

German Environment Agency

Umwelt
Bundesamt 

LUWQ 2025

Options to achieve the good ecological state of the Wadden Sea

Scenario analyses for the river basins of Elbe and Rhine

Andreas Gericke, Wera Leujak, Andreas Musolff (UFZ)



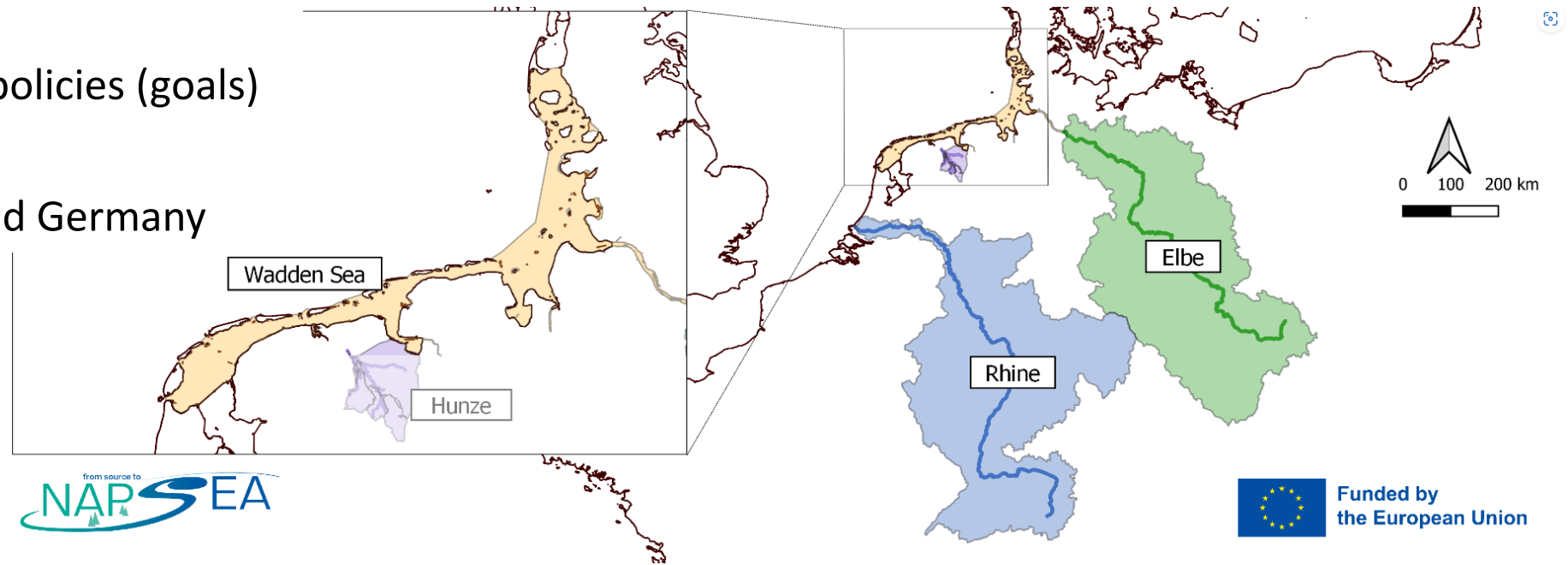
Funded by
the European Union



Jahre
Umweltbundesamt
1974–2024

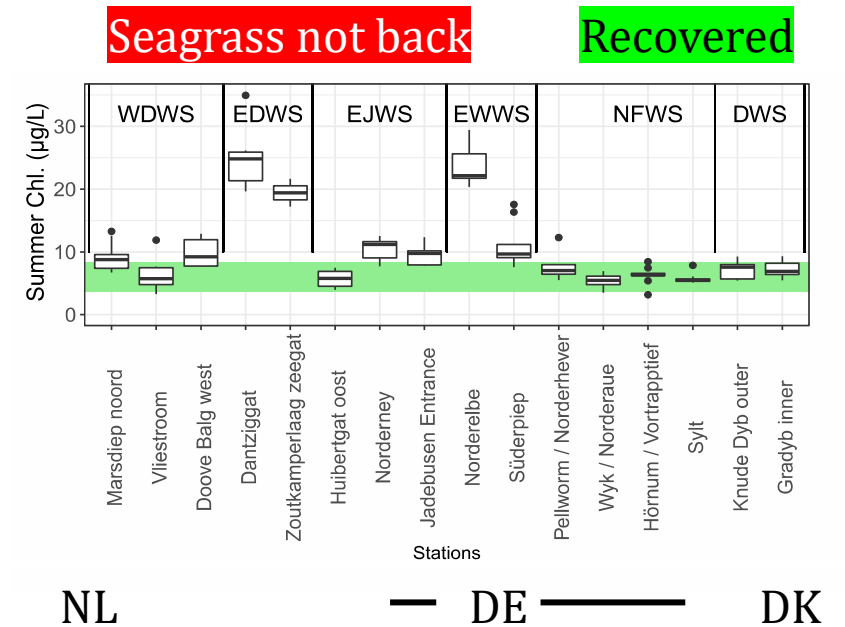
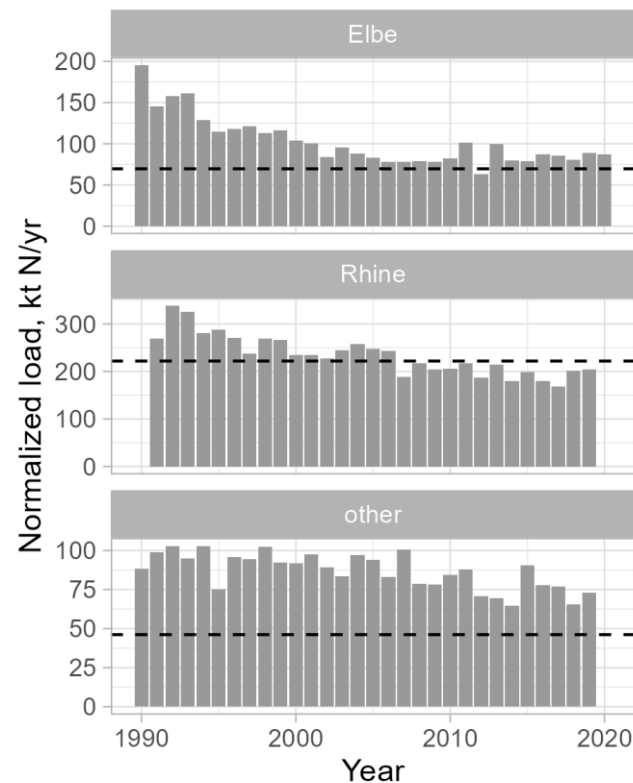
Overview

- Safe ecological boundaries -> needs to reduce riverine nutrient input
- Modelled effects of policies (goals)
- Focus on nitrogen and Germany



Wadden Sea still fails good status due to nutrient input (UBA 2023)

- Minor changes in river load since 2010 after significant decrease
- Atmospheric deposition declines since 1990s
- Rhine meets German target of 2.8 mg/l for rivers to North Sea
- Seagrass partially recovered with lower Chl-a concentration



Left: Normalized nitrogen load of in German tributaries of the North Sea in comparison to loads corresponding to the German target concentration of 2.8 mg N/l, right: chlorophyll concentration (May-Sep) along the Wadden Sea, 2008–16. Value range when seagrass recovery started to accelerate in the North Frisian region in green (van Katwijk et al. 2024).

Substantial load reduction needed for safe ecological boundaries

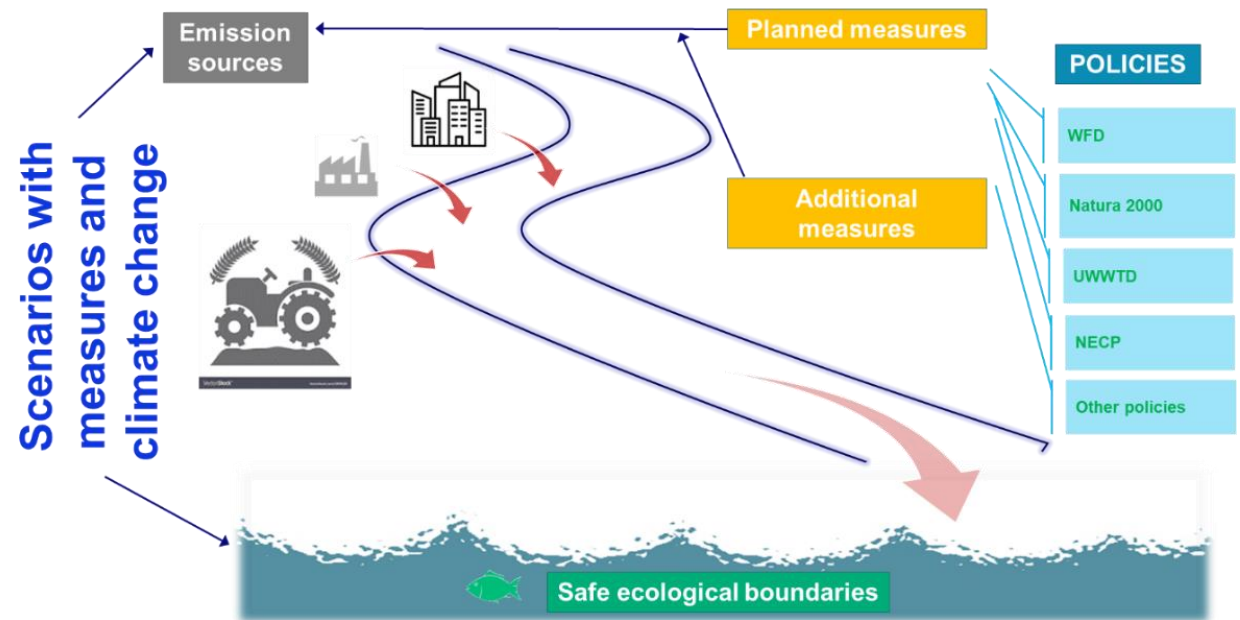
- Regression analyses and modelling – sessions S.1 and E.3
- 30–63% relative to 2010–2017 depending on case study & indicator

Case study	Indicator	Main driver	Reduction need
Wadden Sea	Sea grass recovery	Riverine TN loads	34-43%
Wadden Sea	No blooms non-silicifying algae	Riverine winter N:Si ratio	
	Rhine		50%
	Ems		55%
	Weser		40%
	Elbe		30%
Elbe estuary	O ₂ >7 mg/l	Import riverine organic matter (phytoplankton)	45%
Elbe river	Phytoplankton <40 µg Chl a/l	Organic matter load	63%
Rhine basin	NO ₃ ≤1.9 mg/l		44%

Reduction needs for German tributaries of the Wadden Sea compared to 2010–2017 (van Beusekom et al. 2025, modified)

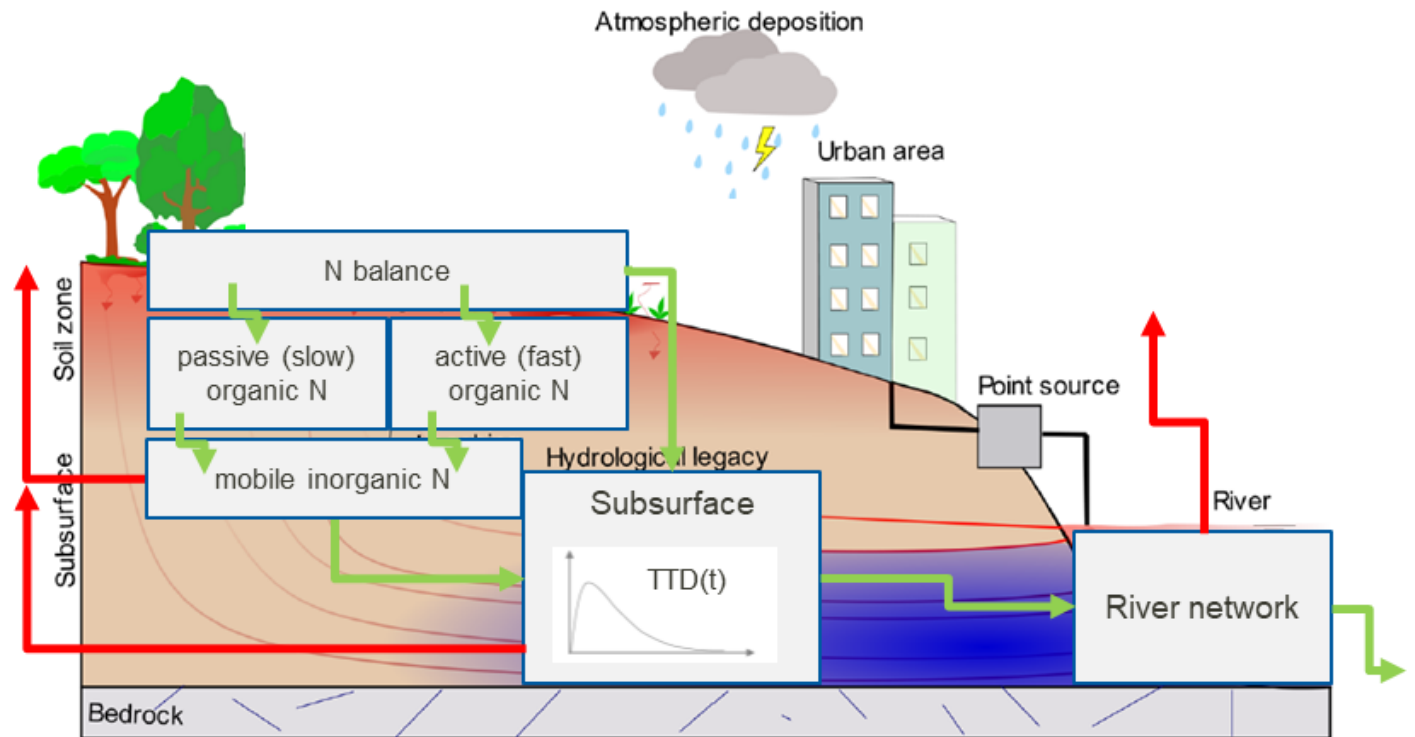
Policy-based scenarios to assess how to achieve reduction needs

- Current sector-specific goals
 1. Urban Wastewater Treatment Directive
 2. Nitrates Directive – agricultural input
 3. NEC Directive – atmospheric deposition
 4. Biodiversity Strategy 2030 etc. – floodplains, riparian zones
- Moderate climate change until 2050 (RCP4.5)
- Stricter policies (increasing level of ambition)
 - A. Nutrient sources (1–3)
 - B. Synergies with enhanced floodplains
 - C. More drastic changes (2–3)



Process-based model and commonly available datasets

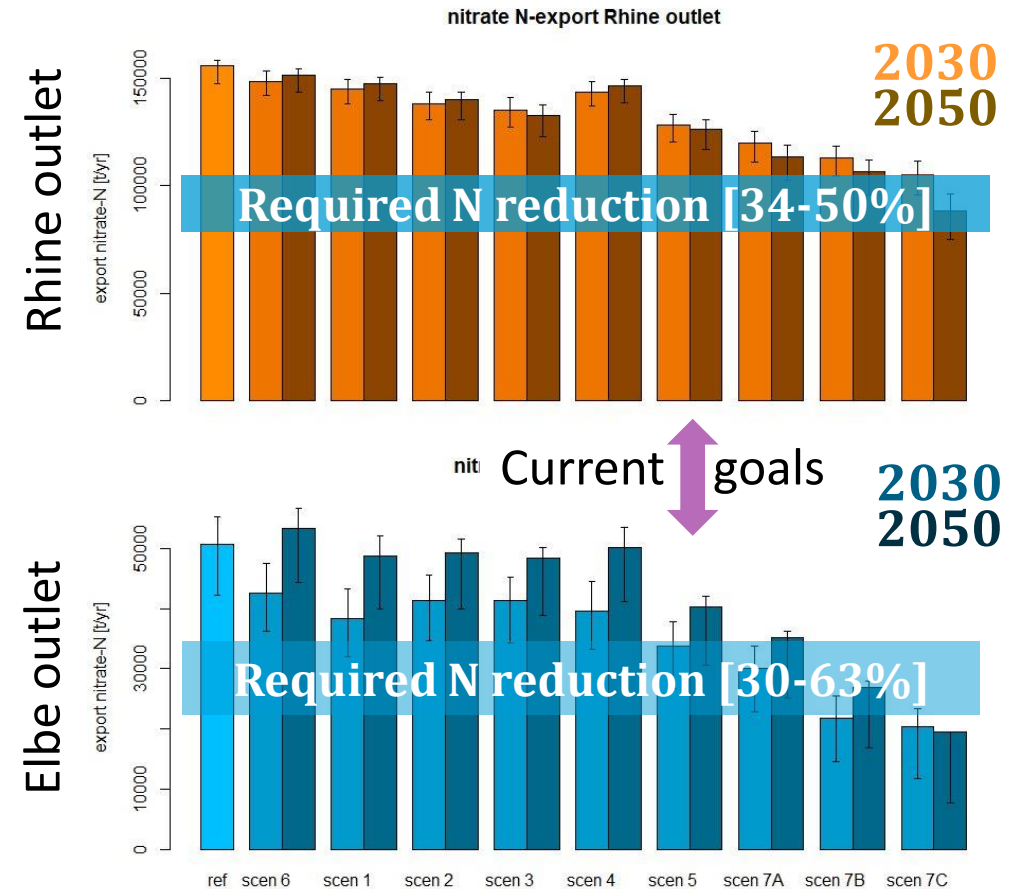
- Model mQM (Nguyen et al. 2021) calibrated against annual NO_3 concentration (1950–2021)
- European data (UWWTD reporting, EMEP) & national data (N surplus, floodplains)
- Linear interpolation current years and scenario data for 2030/2050



Model compartments and nitrogen flow paths in mQM, Lutz et al. (2022)

Current policy goals and measures insufficient for safe ecological boundaries

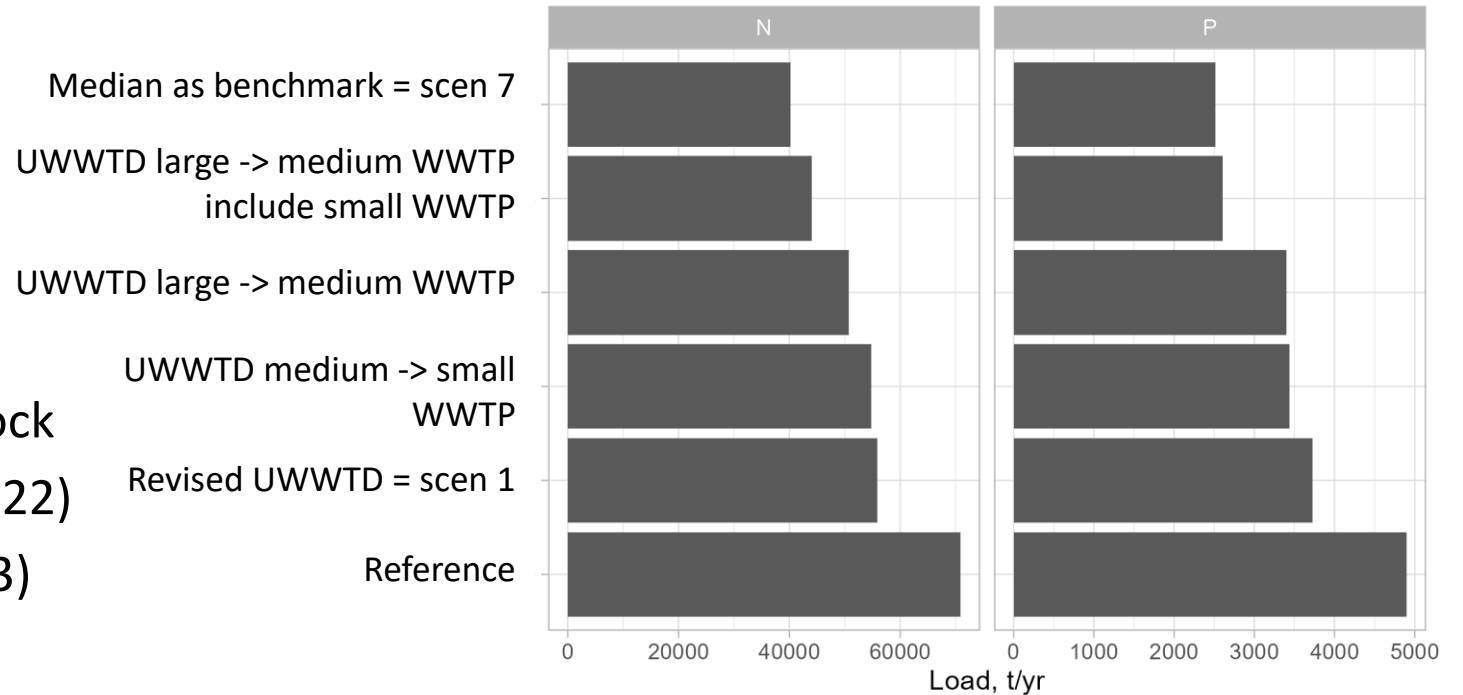
- Most ambitious scenario to safely reach reduction needs under variable effects of climate change
- ~ 10 yrs (median) travel time in subsurface zone



Nitrate loads at the outlets of rivers Rhine (top) and Elbe (bottom) for reference period (2010-2020), only climate change (scen 6), and policy scenarios (scen 1-5, 7A-C) with error bars showing the model uncertainty (Musloff et al. 2025).

Most ambitious scenario comprises...

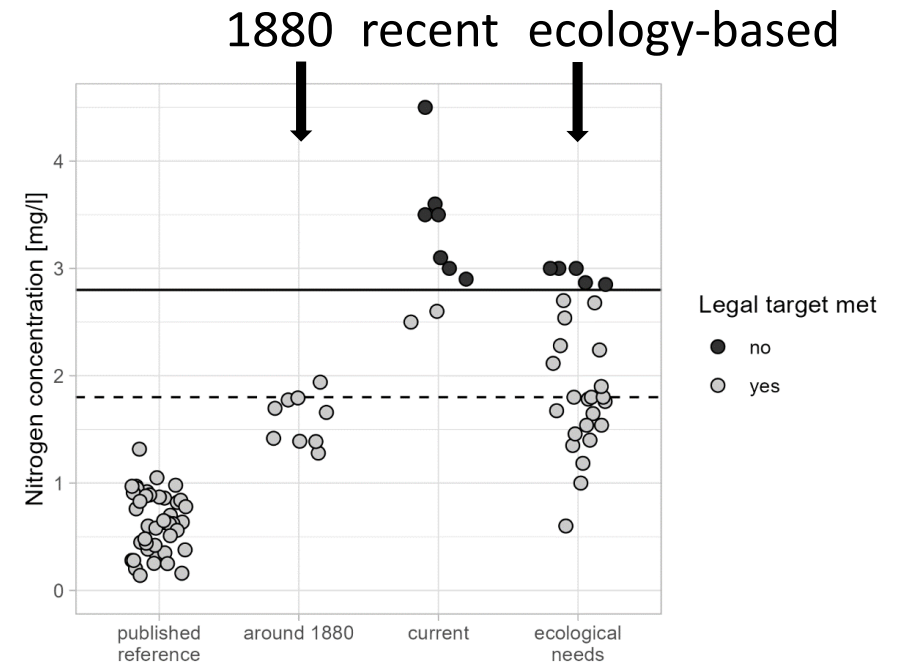
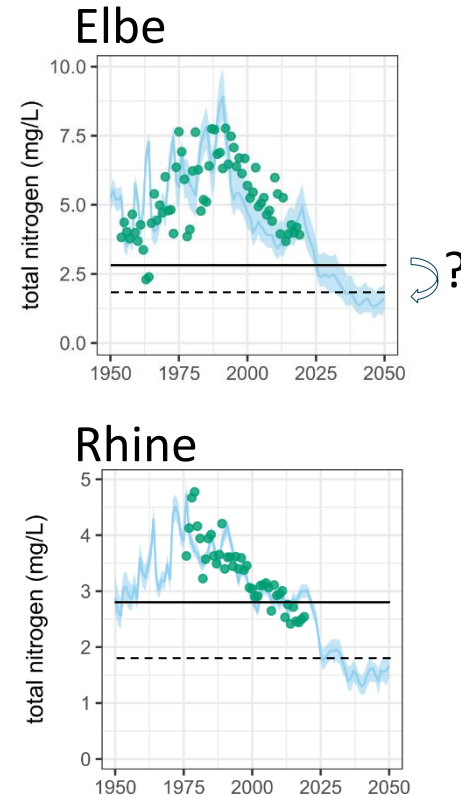
- Size-specific benchmarks for target retention **and** outflow concentration
- Fertilization 80% of plant demand (DE, Häußermann et al. 2025)
- Full program of measures & less livestock
 - Atmosph. deposition (Denby et al. 2022)
 - Soil N surplus (NL, de Vries et al. 2023)
- More retention in floodplains
 - Reconnect 30% of former floodplain (DE)
 - Turn “green rivers” to “blue rivers” (NL)



Nutrient load to surface waters in alternative scenarios for wastewater treatment. Scenario 7 is the strictest one.

Stricter target N concentrations in German regulation recommended

- German N target too high for good status coastal waters (cf. EUNÄP 2015)
- Median ecology-based values (NAPSEA & AquaSense 1995) = 1.8 mg/l \triangleq -36%
- Close to concentrations 1880 at basin outlets (Gericke et al. submitted)
- Achievable with most ambitious scenario



Left: Total N concentrations at the outlet of r. Elbe and Rhine at the German border estimated from modelled NO_3 concentrations for the most ambitious scenario 7C, right: historical, current, ecology-based N concentrations at the limnic-marine and national border compared to published reference values. Horizontal lines show the German target N concentration (solid) and the median of ecological-based targets (broken, Gericke et al. Environ. Sci. Eur. (accepted), modified).

Thank you!

Andreas Gericke (Andreas.Gericke@uba.de)

Wera Leujak (Wera.Leujak@uba.de)

Andreas Musolff (Andreas.Musolff@ufz.de)

<https://napsea.eu>



**Jahre
Umweltbundesamt
1974–2024**