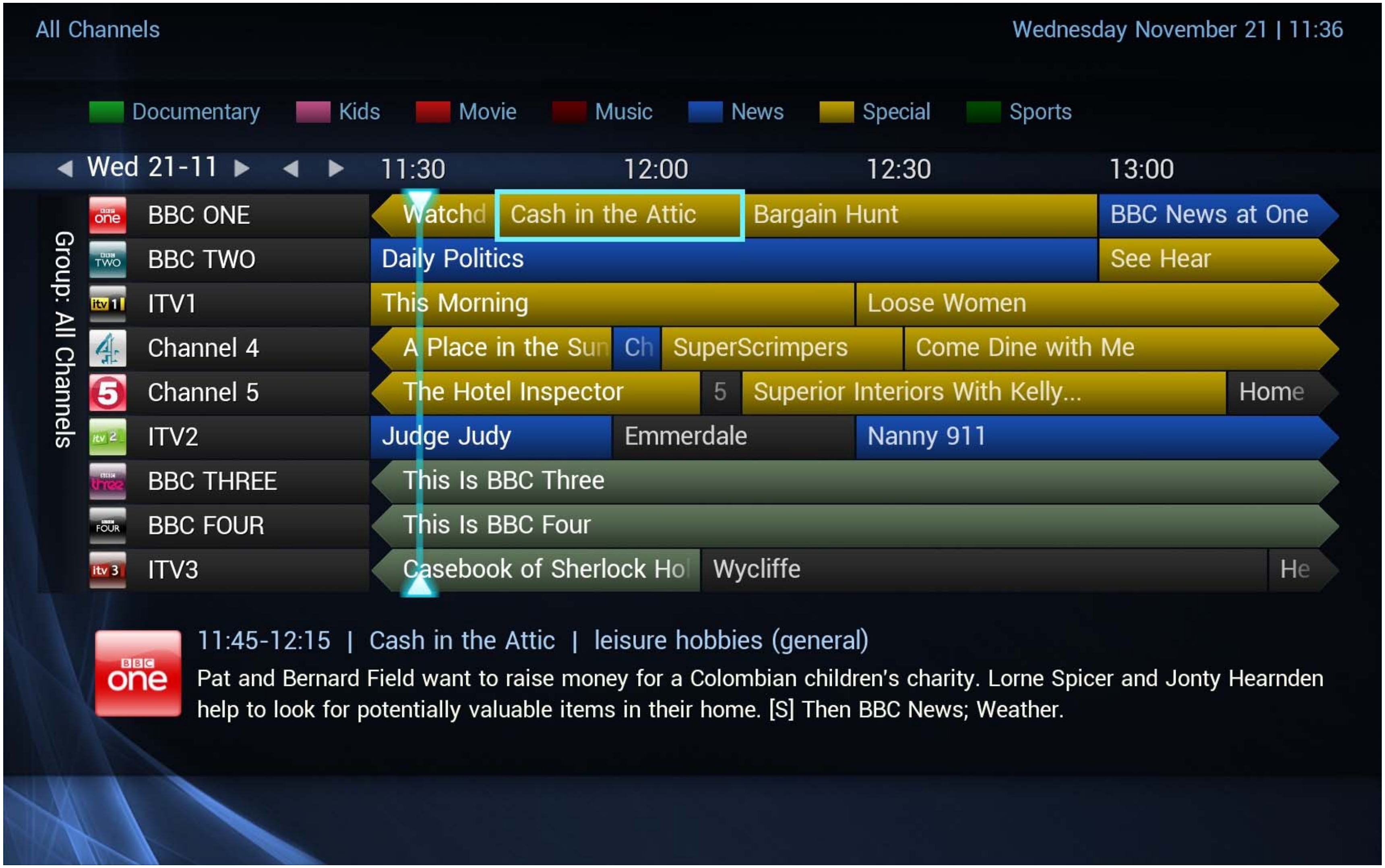
TECHNICAL DIFFICULTIES

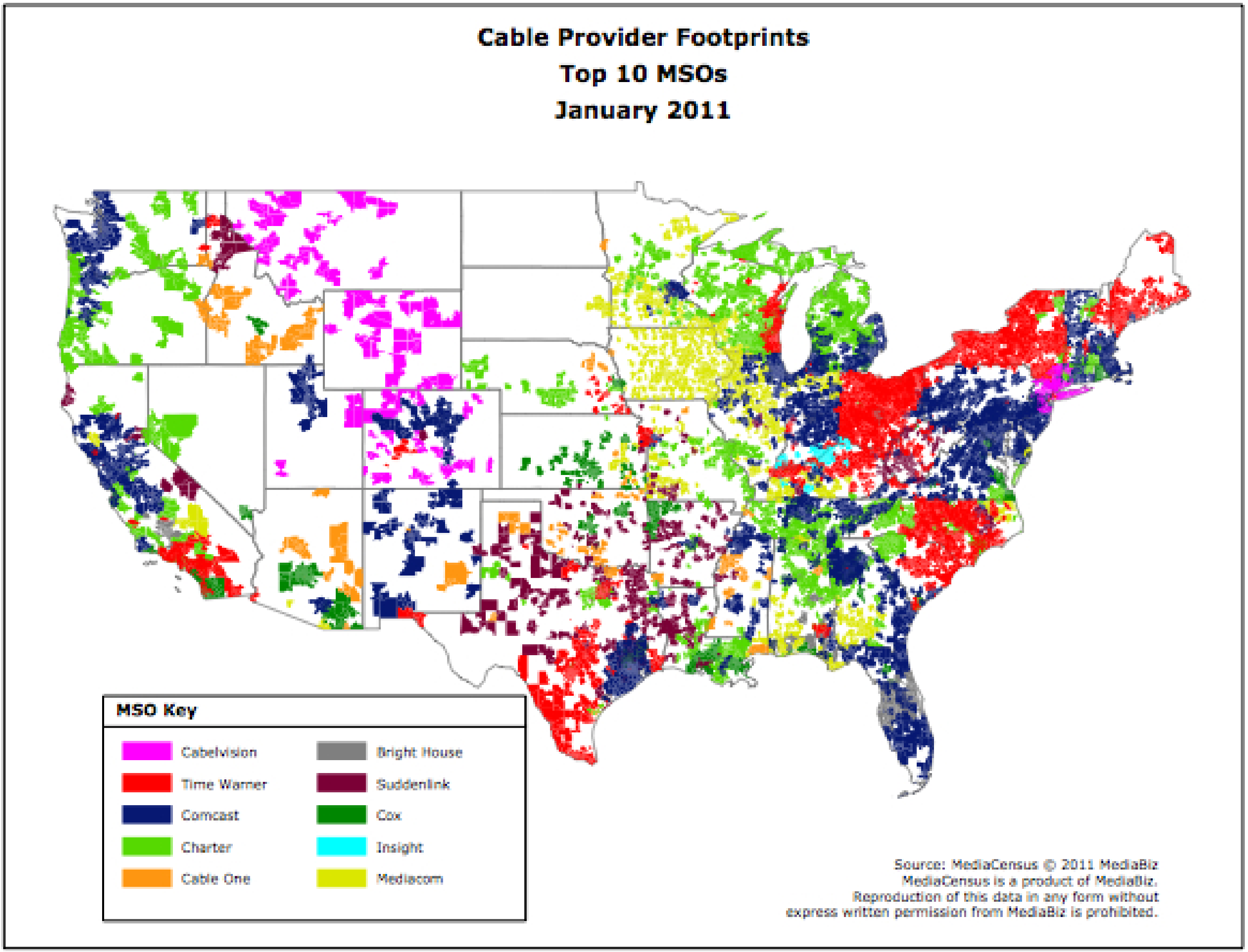
How are modelers like your TV cable provider? The pitfalls of lake modeling in a cornered marketplace

J. Thad Scott
University of Arkansas

TECHNICAL DIFFICULTIES



How is it that I pay $150 per month for 350 channels and….
There is never anything to watch!



http://tvbythenumbers.zap2it.com/

There are <u>very few companies</u> that own the necessary infrastructure to <u>provide service</u>

TRUE FOR TV CABLE PROVIDERS

TRUE FOR LAKE MODELERS

“*All models are wrong, but some are useful*”

George E.P. Box – Statistician, Princeton University

Types of Models:

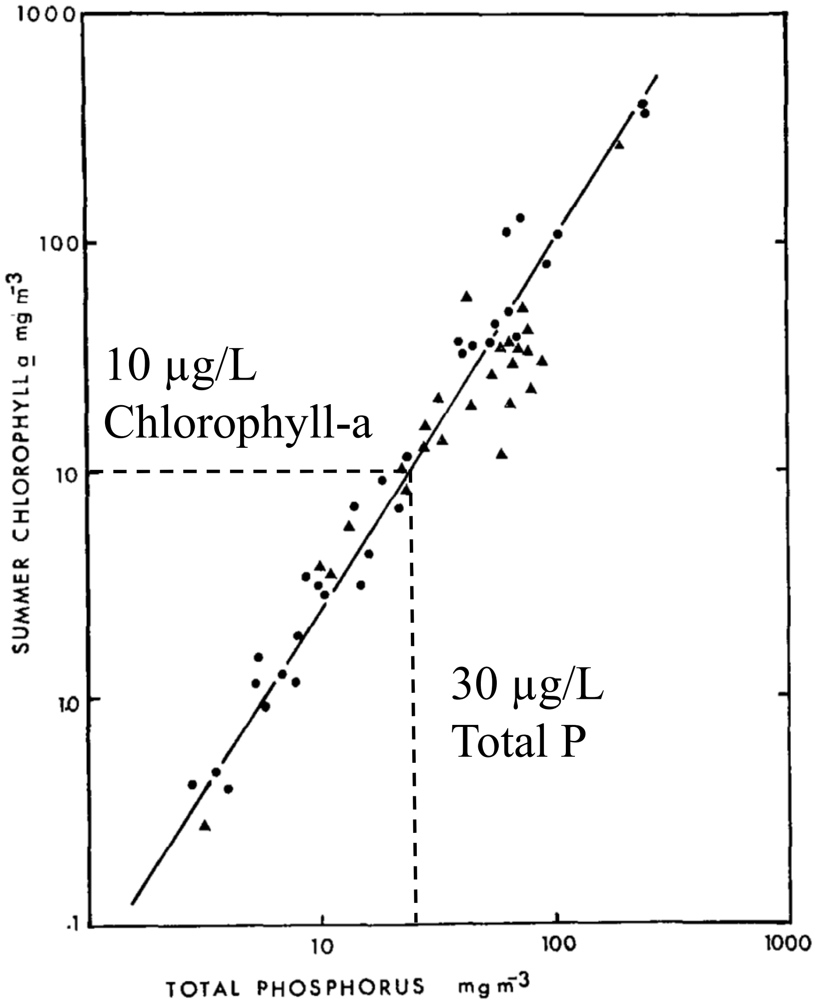
Statistical – linear and non-linear regression, logistic regression, hierarchy, categorical (anything with a *p* value)

Other empirical – simple mathematical formulations that directly link predictor and outcome (usually involve statistics)

Physically-based models – complex mathematical formulations to simulate physical, chemical, and biological variation on a short time step (often daily)

Let's cover some lake models used for eutrophication management and TMDL work

Examples of Models: Statistical



The phosphorus–chlorophyll relationship in lakes[1,2]

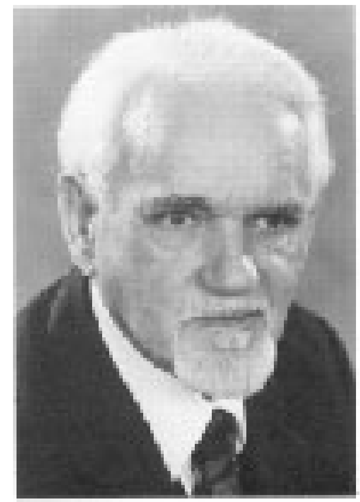
P. J. Dillon[3] and F. H. Rigler
Department of Zoology, University of Toronto, Toronto, Ontario

$y = mx + b$

Summer chla = m[P] + b

Examples of Models: Other Empirical

Vollenweider (1968)



$$L_c = \frac{[P]_c \times q_s}{(1 + \sqrt{\tau_w})}$$

L_c = critical P load (mg P m^{-2} y^{-1})
$[P]_c$ = critical P concentration of lake (mg/L)
q_s = annual hydraulic load (m y^{-1})
τ_w = average water residence time (y)

Timestep = annual

Combination of Vollenweider with Dillon and Rigler gets you:

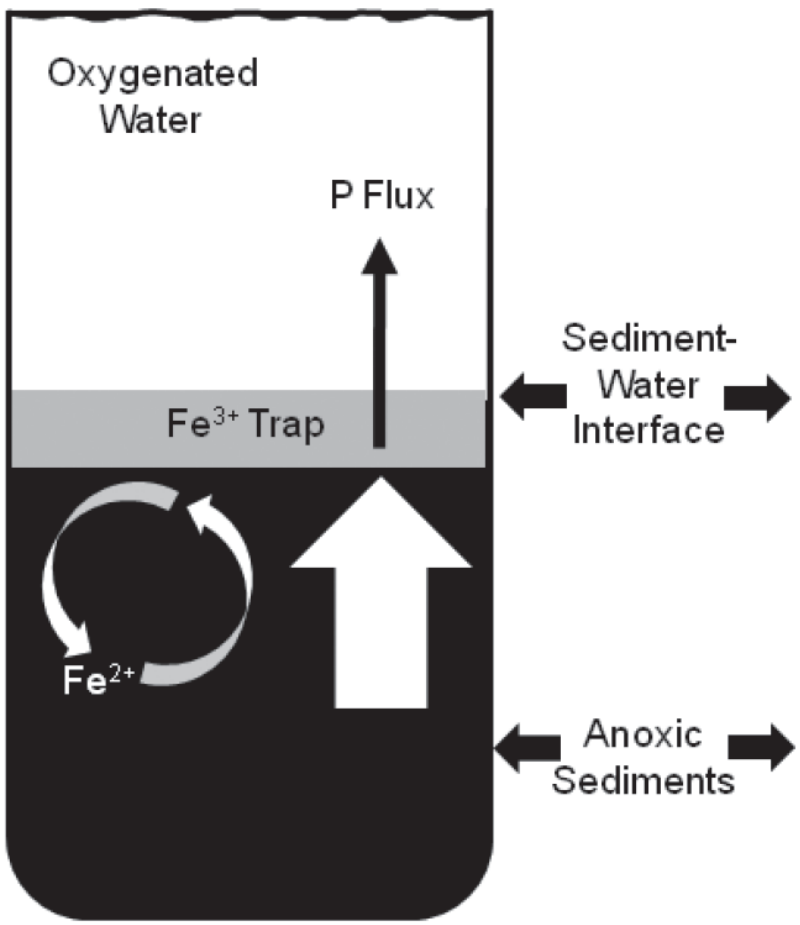
The annual phosphorus load reduction needed to reduce algal biomass to a certain level

This assumes:

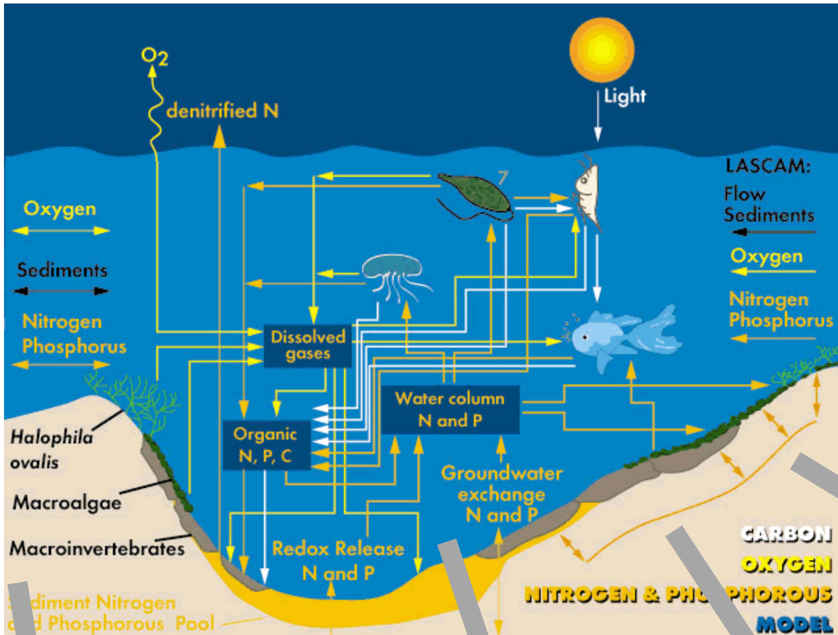
1. Lake has come into equilibrium with watershed
2. Other factors like internal loading do not dominate

We deal with these assumptions by increasing model complexity:
<u># of processes simulated and a finer resolution time step</u>

Internal P loading is controlled by and influences multiple in-lake variables



Examples of Models: Physically-based



Algal Dynamics

$$S_a = \underbrace{K_{ag}\Phi_a}_{\text{growth}} - \underbrace{K_{ar}\Phi_a}_{\text{respiration}} - \underbrace{K_{ae}\Phi_a}_{\text{excretion}} - \underbrace{K_{am}\Phi_a}_{\text{mortality}} - \underbrace{\omega_a \frac{\partial \Phi_a}{\partial z}}_{\text{settling}}$$

Dissolved OM Decomp & Settling

$$S_{LDOM} = \underbrace{\sum K_{ae}\Phi_a}_{\text{algal excretion}} + \underbrace{\sum (1-P_{am})K_{am}\Phi_a}_{\text{algal mortality}} + \underbrace{\sum K_{ee}\Phi_e}_{\text{epiphyton excretion}} + \underbrace{\sum (1-P_{em})K_{em}\Phi_e}_{\text{epiphyton mortality}} - \underbrace{\gamma_{OM} K_{LDOM}\Phi_{LDOM}}_{\text{labiole DOM decay}} - \underbrace{K_{L\to R}\Phi_{LDOM}}_{\text{labile to refractory DOM decay}}$$

Heat exchange

$$H_{aw} = -K_{aw}(T_w - T_e)$$

Flow

$$Q = C_D C_v \frac{2}{3}\sqrt{\frac{2}{3}g}\, W H^{3/2}$$

Particulate Matter Decomp & Settling

$$S_g = \underbrace{-K_0\,\theta_g^{(T\text{-}20)}}_{\text{0-order decay}} - \underbrace{K_1\theta_g^{(T\text{-}20)}\Phi_g}_{\text{1st-order decay}} - \underbrace{\omega_g \frac{\partial \Phi_g}{\partial z}}_{\text{settling}}$$

What modelers promise and what they provide are often very different

WHY?

Five reasons modeling efforts sometimes derail

- Science is used as a tool to perform lake models rather than lake models being used as a tool to perform science

- Biological variables cannot be simulated as well as physical and chemical variables

- Lake models need sufficient data for calibration and validation

- Different ecosystem process control biological structure and function in different lakes

- Inference should be based on straightforward hypothesis testing of well-calibrated and validated models

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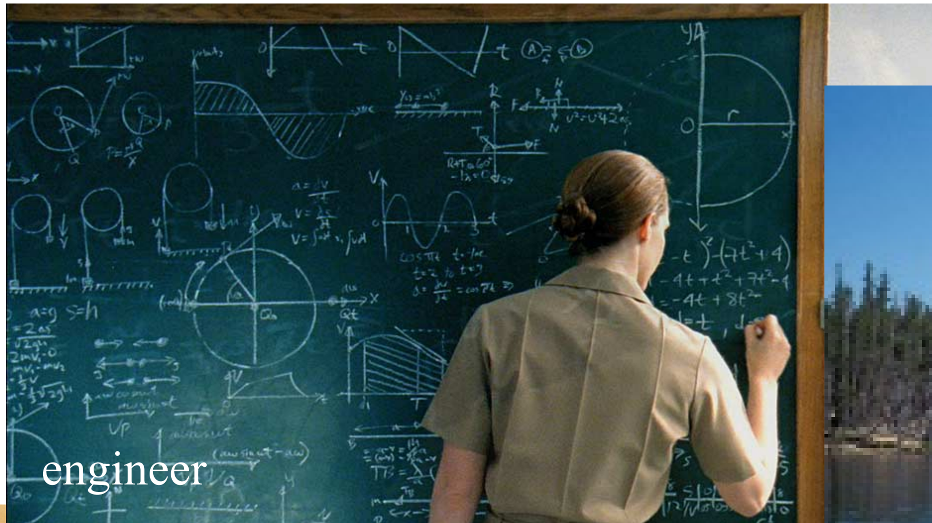
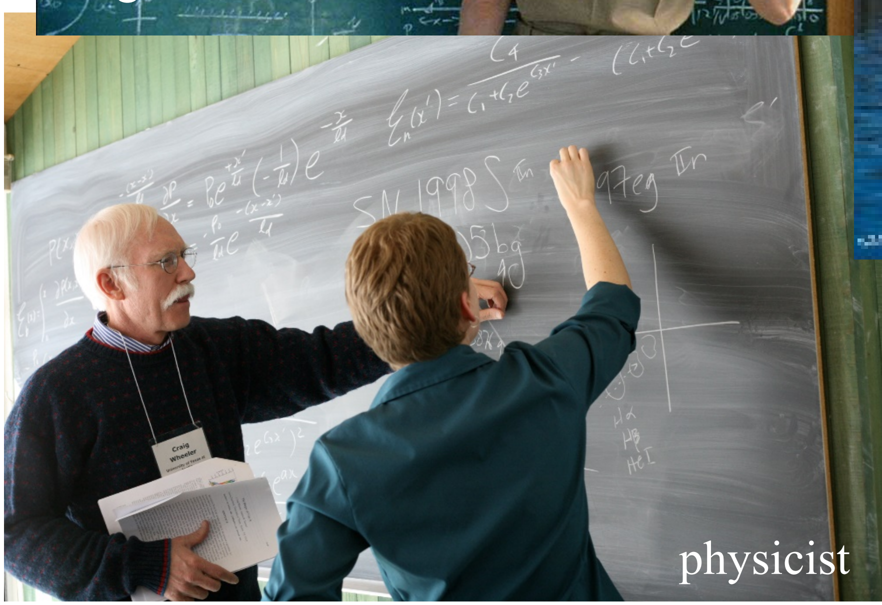


engineer



physicist

limnologist

HAVE YOU HUGGED A LIMNOLOGIST TODAY ?

"LIMNOLOGY" – THE STUDY OF INLAND WATERS

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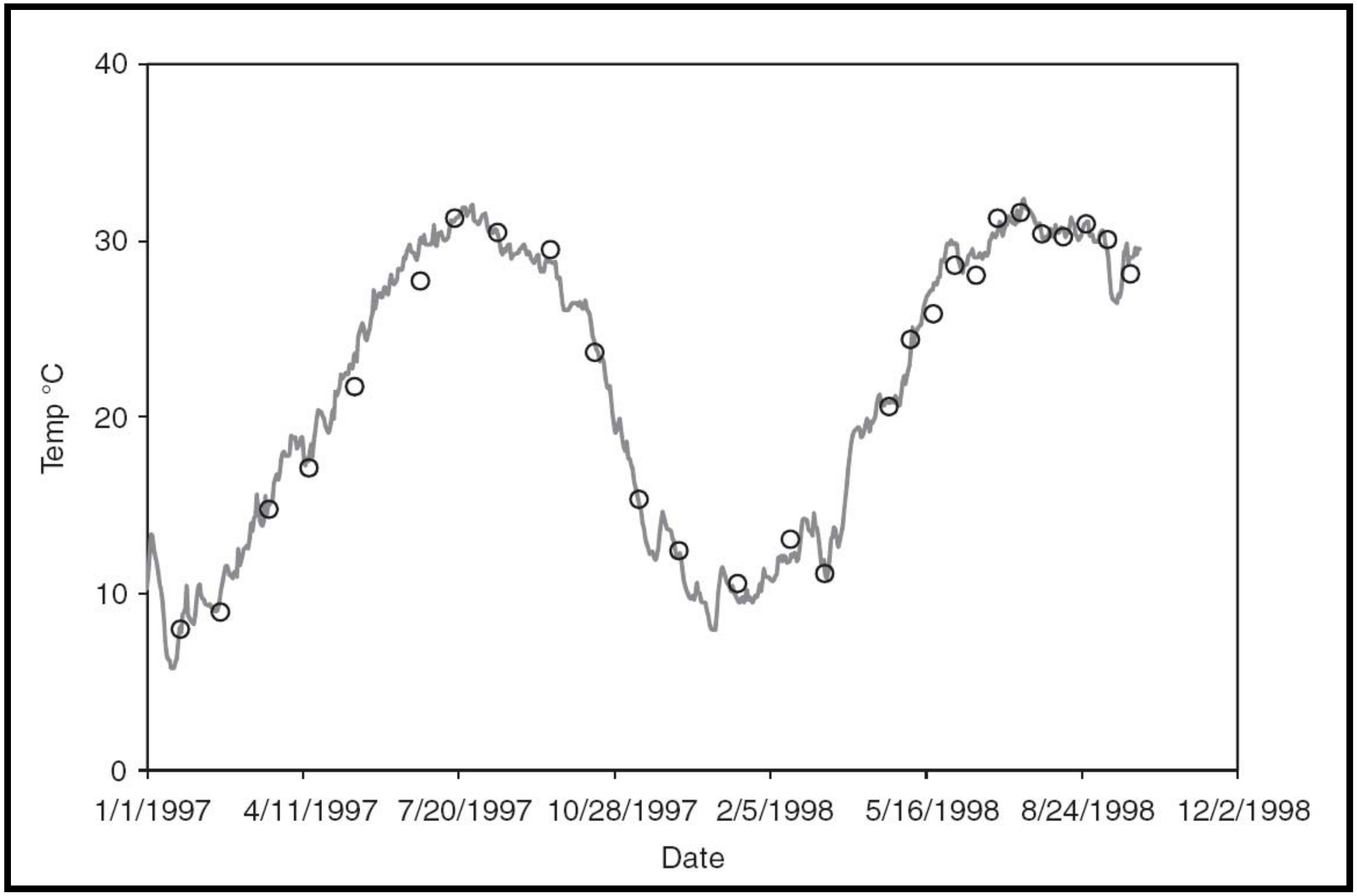

White et al. 2010

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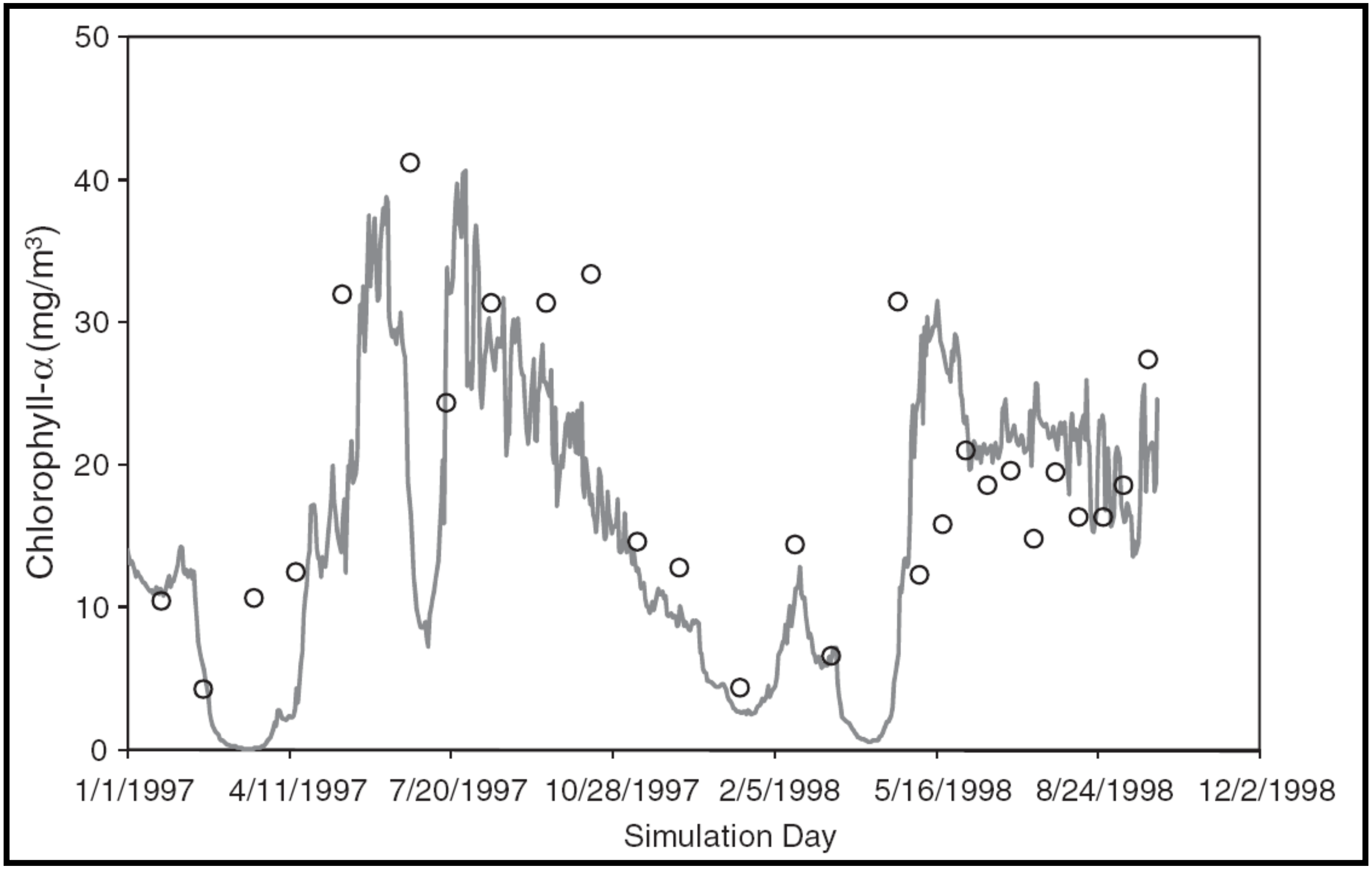

White et al. 2010

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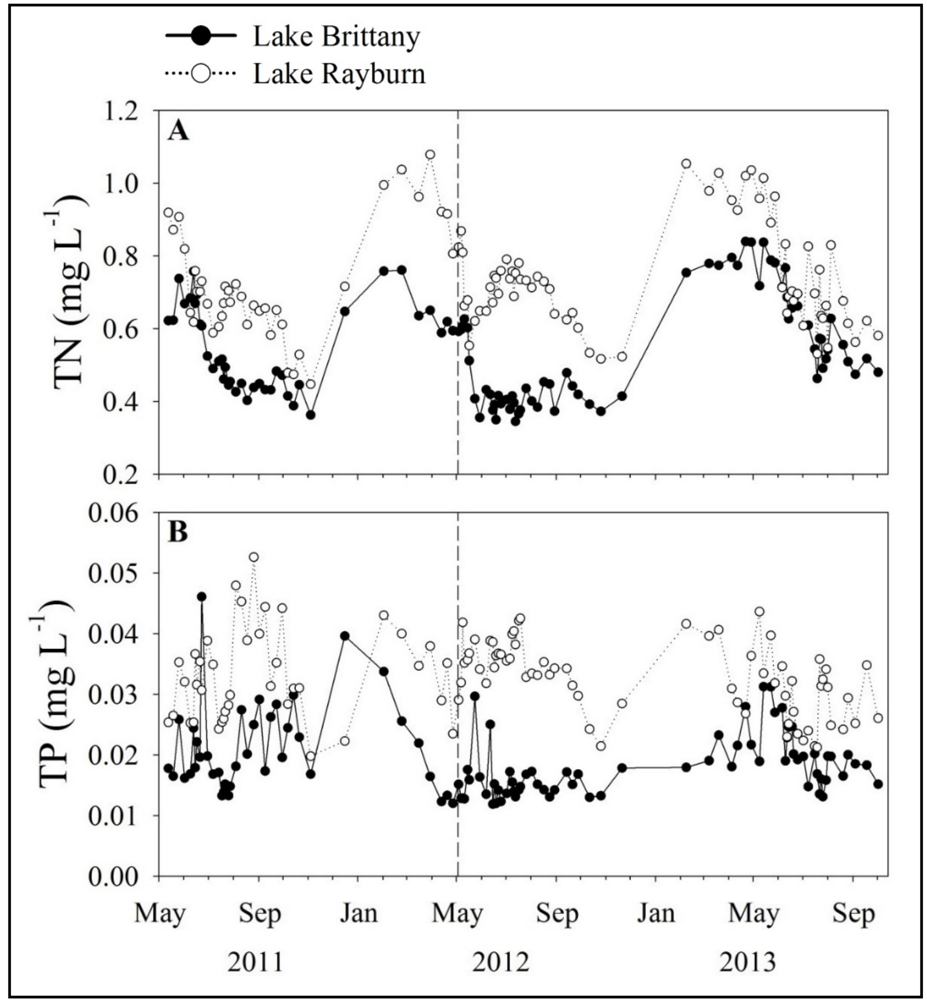
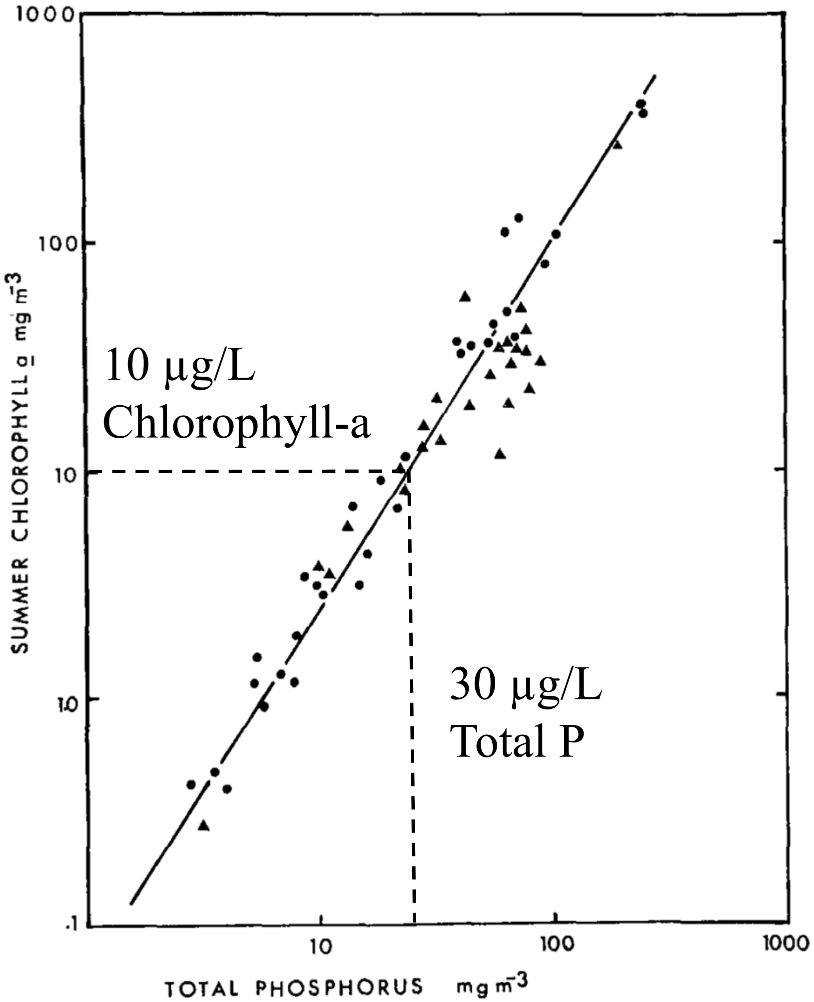
- Most advanced models run on a daily time step
- Daily calibration data is not an option
- Daily and weekly variation can be substantial
- What resolution of monitoring data is needed for calibration?



- Different ecosystem process control biological structure and function in different lakes



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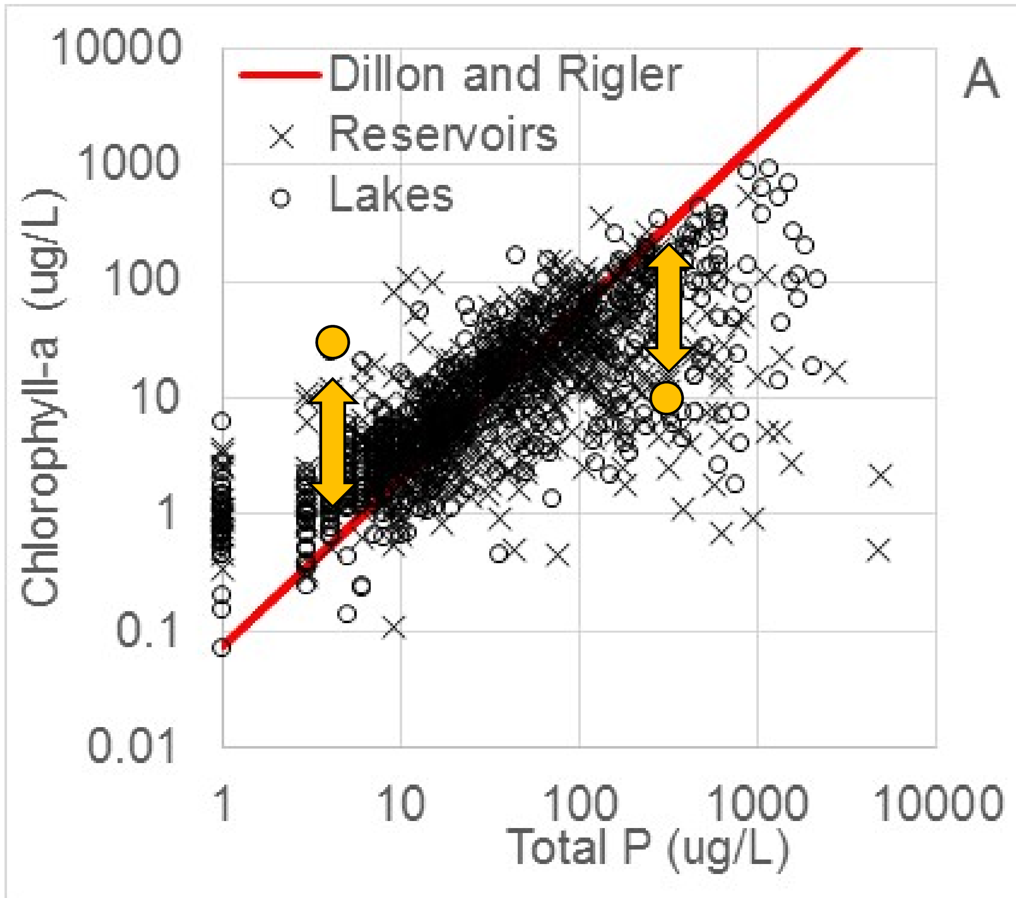

EPA National Lake Assessment Data 2007
http://water.epa.gov/type/lakes/lakessurvey_index.cfm

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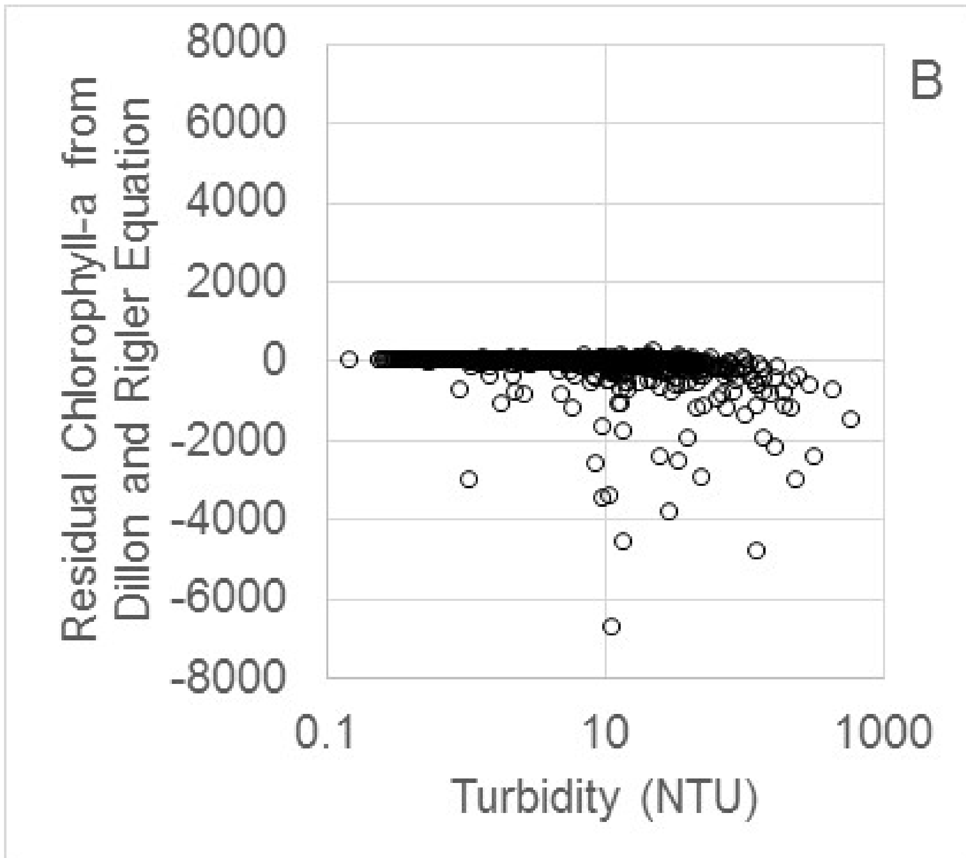

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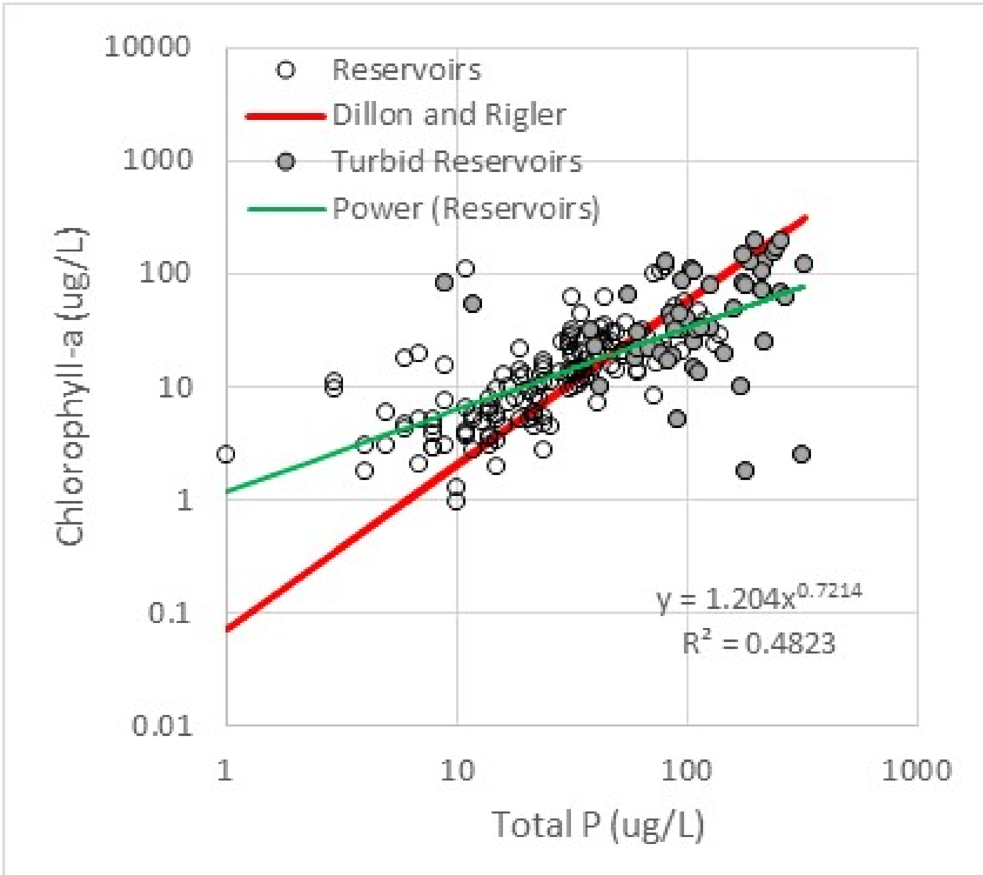

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- Inference should be based on straightforward hypothesis testing of well-calibrated and validated models

Testable modeling hypotheses:

Twenty five percent reduction in P loading will reduce average annual algal biomass by 5x because lake processes are in equilibrium with watershed loading

Untestable modeling hypothesis:

Blue-green algae will dominate algal biomass under increased CO_2 conditions because blue-greens outcompete other algae during summer CO_2 drawdown

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Modeling as a tool to do science
REQUIRES multidisciplinary collaboration

Higher education institutions need to:

- Promote modeling opportunities at B.S. and M.S. levels
- Use models for hypothesis testing
- Get involved in model applications

Federal and State agencies that need modeling efforts need to:

- Consider the cost benefit of a poorly constructed model with more empirical data
- Use resources to promote responsible and quality model development through systematic programs

THIS CAN HELP US AVOID:


TECHNICAL DIFFICULTIES
Thank you!
Questions?
TECHNICAL DIFFICULTIES