Sustainable pesticide use practices for the protection of water resources

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Agricultural Experiment Station and Extension Service
Oregon State University
Impact of Agriculture and Forestry on Salmonids in the Pacific Northwest
Washington Toxics Coalition v EPA
Ninth Circuit Court of Appeals (2001)
EPA failure to consult with NOAA regarding the registration of 54 pesticides.

28 Evolutionarily Significant Units

- Oncorhynchus kisutch
- Oncorhynchus keta
- Oncorhynchus nerka
- Oncorhynchus mykiss
- Oncorhynchus tshawytscha
PNW Stakeholders

• Pesticide users
  – Industry
  – Agriculture
  – Forestry
  – Rights of Way
  – Municipal
  – Residential

• Federal Government
• State Government/PSP/WQPMT
• Tribes
• Land Grant universities
• Watershed Councils
• Non-Governmental Organizations
• Soil and Water Conservation Districts
• Irrigation districts
• Public
Pesticide Surface Water Monitoring in the U.S. and Oregon

- USGS Monitoring
  - National Water Quality Assessment Program (NAWQA)
  - Clackamas studies

- DEQ/ODA Monitoring
  - Pesticide Stewardship Partnership (PSP)
    - 9 Watersheds
    - 4 in Willamette Valley
• Evaluate current pesticide risk assessment approaches relating to ESA listed species (biological opinions)

• Reach consensus on common risk assessment methods
  – Modelling/model assumptions
  – Geospatial information
  – Characterize effects direct, indirect, sublethal and cumulative; mixtures and inert ingredients
  – Characterize uncertainty
Willamette Basin (HUC 4)
  12 HUC 8 subbasins
  388 HUC12 watersheds

Diverse agriculture (170 crop varieties), forestry, urban pesticide use practices

More than 500 pesticide active ingredients registered in Oregon

Pesticide co-occurrence with salmon/food web life histories?
FIFRA/FQPA Federal – State Partnerships designed to Achieve Safe and Beneficial Pesticide Use

- Risk Reduction Thru Integrated Protection Programs
  - Risk Assessment
  - Risk Management
  - Risk Mitigation
  - Individual Action

Potential Pesticide Risks

- Risk characterization through sound science
- Cost effective requirements to insure safe use
- Clear understanding of label restrictions and use mandates
- Informed decision-making at the frontline of pesticide use

Safe & Beneficial Use
Pacific Salmonid Biology, Food Web and Critical Habitat
Fig. 1. Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modeling structure and tools.
Fig. 1. Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modeling structure and tools.

René P. Schwarzenbach et al. Science 2006;313:1072-1077
Risk: Conceptual Framework

- Opportunities for Pesticide Exposure
- Human/wildlife Susceptibility and Behavior

Risk
The core concept of sustainability\(^1\) is that lasting success requires an integrated approach to:

- producing food, fiber, and other products
- farm and forest profitability
- quality of life for farmers, foresters, and communities
- stewardship of natural resources

Sustainability requires recognizing and acting upon productivity, economic, social, and environmental goals as a simultaneous set of system attributes.

Technology to Enable Sustainable Production

- Farm/forest operations management
- Agronomy/horticulture/animal science/forest science
- Pest management/IVM
- Nutrient management
- Water Management
- Natural resource stewardship
- Supply chain management
- Information management

Farm/Forest Production System

Digital Agriculture and Forestry
## Herbicides Commonly Used in the Pacific Northwest

<table>
<thead>
<tr>
<th>Trade name</th>
<th>Common name</th>
<th>½ life (days)</th>
<th>Koc</th>
<th>Water sol (mg/L)</th>
<th>Vapor pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sencor</td>
<td>Metribuzin</td>
<td>40</td>
<td>60</td>
<td>1220</td>
<td>1.0x10^-5</td>
</tr>
<tr>
<td>Banvel</td>
<td>Dicamba (acid)</td>
<td>14</td>
<td>2</td>
<td>400000</td>
<td>3.4x10^-5</td>
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<tr>
<td>Milestone</td>
<td>Aminopyralid</td>
<td>35</td>
<td>11</td>
<td>2480</td>
<td>7.1x10^-11</td>
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<tr>
<td>Garlon</td>
<td>Trichlopyr</td>
<td>30</td>
<td>210</td>
<td>260</td>
<td>3.0x10^-8</td>
</tr>
<tr>
<td>Dual</td>
<td>Metolachlor</td>
<td>90</td>
<td>200</td>
<td>530</td>
<td>3.1x10^-5</td>
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<tr>
<td>Roundup</td>
<td>Glyphosate</td>
<td>47</td>
<td>24000</td>
<td>530000</td>
<td>0</td>
</tr>
<tr>
<td>2,4-D</td>
<td>2, 4 D acid</td>
<td>10</td>
<td>20</td>
<td>89</td>
<td>1.1x10^-7</td>
</tr>
<tr>
<td>2,4-D ester</td>
<td>2,4-D butoxyethyl ester</td>
<td>7</td>
<td>500</td>
<td>100</td>
<td>1.0X10^-7</td>
</tr>
<tr>
<td>Chopper</td>
<td>Imazapyr</td>
<td>90</td>
<td>100</td>
<td>1100</td>
<td>1.3x10^-11</td>
</tr>
<tr>
<td>Velpar</td>
<td>Hexazinone</td>
<td>90</td>
<td>54</td>
<td>3300</td>
<td>8.2x10^-11</td>
</tr>
<tr>
<td>Kerb</td>
<td>Pronamide</td>
<td>60</td>
<td>800</td>
<td>15</td>
<td>8.5x10^-5</td>
</tr>
<tr>
<td>Oust</td>
<td>Sulfometuron methyl</td>
<td>28</td>
<td>78</td>
<td>70</td>
<td>1.7x10^-16</td>
</tr>
<tr>
<td>Goal</td>
<td>Oxyfluorfen</td>
<td>35</td>
<td>100000</td>
<td>0.1</td>
<td>2.0x10^-7</td>
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<tr>
<td>Prowl</td>
<td>Pendimethalin</td>
<td>90</td>
<td>500</td>
<td>0.3</td>
<td>9.4x10^-6</td>
</tr>
<tr>
<td>Buctril</td>
<td>Bromoxynil</td>
<td>7</td>
<td>10000</td>
<td>0.8</td>
<td>4.8x10^-6</td>
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<tr>
<td>Dachthal</td>
<td>DCPA</td>
<td>100</td>
<td>5000</td>
<td>0.5</td>
<td>2.5x10^-6</td>
</tr>
</tbody>
</table>

OSU Extension Pesticide Properties Database EM 8709
Soil and Water Assessment Tool (SWAT)

Conceptual model

↓

Process model (computer)

↓

ArcSWAT (GIS), use of spatial data (maps)

↓

Describe daily changes in watershed

↓

Pesticides in surface water

Daily Pesticide Load Following Early Season Application
Soil and Water Assessment Tool (SWAT)

- Watershed scale model\(^1\)
  - Developed by USDA Agricultural Research Service
  - Based on over 40 years of expertise

- Developed to evaluate the impact of land management practices on:
  - Hydrology
  - Erosion/Sediment transport
  - Nutrient fate
  - Pesticide fate

- Physically based process model that operates on a daily time step

- GIS interface, ArcSWAT, used for spatially explicit parameterization using readily available data
Watershed scale modeling of pesticide fate

Modeling spray drift and runoff-related inputs of pesticides to receiving water

Xuyang Zhang, Yuzhou Luo, Kean S. Goh
California Department of Pesticide Regulation, Sacramento, CA, 95814, United States

Evaluation of Watershed-Scale Simulations of In-Stream Pesticide Concentrations from Off-Target Spray Drift

Michael F. Winchell, Naresh Pai, Benjamin H. Brayden, Chris Stone, Paul Whaling, John P. Hanzas, and Jody J. Stryker

A Systems Approach to Modeling Watershed Ecohydrology and Pesticide Transport

Philip Janney and Jeffrey Jenkins

Core Ideas
- Sequential model optimization incorporating local knowledge improved ecohydrologic estimates.
- Probabilistic pesticide application provided more realistic model estimates of solute transport.
- This modeling application allows a systems approach to sustainable agricultural practices.
Zollner Creek Watershed, Willamette Basin, Oregon

- HUC12 - 15mi² watershed
- Watershed area 90% agriculture: > 600 fields, >30 crops
- Pesticide surface water monitoring since 1993 (USGS and Oregon DEQ)
- Contains critical habitat for Upper Willamette chinook and steelhead ESUs
- Weather characterized by dry summers and wet winters
- USGS stream flow gage (Station ID: 14201300)
Flow Statistics
NSE = 0.75
PBIAS = -17.1%
RSR = 0.25
R² = 0.77

Characterizing Pesticide Use Patterns

- All authorized uses (federal/state labeled uses)
- Actual use records
  - Proprietary
  - Logistically difficult
  - Retrospective
- Probabilistic methods based on local knowledge
  - Realistic boundary conditions (pest management along crop timelines)
  - Characterize complex decision making process (producers, CCAs, Extension)
  - Both retrospective and prospective – evaluate future outcomes

Labels for Oregon – PICOL database

Collaborate with CCAs and growers to refine use estimates

Create boundary conditions for probabilistic analysis of application practices
Atrazine Authorized Use in the Zollner Creek Watershed
Chlorpyrifos Authorized Use in the Zollner Creek Watershed
Trifluralin Authorized Use in the Zollner Creek Watershed
Trifluralin Use - PNW Herbicide Handbook

• Pre-plant soil incorporated:
  • Broccoli: May-July; 0.5-1 lb AI/A; 3-4” incorporation
  • Cauliflower: May-July; 0.5-1 lb AI/A; 3-4” incorporation
  • Green beans: May-July; 0.5-0.75 lb AI/A; 2-3” incorporation
  • Peas: May-July; 0.5-0.75 lb AI/A; 1-2” incorporation

• Spring pre-emergent:
  • Caneberries (nonbearing): March-April; 2.5-5lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  • Field grown nursery: March-April; 2-5lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  • Filberts: March-April; 0.5-1lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate

• Fall pre-emergent:
  • Alfalfa: September-October; 2lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  • Grass seed: September-October; 2lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  • Winter wheat: October-November; 0.5-1lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
Probabilistic Assessment of Application Patterns

• Management operations randomized by field
  • Applications limited to workable days
  • Application rates were both probabilistic and deterministic
  • Pesticides Properties DataBase\(^1\) representative values

• Monte Carlo methods utilized to create spatial and temporal distribution of application patterns
  • 500 SWAT scenarios generated and run

• Generate a distribution of spatial and temporal patterns of pesticide use practices
  • Estimate likely pesticide use patterns

\(^1\)PPDB: Pesticide Properties DataBase, University of Hertfordshire.
Generalized (not actual) Distribution of Chlorpyrifos Applications - 2011

<table>
<thead>
<tr>
<th>CROP TYPE</th>
<th># POTENTIAL APPLICATION SITES</th>
<th>APPLICATION PERIOD</th>
<th>PROBABILITY OF APPLICATION</th>
<th># WORKABLE DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed/Sod Grass</td>
<td>82</td>
<td>Sept-Oct</td>
<td>0.1</td>
<td>15</td>
</tr>
<tr>
<td>Nursery</td>
<td>35</td>
<td>Apr-July</td>
<td>0.4</td>
<td>36</td>
</tr>
<tr>
<td>Orchard</td>
<td>3</td>
<td>Mar-Apr</td>
<td>0.75</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>May-Aug</td>
<td>0.1</td>
<td>54</td>
</tr>
<tr>
<td>Vegetable</td>
<td>2</td>
<td>Apr-May</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Apr-June</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>May-July</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>June-July</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Aug-Sept</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>

1 of 500 daily simulations
SWAT Estimates of Daily Chlorpyrifos Concentration

**Daily SWAT Estimated Chlorpyrifos Concentrations: 2010**

- **Date**
- **Chlorpyrifos Concentration (ng/L)**
- **Precipitation (mm)**
- **SWAT Mean Daily Concentration (ng/L)**
- **DEQ Chlorpyrifos (ng/L)**
- Non-detects
- OPP Acute Invertebrate Benchmark
- OPP Chronic Invertebrate Benchmark

**Daily SWAT Estimated Chlorpyrifos Concentrations: 2011**

- **Date**
- **Chlorpyrifos Concentration (ng/L)**
- **Precipitation (mm)**
- **SWAT Mean Daily Concentration (ng/L)**
- **USGS Chlorpyrifos (ng/L)**
- **DEQ Chlorpyrifos (ng/L)**
- Non-detects
- OPP Acute Invertebrate Benchmark
- OPP Chronic Invertebrate Benchmark

10/17/2019
SWAT Estimates of Daily Atrazine Concentration

**2010 Zollner Creek SWAT Estimated Average Daily Atrazine Surface Water Concentration**

- **Opp Acute Nonvascular Plant Benchmark:** 1000 ng/L
- **Opp Chronic Fish Benchmark:** 5000 ng/L

**2011 Zollner Creek SWAT Estimated Average Daily Atrazine Surface Water Concentration**

- **Opp Acute Nonvascular Plant Benchmark:** 1000 ng/L
- **Opp Chronic Fish Benchmark:** 5000 ng/L

**Observed Atrazine Concentration (ng/L)**

**Mean SWAT Estimated Concentration (ng/L)**

**Grey Area = 5th-95th percentile**

---

**Date**

- Jan-10
- Feb-10
- Mar-10
- Apr-10
- May-10
- Jun-10
- Jul-10
- Aug-10
- Sep-10
- Oct-10
- Nov-10
- Dec-10

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**Atrazine Concentration (ng/L)**

- 0
- 100
- 200
- 300
- 400
- 500
- 1000
- 2000
- 3000
- 4000
- 5000

**Precipitation (mm)**

- 0
- 100
- 200
- 300
- 400
- 500
- 1000

---

**Mean SWAT Estimated Concentration (ng/L)**

**Grey Area = 5th-95th percentile**

**Observed Atrazine Concentrations (ng/L)**

---

**Date**

- Jan-11
- Feb-11
- Mar-11
- Apr-11
- May-11
- Jun-11
- Jul-11
- Aug-11
- Sep-11
- Oct-11
- Nov-11
- Dec-11

---

**Atrazine Concentration (ng/L)**

- 0
- 100
- 200
- 300
- 400
- 500
- 1000
- 2000
- 3000
- 4000
- 5000

**Precipitation (mm)**

- 0
- 100
- 200
- 300
- 400
- 500
- 1000

---
SWAT Estimates of Daily Trifluralin Concentration

2010 Trifluralin Daily Concentration Estimates

2011 Trifluralin Daily Concentration Estimates

OPP Acute Fish Benchmark: 9250 ng/L
OPP Chronic Fish Benchmark: 1900 ng/L

- SWAT Median Daily Trifluralin Concentration (ng/L)
- Precipitation (mm)
- DEQ Grab Sample NonDetects (ng/L)
- OPP Acute Fish Benchmark: 9250 ng/L
- OPP Chronic Fish Benchmark: 1900 ng/L

10/17/2019
Passive Sampling Device 21 day Time Weighted Average Pesticide Concentrations in Surface Water

Lay Flat Tubing (LFT) passive samplers deployed continuously every ~21 days
Transferability of Watershed Assessment Framework
OSU application of SWAT:
Integrate Institutional knowledge/local expertise
Evaluate forestry IVM/herbicides in surface water
Estimate daily loading – benchmark exceedances
Inform best management practices/success stories
Fostering sustainable practices through participative modeling

Institutional knowledge and expertise

OSU Extension Watershed Assessment Framework (powered by SWAT)

Local knowledge and expertise

Rapid evaluation of sustainable practices

Demonstrated Stewardship