THE USE OF HIGH-FREQUENCY IN-SITU SENSOR MEASUREMENTS OF NITRATE CONCENTRATIONS FOR EXPLORING THE UNCERTAINTY OF MONTHLY AND ANNUAL LOAD CALCULATIONS IN TWO HEADWATER DANISH STREAMS

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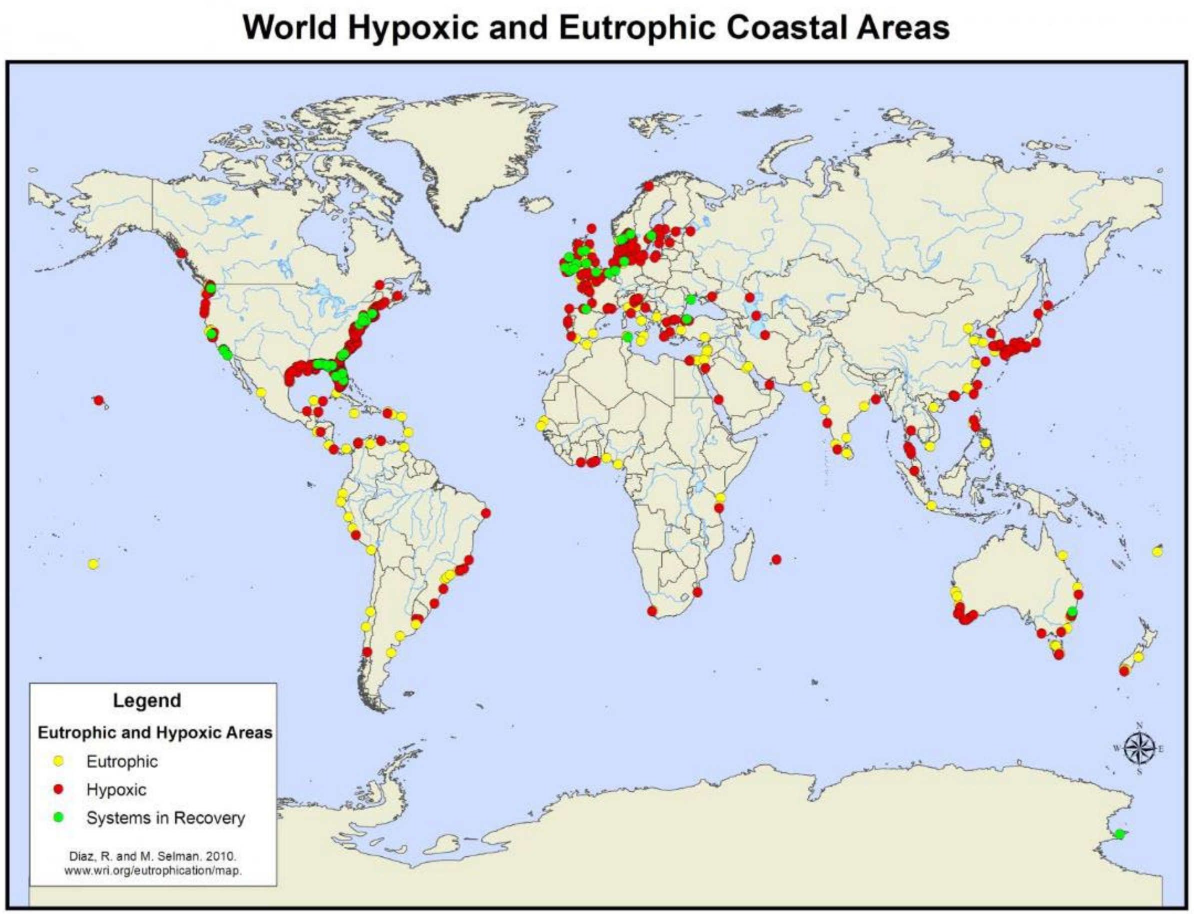
BACKGROUND
EUTROPHICATION – BALTIC SEA

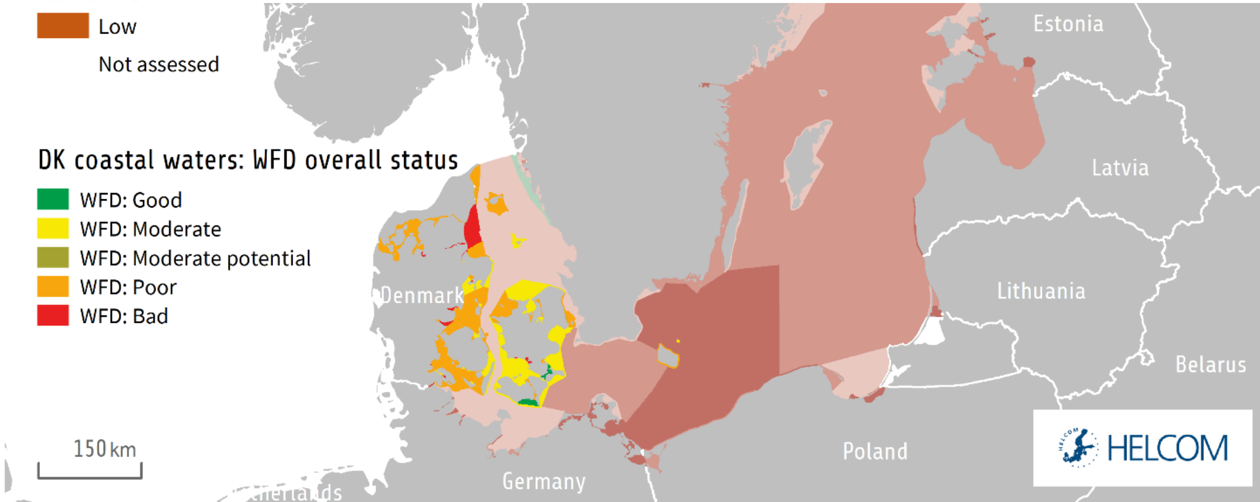
Eutrophication

is a consequence of nutrient over-enrichment of a water body, mostly because of inputs of nitrogen and phosphorus (EEA, 2019).

- Algal blooms
- Conditions of oxygen depletion
- Bad water quality
- Unclear water

- One of the biggest challenges for coastal waters is the supply of nutrients, in particular nitrogen (N), phosphorus (P), and runoff from the catchments (Miljøstyrelsen, 2021)





BACKGROUND:
HOW IS THE NUTRIENT TRANSPORT CALCULATED IN NOVANA, DENMARK?

Water sample

Photo: H. Stenholt

N/P concentration measured

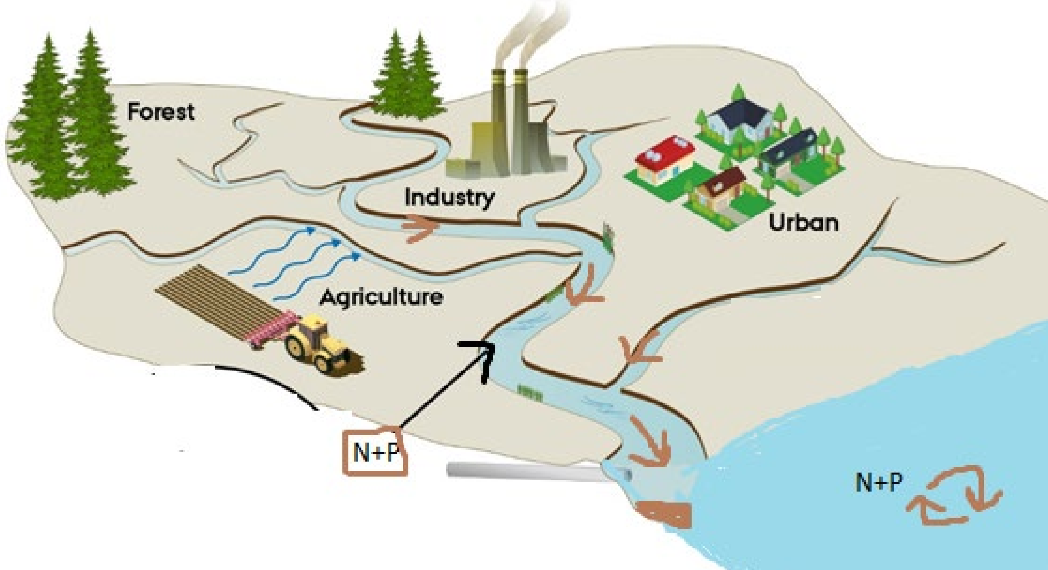
12 annual water samples
18 annual water samples

X

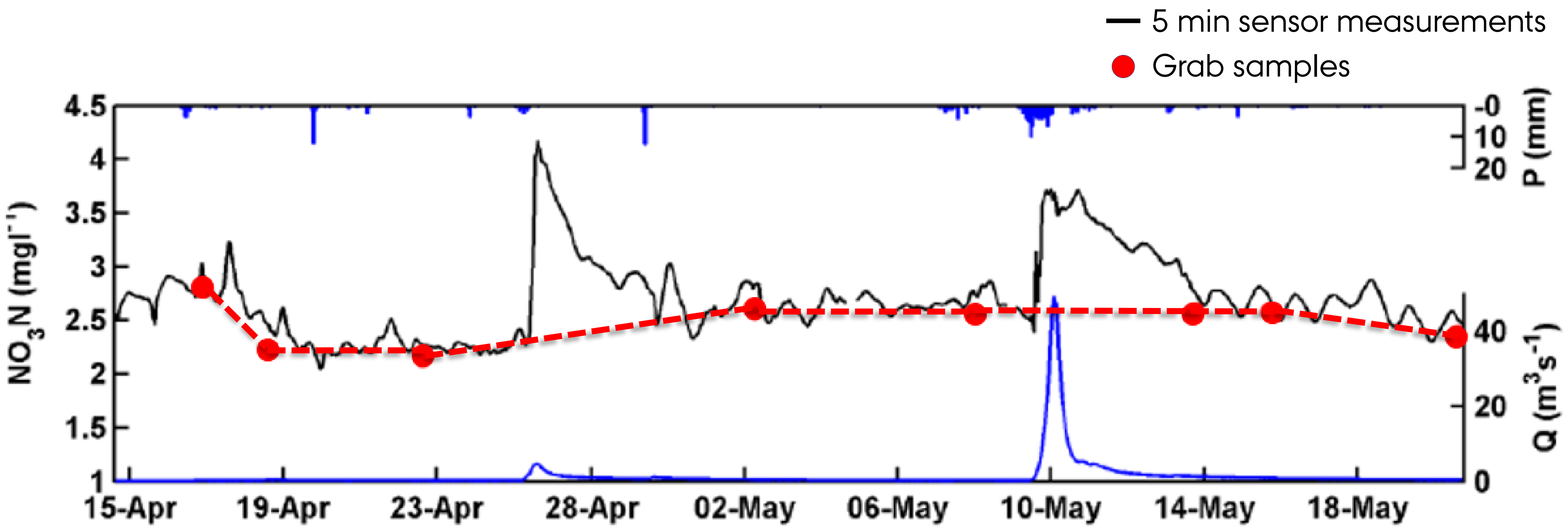
Discharge

Water level is measured every 15 minute

➡ **N/P transport**



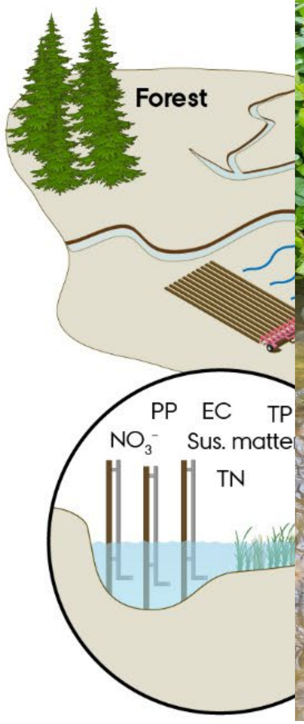
Background: High-resolution sensor measurements



Modfied from: Bieroza et al., 2014

Sensor measurements:
Much better data coverage.
Higher precision.
Lower derived costs for the environment and society

INDUSTRIAL PHD PROJEKT: SENTEM (SENSORS APPLICATION FOR HIGH TEMPORAL RESOLUTION MONITORING IN DANISH STREAMS)



Danish streams

d to handle quality assurance

control (QC) of sensor data

ensor data can be used to

nsport calculations in the

NITRATAX plus Ultraviolet sensor (Nitrate) – Measuring frequency: every minute

Financed by:

HACH

Innovationsfonden

AIMS AND METHODS

Aims:

1): To explore the uncertainty of monthly and annual NO3-N loads using different grab sampling strategies and high-frequency sensor dataset from two Danish headwater streams for two years.

2): Investigate if the uncertainties can be related to stream hydrology (Richards-Baker Flashiness Index)

Methods:

- Sensor data from two hydrological years have been cleaned using SentemQC and steps described in van't Veen et al. (in review)

- Five sampling strategies: Daily, weekly, fortnightly, 18 annual samples, and monthly.
- Monte Carlo simulations to calculate nitrate load
- We simulated 1000 loads for each strategy and each stream and calculated uncertainty parameters (bias, precision(SD), and total uncertainty(RMSE)).
- We calculated the Richards-Baker Flashiness Index and compared it to the uncertainty parameters

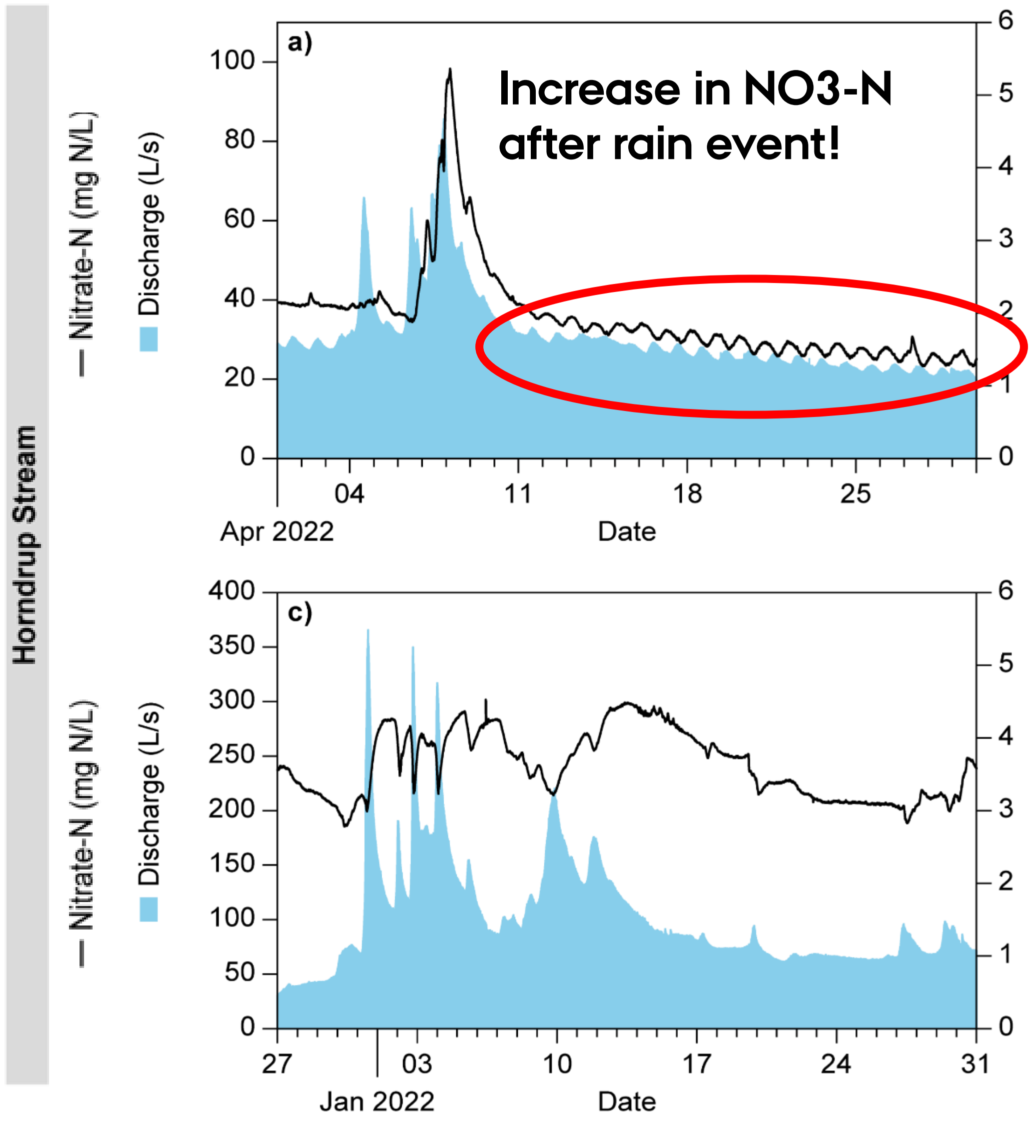
STUDY SITES

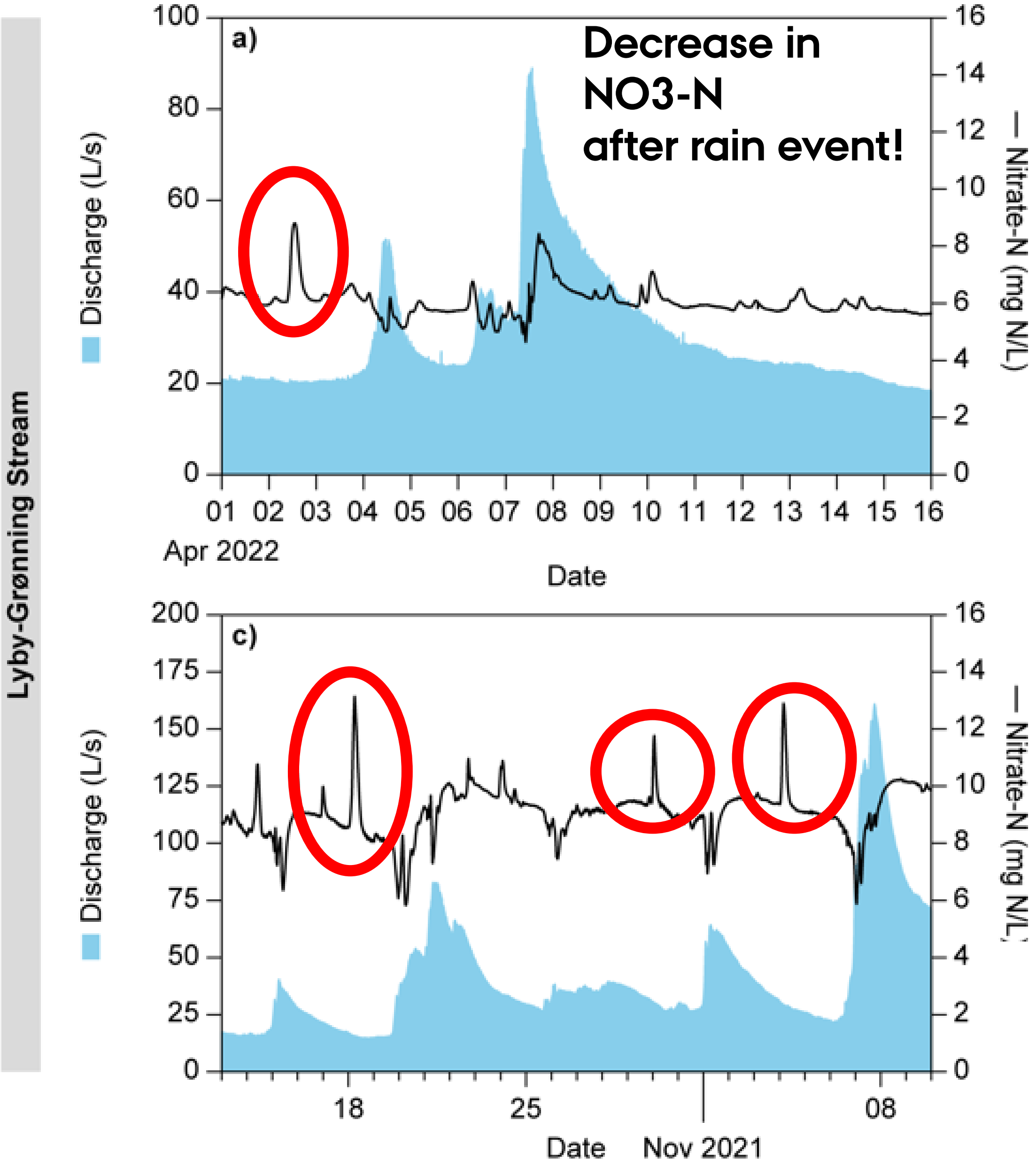
Lyby-Grønningen Stream (Salling)
11.3 km2
Nitrate was measured every minute

Horndrup Stream (Skanderborg)
5.5 km2
Nitrate was measured every minute

Measuring period June 1 2021, to May 31, 2023

RESULTS ZOOM





Daily variation
Biological uptake benthic algae?
+ denitrification

Nitrate-N:
- Max conc: night ca. at 06.00
- Min conc: day ca. at 18.00

High NO3-N peaks independent of water flow!

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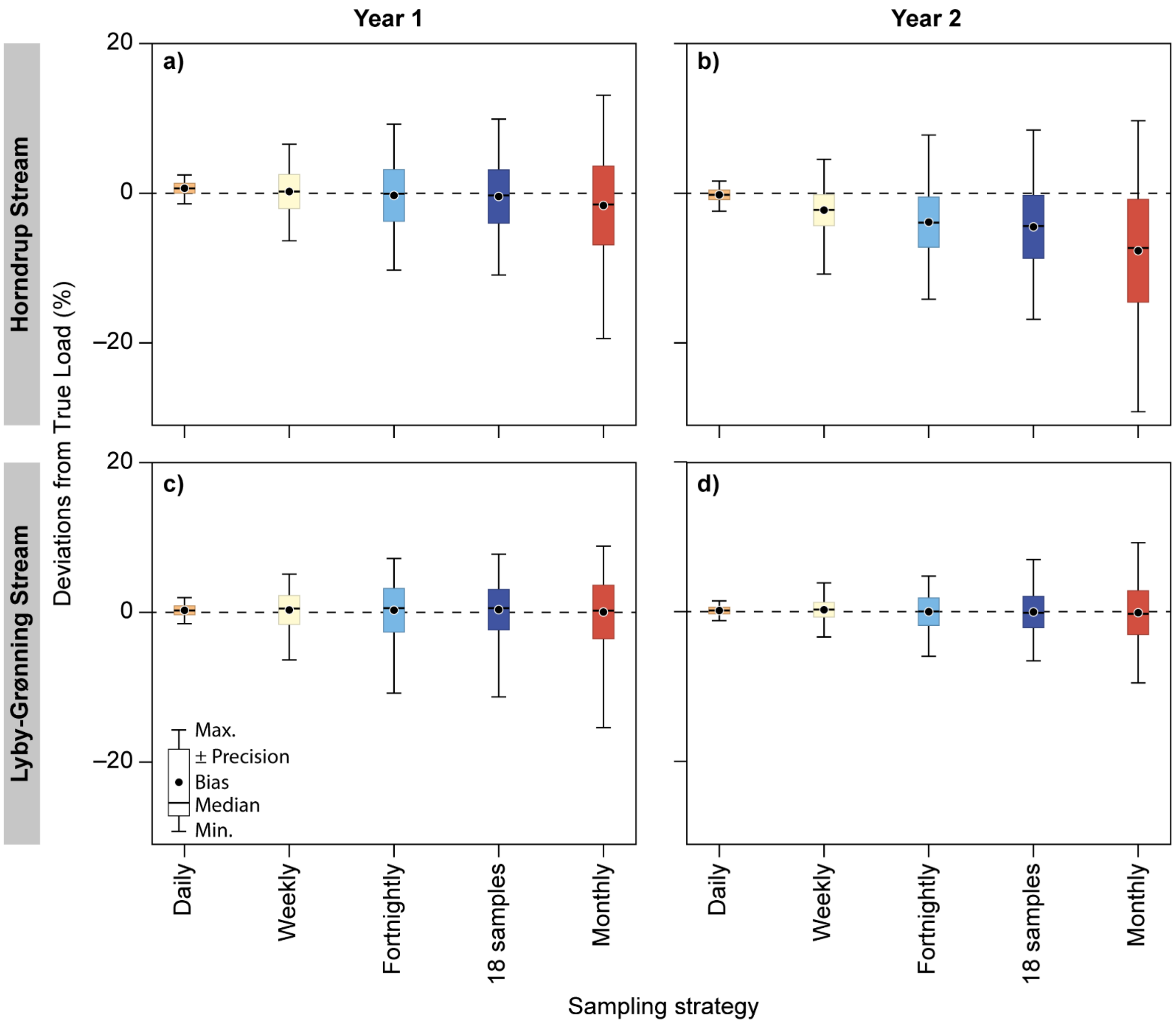
ANNUAL NO3-N LOAD



Uncertainty increases with fewer water samples included in sampling strategy

Bias and RMSE of the annual load estimates for all strategies was for:

Horndrup Stream < ±7,7 %

Lyby-Grønning Stream < 10,3 %

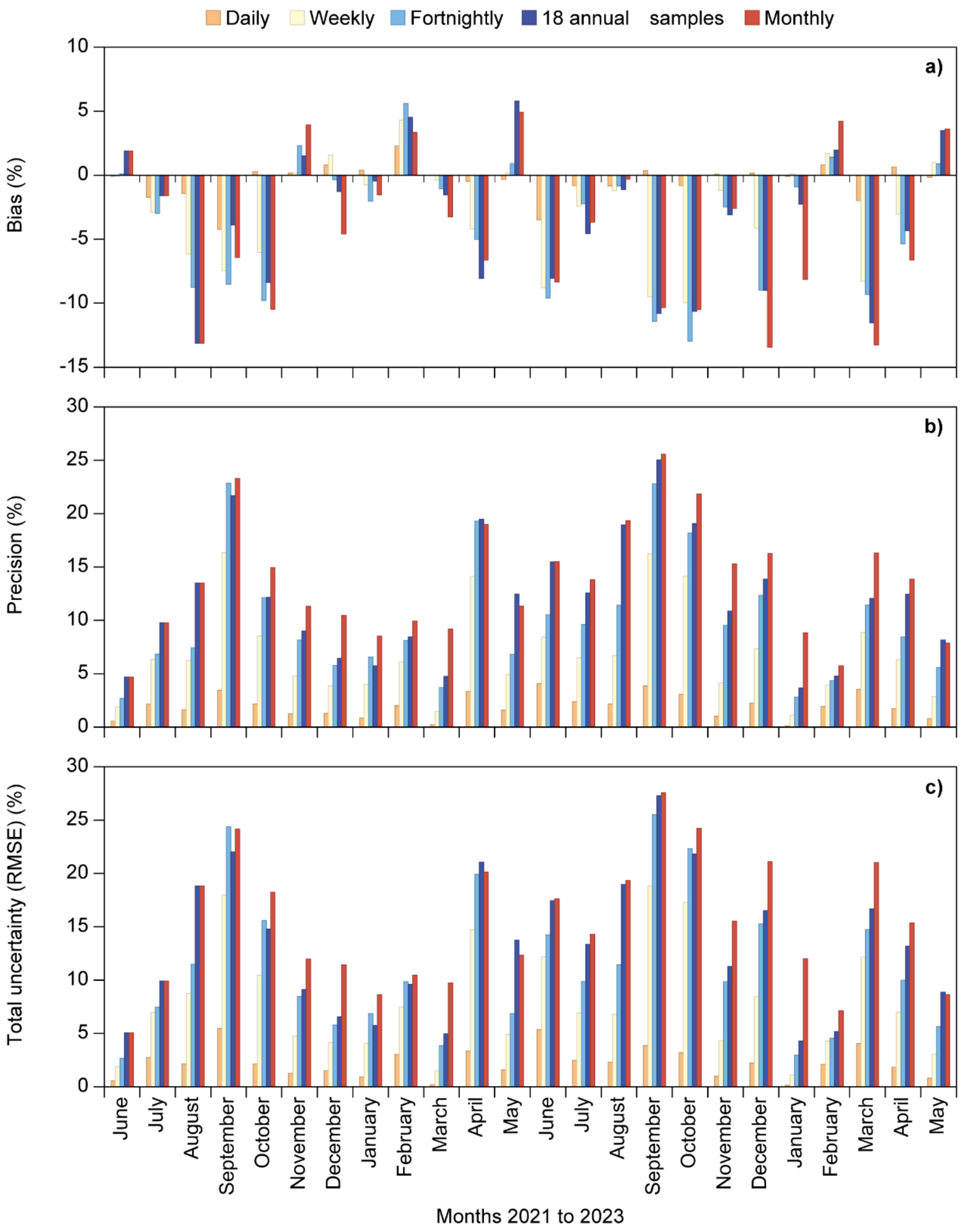
MONTHLY LOAD UNCERTAINTY HORNDRUP STREAM

Uncertainty increases with fewer water samples included in sampling strategy

Overall underestimation of NO3-N load

Avg. Bias with a monthly sampling strategy =-4% (max: -13%)

Total uncertainty(RMSE) average = 15%



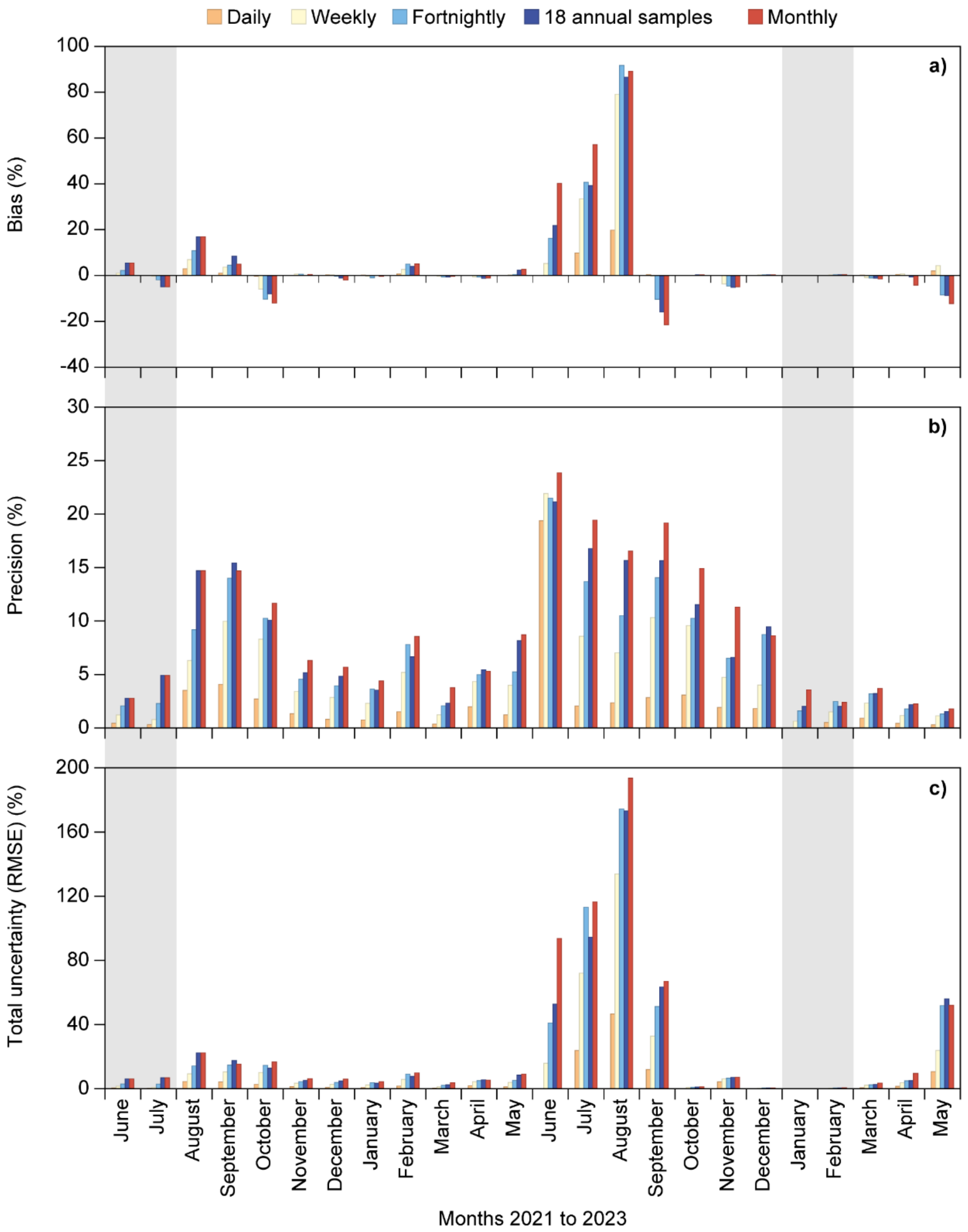
MONTHLY LOAD UNCERTAINTY LYBY-GRØNNING STREAM

Uncertainty increases with fewer water samples included in sampling strategy

Overall overestimation of monthly NO3-N load

Avg. Bias with a monthly sampling strategy =7% (max: 89%)

Total uncertainty(RMSE) average = 27%

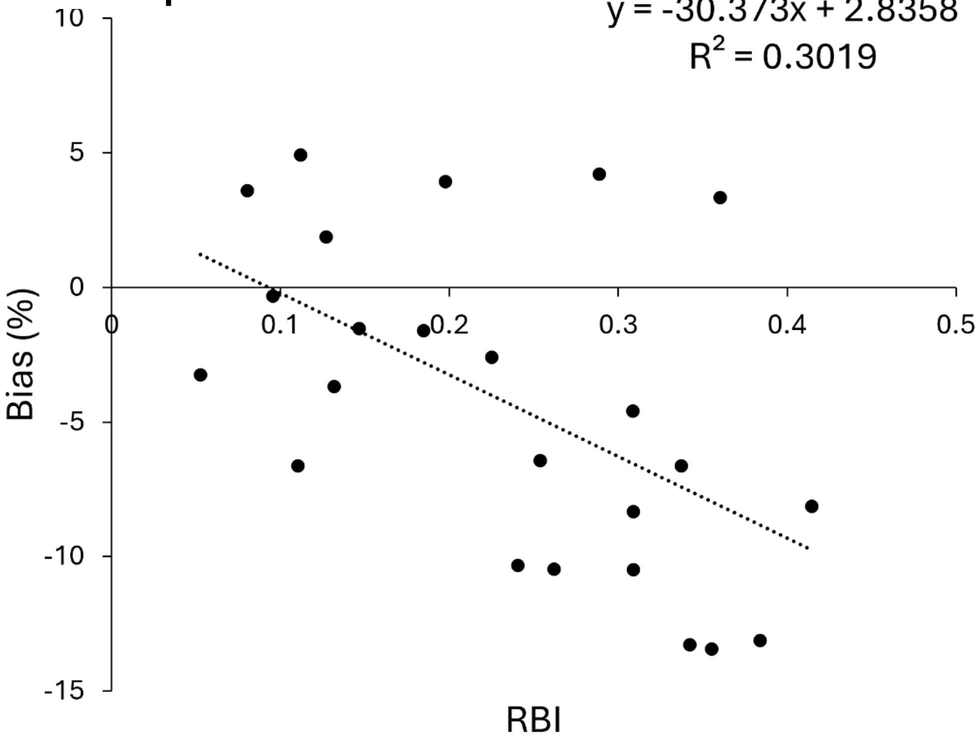


RICHARD BAKER FLASHINESS INDEX (RBI) VS UNCERTAINTY BASED ON MONTHLY SAMPLING STRATEGY

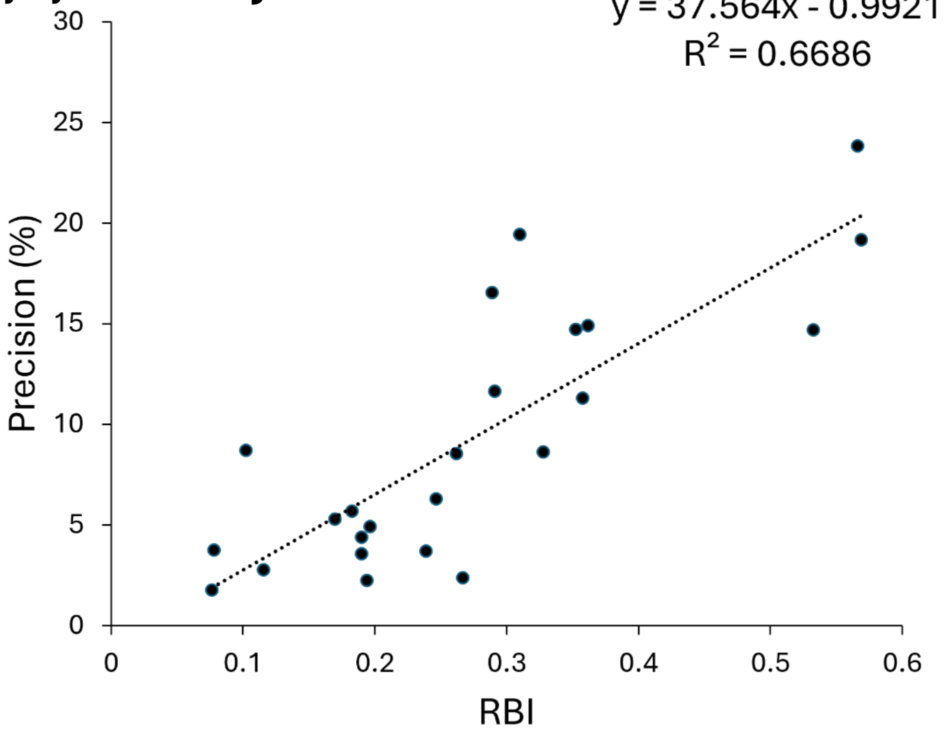
Horndrup Stream: Significant (P=0.005) negative linear correlation between bias and RBI.

Lyby-Grønning Stream: Significant (P<0.001) linear correlation between precision (std) and RBI for both monitoring years

Horndrup Stream



Lyby-Grønning Stream



MAIN FINDINGS

- All sampling strategies:
  underestimated the annual nitrate transport in Horndrup Stream ⬇
  overestimated the annual nitrate transport in Lyby-Grønning Stream ⬆

- The uncertainty was much higher for the calculated monthly transports!
- The overall average monthly uncertainty was 15% and 27%.

- The introduction of sensors for measuring nutrient concentrations in streams provides unique opportunities to achieve accurate assessments of the load to lakes and coastal waters, especially monthly loads.
- Cost. What level of uncertainty do we accept for future load estimates regarding regulation and costs?

- This is relevant in relation to The Green Tripartite Agreement in Denmark
- Need to investigate larger streams

QUESTIONS?☺

References:

- Bieroza *et al.*, 2014, Understanding nutrient biogeochemistry in agricultural catchments: the challenge of appropriate monitoring frequencies, *Env Sci Process & Impacts*, 16, 1676-1691

- Miljøstyrelsen, 2021. Tilstanden i det danske vandmiljø, Vand og Jord, 2021, nr. 3

- van't Veen, S.G.M. *et al.* (under review) 'SentemQC - A novel and cost-efficient method for quality assurance and quality control of high-resolution frequency sensor data in fresh waters', *Open Research Europe*, 4, p. 244. Available at: https://doi.org/10.12688/openreseurope.18134.1.