Reduced Nitrogen in Coastal Waters

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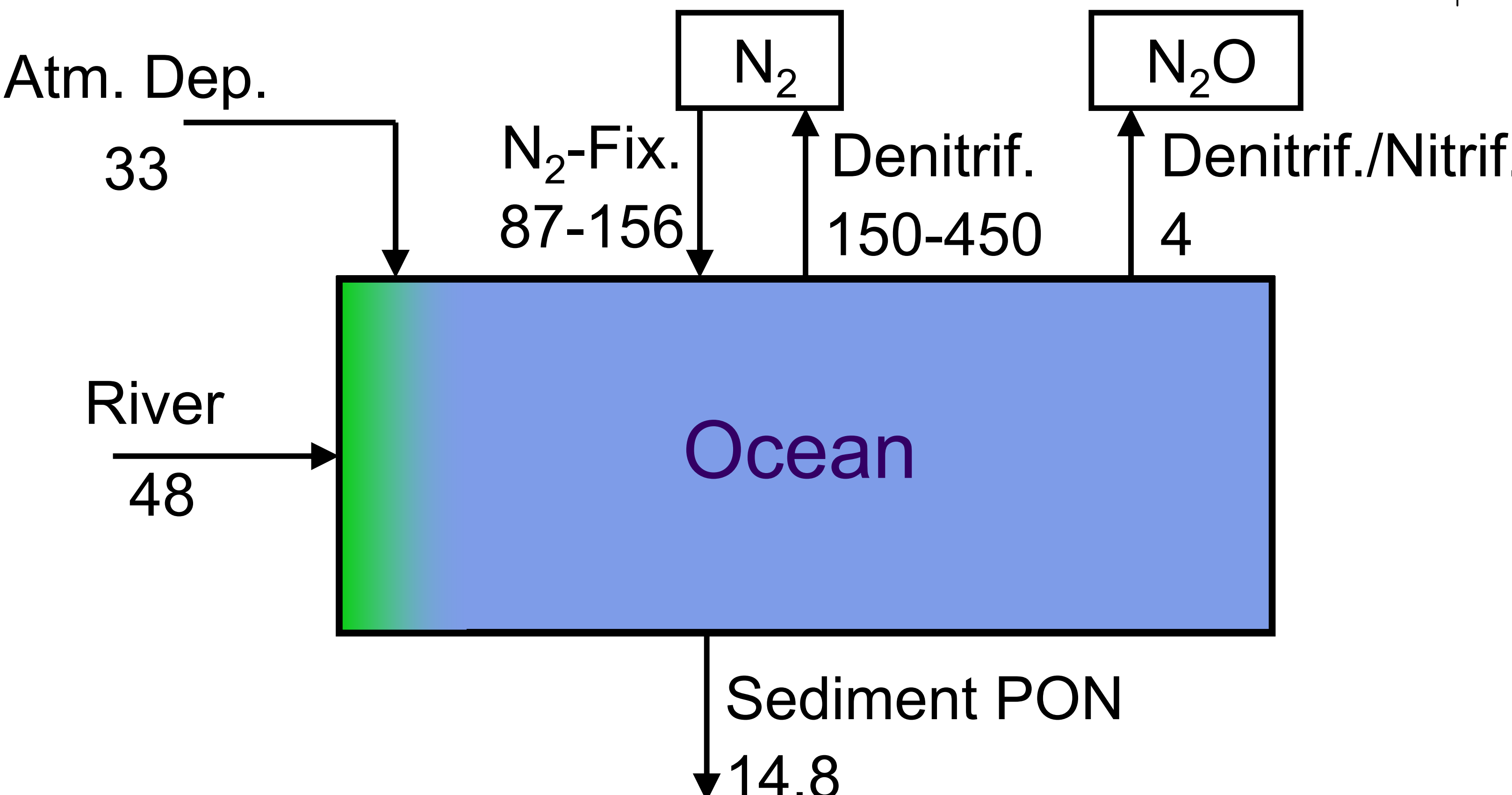
Topics of this talk

- N-cycling of coastal zones and human impact
- Eutrophication in the Baltic Sea – a vicious cycle?
  - The role anoxia in N- transformations
  - The role of benthic life for N-removal
- Summary

N-Budget for the Ocean (10^6 t a^{-1})

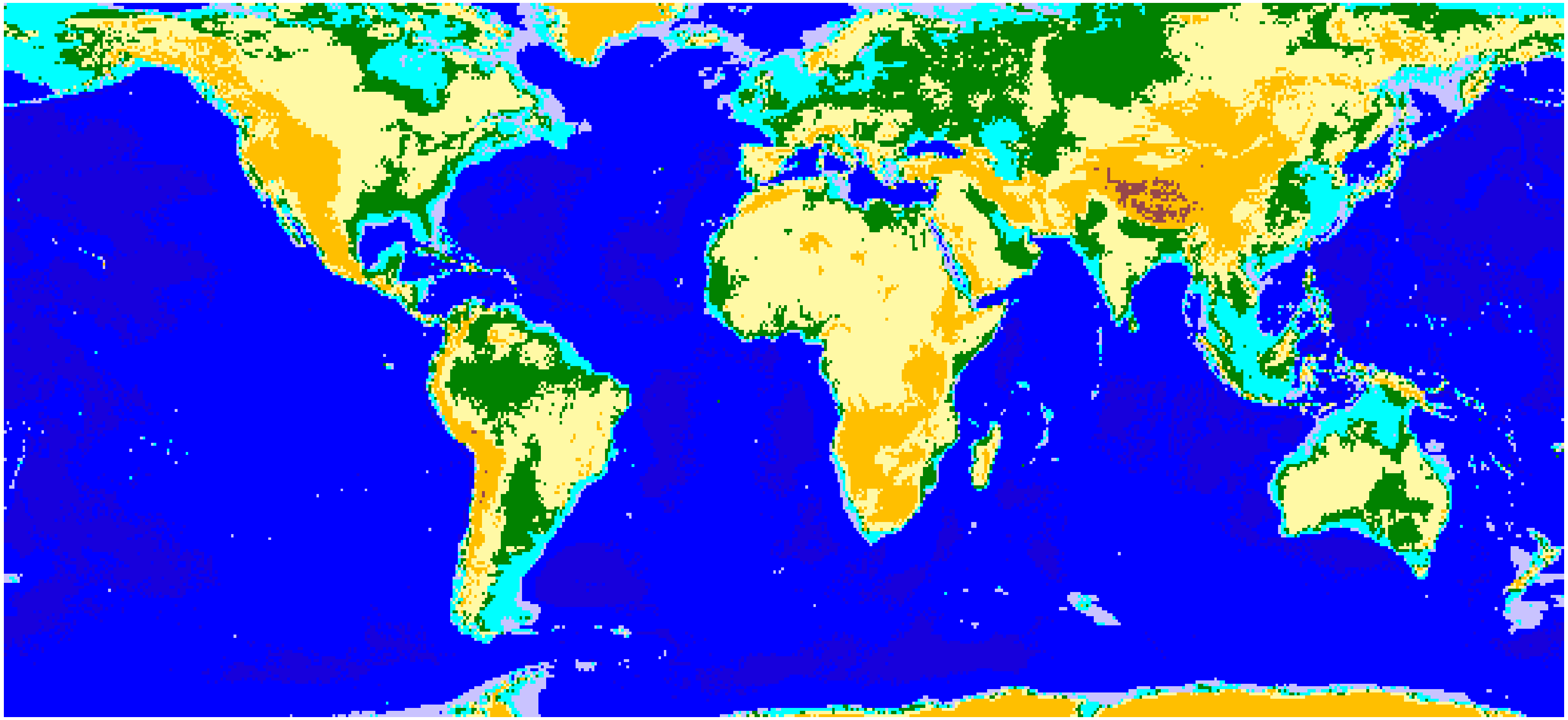


inputs: 168.0 – 237.0

losses: 168.8 – 468.8

(Galloway et al., subm.)

Land Ocean Interaction in the Coastal Zone
„LOICZ-domain“



Coastal shelves 0-200 m (cover 5% of global ocean surface)

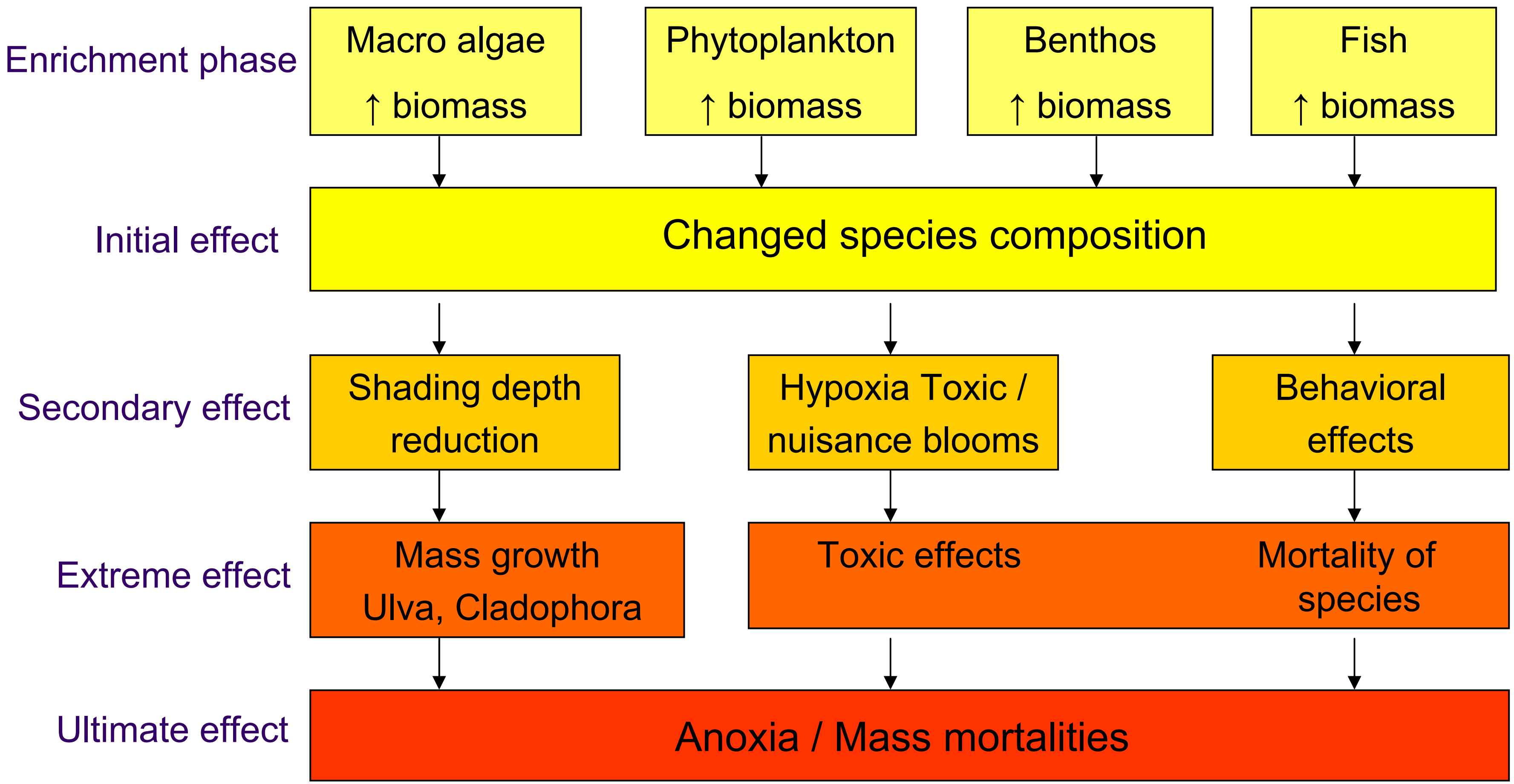
Loicz webpage

The role of coastal seas

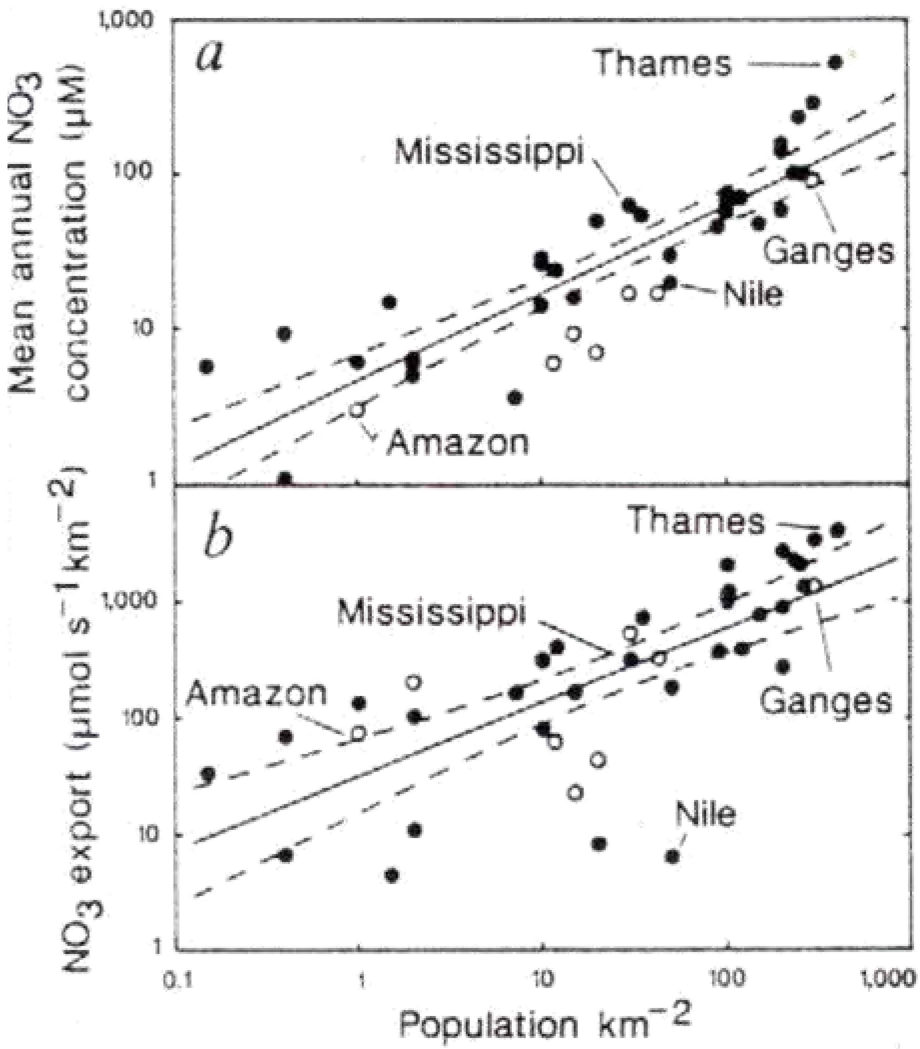
- Traffic and transport, recreation and housing
- → 35% increase of population living within 60 miles of the coastlines by 2025 compared to 1995.
  This means that 2.75 billion will life within a narrow coastal strip in 20 yrs. from now. (http://www.livescience.com/)
- Nourishment of people since coastal seas are the most productive fisheries zones in the world.
- At the same time these zones are endangered through:
  - Sea level rise (esp. southern hemisphere)
  - Storms and hurricanes
  - Human activities (constructions etc.)
  - Eutrophication
  - Anoxia

Eutrophication cascade

from Gray, 1992



NO_3^- concentration and export



Note!

Neither the length of the rivers, water flow and size of drainage basin correlates to nutrient river loads!

But the population in the drainage basin does correlate!

Peierls et al. 1991

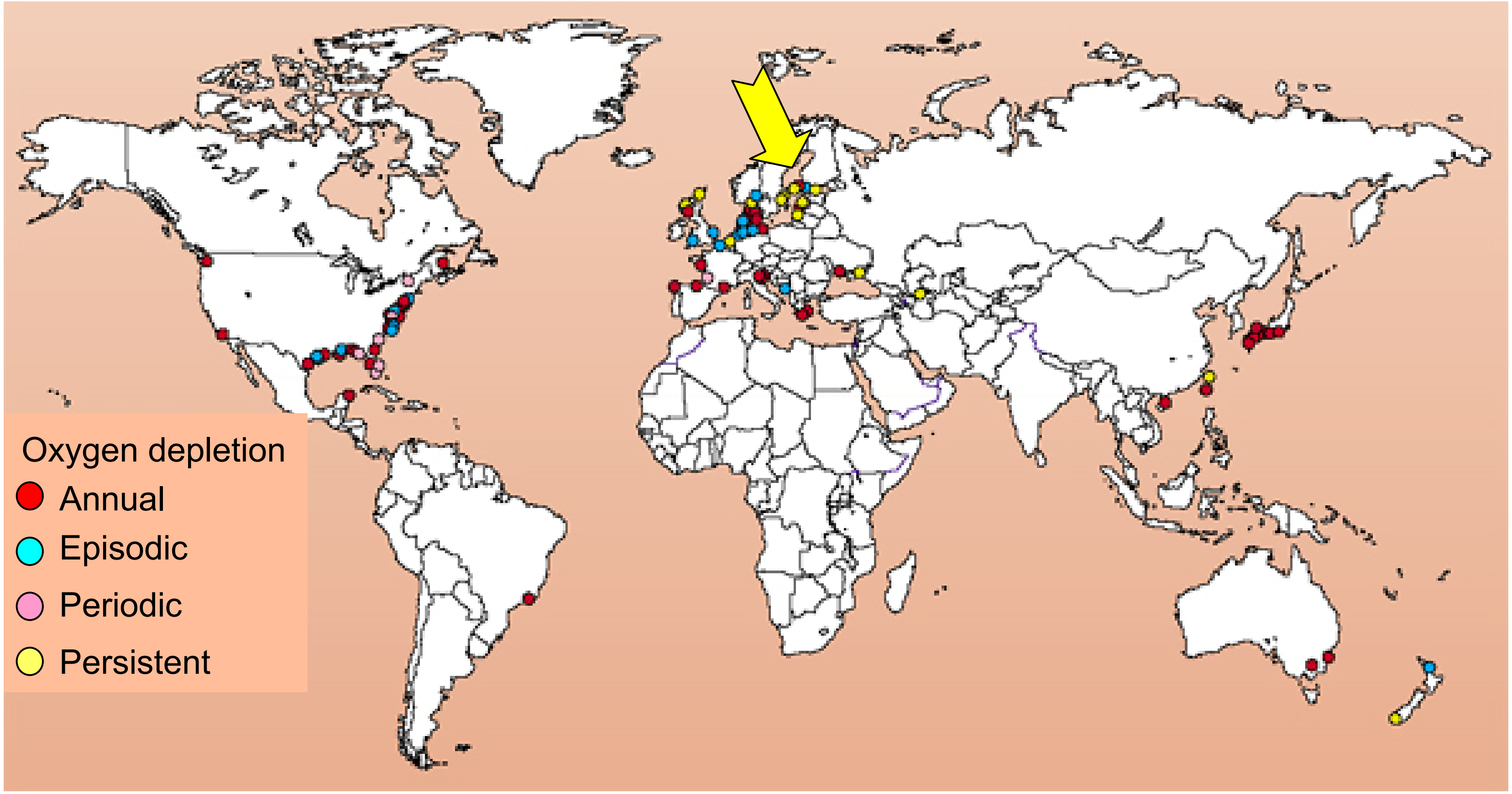
Links between coastal hypoxia and mankind (after Diaz & Rosenberg, 2001)

Coastal population with rising standards of living.
⇒ nutrient input from STP and direct land runoff
⇒ atmospheric deposition N from combustion and from fertiliser/manure use on agricultural land.

Coastal nutrient input leads OM production (=eutrophication)
⇒ anoxia can develop when stratification minimizes vertical exchange processes

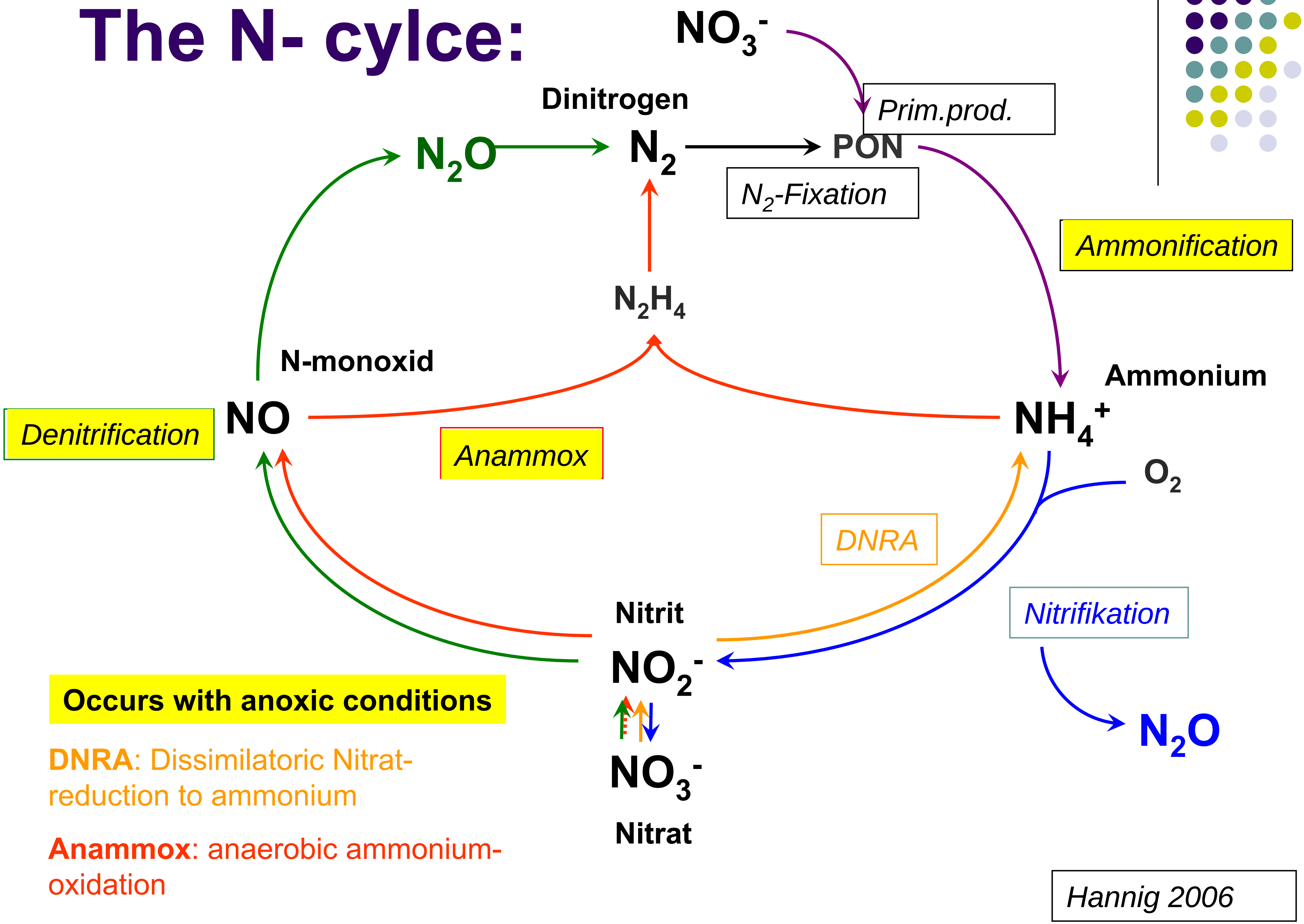
this is the case in estuaries ⇒ halocline
or in summer ⇒ thermocline

Zones with oxygen depletion



http://upload.wikimedia.org/

The N- cylce:



NO3-
Prim.prod.
Dinitrogen
N2O
N2
PON
N2-Fixation
Ammonification
N2H4
N-monoxid
Ammonium
Denitrification
NO
NH4+
Anammox
O2
DNRA
Nitrit
Nitrifikation
NO2-
N2O
Occurs with anoxic conditions
NO3-
DNRA: Dissimilatoric Nitrat-reduction to ammonium
Nitrat
Anammox: anaerobic ammonium-oxidation
Hannig 2006

More consequences of O_2 depletion

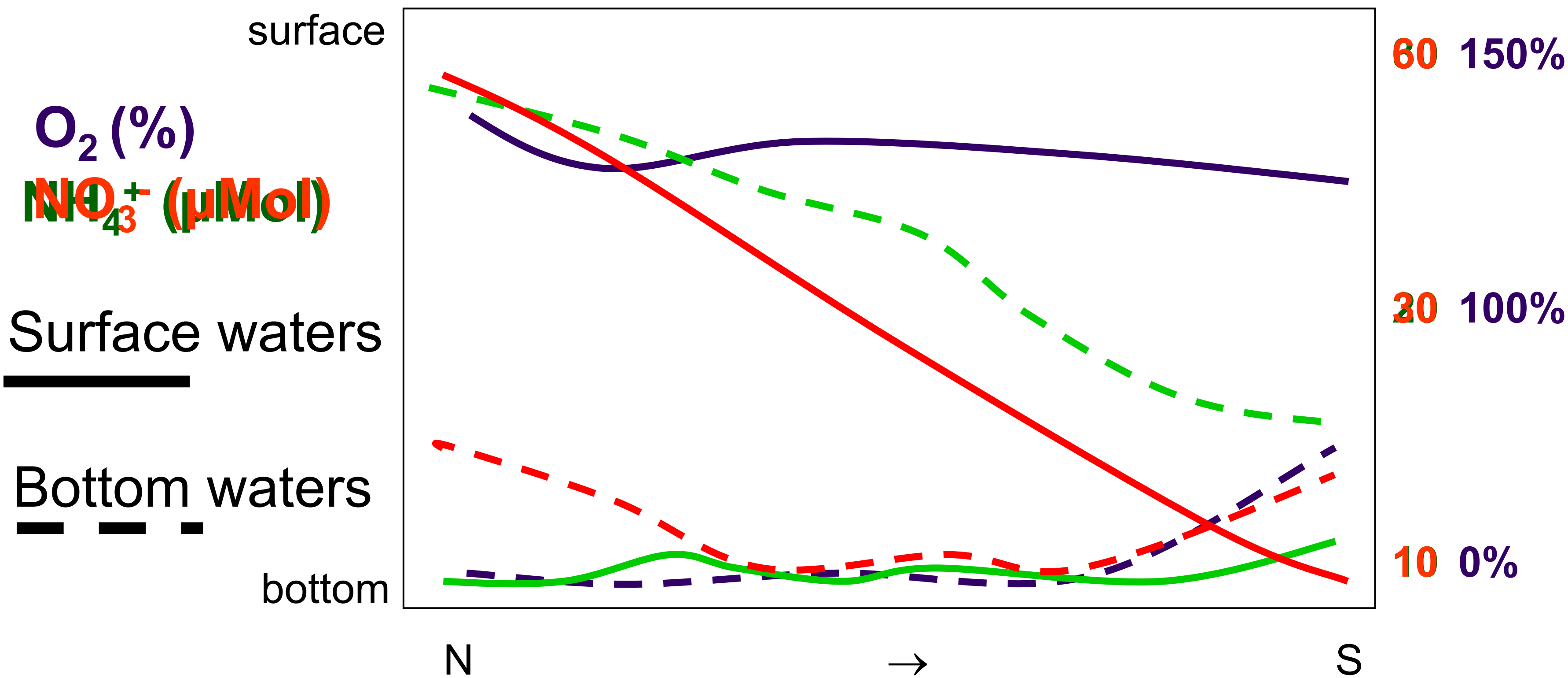
- Other oxidation agents than O_2 are used by bacteria e.g. $SO_4^{2-} \rightarrow H_2S$
- Nitrification and Denitrification produce N_2O
- Metal speciation changes

oxic anoxic

e.g. Fe III $(OH)_3$ $PO_4^{3-} \rightarrow$ Fe II + PO_4^{3-}

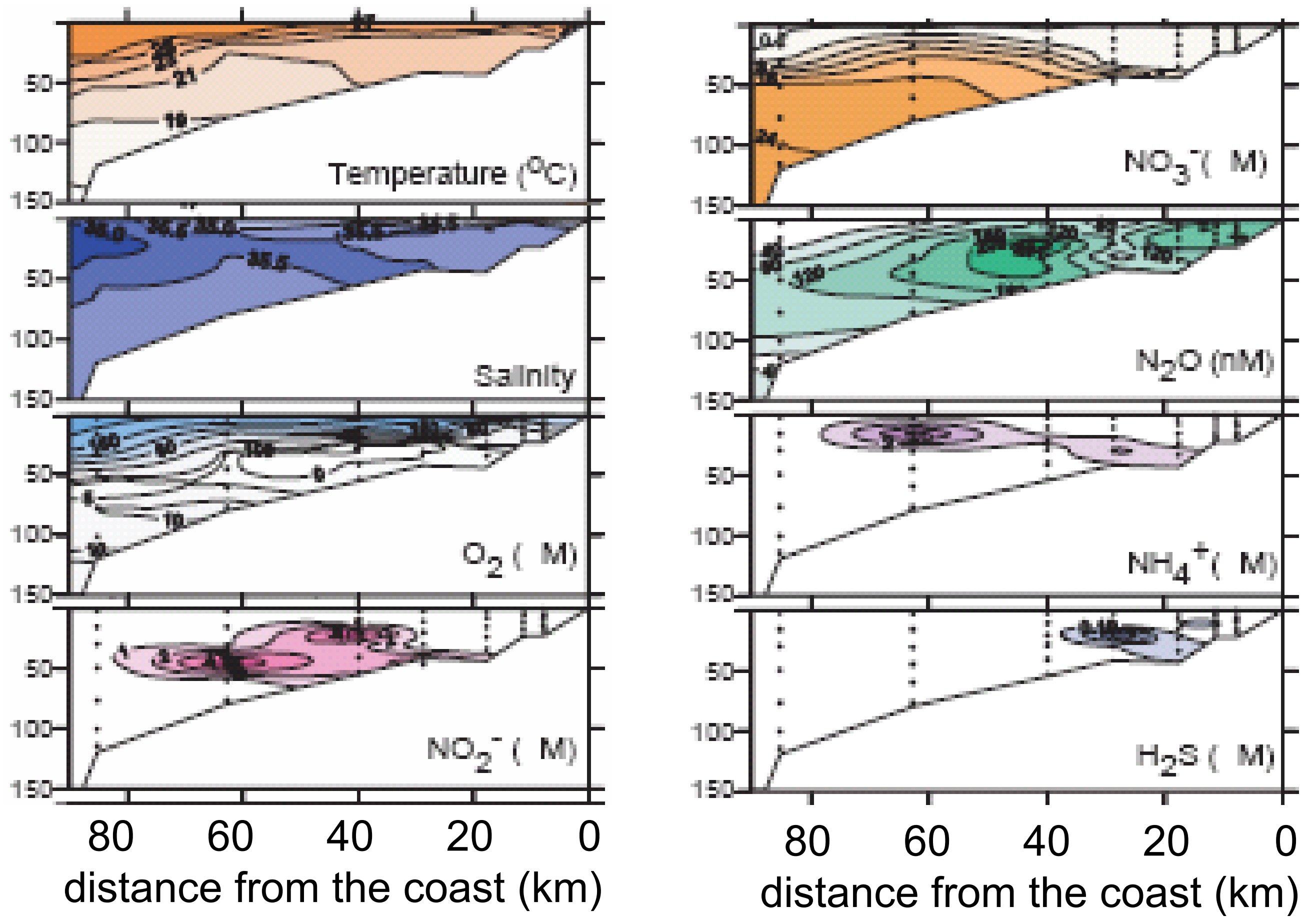
Chesapeake Bay

Hypoxia below the mixed layer: Chesapeake Bay



after Horrigan et al. 1999

Hypoxia below the mixed layer: Data from the Indian Shelf

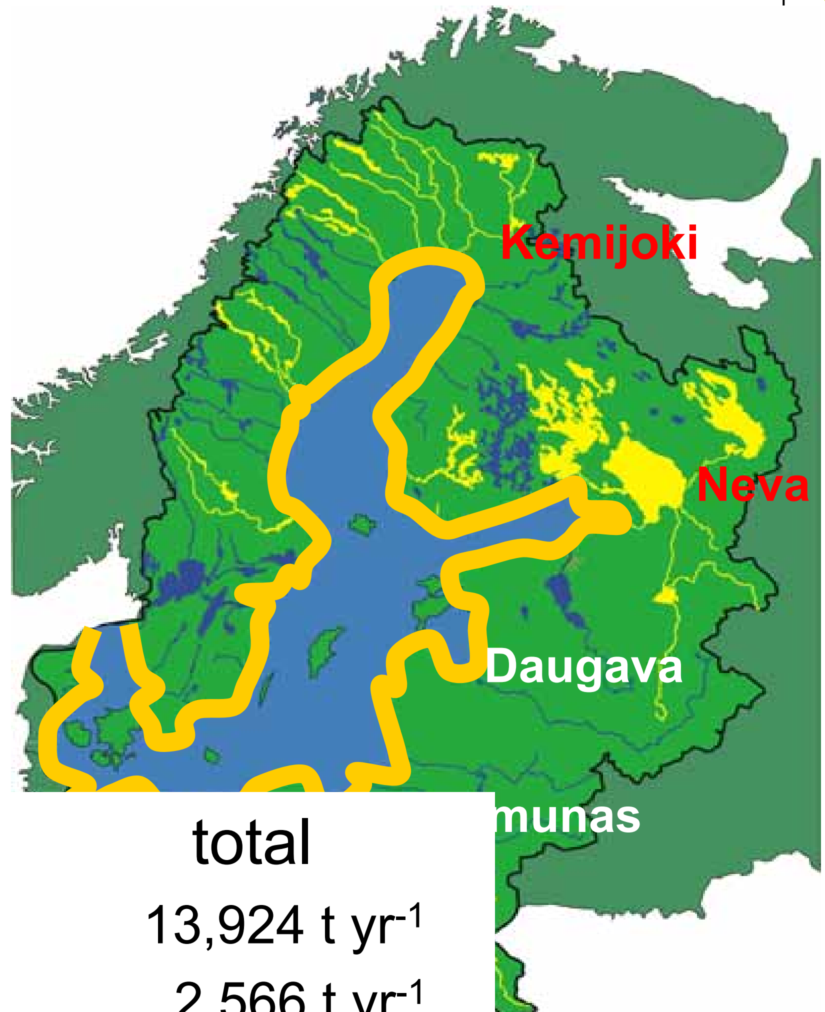


…here denitrification is suggested to produce the N_2O

Naqvi et al. BGD, 2006

The Baltic Sea

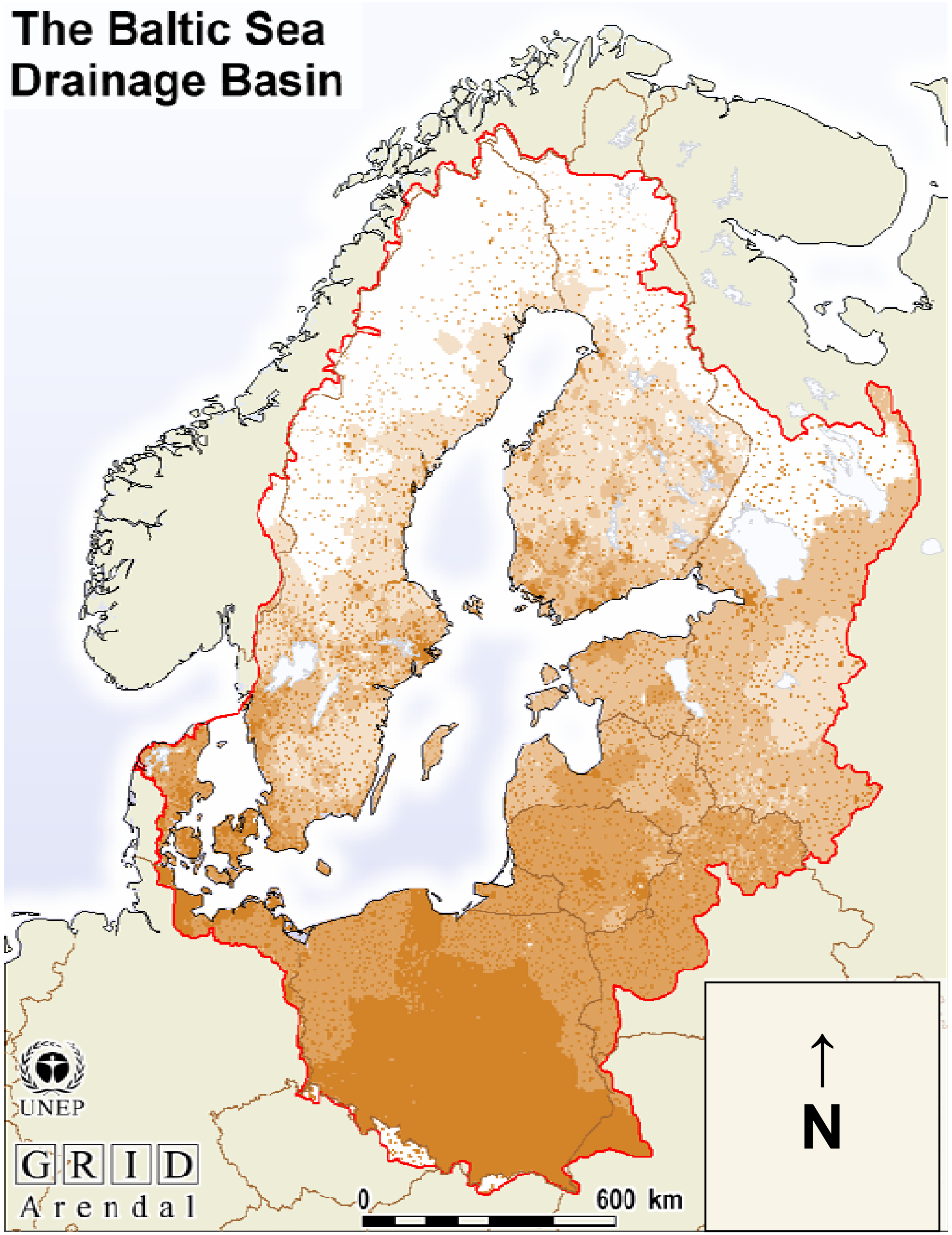
Surface area:	415,266 km²
Catchment area:	1,720,270 km²
Population:	85 million
Within 10 km:	**15 million**
Fresh water:	15,190 $m^3 s^{-1}$
Six largest:	**6,565 $m^3 s^{-1}$**



Nitrogen Sources (Baltic Sea)

		rivers-DE	total
(1)	Nitrate	13,400	13,924 t yr^{-1}
(2)	DON	1,990	2,566 t yr^{-1}
(3)	Ammonium	1,206	4.650 t yr^{-1}

importance

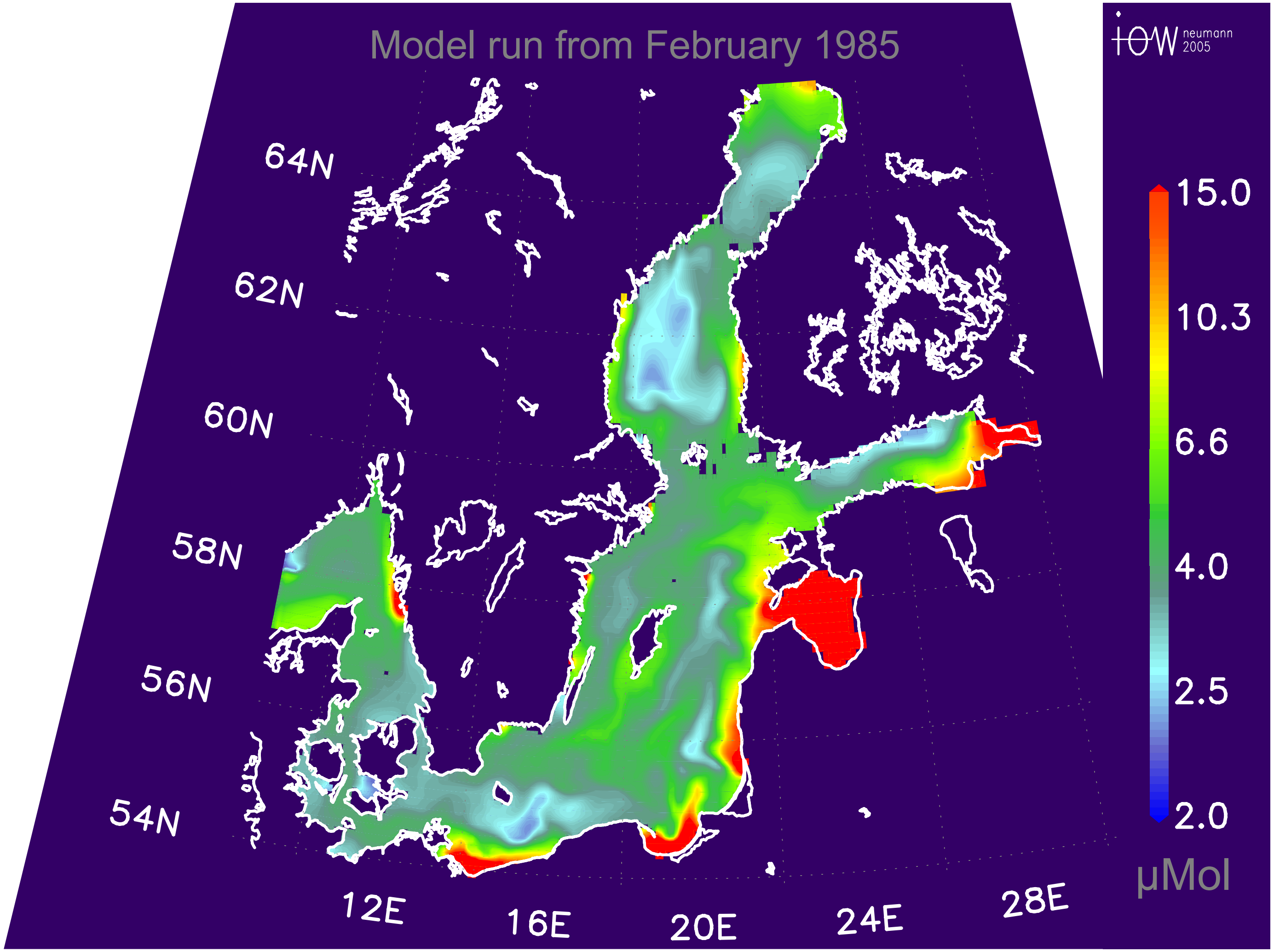


Population density [People km^{-2}]

(white)	0-1
(lightest brown)	1-5
(light brown)	5-12
(medium brown)	12-38
(dark brown)	38-11,000

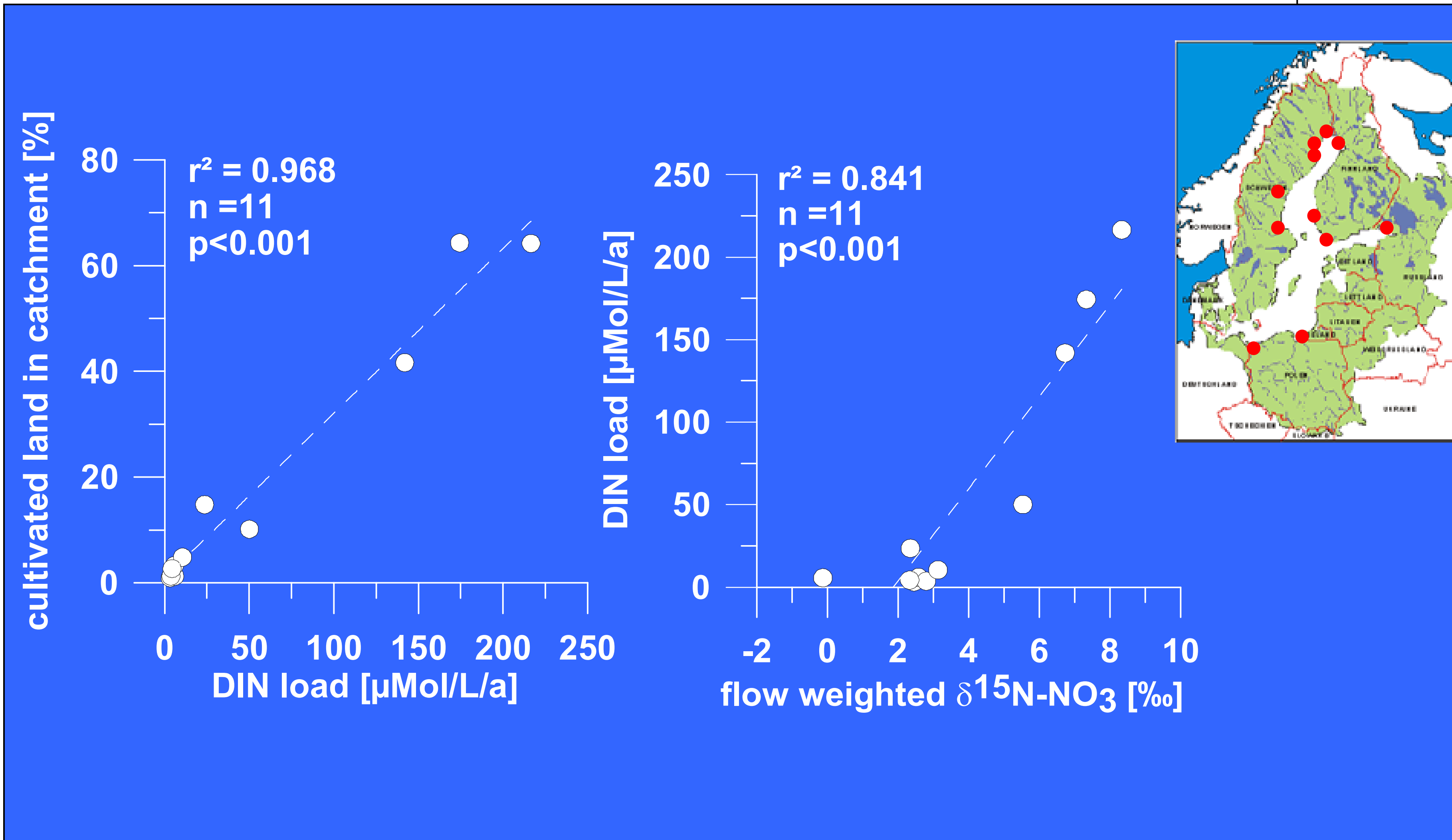
Σ 85 million

Winter DIN concentration in the Baltic Sea



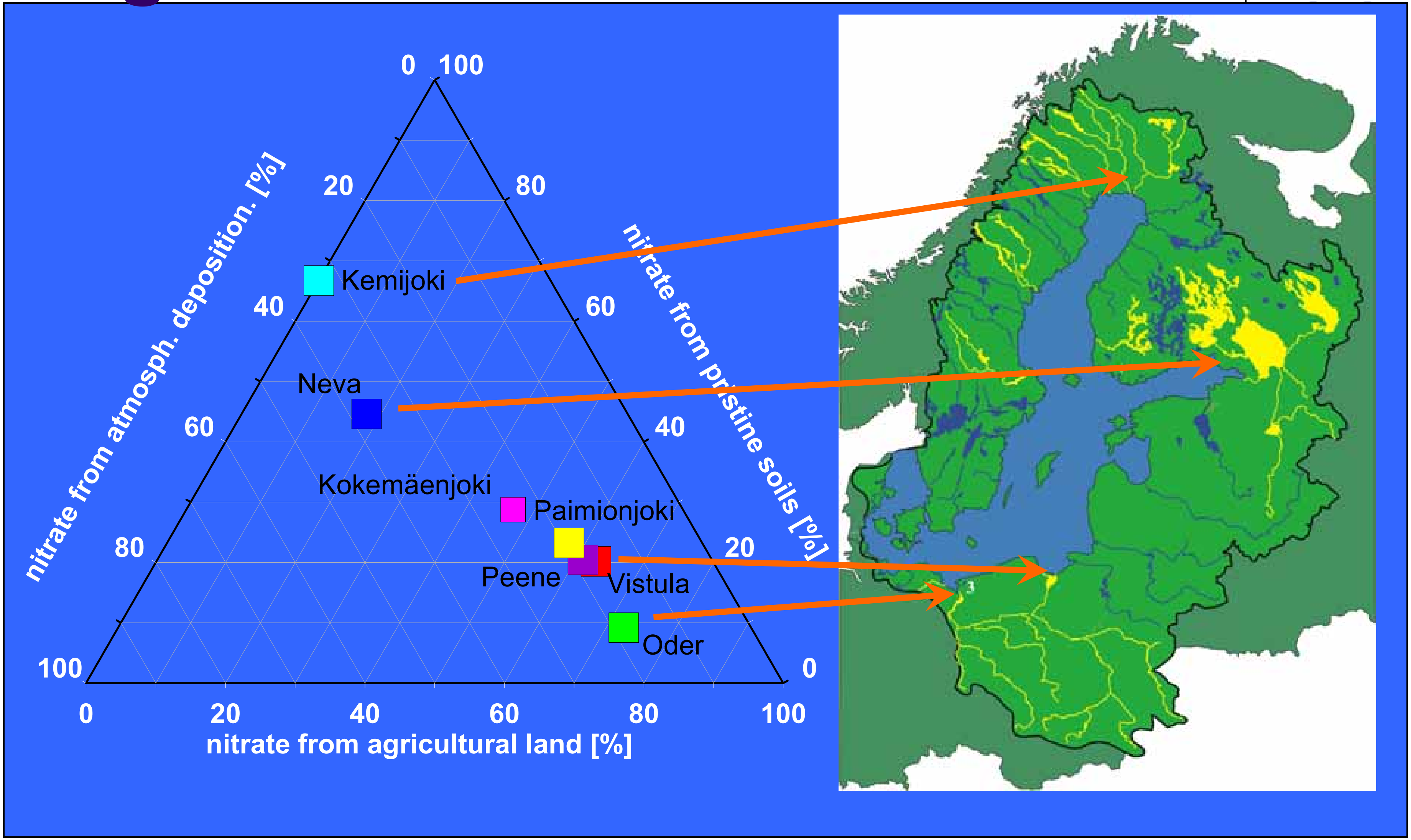
Neumann, 2005

Relationship between DIN load – landuse and $\delta^{15}N\text{-}NO_3$



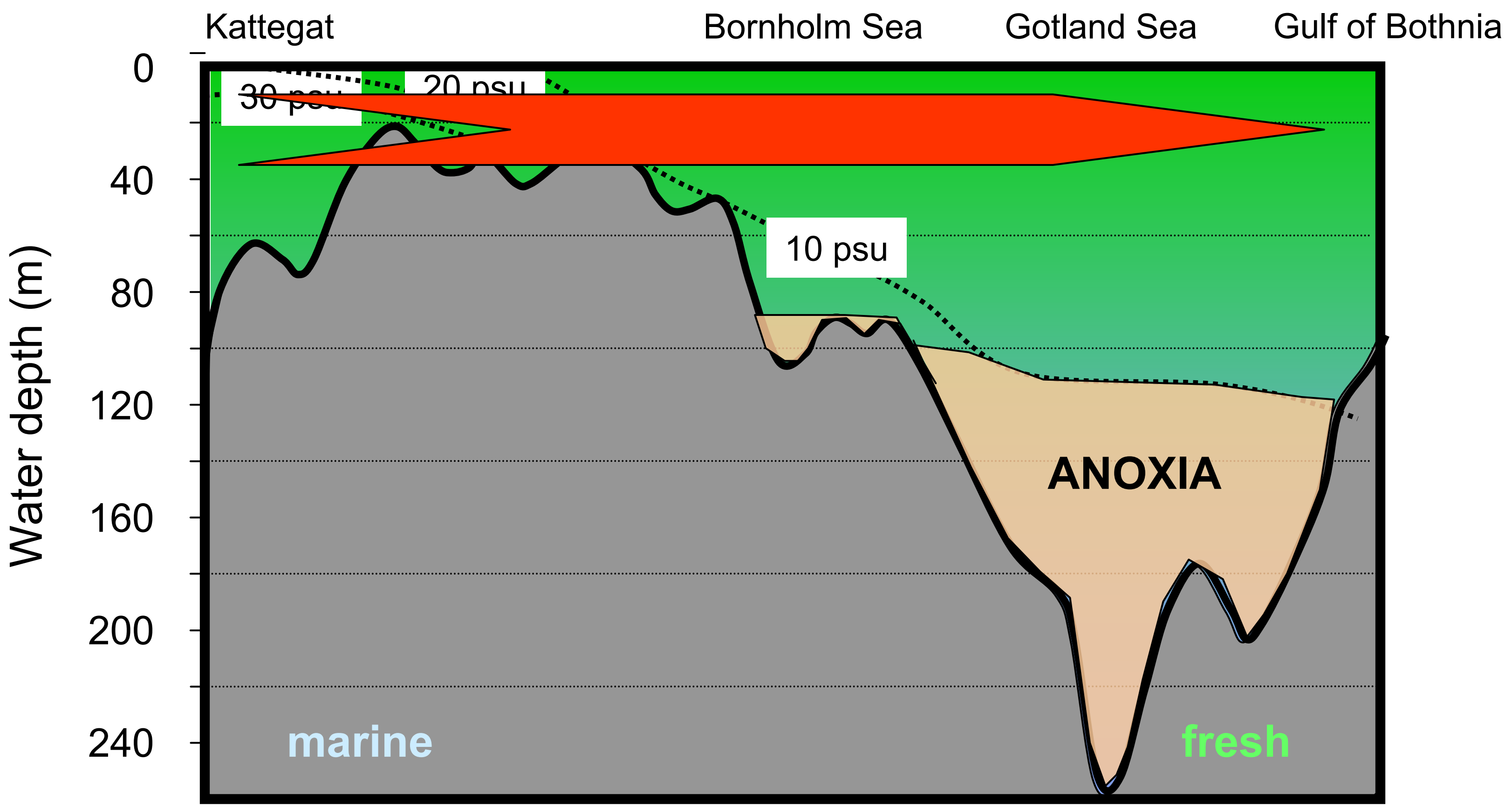
Voss et al. 2006

Land use and isotope signatures

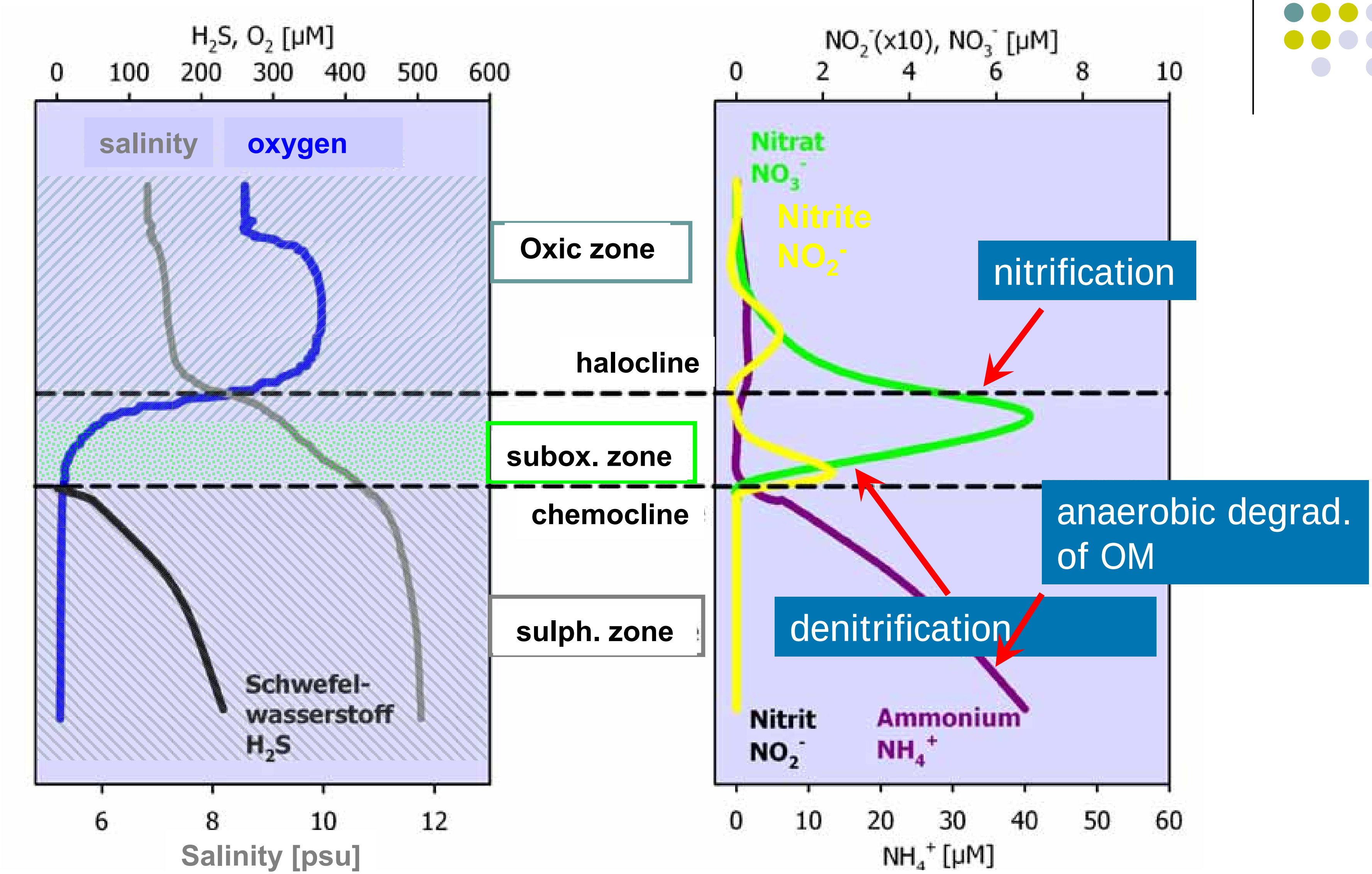


Voss et al. 2006

Baltic Sea salinity distribution



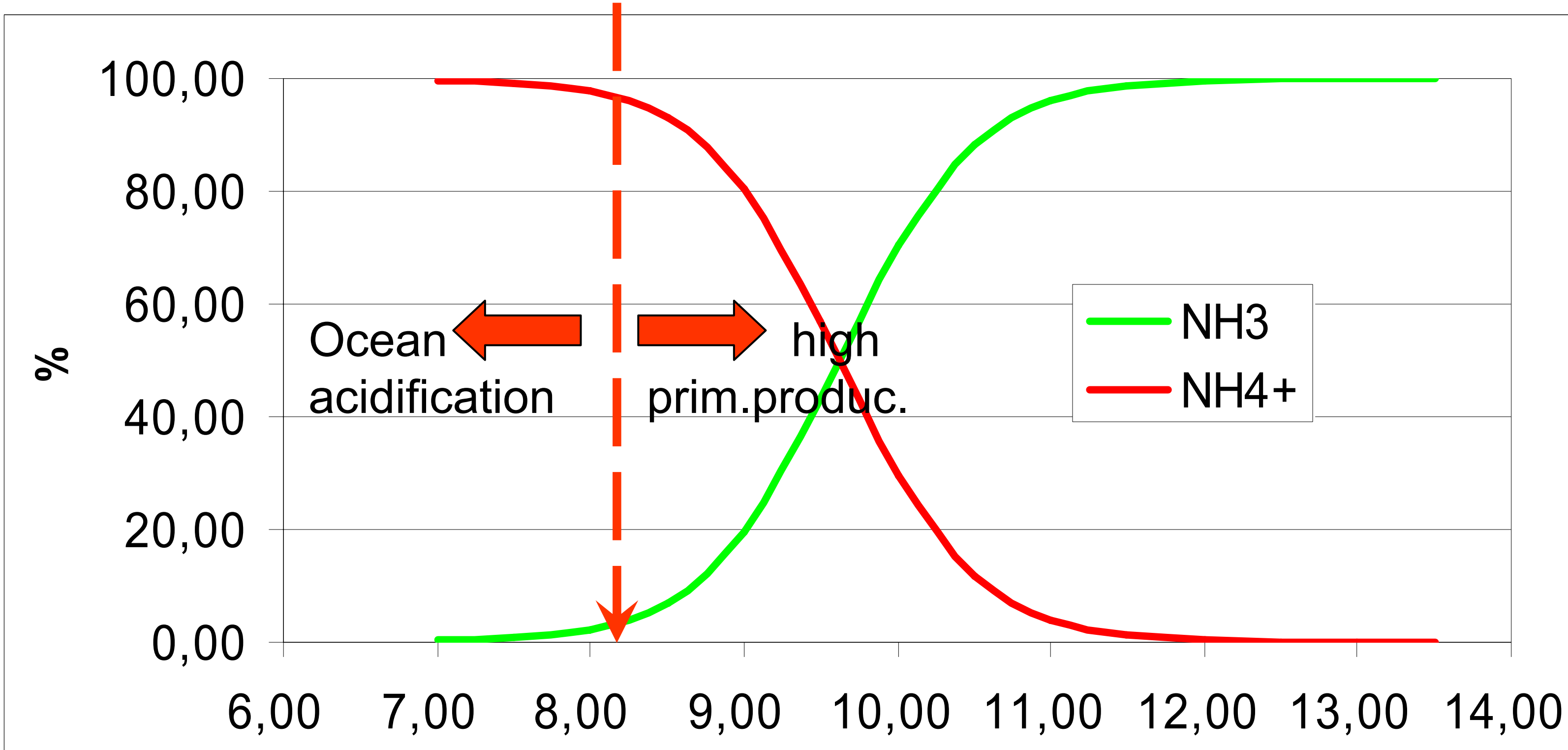
Stratification in the Baltic Sea



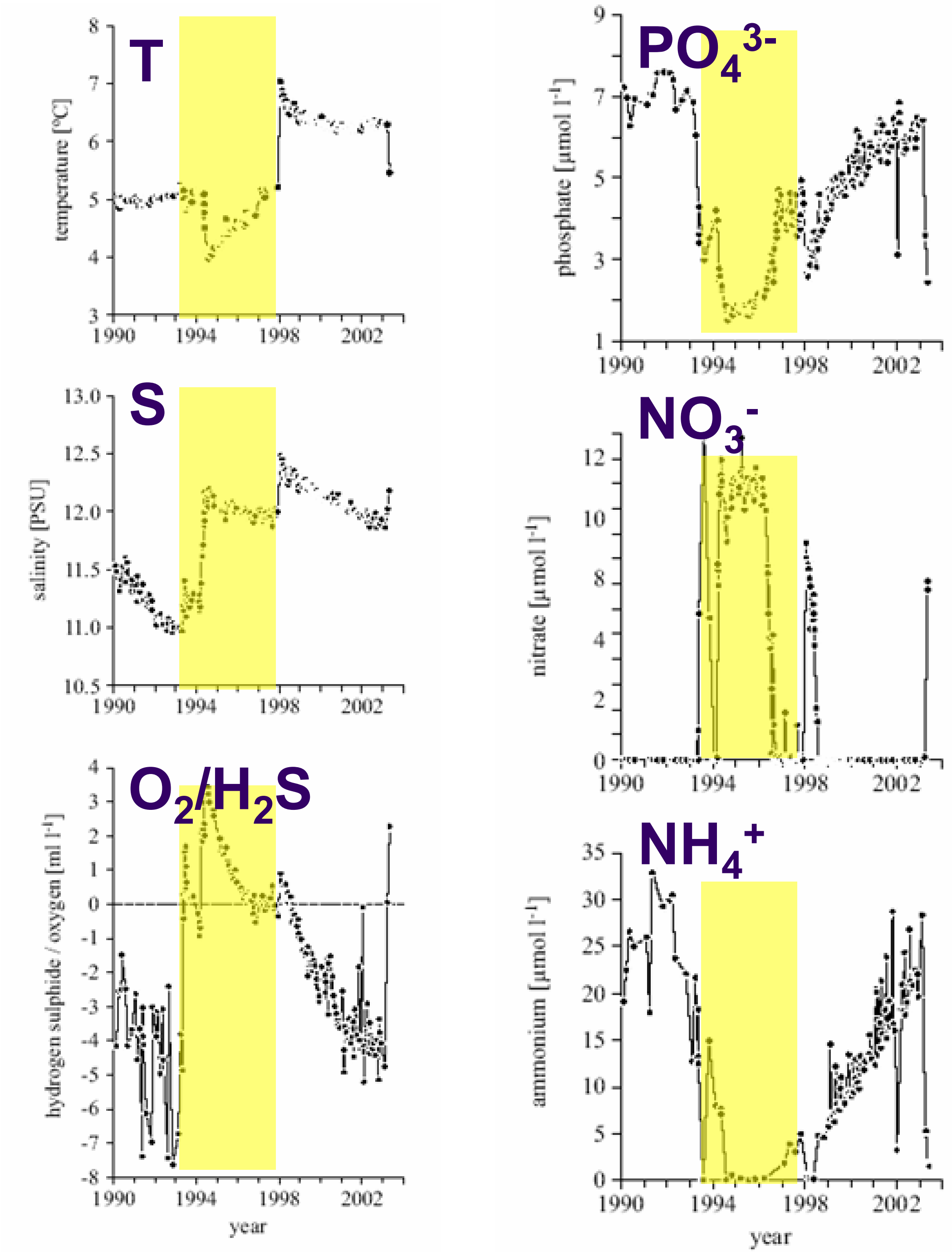
from Hannig, 2006

pH dependency of the NH_3/NH_4^+ equilibrium (20°C, 35 psu)

Preindustrial seawater value (4% NH_3, 96% NH_4^+)



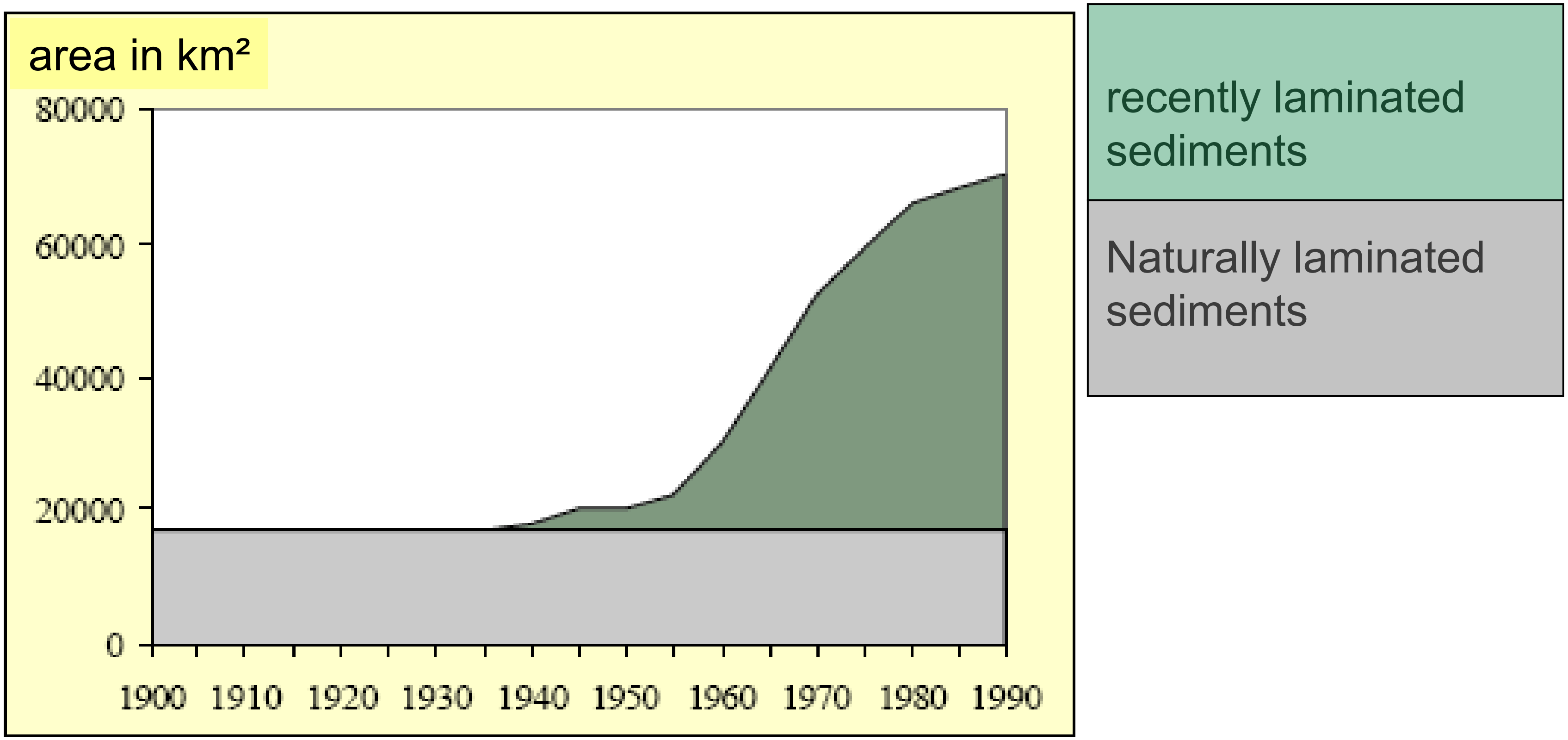
→ Direct toxicity for animals is hardly given through ammonia



Typical changes in the Baltic Proper deep waters after an inflow event

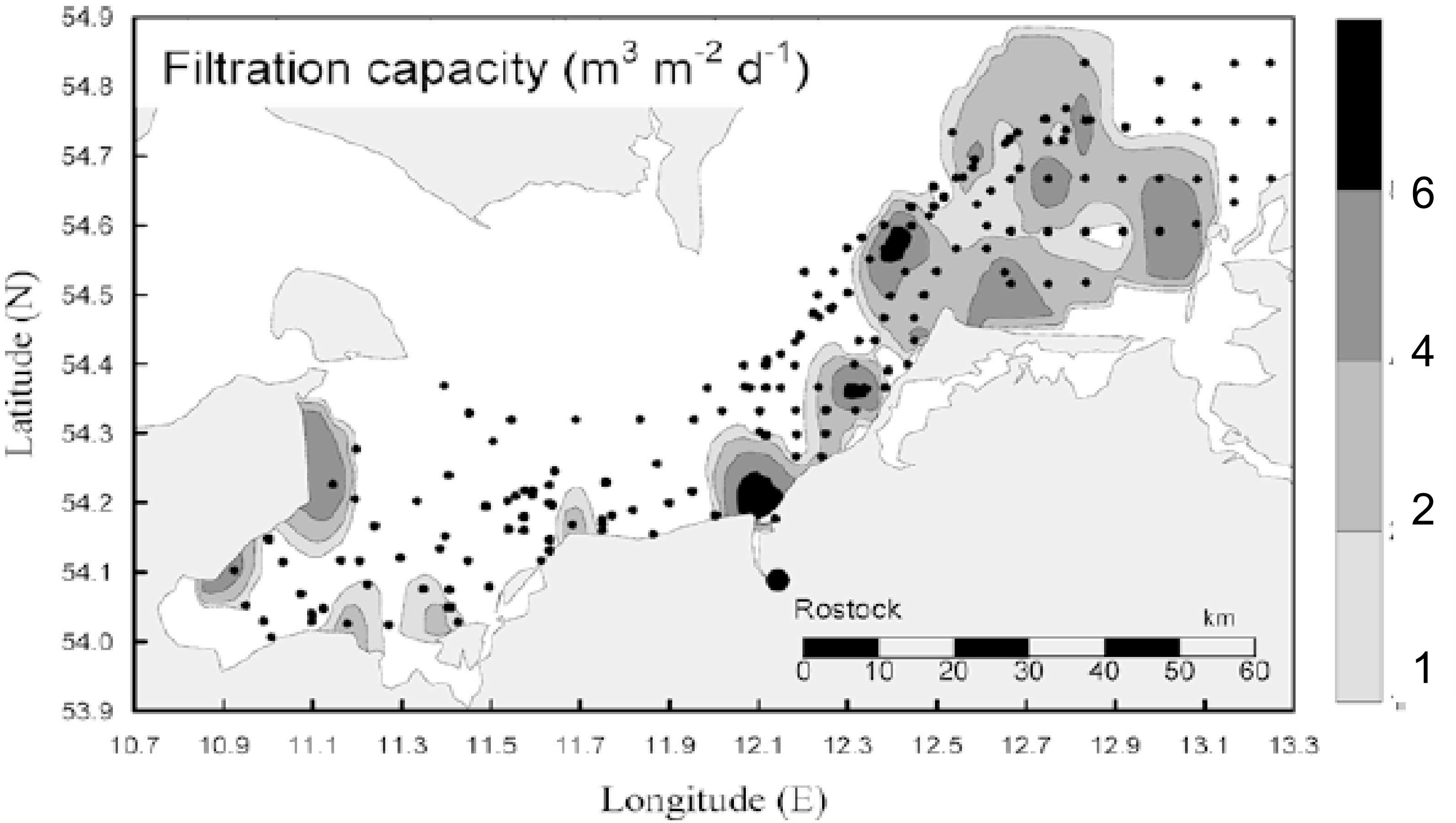
Cyanobacteria

Anoxia in the Baltic Sea

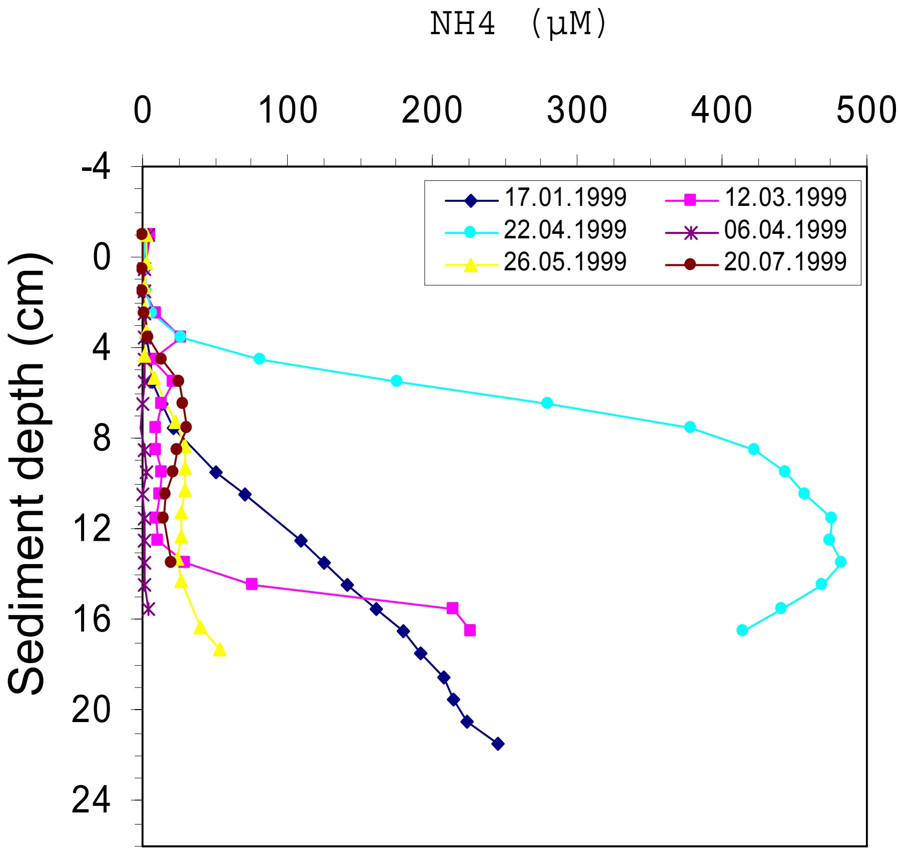


Johnsson et al. 1990

Filtration capacity M. arenaria



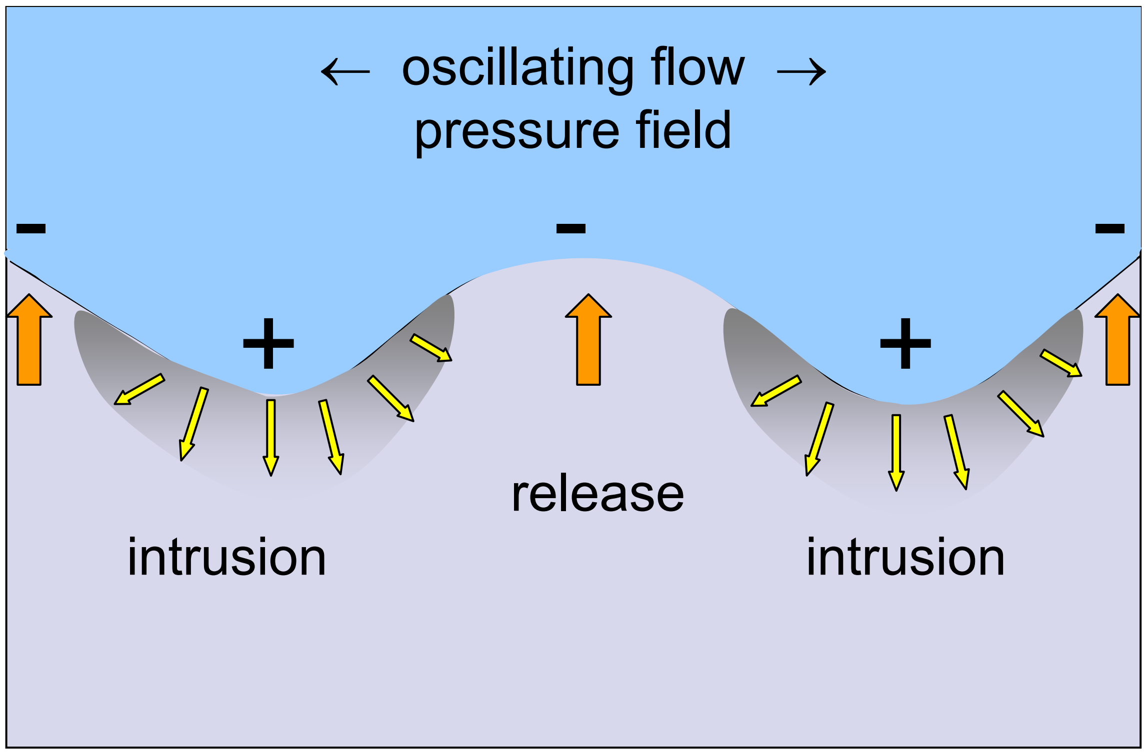
Nutrients in pore waters of sandy sediments



Highly variable between 500 and almost 0 µmol L^{-1}

Physical oxygenation:

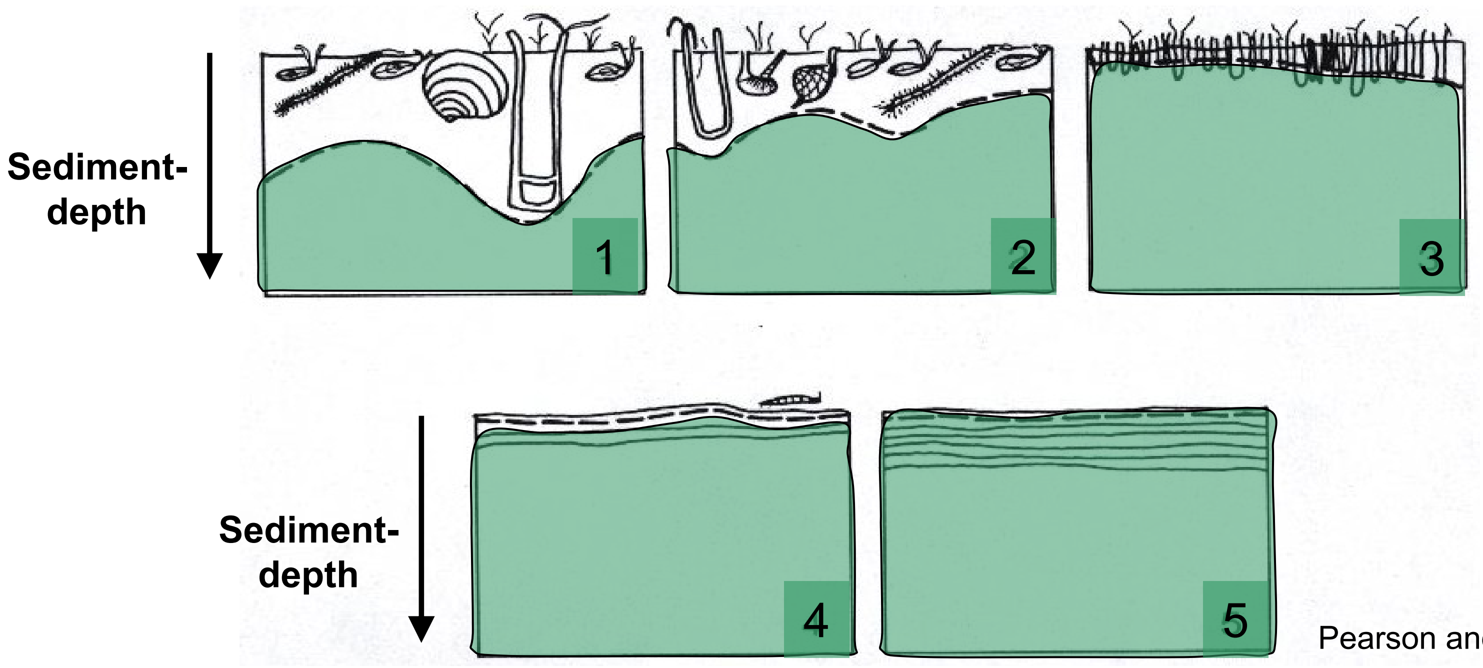
Pore water flow and current induced pressure field



each m² of coarse grained sediment can filter up to 850mg $C_{org.}$ d^{-1}

Precht and Huettel, 2004
Rusch and Huettel, 2000

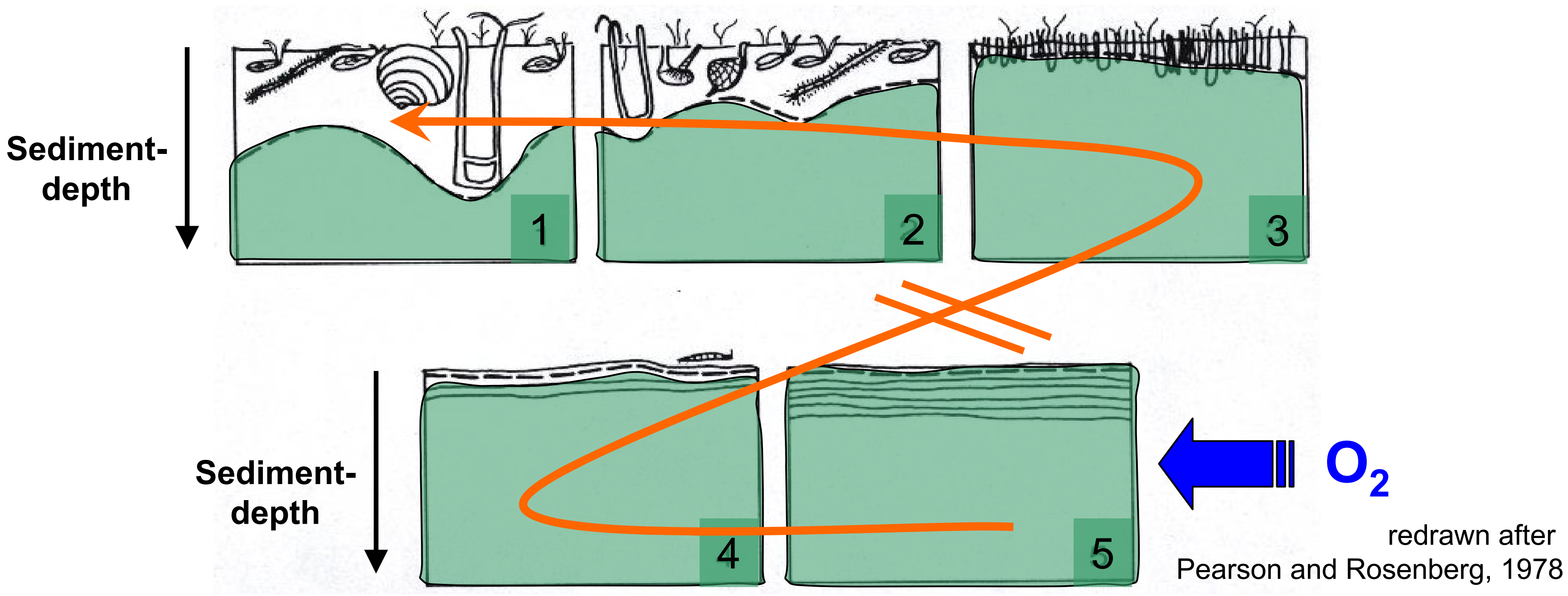
Succesion of benthic life under less and less oxygen



redrawn after
Pearson and Rosenberg, 1978

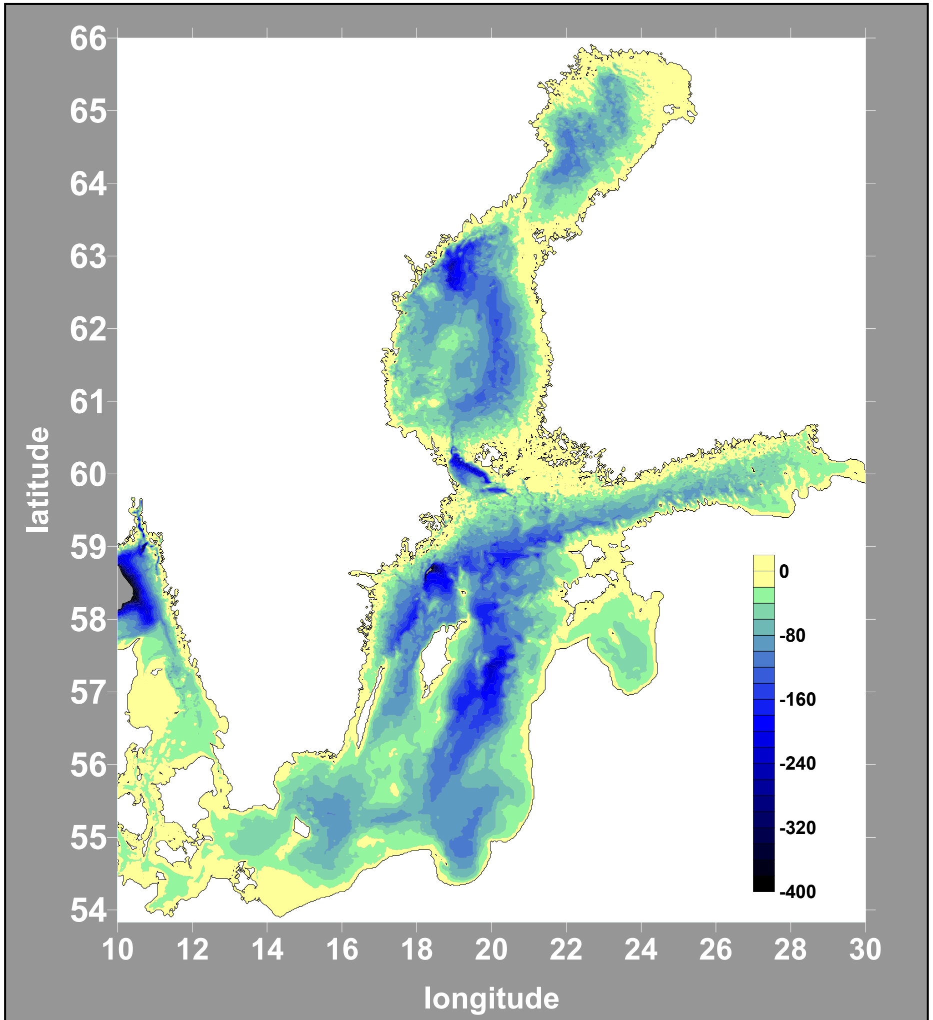
➡ The situation in the western Baltic Sea has worsened from 1932 to 1989 years by at least 1 stage (Ruhmor 1996).

Succesion of benthic life under less and less oxygen



There is hardly a way back from stage 5 to 1!

Extension of sandy sediments



These sediments seem to guarantee:

⇒ rapid removal of large quantities of organic carbon
⇒ high nitrification capacity
⇒ removal of river N-loads before these can enter the open Baltic Sea

Summary

- Human activities have lead to enhanced N-input into coastal zones (not so much reduced N compounds).
- This N enters coastal seas mainly in oxidized forms. Under anoxic conditions NH_4^+ is produced and not further nitrified and may accumulate under statified conditions.
- Coastal seas release N_2O in rather unknown quantities.
- Biological activity of benthic life forms aerates the sediments (sandy, muddy) efficiently. When benthic life has died off it cannot easily return.
- Coastal sandy sediments are an efficient filter system for the organic loads, they even enhance nitrification and presumably also denitrification.