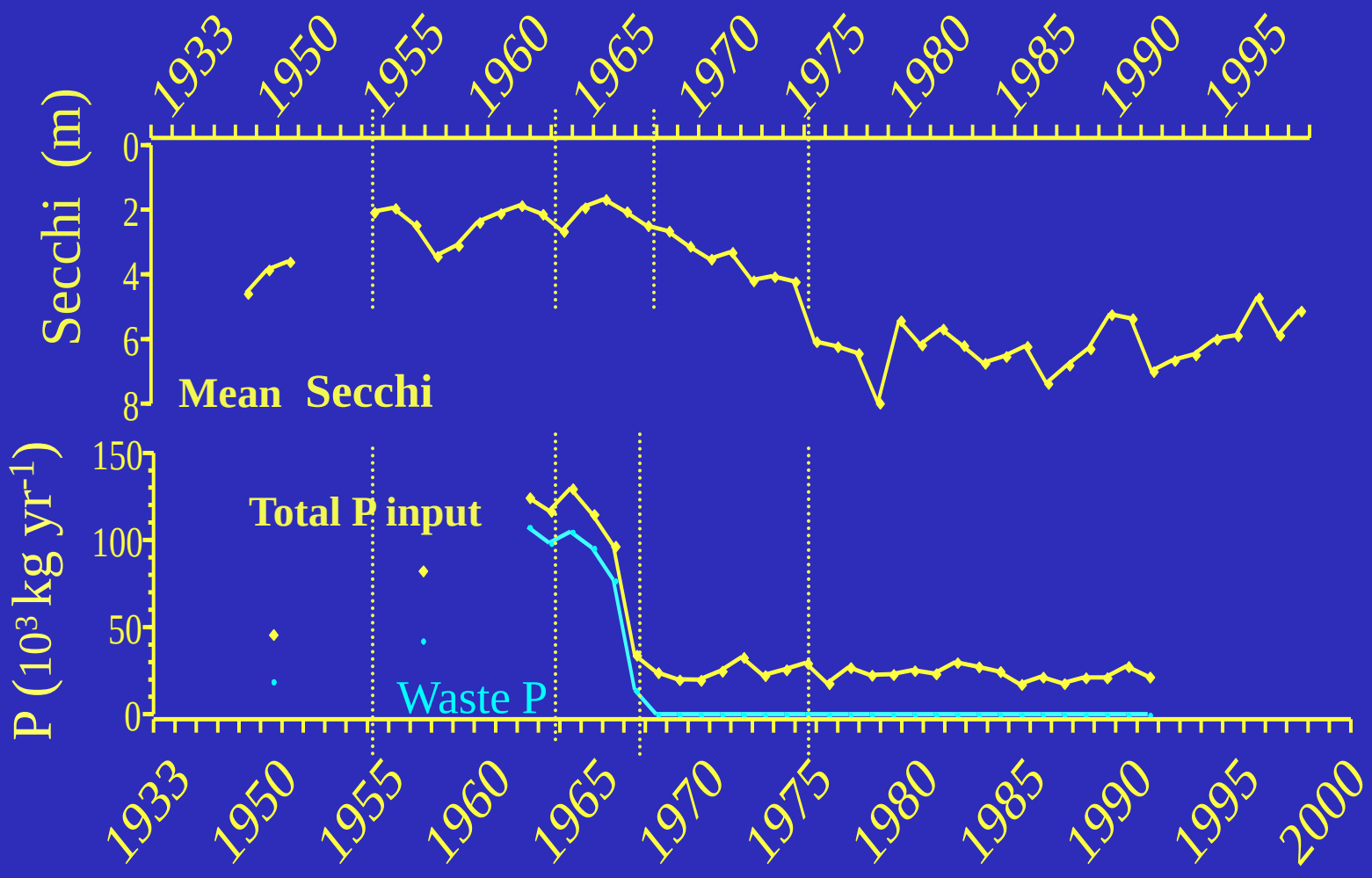
Historical perspective of eutrophication

Erik Jeppesen, Aarhus University,Denmark

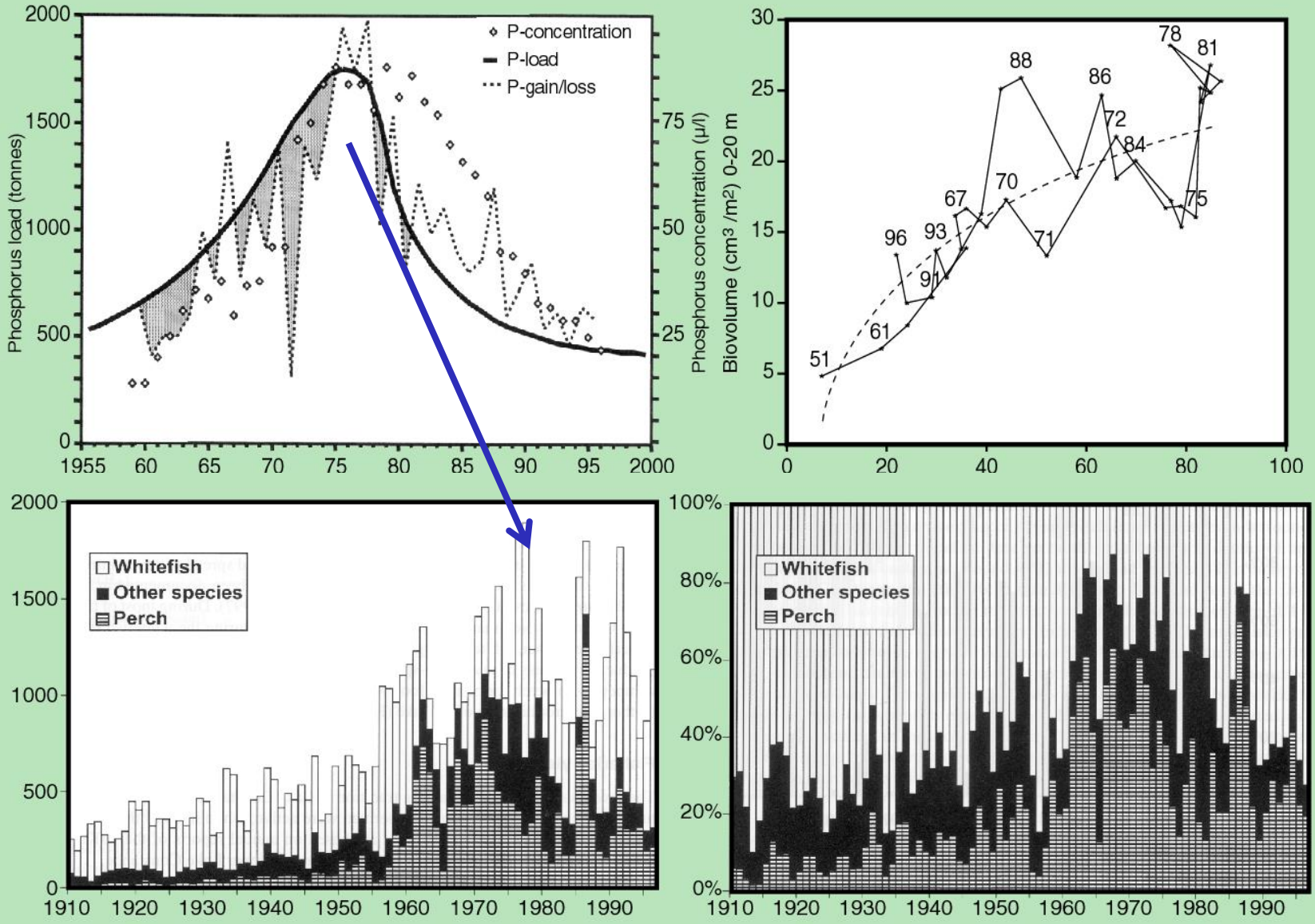


Lake Washington (Lake Edmondson)

Hampton and Winder

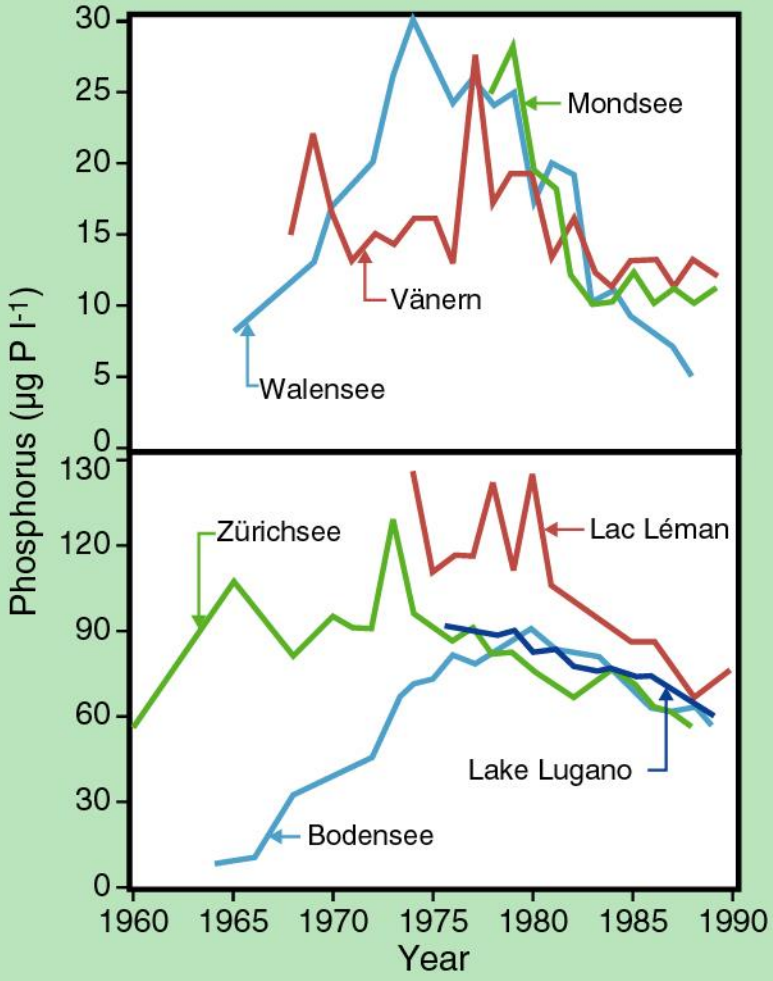
Lake Constance, Germany

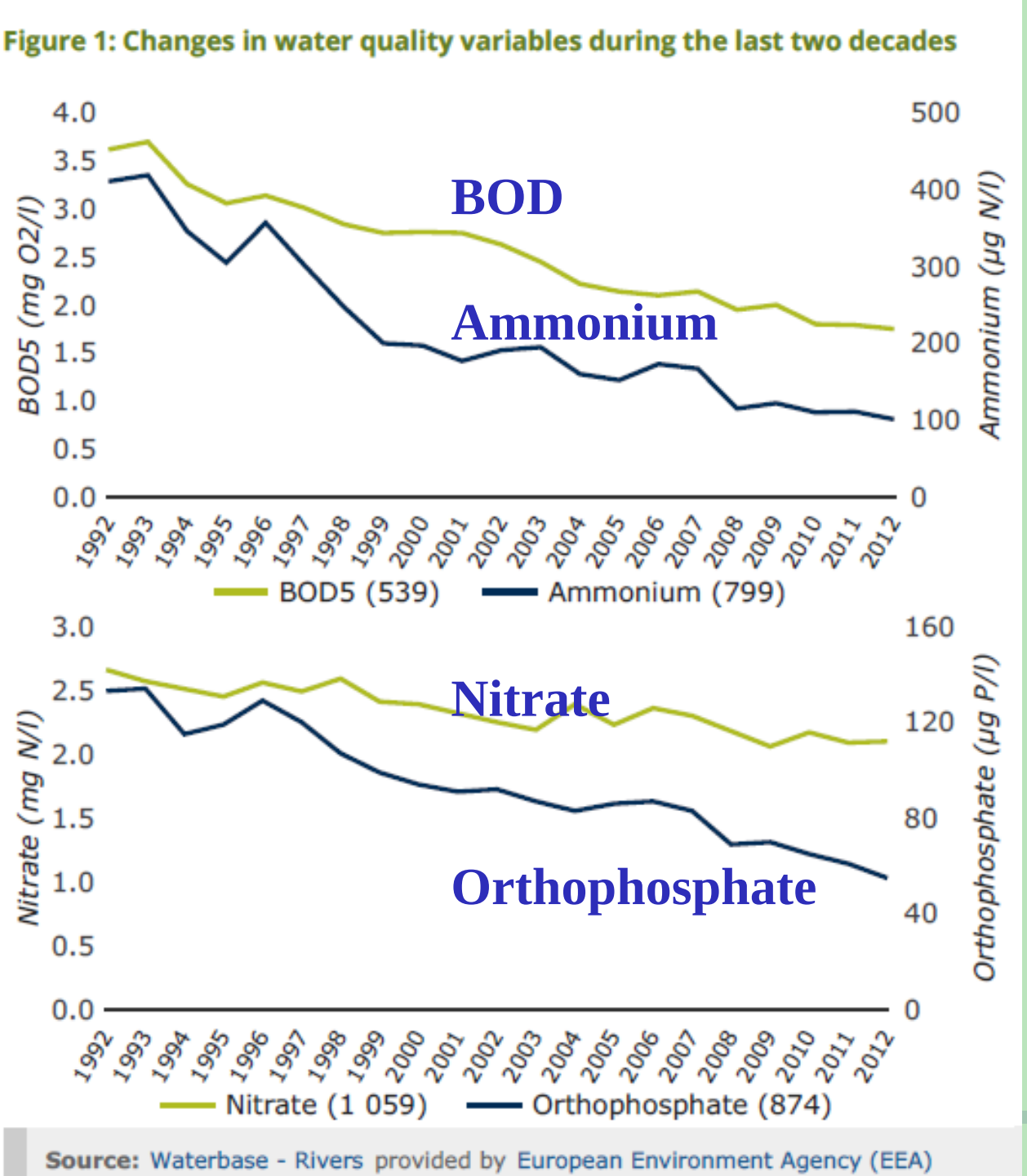
530 km2, mean depth 100 m



(R.Eckmann and R. Rôsch, 1998)

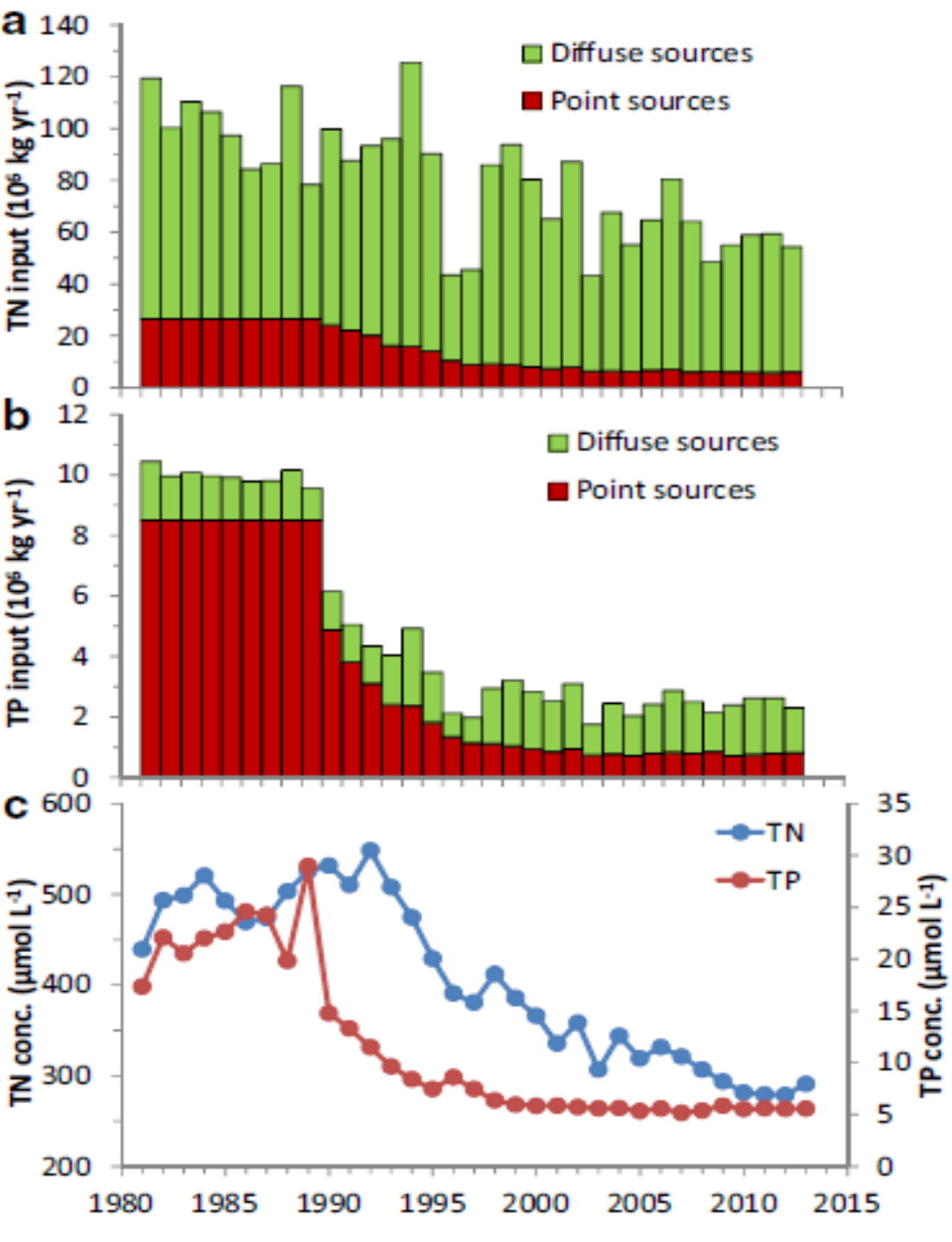
TP loading reduction





Major changes In European waters in BOD, inorganic N and Orhto-P

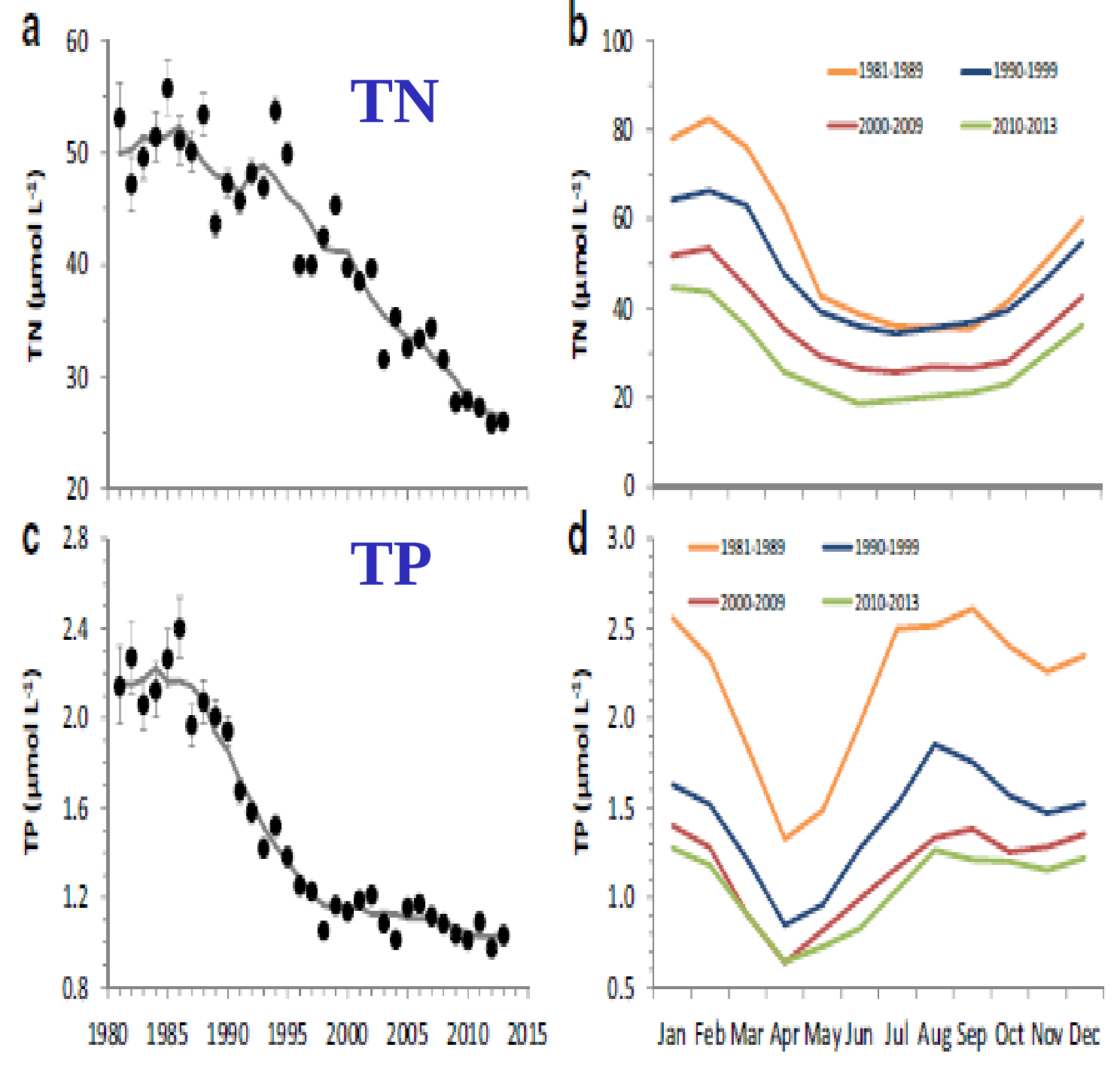
Severe problems – e.g. channelised streams



Loading to coastal waters in Denmark

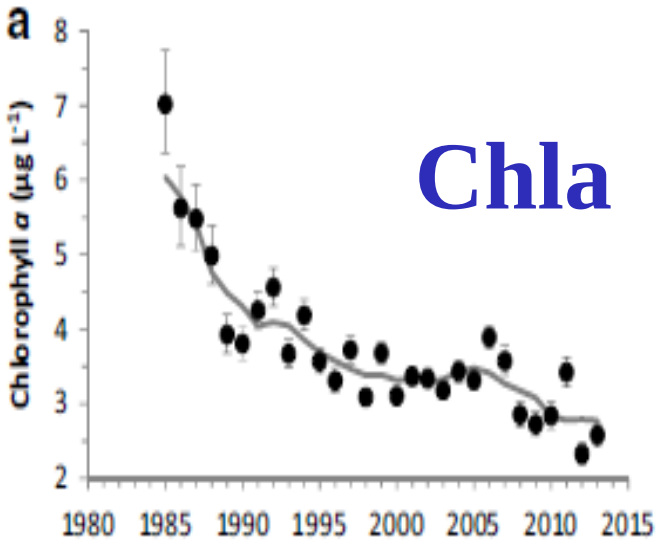
and concentrations

Riemann et al. 2015

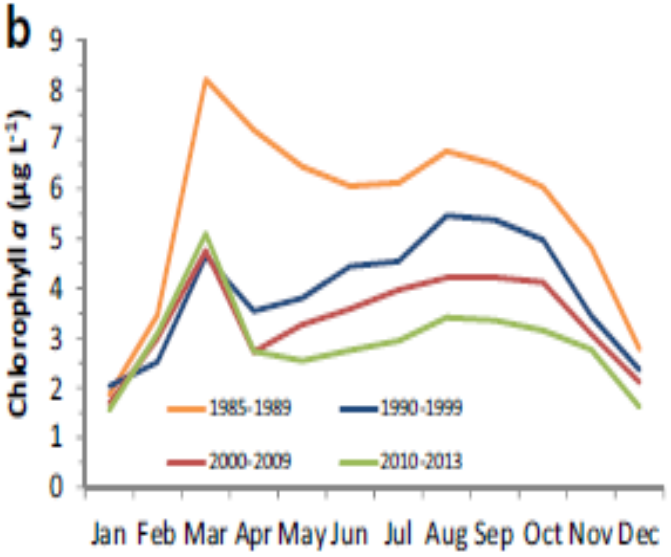


Riemann et al. 2015

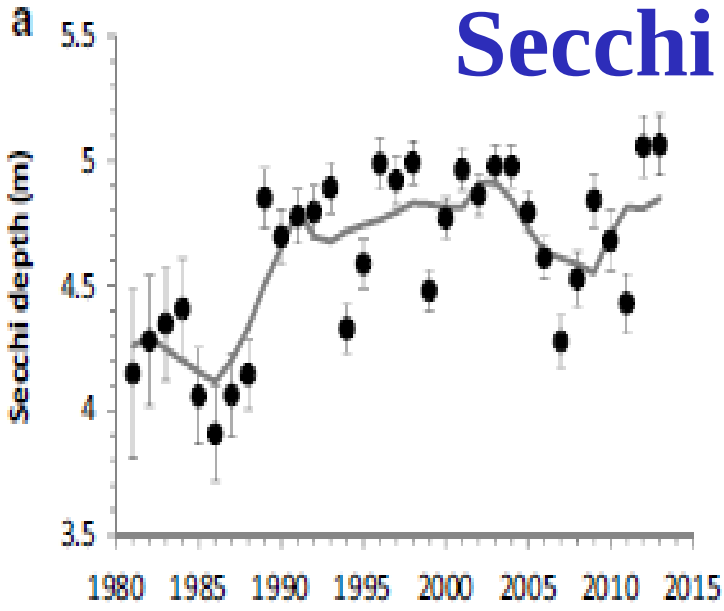
Chlorophyll a and Secchi depth

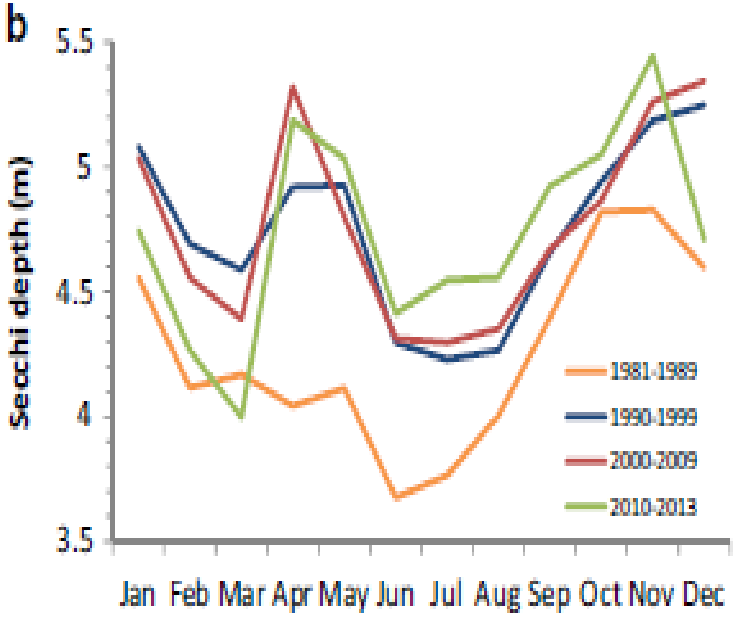


Chla

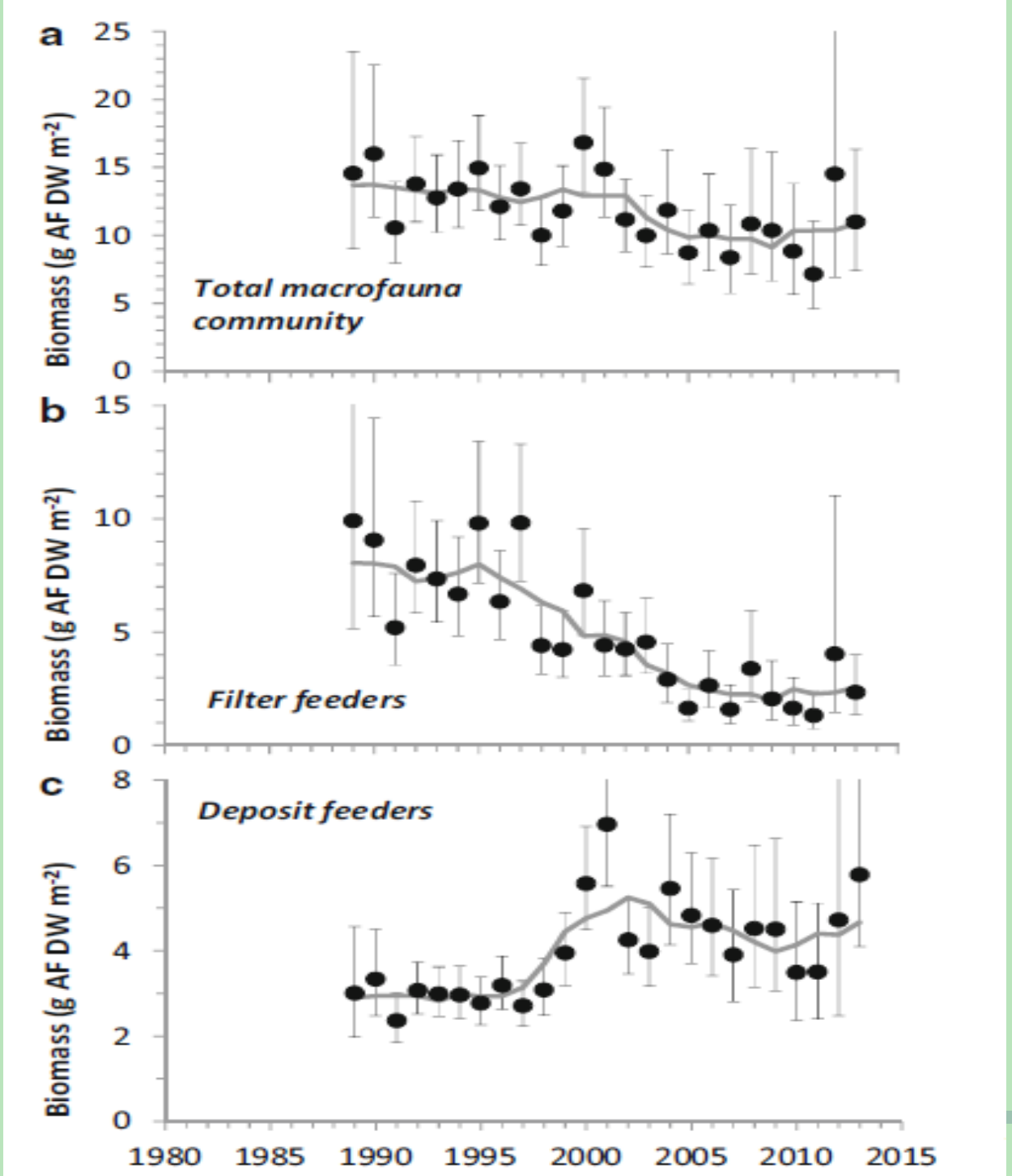


Secchi





Riemann et al. 2015



Total macrofauna

Filter feeders

Deposit feeders

Riemann et al. 2015


华东旅游网
www.3349.com

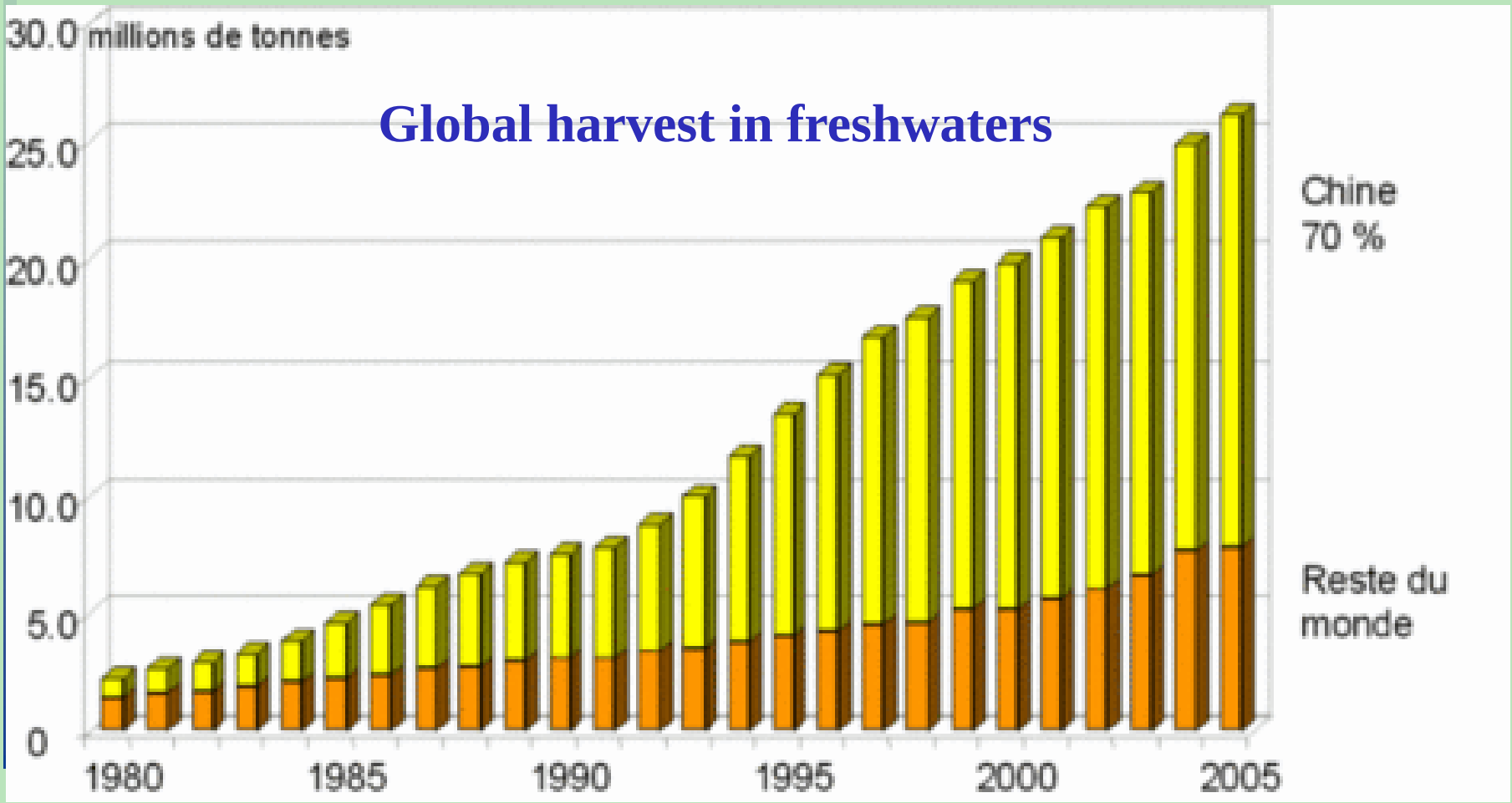
Cyanobacterial blooms in Lake Dianchi

Sewage from Kunming of key importance

Water hyacinth in Lake Dianchi

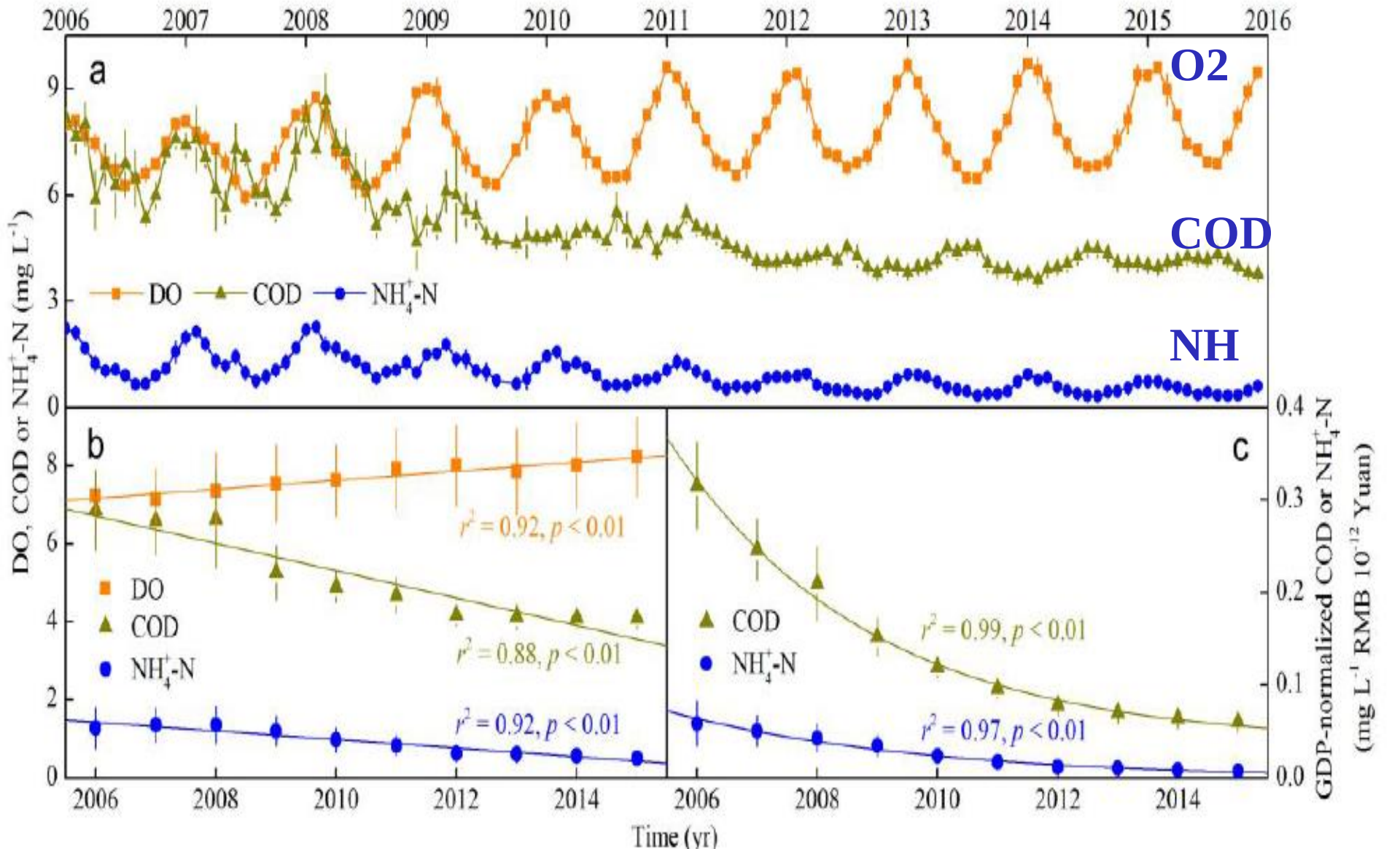
High fish production in natural lakes implying stocking and or feeding

leads to a major detrioration of water quality

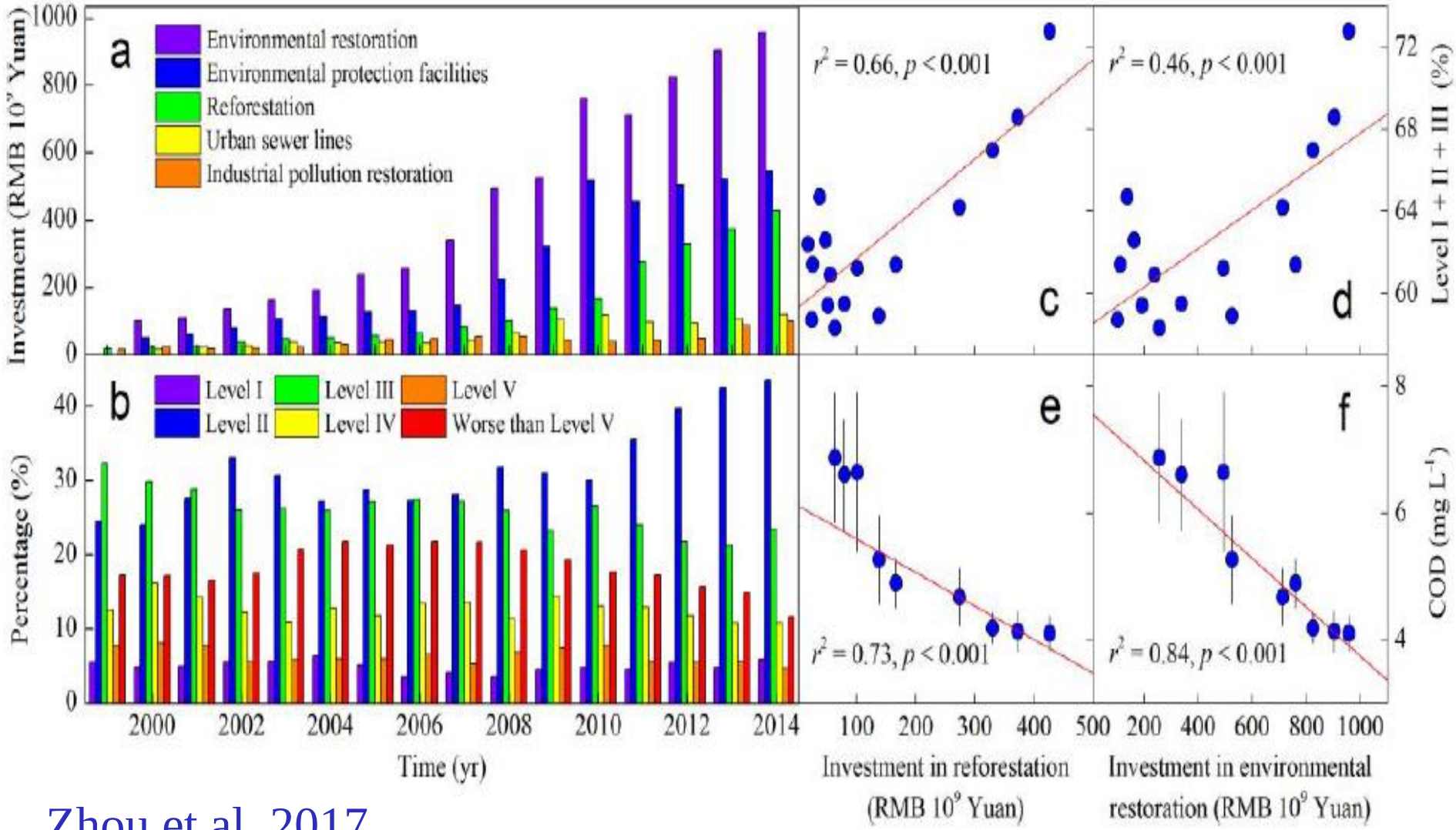


Changes in Chinese rivers

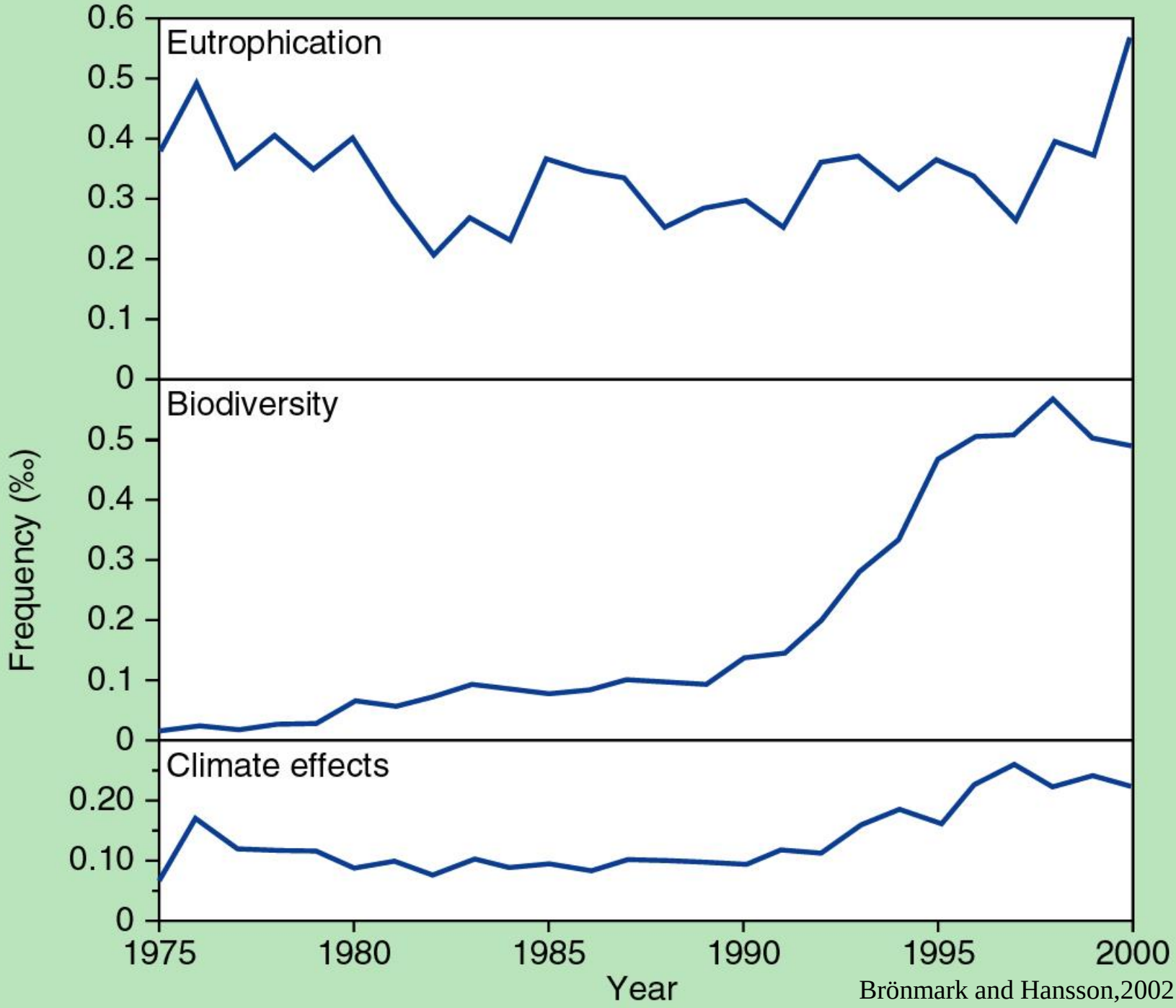
Zhou et al., Water Research, 2017press



Improvments in China in the last decade

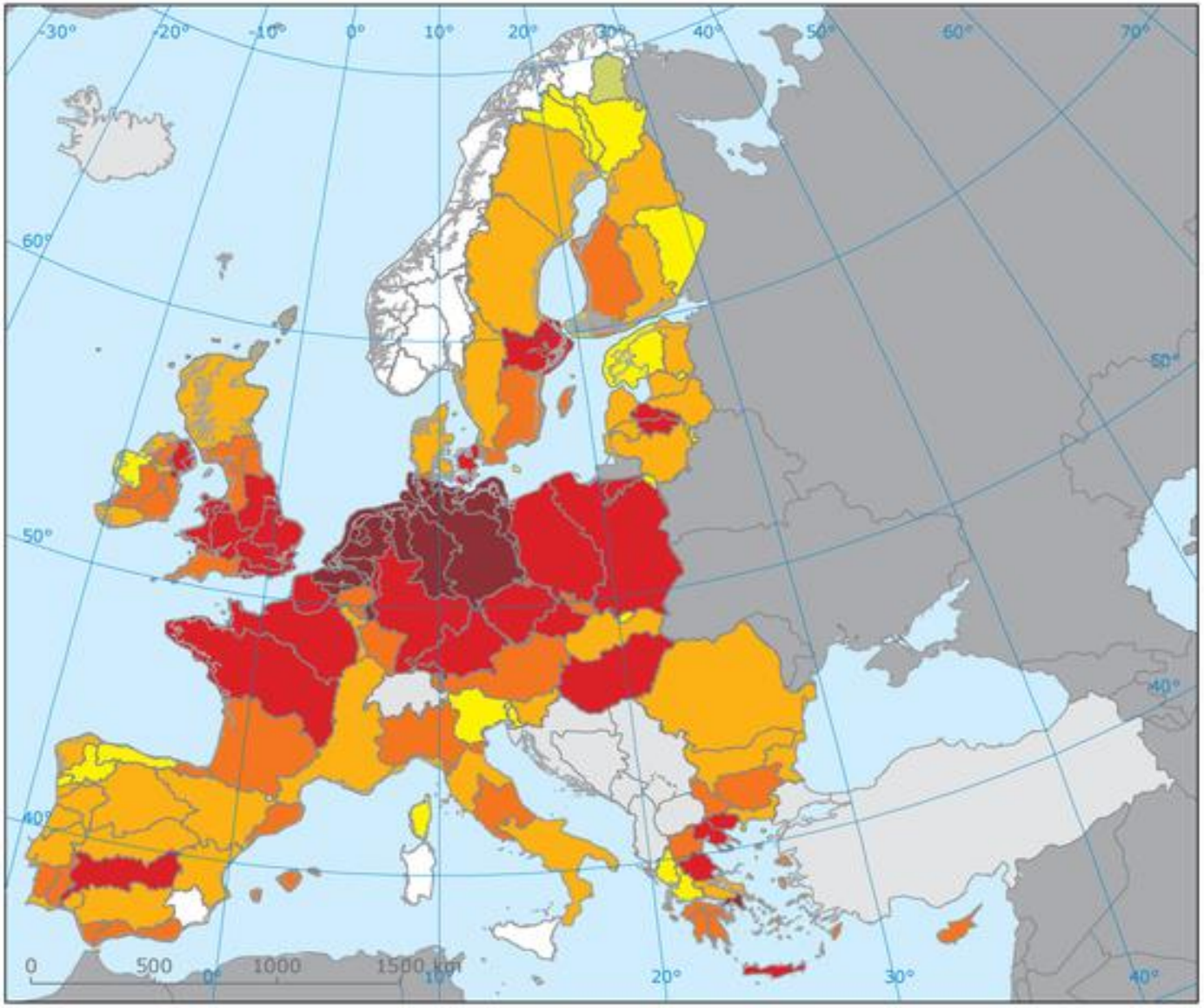


Zhou et al, 2017



Brönmark and Hansson,2002

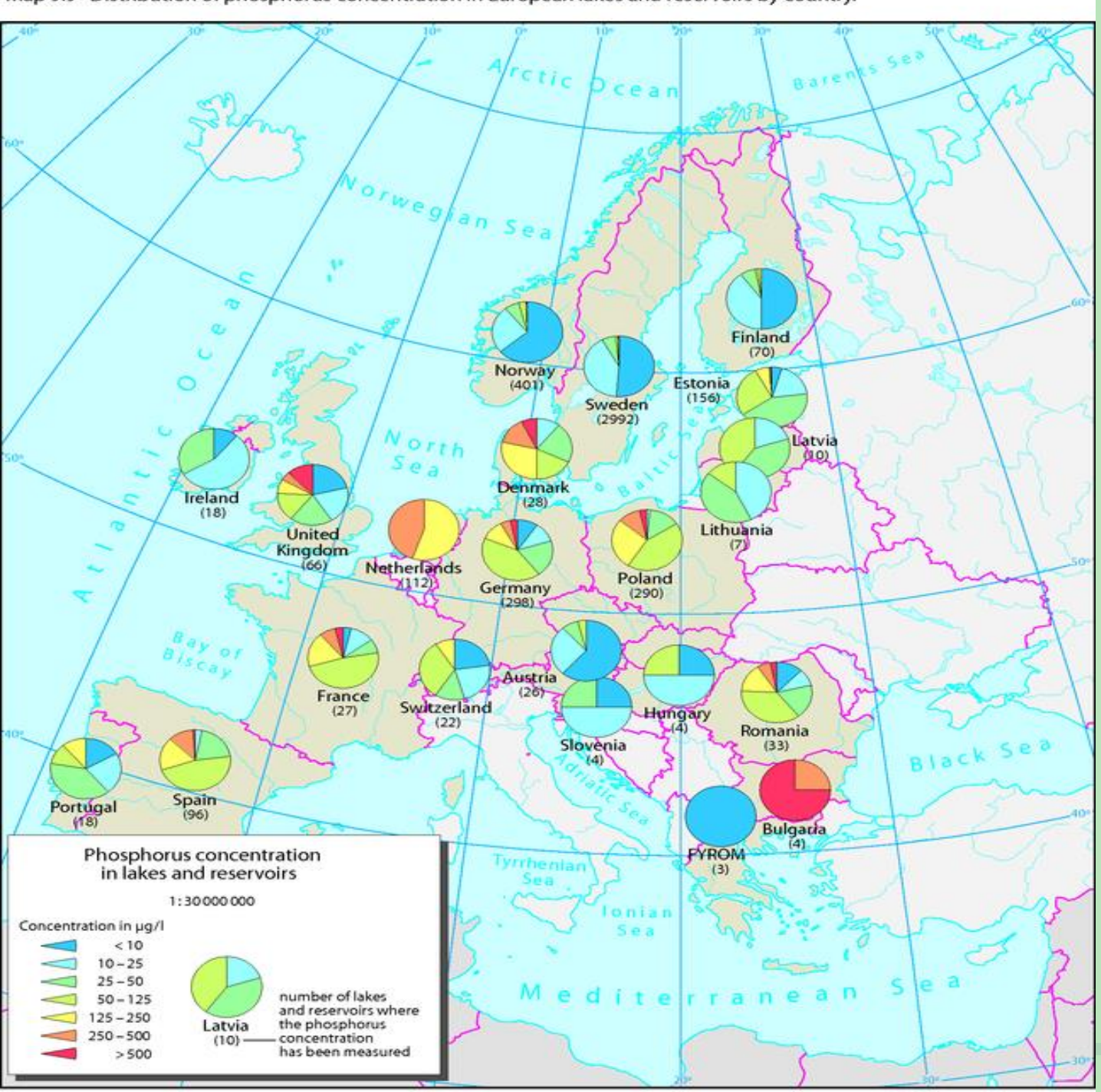
Map 1: Proportion of classified river and lake water bodies in different River Basin Districts (RBD) holding less than good ecological status or potential



Proportion of classified river and lake water bodies in different River Basin Districts (RBD) holding less than good ecological status or potential

- < 10%
- 10–30%
- 30–50%
- 50–70%
- 70–90%
- ≥ 90%
- EEA member countries not reporting under Water Framework Directive
- No data
- Outside coverage

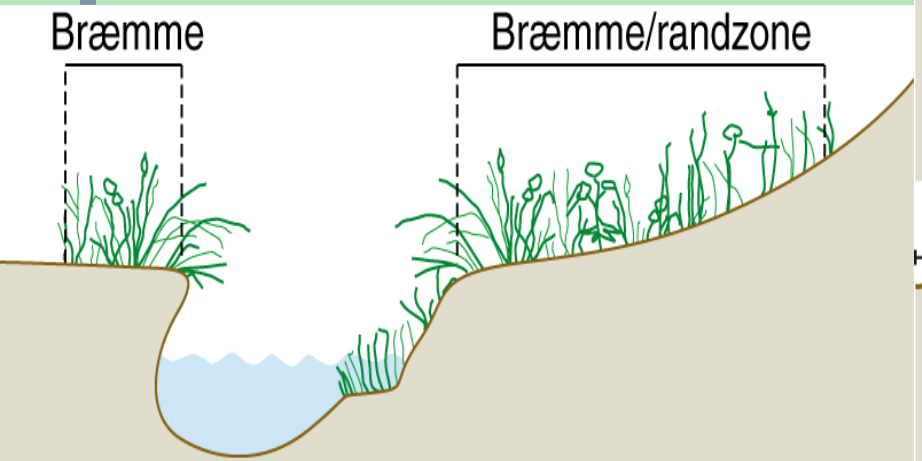
Lake TP

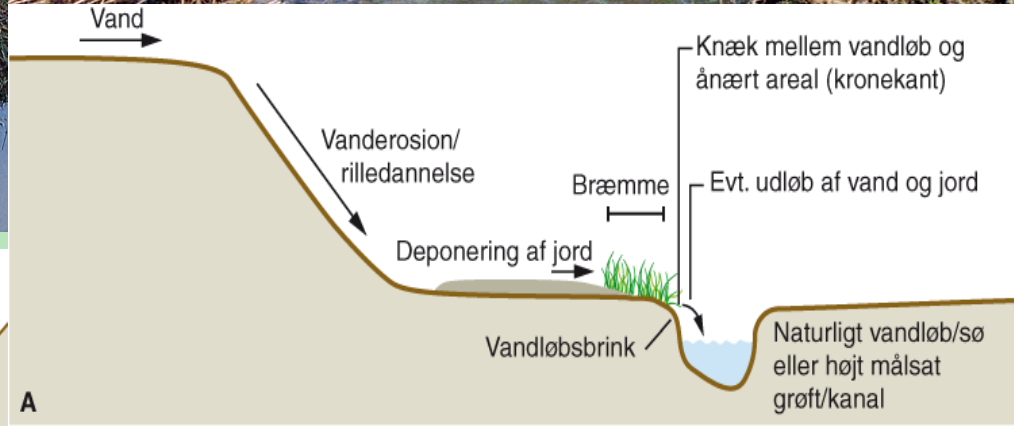

Arctic Ocean
Barents Sea
Norwegian Sea
Atlantic Ocean
North Sea
Baltic Sea
Bay of Biscay
Black Sea
Adriatic Sea
Tyrrhenian Sea
Ionian Sea
Mediterranean Sea
Finland (70)
Norway (401)
Sweden (2992)
Estonia (156)
Latvia (10)
Ireland (18)
Denmark (28)
Lithuania (7)
United Kingdom (66)
Netherlands (112)
Germany (298)
Poland (290)
France (27)
Switzerland (22)
Austria (26)
Hungary (4)
Romania (33)
Slovenia (4)
Portugal (18)
Spain (96)
Bulgaria (4)
FYROM (3)
Phosphorus concentration in lakes and reservoirs
1:30 000 000
Concentration in µg/l
< 10
10 – 25
25 – 50
50 – 125
125 – 250
250 – 500
> 500
Latvia (10)
number of lakes and reservoirs where the phosphorus concentration has been measured

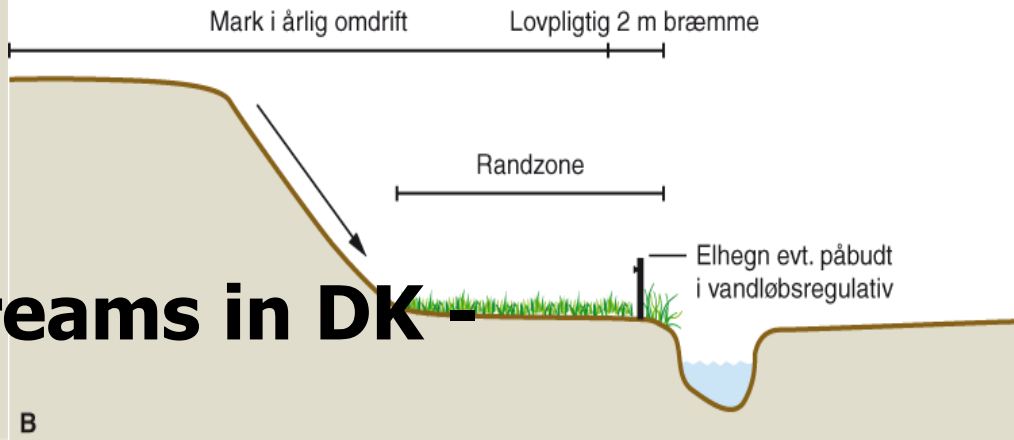
Diffuse pollution a hot topic in DK !

My country!

5 mill. people (great sewage treatment) and 20 mill. pigs and cattle, walking around even without any underpants!!!!!

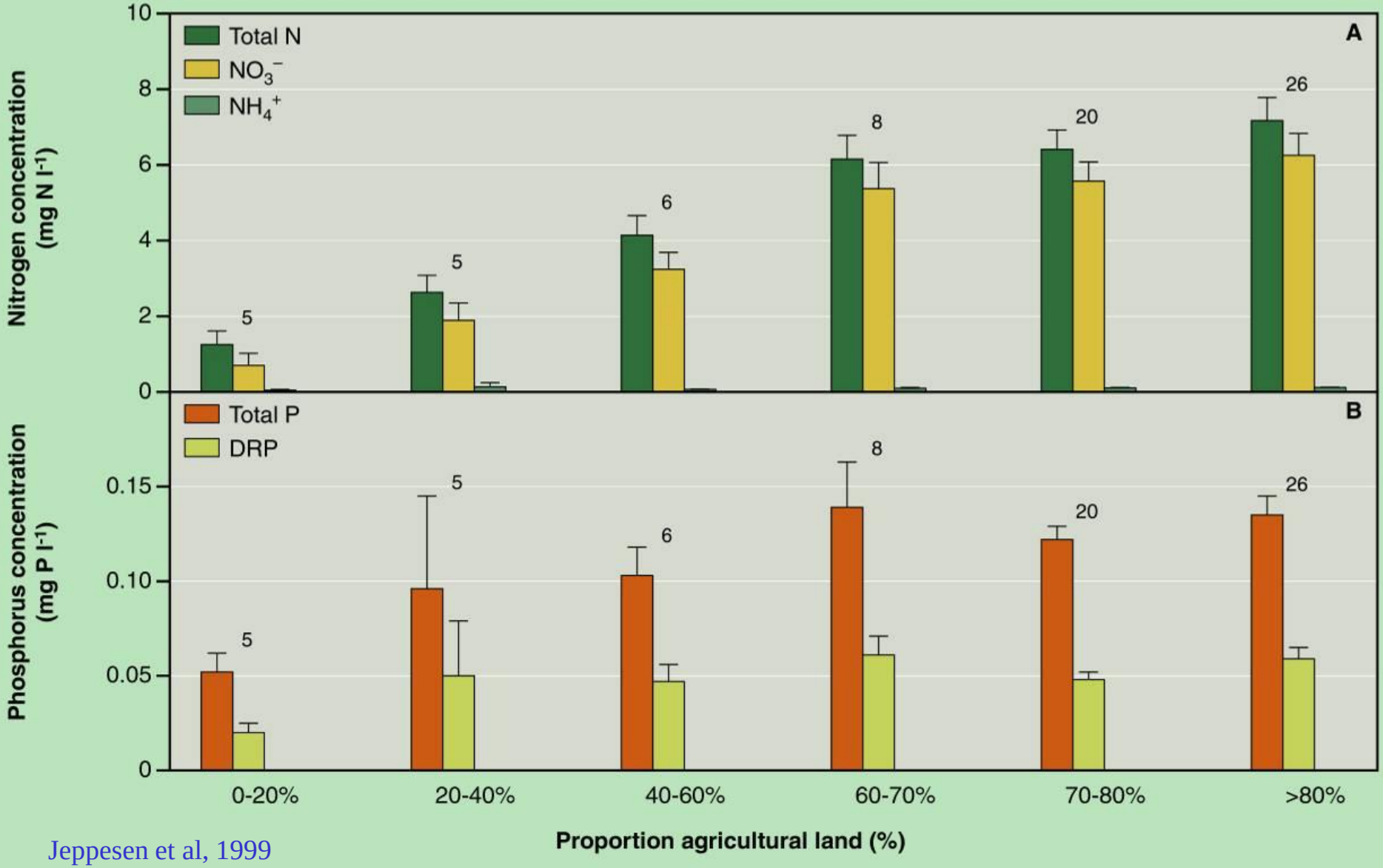




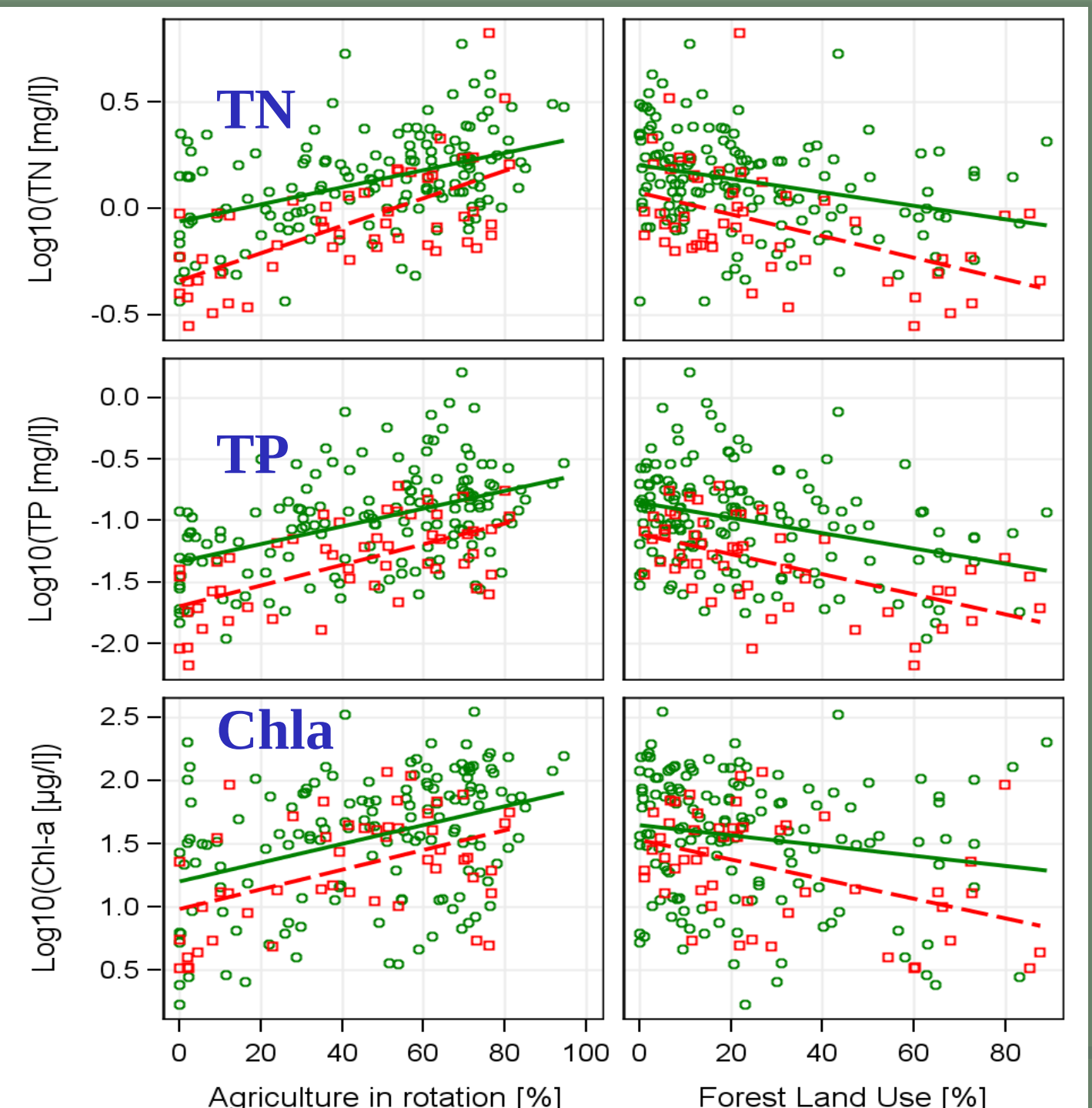


10 m now along all streams in DK - on each side☺

Nitrogen and phosphorus loading depend on catchment type (Danish lakes)



Jeppesen et al, 1999



Shallow
Deep

Nielsen et al, 2011

Danish Action Plans

NPo Action Plan - 1985.

Action Plan for the Aquatic Environment I - 1987.

Action Plan for Sustainable Agriculture, 1991 and 1996.

Action Plan for the Aquatic Environment II - 1998

Action Plan for the Aquatic Environment III – 2004

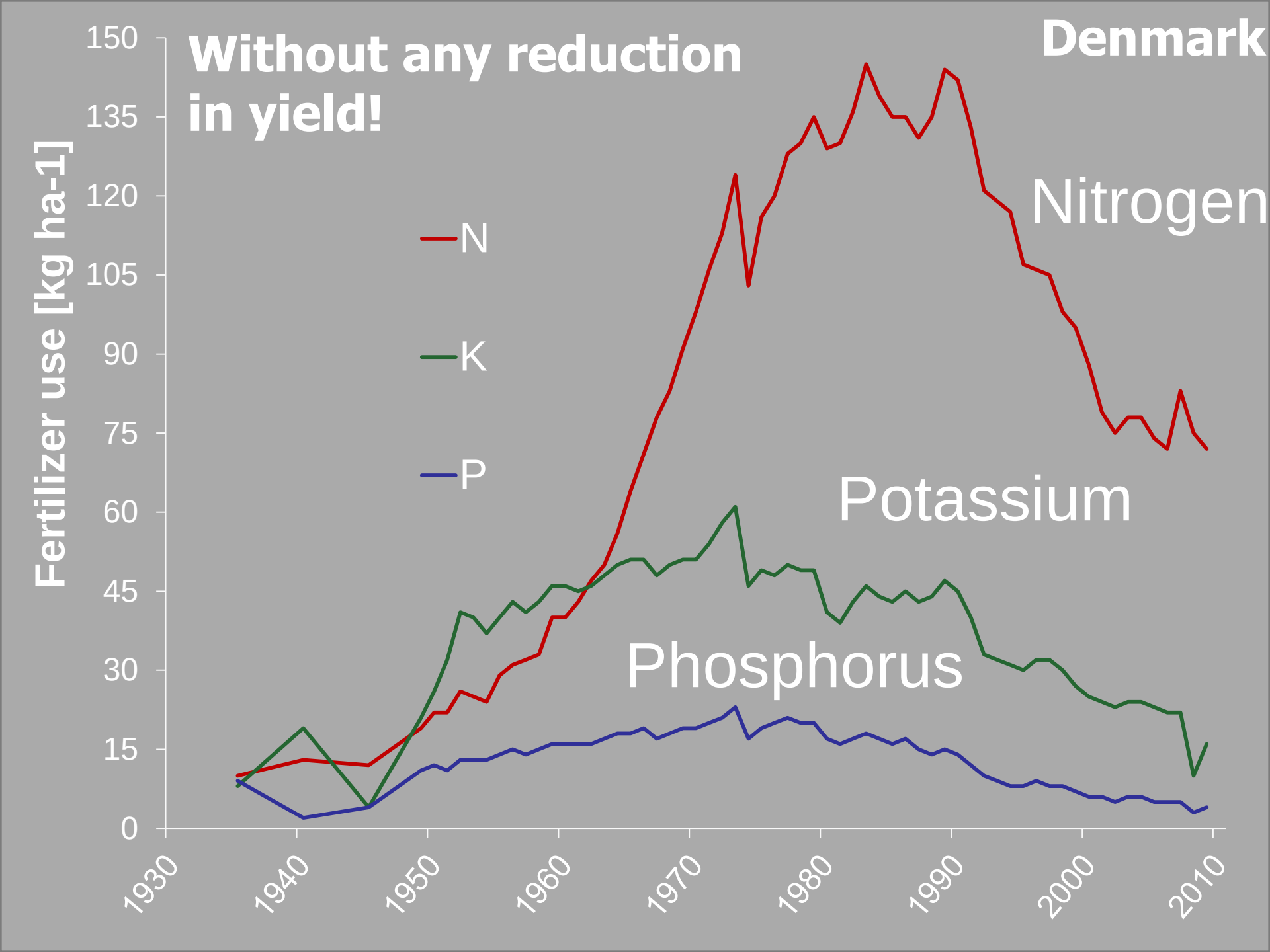
Water Framework Directive – 2009-2015

Mitigation of Nitrogen and Phosphorus leaching

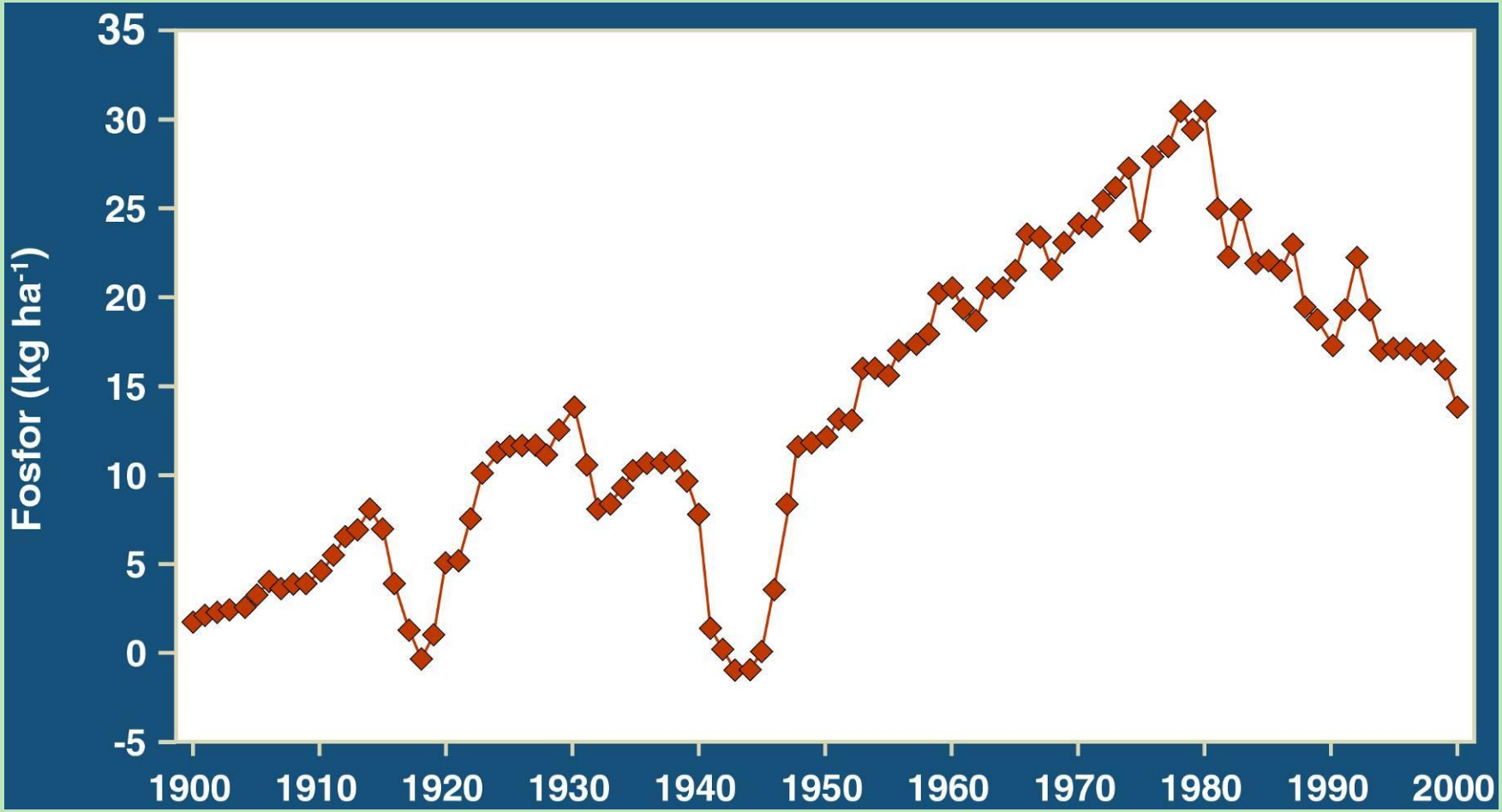
- Green fields in winter
- Livestock harmony
- Demand for building of slurry tanks (6-9 months storage capacity)
- Crop and fertiliser plans
- Fertiliser accounts and levy system
- Nitrogen quota system
- Catch crops
- 10 % reduction in nitrogen standards for crops
- Required utilisation of nitrogen in animal manure
- Livestock density requirements
- Potential taxes on P fertilisation planned

Storage capacity for slurry -DK

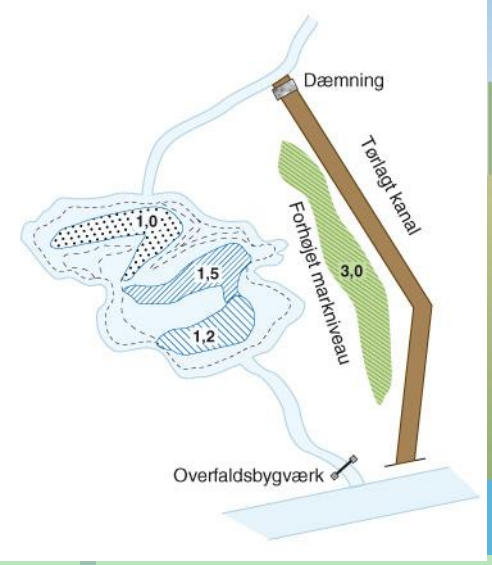
Kronvang et al, 2007


Without any reduction in yield!
Denmark
Fertilizer use [kg ha-1]
150
135
120
105
90
75
60
45
30
15
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
N
K
P
Nitrogen
Potassium
Phosphorus

Net accumulation of phosphorus in Danish agriculture



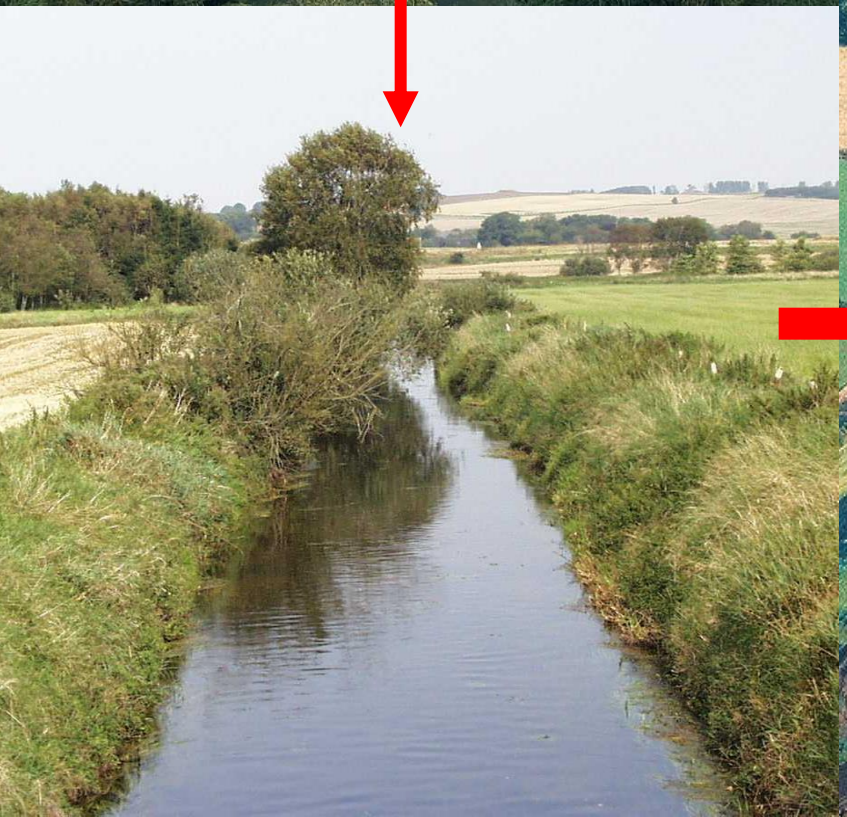
(Dalgaard & Kyllingsbæk, 2003)

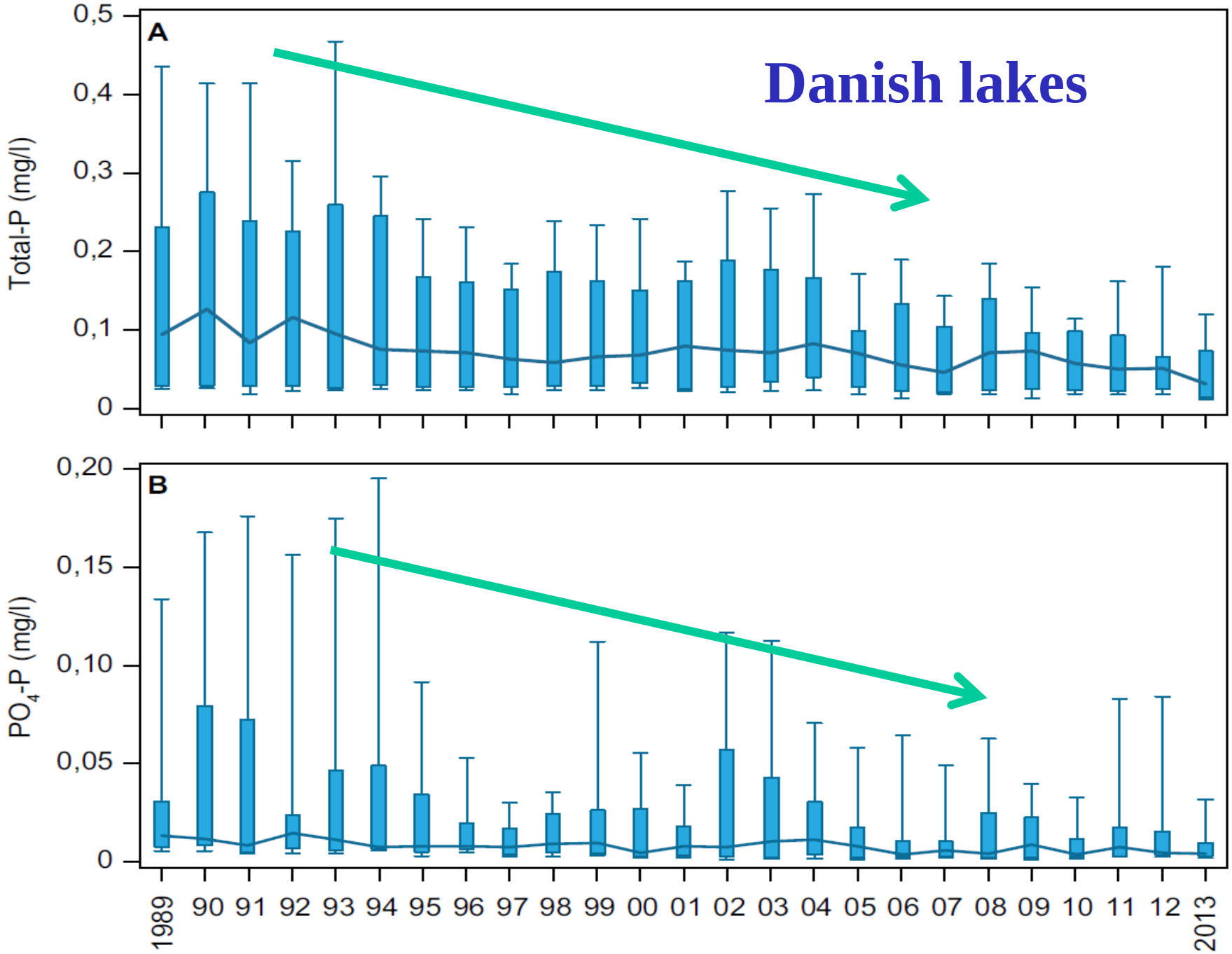


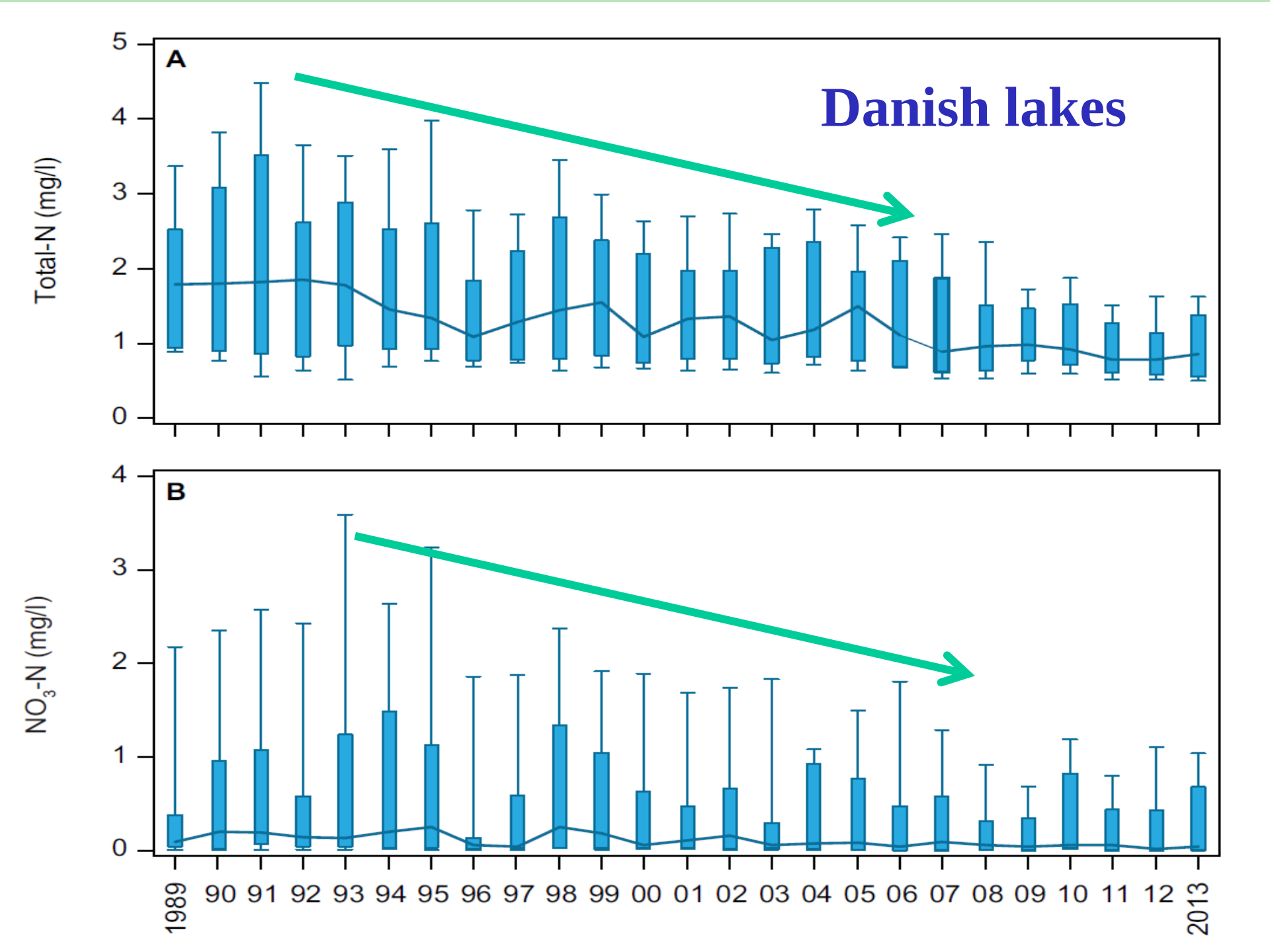
Artificial wetlands

Carlos C. Hoffman

Bring the river valleys back to the rivers!!




Danish lakes
A
B
Total-P (mg/l)
PO_4-P (mg/l)
0,5
0,4
0,3
0,2
0,1
0
0,20
0,15
0,10
0,05
0
1989
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
11
12
2013


Danish lakes
A
B
Total-N (mg/l)
NO_3-N (mg/l)
0
1
2
3
4
5
1989
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
11
12
2013

Environmental Science & Technology

Feature

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Reducing Phosphorus to Curb Lake Eutrophication is a Success

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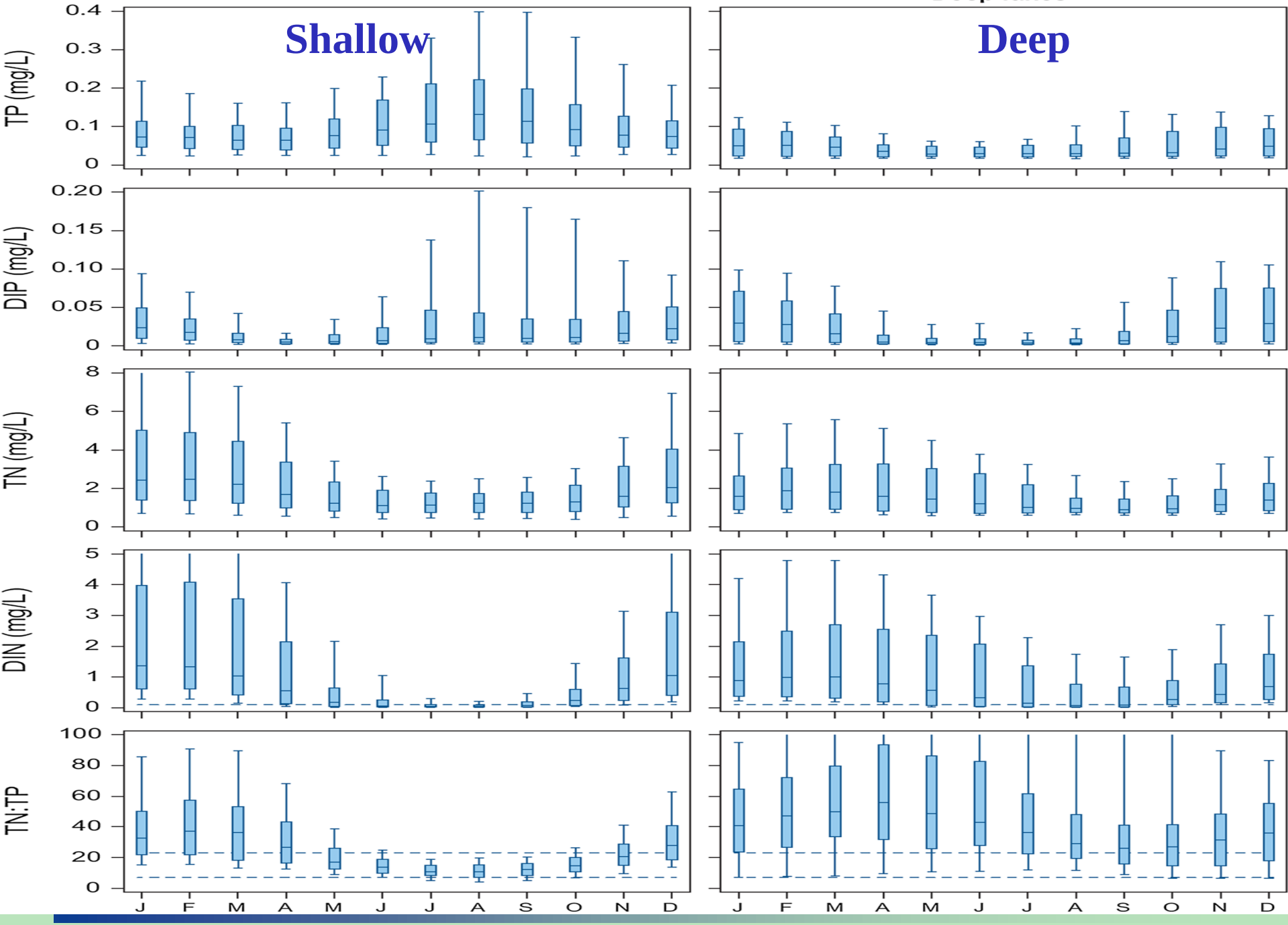
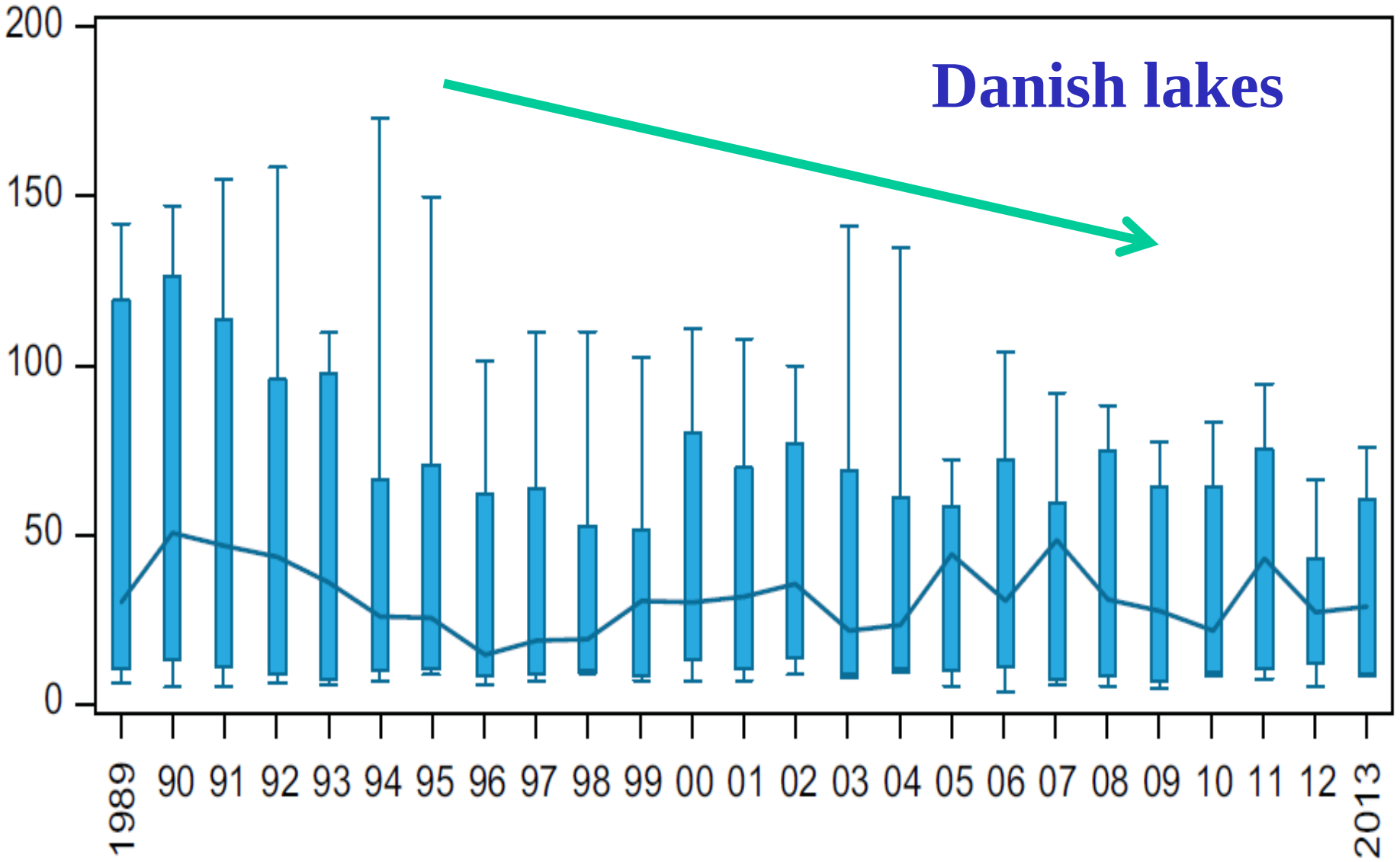
ABSTRACT: As human populations increase and land-use intensifies, toxic and unsightly nuisance blooms of algae are becoming larger and more frequent in freshwater lakes. In most cases, the blooms are predominantly blue-green algae (Cyanobacteria), which are favored by low ratios of nitrogen to phosphorus. In the past half century, aquatic scientists have devoted much effort to understanding the causes of such blooms and how they can be prevented or reduced. Here we review the evidence, finding that numerous long-term studies of lake ecosystems in Europe and North America show that controlling algal blooms and other symptoms of eutrophication depends on reducing inputs of a single nutrient: phosphorus. In contrast, small-scale experiments of short duration, where nutrients are added rather than removed, often give spurious and confusing results that bear little relevance to solving the problem of cyanobacteria blooms in lakes.

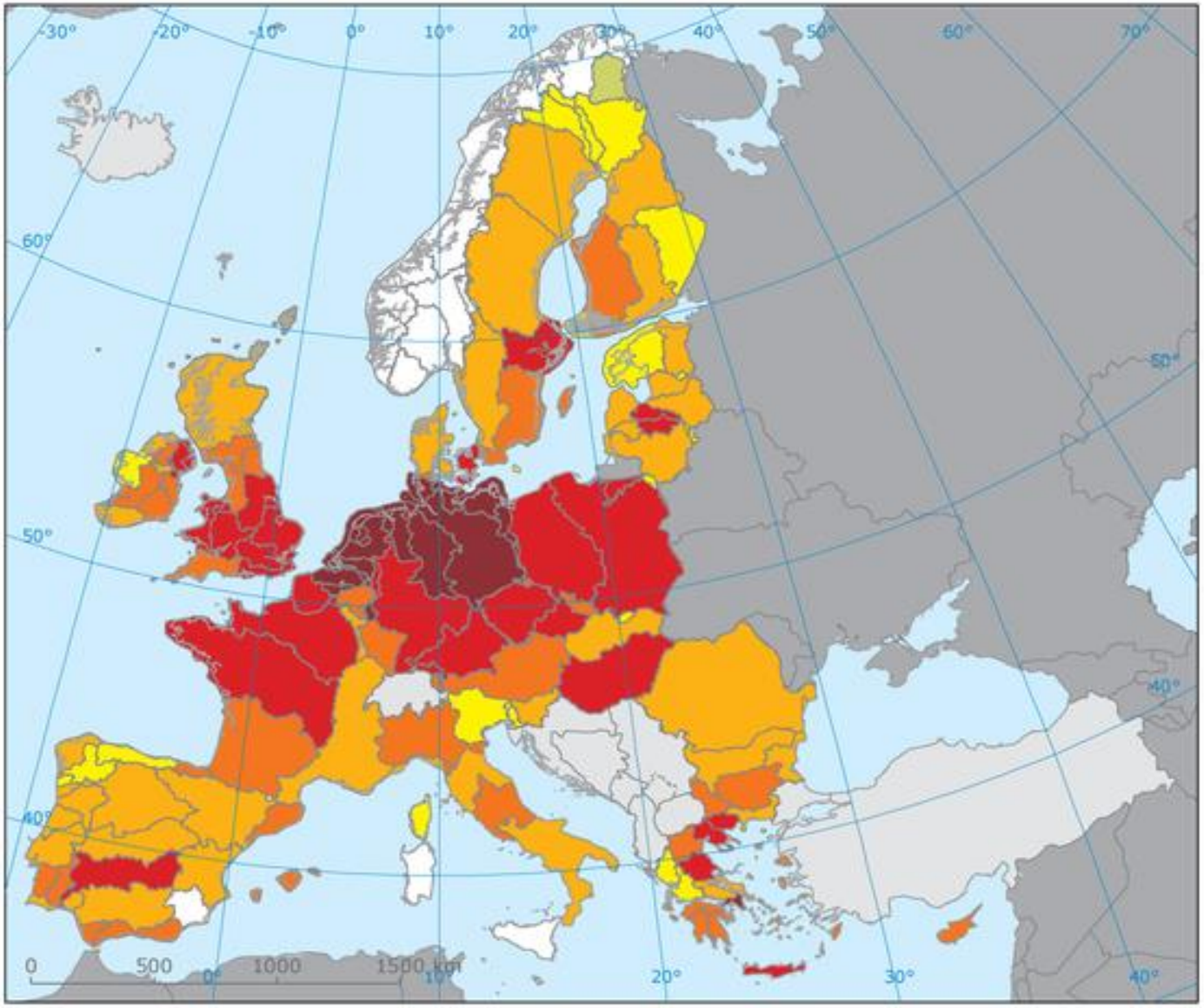


Søndergaard et al, 2017

Chlorophyll a (ug l-1)



Map 1: Proportion of classified river and lake water bodies in different River Basin Districts (RBD) holding less than good ecological status or potential



Proportion of classified river and lake water bodies in different River Basin Districts (RBD) holding less than good ecological status or potential

- < 10%
- 10–30%
- 30–50%
- 50–70%
- 70–90%
- ≥ 90%
- EEA member countries not reporting under Water Framework Directive
- No data
- Outside coverage

Water quality has improved but the nutrient load of water bodies remains a problem

Water quality and nutrient loading

5-10 year trends:

Water quality has improved, although concentrations of nutrients in many places are still high and affect the status of waters.

20+ year outlook:

In regions with intensive agriculture production, diffuse nitrogen pollution will still be high, resulting in continued eutrophication problems.

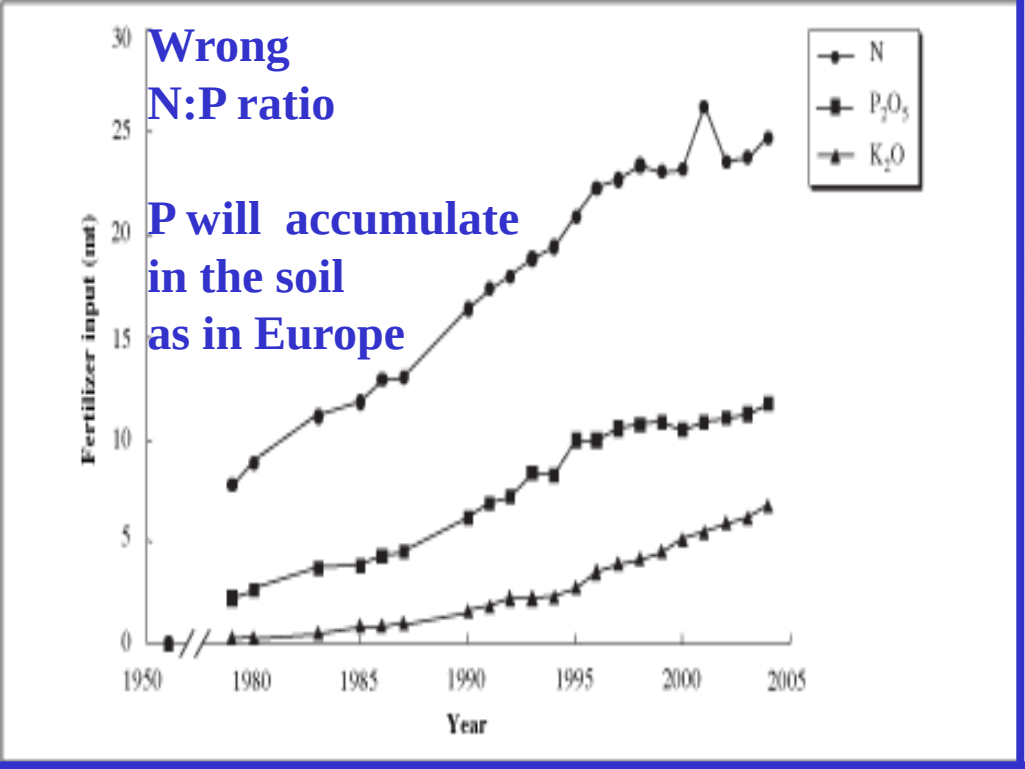
And TP!

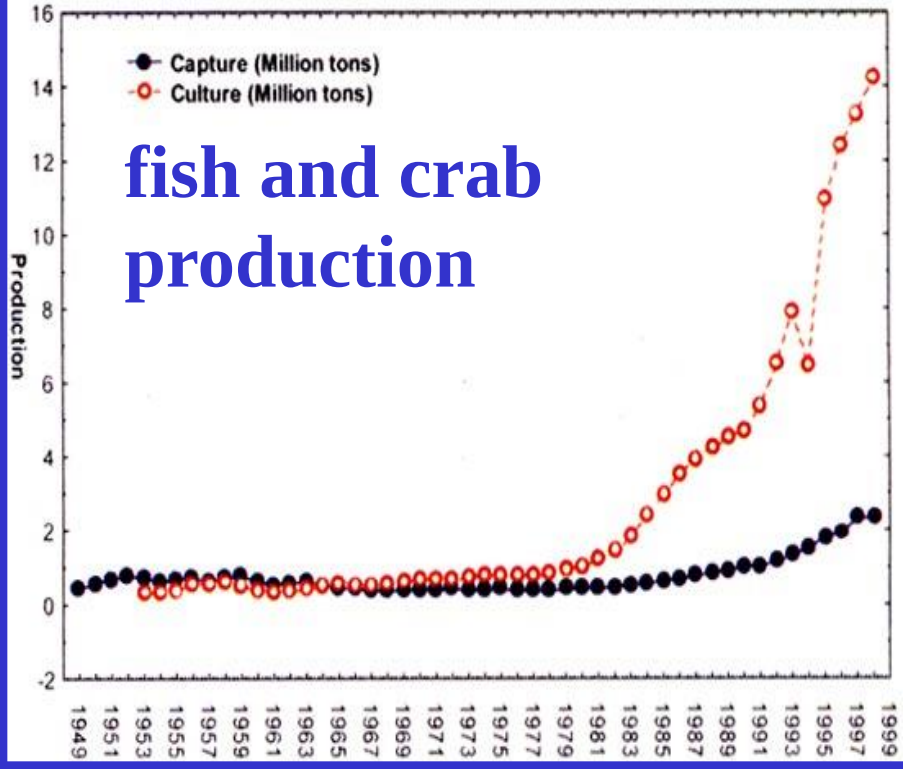
Progress to policy targets:

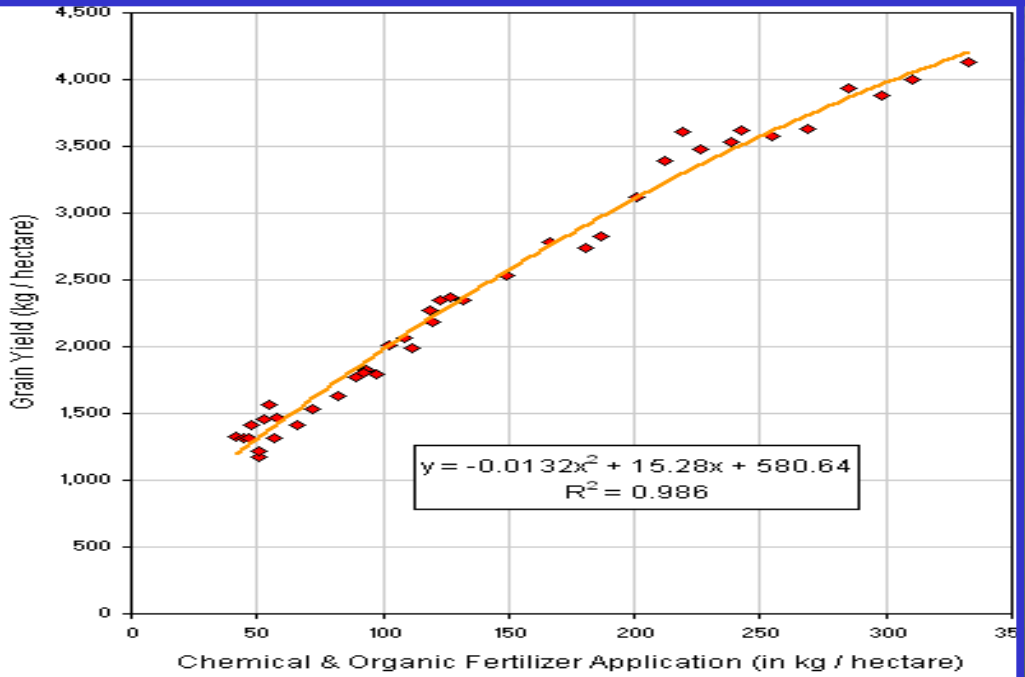
Although the Urban Waste Water Treatment Directive and the Nitrates Directive continue to deliver pollution control, diffuse nitrogen pollution remains problematic.

And TP!

Source: EEA. SOER 2015 Synthesis report.

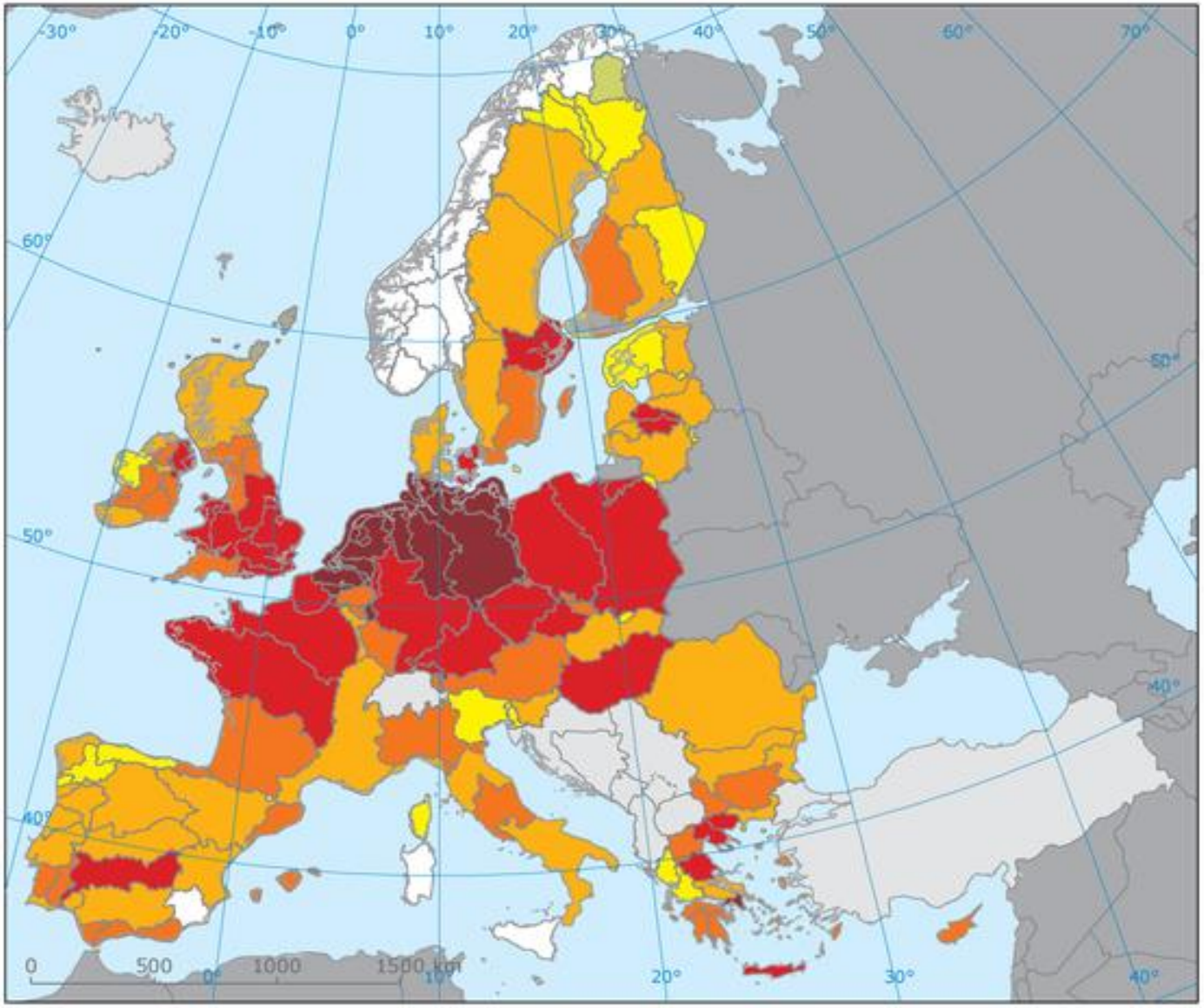

Wrong
N:P ratio
P will accumulate
in the soil
as in Europe
N
P_2O_5
K_2O
Fertilizer input (mt)
Year


Capture (Million tons)
Culture (Million tons)
Production
fish and crab
production

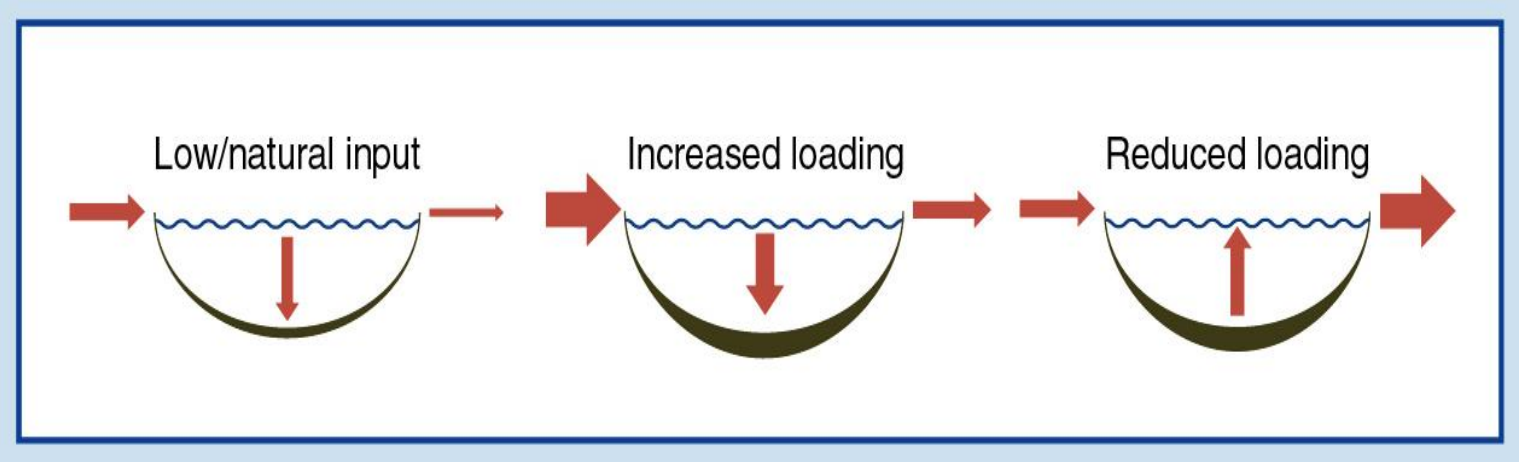

Grain Yield (kg / hectare)
y = -0.0132x² + 15.28x + 580.64
R² = 0.986
Chemical & Organic Fertilizer Application (in kg / hectare)

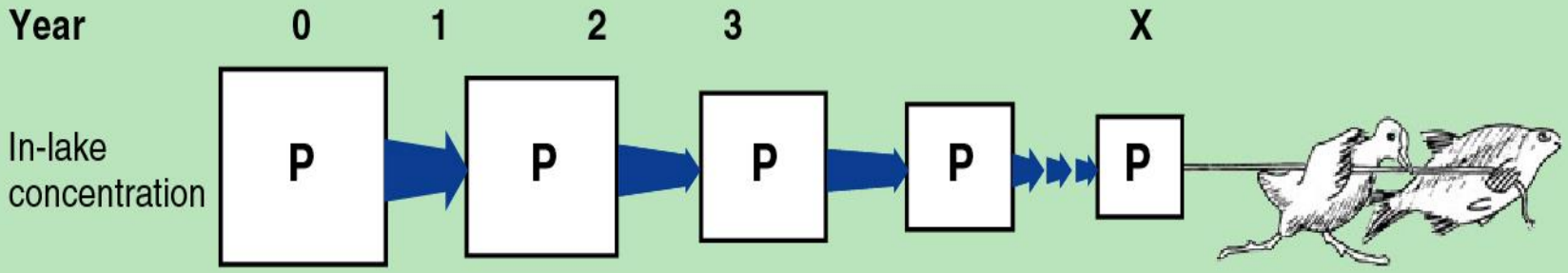

115
YAMAHA

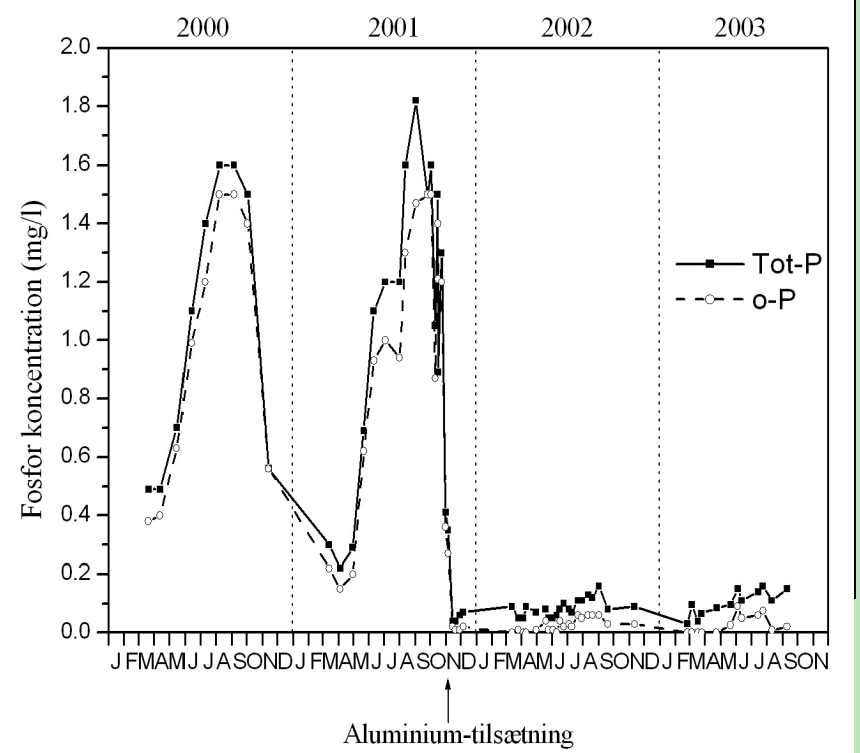
Takes time to respond to loading reduction

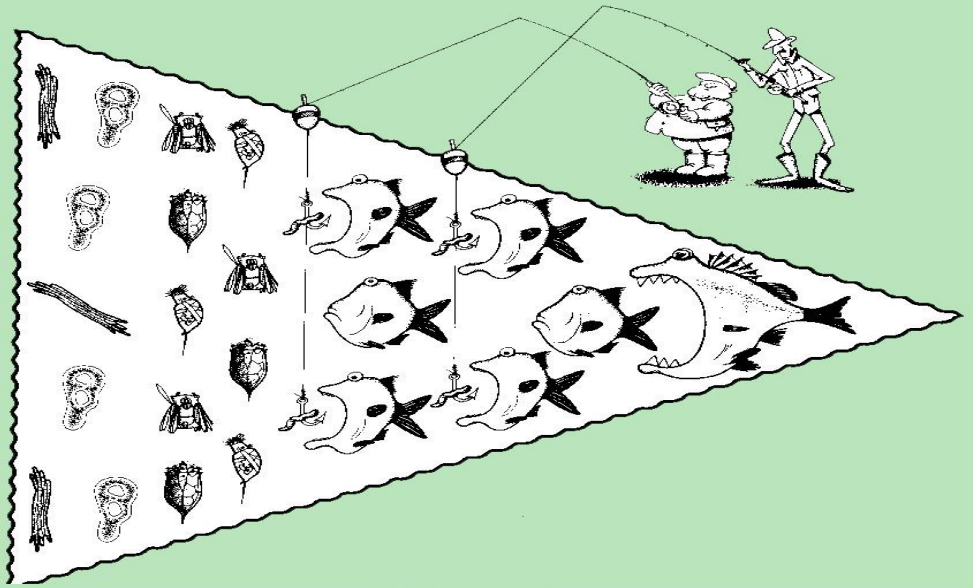


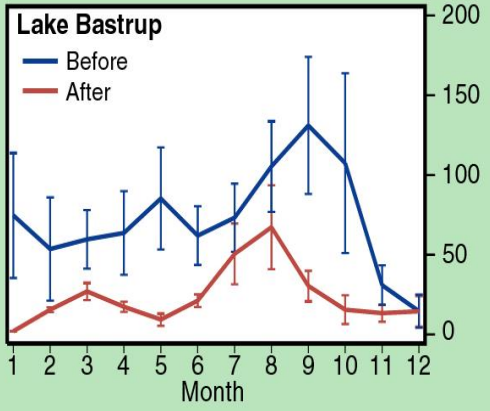
Chemical and biological resistance may delay lake recovery

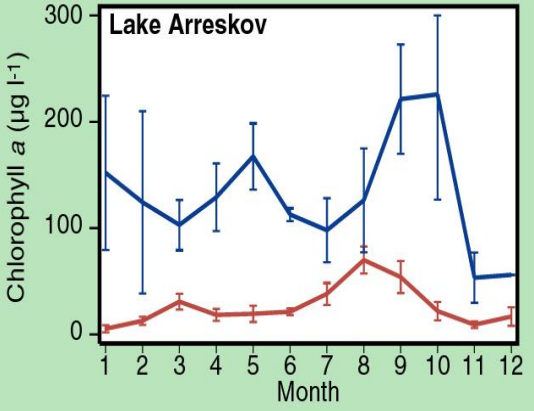


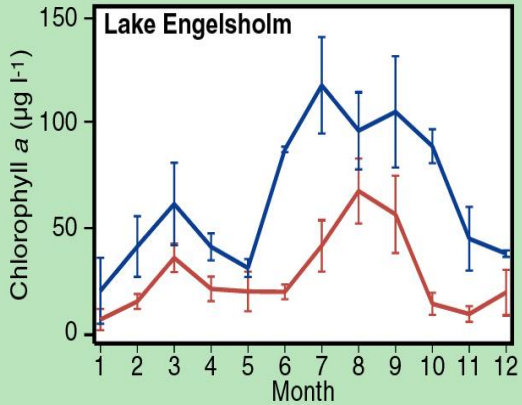



2000
2001
2002
2003
Fosfor koncentration (mg/l)
Tot-P
o-P
J FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASON
Aluminium-tilsætning

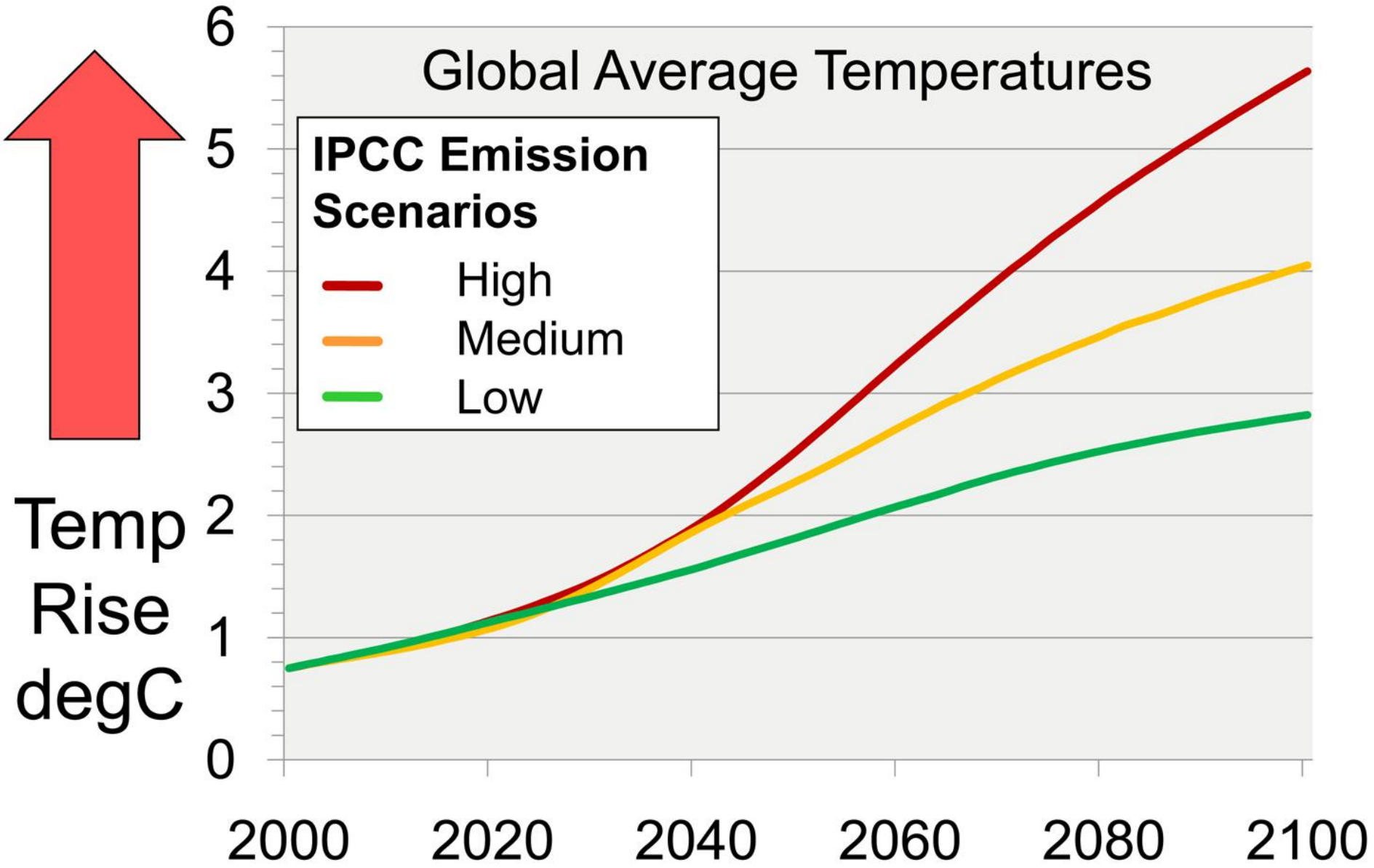



Lake Bastrup
Before
After
Month


Lake Arreskov
Chlorophyll a (µg l-1)
Month


Lake Engelsholm
Chlorophyll a (µg l-1)
Month

Expected changes in temperature



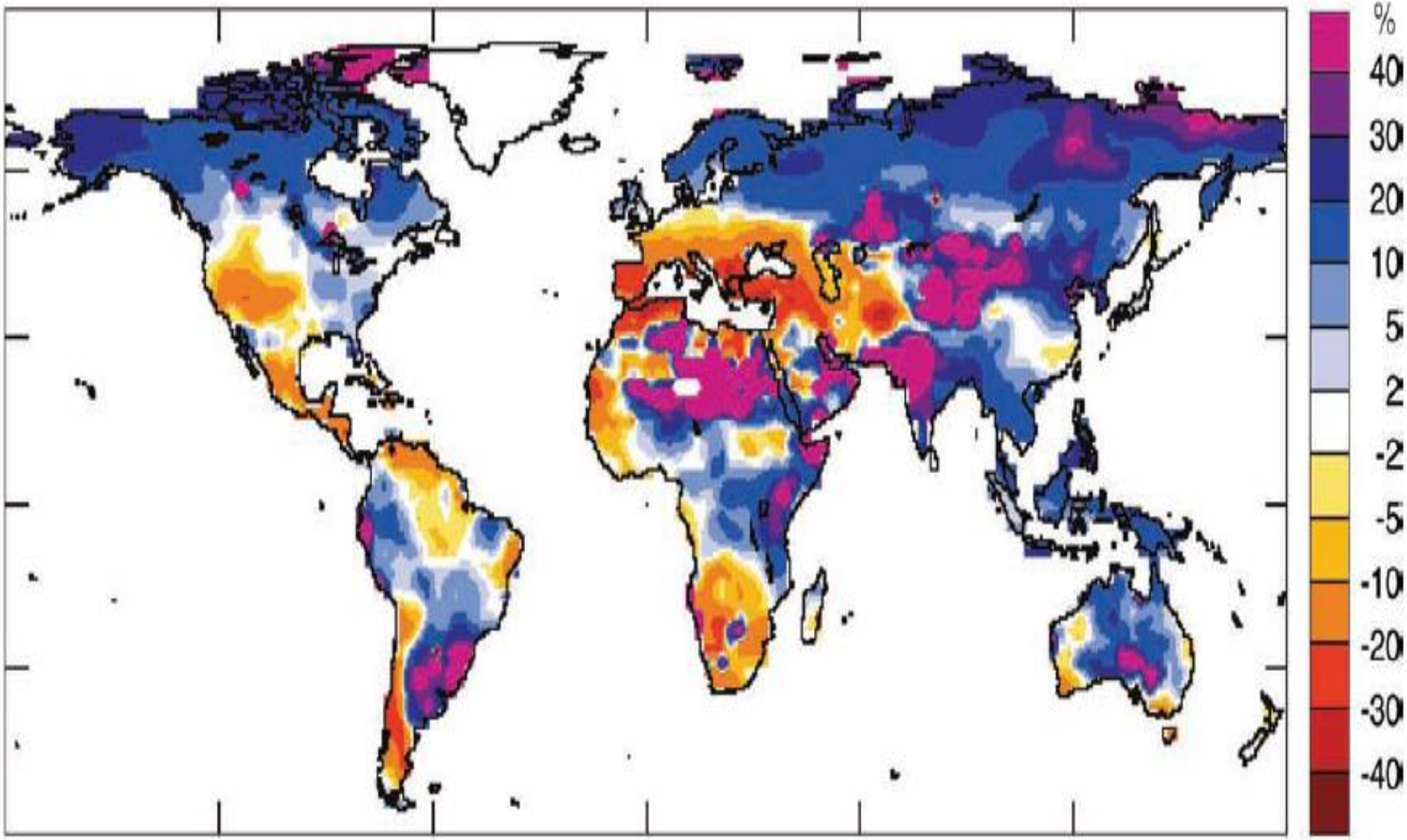
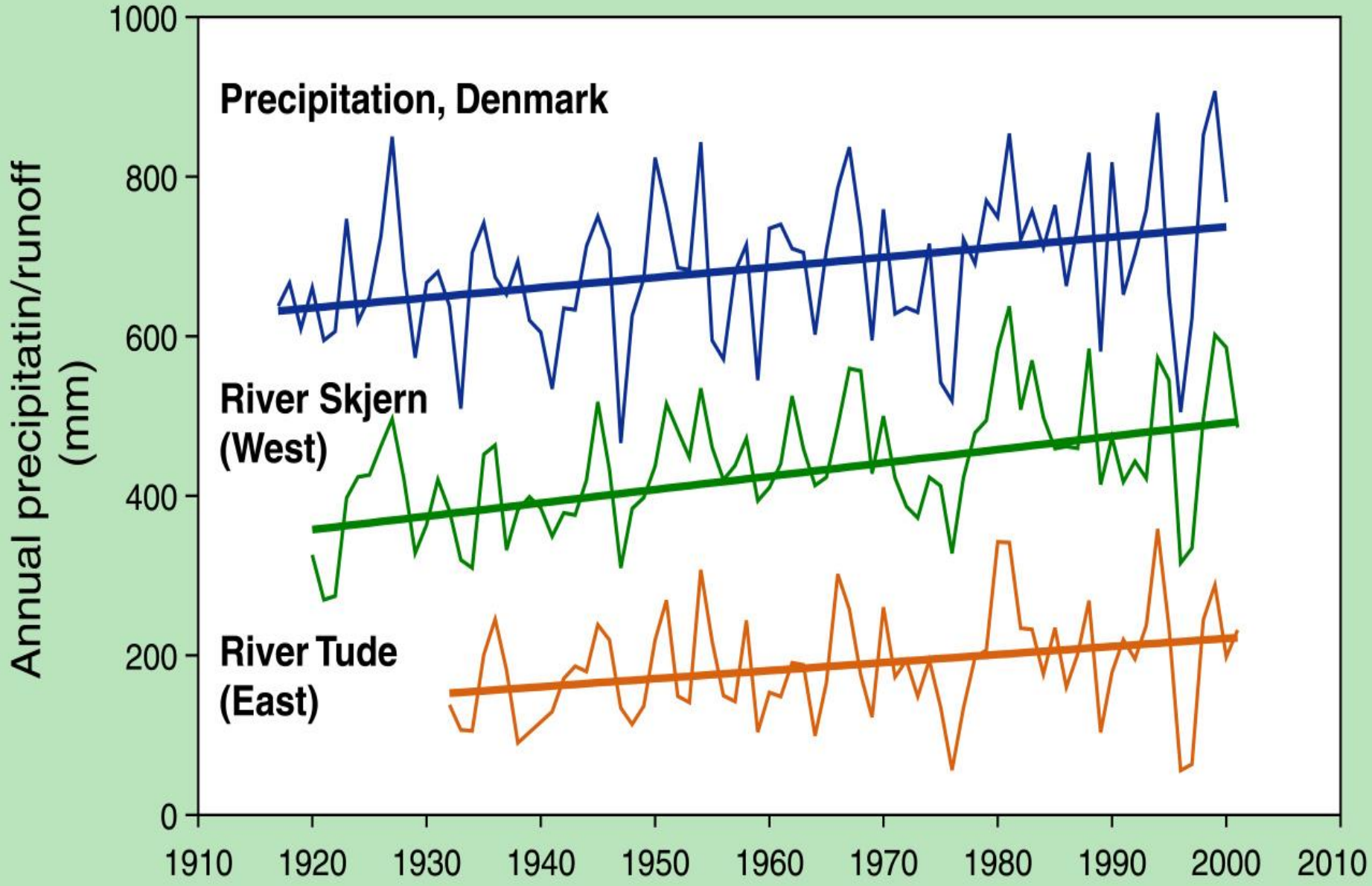
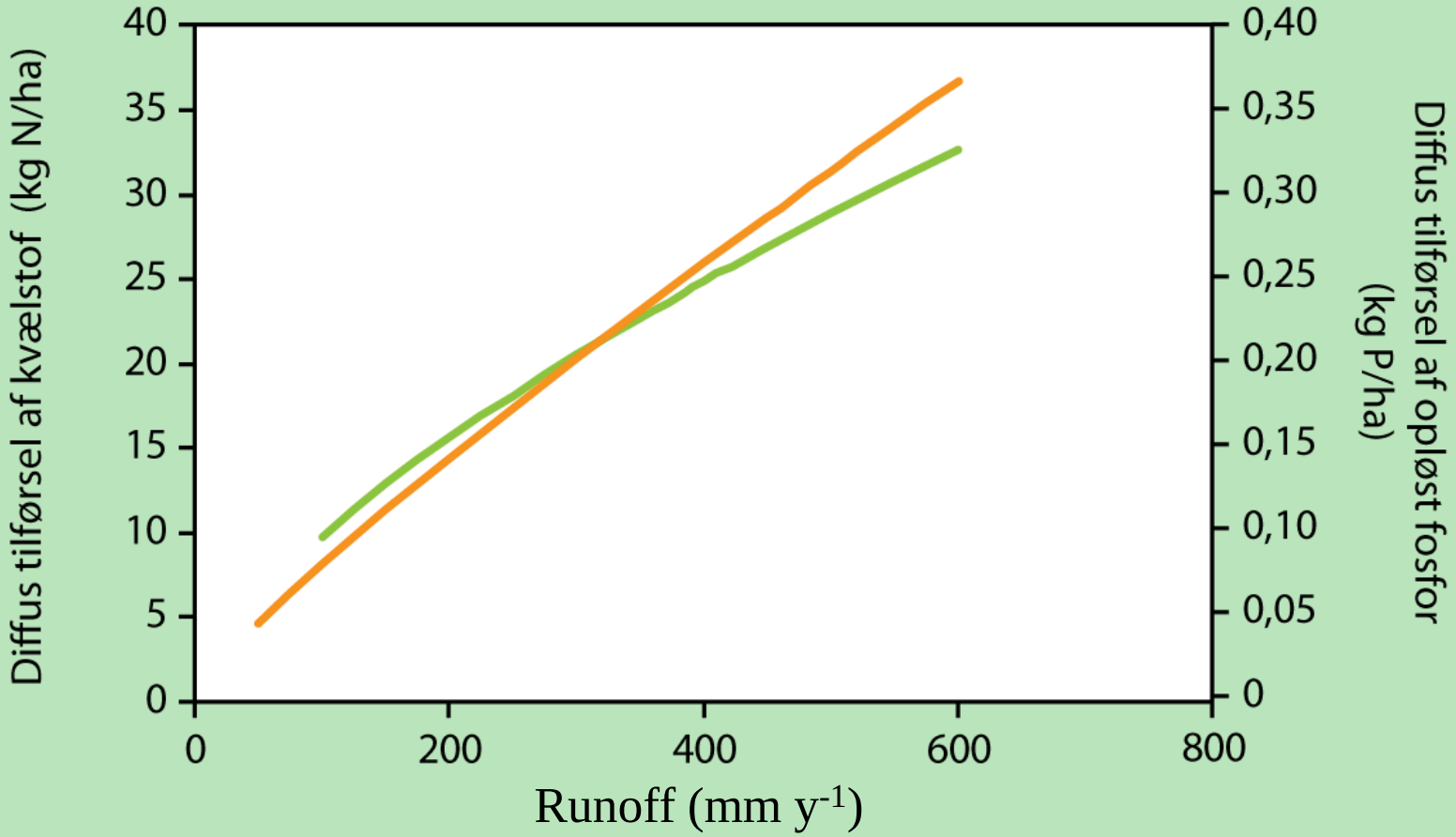


Figure 3.4. *Change in annual runoff by 2041-60 relative to 1900-70, in percent, under the SRES A1B emissions scenario and based on an ensemble of 12 climate models. Reprinted by permission from Macmillan Publishers Ltd. [Nature] (Milly et al., 2005), copyright 2005.*


Precipitation, Denmark
River Skjern
(West)
River Tude
(East)
Annual precipitatin/runoff
(mm)
1000
800
600
400
200
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Loading depending on runoff

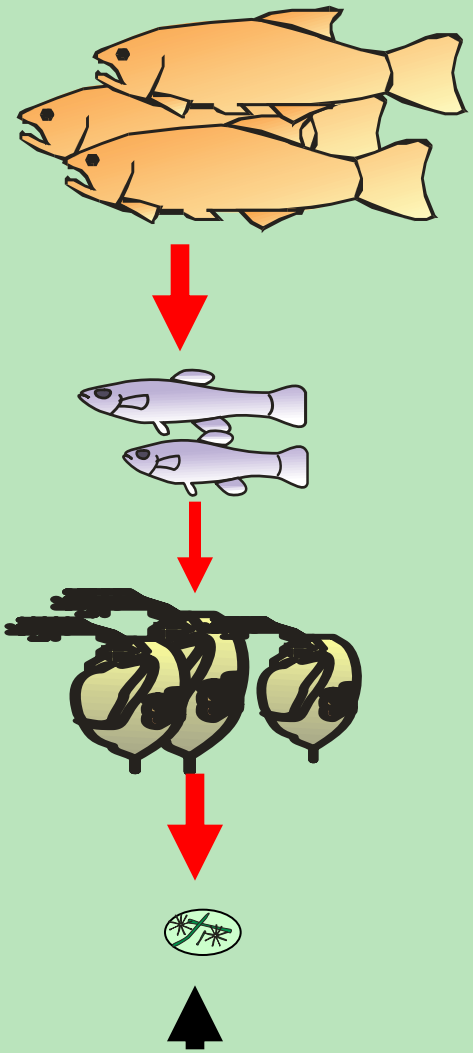
Diffuse N **Diffuse P**



33-42% increase in the last 80 years due to increase in discharge – present days fertilisation

Jeppesen et al, 2009

Temperate lake in balance



Nutrients

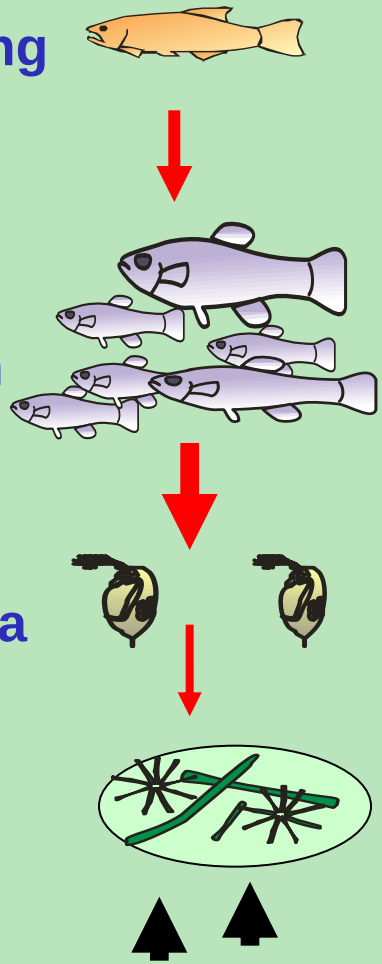
Degraded temperate lake

fish eating fish

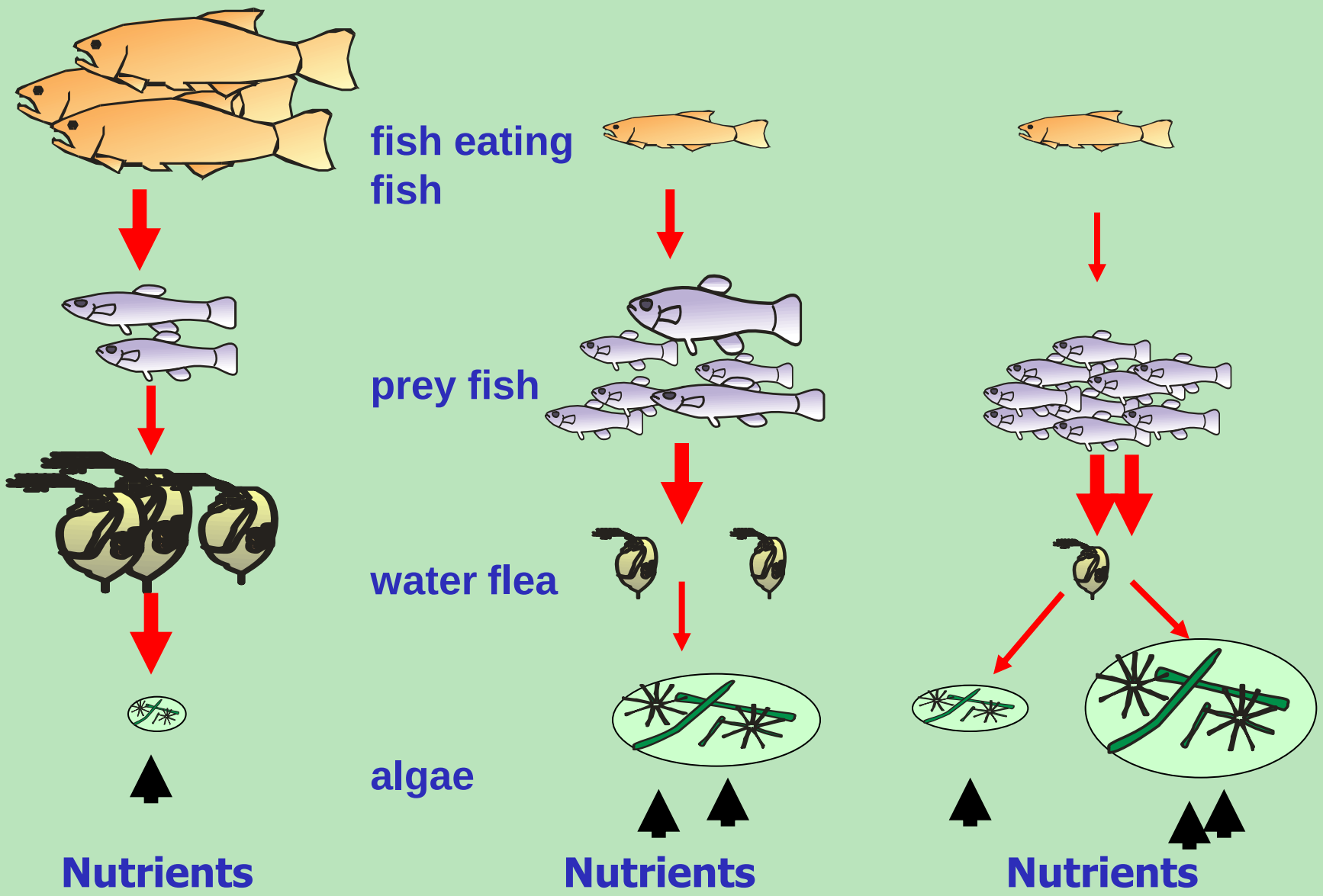
prey fish

water flea

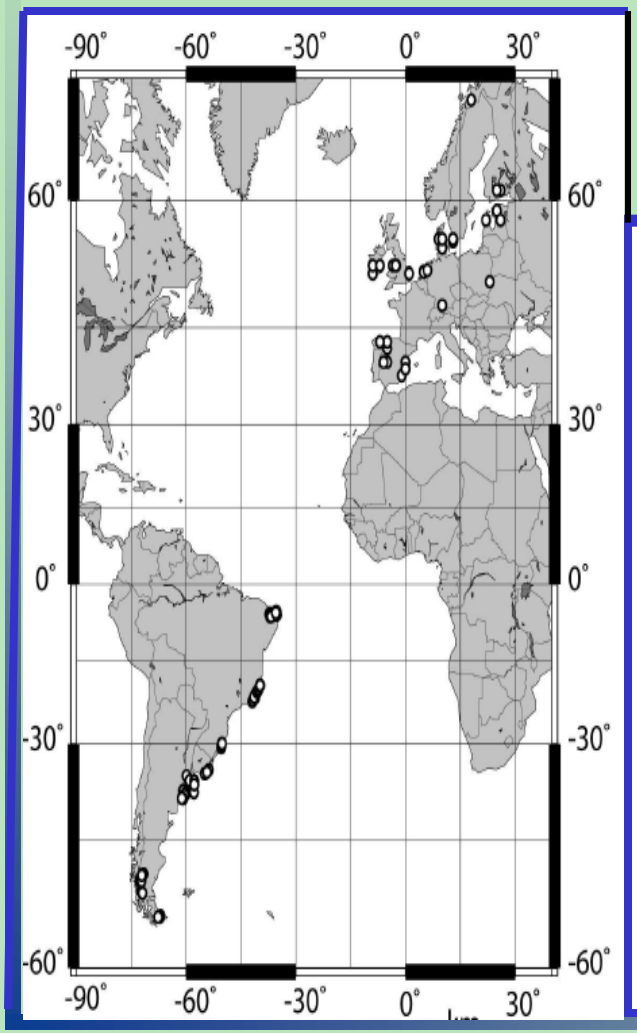
algae

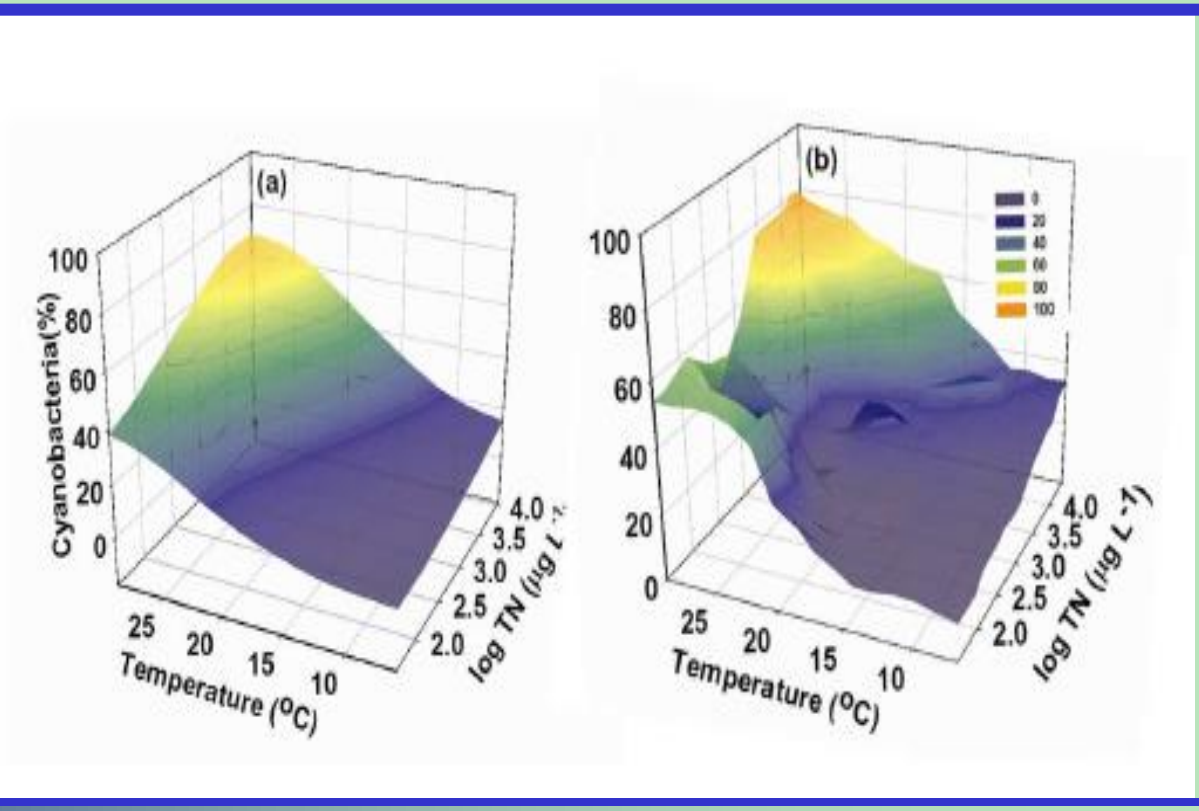


Nutrients

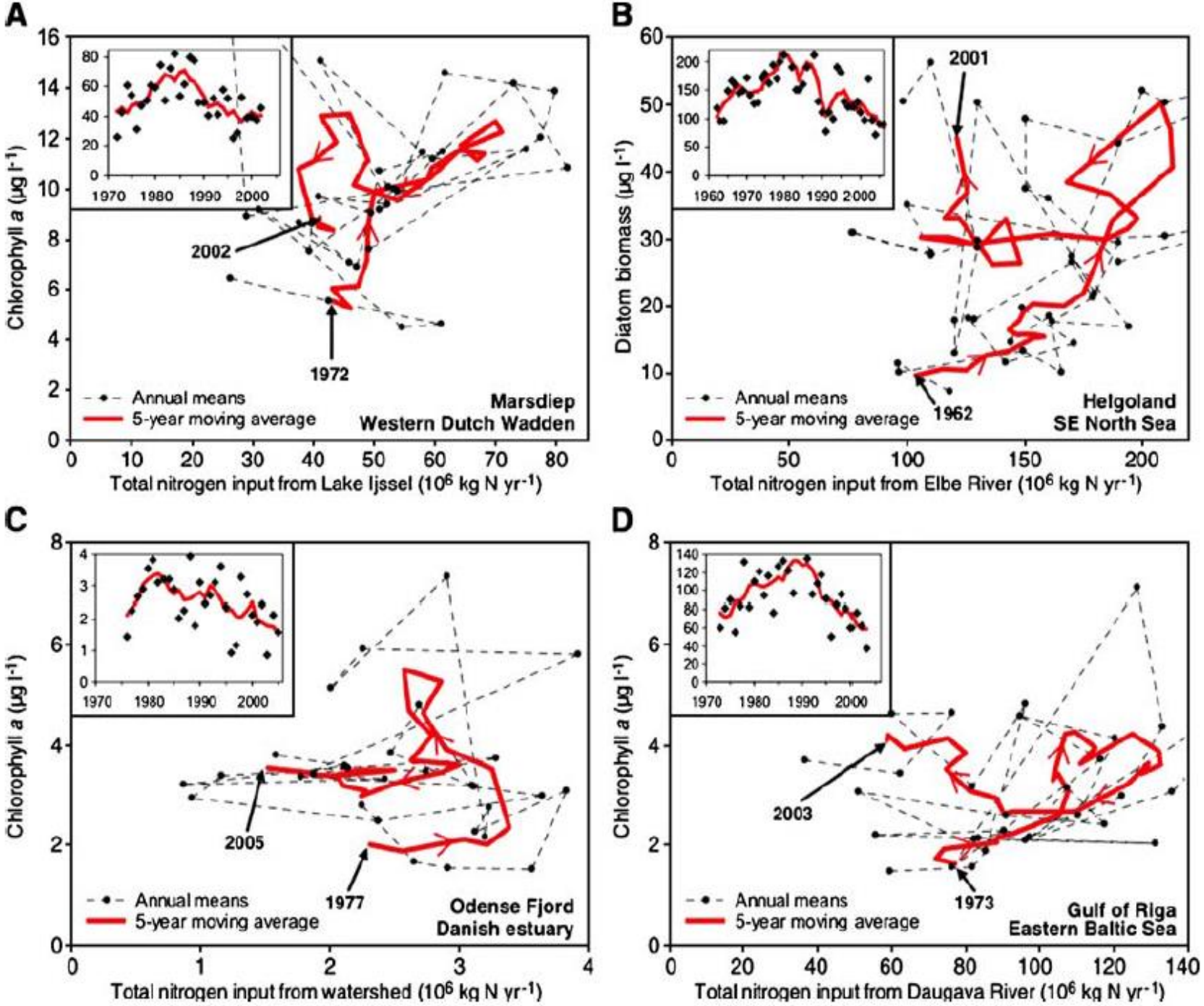

Temperate lake in balance
Degraded temperate lake
Warm lakes
fish eating fish
prey fish
water flea
algae
Nutrients
Nutrients
Nutrients

SALGA and ECOFRAME-lakes

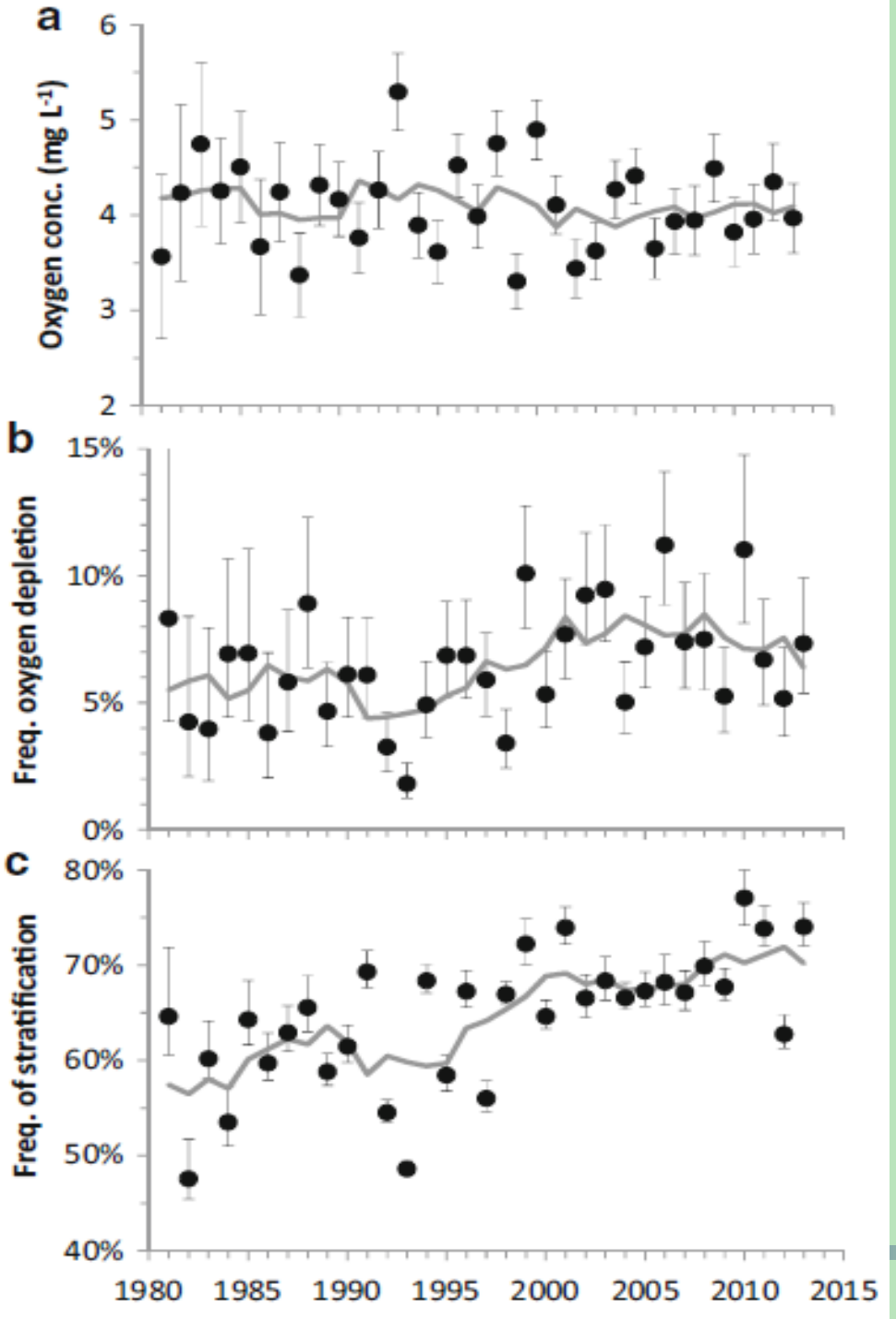




Kosten et al , GCB, 2012

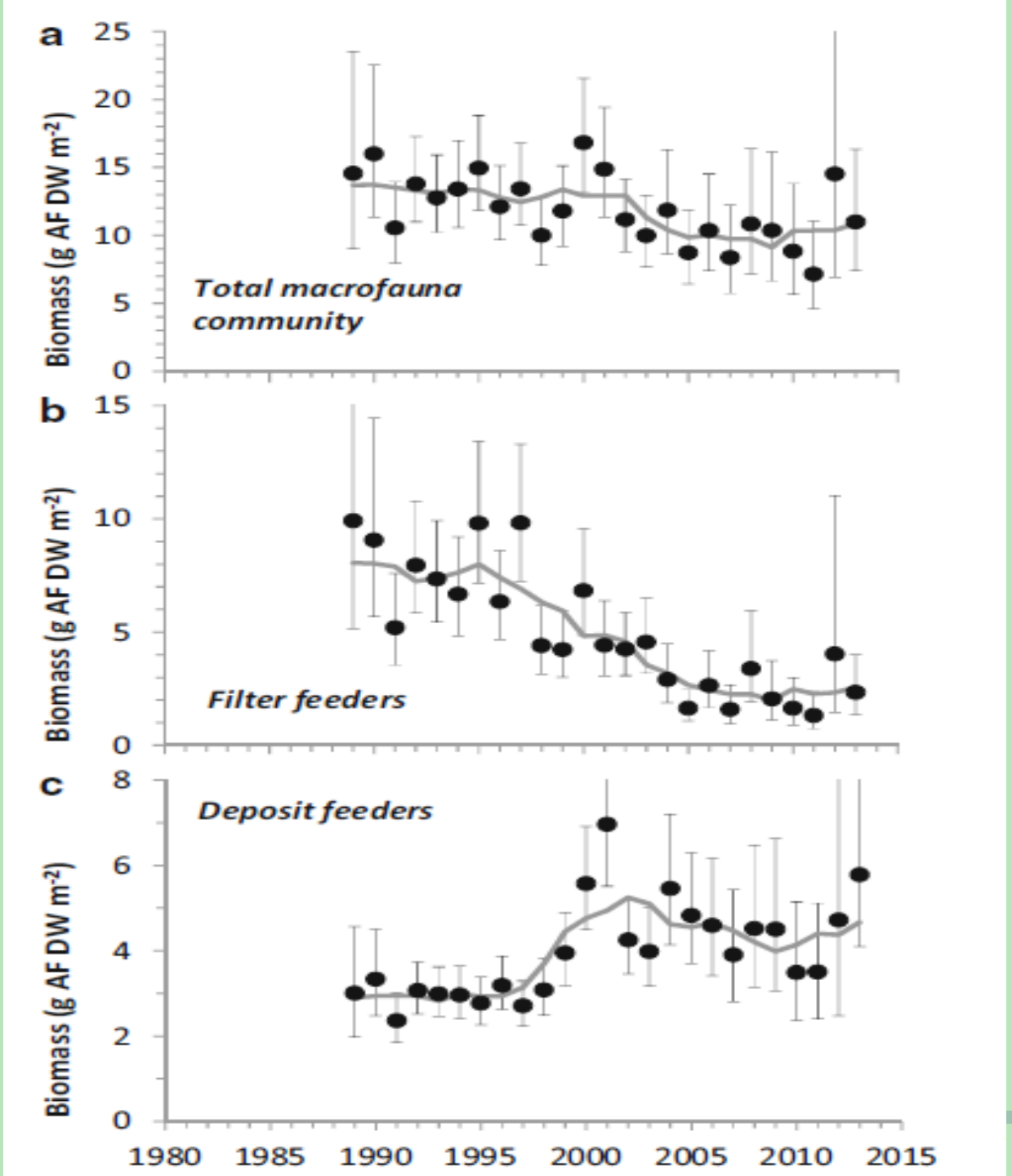


Duartes et al, 2012



Climate Change effects?

Riemann et al, 2015



Total macrofauna

Filter feeders

Deposit feeders

Riemann et al. 2015

Warming effects

- Stratification more pronounced or initiated
- Warming enhances the risk of eutrophication and enhances the Chla:TP ratio,lower water clarity
- Higher risk cyanobacteria blooming
- Higher predation from fish, less zooplankton grazing, more truncated food webs with higher degree of omnivory
- Lower nutrient thresholds needed to obtain/maintain ”good ecological status”

Climate change - actions

Many of the symptoms of warming are similar to those of europhication – so we can compensate to some extent by taking….

Action folks!!!!

Reduce the external nutrient loading!

6 degree warming….

Then we need to reduce the external loading of P and N by about 76% to reach the present water quality state (Chlorophyll a and Secchi depth)!!

A bit scaring

Thanks for inviting me