Ecological Risk Assessment and the Tittabawassee River, Why, How and Who Cares

Chippewa Nature Center, April 13 2006

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Michigan State University
Special Thanks to
Chippewa Nature Center

>55 Participating Landowners

Shiawassee National Wildlife Refuge

Mike Bishop
Alma College

Dow Chemical Company
Objectives of presentation

- Explain ecological risk assessment
- What are they used for and by whom?
- What information is typically collected?
- A description of MSU wildlife studies
Useful Definition of Risk

- The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment (Society for Risk Analysis)
Risk Decisions

- Humans make risk management decisions all the time
  - Risk of adverse effects is never zero
  - Almost every decision has associated risk (even no decision)
- Direct risks to humans more easily understood than risks to the environment
Ecosystem and Human Health Risk Assessment

Underpinnings very different

- Human health risk assessment, protecting the individual (1 in a million)
- Ecological risks assessment, protecting populations, communities and ecosystem function
How do HHRAs and ERAs deal with uncertainty?

- Precautionary Principle
- Data collection intensity, time, space, replication
- Multiple Lines of evidence approach
Uncertainty vs. Data

More Uncertainty

Protective

Data

Assumptions

Population Health Threshold

More Certainty

Predictive

Uncertainty
Three lines of evidence

- Dietary exposure assessment
- Tissue based exposure assessment
- Population health measurements
USEPA Definition of Ecological Risk

The likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors

Exposure: The experience of coming into contact with some environmental condition or influence.

Stressor: An activity or experience (chemical, physical, biological) that has the potential to cause stress.

Receptor: Ecological value to be protected
Very Brief Toxicology 101

☑ Elements of toxicology:

☑ **Exposure** - very important - without exposure, no risk

☑ **Dose-response** relationships

☑ “The dose makes the poison” - paraphrased from Paracelsus (1534)
Exposure $\times$ Effects = RISK

Analysis

- Frequency
- Exposure
- Toxicity
- Risk
- Concentration
A Ecological Risk Assessment Provides:

- Clear and consistent risk characterization of valued endpoints
- Systematic means of quantifying, comparing and prioritizing risks (and solutions)
- Basis for risk-benefit and risk management decisions
- A transparent process (credibility)
- Understanding by all interested parties (stakeholder input)
Exposure characterization

ANALYSIS

Effect characterization

Problem Formulation and Hazard Identification

Exposure characterization

Risk Characterization

RISK ASSESSMENT

RISK MANAGEMENT

Planning

DATA GATHERING

Laboratory toxicological studies

Extrapolation methods

Measurements of exposure and dose

Epidemiology and population-level studies

Research needs identified

Development of regulatory options

Identification of mitigation options

Evaluation of public health, environmental, economic, social, and political consequences of regulatory options

Regulatory decision

Risk communication

Research needs identified
Ecological risk assessment

Planning

Problem Formulation and Hazard Identification

ANALYSIS

Effect characterization
Exposure characterization

Risk Characterization
ERA Planning

- Identify Interested Parties (Stakeholders): Regulators, Industry/Developers, Environmentalists, Public, Community, Non-government organizations, Scientists, Engineers, Bureaucrats, Politicians

- Identifying Hazards (stressors): Chemical, Physical, Biological, Habitat loss

- Stressor Characteristics: Intensity, Duration, Frequency, Timing, Boundary
Ecological risk assessment

Planning

Problem Formulation and Hazard Identification

ANALYSIS

Effect characterization

Exposure characterization

Risk Characterization
Problem Formation

- Develop conceptual site Model
- Identify assessment and measurement endpoints
- Develop analysis plan
Conceptual Site Models

(connection between the stressor and the receptor?)

- Development of working hypotheses as to how the stressor might affect components of the ecosystem
- Are there complete exposure pathways between sources and receptors?
- Can be a schematic, illustration, or text
Aquatic Exposure Pathways

- Tree swallow
- Aquatic emergent insects
- Sediments
- Kingfisher
- Great blue heron
- Fish
- Crayfish
- Frogs
- Aquatic vegetation
- Benthic insects

Conceptual Site Model
Dual Exposure Pathways

- Mink
- Great horned owl
- Small mammals
- Fish
- Crayfish
- Frogs
- Mink
- Terrestrial insects
- Aquatic vegetation
- Muskrats
- Swallows
- Benthic insects
- Aquatic emergent insects
- Sediments
- Soils
- Small mammals
- American robin
- Terrestrial insects
- Soils
Assessment Endpoints:

- Explicit expressions of the actual value that is to be protected. These are the ultimate focus in risk characterization and act as a link to the risk management process (such as the policy goals).

  example - population sustainability and reproductive success of Blue birds
Assessment endpoints must have the following characteristics:

- Ecologically relevant
- Susceptible to the stressor
- Societal value - T&E species, recreationally important species
- Unambiguous
**Measurement endpoints:**

- Measurable variables which are related quantitatively or qualitatively to the assessment endpoints

**Example** - Concentrations of contaminants in the eggs of Great Horned Owls; number of GHO nestlings fledged/nest.
Measurement endpoints should have the following characteristics:

- Relevance to an assessment endpoint
- Consideration of indirect effects
- Sensitivity and response time
- Diagnostic ability
- Practicality issues
Ecological risk assessment

Planning

Problem Formulation and Hazard Identification

ANALYSIS

Effect characterization
Exposure characterization

Risk Characterization
Exposure Assessment

- To what extent are our receptors exposed
  - Route
  - Intensity
  - Duration
  - Frequency

- What are the site-specific physical and chemical conditions affecting exposure?
Effect Assessment

- Dose response relationship (toxicity)
  - Literature review (Field or Laboratory studies)
  - Controlled laboratory study (dose response)

- How much exposure is tolerable (safe level)?

- What level of exposure results in adverse effects (how much is too much, and what effects should we look for)?

- Population health measurements (site-specific study)
Ecological risk assessment

Planning

Problem Formulation and Hazard Identification

ANALYSIS

Effect characterization
Exposure characterization

Risk Characterization
Exposure X Effects = RISK
Exposure characterization

Problem Formulation and Hazard Identification

Effect characterization

Exposure characterization

Risk Characterization

RISK ASSESSMENT

DATA GATHERING

Laboratory toxicological studies

Extrapolation methods

Measurements of exposure and dose

Epidemiology and population-level studies

Research needs identified

RISK MANAGEMENT

Development of regulatory options

Identification of mitigation options

Evaluation of public health, environmental, economic, social, and political consequences of regulatory options

Regulatory decision

Risk communication

Ecological risk assessment

ERA Framework

Planning
Field Studies in Support of a Baseline ERA

Aquatic Toxicology Laboratory
Michigan State University

Dr. Matthew Zwiernik
Dr. John Giesy
Jeremy Moore
Dusty Tazelaar
Tim Fredricks
Sarah Coefield
Rita Seston
Mike Fales
Lori Williams
David Hamman
Emily Koppel
Melissa Palmer
The MSU Approach

- Utilize multiple lines of evidence
- Conduct research in an open and transparent manner
- Utilize local assets
- Provide data to all interested parties simultaneously
- Adhere to USEPA guidelines
- Work, live, collect and compare data from the Tittabawassee river drainage basin
Tittabawassee River Ecological Studies

- Food web dietary items
- Song birds
- Fish eating birds
- Raptors
- Migratory waterfowl
- Mink
Tittabawassee River Ecological Studies

Mink
Mink Study Design

Site-specific, Multiple-year, Multiple-line of evidence approach

- **Habitat suitability**

- **Dietary exposure assessment**
  - Determine dietary composition
  - Analyze identified dietary items for contaminants
  - Predict exposures

- **Tissue based exposure assessment**
  - Quantify contaminants in mink liver

- **Population health**
  - Abundance
  - Morphological measurements
    - Population demographics (sex, age, weight, length)
    - Nutritional status
    - Reproductive history (female)
    - Baculum length
    - Organ and jaw histology
### Habitat Suitability and Abundance

<table>
<thead>
<tr>
<th></th>
<th>Pine River</th>
<th>Chippewa River</th>
<th>Tittabawassee River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat Suitability</td>
<td>70%</td>
<td>59%</td>
<td>51%</td>
</tr>
<tr>
<td>100% = Excellent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0% = Poor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Mink / km</td>
<td>1.46</td>
<td>0.44</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Study areas have appropriate habitat and support mink year round.
Mink 1: Dietary exposure

- Stomach content analysis (presented)
- Scat analysis
Mink

2: Dietary exposure

Tittabawassee River site specific

- Fish: 52%
- Crayfish: 9%
- Muskrat: 19%
- Small Mammals: 8%
- Amphibians: 8%
- Vegetation: 4%
Study Design

Tittabawassee River Study Area
Ecological Risk Assessment

- Site 1
- Reference Area
- Site 2
- Midland, MI
- Target Area
- Site 3
- Site 4
- Site 5
- Site 6

0 2.5 5 10 15 Kilometers
Food Web Sampling
### Mink 2: Dietary exposure

<table>
<thead>
<tr>
<th>Prey item</th>
<th>Reference</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment</td>
<td>0.69</td>
<td>14.5 - 714</td>
</tr>
<tr>
<td>Forage fish</td>
<td>0.45</td>
<td>28.8 - 72.4</td>
</tr>
<tr>
<td>Muskrat</td>
<td>0.16</td>
<td>7.79 - 11.9</td>
</tr>
<tr>
<td>Crayfish</td>
<td>0.24</td>
<td>13.2 - 96.7</td>
</tr>
<tr>
<td>Small mammals</td>
<td>1.69</td>
<td>75.6 - 115</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0.81</td>
<td>1.84 - 4.27</td>
</tr>
<tr>
<td>Amphibian</td>
<td>0.64</td>
<td>16.9 - 119</td>
</tr>
</tbody>
</table>
Mink 2: Dietary exposure

Comparison of TEQ WHO-mammalian congener distribution: mink liver vs. diet

Mink liver congener profile  Diet as predicted by site-specific liver, and Tillitt BAF (1996)  Measured diet based on site-specific composition

- 123678-HxCDF
- 123478-HxCDF
- 23478-PeCDF
- 2378-TCDF
- 12378-PeCDD
- 2378-TCDD
Mink

3: Tissue based exposure assessment

Mink liver TEQ_{WHO-mammalian} (ng/kg)

Reference areas    Target areas
Mink

3: Tissue based exposure assessment

Mink liver TEQ, WHO-mammalian (ng/kg)

Sanford
Chippewa Nature Center
Tittabawassee
Upstream
Smiths Crossing
Tittabawassee Township Park
Freeland Festival Park
Imerman Park

DEPARTMENT OF
ZOOLOGY
THE INTEGRATIVE STUDY OF ANIMAL BIOLOGY
MICHIGAN STATE UNIVERSITY
Mink 4: Population health

- Track surveys
- Visual observations
- Trapping success
- Mink scat
Mink

4: Population health

Mink Sex

Sex

FEMALE
MALE
Mink Morphological Data

<table>
<thead>
<tr>
<th></th>
<th>Reference N=20</th>
<th>Target N=14</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Body Weight (Male)</td>
<td>872 g</td>
<td>139 g</td>
</tr>
<tr>
<td>Body Weight (Female)</td>
<td>482 g</td>
<td>78.9 g</td>
</tr>
<tr>
<td>Body Length (Male)</td>
<td>56.3 cm</td>
<td>2.7 cm</td>
</tr>
<tr>
<td>Body Length (Female)</td>
<td>18.7</td>
<td>1.16</td>
</tr>
<tr>
<td>Age (Male)</td>
<td>1.8 yrs</td>
<td>0.8 yrs</td>
</tr>
<tr>
<td>Age (Female)</td>
<td>2.3 yrs</td>
<td>0.7 yrs</td>
</tr>
<tr>
<td>Liver Weight (Male)</td>
<td>51.3 g</td>
<td>10.8 g</td>
</tr>
<tr>
<td>Liver Weight (Female)</td>
<td>26.4 g</td>
<td>2.23 g</td>
</tr>
<tr>
<td>Nutritional Status</td>
<td>1.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

(3=excellent, 1=poor)

No significant difference between sites at (p=0.05)
Additional Parameters

- Brain weight
- Liver wt. to brain wt. ratio
- Baculum length
- Male to female ratio
- Placental scars
- Histology
  - Liver
  - Kidney
  - Brain
  - Jaw

No significant difference between sites at p=0.05
Mink Preliminary observations

- Study area habitat is suitable for Mink
- Mink are present within the study area year round
- Exposure is significantly greater downstream
- Mink abundance does not appear to be significantly different between or among target and reference sites
- Mink population health (based on morphological and histological measurements) within the basin appears to be good and is not different between target and reference sites
Ecological Risk Assessments (ERAs) determine risk of harm to valued ecological components.

ERAs provide for a systematic means of quantifying, comparing and prioritizing risks (and solutions).

ERAs are used by risk managers for risk-benefit, cost-benefit and risk management decisions.

ERAs move from protective to predictive as uncertainty is reduced.

Exposure and toxicity are key components of risk.
Summary

- MSU studies are site specific, multi-year, multi-line of evidence approach
- For mink abundance does not appear to be significantly different between or among target and reference sites
- Mink dibenzo-furan exposure (dietary and tissue based) is significantly greater downstream of Midland
- Mink population health (based on morphological and histological measurements) within the basin appears to be good and is not different between target and reference sites
Chippewa Nature Center
Seminar Series

Wildlife Health Within the Tittabawassee River Basin

Chippewa Nature Center 400 S. Badour Road  Midland, Michigan 48640  p: (989) 631-0830

All Sessions of the Seminar Series will be held in the Visitor Auditorium at 7:00 p.m.

Seminar Series delivered by the Aquatic Toxicology Laboratory of the National Food Safety & Toxicology Center, Michigan State University

April 13, 2006 7:00 p.m.

Ecological Risk Assessment: and the Tittabawassee River, Why, How, and Who Cares?

Presenter: Matthew Zwiernik, PhD  Professor, Michigan State University

- What is an ecological risk assessment?
- What is it used for?
- What information is typically collected?
- Who uses an ecological risk assessment?
- A description of the MSU Wildlife studies.

April 20, 2006 7:00 p.m.

Fishing for Answers! Using Two Fish-Eating Birds (the Belted Kingfisher and Great Blue Heron) as Receptors in the Tittabawassee River Ecological Risk Assessment

Presenter: Rita Seston, Doctoral Candidate  Michigan State University

- Background information on both the Belted Kingfisher and Great Blue Heron.
- Characteristics of the Belted Kingfisher and Great Blue Heron that make them desirable species to study.
- Overview of how these species will be used in the Tittabawassee River Risk Assessment.
- Summary of dietary exposure information from the first year of study.
- Overview of methods used to gather all the necessary information.

April 27, 2006 7:00 p.m.

WHOOSH WHOOOOOOO! The Great Horned Owl (Bubo Virginianus) as a Terrestrial Indicator Species in the Ecological Risk Assessment for the Tittabawassee River and Floodplain

Presenter: Sarah Coefield, Doctoral Candidate  Michigan State University

- Discussion of the natural history of the Great Horned Owl.
- Why the Great Horned Owl is an appropriate species for study.
- Methods used to study the Great Horned Owl and its dietary items.
- Work that has been completed with the Great Horned Owls in the Tittabawassee Floodplain.
- Dietary exposure at reference areas compared to target locations.

May 4, 2006 7:00 p.m.

From Bugs to Birds: An Assessment of Song Bird Dietary Exposure to PCDFs and PCDDs in the Tittabawassee River Floodplain

Presenter: Timothy Fredricks, Doctoral Candidate  Michigan State University

- Discussion of some characteristics of House Wren, Tree Swallow, and Eastern Bluebird.
- Why we choose these species of songbird to study.
- Why and how song birds are important in the risk assessment process.
- Overview of dietary information from the first year of the study.
- Dietary exposure estimates at reference areas compared to target locations.