Linking Pollution to Water Body Integrity - First Year of Research

Vladimir Novotny
CDM Chair Professor
Northeastern University

STAR WATERSHED PROJECT
FUNDED BY USEPA 2003-2007

Development of Risk Propagation Model for Estimating Ecological Response of Streams to Anthropogenic Stresses and Stream Modification

- Project Team
  - PI - Vladimir Novotny, NEU Center for Urban Environmental Studies
  - Co-PI's NEU CUER
    - Elias Manolakos
    - Ferdinand Hellweger
    - Ramanitharan Kandiah
  - Co-PI Univ. of Wisconsin Milwaukee
    - Timothy Ehlinger
  - Co-PI Marquette University
    - Neal O'Reilly
  - Co-PI Illinois State Water Survey
    - Alena Bartosova
  - 5 graduate students

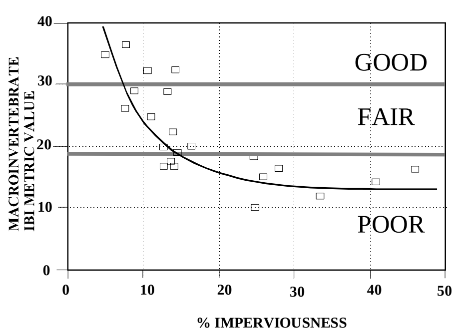
Project objectives

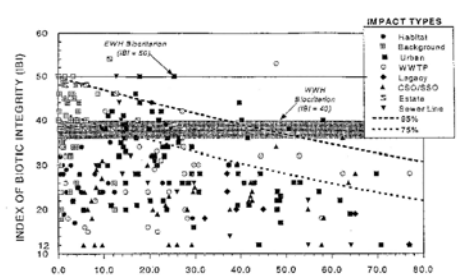
- A model that will include stresses such as
  - Pollutant inputs
  - Watershed and water body modification
    - Land use changes
    - Chanelization and impoundments
    - Riparian corridor modifications
- Development of a quantitative layered risk propagation from basic landscape and watershed stressors to the biotic IBI endpoints
- Study the possibility of mitigating the stresses that would have the most beneficial impact on the biotic endpoints
- Apply the model to another geographic region

NUMERIC INDICES OF BIOTIC INTEGRITY

- Fish
- Benthic macroinvertebrates
- Physical - Habitat

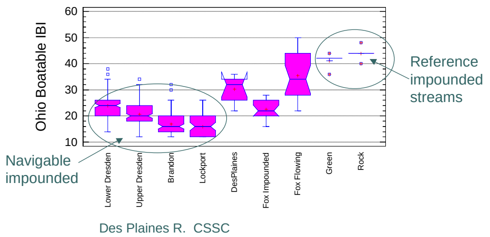
SIMPLISTIC RELATIONSHIPS





A more realistic relationship of IBI to a single stressor Yoder

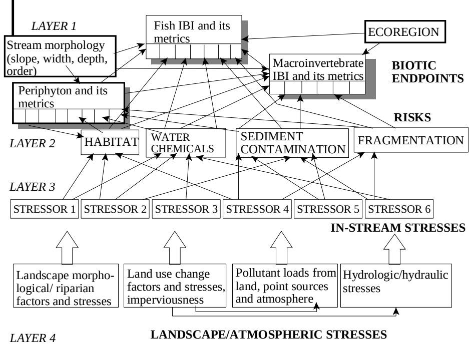
Impact of pollutants and channel modification Northeast Illinois Rivers



Model Development

- Analyze individual risks of stressors
- Assemble a large data base
  - Midwest (Illinois, Wisconsin, Ohio)
- Define structural and functional components of the model
- Develop a layered hierarchical model
- Assemble a data base for testing and transferability of the model (e.g., Charles River)
- Test the model and its *a priori* predictability

STRUCTURAL AND FUNCTIONAL MAZE



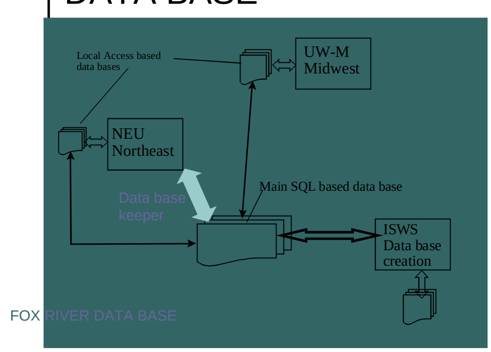
RISKS

- Pollutant (chemical) risks, acute and chronic, in the water column
  - Key metrics: Priority (toxic) pollutants, dissolved oxygen, turbidity (suspended sediment), temperature, pH.
  - Variability: flow , DO, temperature
- Pollutant risk (primarily chronic) in sediment
  - Key metrics: Priority pollutants, ammonium, dissolved oxygen in the interstitial layer (anoxic/anaerobic or aerobic), organic and clay content
- Habitat degradation risk
  - Key metrics: Texture of the sediment, clay and organic contents, embeddedness, pools and riffle structure, bank stability, riparian zone quality, channelization and other stream modifications
- Fragmentation risk
  - *Longitudinal* - presence of dams, drop steps, impassable culverts
  - *Lateral* - Lining, embankments, loss of riparian habitat (included in the habitat evaluation), reduction or elimination of refugia
  - *Vertical* - lack of stream - groundwater interchange, bottom scouring by barge traffic, thermal stratification/heated discharges, bottom lined channel

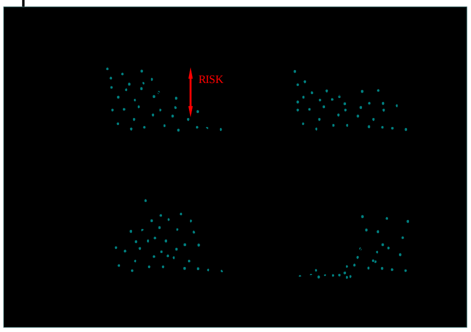
Fragmentation Risk

Fragmentation can result from any factor (biotic or abiotic) that causes decrease in the ability of species to move/migrate among sub-populations or between portions of their habitat necessary for different stages of their life (e.g spawning migrations) and it can be both physical (e.g., biologically impassable culverts, dams, waterfalls, road crossings and bridges) and caused by pollutants (e.g., localized fish kills or a polluted mixing zone without a zone of passage or a thermal plume or stratification).

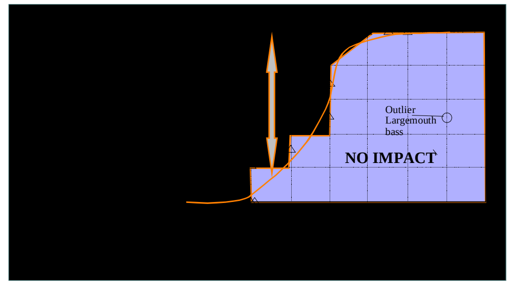
DATA BASE



Functional components
Maximum Species Richness



Stressor – Endpoint Relationships
Fish vs. Dissolved Oxygen



Example of simple risk model

Probability of taxa survival

$$p_E^{(taxa)} = \prod_{i=1}^{N} \left(1 - p_S^{(taxa|hab\_i)}\right)$$

$$ICI = a p_E^{taxE} + b p_E^{gavg} + cWQ_c + dSed + e$$

where p_E $^{(taxa)}$ is the joint probability of taxa extinction, *pS(taxa|hab_i)* is the probability of taxa survival due to habitat condition *I* and *N* is the total number of habitat characteristics influencing the taxa.

The Model (additive risks)

$$ICI = a p_E^{taxE} + b p_E^{gavg} + cWQ_c + dSed + e$$

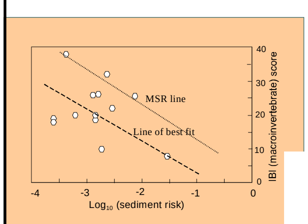
ICI = index of biotic integrity (macroinvertebrate)

p_E^{taxE} and p_E^{gavg} = respective risks due to habitat impairment to mayfly taxa and a geometric mean of all habitat risk components respectively

WQ_c = the summation of chronic risks due to water column contamination

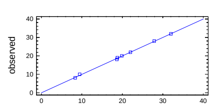
Sed =is the summation of the chronic risks due to contamination of sediments

Single vs. multiple stressor/IBI relationship

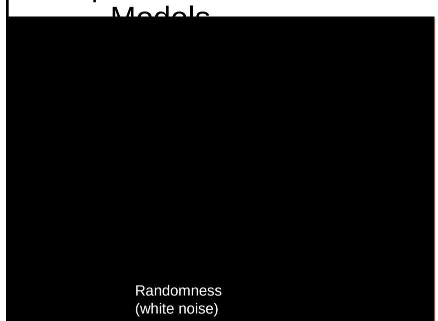


Single stressor effect

Multivariate model – predicted and calculated from observed metrics – Regional data – Southeastern Wisconsin



Artificial (Feed forward/backward) Neural Nets or More Advance Learning Models

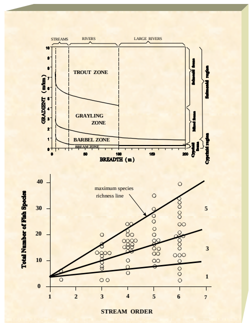


Network based schemes which can flag the formation of parameter patterns that start affecting severely metrics that contribute to IBI

CATEGORIZATION OF STRESS

- Stream Classification
  - Rosgen morphological
  - Stream order
- Ecoregional
  - Reference water bodies
- Hydraulic modification
  - Natural
  - Impounded
  - Channelized
  - Navigation
- Chemical risks
  - Water
  - Sediment
- Etc.

Linked to the Habitat risk and IBI metrics



USE OF THE MODEL

- Watershed and water/body vulnerability classification (another project)
- Assist watershed manager with selection of priority watersheds
- Development of watershed wide best management practices
- Watershed mapping based on vulnerability
- TMDL

Northeastern University established Center for Urban Environmental Studies

www.coe.neu/environment

novotny@coe.neu.edu

First year accomplishments

- Interdisciplinary team was formed
  - Northeastern University
  - University of Wisconsin/Marquette University
  - Illinois Water Survey
- Two Technical Review Reports
- Methodology was developed
- Data Base development
- Four review publications submitted