Revising the kinetics of nitrate dissipation in wetlands and streams

François Birgand[1], Marc Horstman[2],
Brian Reich[3]

1: NCSU-BAE 2: Dewberry & Davis , Inc. 3: NCSU-Statistics

Nitrate dissipation rate kinetics in wetlands and streams

Advection term

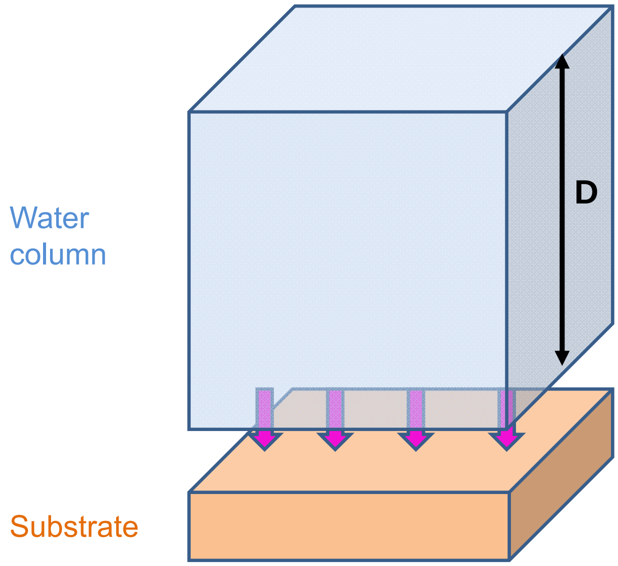
Dispersion term

$$\frac{\partial C}{\partial t} = -\frac{Q}{A}\frac{\partial C}{\partial x} + \frac{1}{A}\frac{\partial}{\partial x}\left[AD\frac{\partial C}{\partial x}\right] - \frac{v_f}{h}C + \frac{1}{h}k_B C_B$$

Process term

Stream Solute workshop (1990)

Empirical surficial removal rates



R [$M.L^{-2}.T^{-1}$]

$$\boxed{R = v_f.C = \rho.C}$$

$$C = C_0\, e^{-\frac{\rho}{D}t}$$

What does the diffusion theory say?

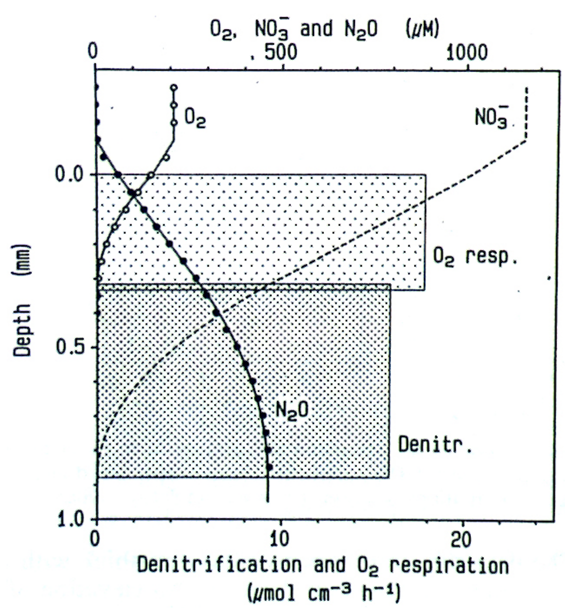
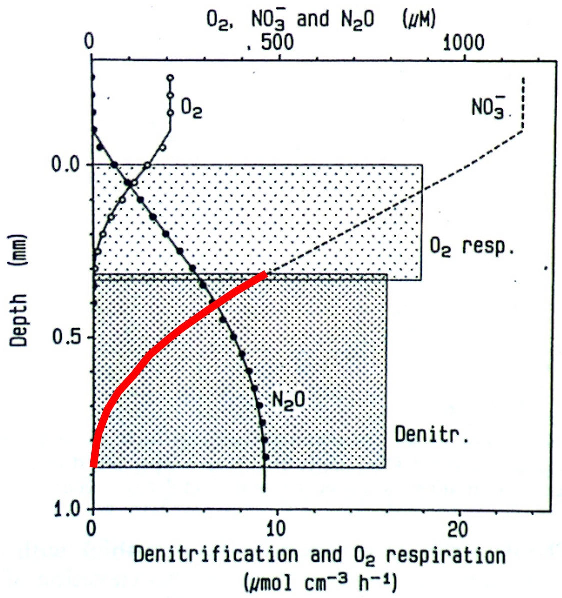


Fig. 1. Steady-state profiles of O_2 and N_2O in an acetylene-inhibited biofilm from Døde Å measured at the in situ NO_3^- concentration (1,180 μM). Oxygen respiration rates were calculated from the O_2 profile, whereas both the NO_3^- profile and the denitrification rates (in N-equivalents) were estimated from the N_2O profile. Circles indicate measured concentrations, whereas curves are simulated profiles.

Nielsen et al., 1990a

What does the diffusion theory say?



- Constant denitrification volumetric dissipation rates
- Parabolic shape of the [NO3] microprofile

$$\boxed{R = v_f . C^{½} = \gamma . C^{½}}$$

Nielsen et al., 1990a

Two approaches

- Empirical method: removal rates proportional to [NO_3^-]
- $R = \rho C$

- Theoritical approach of nitrate diffusion into sediment due to denitrification
- $R = \gamma C^{½}$
- Efficiency loss model
- $R = \gamma C^{\alpha}$

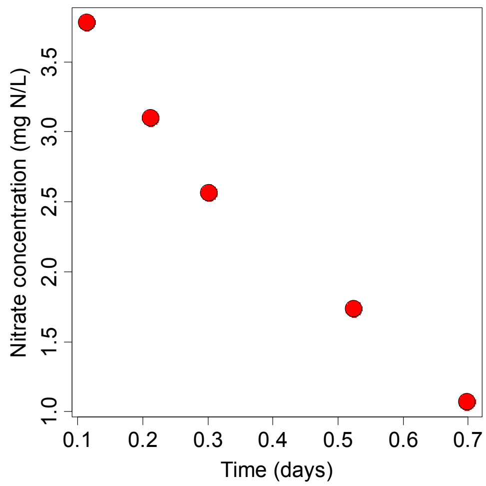
Is any one correct? Which one is it?

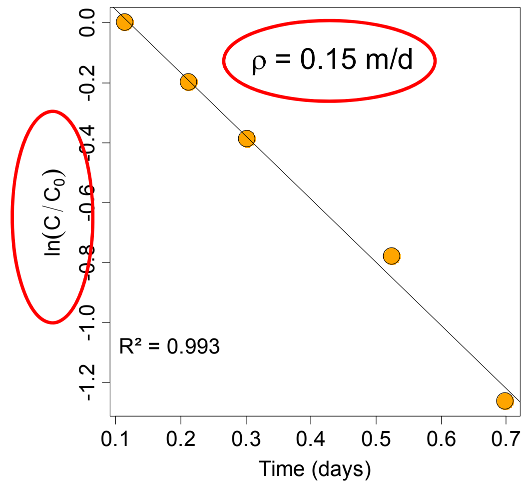
Method: mesocosm study

- <u>Hypothesis</u>: water recirculation velocities above substrate increases nitrate removal rates

Recirculating water above wetland sediment

Common general approach to extract kinetics

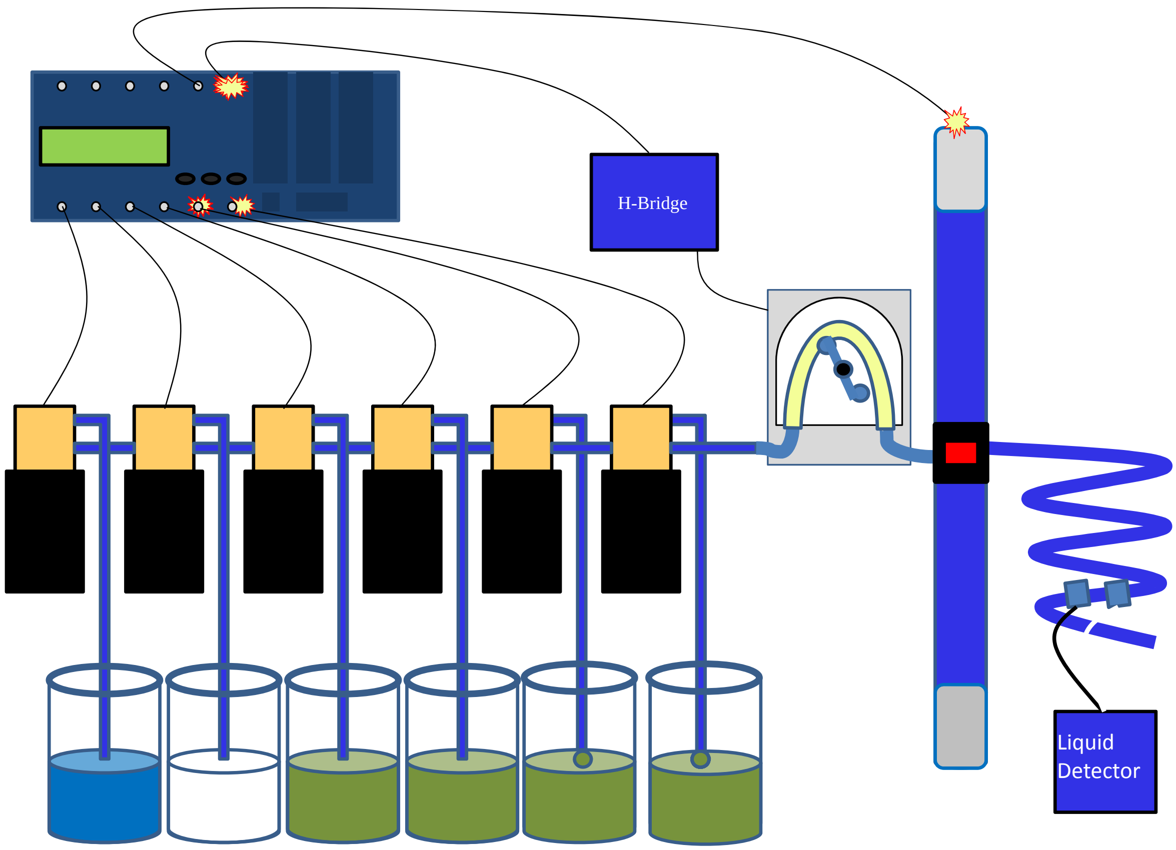




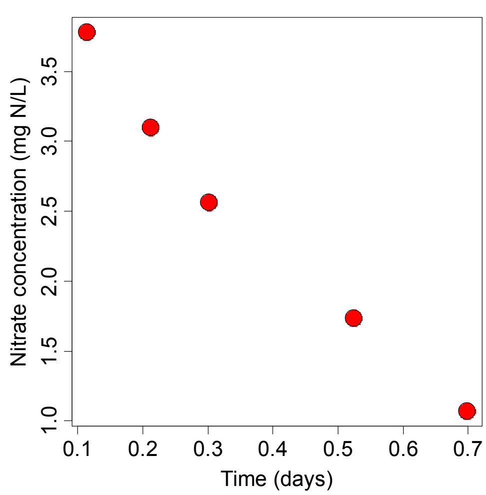
$$C = C_0\, e^{-\frac{\rho}{D}t} \Rightarrow \ln\left(\frac{C}{C_0}\right) = -\frac{\rho}{D}t$$

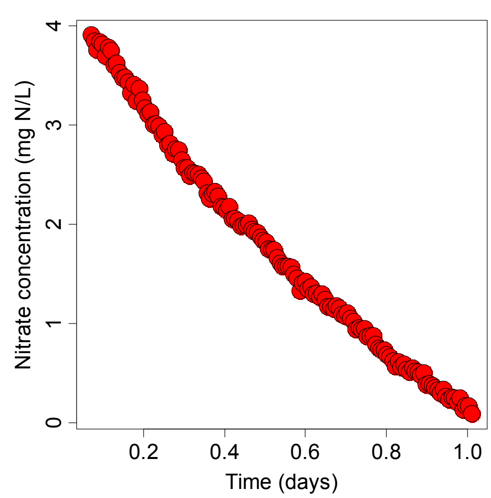
Lessons learned from high time resolution data

- Hypothesis: missing information in infrequent data points
- Method: designed and built a multiplexed portable lab for high frequency data acquisition

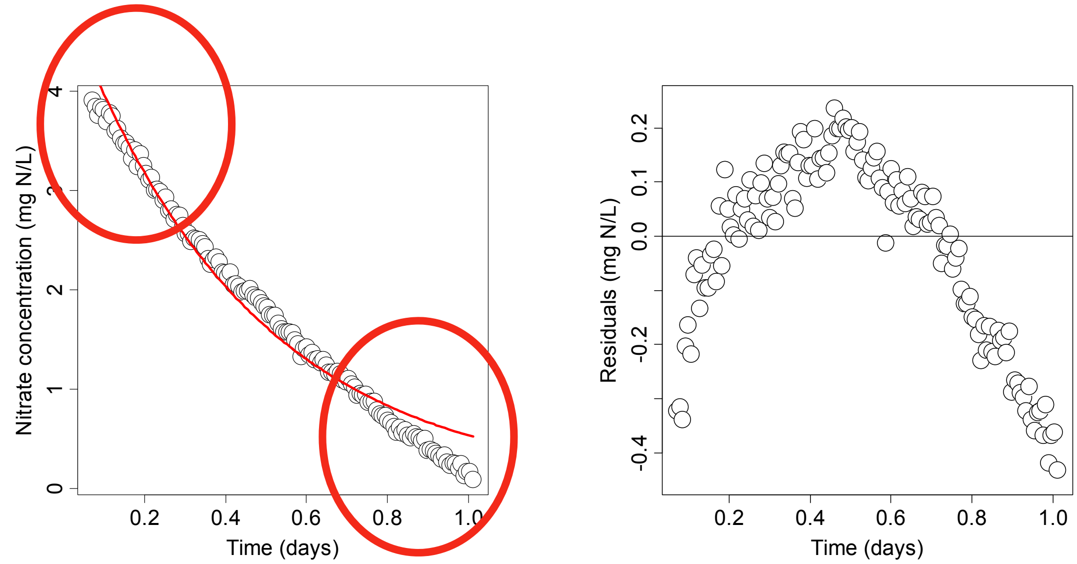


Enhanced information

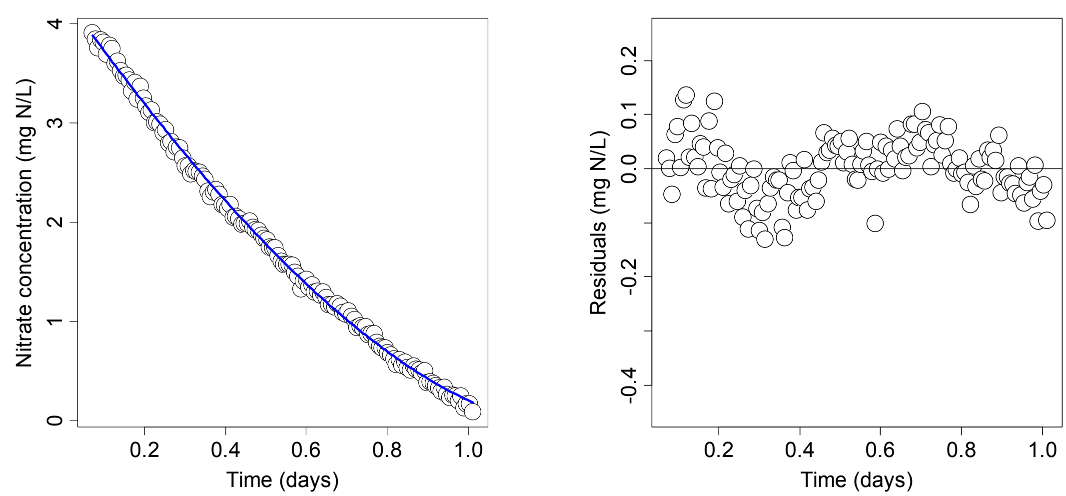




First order rate kinetics results (1)

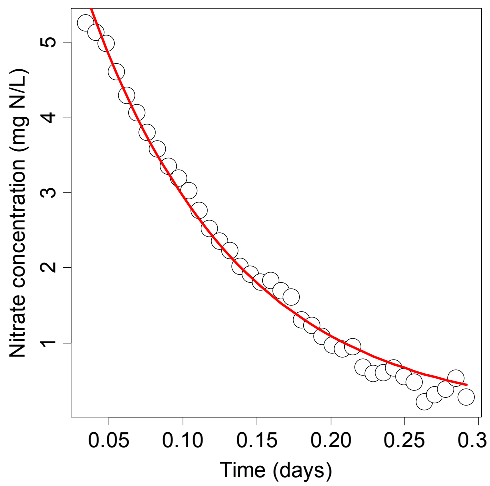


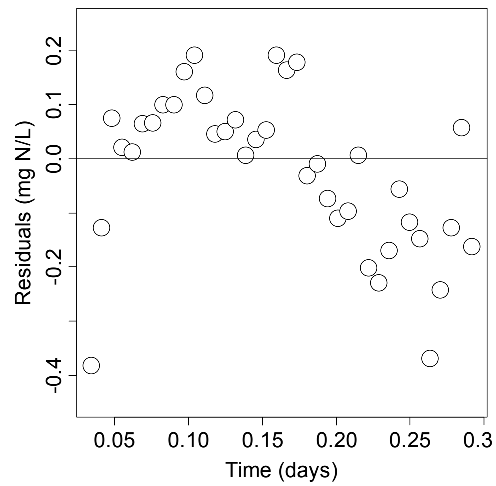
"Less than first" order rate kinetics results (1) (non linear regression)



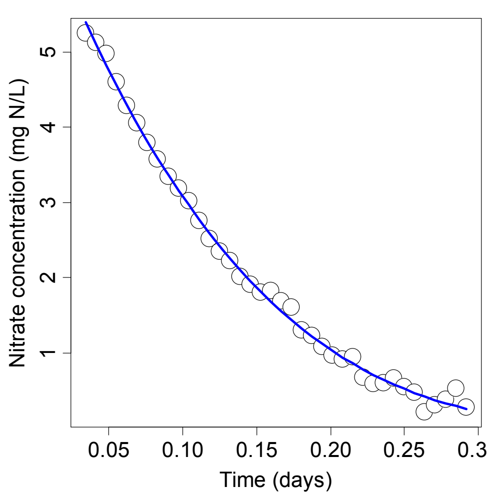
$$R = 0.24 \times C^{0.37}$$

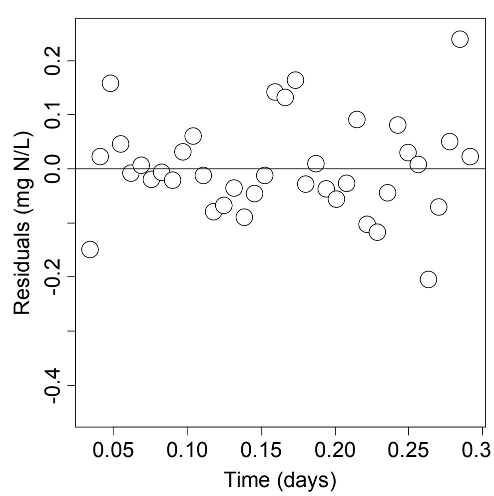
First order rate kinetics results (2)





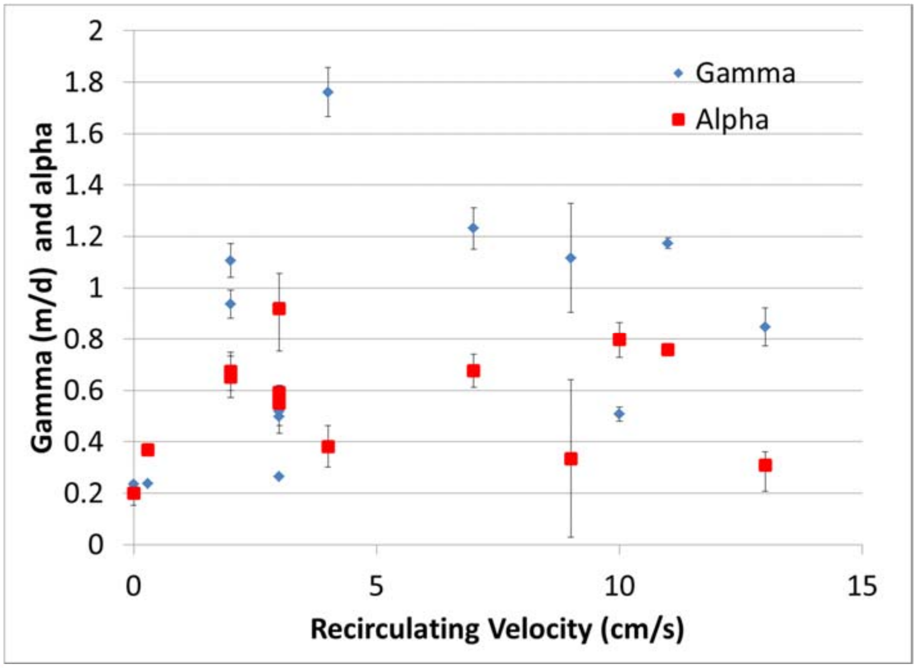
"Less than first" order rate kinetics results (2)



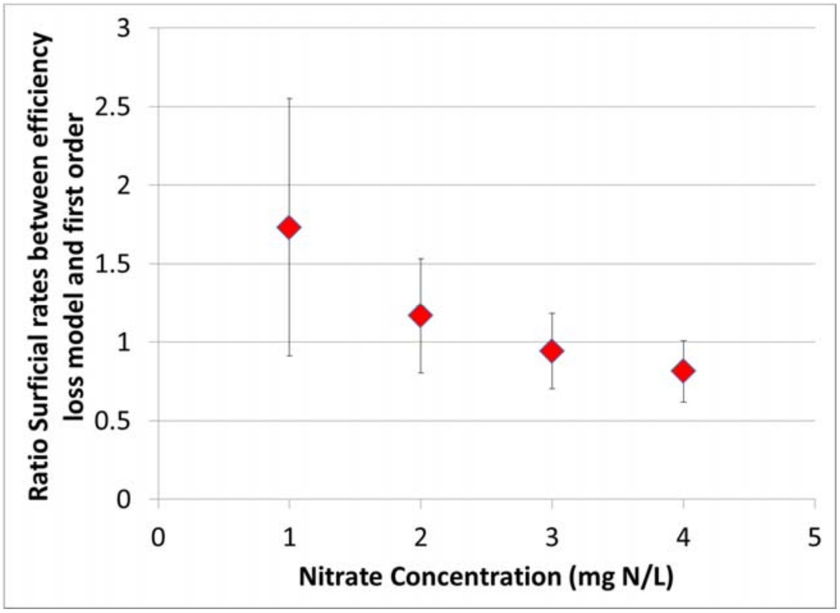


$$R = 0.9 \times C^{0.73}$$

Kinetics vary with recirculating velocities



Model kinetics comparison: surficial rates



$$R = \rho . C$$

$$R = \gamma . C^{\alpha}$$

Take home points - Conclusion

- First order rate kinetics in wetlands (and streams?) do not fit data the best
- Efficiency loss model more appropriate
- Kinetics vary with recirculating velocities and flow
- Nitrate losses underestimated for low (< 2 mg N/L) concentrations using common approach
- Needs to be confirmed