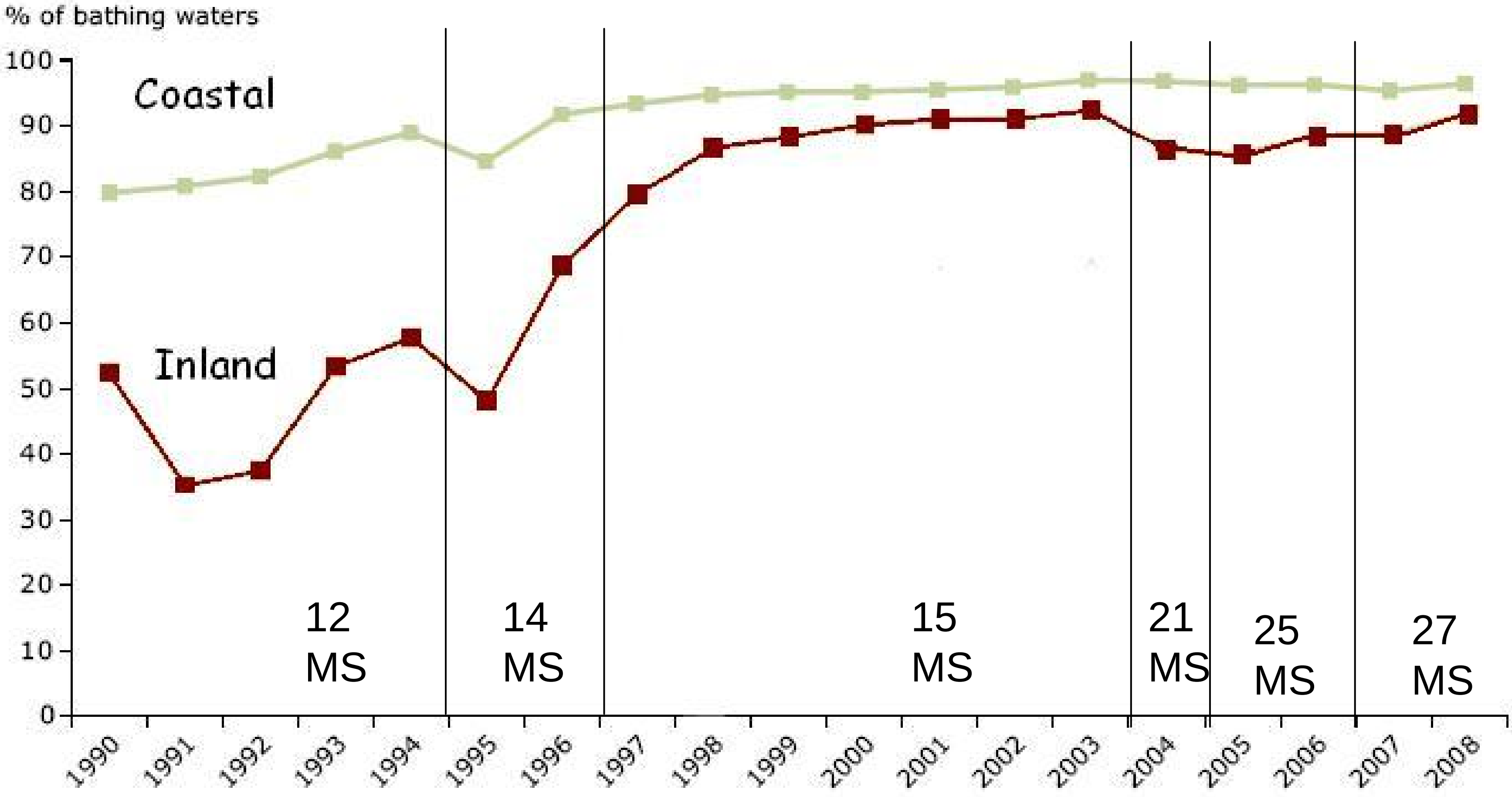
Trends in nitrates 1992-2004



- Effect of EU measures (the Nitrates Directive)
- Decrease in agricultural activities

Percentage of river monitoring stations reporting trends

Compliance of EU bathing waters with Bathing Water Directive standards



EEA, 2009, http://www.eea.europa.eu


Direct climatic impact

http://www.climate-and-freshwater.info/

Climate Change
and Freshwater

"Indicating the status of freshwater ecosystems under changing climatic conditions."

Freshwater type.

Climate change - a threat to aquatic ecosystems

Rivers, lakes and wetlands are under intense pressure from multiple use, pollution and habitat degradation. The services that aquatic ecosystems can provide to society have been reduced, and the biota is strongly affected, with several aquatic species disappearing from entire ecoregions.

In Europe, the principal legal instrument to halt the deterioration of aquatic ecosystems is the **Water Framework Directive**, which aims at restoring aquatic ecosystems back to good status; this is a task for generations. Many indicators have been developed to reflect the status of water bodies and the success of restoration.

Climate change, however, may counteract attempts to restore aquatic ecosystems. It adds additional threats (such as increase in water temperature) and it interacts in complex ways with other stressor types, such as eutrophication.

This website aims to give an overview on how Climate Change **affects freshwater ecosystems in Europe** and worldwide, and how it could be regarded in freshwater ecosystem monitoring. Individually we provide information on:

- **Presently used assessment systems** for aquatic ecosystems in Europe and how they address Climate Change effects
- **Case studies** addressing the effects of Climate Change on aquatic ecosystems
- **Indicators** potentially suited to detect the effects of Climate Change on European aquatic ecosystems
- **Aquatic species** which are affected by (or benefiting from) Climate Change

Please select the major ecosystem type you are interested in to find out more.

Lowland river

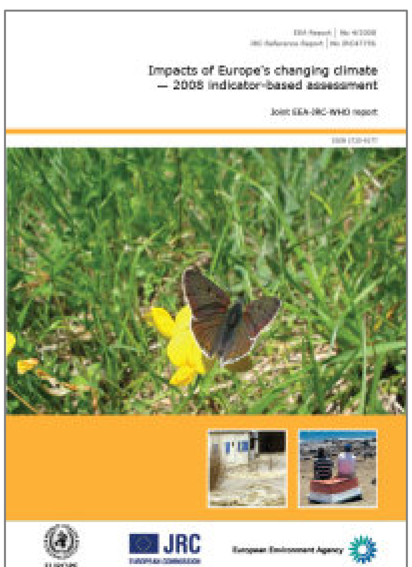
Complex interactions of the river and surrounding wetlands: affected by intense land use and droughts.

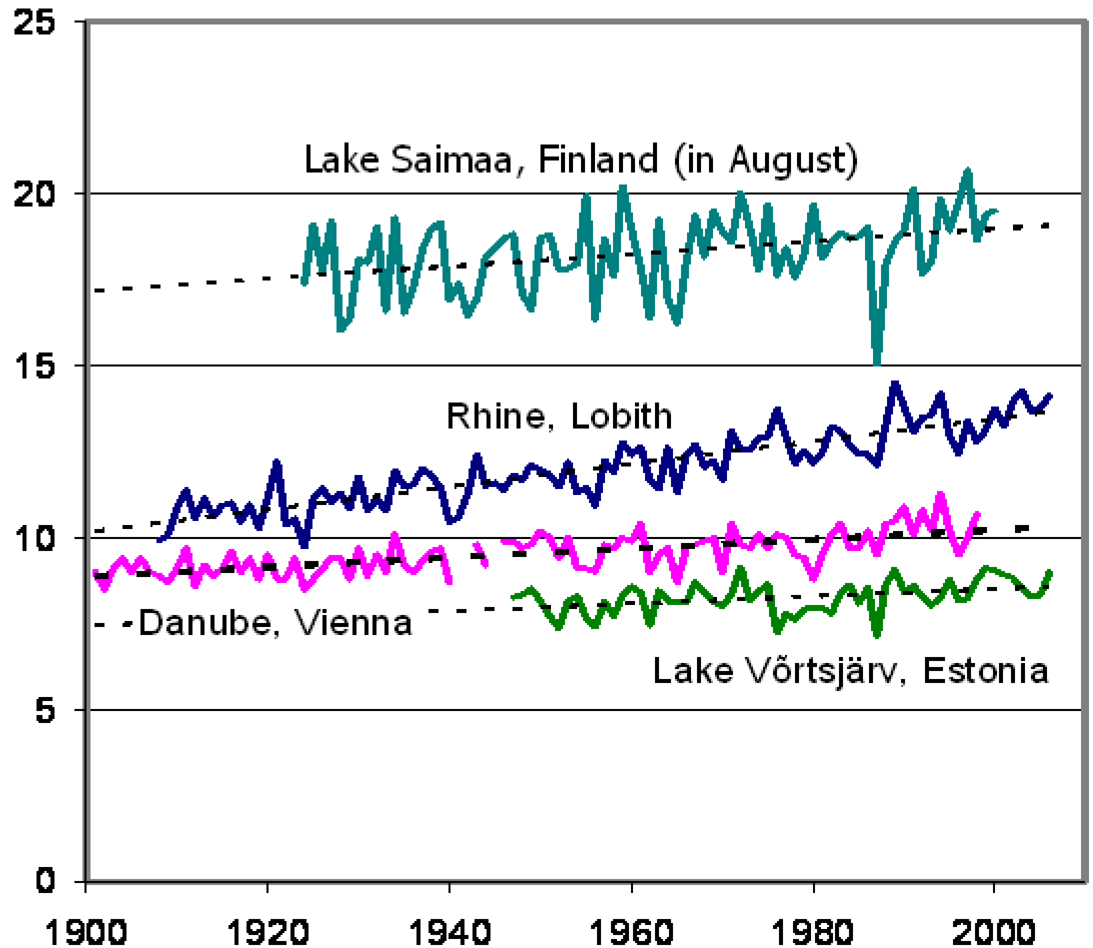
Alpine lake

Nutrient poor (oligotrophic) lakes: increased water temperature alters nutrient status and food chains.

Water temperature in lakes and rivers

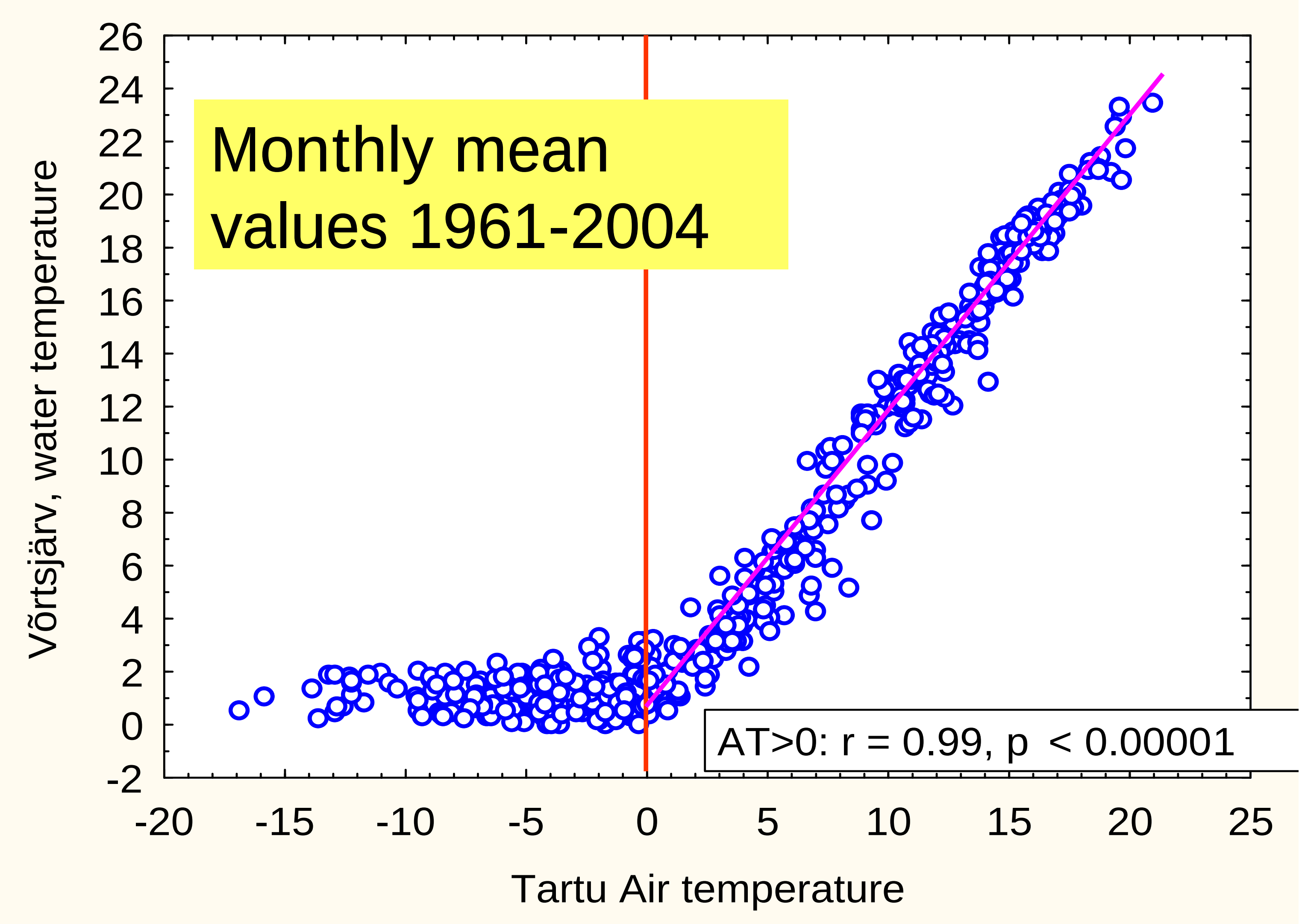
- Increase 1-3 °C
- 2/3 of the increase in R. Rhine is caused by the discharge of cooling waters



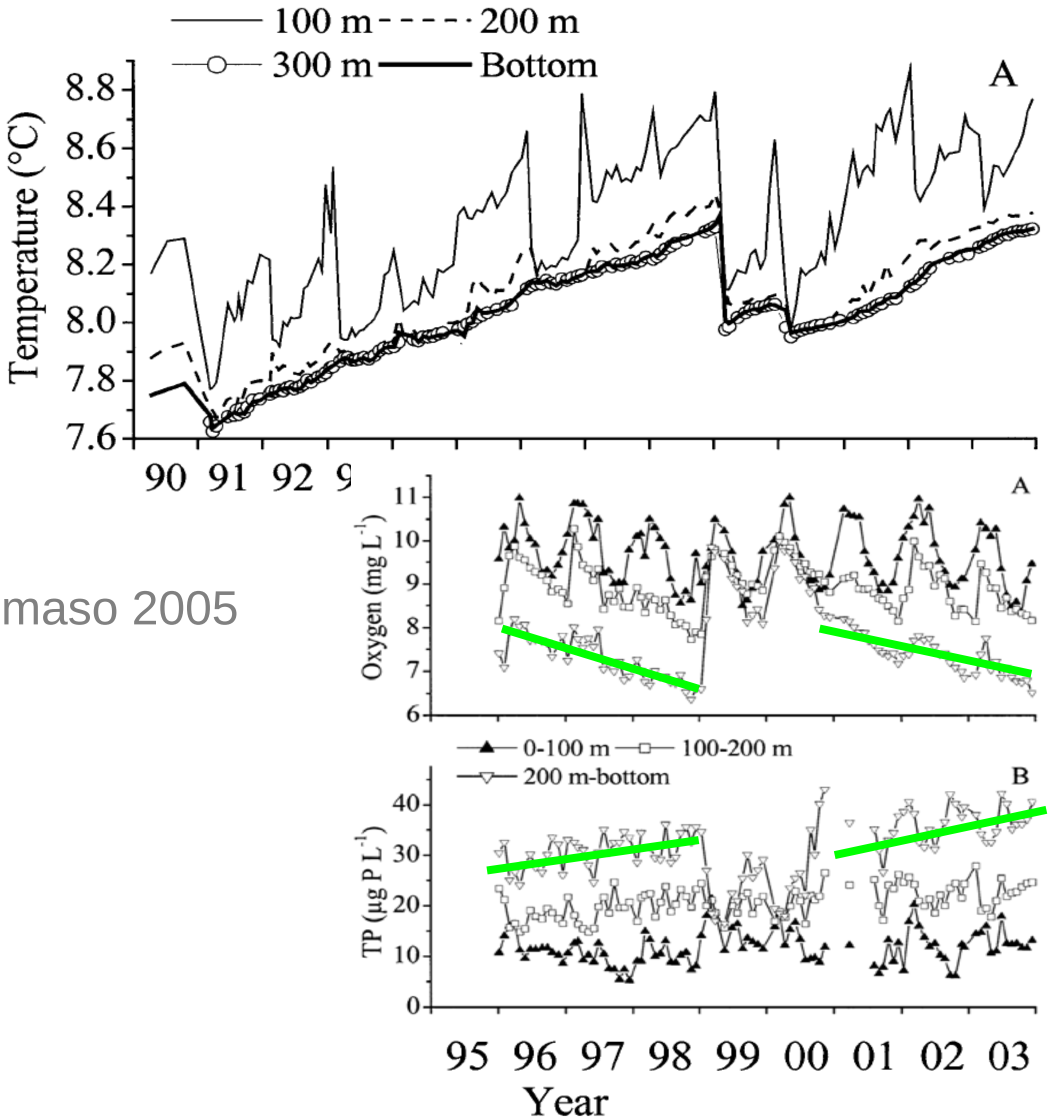


EEA – JRC – WHO, 2008, Indicator based assessment

Water temperature depends on air temperature



Deep water warming in perialpine lakes



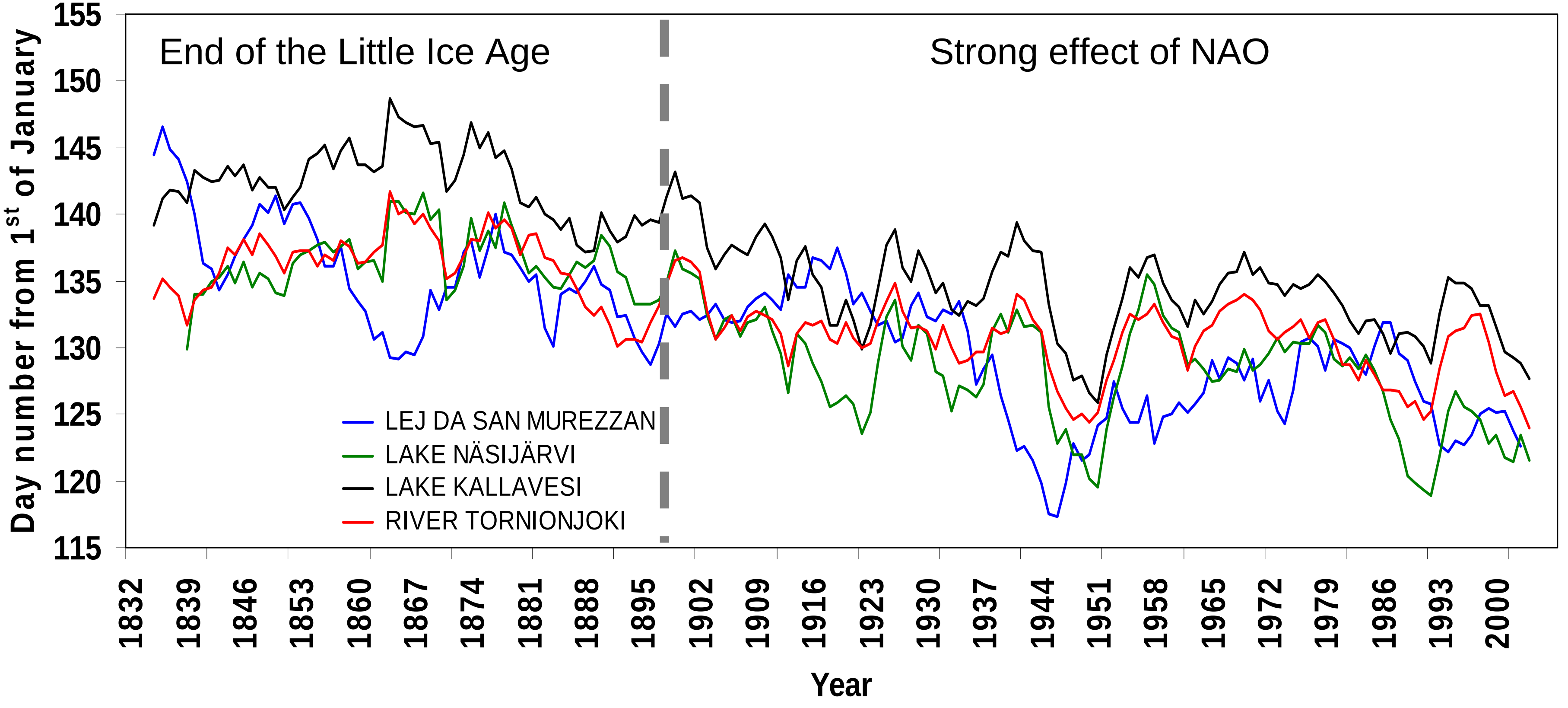
T°

O_2

TP

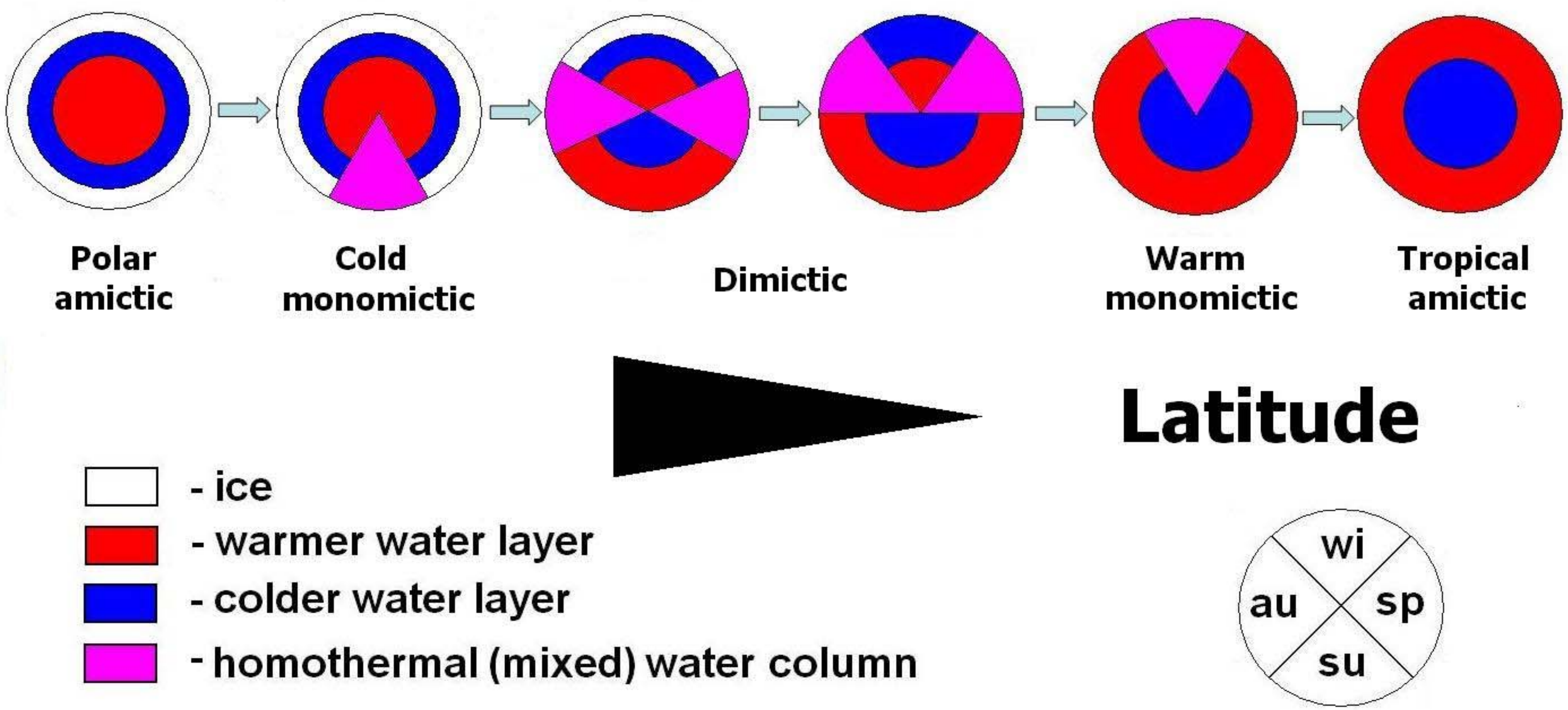
Salmaso 2005

Ice break-up dates in Europe 1832-2006



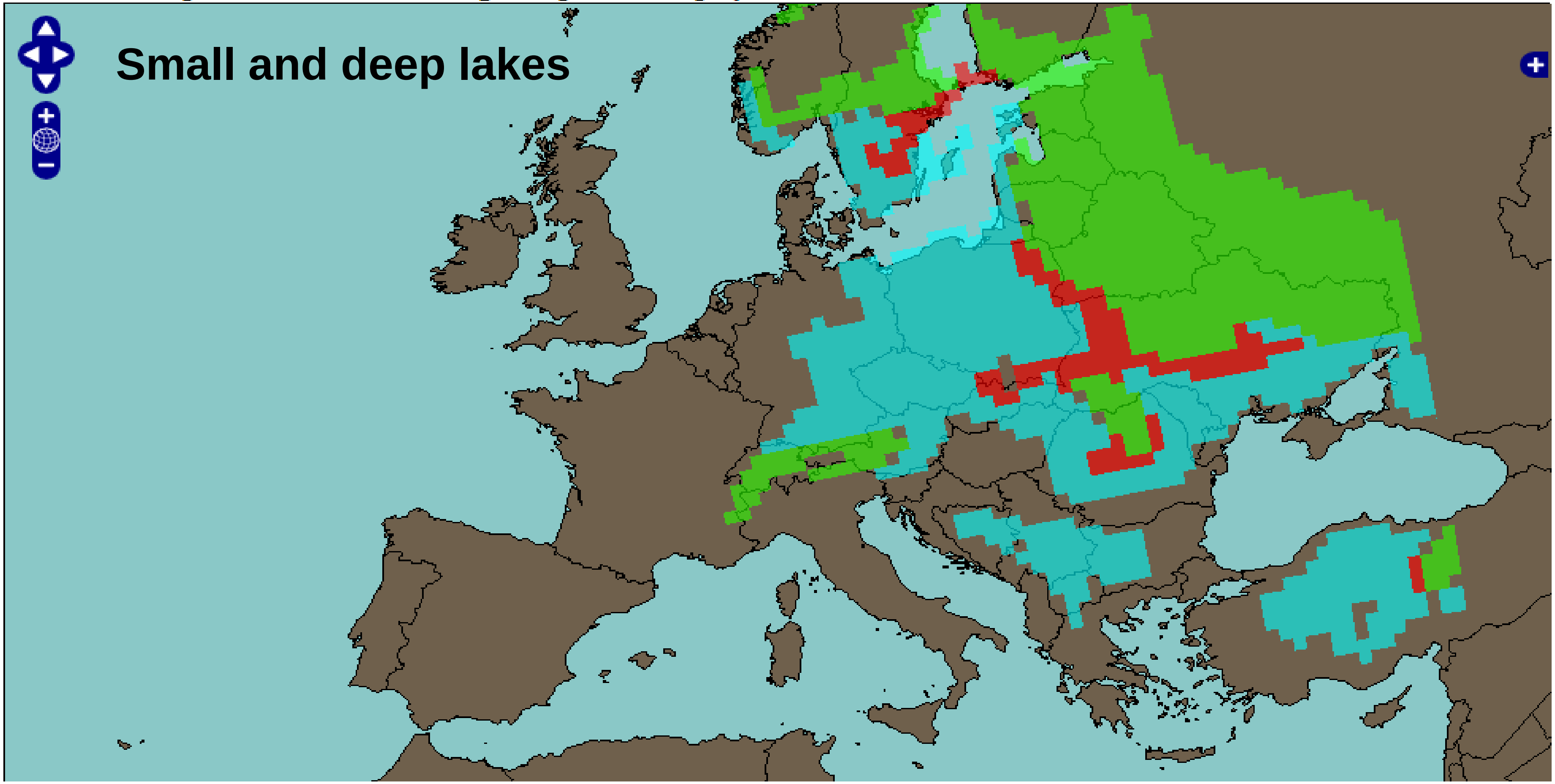
EEA – JRC – WHO, 2008, Indicator based assessment

Mixing regimes



Nõges et al. 2009

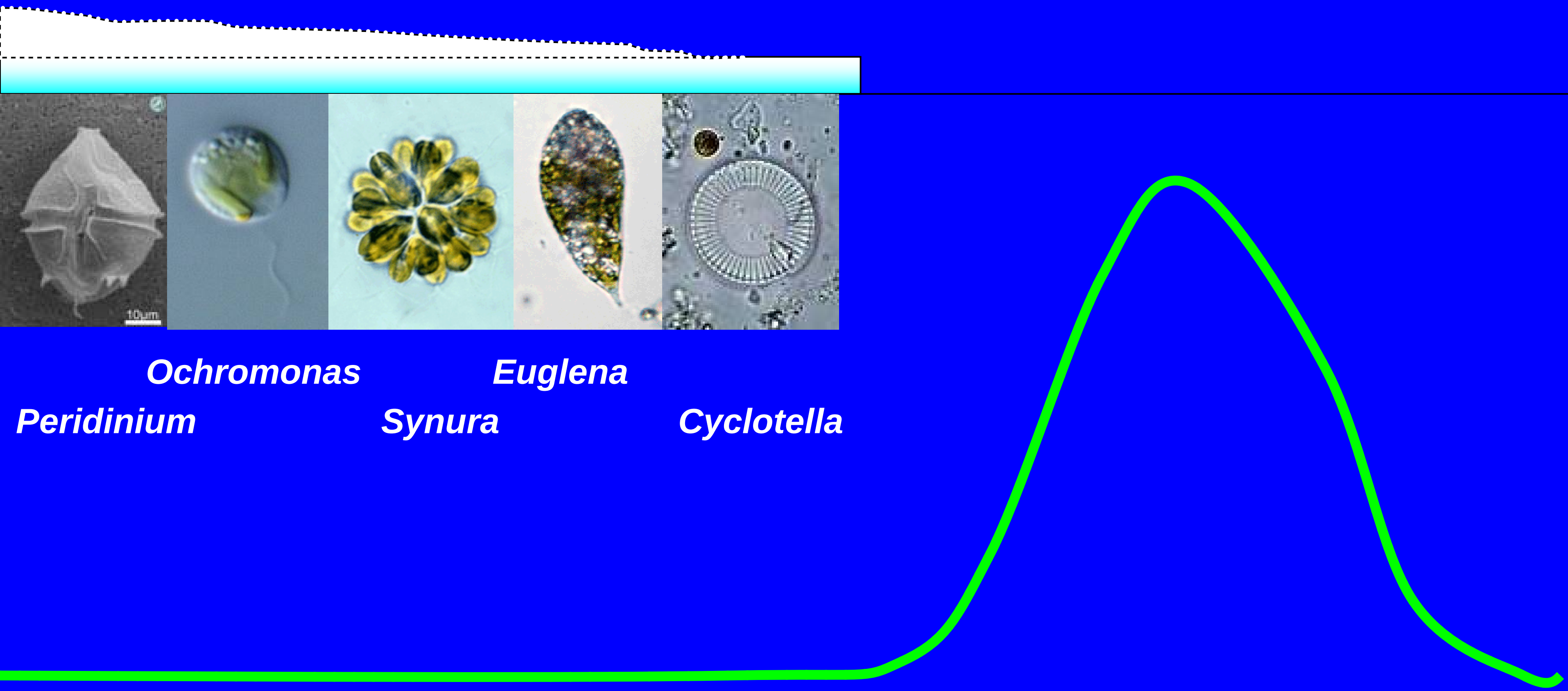
CLIME Maps of Climate Change impacts on physical characteristics of lakes



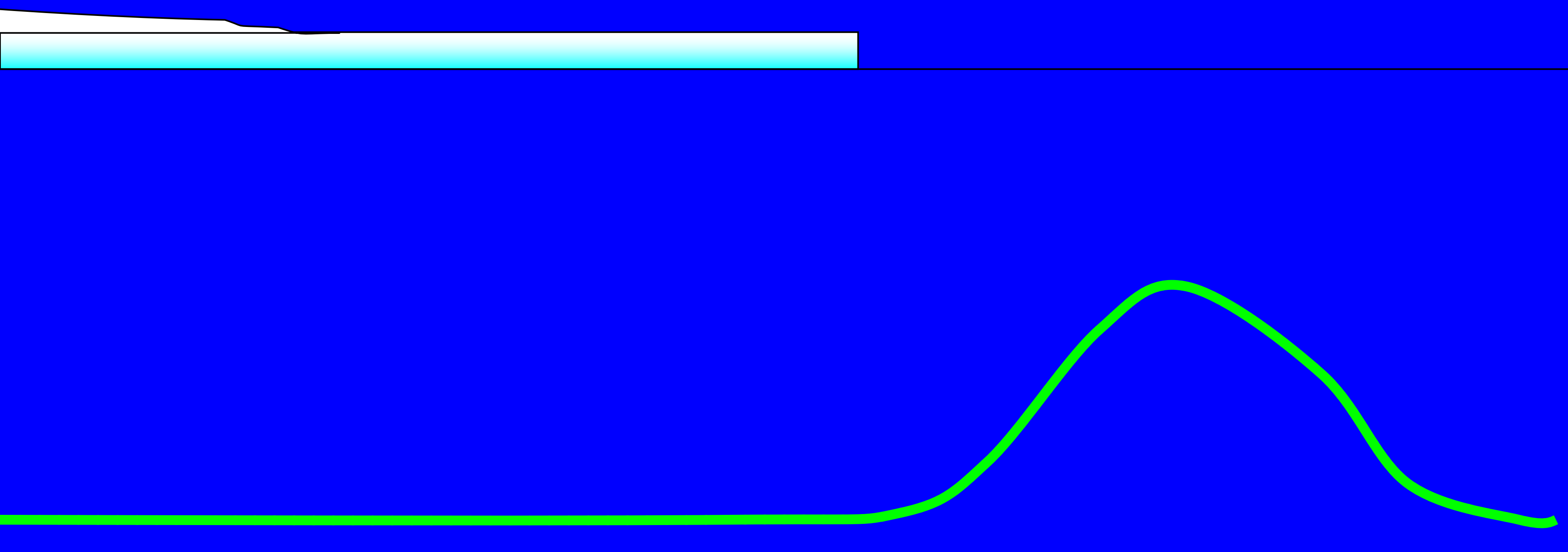
- Shift from being typically ice-covered in all winters to being ice-free in some winters.
- Shift from being ice-free in some winters to being typically ice-free in all winters.
- Shift from being typically ice-covered in all winters to being typically ice-free in all winters.

http://clime.tkk.fi/jrc/ Jolma & Kaitaranta, 2009

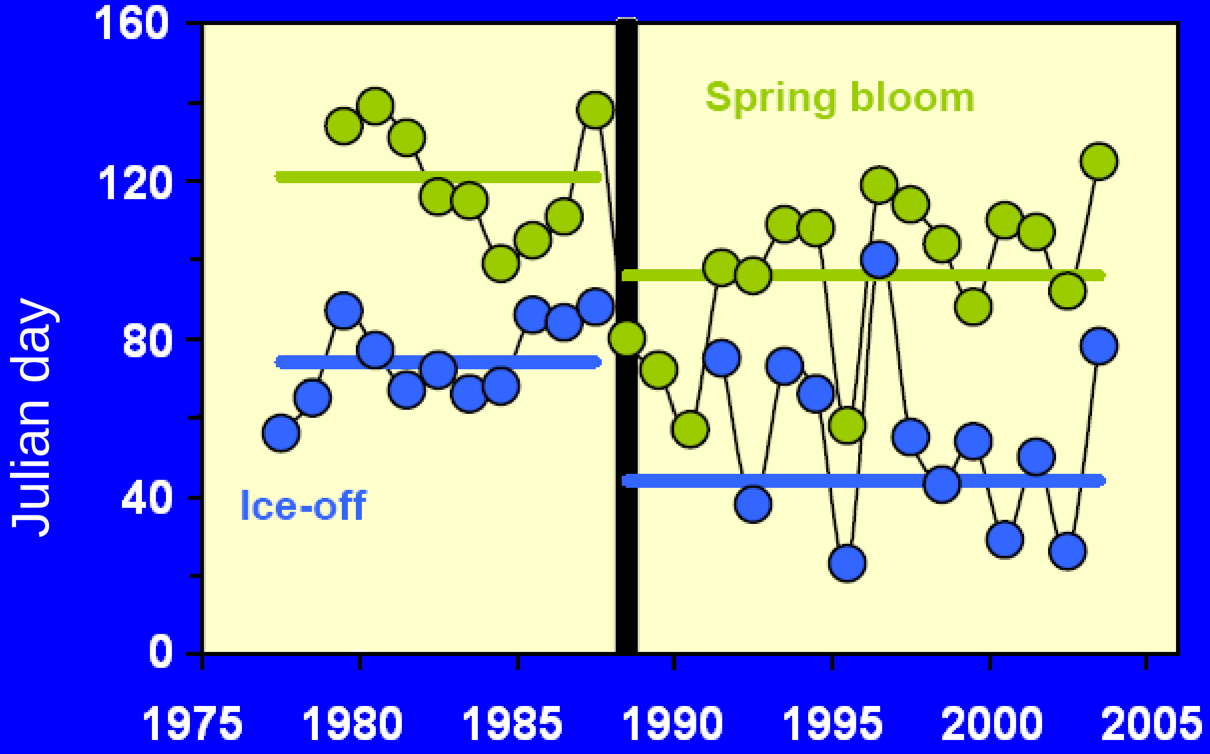
Ice breakup



Ice breakup



Müggelsee



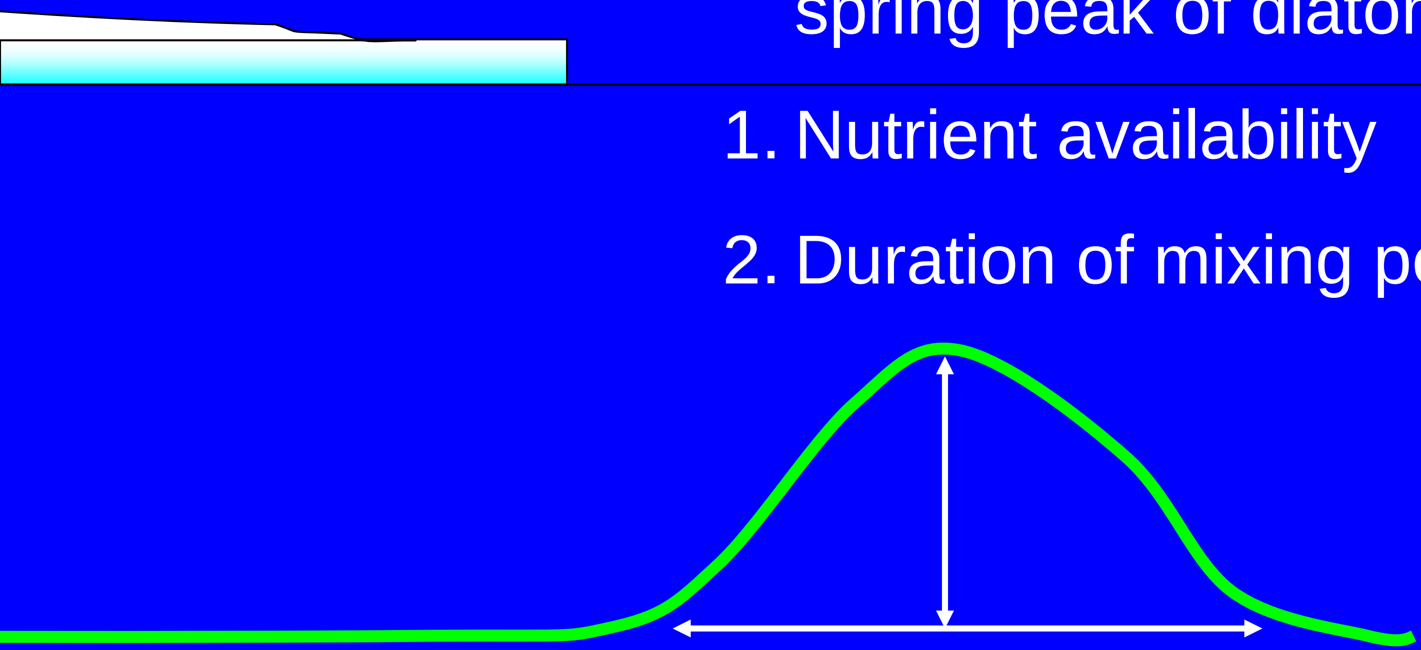
- Between 1979 and 2003, the timing of the spring bloom advanced by 28.5 days.
- A switching point occurred in 1988

Adrian et al. 2006

Duration of spring bloom

Both the height and duration of the spring peak of diatoms depend on:

1. Nutrient availability
2. Duration of mixing period

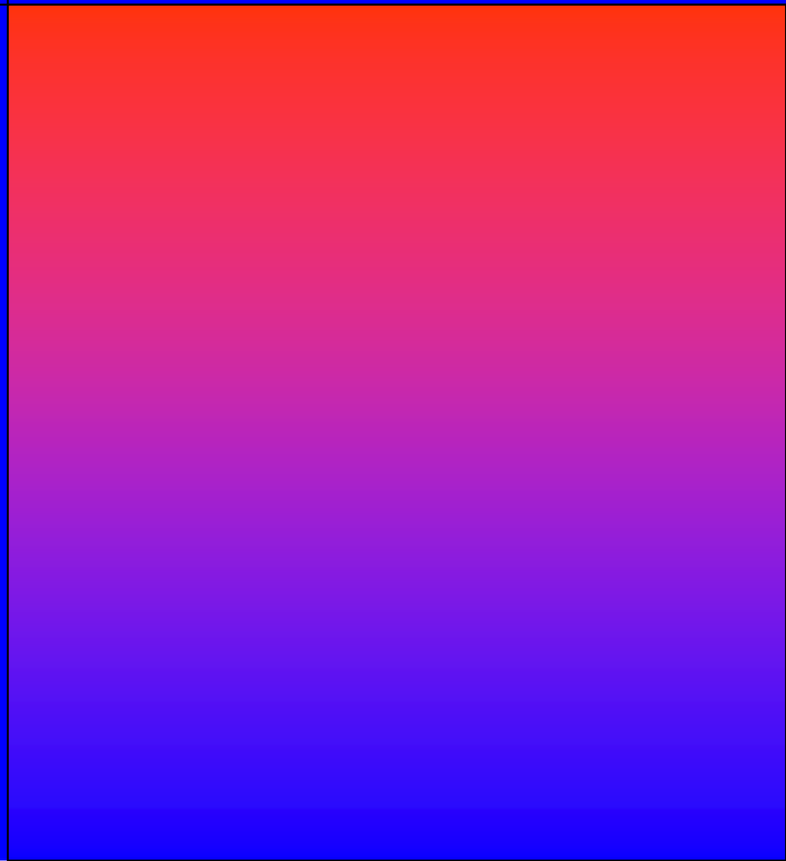


Blenckner 2005

Duration of spring mixing

Earlier ice breakup may result in

1. Longer mixing period

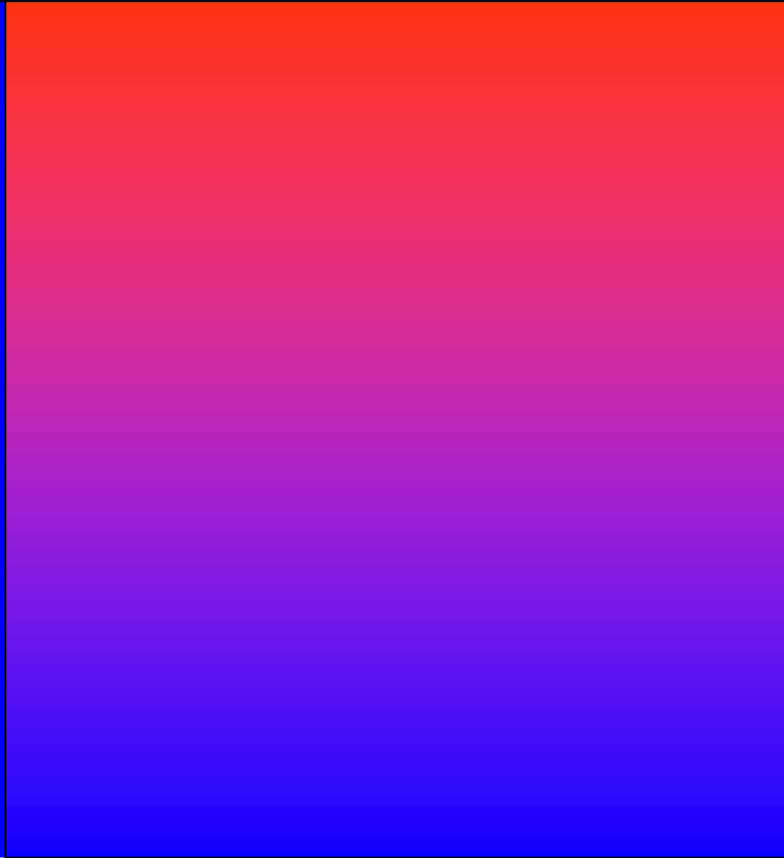


Duration of spring mixing

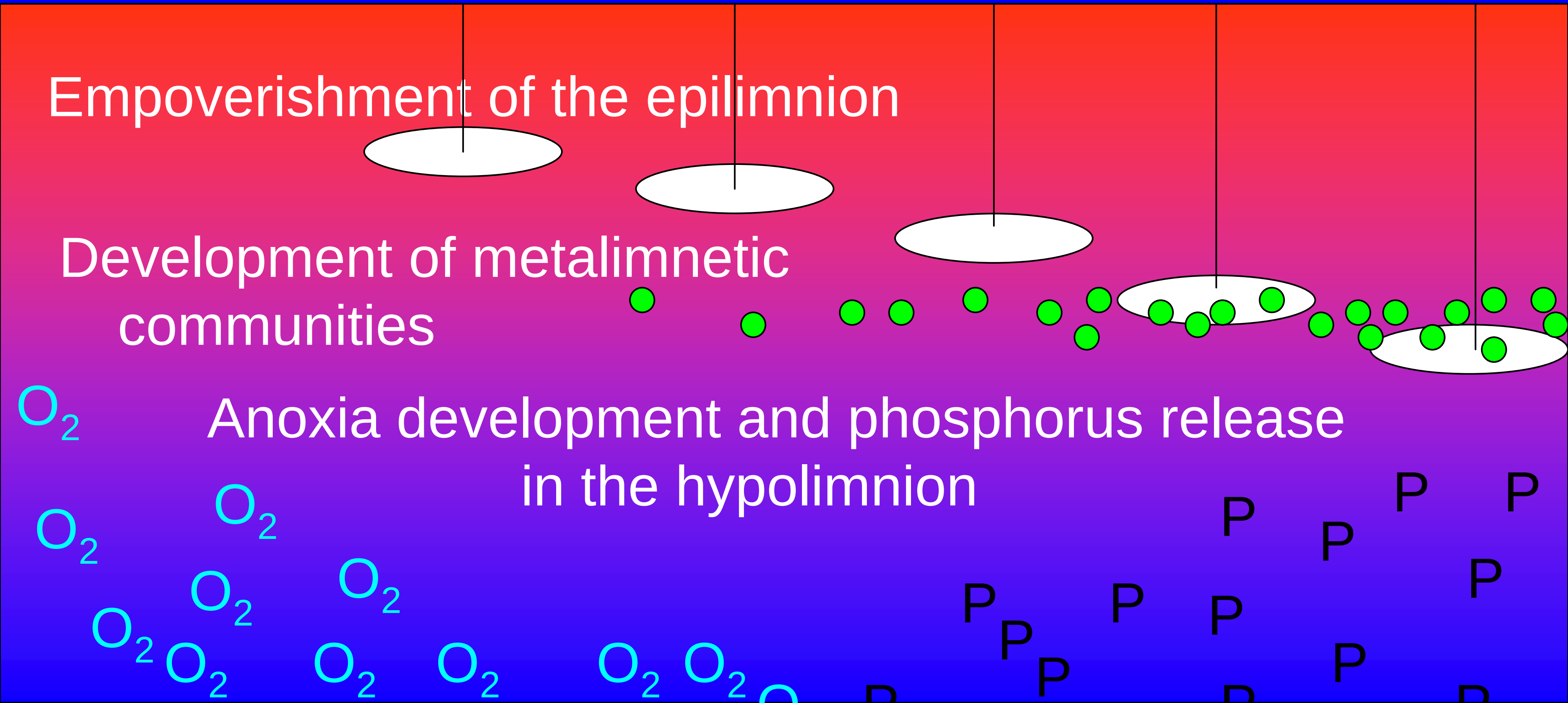
Earlier ice breakup may result in

1. Longer mixing period

2. Longer stratified period



Effects of longer stagnation period



CLIMATE

Blooms Like It Hot

Hans W. Paerl[1] and Jef Huisman[2]

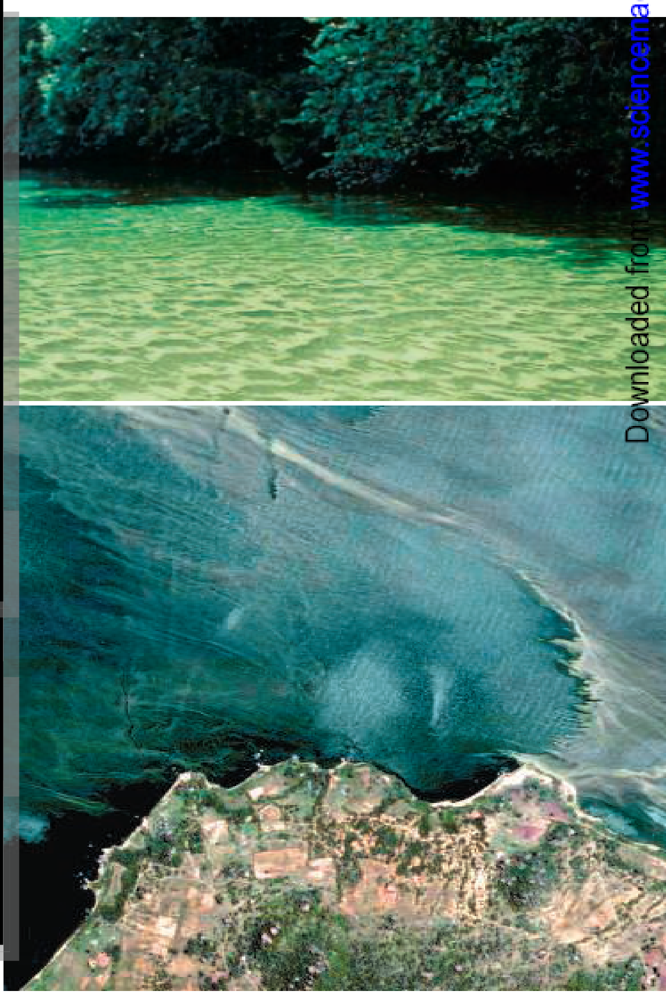
A link exists between global warming and the worldwide proliferation of harmful cyanobacterial blooms.

Cyanobacteria generally grow better at higher temperatures (often above 25°C) than do other phytoplankton

Lakes stratify earlier in spring and destratify later in autumn, which lengthens optimal growth periods. Many cyanobacteria exploit these stratified conditions .....

phytoplankton, thus suppressing their oppo-

Cyanobacterial blooms may even locally increase water temperatures through the intense absorption of light.



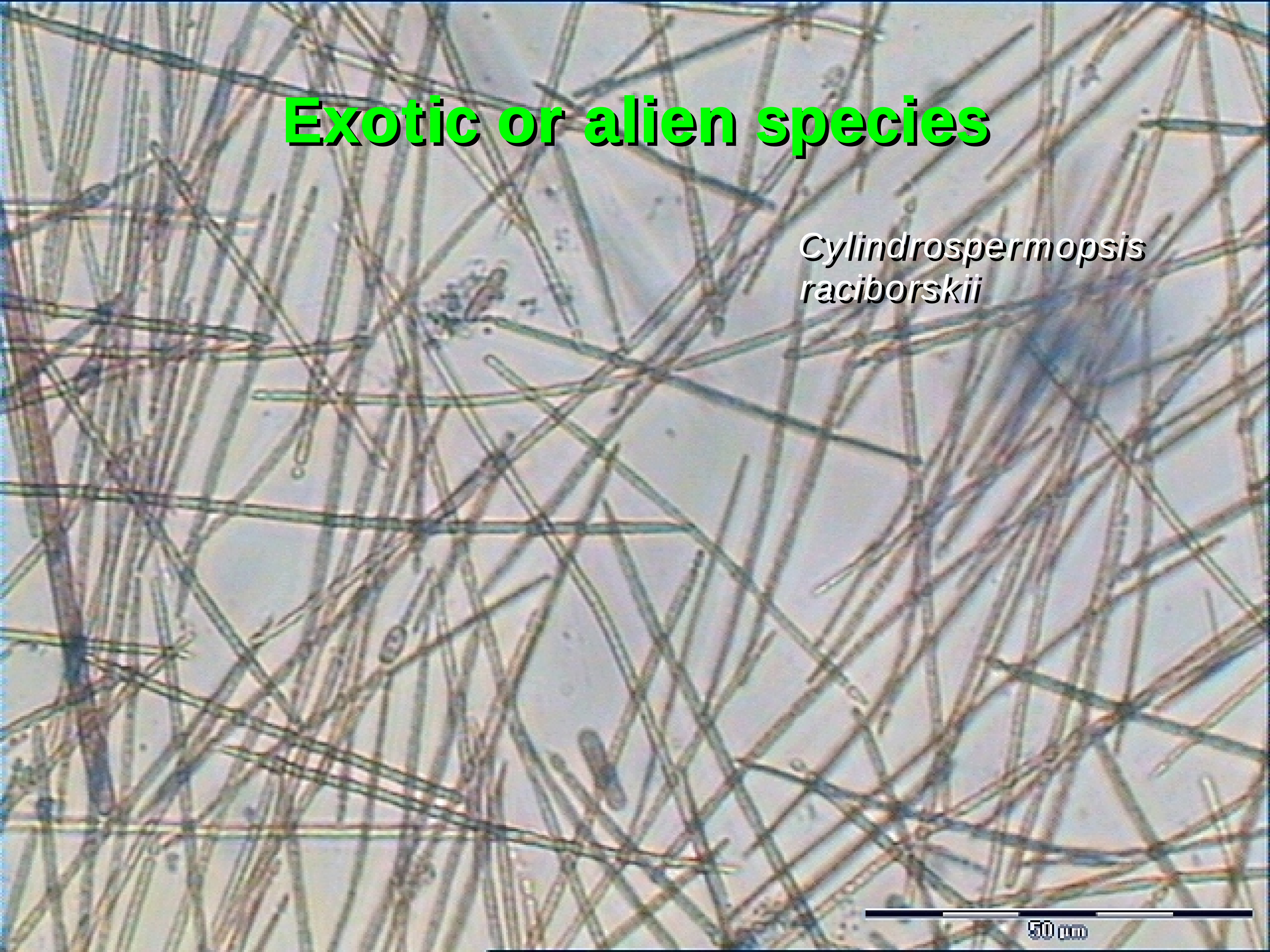
Undesired blooms. Examples of large water bodies covered by cyanobacterial blooms include the Neuse River Estuary, North Carolina, USA (top) and Lake Victoria, Africa (bottom).

nutrient loads will be captured, eventually promoting blooms. This scenario takes place when elevated winter-spring rainfall and flushing events are followed by protracted periods of summer drought. This sequence of

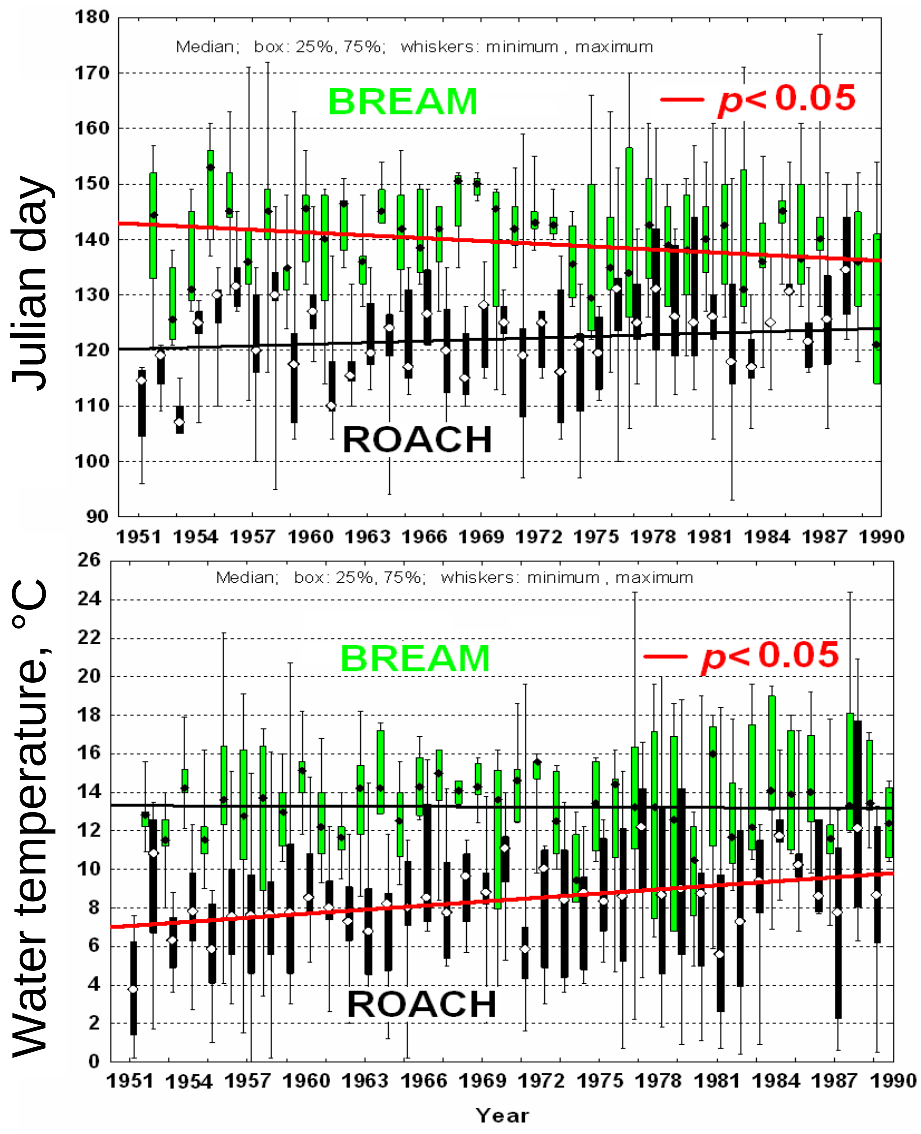
[1]Institute of Marine Sciences, University of North Carolina at Chapel Hill, Morehead City, NC 28557, USA. E-mail: hpaerl@email.unc.edu [2]Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, 1018 WS Amsterdam, Netherlands. E-mail: jef.huisman@science.uva.nl

CREDITS: (TOP) HANS PA

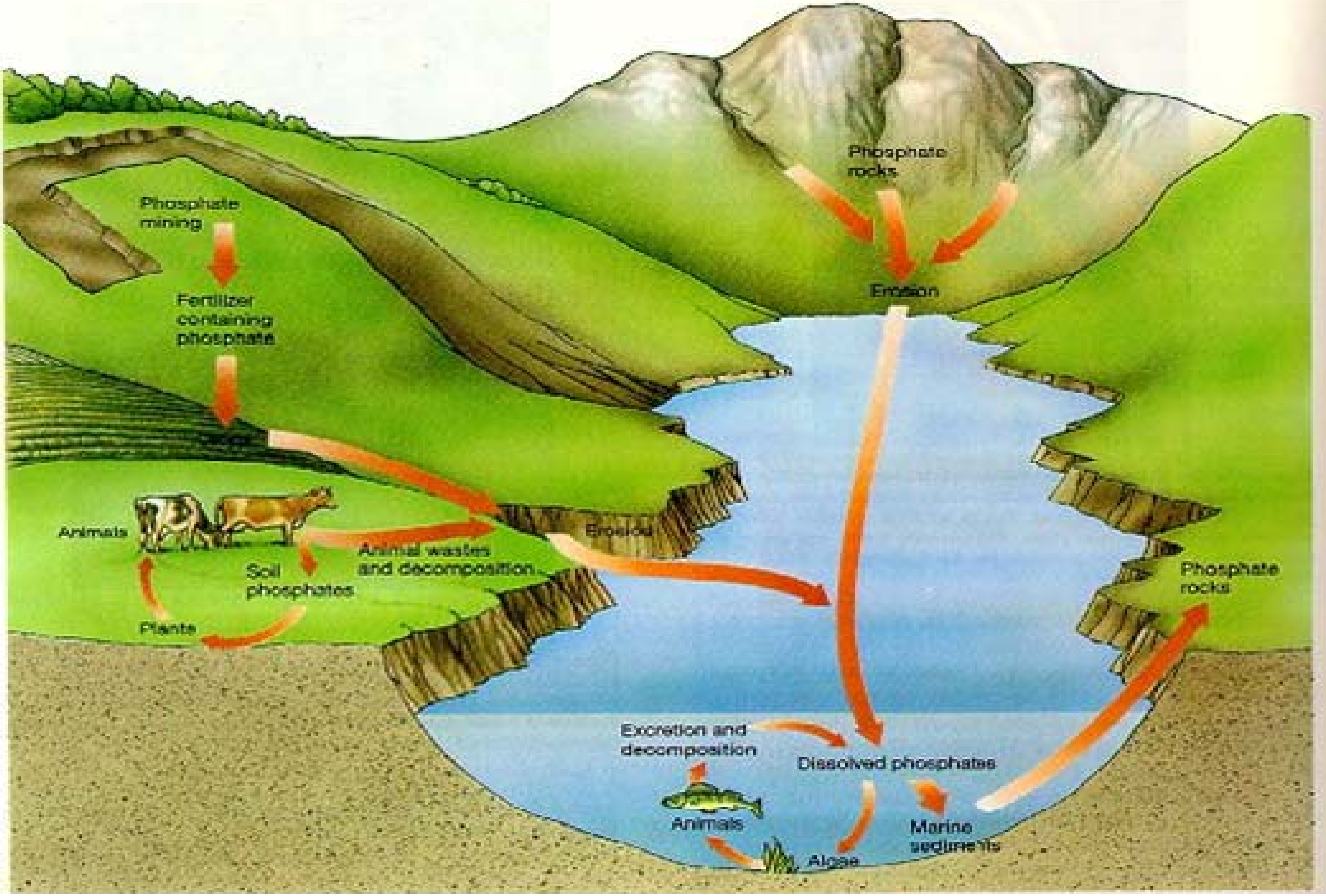
Exotic or alien species



Spawning of bream and roach in Estonia



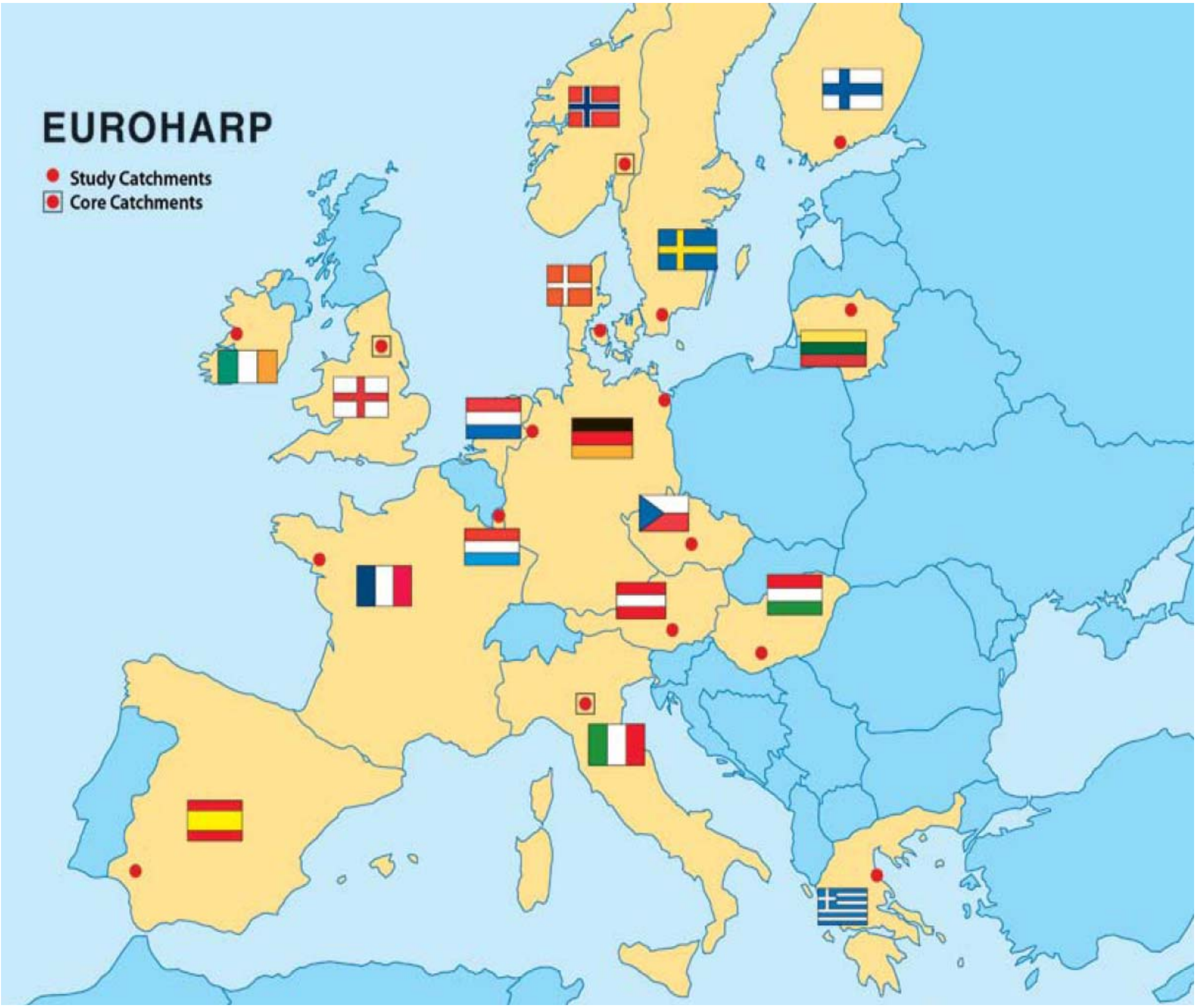
- Within forty years (1951-90), the spawning of **bream** shifted, on average, to a **ten days earlier** period but the range of spawning temperature remained unchanged
- There was no significant shift in the spawning time for **roach**, but the **spawning temperature increased** by about three degrees.



Effects through catchment processes

Towards European Harmonised Procedures for Quantification of Nutrient Losses from Diffuse Sources (2002-2005)

- 9 models tested in 17 catchments
- Eurajoki FI

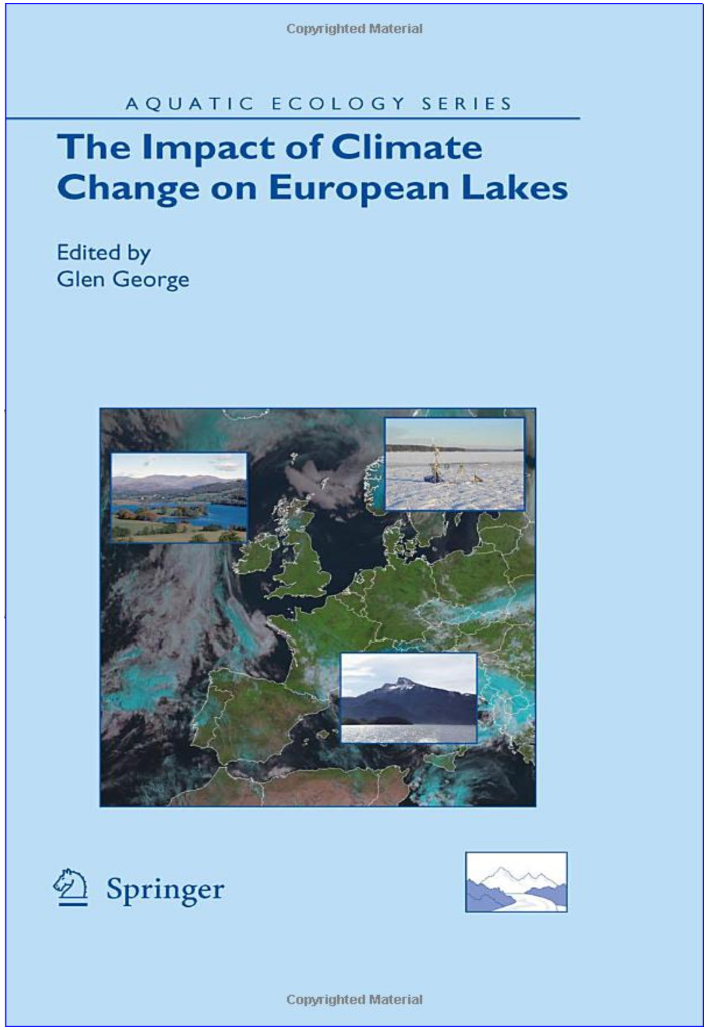


EUROHARP: Major factors leading to losses of nutrients

(F. Bouraoui et al., J. Env. Monitoring, 2009)

- Climatic variables, in particular **total rainfall** explained most of the variance in the **nutrient load** at the catchments outlet.
- **P concentration** - mostly controlled by **rain intensity** (amount of rainfall during a rainy day) and by **population density**.
- **N concentration** - mainly controlled by the extent of the **agricultural area**.

- Replacement of winter snow by more erosive rain increases erosion from fields in agricultural areas

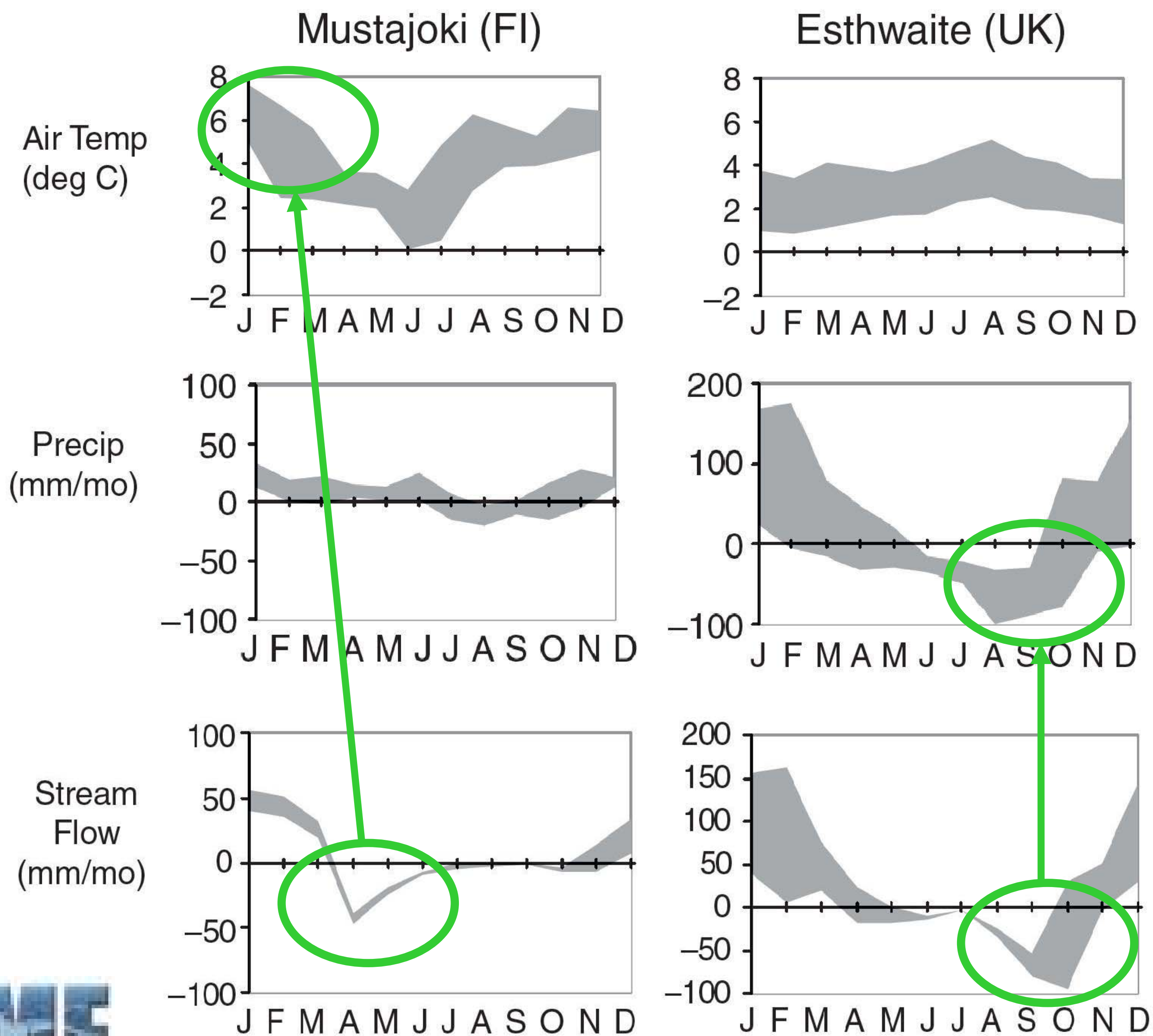


2010. 450 pp. 24 Ch.
Aquatic Ecology Series

CLIME

- **Observations and projections (2071-2100) of CC impacts on**
  - **hydrology**
  - **supply and re-cycling of N & P**
  - **flux of DOC from catchments**
  - **dynamics of phytoplankton**
- **Regional differences**
  - **Northern Europe**
  - **Western Europe (GB and Ireland)**
  - **Central Europe**

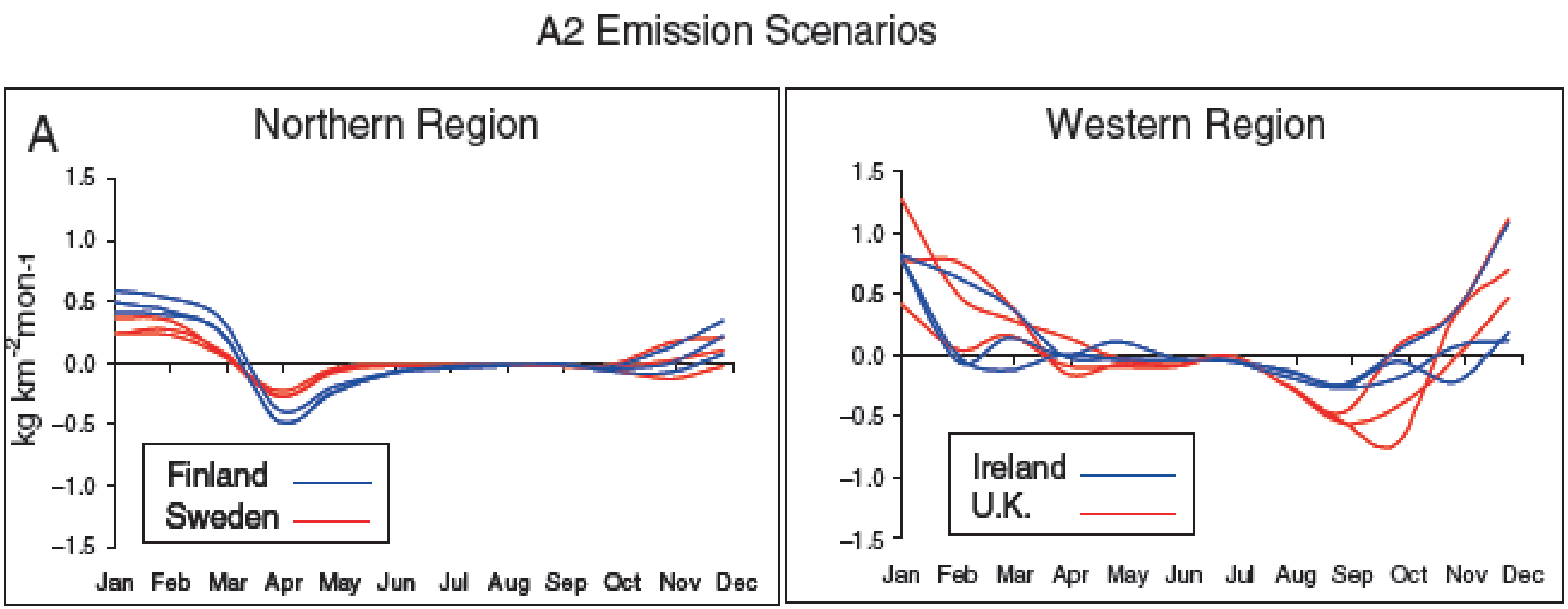
Projected CC impacts on hydrology



Schneiderman et al.

Projected changes of P loads

- Small changes in total annual P export
- Changes in **timing of P loadings**
- Higher T and lower O_2 $\Rightarrow$ **higher internal load**

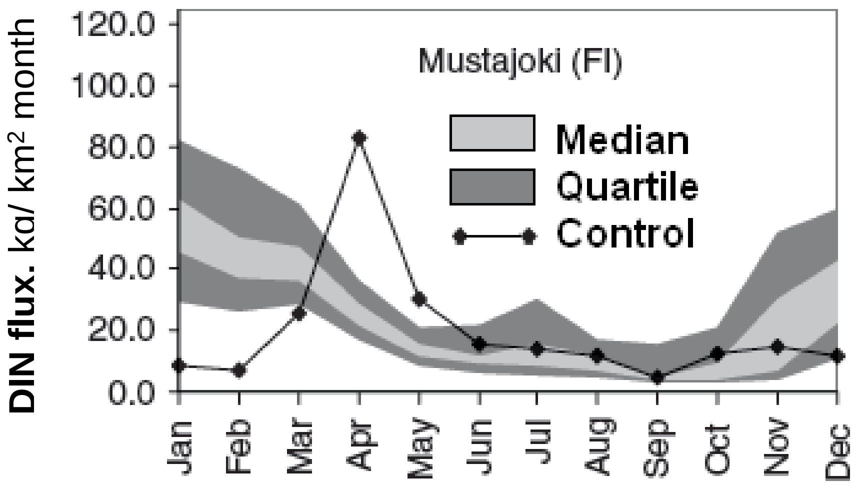


CLIME

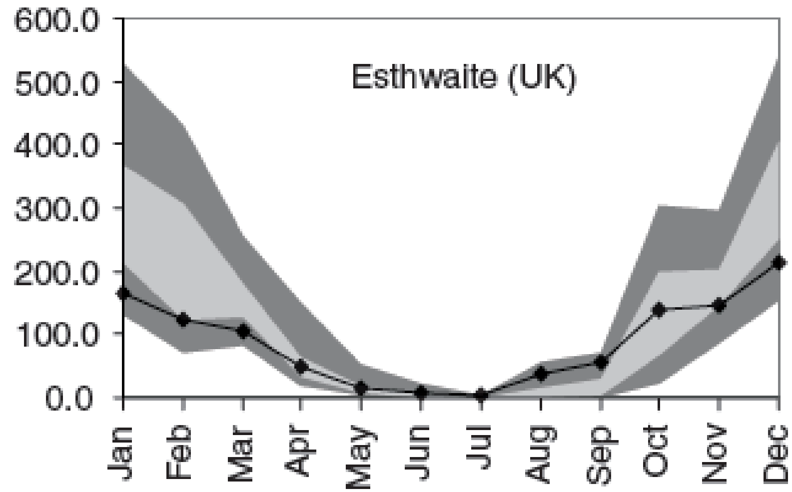
Pierson et al.

Projected changes in N loads

Nordic catchment

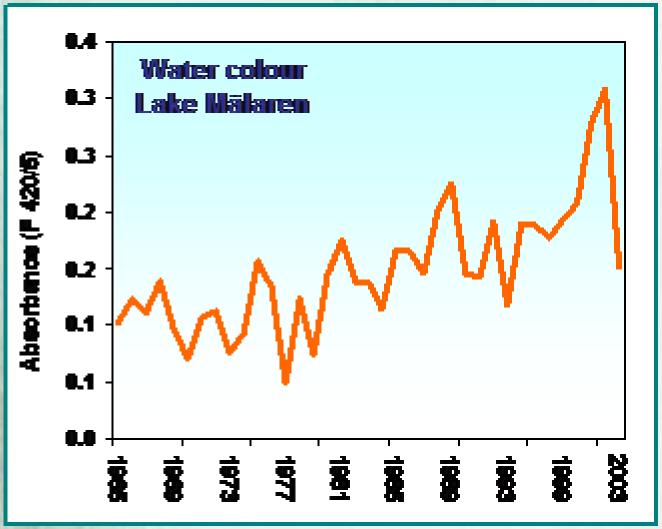


Western catchment



- **Increase of total annual N loss from the catchments**
- **Nordic catchments change most -** high sensitivity to small variations in rainfall and temperature

Moore et al.



Water color changes in Lake Mälaren 1965-2003

Nordic countries have experienced a doubling or even a tripling of water colour levels over the last decades

The impact of climatic factors on DOC production and transport is complex and includes the combined effects of both temperature and precipitation on the decomposition, solubility and hydrological transport of these compounds (Jennings et al. 2010)

Global Change Biology (2006) **12**, 2044–2053, doi: 10.1111/j.1365-2486.2006.01241.x

OPINION

Alternative explanations for rising dissolved organic carbon export from organic soils

CHRISTOPHER D. EVANS,* PIPPA J. CHAPMAN,† JOANNA M. CLARK,† DON T. MONTEITH‡ and MALCOLM S. CRESSER§

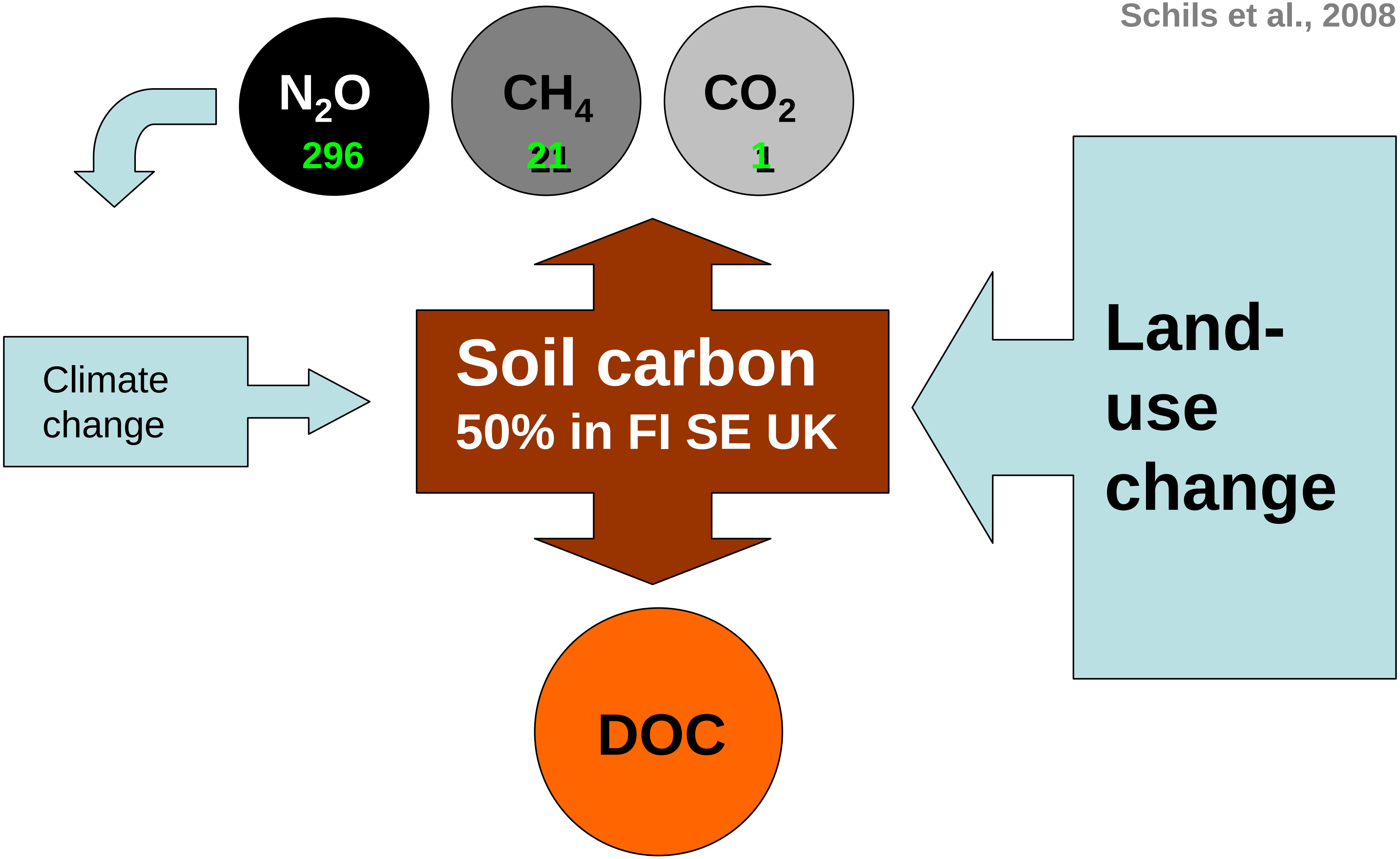
**Centre for Ecology and Hydrology, Bangor LL57 2UP, UK, †Earth and Biosphere Institute, School of Geography, University of Leeds, Leeds LS2 9JT, UK, ‡Environmental Change Research Centre, University College London, London WC1H 0AP, UK, §Environment Department, University of York, York YO10 5DD, UK*

- **Mobility of DOC has increased due to increased soil water pH resulting from reduction of atmospheric sulphate deposition**

Soil carbon and climate change

ClimSoil
CLIMATE CHANGE SOIL CARBON

Schils et al., 2008



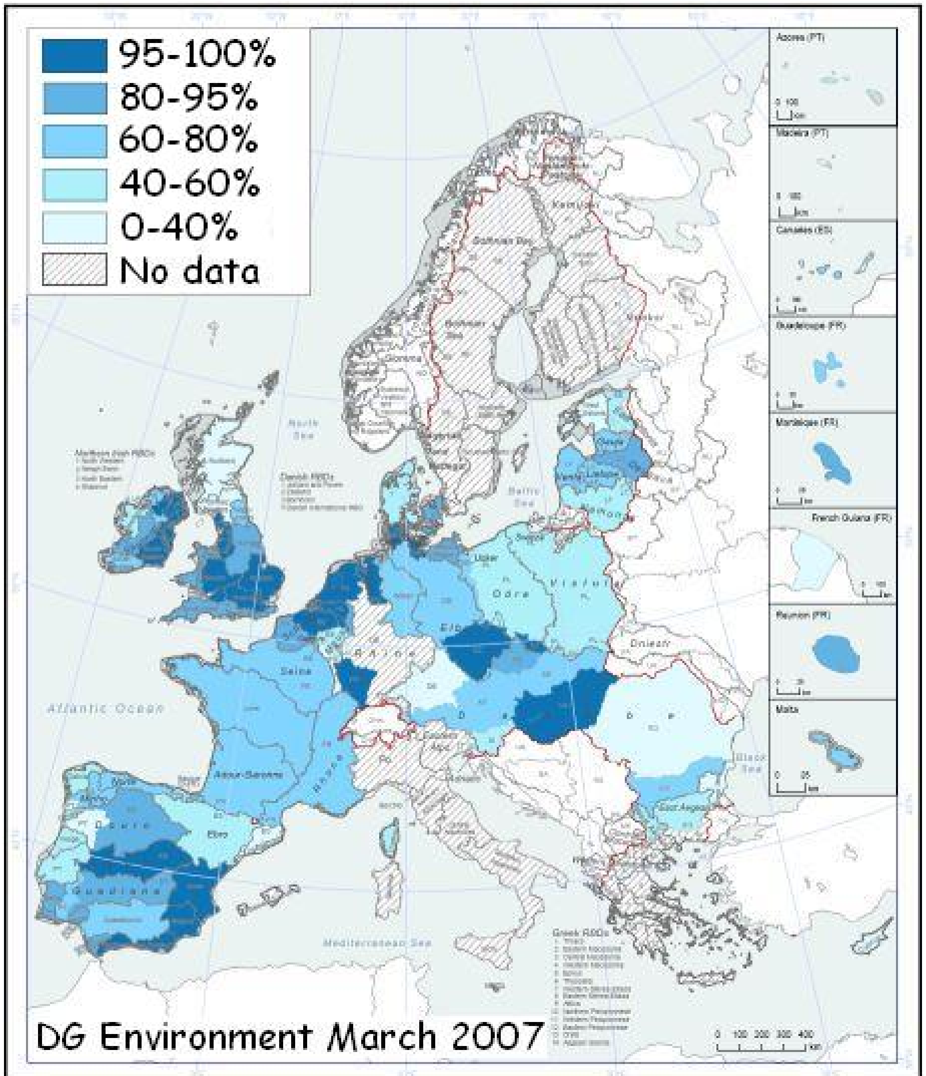
CC induced reacidification of surface waters

- In acid sulphate soils, climate-induced **droughts** may cause **reacidification** to the levels of late 1970s
  - **oxidation** of previously stored reduced **S-compounds** in wetlands during drought **low-flow** periods
  - subsequent **efflux of sulphates upon re-wetting**

(Aherne et al., 2007)

CC and water policy

Water bodies at risk not to meet the WFD objectives

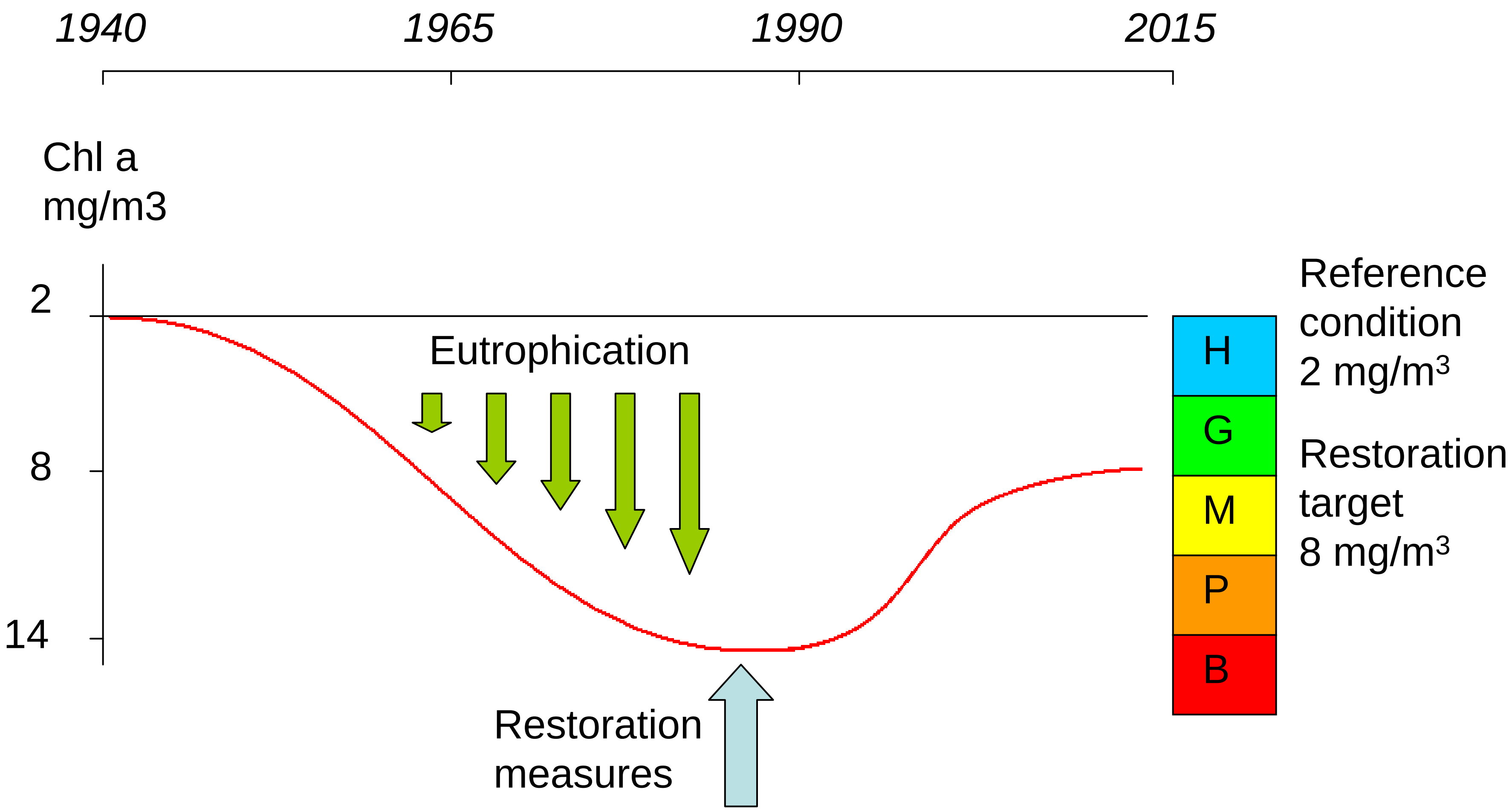


- Number of water bodies meeting WFD objectives was low, sometimes only 1% and generally less than 40%.
- Significant pressures were diffuse pollution and physical degradation
- In southern Europe, over-exploitation of water resources.

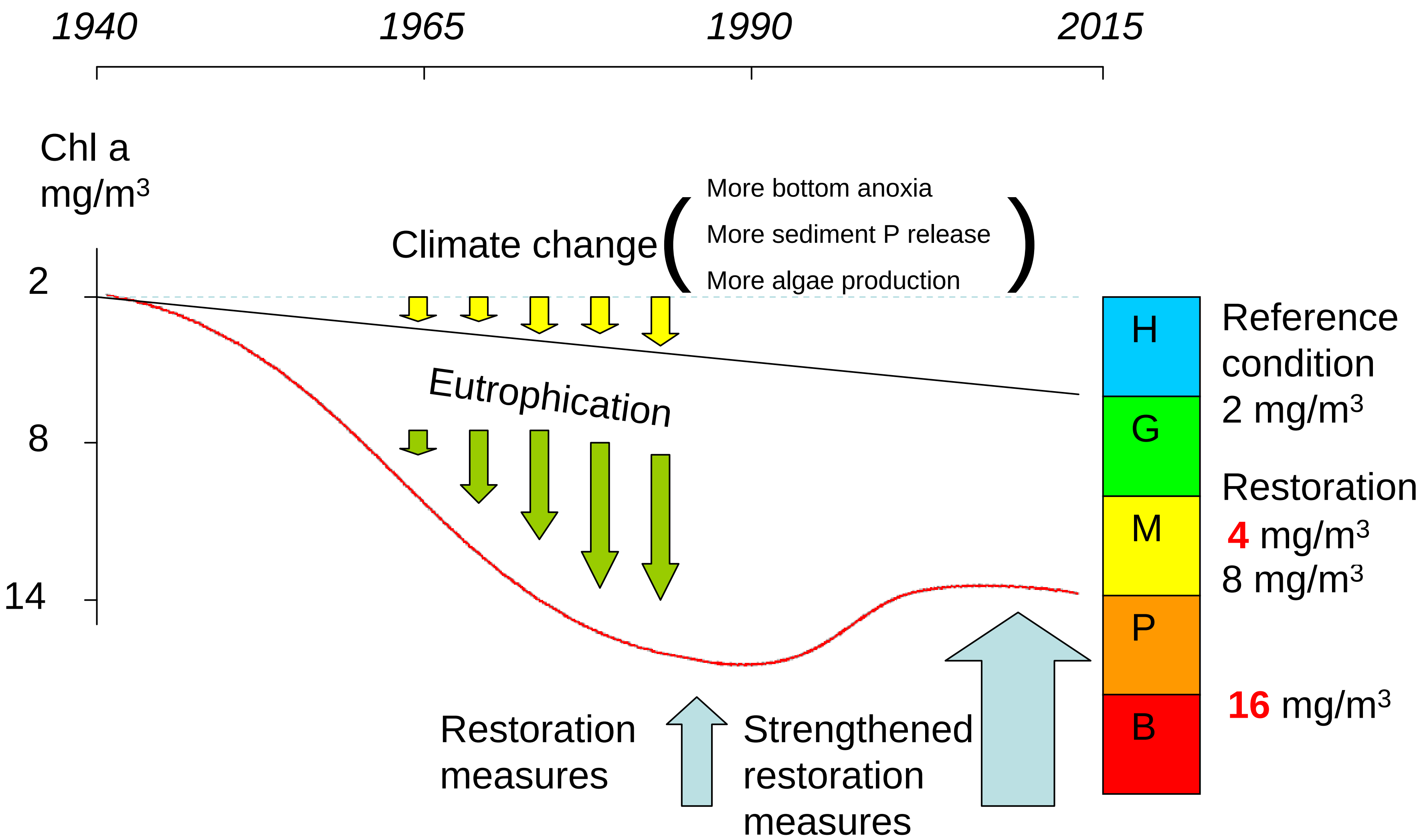
1st WFD implementation report, 2007

CC sensitive aspects of ecological status assessment

- Typology of water bodies
  - Typology criteria
    - **Depth**
    - **Residence time**
    - **Mixing characteristics**
    - **Water level regime**
    - **Mean air temperature**
    - **Background nutrient status**
- Ecological quality assessment
  - Type specific reference conditions
  - Quality class boundaries



Approach without considering CC



Moving the targets (after having done the best with restoration measures)

Technical Report - 2009 - 040

COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)

Guidance document No. 24

RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE

Guidance document

<u>Guiding principles</u>

(11)

1. Assessing direct and indirect climate pressures
2. Detecting climate change signals
3. Monitoring change at reference sites
4. Setting objectives

- -

↓

<u>Suggested actions</u>

Practical actions to be taken in order to apply the principles

↓

<u>Examples</u>

Principles and actions in practice (BMPs)

Examples of adaptation measures

- “Win-win” measures
  - Reduction of water use
  - Optimization of fertilizer use
  - Buffer strips
- “No regret” measures
  - Restoration of natural river beds and flood plains
  - Restoration of wetlands
  - Reforestation
  - Erosion control measures
- Potentially counter-productive measures
  - “Naturalisation” of rivers in densely populated areas
  - Dam construction
  - Modifications of land-use practices
  - Production of biofuels

Major CC related processes & concerns

Changes in hydrology (river flow, lake levels, retention time, ice regime)

Changed mobility of pollutants in soil and lake sediments

Increased thermal stability of lakes

Shifted timing of meteorological and biological processes

Nutrient loads

Oxygen depletion

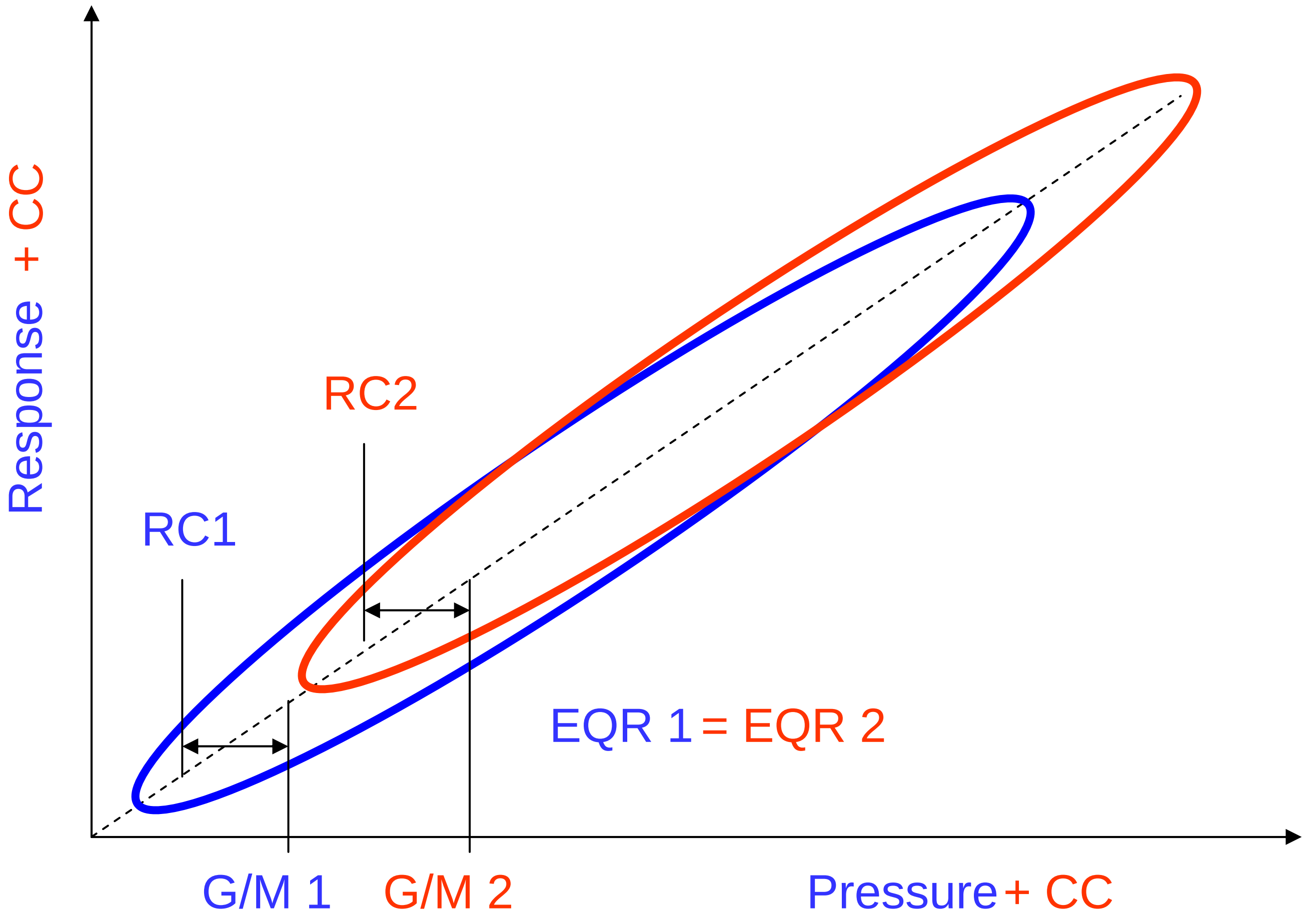
Natural organic compounds

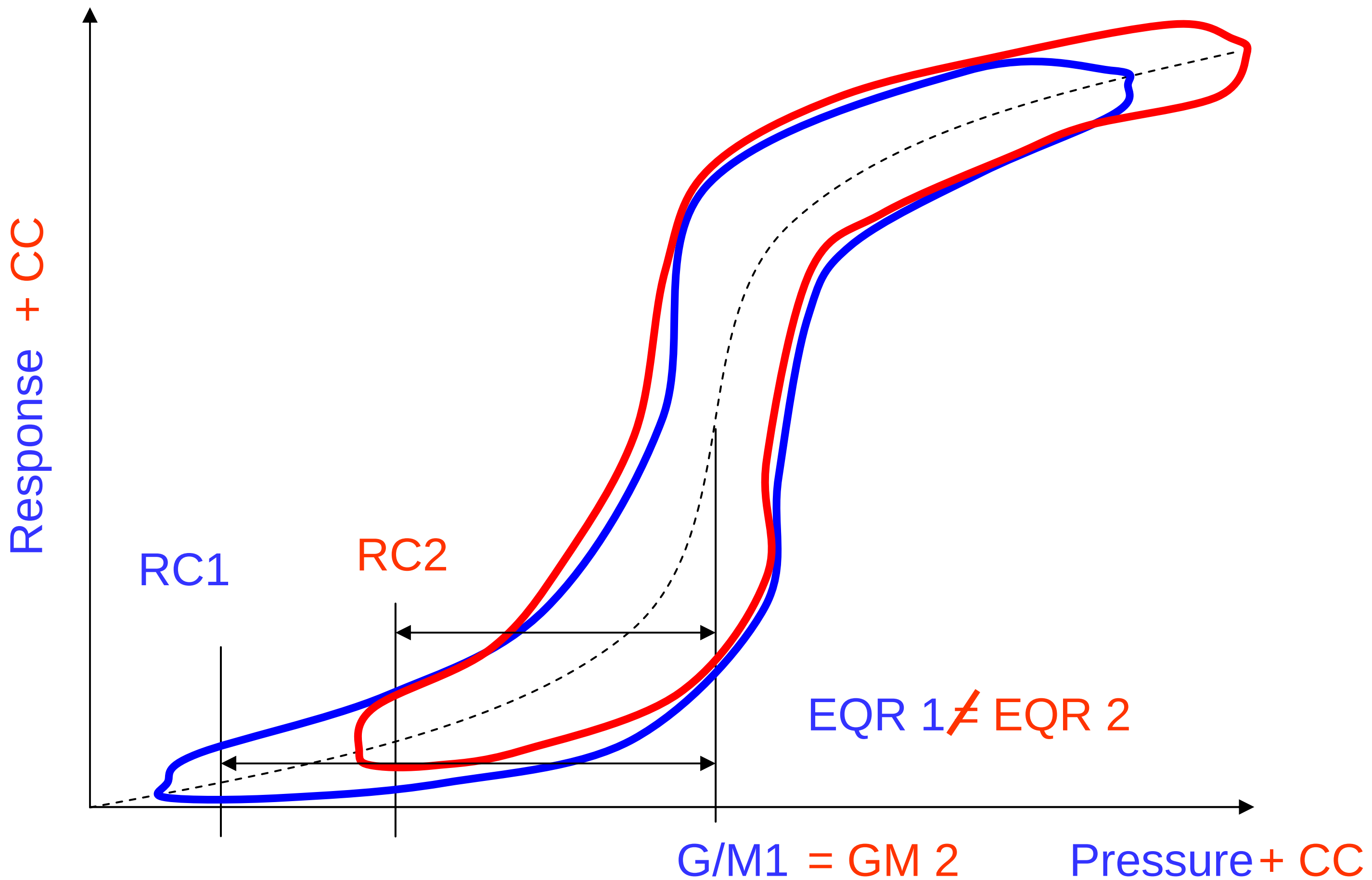
Hazardous substances

Ecological status (effects on biota)

- Habitat fragmentation
- Habitat shift
- Loss of biodiversity
- Alien species

Thank you!


Response + CC
RC2
RC1
EQR 1 = EQR 2
G/M 1
G/M 2
Pressure + CC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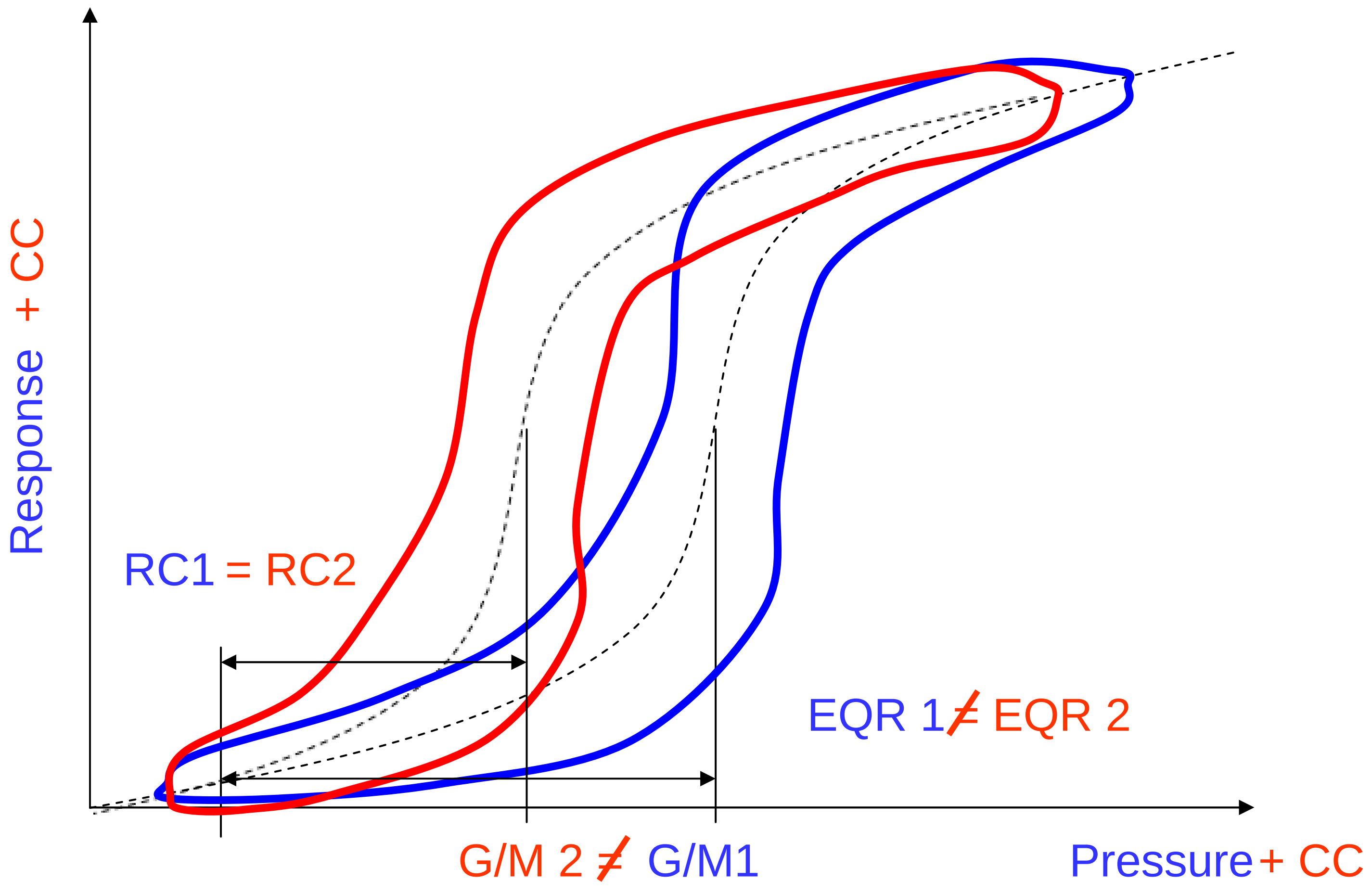
Response + CC
RC1 = RC2
EQR 1 ≠ EQR 2
G/M 2 ≠ G/M1
Pressure + CC