'Estuaries in a changing world'
10th IEBS, Xiamen, China, May 18-22, 2008

"Natural and anthropogenic controls of nutrient input to estuaries from temperate to tropical regions"

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Global frame: land – ocean fluxes

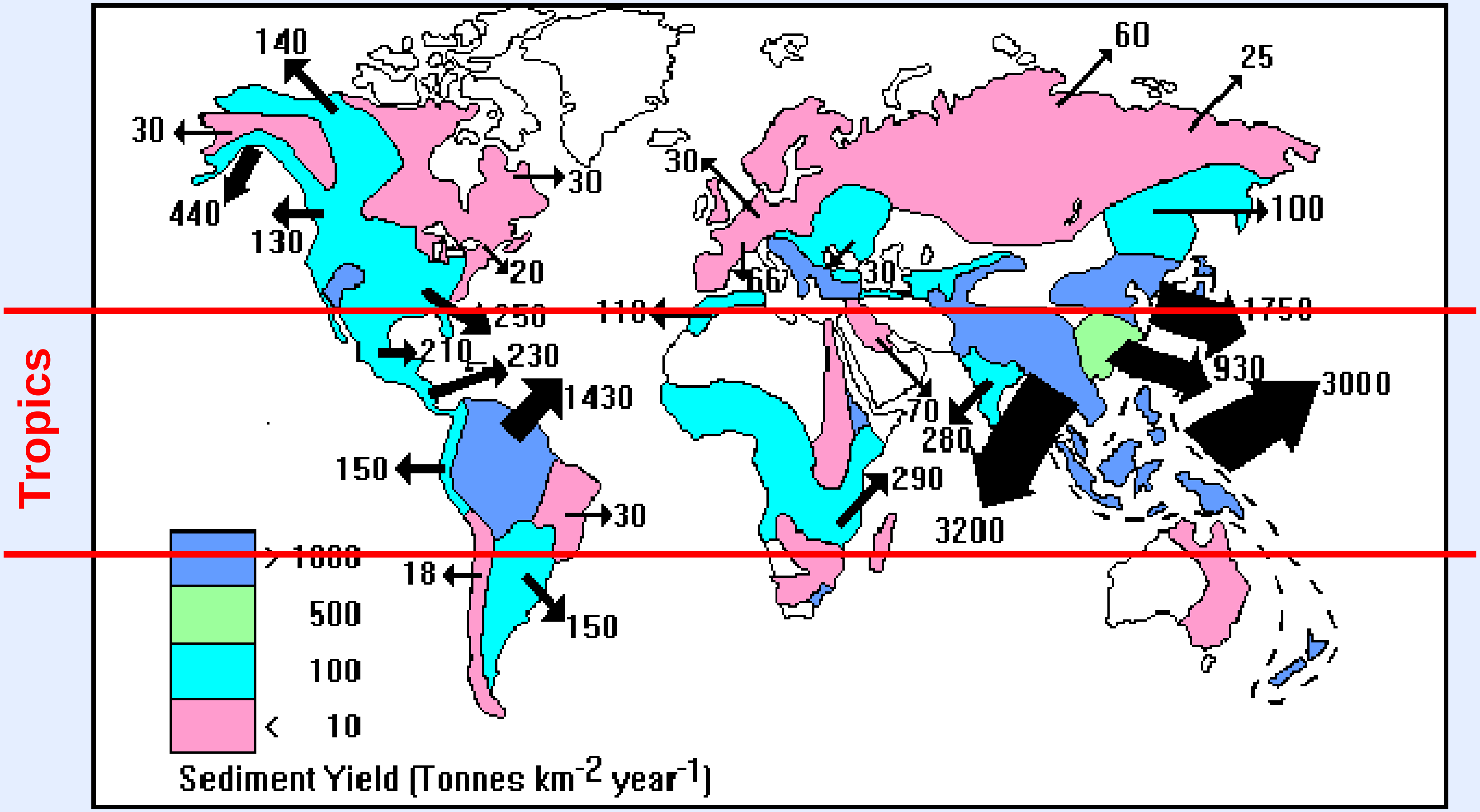
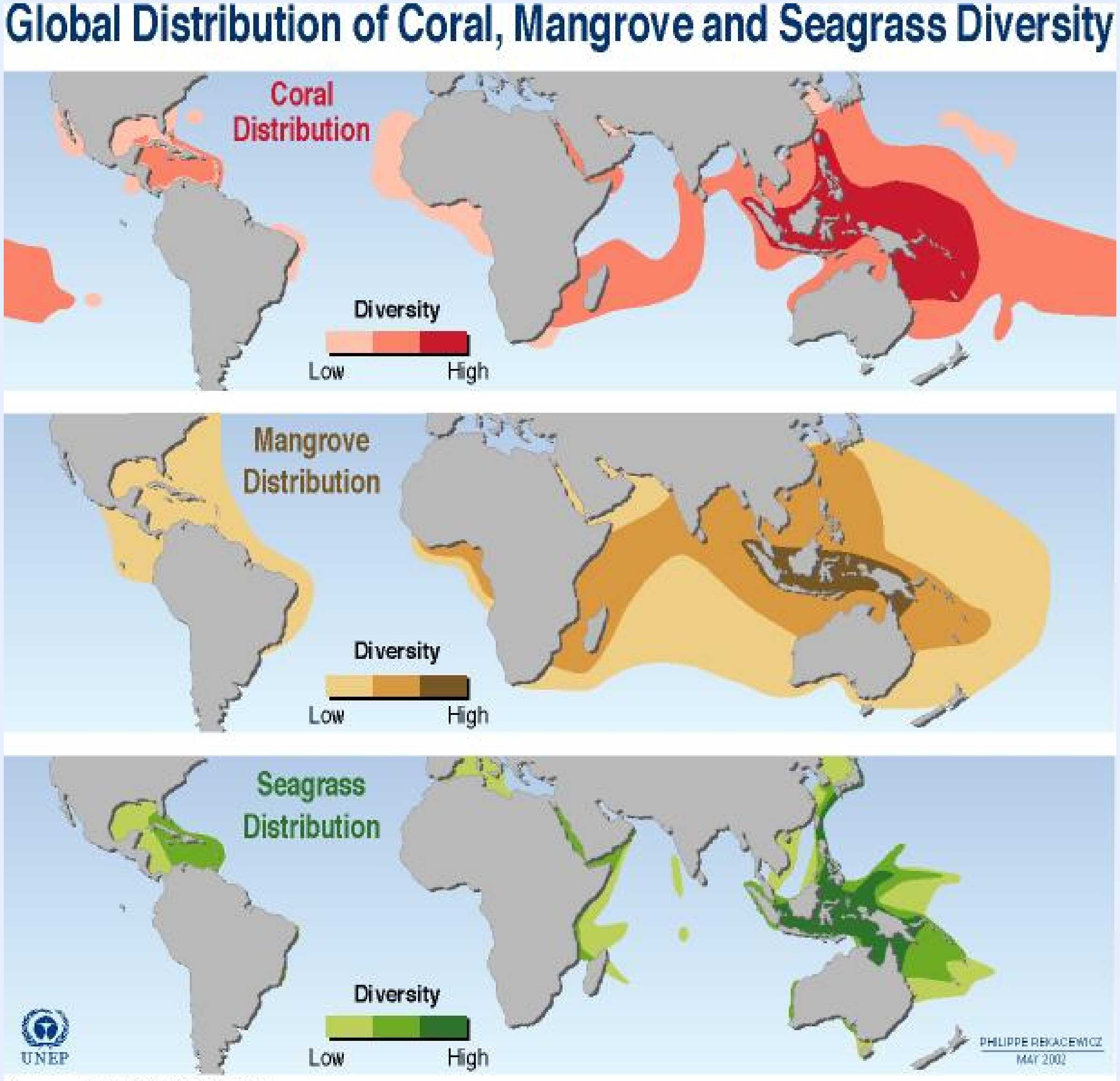


Figure 5 ***Global pattern of sediment yield, with river output of sediment to the oceans (tonnes x10^6) (Ref. 6). (Reproduced by permission)***

Tropical regions receive ¾ each of water discharge and of sediment input

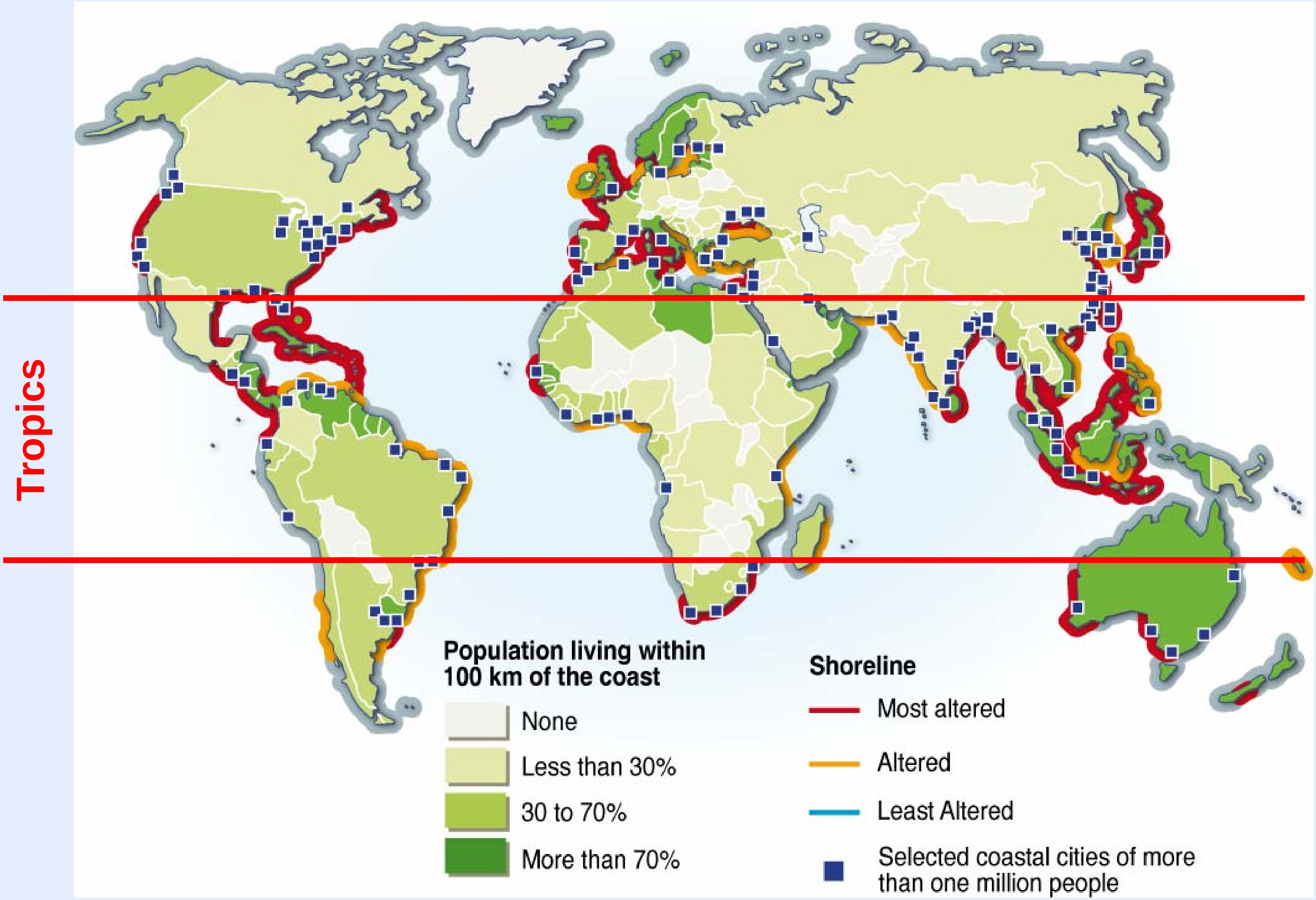
Source: www.gemswater.org

Global frame: biodiversity, productivity



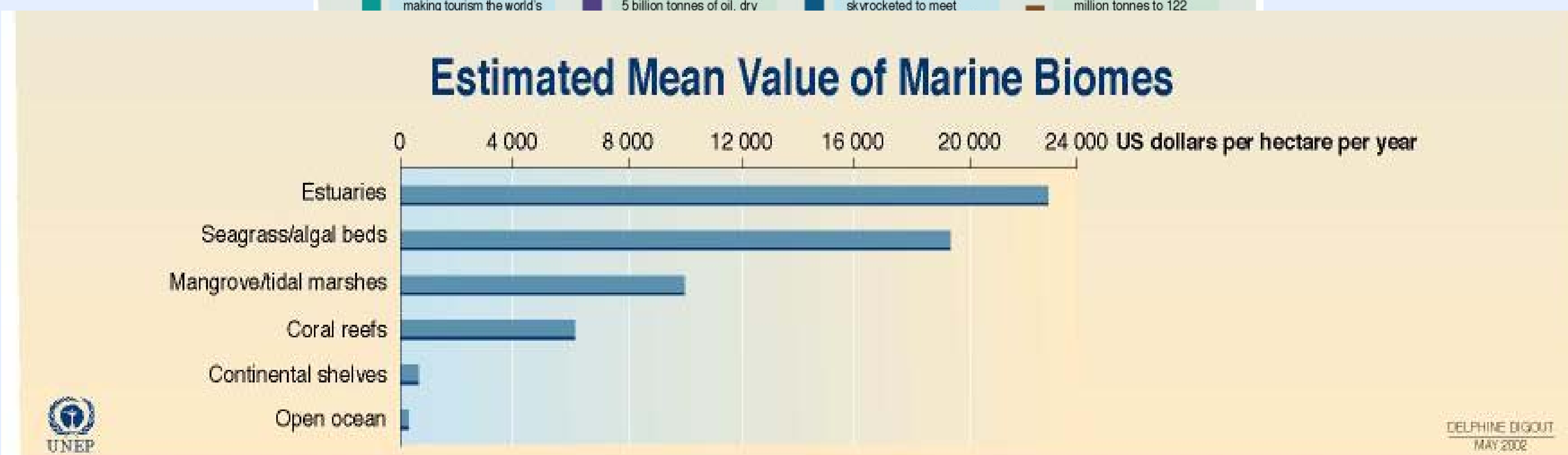
Source : UNEP-WCMC, 2001.

Global frame: human activities



Source: Burke et al. World Resources Institute, Washington DC, 2001; Paul Harrison and Fred Pearce, AAAS Atlas of Population and Environment 2001, AAAS, University of California Press, Berkeley.

Global frame: economy



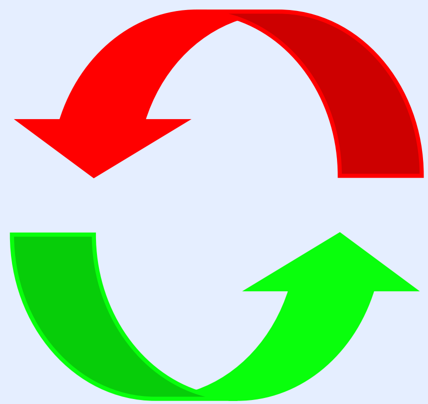
Source: Anne Platt McGinn, *The Health of Oceans*, Worldwatch paper 145, Worldwatch Institute, 1999, Washington DC (www.worldwatch.org) ; Costanza, R., et al, *The Value of the World's Ecosystem Services and Natural Capital*, Ecological Economics, 1998.

Source: Anne Platt McGinn, *The Health of Oceans*, Worldwatch paper 145, Worldwatch Institute, 1999, Washington DC (www.worldwatch.org) ; Costanza, R., et al, *The Value of the World's Ecosystem Services and Natural Capital*, Ecological Economics, 1998.

River loads

1st order control: geology, climate, hydrology, vegetation

2nd order control: human activities



Reverted in many regions during the 'Anthropocene'

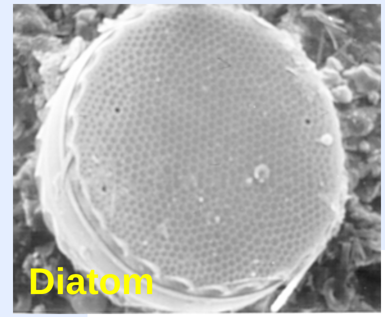
Human activities affecting coastal ecosystems:

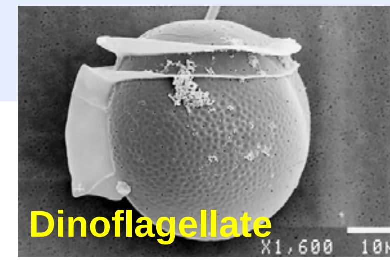
Temperate regions

Danube – NW Black Sea

NW Black Sea coastal waters

Early 1970s: building of dams, industry, agriculture

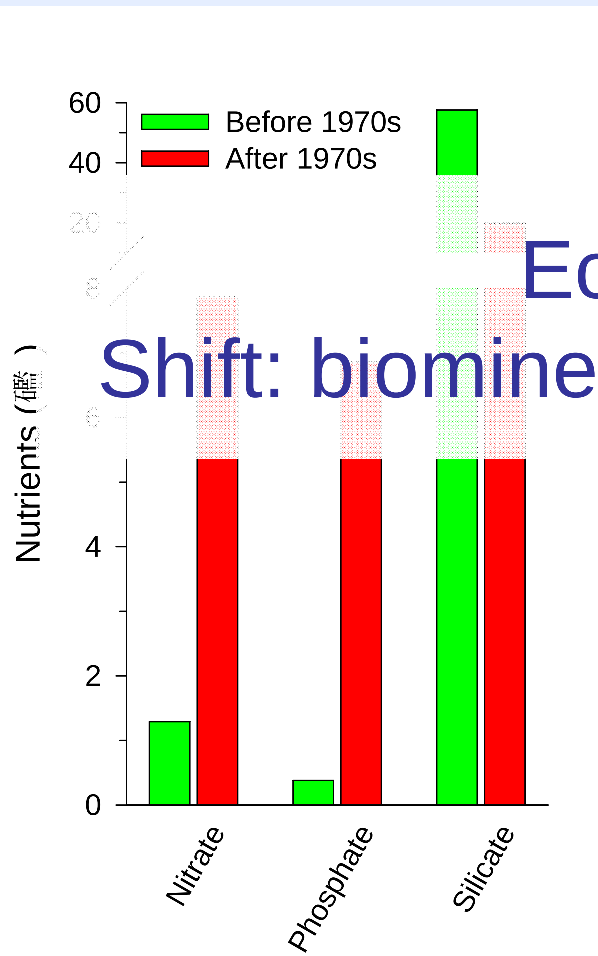


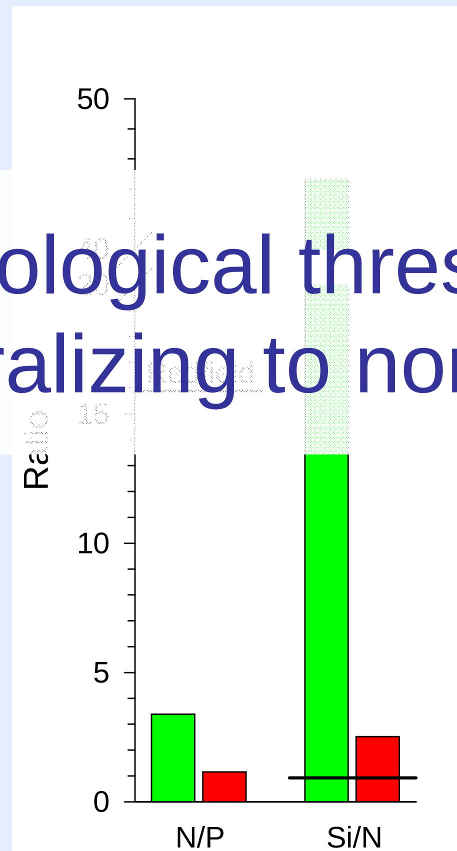


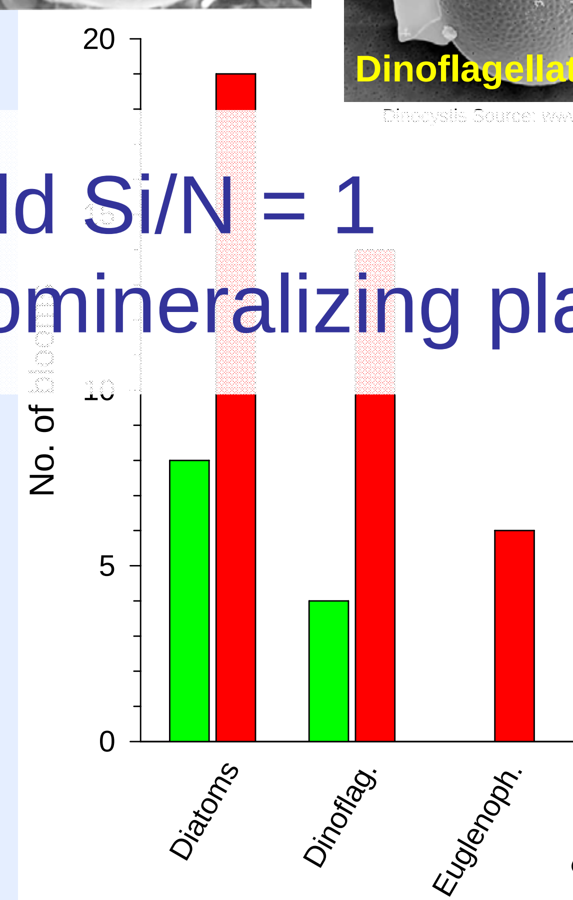
Dinocystis Source: www.aad.gov.au

Ecological threshold Si/N = 1

Shift: biomineralizing to nonbiomineralizing plankton

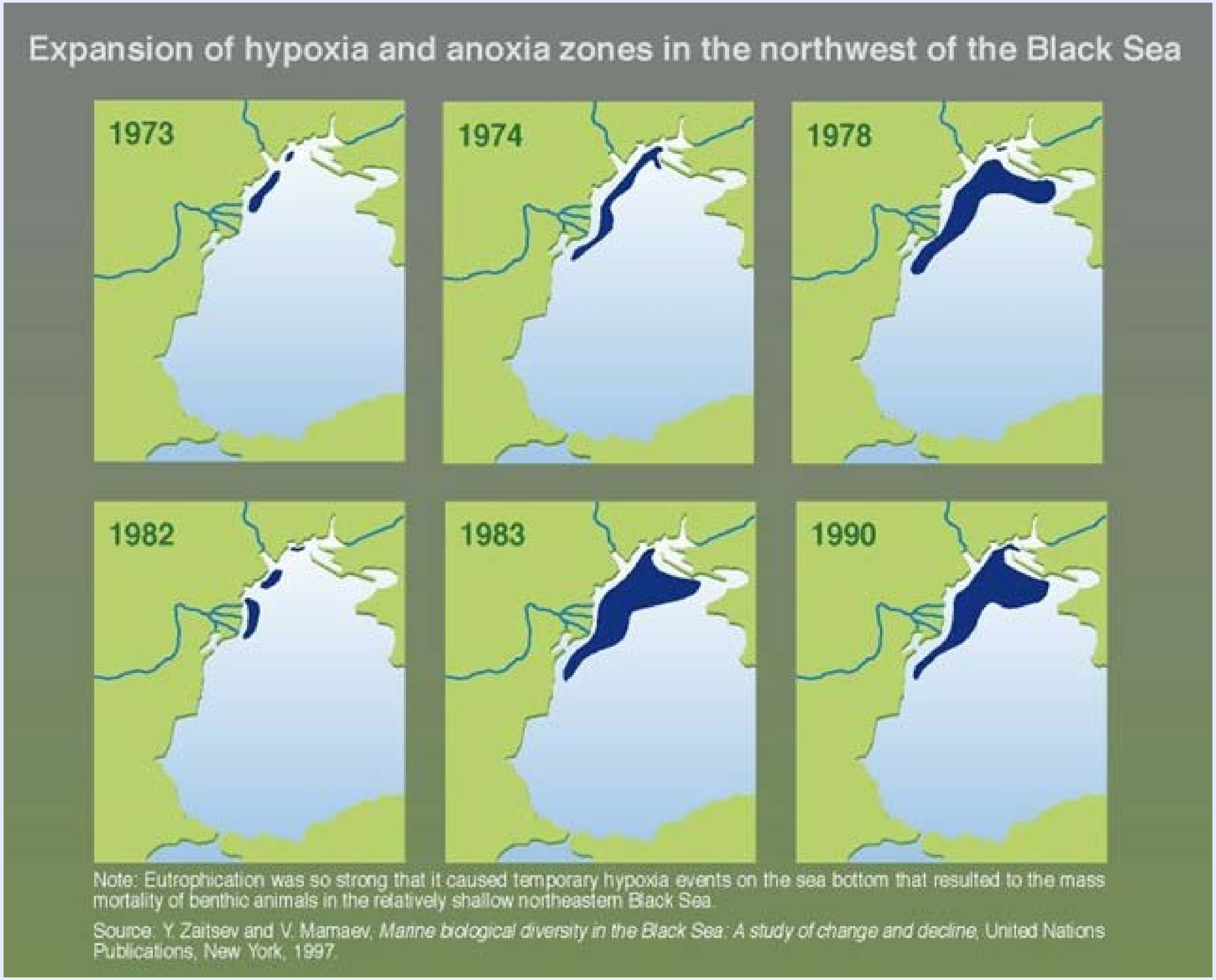






http://www.soes.soton.ac.uk/staff/tt/

Source: A. Cociasu et al., 1996: Long-term ecological changes in Romanian coastal waters of the Black Sea.- Mar. Poll. Bull. 32: 32-38.



→ Mass mortality of organisms, release of greenhouse gases

Consequences

- Changes in amount and composition of nutrients
- Eutrophication, hypoxia
- Changes in plankton/benthos communities and foodweb
- Change/loss of biodiversity
- Release of greenhouse gases
- Change in carbon sequestration

The global view:

N, P, Si

River – ocean fluxes of nitrogen and phosphorus

Coupling of DIN and DIP inputs

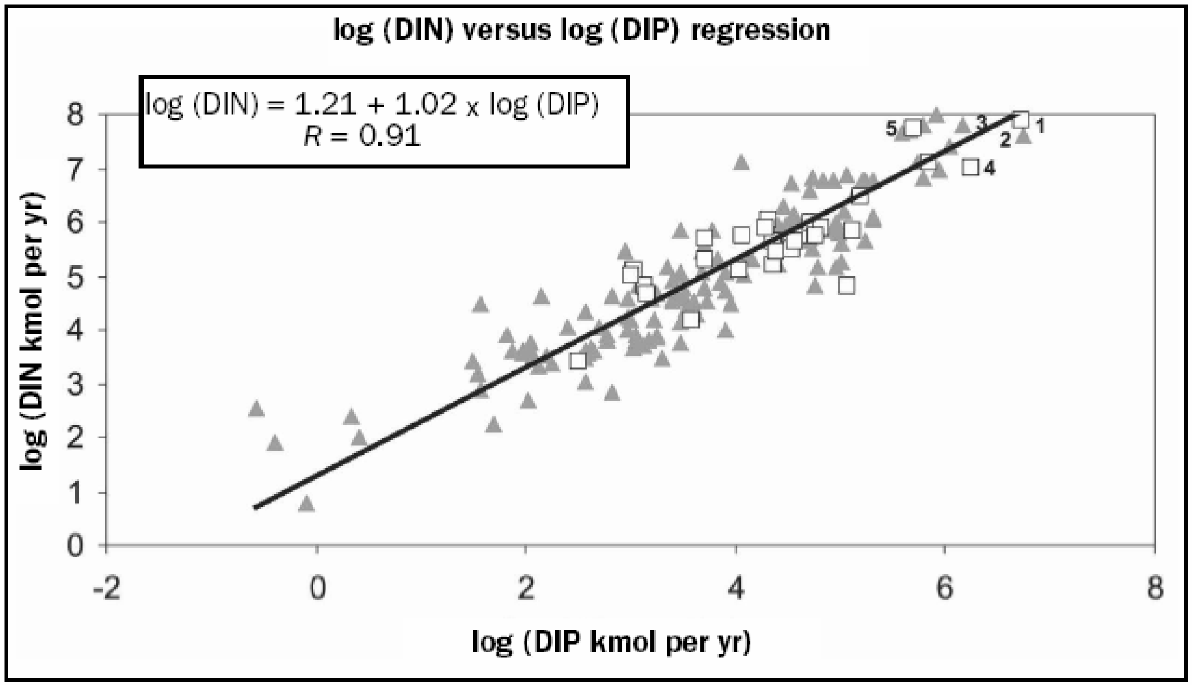
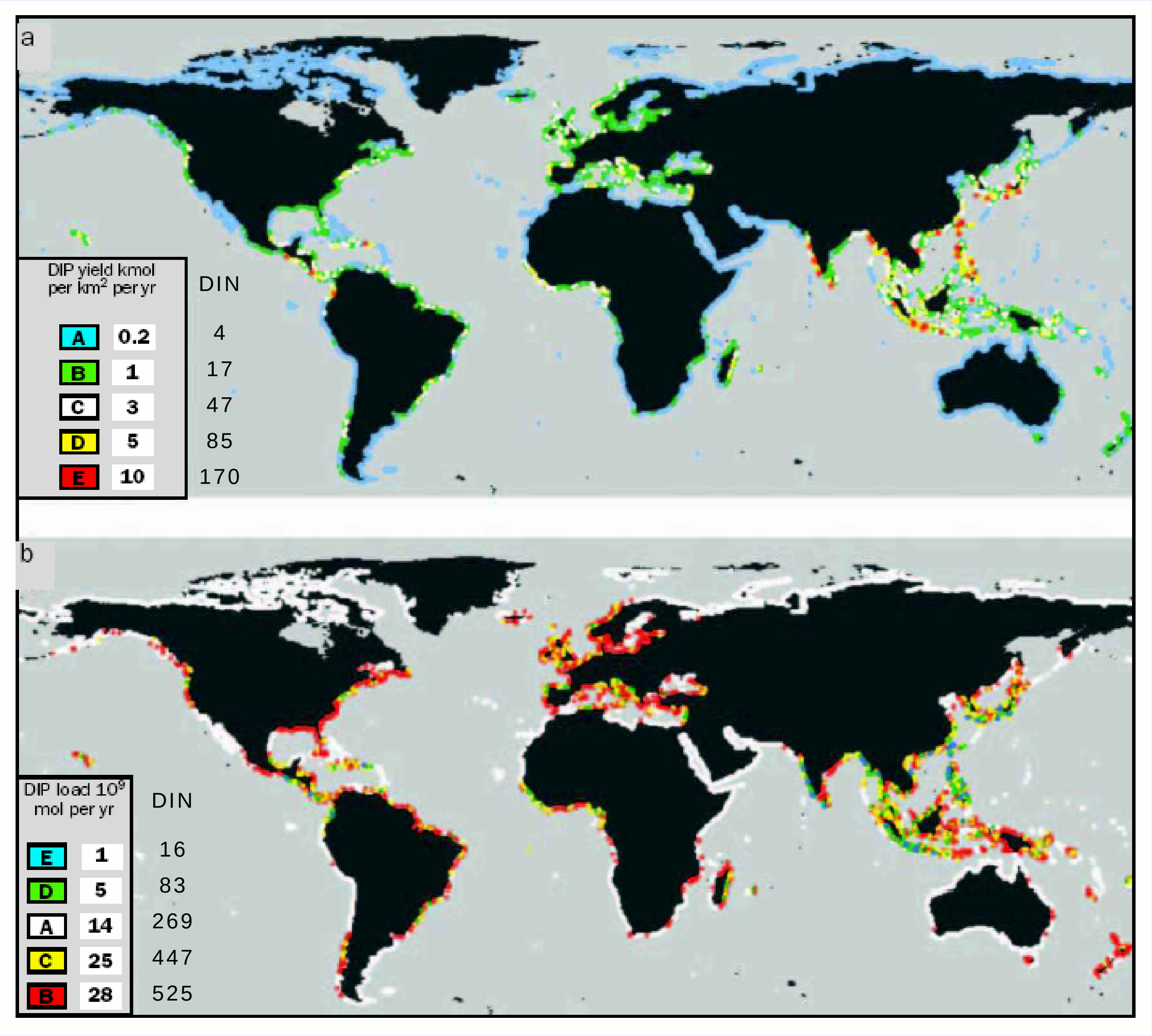


Figure 2. Model II regression line for log dissolved inorganic nitrogen (DIN) versus log dissolved inorganic phosphorus (DIP). Note that slope does not differ significantly from 1. Gray triangles represent Land–Ocean Interactions in the Coastal Zone data; open squares represent data from Meybeck and Ragu (1997). Five large river basins are identified: (1) Amazon, (2) Congo, (3) Rio de la Plata, (4) Amur, and (5) Changjiang.

Synthesis of data sets from 165 rivers by Smith et al. (2003)

Source: S. Smith et al., 2003: Humans, hydrology, and the distribution of inorganic nutrient loading to the ocean.- BioScience 53: 235-245.

River – ocean fluxes of nitrogen and phosphorus



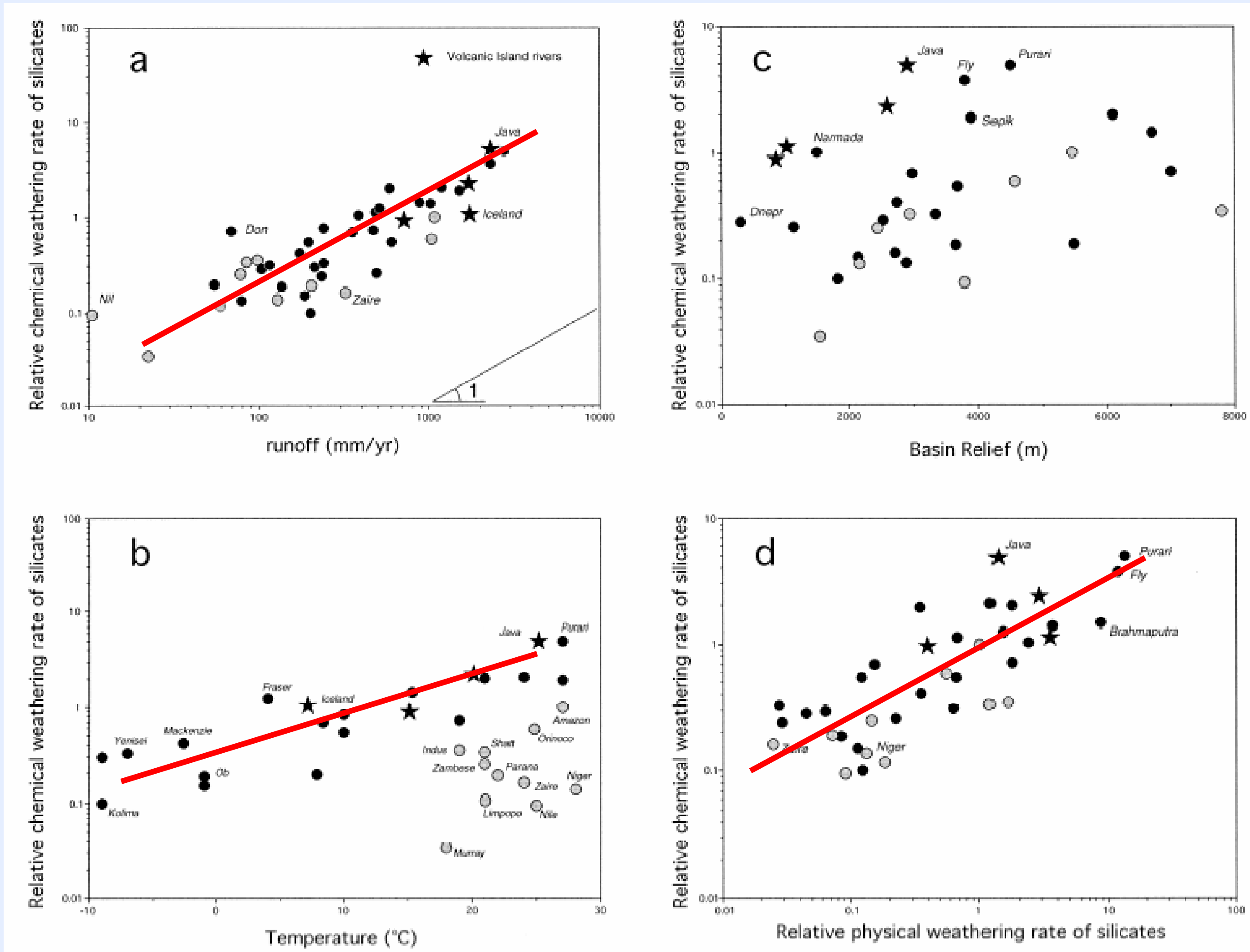
Parameterization:

Population density
+
runoff

N and P inputs have trebled from the 1970s to the 1990s

Source: S. Smith et al., 2003: Humans, hydrology, and the distribution of inorganic nutrient loading to the ocean.- BioScience 53: 235-245.

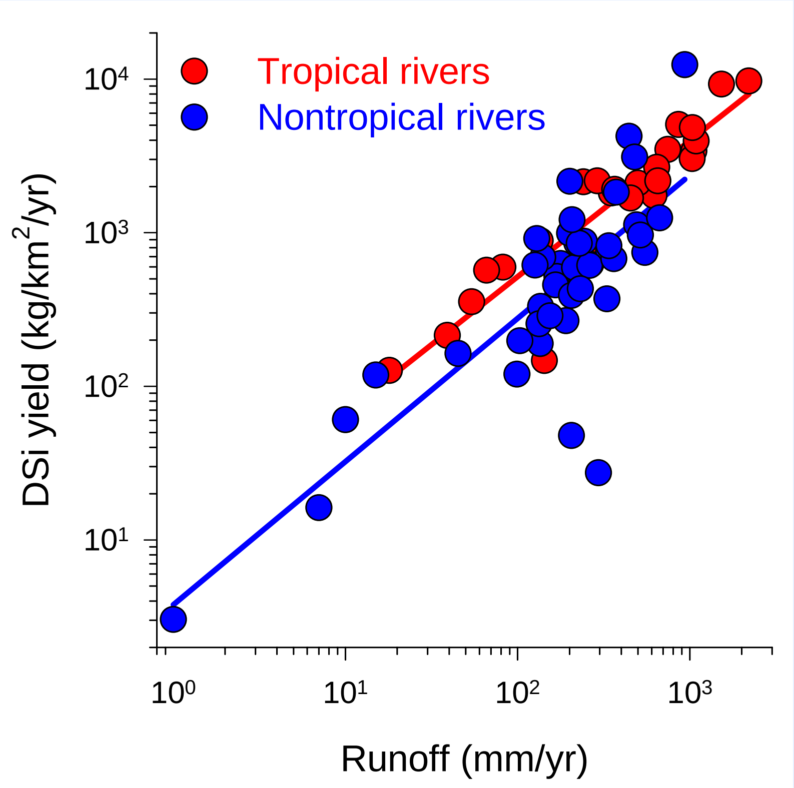
River – ocean fluxes of silicon

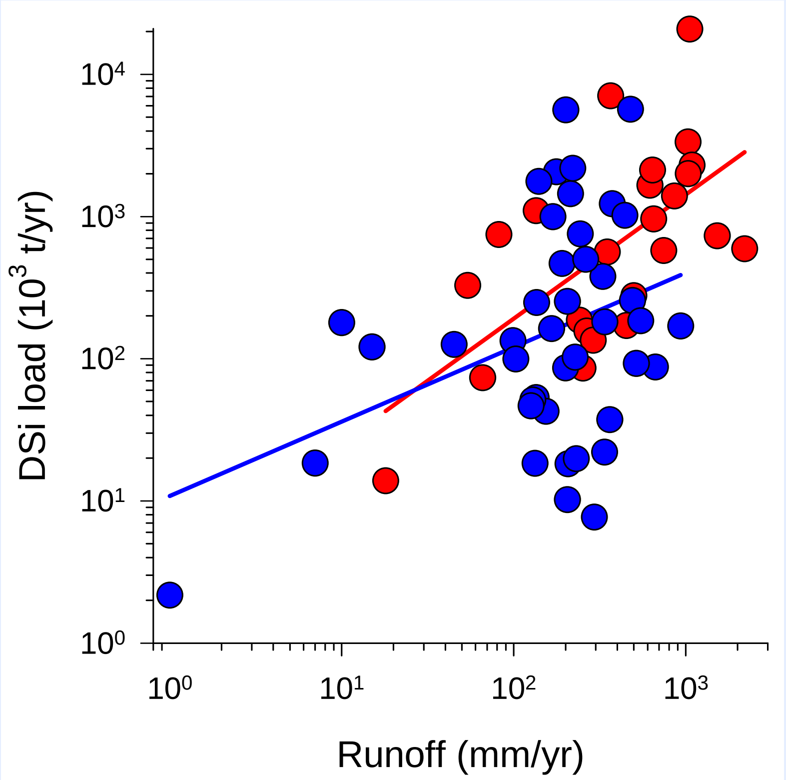


Controls: physical weathering + runoff + runoff temperature

Source: J. Gaillardet et al., 1999: Global silicate weathering and CO_2 consumption rates deduced from the chemistry of large rivers.- Chemical Geology 159: 3-30.

River – ocean fluxes of silicon





Silicon yield and load is much higher in tropical than in nontropical rivers

What do we know so far?

- Riverine N and P inputs have trebled globally (1970s – 1990s)
- Si reduced in several nontropical rivers
- Si river load is controlled by physical weathering, runoff and runoff temperature
- Si yield and load is much higher in tropical than in nontropical rivers
- Ecological thresholds (Redfield ratio N/P, Si/N) lead to changes in abundance and composition of plankton/benthos communities
- Deterioration of water quality: bad living conditions + release of greenhouse gases

Is it valid for the whole planet?

Human activities affecting coastal ecosystems:

Tropical regions

Kallada River – Ashtamudi estuary, India

Brantas River – Madura Strait, Indonesia

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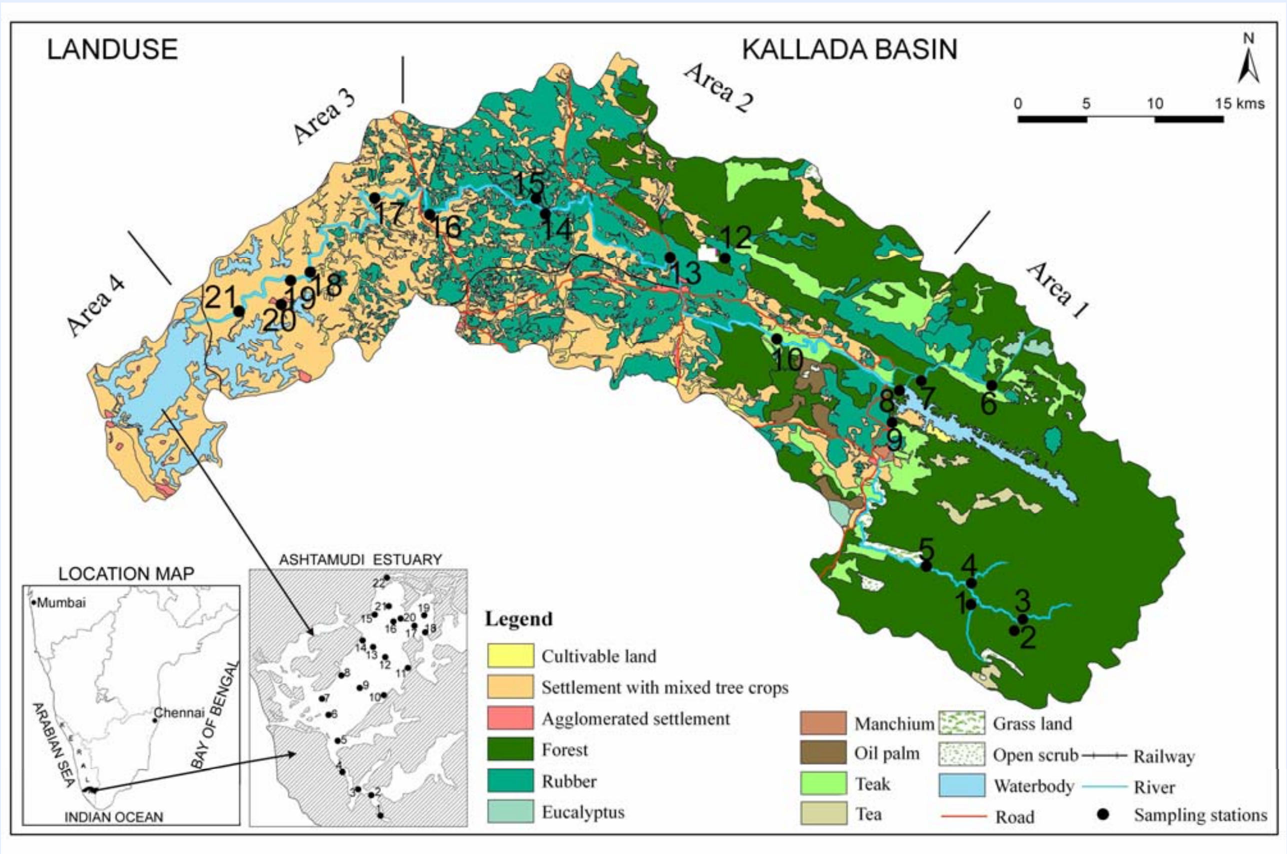
Kallada River – Ashtamudi estuary, India



Laterite soil: firm, fine-grained, acidic, iron-rich, nutrient-poor

Land use: tea, rubber, coconut, rice, banana, teak

State of Kerala, India

- Area 38,863 km^2, 63 % agriculture
- Population density 819 inh km^{-2}
- 44 small- to medium-sized rivers

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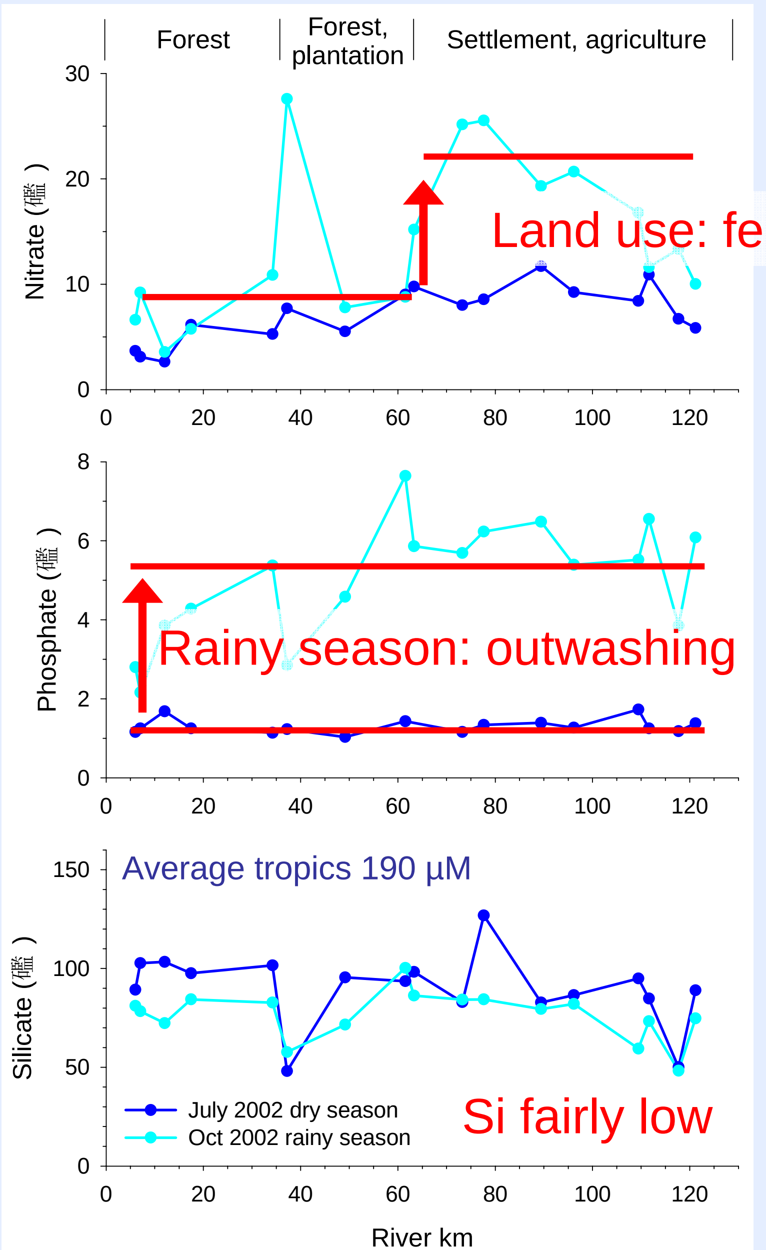

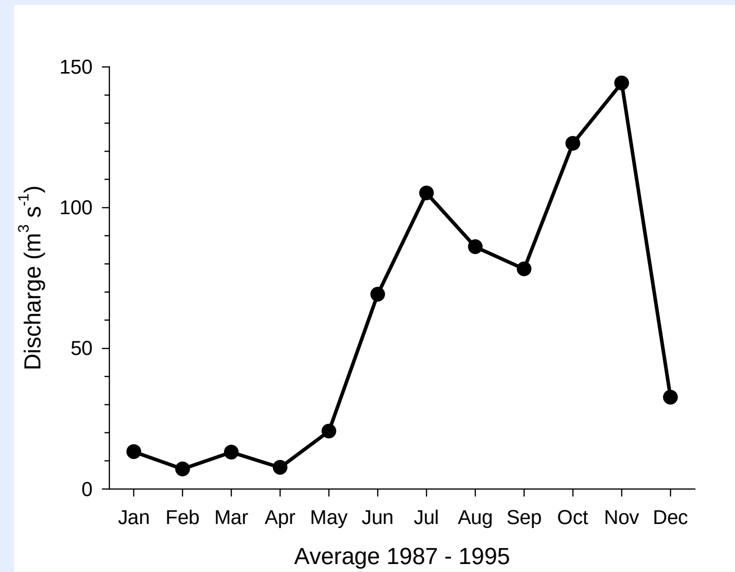

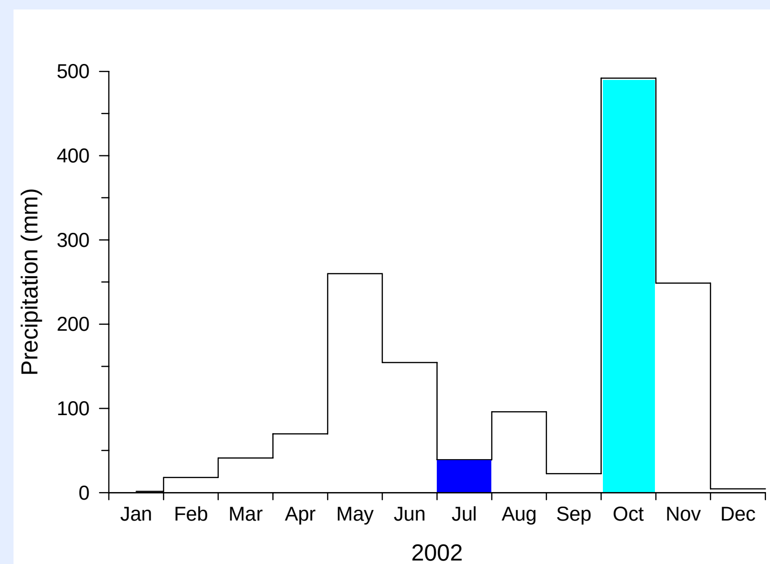

Kallada River – Ashtamudi estuary, India

Natural and anthropogenic controls of river load

• reduced weathering and erosion because of Precambrian basement rocks and firm laterite soils, but increased washout/surface runoff
→ low TSM (<50 mg l^{-1}), low silicate

• crop demand may differ from supply of fertilizer mix (N/P ratio)
→ efficient N uptake, limited P uptake

• less fertilizer application than in other regions

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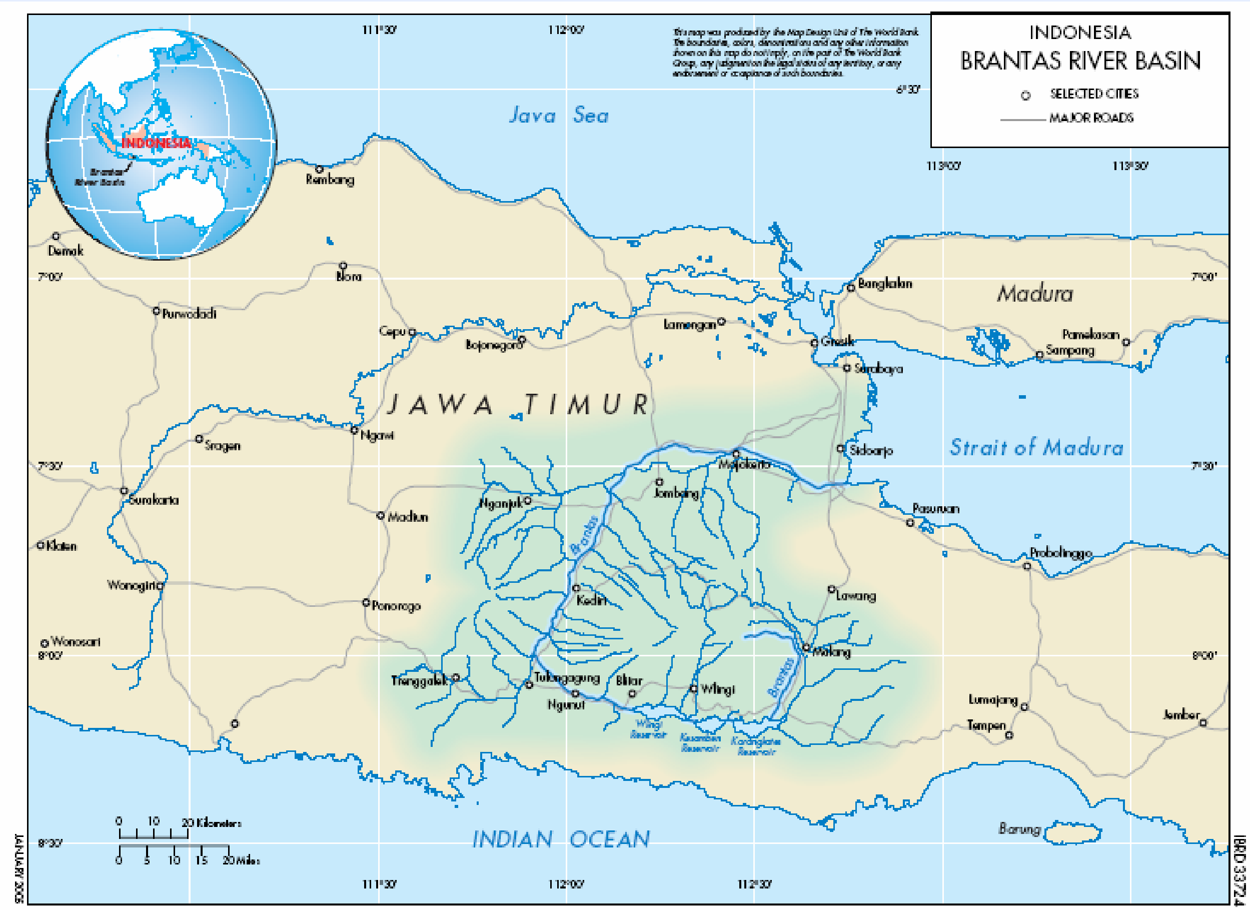
Brantas River – Madura Strait, Indonesia



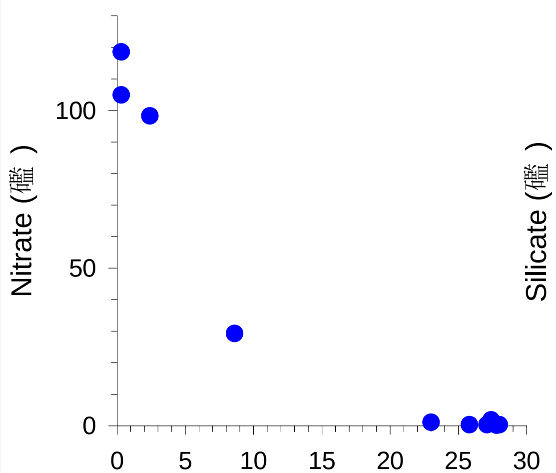
Brantas River catchment, East Java

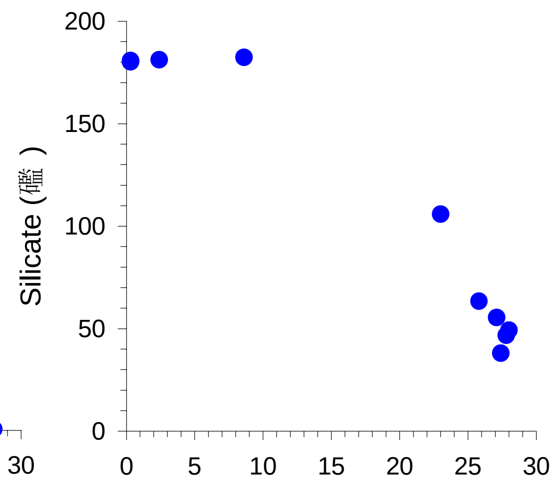
- Area 11,800 km^2, 55 % agriculture
- Population density 1,249 inh km^{-2}
- 7 large dams + numerous weirs

Source: A. Bhat, K. Ramu, K. Kemper, 2005: Institutional and policy analysis of river basin management: The Brantas River basin, East Java, Indonesia. World Bank Policy Research Working Paper No. 3611.

Brantas River – Madura Strait, Indonesia

Dry season nutrient dynamics

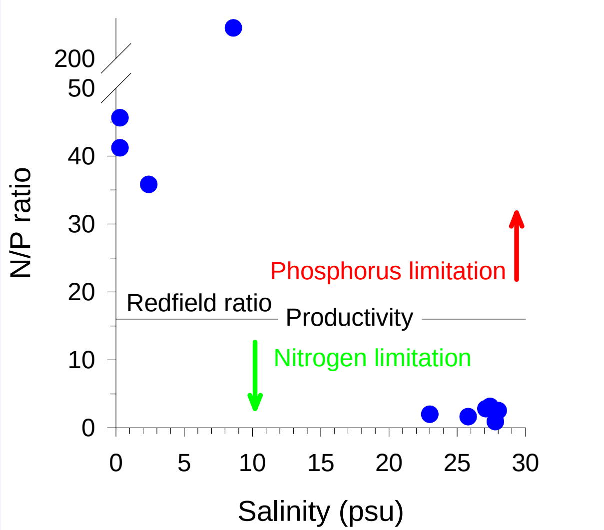


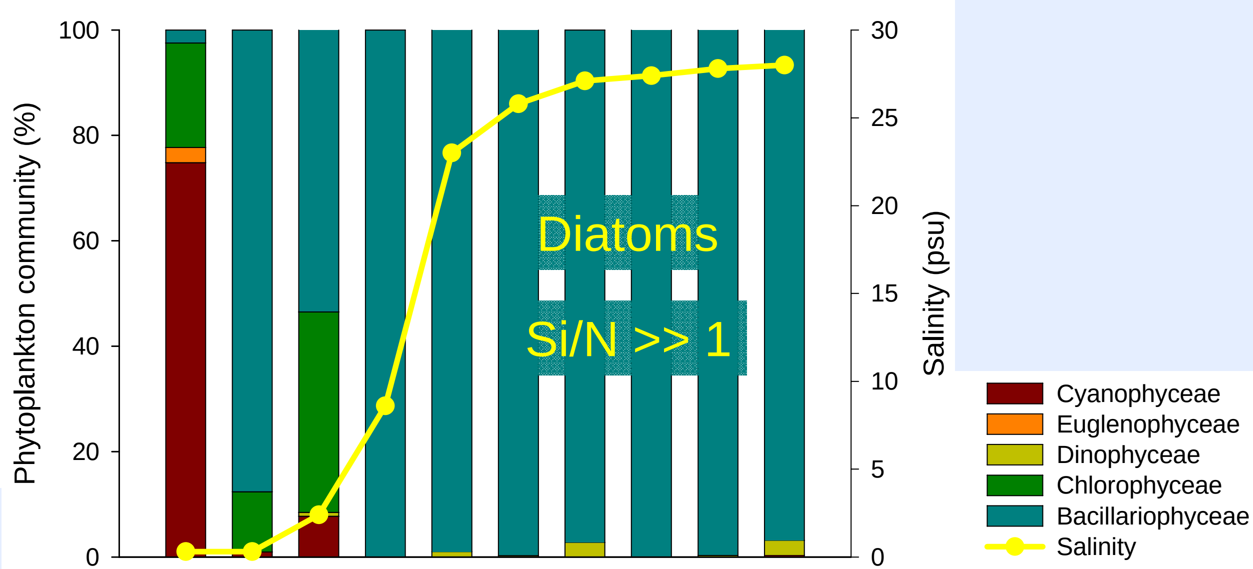


- dramatic drop of nitrate in estuary
- from P- to N-limitation, no Si-limitation
- high phytoplankton biomass, diatoms dominate phytoplankton
- N source?

→ **No community shift in estuary**

→ **No water column hypoxia**





Tropical rivers and the global view

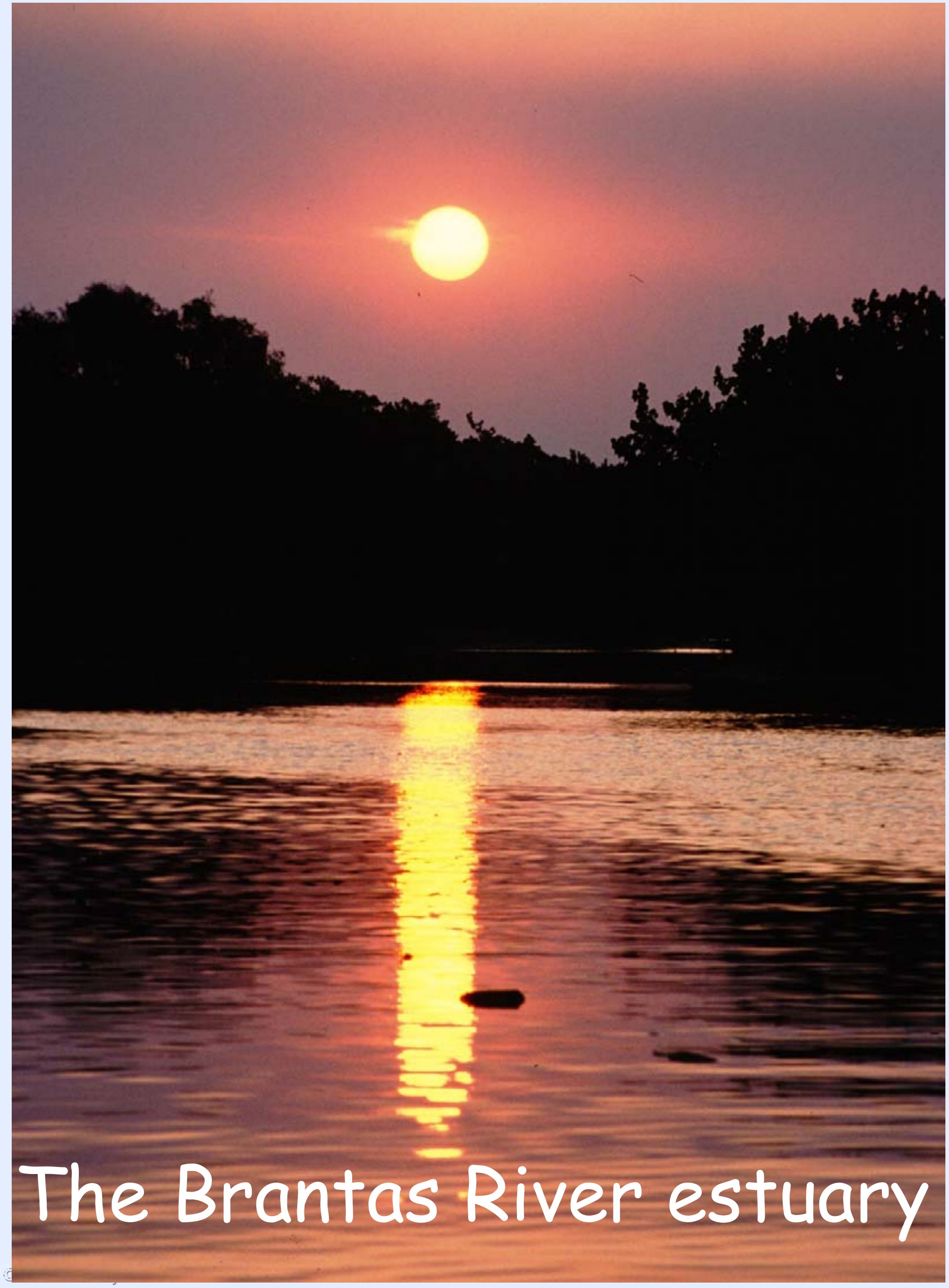
	Nitrate-N	Phosphate-P (10^3 M km^{-2} yr^{-1})	Silicate-Si	N/P	Si/N
Large tropical rivers	13.1	0.9	81.1	14.6	6.2
Nontropical rivers	23.2	1.6	36.6	14.5	1.6
Kallada, India	10.1	6.0	81.3	1.7	8.0
Brantas, Indonesia	91.1	2.9	496.7	31.4	5.5

DIN (10^3 M km^{-2} yr^{-1})	170	85	47	17	4
DIP (10^3 M km^{-2} yr^{-1})	10	5	3	1	0.2

Smith et al. (2003)

Thoughts on 'Estuaries in a changing world'

- 'Nutrient pollution' is global, but the biogeochemical and ecological response of estuaries/coastal seas differs depending on the geographical variation of natural vs. anthropogenic controls of river loads.
- Ecological thresholds are an important control of the biogeochemical cycling of elements in estuaries/coastal seas.
- Excess nitrate + low Si/N = reduced uptake → shift from anthropogenically enhanced C sink to anthropogenically enhanced N_2O source?
- Global warming and change in moisture distribution will change Si and alkalinity inputs → consequences for estuarine biogeochemistry?
- More data and knowledge on processes and fluxes are required from tropical rivers/estuaries, because major part of the global nutrient input into the ocean occurs there.



Thank you!

Xie xie!

Danke!