TMDLs and Statistical Models

Kenneth H. Reckhow

Duke University

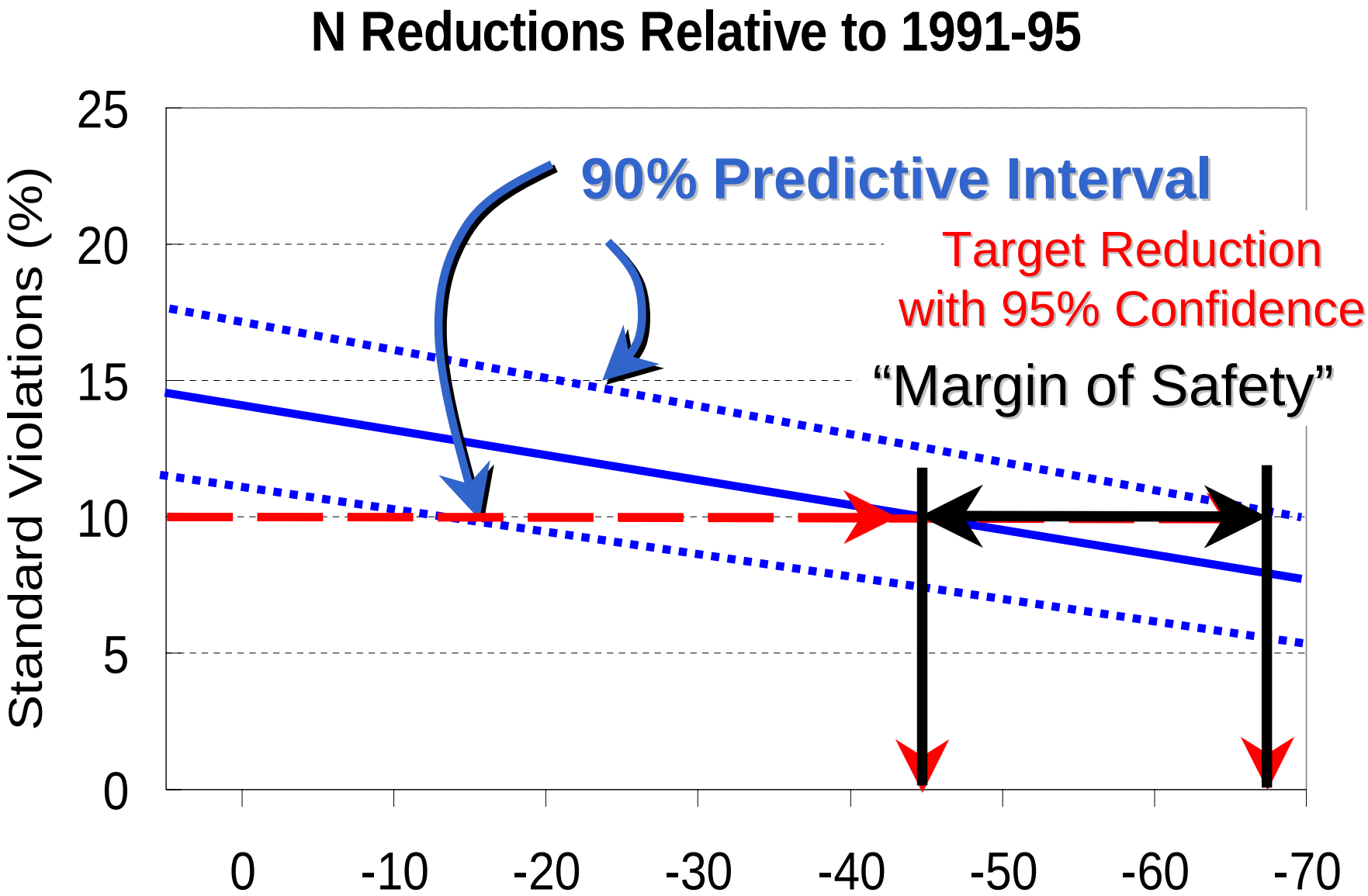
TMDL Applications

- **Forecast and establish initial pollutant allocation**

Forecasting

The problem with water quality forecasting is that we're not terribly good at it.

Result: prediction uncertainty is high


N Reductions Relative to 1991-95
Standard Violations (%)
25
20
15
10
5
0
0
-10
-20
-30
-40
-50
-60
-70
90% Predictive Interval
Target Reduction
with 95% Confidence
“Margin of Safety”

TMDL Applications

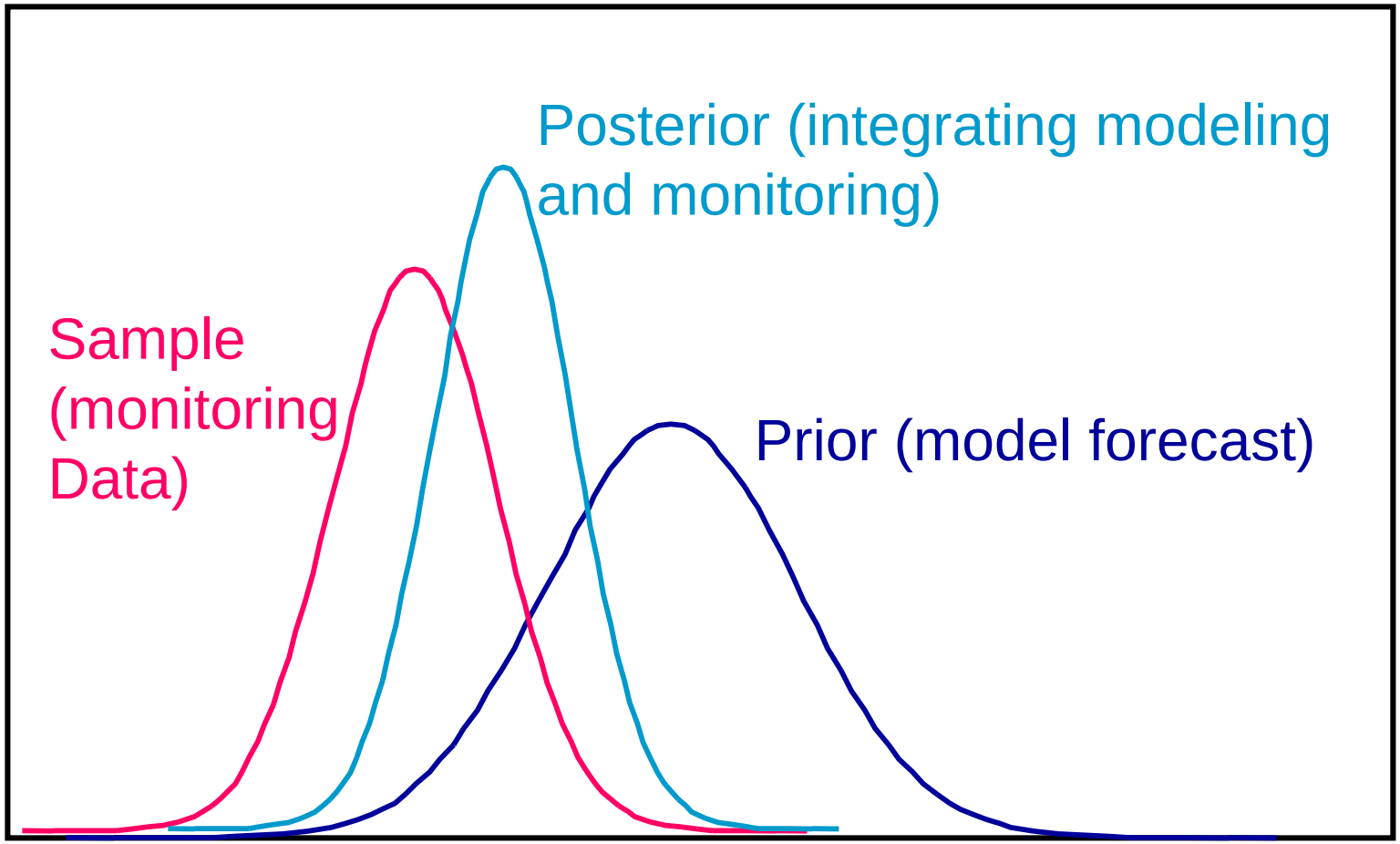
- Forecast and establish initial pollutant allocation
- **Update and modify through adaptive implementation**

TMDL Implementation

- TMDLs should be adaptive

- Modeling approaches need to be developed that integrate model forecasts with post-implementation monitoring (e.g., Bayesian analysis, Kalman filter, data assimilation).

Adaptive Implementation: Bayesian Analysis



Bayes (Probability) Networks

Conditional probability models that can be mechanistic, statistical, judgmental use probability to express uncertainty use Bayes theorem for adaptive implementation updating.

The Negative Effects of Excessive Nitrogen in an Estuary

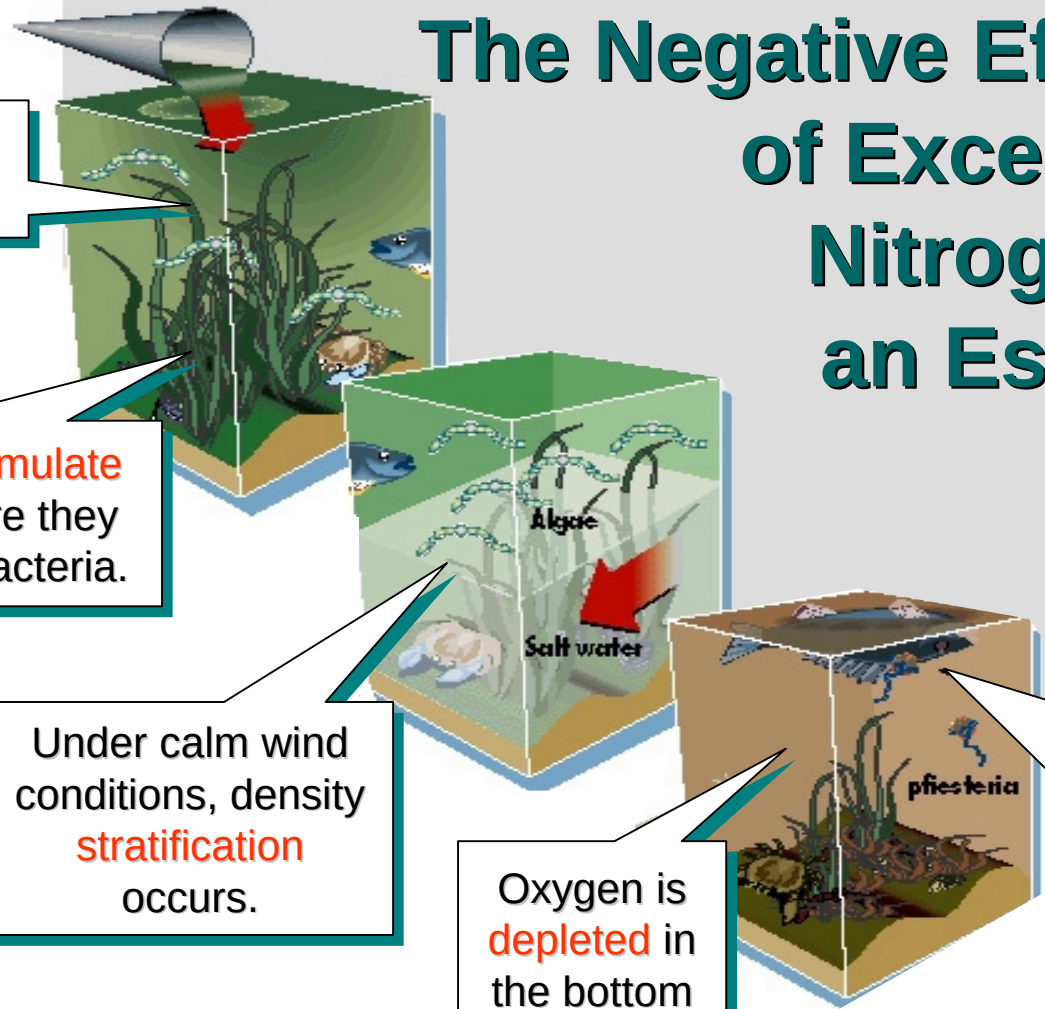
Nitrogen stimulates the growth of algae.

Algae die and accumulate on the bottom where they are consumed by bacteria.

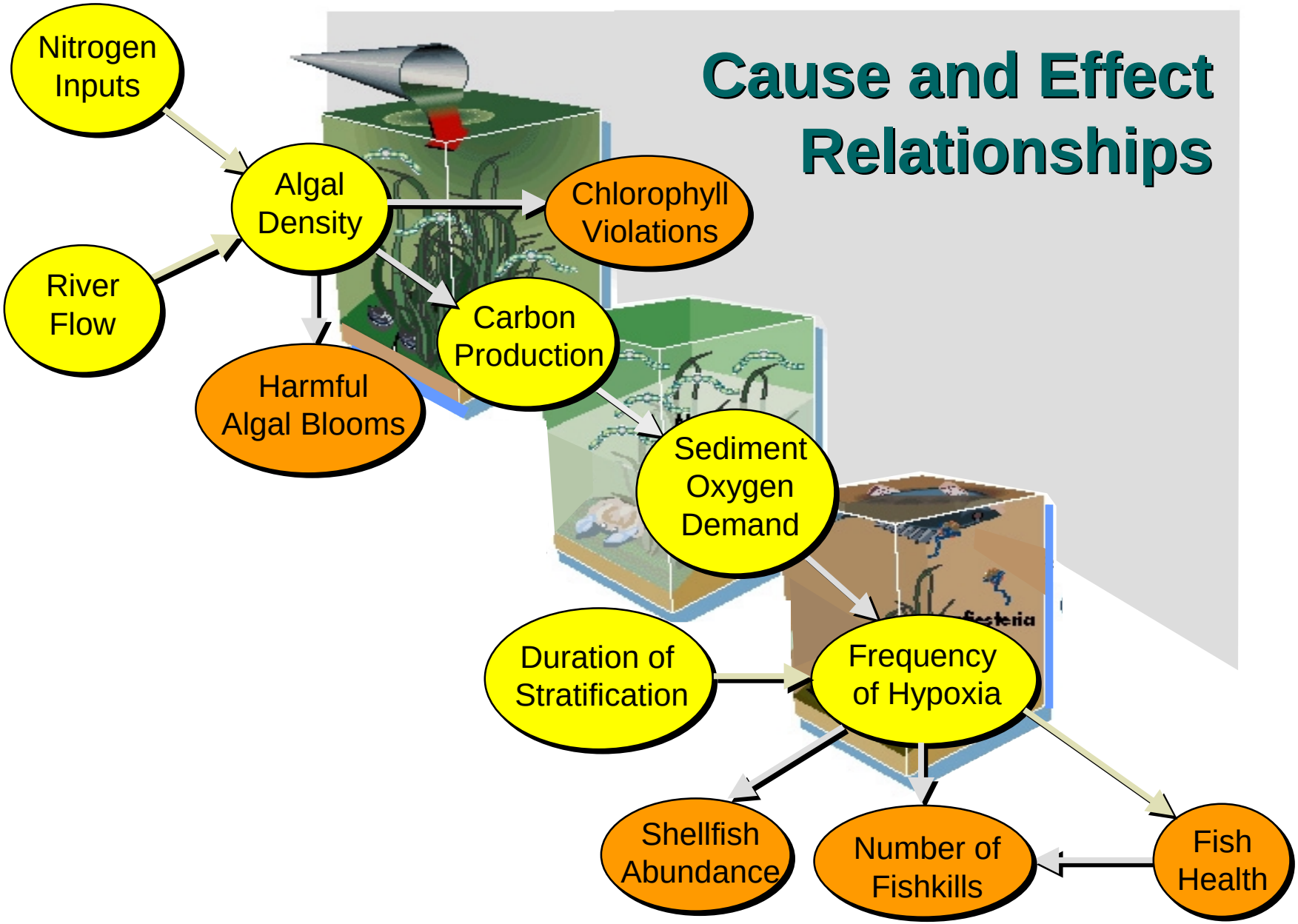
Under calm wind conditions, density stratification occurs.

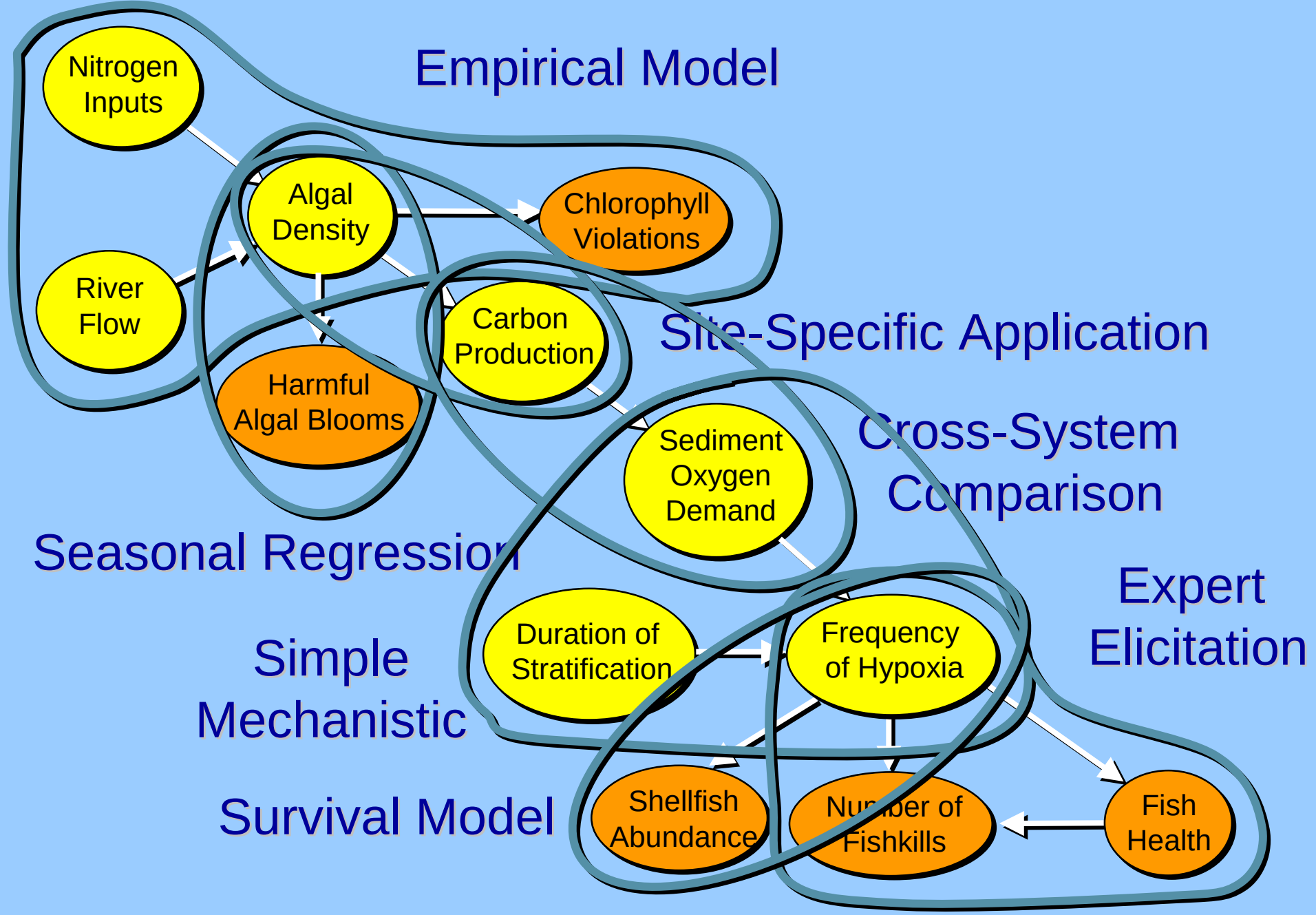
Oxygen is depleted in the bottom water.

Fish and shellfish may die or become weakened and vulnerable to disease.



Cause and Effect Relationships




Empirical Model
Nitrogen Inputs
Algal Density
Chlorophyll Violations
River Flow
Carbon Production
Harmful Algal Blooms
Site-Specific Application
Cross-System Comparison
Sediment Oxygen Demand
Seasonal Regression
Expert Elicitation
Duration of Stratification
Frequency of Hypoxia
Simple Mechanistic
Survival Model
Shellfish Abundance
Number of Fishkills
Fish Health

Research Opportunities

- With SPARROW linked to a waterbody model, post-implementation monitoring could be designed for Bayesian updating.
- This would allow more accurate assessment of the effectiveness of NPS controls, and targeting of BMP improvements.