Bayesian Structural Equation Modeling: A New Methodological Tool for Unraveling Ecological Patterns

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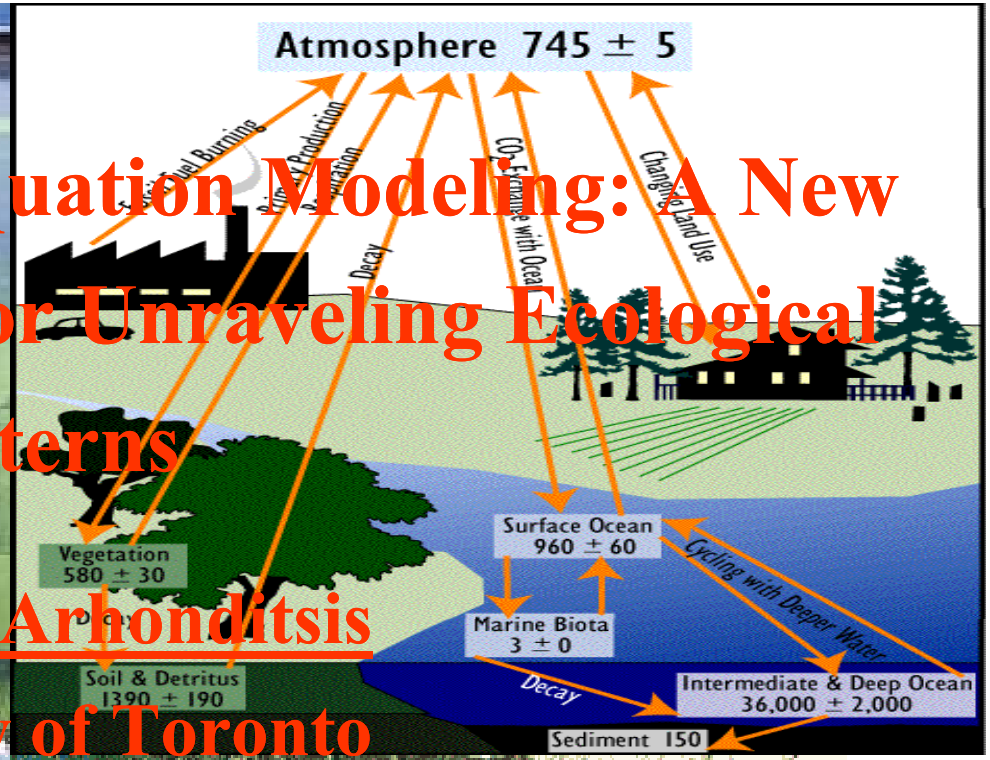
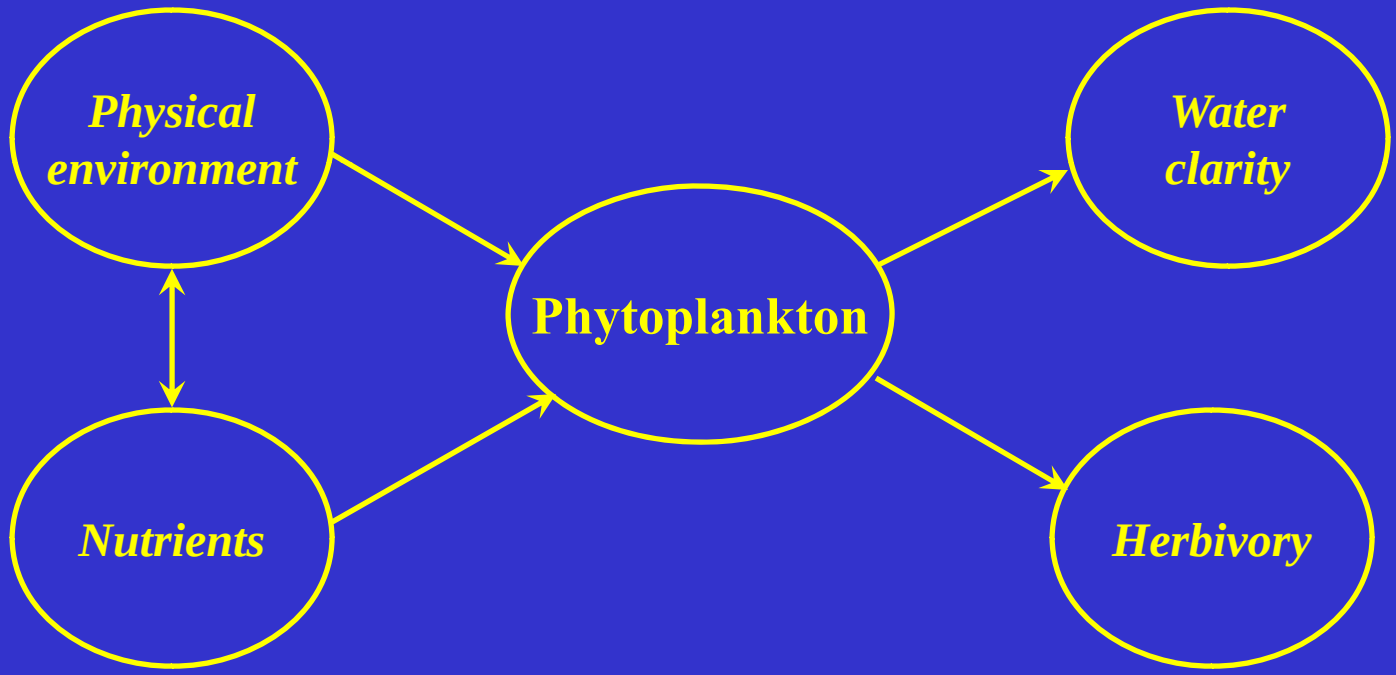


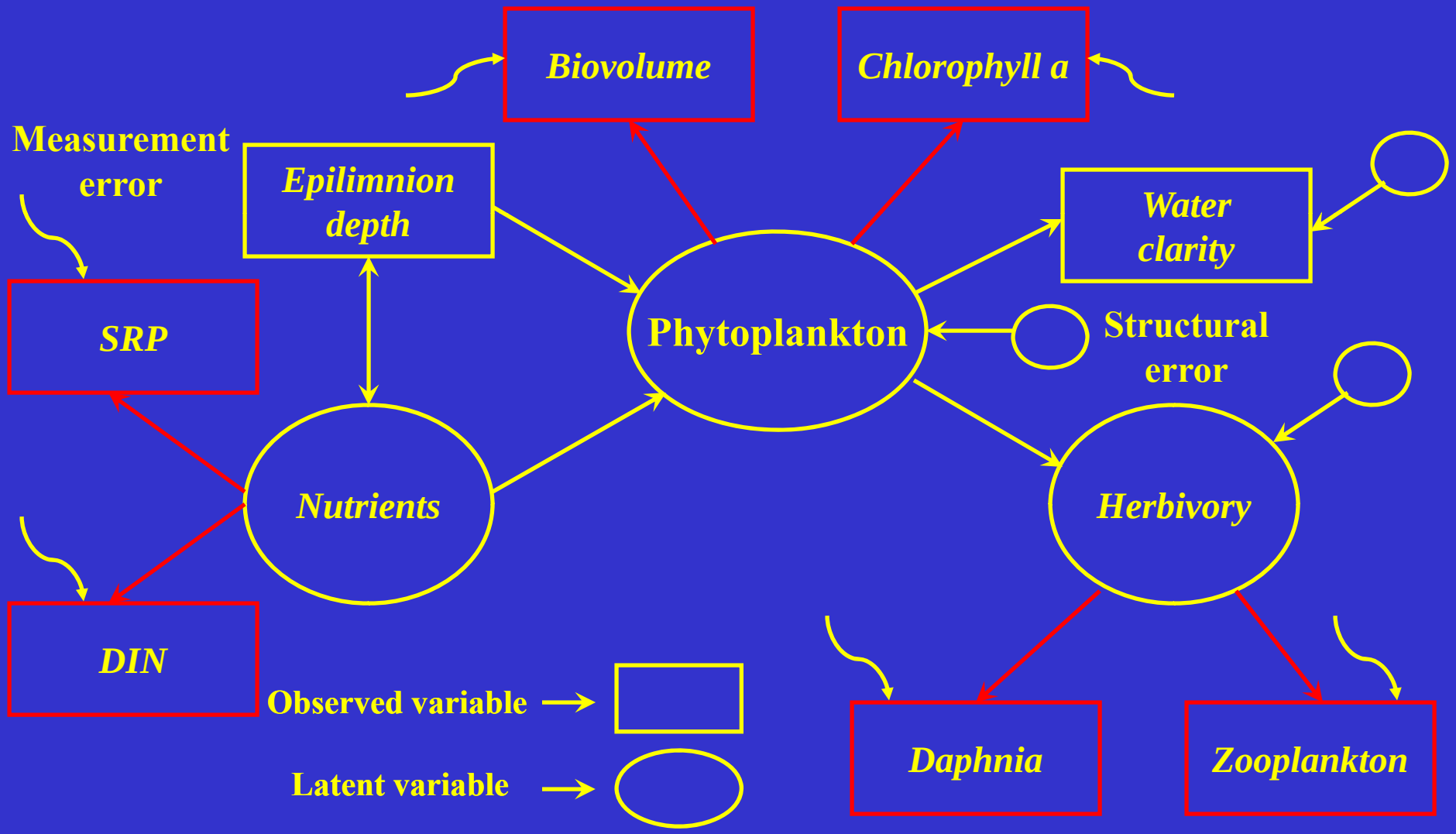
What is missing from the common ecological practice is a statistical method that…

i) can translate fairly complicated ecological phenomena and express them as a function of several conceptual environmental factors

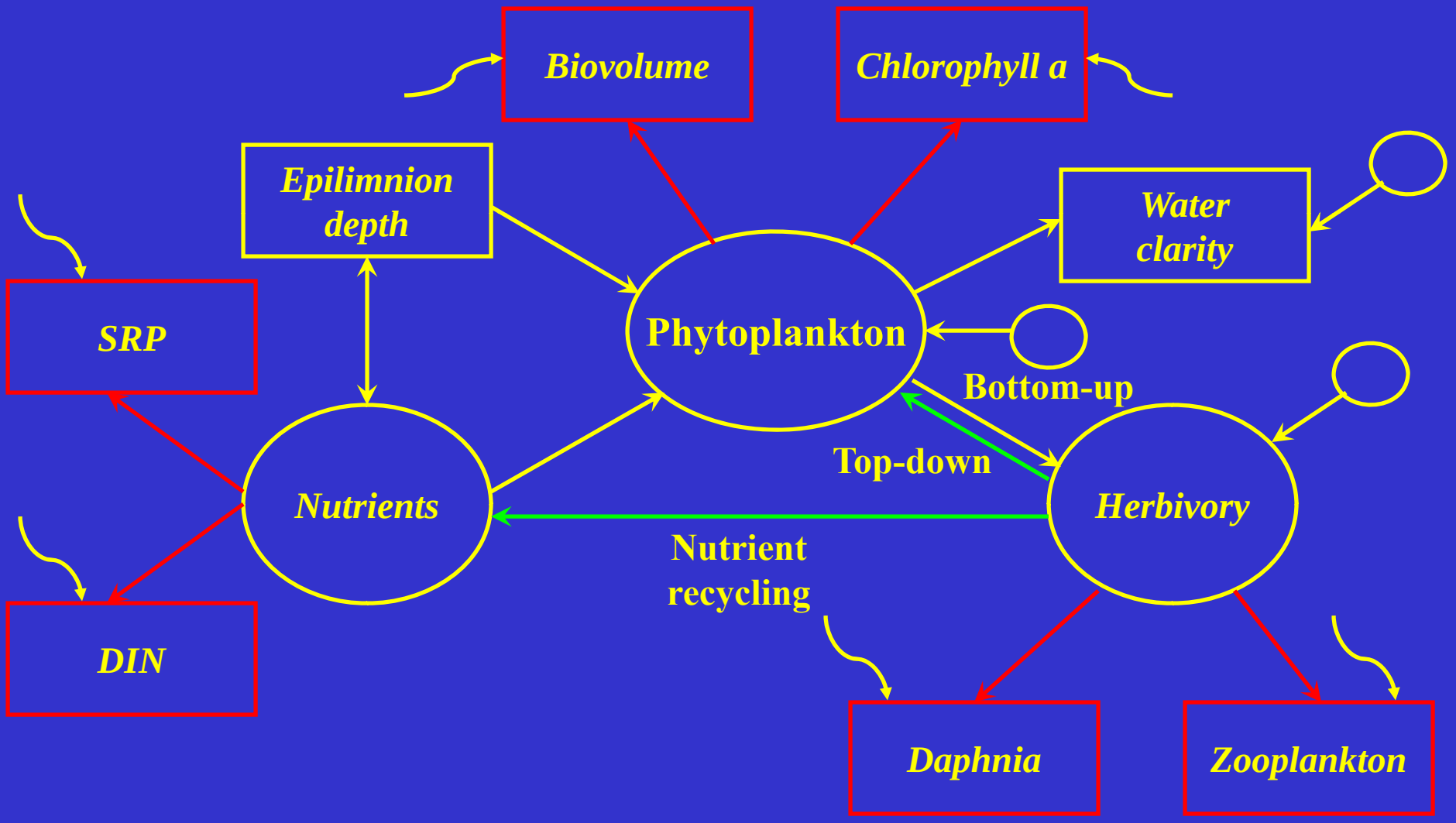


Epilimnetic phytoplankton dynamics

ii) link the conceptual factors of interest with routinely measured variables by explicitly acknowledging that none of those reflects perfectly the underlying property



iii) test both direct and indirect paths of this ecological structure and identify the importance of their role



Advantages of Structural Equation Modeling

- **In contrast with regression analysis:**

  i) **the predictor variables are NOT assumed to be free of measurement error or uncontrolled variation,**

  ii) **hypotheses are formulated in a way that allows for the inclusion of unobserved, "latent" variables and NOT only directly observed variables,**

  iii) **provides a flexible tool for testing both direct and indirect paths of ecological structures and identify the importance of their role**

- **Principal component analysis also has the ability to reduce a set of correlated variables to higher-order components but has a limited flexibility to specify the model structure prior to the analysis and does not account for measurement error**

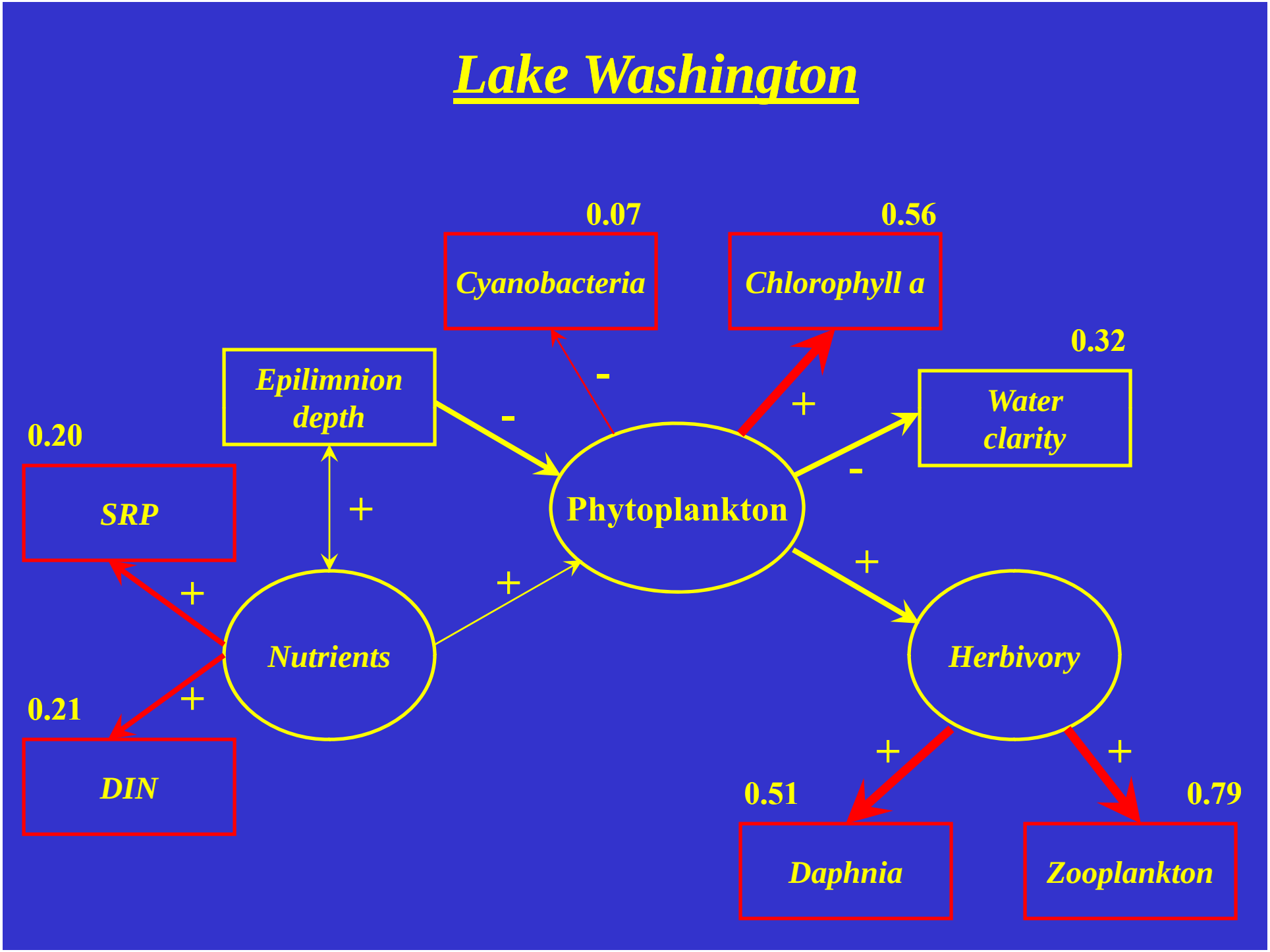
"…Thinking only in terms of directly observable variables confines our horizons and limits our assessment of complex systems…."
Malaeb et al. (2000, pg 95)

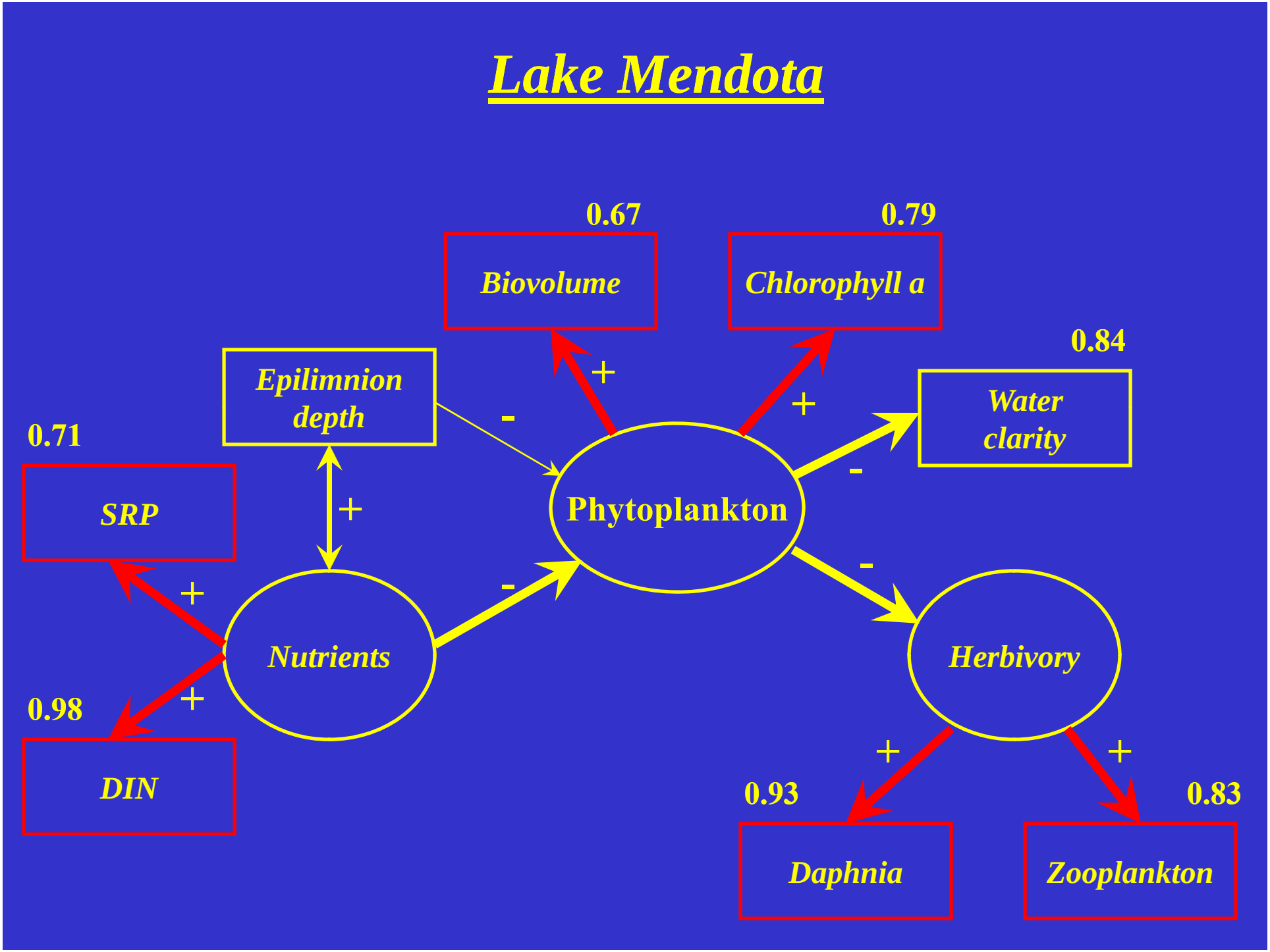
Application of Structural Equation Modeling

Lake Washington (mesotrophic environment)

Lake Mendota (eutrophic environment)

Lake Washington




Lake Mendota
0.67
Biovolume
0.79
Chlorophyll a
0.84
Water clarity
Epilimnion depth
0.71
SRP
Phytoplankton
Nutrients
Herbivory
0.98
DIN
0.93
Daphnia
0.83
Zooplankton
+
-
+
+
-
+
-
+
+
+
+

Bayes' Theorem

$$p(\theta|D) \propto p(\theta)\, L(D|\theta)$$

Posterior belief on θ after observing the new data

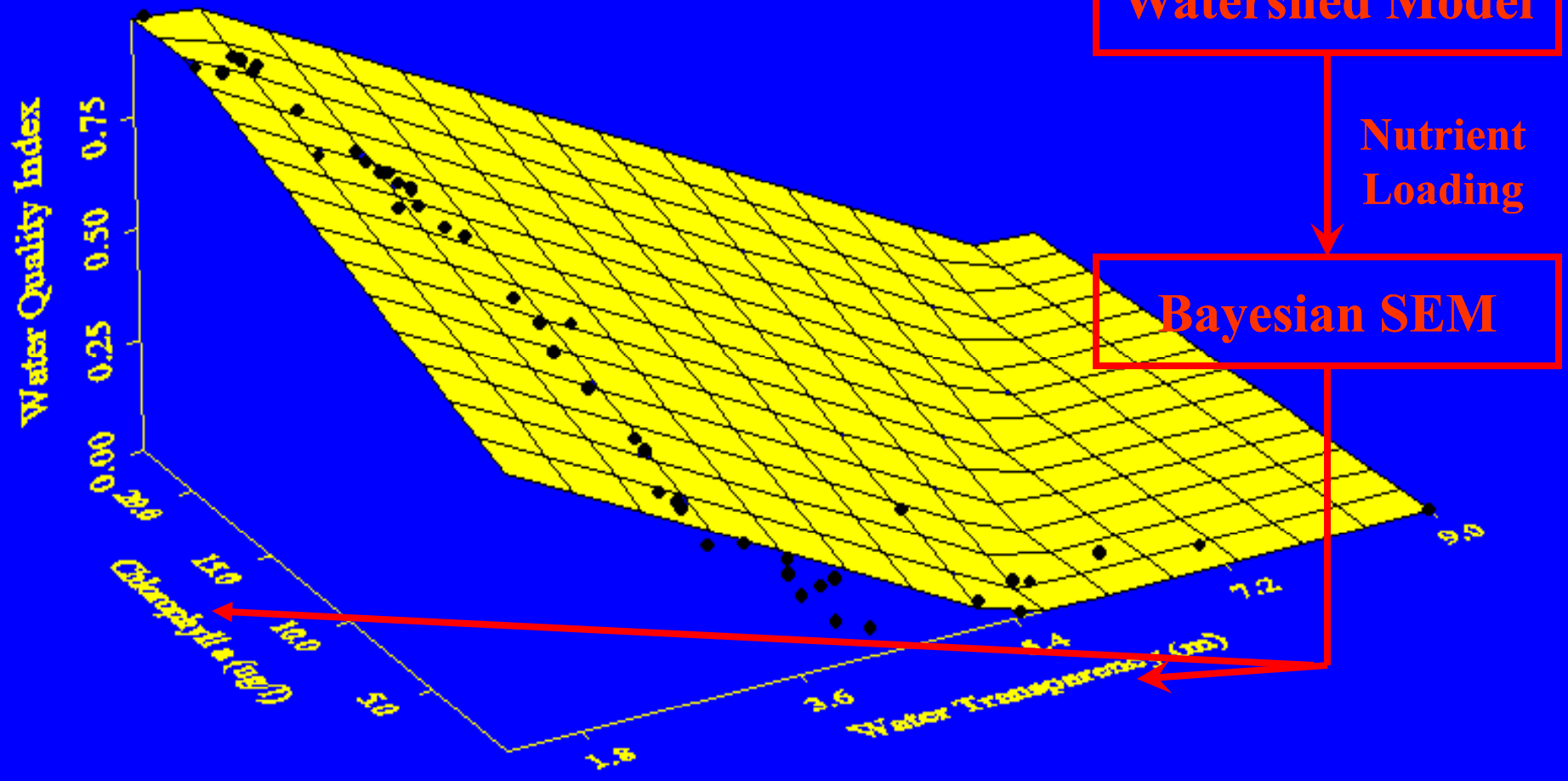
Prior beliefs on θ

***likelihood function*: used to update the prior beliefs on θ to account for the new data**

Sequential updating

- **Repeated use of the Bayes' Theorem**
- **Current posterior becomes prior when new data are available**

- Realistic ecological structures subject to sequential updating with routinely monitored environmental variables
- Predictions that account for the uncertainty in both model parameters and predictions



Follow-up studies

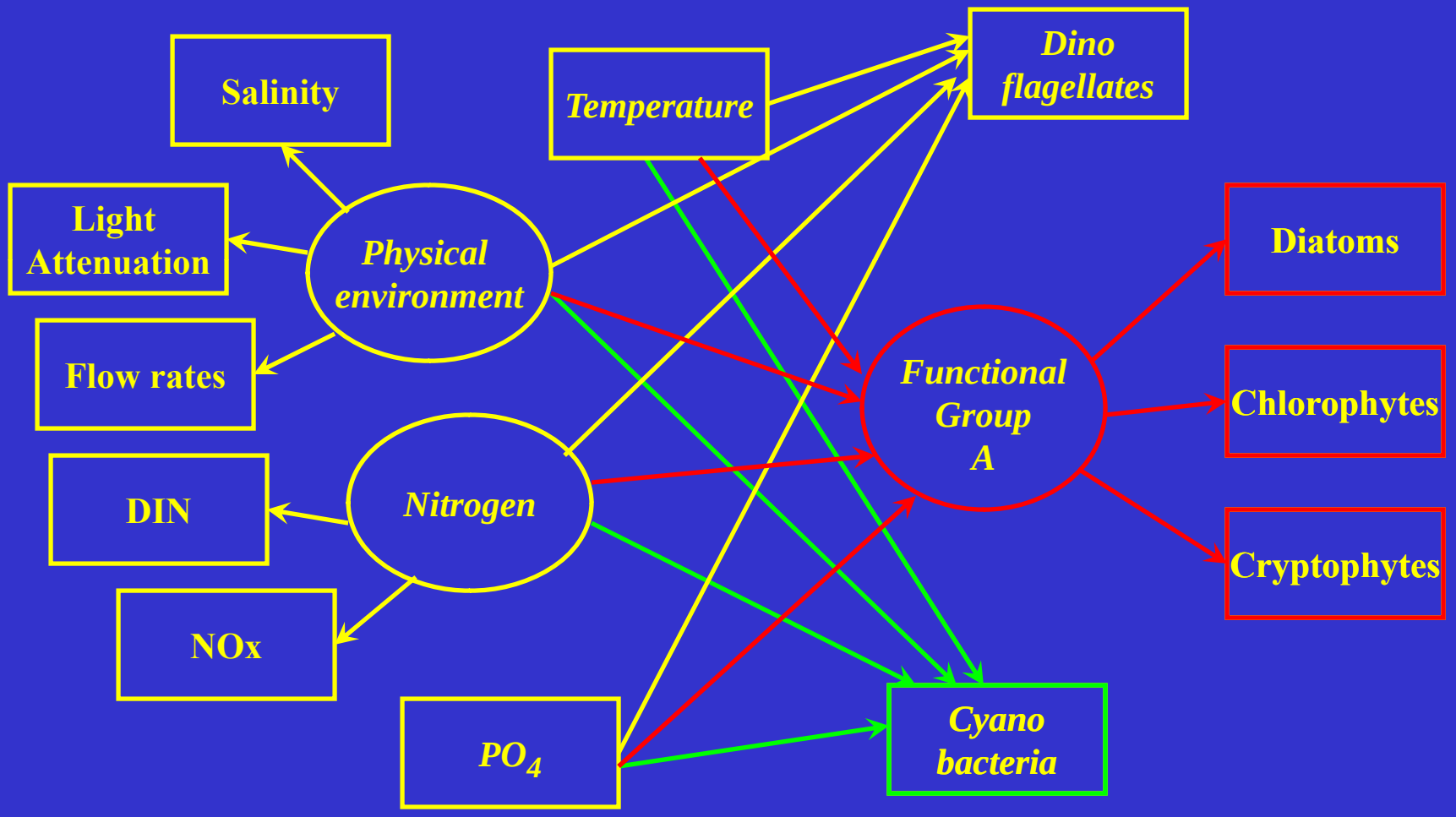
A framework that tests the compatibility of different pre-conceptualizations of the phytoplankton community structure with the observed ecological patterns.

Determination of the optimal phytoplankton community aggregation level

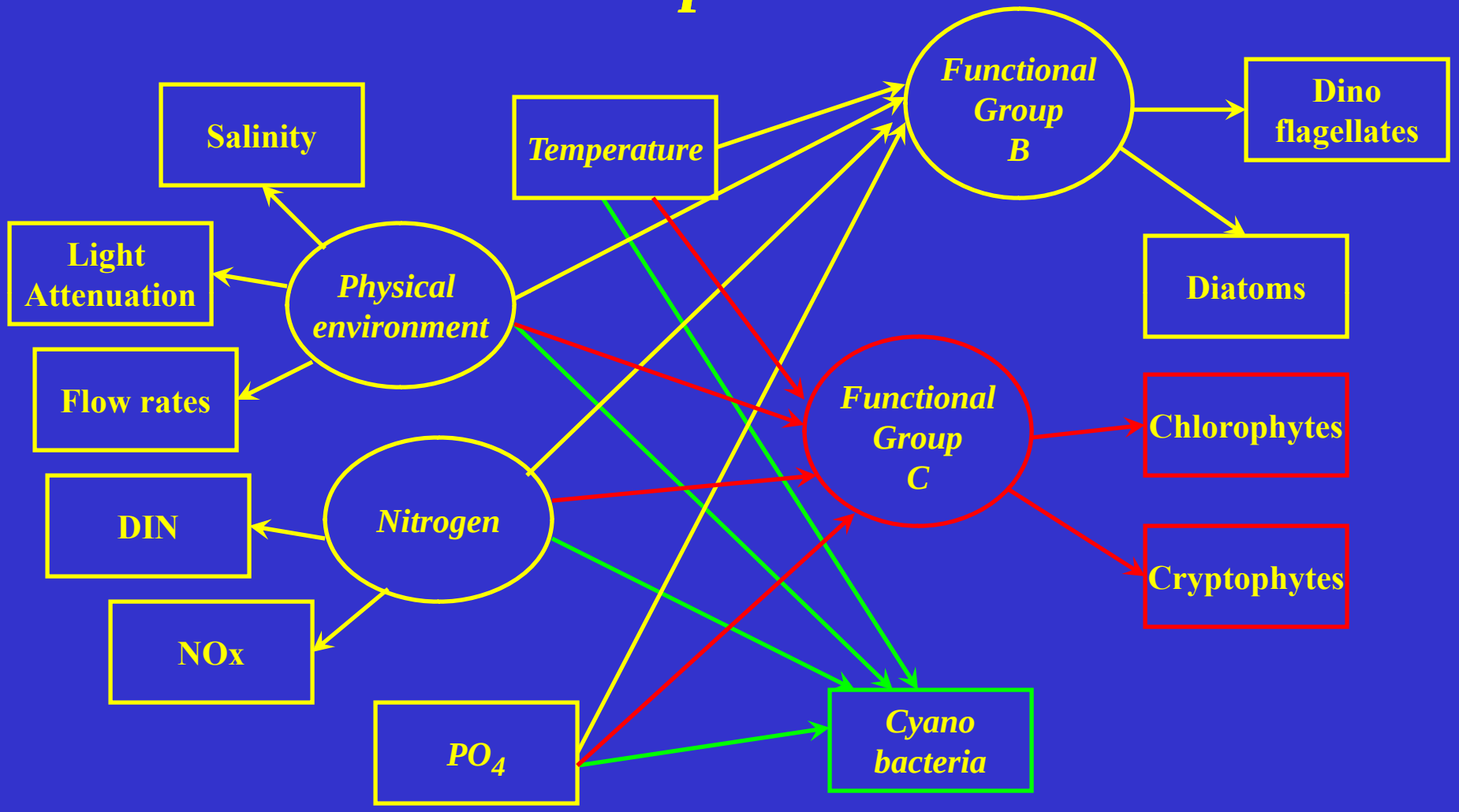
Future perspectives

Flexible modeling tool for biodiversity studies

Hypothesis 1 for the phytoplankton community composition



Hypothesis 2 for the phytoplankton community composition



References

1) Arhonditsis, G.B., Stow, C.A., Steinberg, L.J., Kenney, M.A., Lathrop, R.C., McBride, S.J., Reckhow, K.H. 2006. Exploring ecological patterns with structural equation modeling and Bayesian analysis. Ecological Modelling, 192 (3-4): 385-409

2) Arhonditsis, G.B., Stow, C.A., Paerl, H.W., Valdes-Weaver, L.M., Steinberg, L.J., Reckhow, K.H. Delineation of the role of nutrient dynamics and hydrologic forcing on phytoplankton patterns along a freshwater-marine continuum. Submitted Manuscript.