Linking Watersheds and Landscapes to Aquatic Ecosystems

The Lower Fox River Watershed Monitoring Program
High School Summit: March 9, 2005

The Answers We Find Depend on the Questions We Ask. Finding solutions to today's problems will require new ways of thinking about those problems → Recognizing connections among parts!

Making “Connections - First Step:
Understanding the Hydrologic Cycle

- The Great Connector...
  - Dissolved and Suspended Material
- The Water Cycle ...
  - Atmosphere
  - Precipitation
  - Surface Runoff
  - Infiltration
  - Groundwater
  - Evapotranspiration

Second Step:
Understanding Spatial and Temporal “Scale” of Patterns, Processes and Change
Geological & Ecological Time

- Glacial History
  - What we see today is in great part dependent upon events that happened in the past.
- Ecological Connections
  - What we will see in the future is influences by events today

The Concept of “Landscape”

- Geological
  - Land
  - Water
- Biological
  - Ecoregions
  - Adaptation
  - Migration
  - Extinction
- Human
  - Social - Cultural
  - Economic

Human Impacts on the Land: Land Use in the Great Lakes Basin

- Coniferous Forest
- Mixed Wood and Deciduous Forest
- Low-Intensity Farming / Pasture
- Urban Area
- High Intensity Farming / Pasture

Third Step:
Understanding the Connection between the Land and the Water

- The Watershed Concept
  - The land area that drains into a particular lake or river.
- Multidisciplinary “Teams” for Study and Management
Watersheds, Land Use, and Water

Continuum of Causes & Effects in Watersheds

Factors
Social & Economic  Natural Landscape

Patterns
Land Use

Abiotic Responses
Hydrology ⇔ Chemistry ⇔ Habitat

Biotic Responses
Primary Production
Benthic Invertebrates
Fish Community

Urbanization & the Loss of Fish Species - Southeastern Wisconsin

Land use Changes & Water Quality
Infiltration and Surface Runoff

From Wang et al. 1997

Number of fish species vs. Impervious Surface in Watershed (%)

Number of fish species
0 10 20 30 40

Impervious Surface in Watershed (%) 0 10 20 30 40 50

From Wang et al. 1997

1970

1997

Graph showing the relationship between the number of fish species and the impervious surface in the watershed.
Urbanization = Impervious Surface:  
Low levels of urbanization increase runoff

High levels of urbanization

Effects of Impervious Surface:  
High levels of urbanization

Stream Basics ...  
The Hydrograph

Stream Flow (Q)

“Developed”
✓ Rapid Rise & Fall  
✓ Higher Peak Flow  
✓ Lower Base Flow

Rain Storm  
Days →

Effects of Urbanization on Stream Biological and Habitat Integrity

- Increased Peak Flow during Storms
- Increased Bank Erosion
- Decreased Base Flow and dry Streams
- Decreased Water Quality
- Degradation of Stream Substrates
- Habitat Loss & Fragmentation
- Species Loss - Fish, Invertebrates, Plants
Agricultural Impacts: Non Point Pollution: Nutrients and Sediment

Milwaukee Harbor after heavy rain

Nutrients, Algae, and Dissolved Oxygen

Forested – Agricultural - Urban

Dissolved Oxygen (mg/l)

Nichols Creek
Quaas Creek
Lincoln Creek

The Clean Water Act
TIME TO KEEP THE PROMISE
Goals Clean Waters Act (CWA)

- In Section 101(a) of the federal Clean Water Act (CWA), it is stated that it’s the "Congressional declaration of goals and policy" to achieve the "Restoration and maintenance of chemical, physical and biological integrity of Nation’s waters…"

The 3 Dimensions of Ecological Integrity (CWA)

- Physical Integrity
- Chemical Integrity
- Biological Integrity

Ecological Integrity

Effects of Stress on Components of Biological Integrity

- Biological Condition
- Stressor Gradient [Effect of Human Activity]
- Native Species
- Highly Tolerant Species
- Intolerant Species
- Deformities and Anomalies

Fish Index of Biotic Integrity (IBI)

Tributary 2003 and 2004 Summer Sampling

- Contribution to IBI
- Fish abundance
- Ephemera
- Mayflies
- Sedges
- Spiders
- Leeches
- Insectivore
- Sunfish
- Tullibee
- Darter
- Native species
- Non-native species
Aquatic Macroinvertebrates

Finding Solutions: Understanding Watershed Risks

- **Basic Stress**
  - Regional:
    - Atmospheric deposition
    - Land conversions
    - Wetland damage
    - Intensive agriculture
    - Urban land use
  - Local:
    - Impervious surfaces
    - Point source discharges
    - Construction
    - Traffic
    - Fertilizers
    - Deicing chemicals
    - Channel modifications

- **Impact in Stream**
  - Physical Habitat
    - Flow, Velocity, Bank erosion, Siltation, Embeddedness, Vegetation loss, Loss of floodplains and Riparian Zones
  - Water Quality
    - Toxin concentrations, Temperature, pH, Dissolved oxygen, Nutrients
  - Sediment Quality
    - Pore water toxicity

- **Risk Measurement Endpoint**
  - Habitat Loss / Degradation
  - Population Fragmentation
  - Acute & Chronic Toxicity to Aquatic Species
  - Chronic Toxic Effects on Benthic Species

- **Biological Assessment Endpoint**
  - Fish Growth, Survival, Reproduction, Tissue Contamination, Community Composition (IBI)
  - Aquatic Benthic Macro-Invertebrate Communities

World-wide Issues
Sustainability and Economic Development: Biodiversity, Conservation and Ecology in Romania

- **Historical “Crossroads”** since 750 BC
- **Recent History**
  - Communist Dictatorship
    - 50 Years until 1989
- **Environmental Problems**
  - Industrial Toxins
  - Water Quality
  - Deforestation
- **Ecological Treasures**
  - Carpathian Mountains
  - Danube Delta
  - Black Sea Coast

Carpathian Mountains: UN Designated Bio-Reserve
Transylvania
- Cultural and Historical Nexus
  - Hungarian
  - German
  - Ottoman

The Danube Delta: World Biosphere Reserve

Complex Environmental Issues
- Urban Expansion
  - Creation of “suburban” lifestyle is being promoted to increase property values, growth and economic expansion

- Agricultural “Modernization”
  - Consolidation and expansion of small farms to use “mechanized” farming methods
Small Farm Agricultural Economy

- Average Farm 2.3 hectares in 1995
- USAID Goal of 55 ha by 2005
- ?? Consequences ??

Solutions Seldom Are Simple:
Example: Loss of Tropical Rainforests

- 80% of world species on 8% of the land
- The Most "endangered" Ecosystem in the world
  - 0.7% loss per year

Loss of Forests in Tirimbina Preserve:

1980 2000

Land use Changes in Sarapiquí Costa Rica

- Increases in large banana and pineapple farms
- Small Farms switching from coffee to cattle ranching
Ecology and Global Economics of Coffee

Sustainable Ecosystems
How will we balance the connections between the ecological and economic equations?