WP090 The Use of Bayesian Networks to Integrate Population Modeling, Community Interactions and Ecosystem Services.

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Introduction

A very short introduction to Bayesian Networks

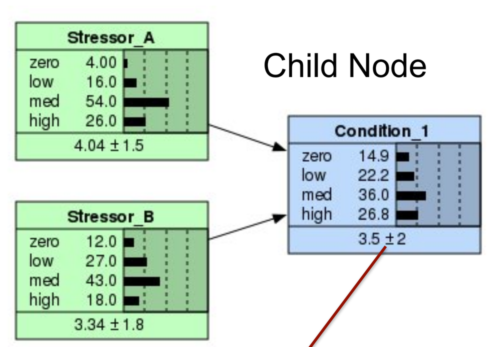
- Structure of Conceptual Model lends itself to using Bayesian Networks
- Bayesian Networks use conditional probabilities – based on the available data, models or expert opinion
- Explicit about uncertainties

Bayesian Network Model Construction

Input Nodes

Frequency of stressor concentrations established by data.

Child Node

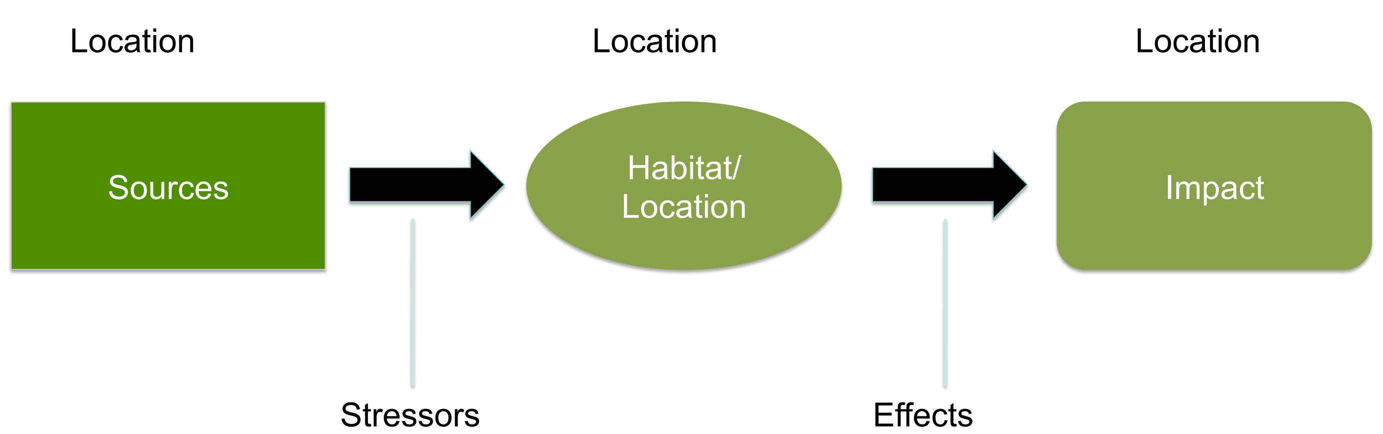


Stressor_A	Stressor_B	zero	low	med	high
zero	zero	100.00	0.000	0.000	0.000
zero	low	90.000	8.000	1.500	0.500
zero	med	75.000	20.000	4.000	1.000
zero	high	60.000	25.000	10.000	5.000
low	zero	75.000	20.000	4.000	1.000
low	low	50.000	35.000	10.000	5.000
low	med	25.000	35.000	30.000	10.000
low	high	10.000	30.000	45.000	15.000
med	zero	25.000	35.000	30.000	10.000
med	low	10.000	30.000	45.000	15.000
med	med	5.000	25.000	50.000	20.000
med	high	1.000	9.000	40.000	50.000
high	zero	15.000	25.000	40.000	20.000
high	low	10.000	15.000	35.000	40.000
high	med	5.000	10.000	30.000	55.000
high	high	1.000	4.000	20.000	75.000

Conditional Probability Table set by data on interactions

All Bayesian networks constructed in Netica

1. Each node (parameter) has 4 potential states or ranks in our formulation corresponding to the relative risk model
2. Define the criteria for each input node
3. Determine the probability distributions for each input node from available data
4. Develop conditional probability tables (CPTs) that define the relationship between input and child nodes



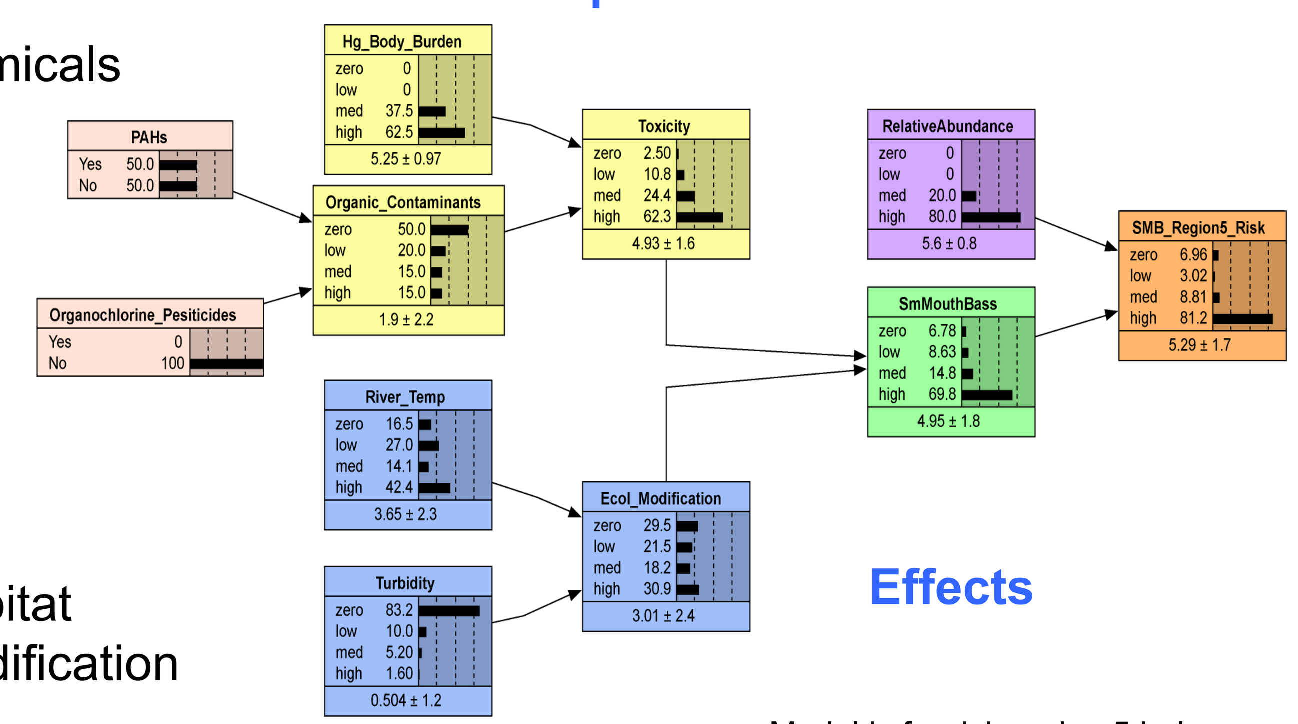
This is the fundamental cause-effect conceptual model for regional scale risk assessment using the relative risk model. In most instances the impact portion corresponds to a loss of valued ecological components and services.

A detailed cause-effect conceptual model provides the linkages between sources, stressors, locations, effects and impacts.

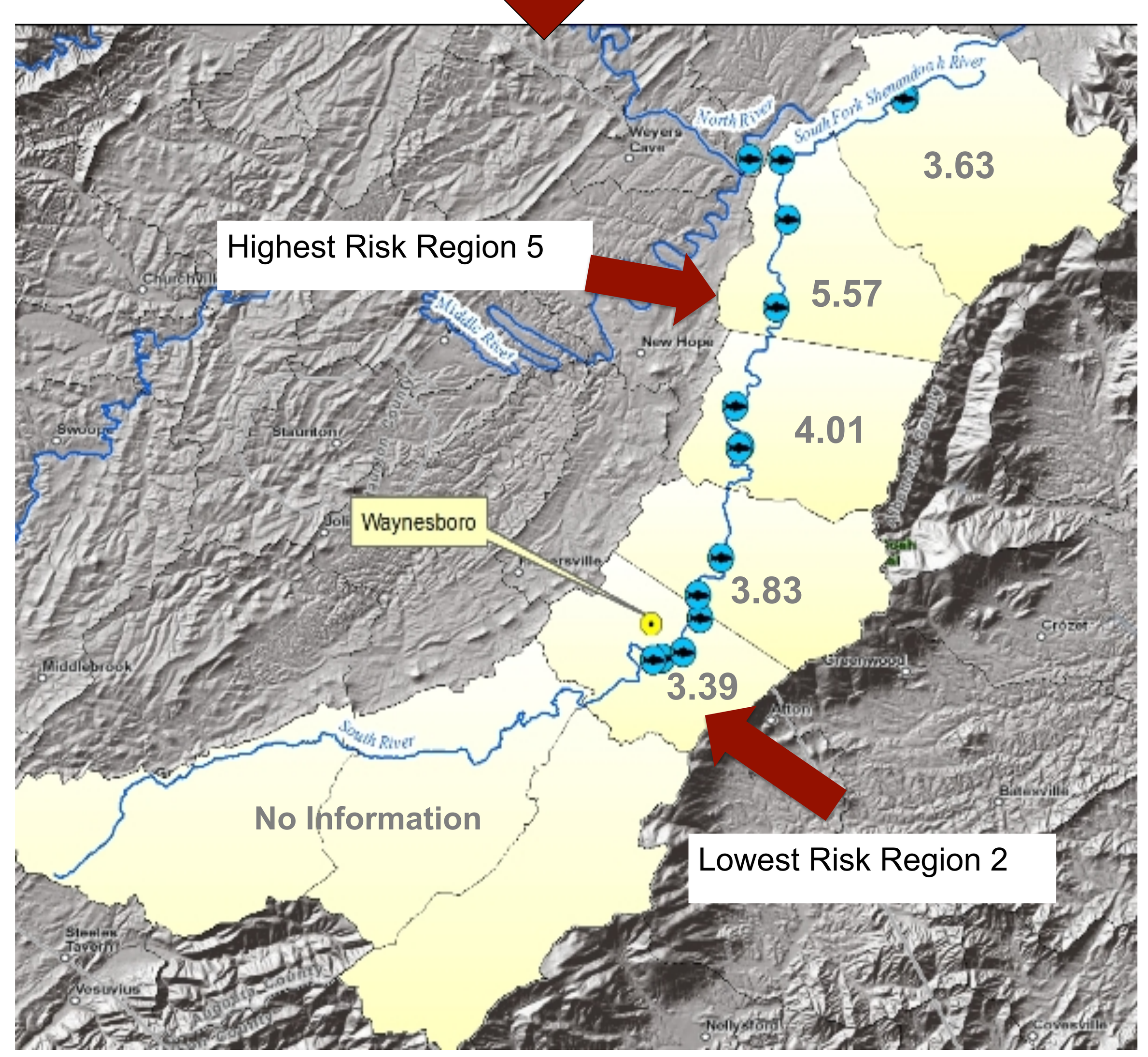
Risk Assessment

A Bayesian network for the calculation of risk to smallmouth bass, an important species and fishing resource for the South River, VA

The risk is to the propogation of the smallmouth bass population in the study area.



Model is for risk region 5 below.

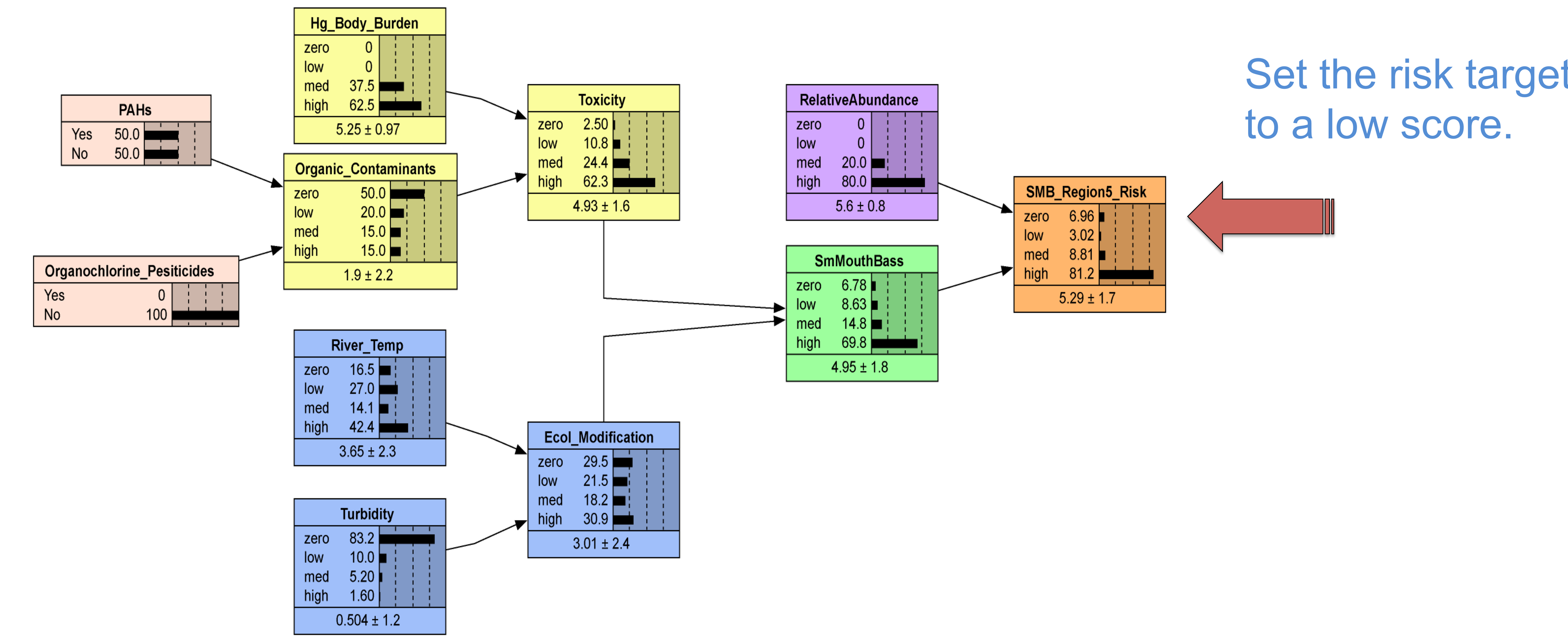


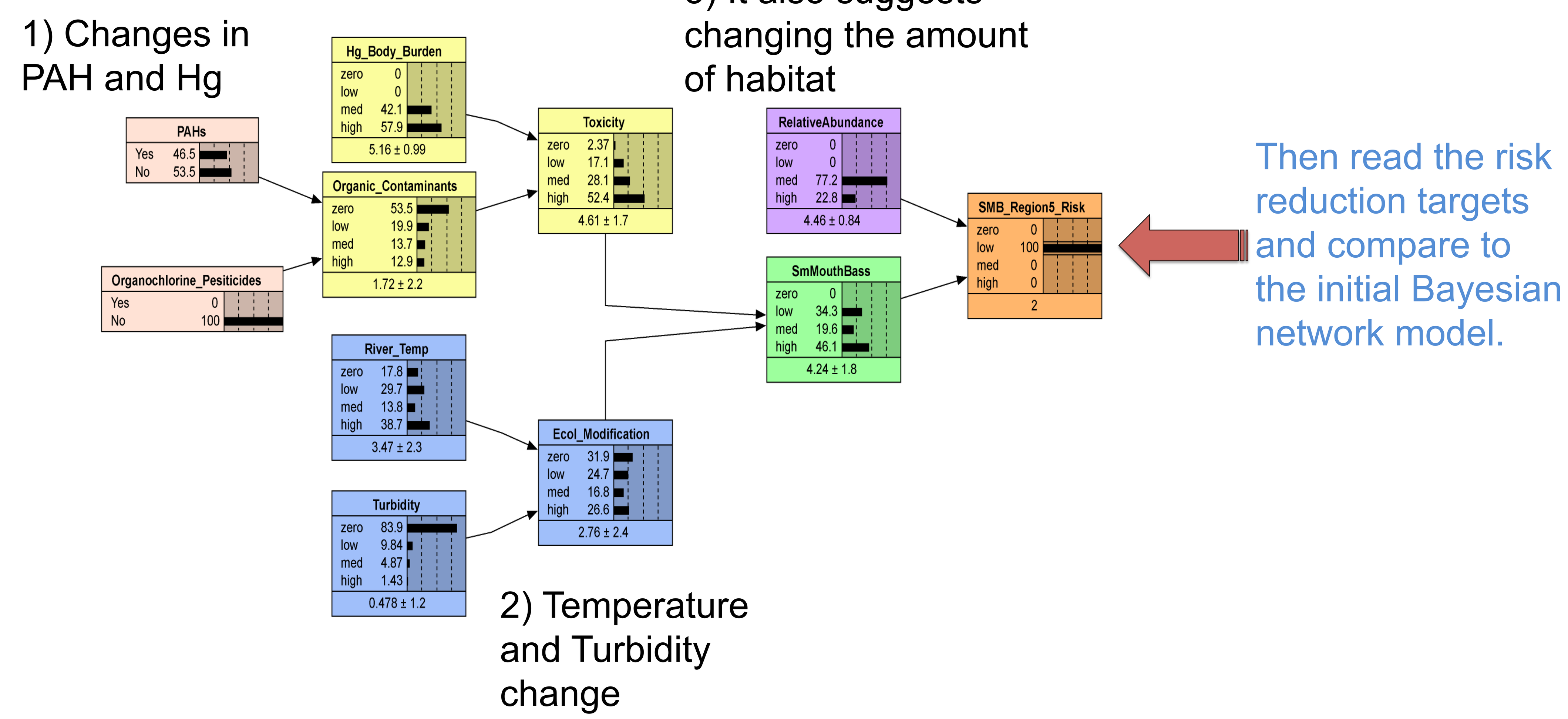
Calculation of risk is interesting and can be useful. Many risk assessment schemes can make an approximation of this, including our usual relative risk model.

However, what is critical is the defining of target risks and estimating the conditions that would provide that reduction of risk. The Bayesian networks do that in a straightforward manner.

Calculation of cleanup requirements to reduce the risk to smallmouth bass populations

First step is to set risk target to low risk at 100 percent





Summary and Conclusions

The BN is very specific and deals very explicitly with uncertainty. The trade off is that sufficient data are required to construct a reasonable CPT.

The risk assessment using the Bayesian network also allows the calculation of restoration strategies and specific management and engineering goals.

We have also used similar approaches to examine the interaction between landscape and population distribution to calculate the risk due to Whirling disease.

Bayesian networks also provide a clear structure that dictates that certain information, especially cause-effect relationships, are clearly understood.

Support-The South River example is based on research funded by DuPont and data were supplied by the South River Science Team. Other research on the application of Bayesian networks to risk assessment was funded by the US Forest Service and the USGS though the Whirling Disease program.

Notes on the rankings in the parent nodes

A critical part of establishing a Bayesian network for regional risk assessment is the establishment of the ranking criteria for the various nodes of the system. Examples are given below for setting ranking criteria for the smallmouth bass model for ecological parameters and for toxicological parameters. As you can observe a variety of data sets and dose-response curves are used in order to set the values within each node.

Defining Ranks

Criteria Ecological Parameters

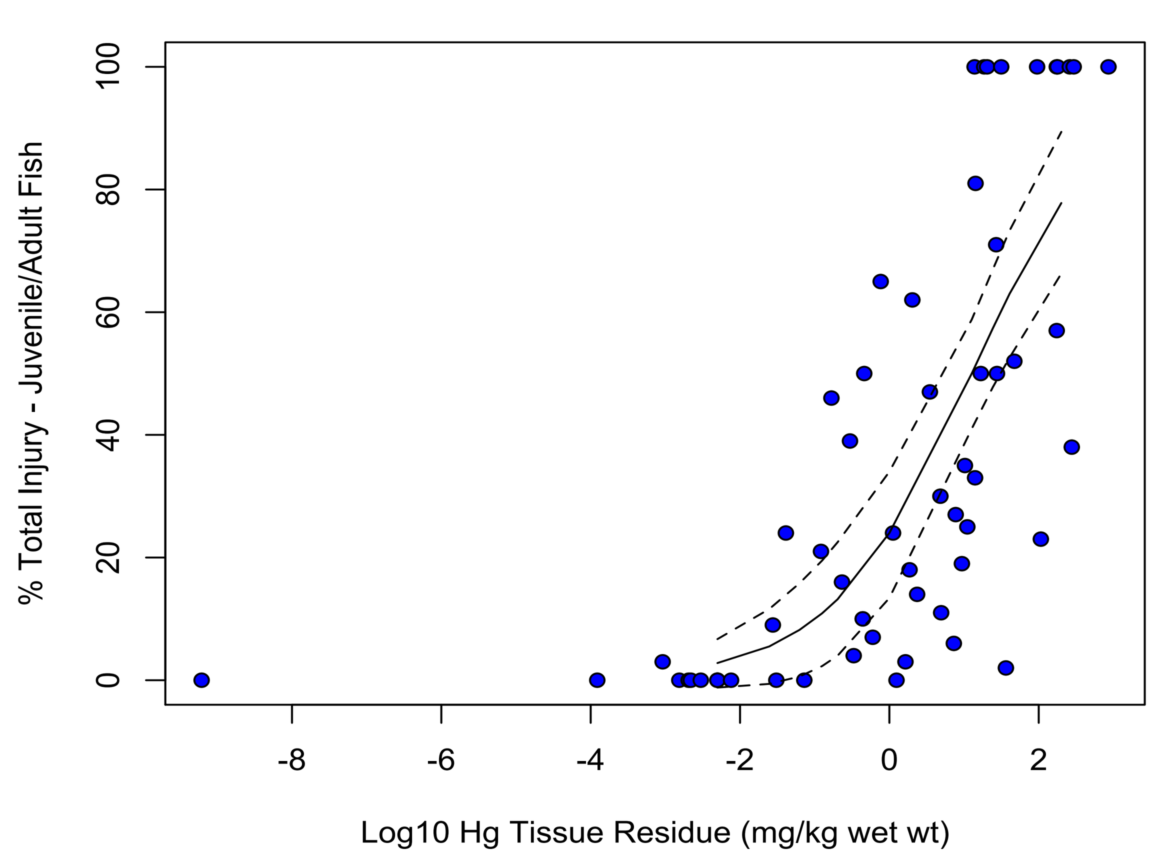
Variable	Description	Rank	Justification/Evidence
River Temperature	Relative frequencies of water temperature data from 2006 for each rank	Zero: 22-26 °C	Optimum temperature for juvenile growth & fry survival, and preferred habitat temp range
		Low: 19-21.9 or 26.1-29 °C	Growth rate reduction for juvenile fish
		Med: 16-18.9 or 29.1-31.9 °C	Estimated 30-50% growth rate reduction
		High: ≤ 15.9 or ≥ 32°C	Upper limit for growth = 27°; no spawning or egg/fry survival
Total Suspended Solids	Relative frequencies of TSS measured in 2006 for each rank	Zero: < 25 mg/L	Preferential habitats ≤ 25
		Low: 25-80 mg/L	Prey consumption decreases above 20
		Med: 80-200 mg/L	Avoidance behavior; & coughing common in adult trout; trout egg mortality; growth retardation & reproductive impacts in largemouth bass
		High: > 200 mg/L	Onset of gill tissue damage in adult trout (no information on smallmouth bass)

Criteria Toxicological Parameters

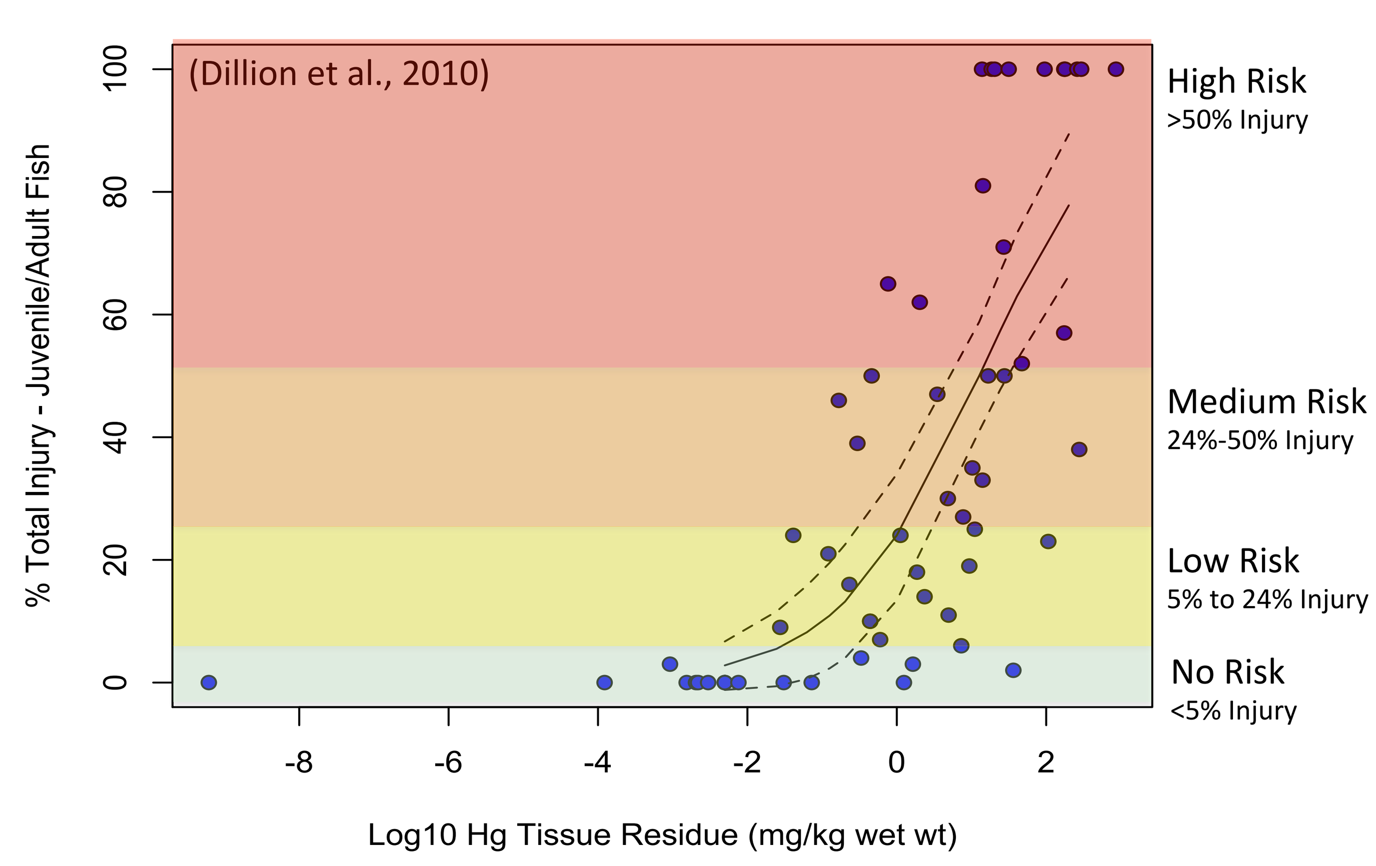
Variable	Description	Rank	Justification/Evidence
PAHs	Relative frequencies of sediment [PAH] with reference to NOAA Screening Quick Reference Tables (SQuiRTs) for Organics in Water and Sediment	Yes: exceeded the LEL No: lower than the LEL	Comparison with the NOAA's Low Effects Limit (LEL) Screening Reference Value
Organic Pesticides	Relative frequencies of water [pesticide] with reference to NOAA SQuiRTs (mostly derived from EPA water quality criteria)	Yes: exceeded the Chronic Level No: lower than the Chronic Level	Comparison with the NOAA's Chronic Toxicological Effects Level
Mercury Body Burden	Methylmercury body burden indicative of internal mercury exposure derived from Dillon et. al, 2010.	Zero: 0.2 mg/kg	< 5% lethality or equivalent endpoints
		Low: 0.3 - 1 mg/kg	5 - 24% lethality or equivalent endpoints
		Med: 1.1 - 3.0 mg/kg	24 - 50% lethality or equivalent endpoints
		High: 3.1 - 10 mg/kg	> 50% lethality or equivalent endpoints

Criteria for Hg Toxicity ranks

Developed Risk Rankings -Based on Dillon et. al, 2010 – summary paper that combined fish mercury toxicity papers to create a dose-response curve for lethality equivalent endpoints (death, spawning success, and developmental abnormalities). The information was cross-referenced risk rankings with EPA National Lake Fish Tissue Study fpr additional confirmation.

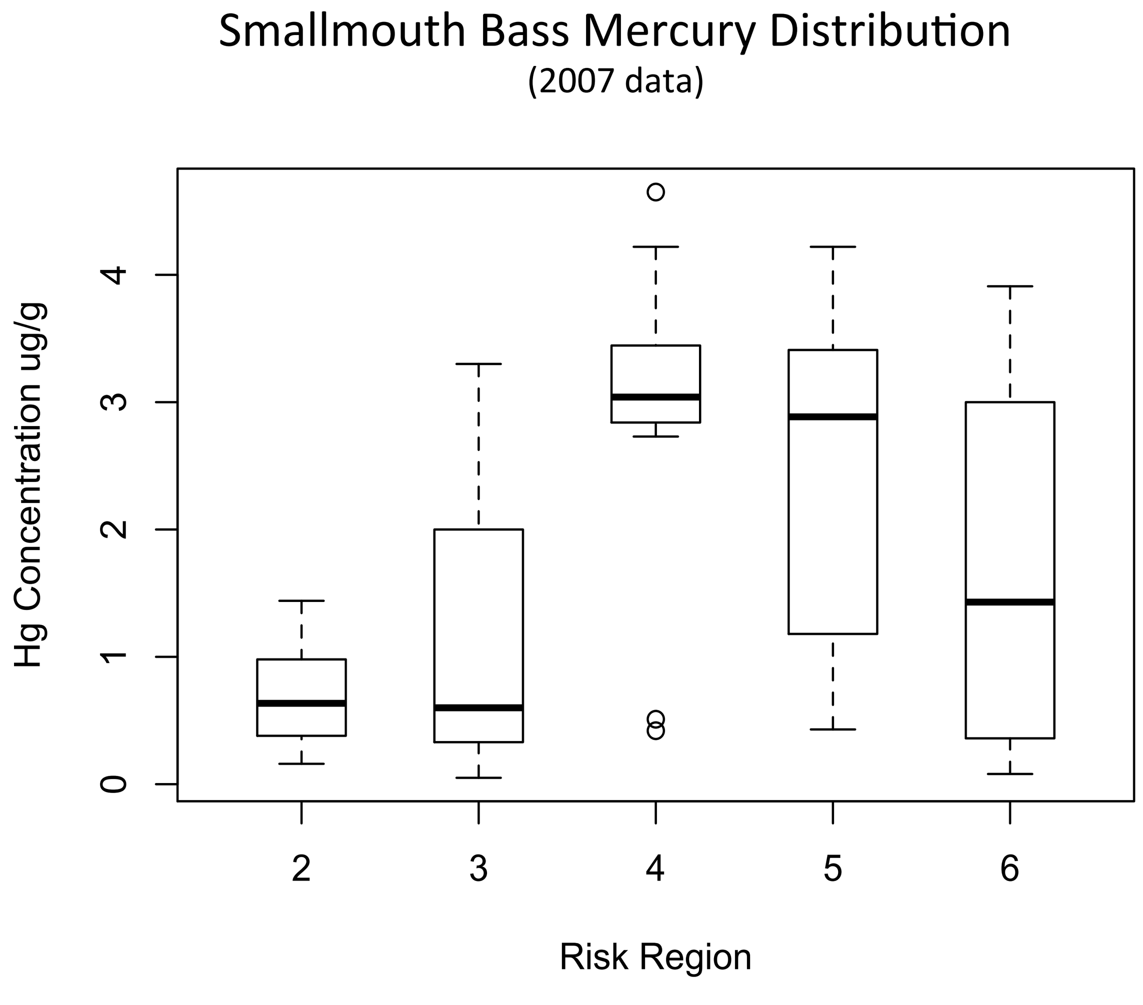


Data converted to ranking criteria



Defining Probability Distributions for Mercury Toxicity

Analyzed Mercury Filet data by Risk Region and compared most recent data 2005 and later. Since there was a statistical difference in data between years – used most recent 2007 data.



We then calculated the frequency of Smallmouth Bass tissue concentrations within each risk level in each risk region.

Dillon T, Beckvar N, Kern J. 2010. Residue-based mercury dose-response in fish: an analysis using lethality-equivalent test points. Environmental Toxicology and Chemistry 11:2559-2565.