Population-Level Ecological Risk Assessment: Pesticide Registration Example

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Presentation Objectives

• Illustrate modeling approaches undertaken to understand risks to populations of wildlife & aquatic life

• Highlight transferable issues & challenges
Outline

• Why populations?
• Population models for risk assessment
• Pesticide scenario
  ▪ regulatory context
  ▪ evolving systems of models
• Transferable issues & challenges
Populations as Assessment Endpoints

- Responsive to intent of legislation & policy
  - “to sustain fish, shellfish, and wildlife populations” (CWA)
  - “ecological effects of most concern are those that can impact populations” (Ecological Risk Assessment Guidance for Superfund)
- Often reflect management goals & objectives (sustainability)
- Responsive to societal values
- Places assessment in an ecological context
- Not responsive in all cases
Modeling Population Risk

• Model selection requires:
  ▪ definition of population & its attributes
    • spatiotemporal frames
    • responsive to management decision
  ▪ consideration of relevant processes & interactions
    • environmental context
    • ecological context
• More than one model may be needed
Tiering to Support Decisions

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions
Models for Different Uses

Theoretical Models
- Account for known relationships
- May be complex

“Physics” Models
- Accurately describe specific situations
- May have limited use in other situations
- Typically detailed

Applied Models

- Applicable in most situations
- Don’t predict specific outcomes well
- Typically “simple”
- Good for exploring relationships

LEVINS (1966, 1968)
Population Models

Level of spatial aggregation

<table>
<thead>
<tr>
<th>Level of biological aggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>individuals identical</td>
</tr>
<tr>
<td>individuals unique</td>
</tr>
</tbody>
</table>

Level of spatial aggregation

<table>
<thead>
<tr>
<th>spatially complex</th>
<th>spatially uniform</th>
</tr>
</thead>
<tbody>
<tr>
<td>metapopulation models</td>
<td>unstructured models</td>
</tr>
<tr>
<td>spatially-structured models</td>
<td>individual-based models</td>
</tr>
</tbody>
</table>

increasing complexity & data requirements
A Pesticides Example

• Regulated in US under Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) to prevent “unreasonable adverse effects on the environment”

• Toxicity data & models used to evaluate risk to non-target species

• Moving towards risk to populations
Conceptualization of Problem

Agricultural Pesticide Application

HUMAN ACTIVITY

FATE & TRANSPORT

 Consumption

EXPOSURE MECHANISMS

DIRECT EFFECTS

INDIRECT EFFECTS

Altered Trophic Dynamics

Altered Habitat

Reduced Survival and Reproduction

Behavioral Modifications

Non-target Terrestrial Populations

Non-target Aquatic Populations

ASSESSMENT POPULATIONS

Spray Drift

Foliar Accumulation

Soil Accumulation

Surface & Groundwater Transport
System of Exposure Models

- Spray drift
- Runoff
- Surface water
- Ground water
Refinements to Assessment Approach

Comparison of exposure & toxicity point estimates

Comparison of distributions of exposure & organism-level effect

Comparison of distributions of exposure & population-level effect

Simulation of exposure & population-level effect in spatial context
Spatially-dependent Modeling – PATCH

The Model’s Movement Process Serves to Link a Collection of Individuals Together Into a Population

- Can model real landscapes
- Pesticides change S, R & M depending on exposure level
- Models multiple attributes
- Requires description of exposure spatially

courtesy of N. Schumaker
A Different Kind of Integration – ALMaSS

- Detailed GIS, including roadside verges, field boundaries & hedgerows
- Fields assigned to farms and farms to farm types & practices
- Seasonal and daily variation in traffic load on all roads
- Soil type, slope and aspect of all areas
- Subdivision of forested areas
- Weather data courtesy of C. Topping
An Agent-based Model

- Simulation
  - farming practices
  - weather & other aspects of environment
  - ecological phenomena
- Biology responds at each time step
  - direct
  - indirect
- Models multiple attributes & nonlinearities
Transferable Issues & Challenges

• Population effects module:
  ▪ data voids – extrapolation, surrogates
  ▪ spatial context & heterogeneity
  ▪ stochasticity
  ▪ density dependence
  ▪ population genetics
  ▪ species interactions
  ▪ multiple stressors

• Linking to physical & chemical modules
  ▪ spatiotemporal scales
  ▪ characteristic time steps (if simulations)