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

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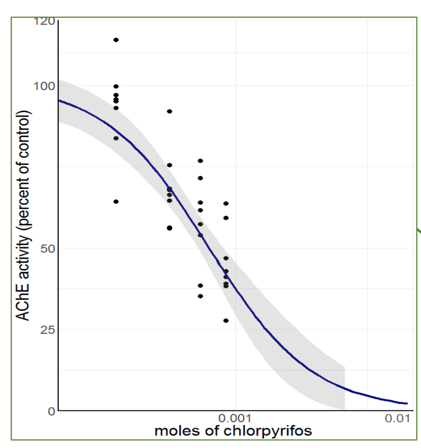
Introduction

There are long-standing uncertainties about toxicity of chemical mixtures to populations. Laboratory toxicity tests have confirmed synergistic and antagonistic effects to individuals, but not to populations. We will conduct a regional scale ecological risk assessment by evaluating the effects chemical mixtures to populations with a new Bayesian Network- Relative Risk Model (BN-RRM) incorporating an Adverse Outcome Pathway (AOP) (Figure 7). We started applying this new BN-RRM framework in a case study with organophosphate pesticide (OP) mixtures (diazinon, chlorpyrifos, and malathion). Acetylcholinesterase inhibition (AChE) was chosen the molecular initiating event and the Puget Sound Chinook salmon (*Oncorhynchus tshawytscha)* and Coho salmon (*Oncorhynchus kisutch)* Evolutionary Significant Units (ESU) were chosen as population endpoints.

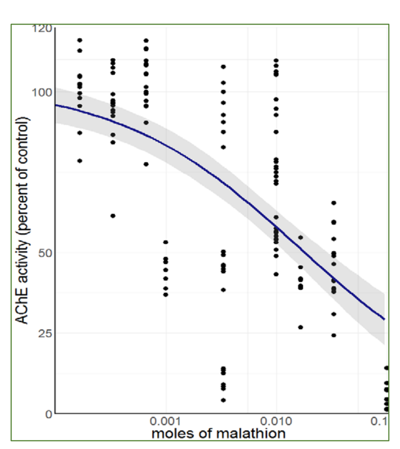
Background

Malathion and chlorpyrifos (Figure 1 and 2) make up of 50% of OP pesticides detected in urban streams in the Pacific Northwest [9]. Urban streams are where Coho and Chinook salmon inhabit and spawn and the streams typically contain two or more OPs [1] [9]. Because mixtures are normally encountered in urban streams, toxicity testing of OP mixtures (Figure 3) is comparable to environmentally realistic exposures [4] [5] [9]

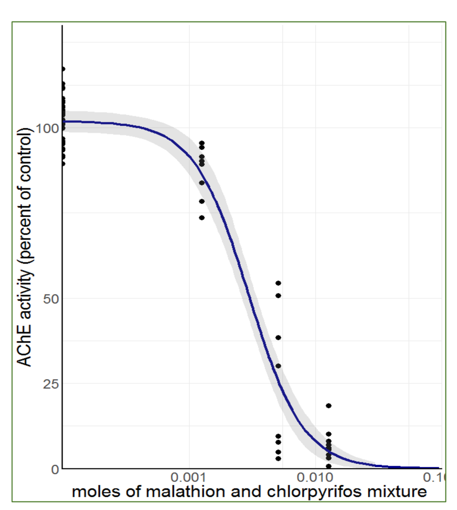
Organophosphate pesticides such as chlorpyrifos and malathion act synergistically to Chinook salmon. The presence of an organophosphate compound such as chlorpyrifos inhibits the enzyme carboxylesterase (CaE) which results in the potentiation of malaoxon, a metabolite of malathion, leading to synergism [3] [6] .



Data from Laetz et al. (2009)

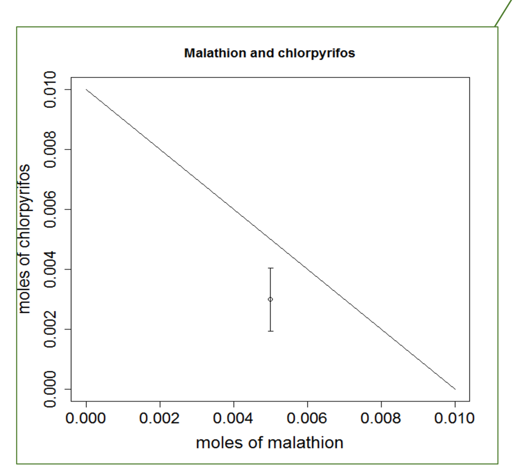


Figures 1, 2 and 3. Dose response curves for the individual chemicals and mixtures will be combined to fit one dose-response surface.



The conversion from chemical concentrations to moles will help facilitate the fit.

Figure 4. Isoboles can account for mixtures that fail the assumption of additivity.

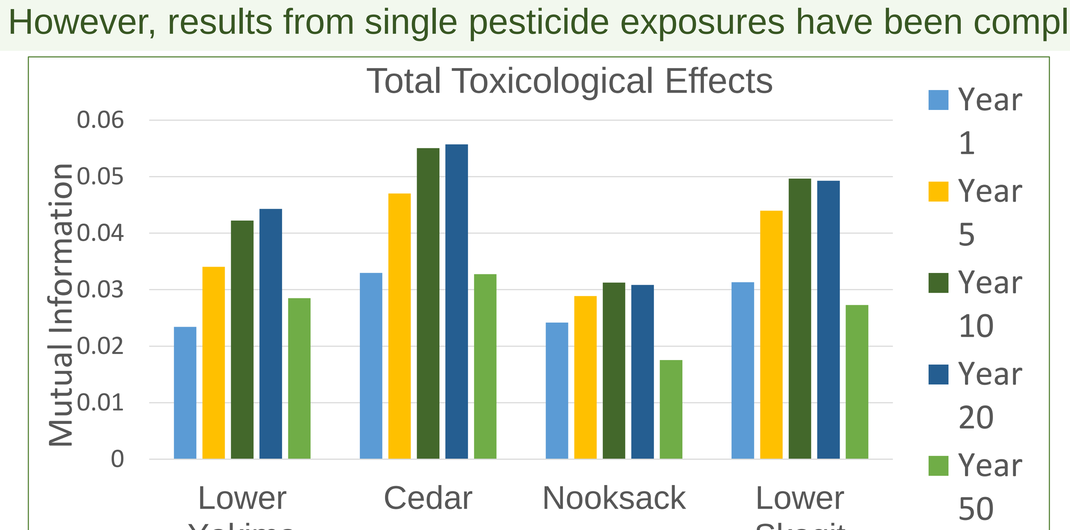


This isobole indicates synergistic toxicity. The point is the EC50 of this mixture and the error bars are the confidence intervals.

Isobole Model Design

Isoboles are contours that can connect two chemicals of equal effect into one response surface (Figure 4). If the isoboles are linear, then the mixture indicates concentration addition. Isoboles which curve towards the origin indicate synergistic mixtures; while ones that curve away from the origin are antagonistic [11]. The next steps will be to create an isobologram and fit mixture rays to a model.

NOTE: Probabilities of population estimations from the organophosphate pesticide mixtures have **NOT** been complied yet. However, results from single pesticide exposures have been complied.



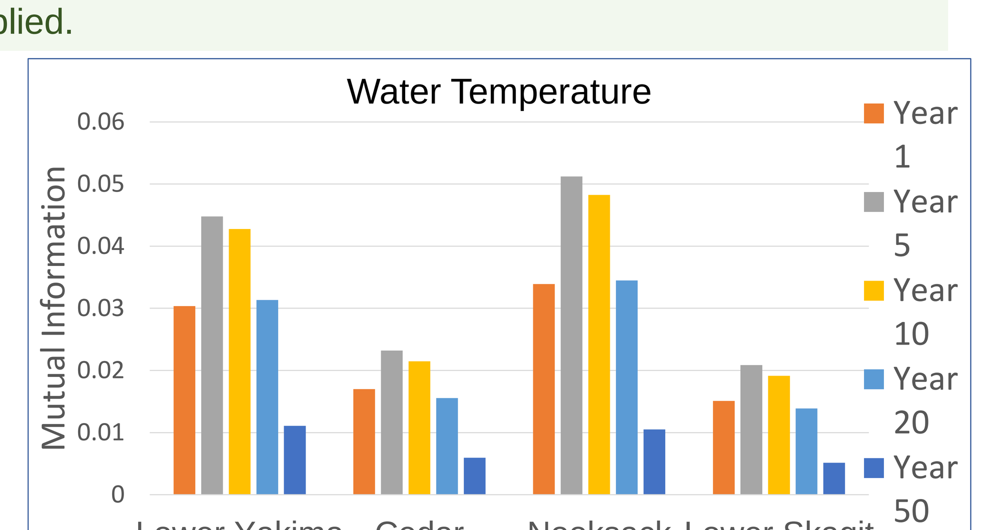


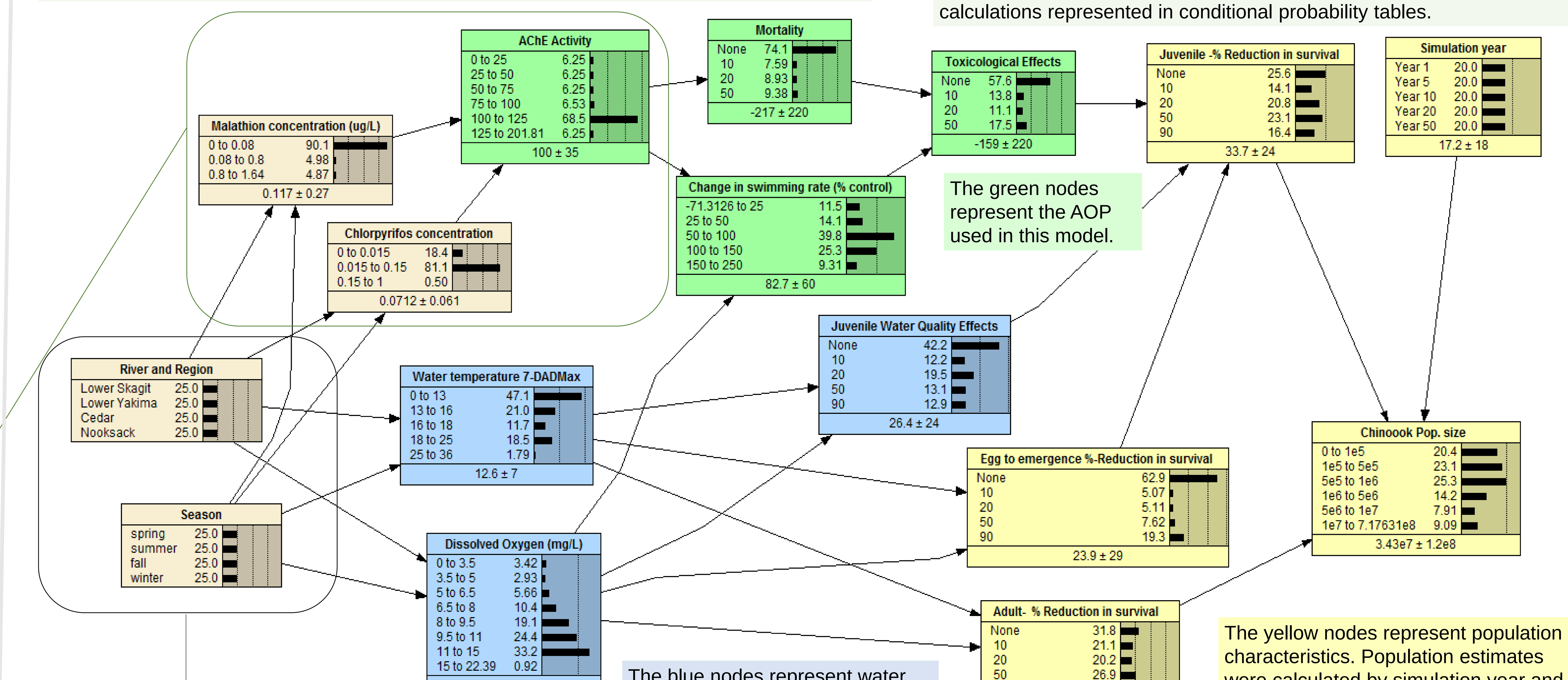
Figure 5 and 6. Sensitivity analysis for toxicological effects and water temperature by watershed per simulation year

Sensitivity Analysis for Single Organophosphate Pesticides

In our model, toxicological effects did not have much of an effect on salmon populations (Figure 5). This is not surprising because our model only accounted for single chemicals. Toxicological effects were more sensitive depending on the watershed. Total toxicological effects are more important in the Cedar and Lower Skagit watersheds for all years. Water temperature (Figure 6) is more important in the Nooksack and Lower Yakima watersheds.

Bayesian Network Depicting the Probability of Chinook Population Size

Figure 7. Bayesian Network made in Netica™ reflect probabilistic risk calculations represented in conditional probability tables.



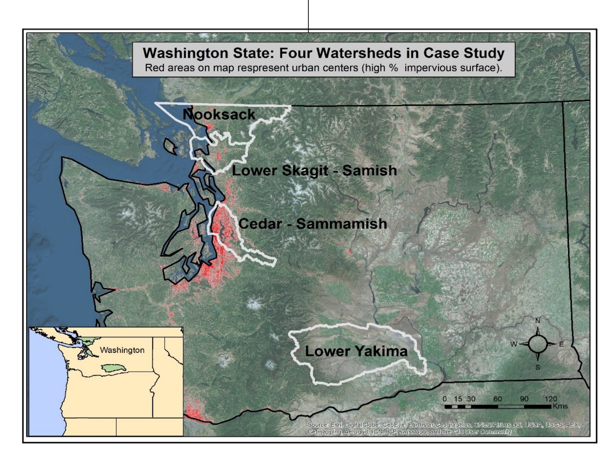


Figure 8. Four study sites will be examined, three in the Puget Sound basin and one in the Columbia river watershed.

Uncertainty Analysis for Single Organophosphate Pesticides

We attempted to make migration nodes to connect olfaction to adult reduction in survival because these OP pesticides have been found to inhibit olfaction [7] [10] [12]. Olfactory inhibition can adversely affect the ability of salmon to return to spawn. However, there is not a clearly defined dose-response relationship between what the role olfaction inhibition plays in homing ability. Therefore, our confidence in the available dataset is low.

We also examined code wire tag (CWT) data to calculate rates of homing and straying during migration. Estimates of smolt-adult return (SAR) percent rates and hatchery escapement numbers were calculated. Our analysis indicates that the CWT data are not sufficient to estimate SAR and escapement rates for our study areas because no percent error rates were given.

What is Next?

- We expect to see a **greater** contribution of toxicological effects with the mixtures
- We will add suitable habitat nodes from Geographic Information Systems (GIS) and other data sets. Adults pick suitable habitats to spawn based on discharge, substrate, streambank condition, riparian vegetation as well as cover & refuge [2]
- Climate change will also be added as a stressor

See also:

Landis et al. (2017) Integrating Adverse Outcome Pathways into the Bayesian Network Relative Risk Model for Landscape Scale Ecological Risk Assessment

Mitchell et al. (2017) Incorporating Spatially Explicit Metapopulation Models as the Adverse Outcome Pathway Endpoint of a Bayesian Network-Relative Risk Model.

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Noocksack Salmon Enhancement Association
King County DNR
King Conservation District
Skagit Conservation district
Yakima Tribal DNR
Samish Tribal DNR

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