Comparison of Storm Intensity and Timing on Modeled Risks from Runoff Contaminants in Two U.S. Regions

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Sheltering Communities from Coastal Storms
Coastal Storms Program – Ecological Assessment Components

- **Risk Assessment**
  - Land uses
  - Toxicology
  - Database
    - [http://www.chbr.noaa.gov/easi](http://www.chbr.noaa.gov/easi)

- **Modeling**
  - Transport and fate
  - Representative watershed

- **Toxicology**
  - Indigenous species
  - To fill information voids
Pilot Areas

Source: www.sjrwmd.org

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Transport and Fate Modeling

- **Three Contaminants chosen by a preliminary risk assessment**
  - Florida – Atrazine, Fipronil, and Imidacloprid
  - PNW – Carbaryl, Diquat Dibromide, Fluoranthene

- **PRZM-3 (Pesticide Root Zone Model)**
  - Groundwater Hydrology and Chemical Transport
  - Effects of Rain, Application, Transpiration, etc.

- **EXAMS-II (Exposure Analysis Modeling System)**
  - Surface Water Effects of Sorption, Biodegradation, Photolysis, etc.
  - Uses Output of PRZM
  - Predicted Concentrations Compared to Aquatic Animal and Human Health Levels of Concern.
PRZM Methods

- Published chemical parameters
- Local meteorological data
  - 2-Yr, 25-Yr and 100-Yr storms
  - Rainfall on the 1st of the month
- Contaminants applied at maximum allowed rate
- Pesticides applied 1, 6 or 16 days before storms
EXAMS Methods

- Used PRZM loadings and other inputs
- Published chemical parameters
- Local meteorological data
Florida PRZM Methods

- Lake Bethel, Florida environment
  - Estuarine headwaters are most susceptible
  - Typical of Southeastern US changing adjacent land uses

- Pesticides applied at maximum allowed rate
  - Atrazine 142 times Fipronil
  - Atrazine 4 times Imidacloprid
  - Imidacloprid 32 times Fipronil
Runoff of Atrazine

- Highest concentration of the 3 pesticides
- Storms:
  - 100-Yr > 25-Yr > 2-Yr
- Application:
  - 1-D > 6-D > 16-D
Runoff of Fipronil

- Lowest concentration of the 3 pesticides
- Storms:
  - 100-Yr > 25-Yr > 2-Yr
- Application:
  - 16-D > 6-D > 1-D

Fipronil Concentrations in Runoff (kg/ha/d)

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Runoff of Imidacloprid

Imidacloprid Concentrations in Runoff (kg/ha/d)

- **Storms:**
  100-Yr > 25-Yr > 2-Yr

- **Application:**
  16-D > 6-D > 1-D
• Odd numbers are littoral
• Even numbers are benthic
• 1 and 2 are closest to shoreline
• 3 and 4 are next
• 5 and 6 are main lake body
Dissolved Chemical Concentrations in Littoral Compartment Nearest Shore

- **Storms:**
  - 100-Yr > 25-Yr > 2-Yr

- **Compartments:**
  - 1 >> 3 > 5

- **Pesticides (concentration not toxicity):**
  - Atrazine > Imidacloprid > Fipronil

- **Application Date:**
  - Atrazine: 1 > 6 > 16
  - Fipronil and Imidacloprid: 16 > 6 > 1

- Note different Scales
Florida Modeling Results

Atrazine

- **Max runoff and erosion**
  - application one day before the rain

- **Peak short term runoff**
  - 13 ug/l
  - approximate chromic toxicity threshold for a copepod
  - near acute toxicity threshold for algae
  - lower than acute toxicity levels for most crustaceans and finfish (Bejarno and Chandler, 2003; Bringman and Kehn, 1976)

- **Storage within core depth**
  - higher than fipronil and imidaclorprid

- **Risk**
  - relatively short lived
  - poses lower risk if storms occur a few weeks after application
Florida Modeling Results

Fipronil

- **Maximum runoff and erosion**
  - application 16 days before rain

- **Peak short term runoff**
  - $5.7 \times 10^{-3}$ ug/l
  - 50 times lower than the acute toxicity threshold for grass shrimp (Key et al, 2003)

- **Risk**
  - highly toxic
  - little chance that levels toxic to important prey would be reached even after a heavy rainfall

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Florida Modeling Results
Imidacloprid

- **Maximum runoff and erosion**
  - application 16 days before the rain

- **Peak short term runoff**
  - 0.63 ug/l

- **Risk**
  - levels suggest little risk
  - has the highest leaching rate
  - the only one to leach below the core depth
  - potential threat to deeper aquifers transport through groundwater.

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http://iml.jou.ufl.edu/projects/Spring04/Paquet/aquifer.html
Florida Modeling Results

Overall

- Each pesticide was storm and application date dependant
- Fipronil
  - Highest toxicity
  - Poses the least risk due to low transport over and through shallow soils
- Atrazine
  - Lowest toxicity
  - Highest threat due to high mobility and high application levels
- In combination
  - All three pesticides can occur in the modeled conditions
  - Key et al. (2006) identified the magnification coefficient of 1.21 to grass shrimp when atrazine, fipronil, and imidacloprid were present together

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Johnson Creek Headwaters – Multnomah and Clackamas Counties, Oregon

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Johnson Creek PRZM Methods

- Johnson Creek headwaters environment
  - Urbanized freshwater stream, spawning salmon habitat
  - Typical of Northwestern US adjacent land uses
- Segmented the watershed according to predominant land use
  - Agricultural
  - Urban
  - Forested
Johnson Creek PRZM Methods

- Carbaryl and Diquat Dibromide were applied at maximum allowed rate
- Pesticides applied 1, 6 or 16 days before storms
- Fluoranthene not included in PRZM model runs
Runoff of Carbaryl

- **Highest concentration of the 2 pesticides**
- **Storms:**
  
  100-Yr > 25-Yr > 2-Yr

- **Application:**
  
  1-D > 6-D > 16-D

- **Landuse:**
  
  Ag > Urban > Forested

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Runoff of Diquat Dibromide

- Lowest concentration of the 2 pesticides
- Storms:
  - 100-Yr > 25-Yr > 2-Yr
- Application:
  - 16-D > 6-D > 1-D
- Landuse:
  - Urban > Ag > Forested

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EXAMS Methods

- Used PRZM loadings and other inputs
- Fluoranthene loading was estimated from reported roadway runoff concentrations (Hewitt and Rashed, 1992) – entered the modeled system on days of rain
- Published chemical parameters
- Local meteorological data

http://web.pdx.edu/

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• Odd numbers are littoral
• Even numbers are benthic
• 1 and 2 are in the agricultural segment
• 3 and 4 are in the urban segment
• 5 and 6 are in the forested segment
Dissolved Chemical Concentrations in Littoral Compartments

- **Storms**: 100-Yr > 25-Yr > 2-Yr
- **Watersheds**: 
  - Carbaryl highest in Forested Segment
  - Diquat highest in Agricultural Segment
  - Fluoranthene highest in Forested Segment
- **Pesticides (concentration not toxicity)**: 
  - Carbaryl > Fluoranthene > Diquat Dibromide
- **Application Date**: 
  - Carbaryl: 1 > 6 > 16
  - Diquat Dibromide: 16 > 6 > 1

- Note different Scales
Johnson Creek Modeling Results
Carbaryl

- **Maximum runoff and erosion**
  - application one or six days before the rain

- **Peak short term runoff**
  - 413 µg/l
  - two orders of magnitude higher than acute toxicity for daphnia
  - near salmonid toxic thresholds
  - exceeds acute toxicity to several crustacean (Verschueren, 1996; Macek and McAllister, 1970; Buchanan et al., 1969; Sanders and Cope, 1966)

- **Risk**
  - high storage
  - short lived

http://www.4j.lane.edu/partners/eweb/ve/salmon/salmon.jpeg
Johnson Creek Modeling Results
Diquat Dibromide

• Maximum runoff and erosion
  ◦ application 16 days before the rain

• Peak short term runoff
  ◦ $5.6 \times 10^{-2}$ ug/l
  ◦ five orders of magnitude less than acute toxicity for rainbow trout and the chinook salmon (Pimentel, 1971; Bond et al., 1960)

• Risk
  ◦ very toxic
  ◦ little chance that toxic levels will occur after heavy rainfall

http://techalive.mtu.edu/meec/module07/exotics_2.htm
Johnson Creek Modeling Results
Fluoranthene

- **Peak short term runoff**
  - 2.0 ug/l
  - approximate acute toxicity thresholds for mysid shrimp and sea urchins (Montizaan, 1989; USEPA, 1991)
  - similar to salmonid acute toxicity levels when UV activated but much lower without UV activation (USEPA, 1991, 1991; Home and Oblad, 1983)

- **Risk**
  - Toxicity from roadway runoff possible under isolated conditions of intense runoff and little mixing
Johnson Creek Modeling Results
Overall

- Both pesticides were storm and application date dependant
- The PAH, fluoranthene, was storm dependant
- Carbaryl
  - 5x more toxic than diquat dibromide to important salmonid species and transported at concentrations 7000 times higher
  - carbaryl poses greater risk to crustaceans followed by fluoranthene
- Fluoranthene
  - poses the greatest risk to spawning salmonids followed by carbaryl

Coastal Storms Initiative
http://www.oregonzoo.org
Overall Summary

- **PRZM Model**
  - Estimates shallow groundwater and runoff contamination
  - Identifies effects on runoff
  - Provides NPS inputs to exposure model

- **EXAMS Model**
  - Estimates surface water and sediment concentrations
  - Used to identify sensitive areas/habitats
  - Effects of storms types, application date
  - Compares pesticides, other contaminants
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