Multiple Water Quality Models to Inform TMDL Decision Making in the Neuse River Estuary

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Massive fish kill hits Neuse

Organic material and sewage cause oxygen levels to drop below what fish and crabs need to live.

Neuse plan clears hurdle, but goals in dispute

Environmental groups say the proposal should reduce pollution by 30 percent. Other officials don't want such a firm commitment.
Low DO and Fish Kills: 94-96

Neuse River Bloom Project
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Neuse River Estuary

Dissolved Oxygen (mg/liter) in BOTTOM WATERS of the Neuse River Estuary

Documented Fish Kill
from NCDEHNR DWO Database

Cherry Point

Streets Ferry

Kilometers

WINTER 1994
SUMMER 1994
WINTER 1995
SUMMER 1995
WINTER 1996
SUMMER 1996
WINTER 1997
Neuse River Estuary

NEUSE RIVER ESTUARY

New Bern
Trent River
CROATAN NATIONAL FOREST

Upper Broad Creek
Goose Creek
Arapahoe
South River

Hancock Creek
Cherry Point
Havelock

Back Creek
Adams Creek
Clubfoot Creek

Pamlico Sound

20 Miles
20 KM
The problem with water quality forecasting is that we’re not terribly good at it.

Result:
Prediction uncertainty is likely to be quite high but is also likely to be unknown.
How do you want it – the crystal mumbo-jumbo or statistical probability?
“There’s a 50% chance of rain, so I only watered half the lawn.”
8 DAY OUTLOOK

TUE  WED  THU  FRI  SAT  SUN  MON  TUE
49   46   58   73   75   73   70   70
35   34   48   53   55   53   55

80%  70%  40%  50%

Much Warmer
Is Scientific Knowledge Sufficient for Environmental Decision Making?

*There is almost always enough scientific knowledge to make an informed decision.*

How Can Limited Scientific Knowledge Support Environmental Decision Making?

*It depends… on the amount of scientific uncertainty and the attitude toward risk.*
How do/should we make decisions when knowledge is uncertain?

How can knowledge of scientific uncertainty improve decision making?
Decision Analysis Provides a Prescriptive Approach for Informing Decision Making Under Uncertainty

• Probability model – this characterizes (scientific) knowledge; for example, this represents the prediction from a water quality model. Since it is probabilistic, it must include uncertainty analysis.

• Utility function – this characterizes the values of the decision makers (or stakeholders).
In theory, the *optimal* decision is found by integrating the probability model with the utility function.

This integration weights the utility (value) function by the probability of various outcomes.

This allows a risk-averse decision maker (through the utility function) to hedge against large losses.

Only when the uncertainty in the scientific assessment (e.g., a WQ model) is determined, can the decision maker explicitly consider attitude toward risk.
Three Different Models were Applied

- CE-QUAL-W2 (NEEM; 2-dimensional)
- EFDC-WASP (3-dimensional)
- A Probability Network Model (Neu-BERN)
Neuse Estuary Eutrophication Model

- **Rivers, Creeks, Groundwater**: Loadings
- **Atmosphere**
- **Exchange**
- **Pamlico Sound**: Exchange

**Neuse River Estuary**
- **Inorganic Sediments**
- **Nutrients**
- **Dissolved Oxygen**
- **Sediment Exchange**

**Growth/Mortality/Recycling**
- **Algae**
- **Organic Matter**
- **Inorganic Carbon**

**Estuarine Circulation**
- **Vertical Mixing**

**Benthic Organic Matter**
**Sediments**
Each conditional distribution can be represented by a separate sub-model.

\[ p(C|N) = p(C|A) \cdot p(A|N,R) \cdot p(R) \]
For the Neuse, the Bayes Network (BN) Model Complemented the Two Mechanistic Models.

• While the BN could not provide the space/time resolution of a detailed mechanistic model to evaluate dissolved oxygen and other small-scale outcomes, it is probabilistic and highly flexible in structure.

• The probabilistic nature of a BN means that prediction uncertainty could be estimated; also, the BN flexibility allows extension of the model for probabilistic prediction of endpoints concerning fish and shellfish.