ES/RP 532
Applied Environmental Toxicology

Lecture 12
Pesticides: Ecological Risk Assessment

Ecorisk Dilemma
- Too many species to protect
- Must accept some adverse effects (practically speaking)
  - Habitat destruction dominates any possible effect that pesticides could have (absent a spill or other intentional misuse)
- Desire to know the likelihood that communities and ecosystems will be affected
  - However, studies are largely based on examining individuals, not higher levels of hierarchy

EPA Objective
- Choose most sensitive organism
- If can protect that organism, then there is a reasonable certainty of no environmental harm

EPA Approach
- EPA findings published in the RED (Registration Eligibility Decision Document)
- Format may vary between pesticide risk assessments, but it is typically in the format of the major RA elements
  - Hazard ID
  - Dose-Response Characterization
  - Exposure Assessment
  - Risk Characterization
- Deterministic Assessment

Hazard Identification
- Acute Toxicity
- Chronic Toxicity
- Sublethal Effects
  - Reproductive potential
  - Predator Avoidance
  - Morphological deformities
  - General health parameters
  - Enzyme activities
  - Other biomarkers of physiological effects
- Community Level Effects

Hazard ID
- OP insecticides about an order of magnitude more toxic than herbicides and fungicides
- Note that pyrethroid insecticides have low mammalian and avian toxicity but very high fish and invertebrate toxicities
- Aquatic invertebrates more sensitive than fish
Acute Toxicity (LC50) of Pesticides to Coho Salmon (or closely related spp.) and Daphnia

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Effect</th>
<th>Fish Species (Age)</th>
<th>Effective Dose (ppb)</th>
<th>LC50 (ppb)</th>
<th>95th Percentile (ppb)</th>
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</thead>
<tbody>
<tr>
<td>Diazinon</td>
<td>Impaired swimming</td>
<td>Rainbow Trout (jv)</td>
<td>5</td>
<td>0.026</td>
<td></td>
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<tr>
<td>Chlorpyrifos</td>
<td>Impaired swimming</td>
<td>Rainbow Trout (juveniles)</td>
<td>7</td>
<td>0.030</td>
<td></td>
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<tr>
<td>Azinphos-methyl</td>
<td>Impaired swimming</td>
<td>Rainbow Trout (juveniles)</td>
<td>1000</td>
<td>0.025*</td>
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<tr>
<td>Carbaryl</td>
<td>Increased predation</td>
<td>Sockeye Salmon (jv &amp; smolts)</td>
<td>700</td>
<td>&lt;0.000</td>
<td>0.035*</td>
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<tr>
<td>Diuron</td>
<td>Increased predation</td>
<td>Sockeye Salmon (jv &amp; smolts)</td>
<td>10</td>
<td>0.026</td>
<td></td>
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<tr>
<td>Atrazine</td>
<td>Increased predation</td>
<td>Fathead Minnow (juveniles)</td>
<td>47</td>
<td>0.026</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Fathead Minnow (juveniles)</td>
<td>7.2</td>
<td>0.030</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Atlantic salmon (fry to adult)</td>
<td>250</td>
<td>0.011</td>
<td></td>
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<tr>
<td></td>
<td>Habitat modification</td>
<td>Blue gill (jv to adults)</td>
<td>20</td>
<td>0.010</td>
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</tbody>
</table>

Hazard Identification--Sublethal Effects

A New Sublethal Hazard?
- Sex reversal in Chinook salmon
- Example of eco-epidemiology
- Three hypothesis
  - Chromosomal translocation
  - Temperature dependent sex determination
  - Endocrine disruption
  - Pesticides the culprit??


Dose-Response Assessment
- EPA chooses the most sensitive species with regard to
  - Acute toxicity
    - Acute 96-h LC50 (fish)
    - Acute 48-h LC50 (invertebrates)
  - Chronic toxicity
    - NOAEC
      - Exposure in water during entire life cycle (invertebrates)
      - Exposure in water during reproductive period (fish)
      - Dietary exposure during reproductive period (birds/rodents)

Electroolfactogram Studies (Moore & Waring 19960)

Atlantic Salmon Response to Female Sex Priming Pheromone

Dose-Response Assessment: Sub-lethal Effects
Tox. Endpoints for Diazinon in EPA RED

- Scud
  - LC50 = 0.2 ppb
- Water flea (Daphnia)
  - NOEC = 0.17 ppb
- Rainbow trout
  - LC50 = 90 ppb
- Brook trout
  - NOEC = 0.55 ppb

Exposure Assessment

Effect of Half-Life on Chlorpyrifos Dissipation From Water

<table>
<thead>
<tr>
<th>Half-Life (Days)</th>
<th>Days After Application</th>
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<tbody>
<tr>
<td>20</td>
<td>0  5  10  15  20  25  30</td>
</tr>
<tr>
<td>7</td>
<td>0  5  10  15  20  25  30</td>
</tr>
<tr>
<td>2</td>
<td>0  5  10  15  20  25  30</td>
</tr>
<tr>
<td>1</td>
<td>0  5  10  15  20  25  30</td>
</tr>
<tr>
<td>0.5</td>
<td>0  5  10  15  20  25  30</td>
</tr>
</tbody>
</table>

Diazinon Residues (ppb) in water as modeled by EPA for apples (NY) and lawns.

Modeled vs. Empirical Residues of Diazinon in Water

<table>
<thead>
<tr>
<th></th>
<th>Peak ppb</th>
<th>60 Day</th>
<th>USGS 95th Percentile</th>
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<tbody>
<tr>
<td>Apple/Pears</td>
<td>1000</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Lawns</td>
<td>10000</td>
<td>1000</td>
<td>100</td>
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EPA Ecorisk Characterization Guidelines

<table>
<thead>
<tr>
<th>Risk Presumption Category</th>
<th>Risk Quotient Calculation</th>
<th>Level of Concern</th>
<th>Effective Safety Factor</th>
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<tr>
<td>Acute High Risk</td>
<td>EEC/LC50</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Acute Restricted Use</td>
<td>EEC/LC50</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>Acute Endangered Species</td>
<td>EEC/LC50</td>
<td>0.05</td>
<td>20</td>
</tr>
<tr>
<td>Chronic Risk</td>
<td>EEC/NOEC</td>
<td>1</td>
<td>1</td>
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</tbody>
</table>

Diazinon Exposure Relative to Hazard Benchmarks

- Apple/Pears
- Lawns
- USGS 95th Percentile

- Rainbow Trout (LC50=90 ppb)
- Brook Trout (NOEC=0.55 ppb)
- Scud (LC50=0.2 ppb)
- Water Flea (NOEC=0.17 ppb)

RQs for Diazinon

Modeled and Empirical Residue Levels

<table>
<thead>
<tr>
<th>Exposure Scenario</th>
<th>Exposure Duration</th>
<th>Fish</th>
<th>Invertebrates</th>
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</thead>
<tbody>
<tr>
<td>Apple/Pear</td>
<td>Acute</td>
<td>0.28</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>28</td>
<td>121</td>
</tr>
<tr>
<td>Lawns</td>
<td>Acute</td>
<td>2.0</td>
<td>912</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>235</td>
<td>928</td>
</tr>
<tr>
<td>Urban Sites</td>
<td>Acute</td>
<td>0.01</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>0.44</td>
<td>1.4</td>
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<tr>
<td>Agric. Sites</td>
<td>Acute</td>
<td>0.0005</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Chronic</td>
<td>0.08</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Bottom Line

Adios Diazinon!
Urban uses withdrawn from market—voluntarily by manufacturer (Syngenta)

Probabilistic Risk Assessment

Where Do Data Distributions Overlap?

Deposition of Herbicides
Canadian Wheat Growing Region
(Waite et al. 1995, ETAC 14:1171)
Guess What? We’ve not really discussed ecological risk!!!!

- Thus far, we’ve only looked at effects on different species, as populations.
- What about the community, and by implications the ecosystem?

*Testing the Hypothesis of Ecological Hazard*

- Field tests
- Mesocosm tests
  - Examine mesocosm studies where a range of toxicant concentrations have been tested
  - The mesocosm should have a diversity of taxa representing multiple trophic functionality

*“Effects of Diazinon on Large Outdoor Pond Microcosms,” Giddings et al., ETAC v. 15, 1996*

- Parameters
  - diaz. conc. vs. time
  - taxa diversity
  - taxa abundance
  - pop’/n. dynamics
  - WQ parameters

- Benchmarks
  - LOEC, time weighted-70 d

- 8 Dosing Levels + Control
- 8 m² surface area, 11.2 m³ water volume

*Summary of Effects-LOECs*

- Zooplankton
  - Total numbers--4.3 µg/L
  - Taxonomic richness--2.4 µ/L

- Insects
  - Total numbers--9.2 µg/L
  - Taxonomic richness--9.2 µg/L

- Fish
  - Survival--54 µg/L
  - Biomass--22 µg/L

- Aggregate LOEC & NOECs
  - LOEC (70-day, 9.2 µg/L)
  - NOEC (70-day, 4.3 µg/L)