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Assessing the effects of chemical mixtures using a Bayesian network-relative risk model (BN-RRM) integrating adverse outcome pathways (AOPs) in three Puget Sound watersheds

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Assessing the Effects of Chemical Mixtures using a Bayesian Network-Relative Risk Model (BN-RRM) Integrating Adverse Outcome Pathways (AOPs) in Four Watersheds

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Study Objective

Develop a method to integrate chemical mixtures & environmental factors for four watersheds

Overview

Introduction-Risk, OPs, Chinook salmon

Methods-Toxicity pathway, Study sites, Bayesian network

Results-Contribution to risk of pesticide toxicity and environmental factors across four watersheds

Conclusion-Pesticides contribute to risk even at the measured concentrations

Risk and Ecological Risk Assessment

Risk is the probability of an effect on a specific endpoint or set of endpoints due to a specific stressor or set of stressors (NASEM 2016).

Endpoint defined as an Entity and Attribute that forms the basis of decision making

Ecological Risk Assessment provides a probabilistic cause-effect framework that organizes relationships between environmental variables in order to facilitate decision-making.

Organophosphate Pesticides and Chinook Salmon

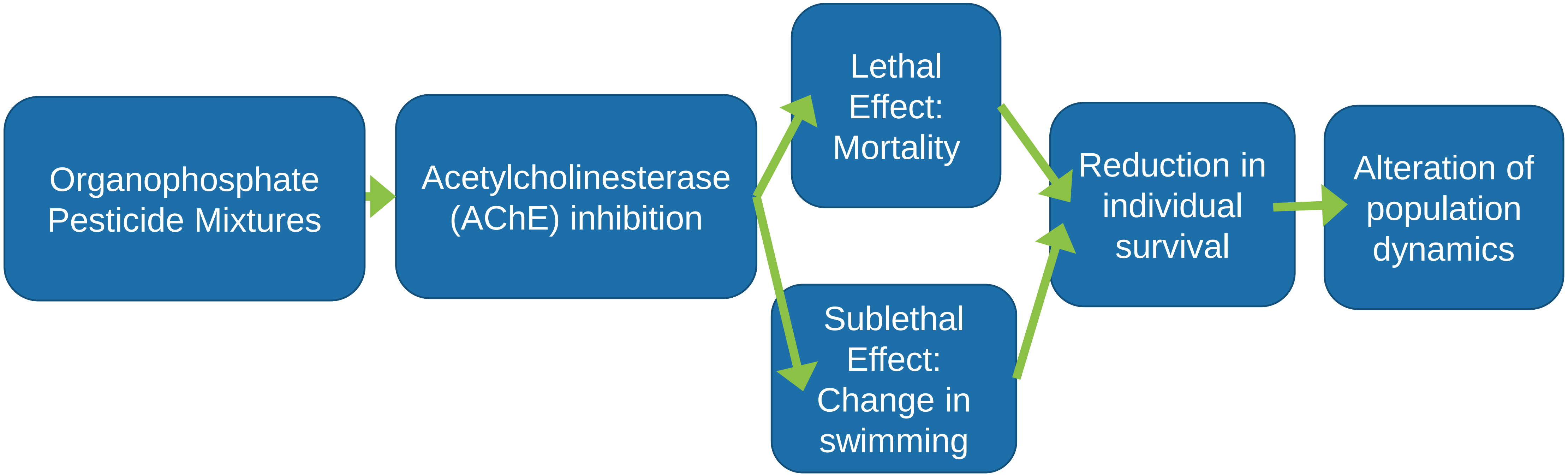
- Commonly used insecticide in agricultural and urban settings

- Environmental mixtures:
  - Malathion
  - Chlorpyrifos
  - Diazinon

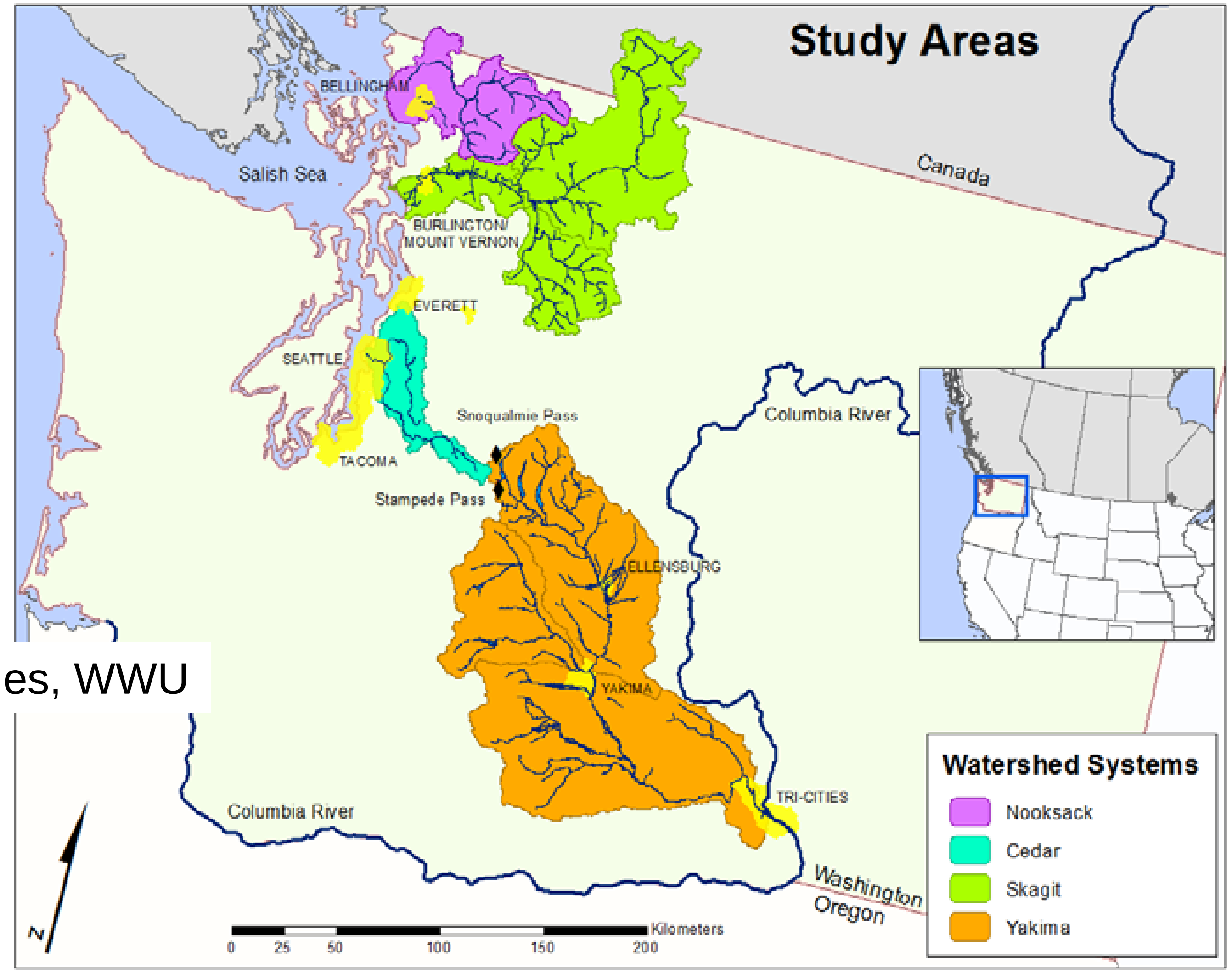
- Known to be neurotoxic to salmon

- **Chinook salmon** are the entity and population size the attribute

The Toxicity Pathway



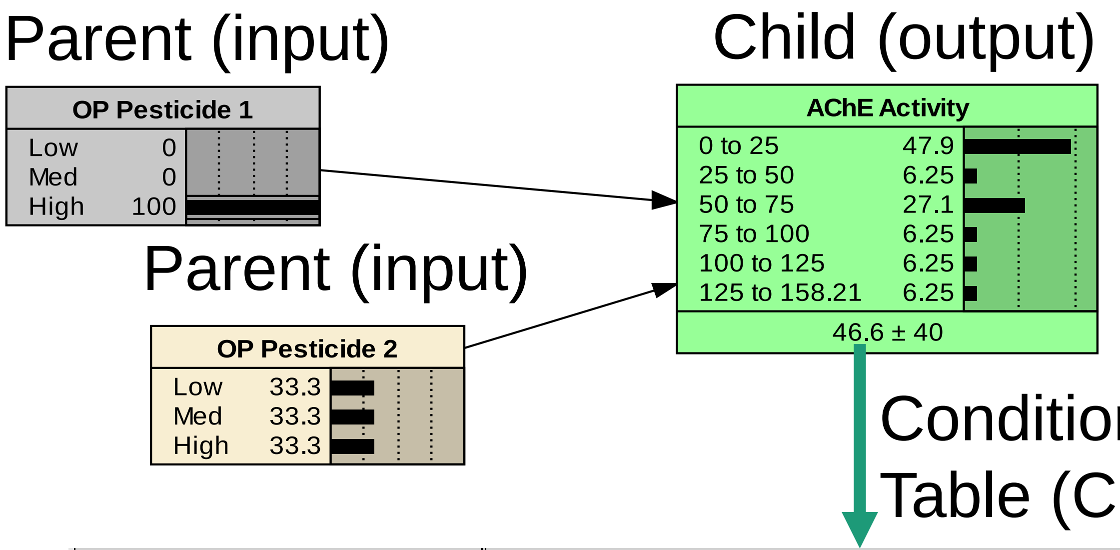
Study Sites



Chris Trines, WWU

Bayesian Network Basics

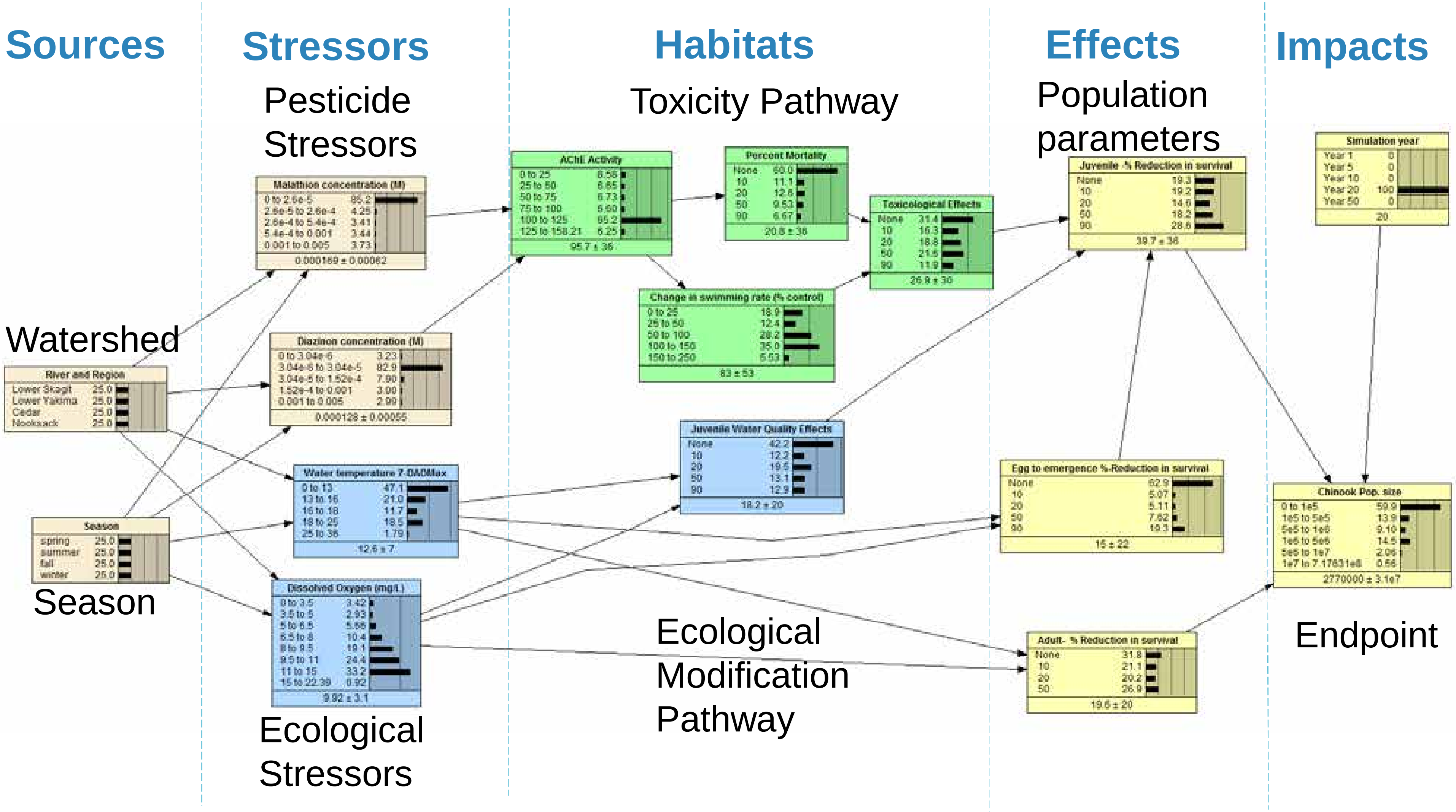
Bayesian Networks are graphical models that use probability networks to describe relationships between variables in a model



Conditional Probability Table (CPT)

OP Pesticide 1	OP Pesticide 2	0 to 25	25 to 50	50 to 75	75 to 100	100 to 125	125 to 158.21
Low	Low	6.25	6.25	6.25	6.25	68.75	6.25
Low	Med	6.25	6.25	6.25	37.5	37.5	6.25
Low	High	6.25	6.25	6.25	37.5	37.5	6.25
Med	Low	6.25	6.25	6.25	37.5	37.5	6.25
Med	Med	6.25	6.25	6.25	68.75	6.25	6.25
Med	High	68.75	6.25	6.25	6.25	6.25	6.25
High	Low	6.25	6.25	6.25	37.5	37.5	6.25
High	Med	68.75	6.25	6.25	6.25	6.25	6.25
High	High	68.75	6.25	6.25	6.25	6.25	6.25

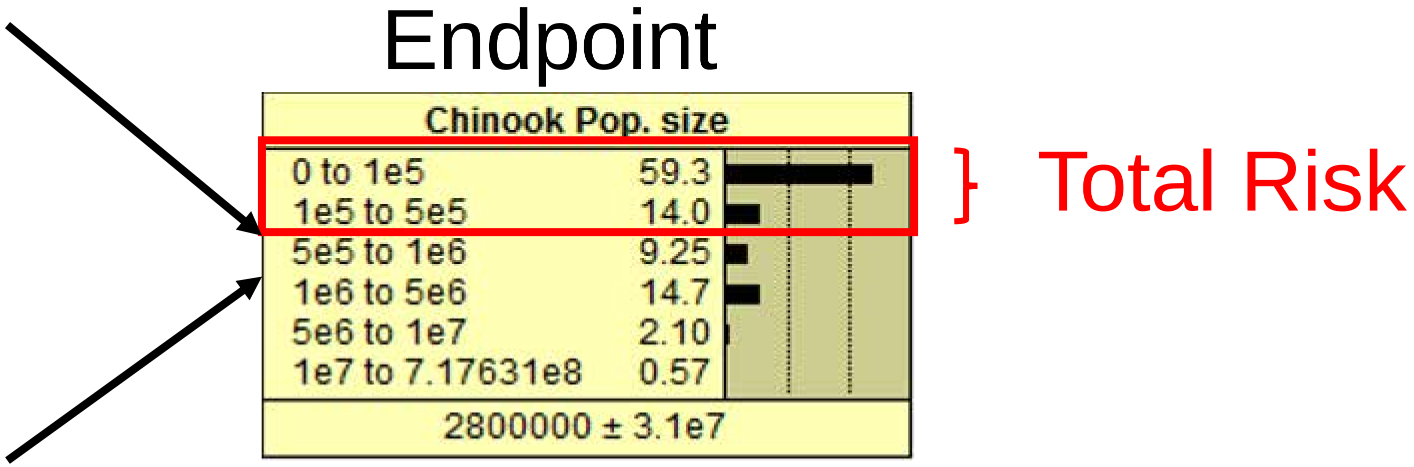
Bayesian Network



Interpreting risk in Chinook population size

- The Puget Sound Partnership management goal is **no net loss**
- Any number below 500,000 fish is defined as a **net loss** in the model
- **Risk** is defined as the probability of not achieving the management goal of at least 500,000 fish

Risk as defined in the model



- Population model simulation outputs by were incorporated into Chinook Population Size

- Total Risk was then calculated by summing probabilities of less than 500,000 fish

Results-Eight Scenarios Presented

- Yakima Watershed example
  - Scenario 1: Measured concentrations in the winter
  - Scenario 2: Synergistic concentrations in the winter
  - Scenario 3: Measured concentrations in the summer
  - Scenario 4: Synergistic concentrations in the summer
- Scenario 5-8: Four watersheds in all seasons

Yakima Winter Summary of Results

Table 1. Risk in Yakima Winter (in percent probability) at year 20

Scenarios in the Yakima Winter	Risk	Change in Risk	Proportion of Risk Due to Toxicity
Only Environmental Stressors	53	-	-
Measured OP Concentrations	67	**14**	**20**
Modeled OP Synergistic Concentrations	74	**21**	**28**

- Measured concentrations (70-90% probability of less than 0.15 µg/L OPs)
- Modeled synergistic concentrations (3-15 µg/L malathion and diazinon, 0.15-1 µg/L chlorpyrifos)

Yakima Summer Summary of Results

Table 2. Risk in the Yakima Summer (percent probability) at year 20

Scenario in the Yakima Summer	Risk	Change in Risk	Proportion of Risk Due to Toxicity
Only Environmental Stressors	80	-	-
Measured OP Concentrations	85	**5**	**7**
Modeled OP Synergistic Concentrations	89	**9**	**10**

- Measured concentrations (70-90% probability of less than 0.15 µg/L OPs)
- Modeled synergistic concentrations (3-15 µg/L malathion and diazinon, 0.15-1 µg/L chlorpyrifos)

All Watersheds During All Seasons

Table 3. Risk in all watersheds during all seasons (in percent probability) at year 20

Scenarios during all seasons in Watersheds	Risk
Skagit	73
Yakima	73
Cedar	72
Nooksack	78

- The risk is about the same in each watershed

Summary of Results

- Contribution of toxicity is greater in the winter and less in the summer

- Synergistic concentrations of OPs does increase risk

- Patterns of risk between watersheds are similar

Conclusions-1

- It is possible to evaluate the total toxicity of mixtures and their contribution to risk

- There is risk to Chinook salmon in the watersheds due to pesticides and environmental factors

- Synergism can be modeled if appropriate

Conclusions-2

- Toxicity is not the major contributor, but can account for 20% of the risk

- OPs measured at each of the study sites does increase risk even when concentrations are low

- Supports Baldwin et al. (2009), Spromberg and Meador (2005) that low concentrations do affect populations

Next Steps

- Metapopulations in the Yakima
  Mitchell et al. in this session

- Incorporate additional environmental factors and a more diverse suite of chemical contaminants.

- Expand the endpoints to other species of salmonids and species supplying equivalent ecosystem services