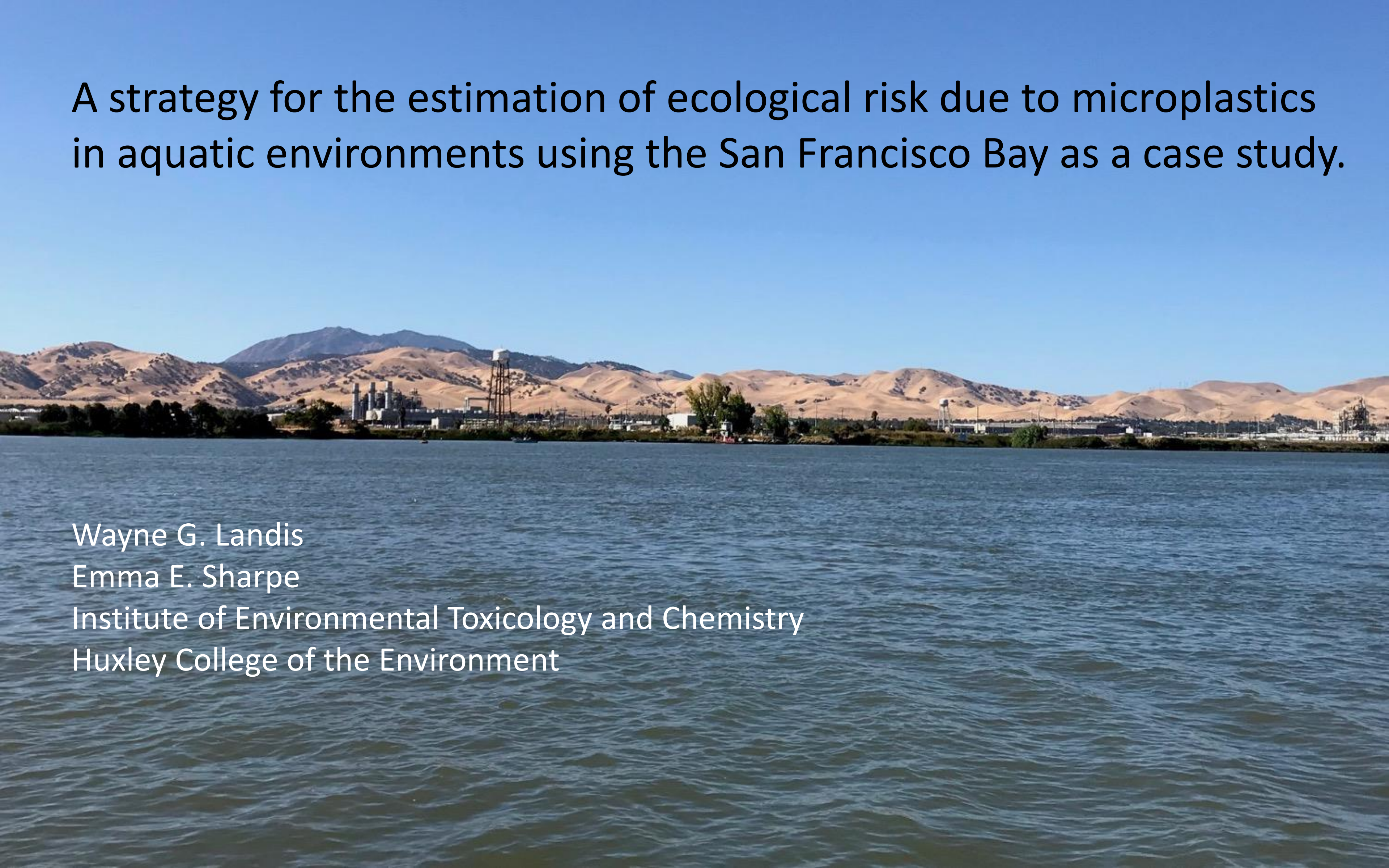
A strategy for the estimation of ecological risk due to microplastics in aquatic environments using the San Francisco Bay as a case study.



Wayne G. Landis
Emma E. Sharpe
Institute of Environmental Toxicology and Chemistry
Huxley College of the Environment

Thanks first to my colleagues…….

Emma E. Sharpe, Skyler R. Elmstrom, Erika Whitney, Cynthia Kuhn, Mikayla Bowers, Eric Lawrence at Western Washington University

The Stacey Harper Laboratory and the The Susanne Bander Laboratory at Oregon State University

Diana Lin, Ezra Miller and their colleagues at the San Francisco Estuary Institute

Support…….

National Science Foundation Growing Convergence Research Big Idea under Grants #1935028 and #1935018

CA Metropolitan Water District, State Water Contractors , CA Department of Pesticide Regulation

The mistakes and misinterpretations are mine.

landis@wwu.edu

Framing the Presentation

The Question

What are the risks of micro and nanoplastics to ecosystem services?

The Issue

There has been a major disconnect between public statements of the risk from credible sources and the results of the currently published risk evaluations.

The contrast between rhetoric and current screening assessments for microplastics

Woods Hole Oceanographic Institution

https://www.whoi.edu/know-your-ocean/ocean-topics/pollution/marine-microplastics/

Society for Science and the Public

https://www.sciencenewsforstudents.org/article/polluting-microplastics-harm-both-animals-and-ecosystems

Harvard University

https://sitn.hms.harvard.edu/flash/2020/14-million-tons-of-microplastic-are-on-the-ocean-floor/

The contrast between rhetoric and current screening assessments for microplastics

Environmental Pollution 242 (2018) 1930–1938

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Risk assessment of microplastics in the ocean: Modelling approach and first conclusions☆

Gert Everaert [a,*], Lisbeth Van Cauwenberghe [b], Maarten De Rijcke [a], Albert A. Koelmans [c], Jan Mees [a], Michiel Vandegehuchte [a], Colin R. Janssen [b]

[a] Flanders Marine Institute, Wandelaarkaai 7, B-8400, Ostend, Belgium
[b] Ghent University, Laboratory of Environmental Toxicology and Aquatic Ecology, Coupure Links 653, B-9000, Ghent, Belgium
[c] Wageningen University, Aquatic Ecology and Water Quality Management Group, P.O. Box 8080, 6700 DD, Wageningen, the Netherlands

Environmental Science & Technology

pubs.acs.org/est

Article

Solving the Nonalignment of Methods and Approaches Used in Microplastic Research to Consistently Characterize Risk

Albert A. Koelmans,* Paula E Redondo-Hasselerharm, Nur Hazimah Mohamed Nor, and Merel Kooi

Cite This: https://dx.doi.org/10.1021/acs.est.0c02982

Read Online

The methods compare PNECs derived from species sensitivity distributions to measured environmental concentrations from a number of sites.

The estimated risk is very low.

The contrast between rhetoric and current screening assessments for microplastics

Environmental Science & Technology
AUTHORCHOICE
pubs.acs.org/est
Critical Review

Quality Criteria for Microplastic Effect Studies in the Context of Risk Assessment: A Critical Review

Vera N. de Ruijter,*,§ Paula E. Redondo-Hasselerharm,§ Todd Gouin, and Albert A. Koelmans

Cite This: *Environ. Sci. Technol.* 2020, 54, 11692−11705 Read Online

This implies that based on the current state-of-the- science, the **WOE for ecological effects is very limited and the environmental risk of MPs is difficult to assess.** The lack of clear evidence for ecological effects in nature **due to relatively poor-quality effects studies available** for the risk assessment process is worrying, particularly given concerns raised by the public and decision-makers to provide a quantitative assessment of the risks for MPs.

Aquatic Toxicology 230 (2021) 105689
Contents lists available at ScienceDirect
Aquatic Toxicology
journal homepage: www.elsevier.com/locate/aqtox

Probabilistic environmental risk assessment of microplastics in marine habitats

Véronique Adam, Alex von Wyl, Bernd Nowack *
Empa, Swiss Federal Laboratories for Materials Science and Technology, Lerchenfeldstrasse 5, 9014, Sankt Gallen, Switzerland

This results in a global RCR with a mean of 4·10− 4 and 2.10− 5 % of its values above 1, showing a very **unlikely but possible risk**.

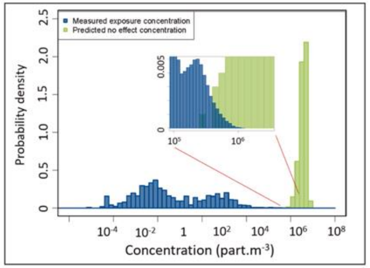


Fig. 3. Worldwide measured environmental concentration (MEC) and predicted no-effect concentration (PNEC) distributions in part m^{-3} for marine habitats.

In contrast we have evidence of toxic effects from tire materials

Tian et. al. 2020 *Science*

EMBARGOED UNTIL 2:00PM US ET, THURSDAY 3 DECEMBER 2020

Science

REPORTS

Cite as: Z. Tian *et al.*, *Science*
10.1126/science.abd6951 (2020).

A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon

Zhenyu Tian[1,2], Haoqi Zhao[3], Katherine T. Peter[1,2], Melissa Gonzalez[1,2], Jill Wetzel[4], Christopher Wu[1,2], Ximin Hu[3], Jasmine Prat[4], Emma Mudrock[4], Rachel Hettinger[1,2], Allan E. Cortina[1,2], Rajshree Ghosh Biswas[5], Flávio Vinicius Crizóstomo Kock[5], Ronald Soong[5], Amy Jenne[5], Bowen Du[6], Fan Hou[3], Huan He[3], Rachel Lundeen[1,2], Alicia Gilbreath[7], Rebecca Sutton[7], Nathaniel L. Scholz[8], Jay W. Davis[9], Michael C. Dodd[3], Andre Simpson[5], Jenifer K. McIntyre[4], Edward P. Kolodziej[1,2,3]*

Yet it has been demonstrated that chemicals derived from tire wear particles do cause toxicity to Coho salmon and population scale effects has been observed throughout Puget Sound.

Outline for the remainder of this talk

1. Terms , definitions and background for microplastics, toxicity and risk assessment

2. The method-Bayesian network relative risk model

3. The San Francisco Bay microplastic risk assessment

4. How to use risk assessment to structure a program to manage microplastics

Terms , definitions and background for microplastics, toxicity and risk assessment

- California State definition of microplastics in drinking water
- Raman or Fourier Transform Infrared (FTIR) spectroscopy used to determine if composition is a synthetic polymer of anthropological origin
- Includes tire wear particles

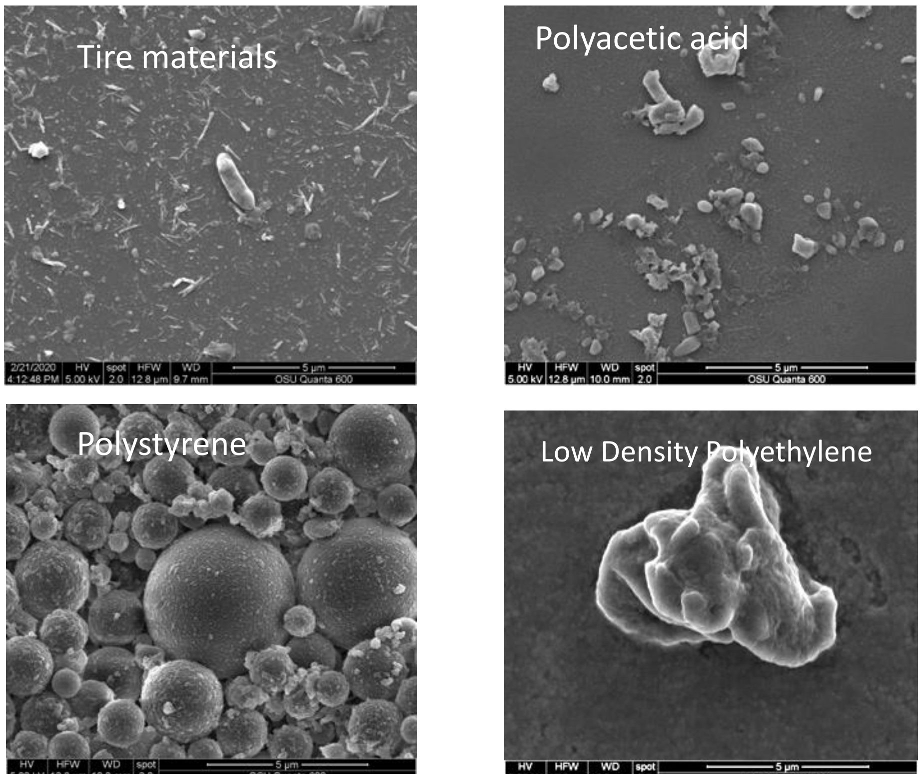
Definition of 'Microplastics in Drinking Water'*

'Microplastics in Drinking Water' are defined as solid[1] polymeric materials[2] to which chemical additives or other substances may have been added, which are particles[2] which have at least three dimensions that are greater than 1 nm and less than 5,000 micrometers (µm)[3]. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded.

CALIFORNIA WATER BOARDS
State Water Resources Control Board

Microplastics as an interesting and ubiquitous stressor

SEM-Jared Stine, OSU



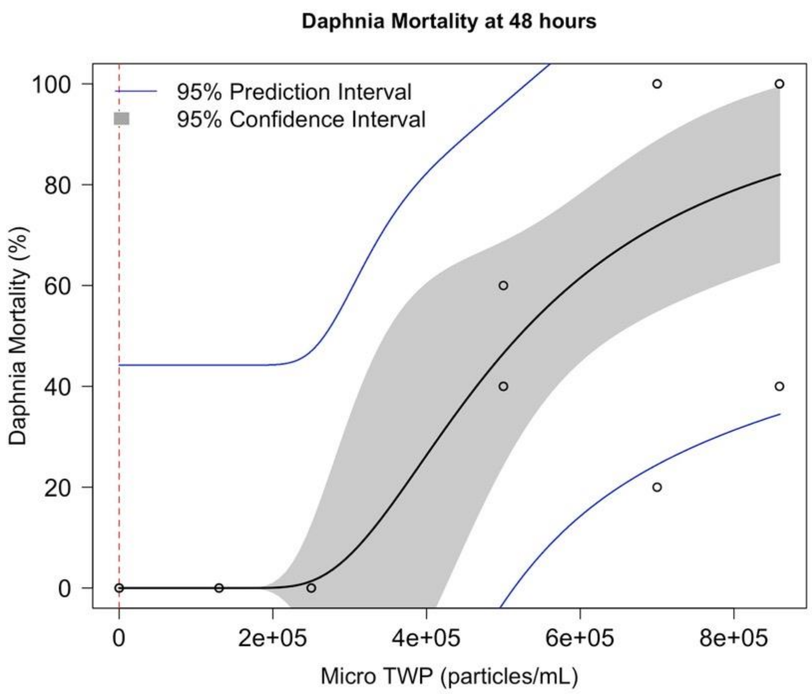
5μm

E. coli 1-2 μm

- A variety of compositions
- A variety of sizes
- Many different shapes and sizes
- Can be found in mixtures in the environment with other plastic materials, chemicals and biologicals

Toxicity is defined as a dose-response with confidence and predictive intervals

- Bryan Harper and Brittany Cunningham-OSU
- Daphnia toxicity data
- 6 concentrations
- 3 replicates



The regression provides an equation that describes toxicity-sounds like science!!

The definition of Risk is based on a probability distribution and not a point

<u>Technical definition</u>: The ***probability*** of an effect on one or more specific endpoints due to a specific stressor or stressors.

In other words, risk reflects how often a specific change or changes in the environment will affect something of **value to society**, such as human health, outdoor recreation, or the survival of an endangered species.

Incorporates Science and Values

Definition of a regional ecological risk assessment

Our working definition of a regional scale risk assessment is: A risk assessment deals at a spatial scale that contains multiple habitats with multiple sources of multiple stressors affecting multiple endpoints and that the characteristics of the landscape affect the risk estimate. Although there may only be one stressor of concern, at a regional scale the other stressors acting upon the assessment endpoints are to be considered.

Landis and Wiegers 2005

The method-Bayesian network relative risk model

The project does not apply species sensitivity distributions but uses a method to answer very specific questions about landscape scale risk.

Integrated Environmental Assessment and Management — Volume 17, Number 1—pp. 79–94
Received: 12 June 2019 | Returned for Revision: 17 July 2020 | Accepted: 23 September 2020 79

Special Series

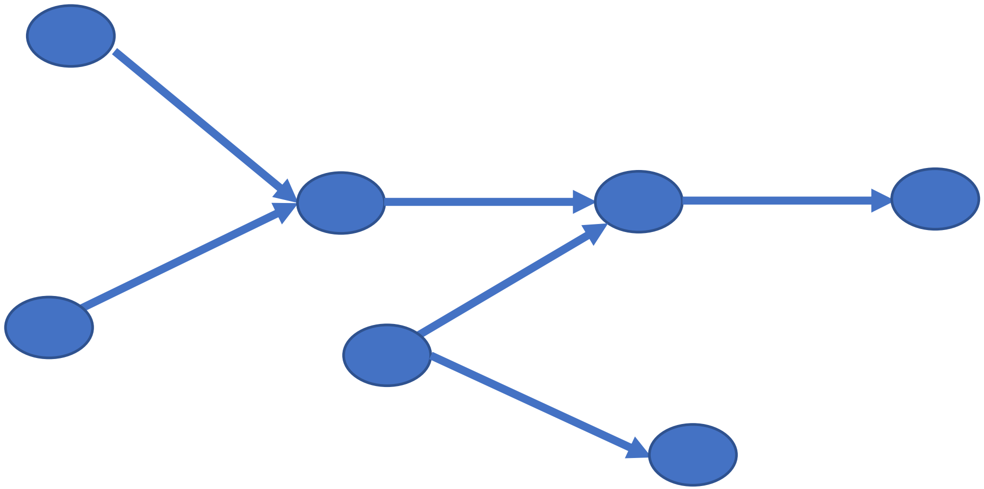
The Origin, Development, Application, Lessons Learned, and Future Regarding the Bayesian Network Relative Risk Model for Ecological Risk Assessment

Wayne G Landis†*

†Institute of Environmental Toxicology and Chemistry, Huxley College of the Environment, Western Washington University, Bellingham, Washington, USA

Short description of Bayesian networks

Directed Acyclic graph-left to right-some draw them vertical.



Bayesian networks (BN) are directed acyclic graphs

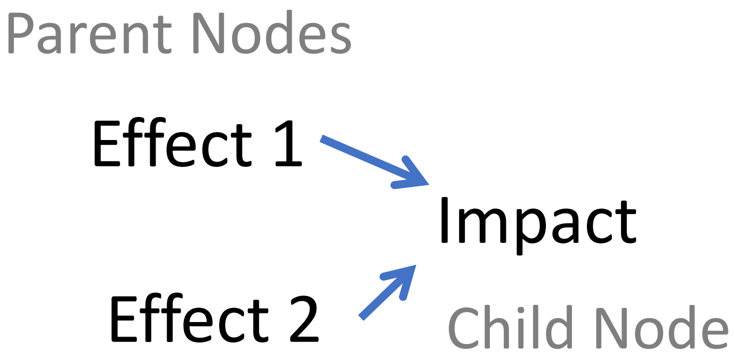
Bayesian Networks (BNs)-short introduction

Bayesian networks are Directed Acyclic Graphs (DAGs) that represent relationships between variables.

Source — Stressor — Habitat — Effect → Impact

In other words, cause-effect pathways also known as conceptual models.

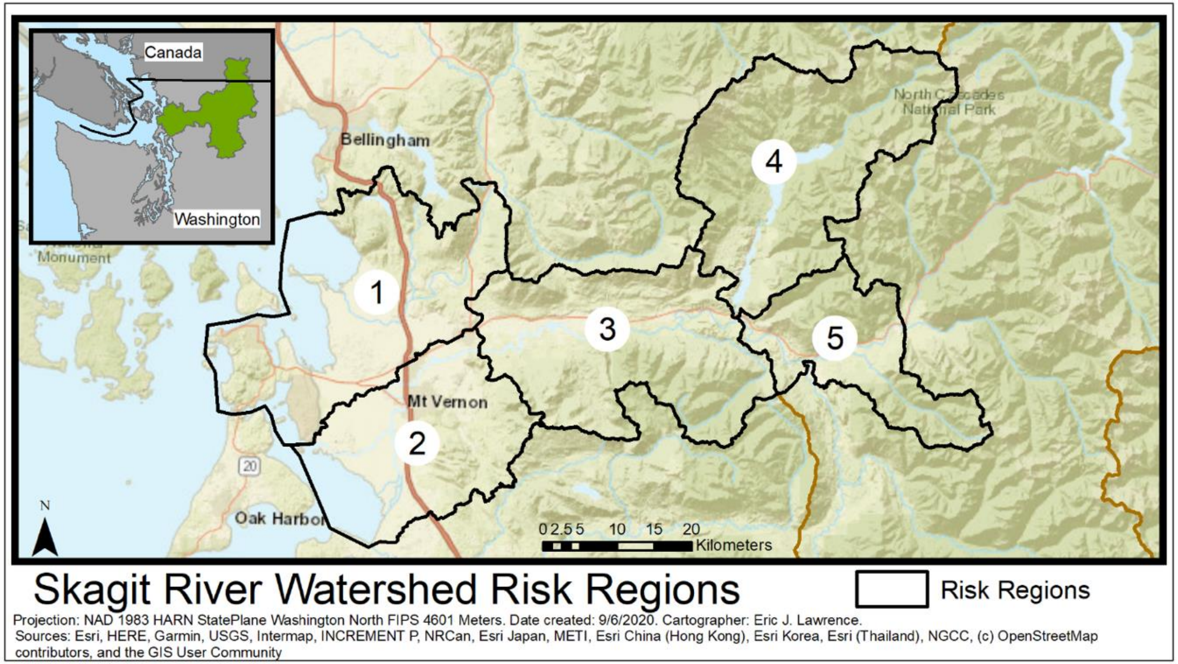
Bayesian Networks (BNs)-even shorter introduction-



The result in the child node is determined by a conditional probability table (CPT).

We make maps of the study site.

- The question is the risk to Chinook salmon due to pesticides, water quality and climate change.



[USGS] U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service. 2013. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (4 ed.): Techniques and Methods 11–A3. Available at https://pubs.usgs.gov/tm/11/a3/. Accessed 17 May 2019.

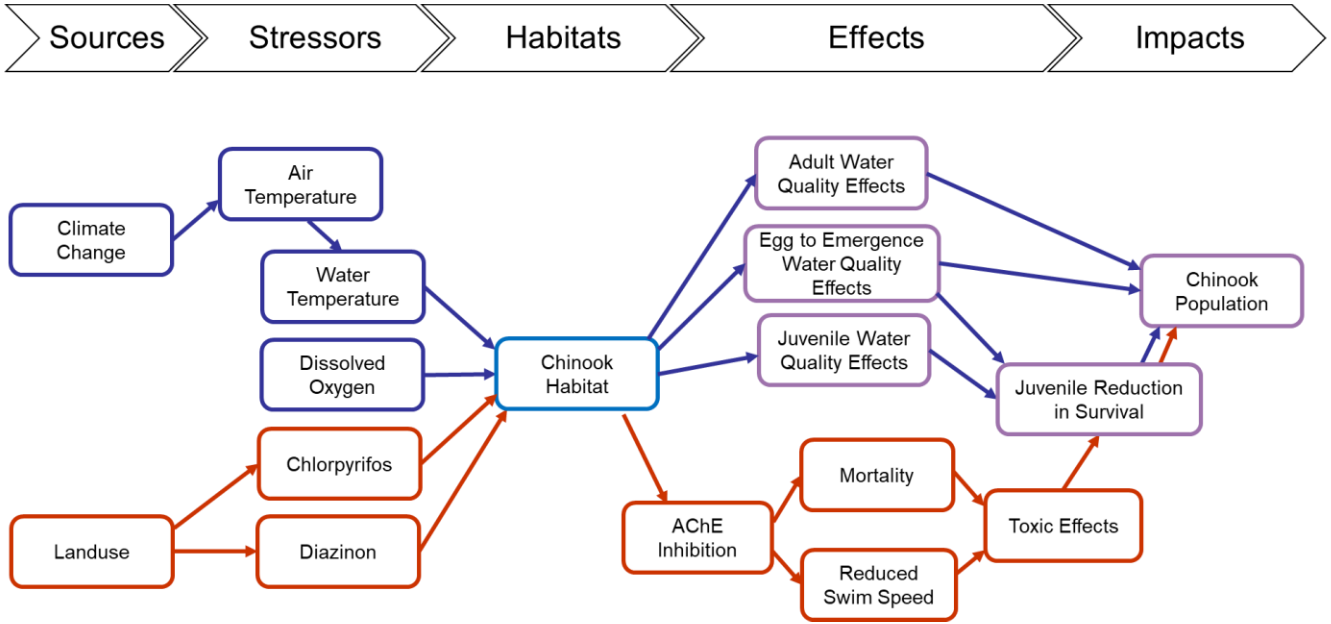
This is the backbone of the risk assessment approach

This is a diagram of the basic risk assessment approach, the boxes are nodes, and the arrows are the cause-effect interactions. The functions describe how the probability distributions for each node interact and result in an estimate of risk to valued ecological services (impacts).

History and details reviewed in Landis (2021)

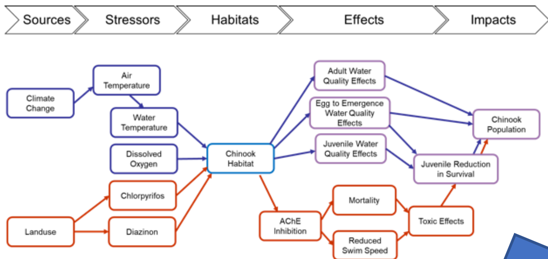
Conceptual model for Skagit River

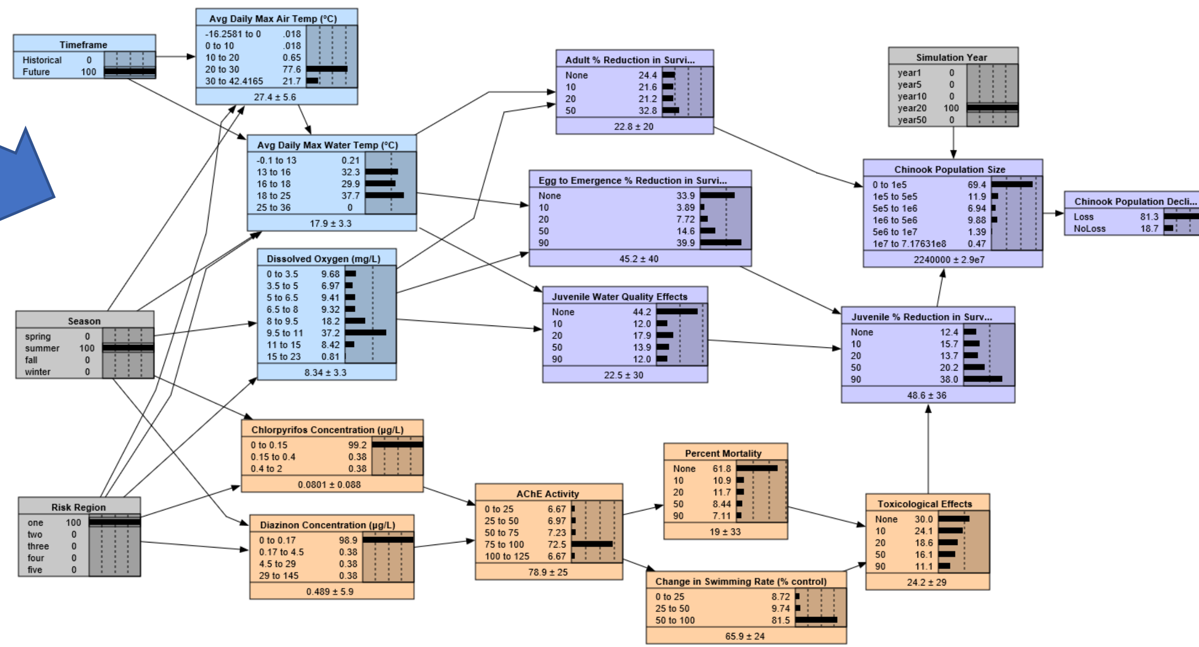
- Blue - Climate / Water Quality pathway
- Orange – Toxicity Pathway
- Purple – Effects and Population modeling.



E. Lawrence thesis

From the conceptual model a Bayesian network is built



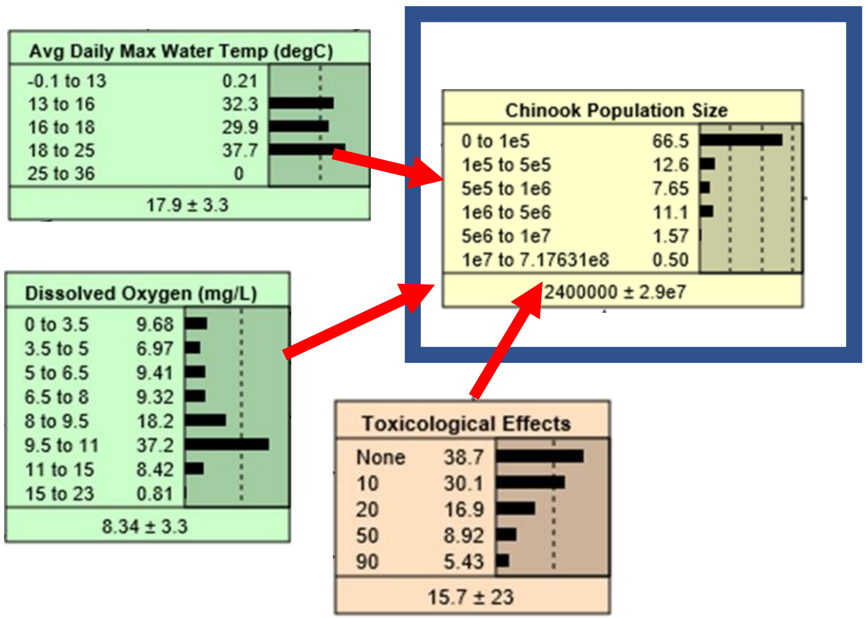


The model is built using Netica software-other types of software can be used.

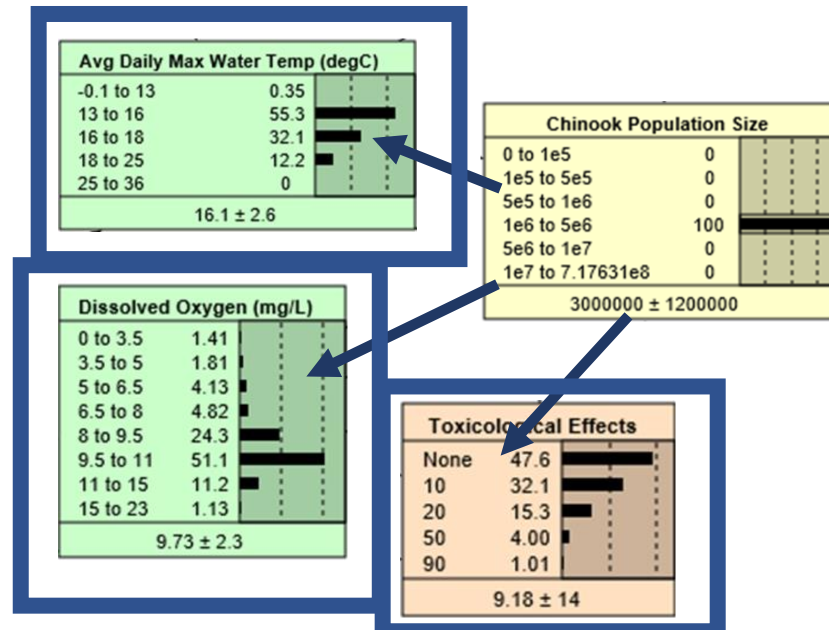
E. Lawrence thesis

The calculations can estimate risk but also generate a potential solution-note the probability distributions

Risk calculation



Potential solution



E. Lawrence thesis

The case study....San Francisco Bay

The case study

The ecological risk assessment for the San Francisco Bay and a blueprint for the Upper San Francisco Estuary.

The approach

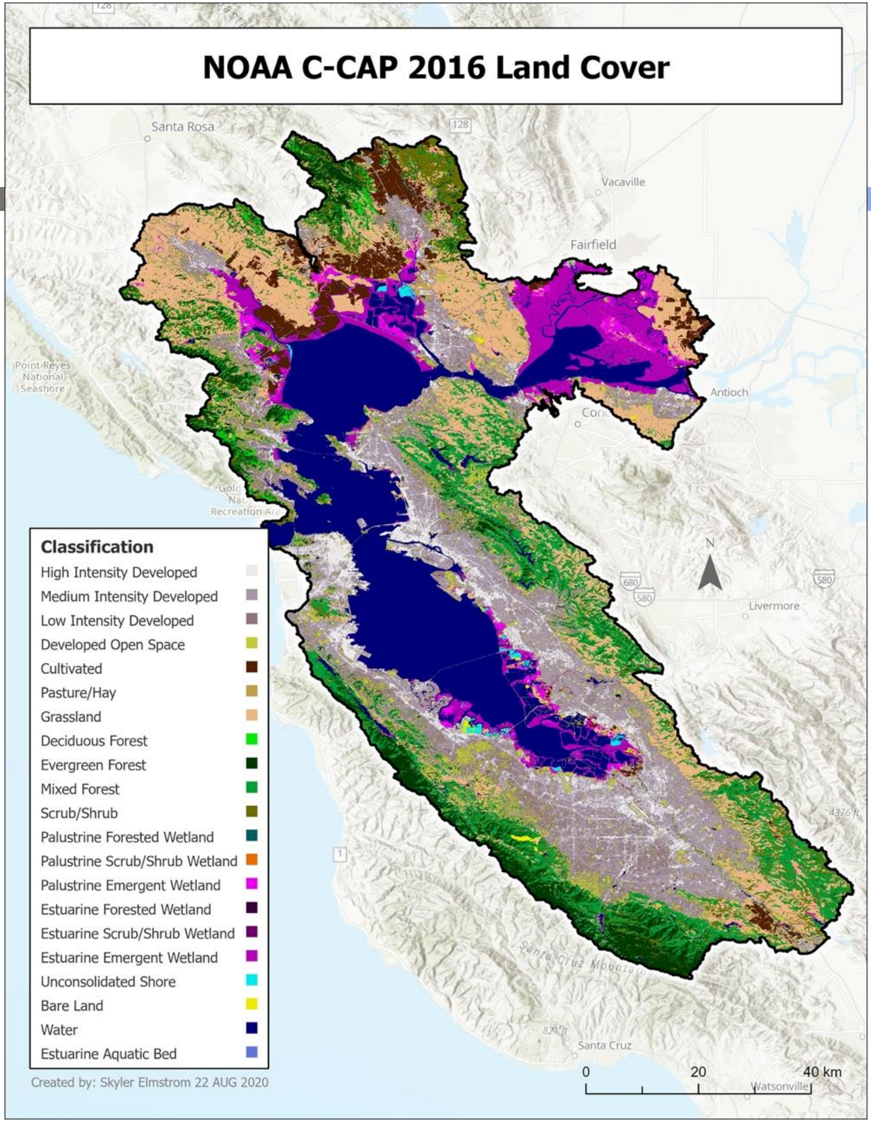
A specific risk assessment framework that has been applied to projects across the world, at a variety of scales, and with multiple stressors and endpoints

San Francisco Bay microplastic risk assessment

Not just San Francisco but a diverse landscape, a major port, a diverse set of industries, and the outflow from the California Delta-Upper San Francisco Estuary.

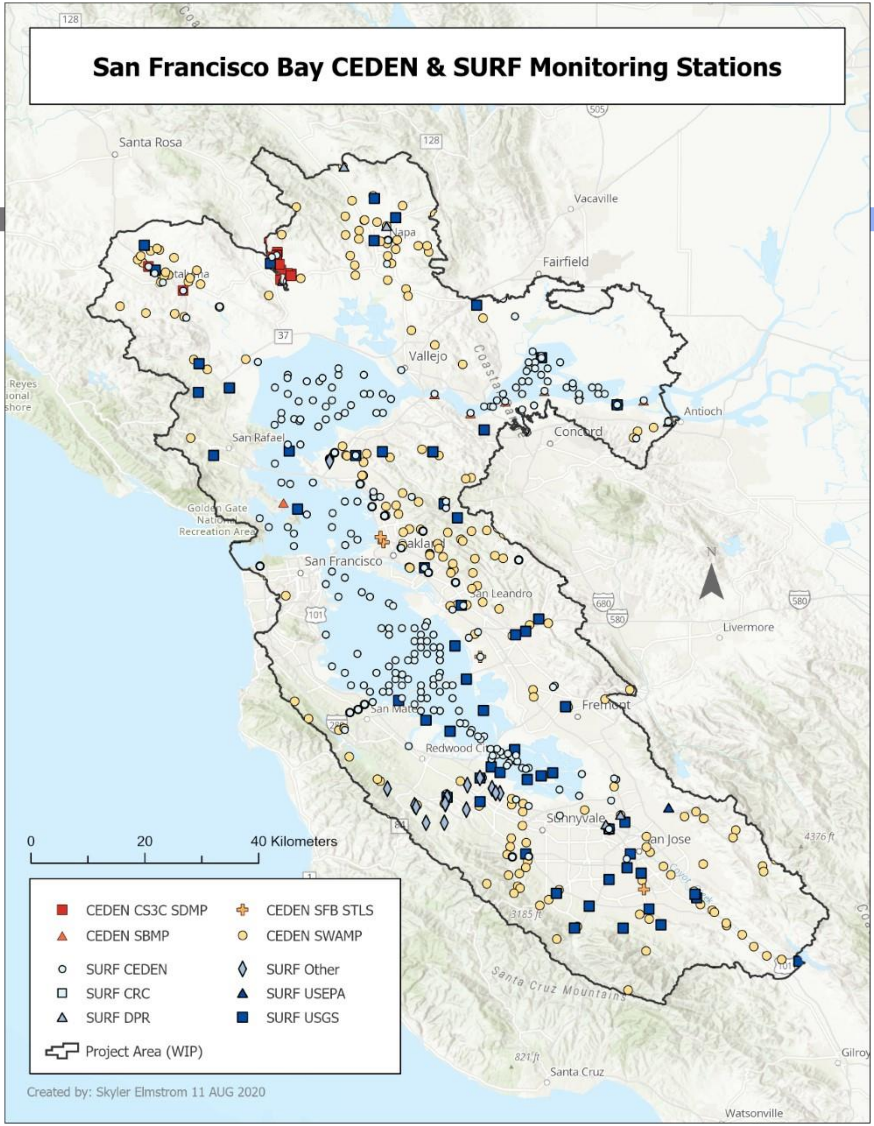
Land Use/Cover

- San Francisco Bay is a major urban, industrial, marine, and recreational hub.
- Nine counties and more than 40 cities containing approximately 7.75 million people.
- Land use includes high density and suburban housing, agriculture, public and protected lands, and industrial and commercial infrastructure.
- Ample sources of micro and nano plastics.



CEDEN and SURF Stations-Data

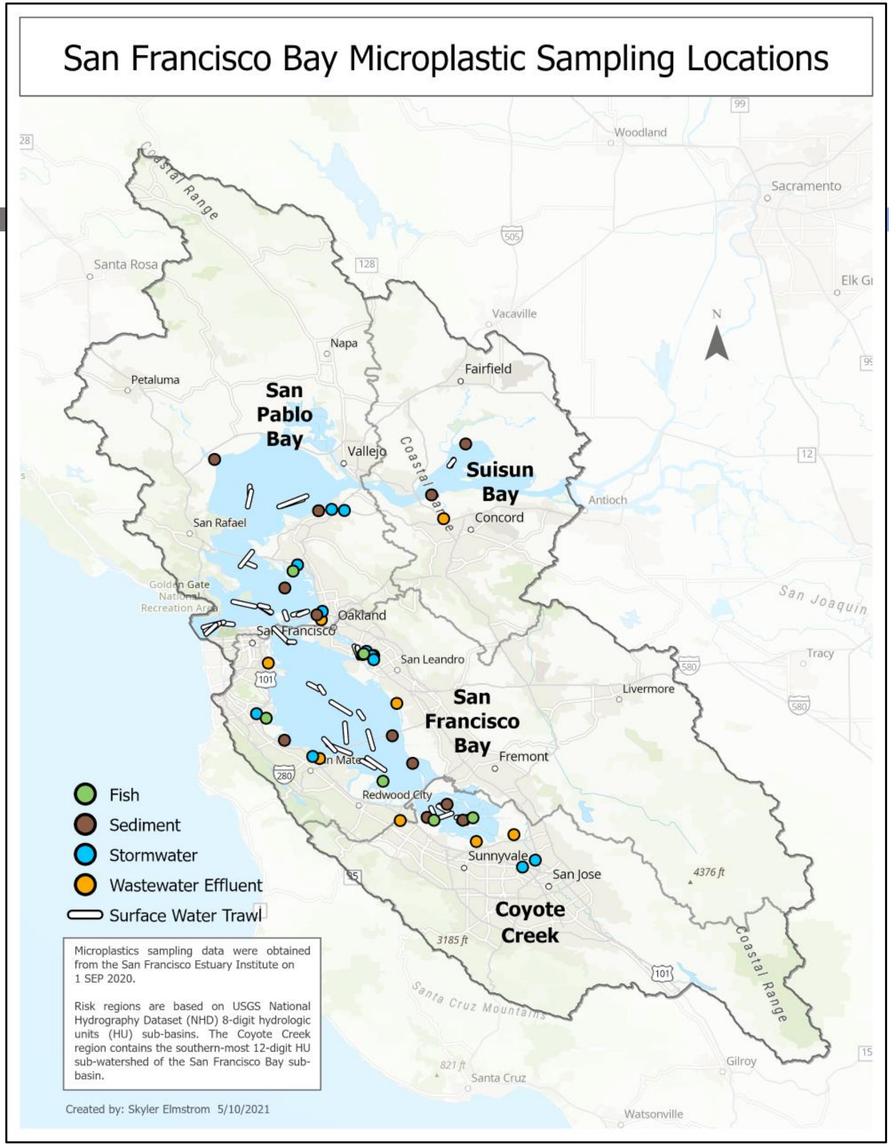
- Dots on the map are sample stations from a variety of different projects and agencies in the area
- These stations are primarily monitoring water quality parameters and contaminant concentrations
- The data are now being organized into a project specific data set placed on a GitHub site.



SFEI-microplastic data

San Francisco Estuary Institute (SFEI) microplastic monitoring sample locations

Additional data on co-contaminants will come from CEDEN and SURF (CA regional databases)

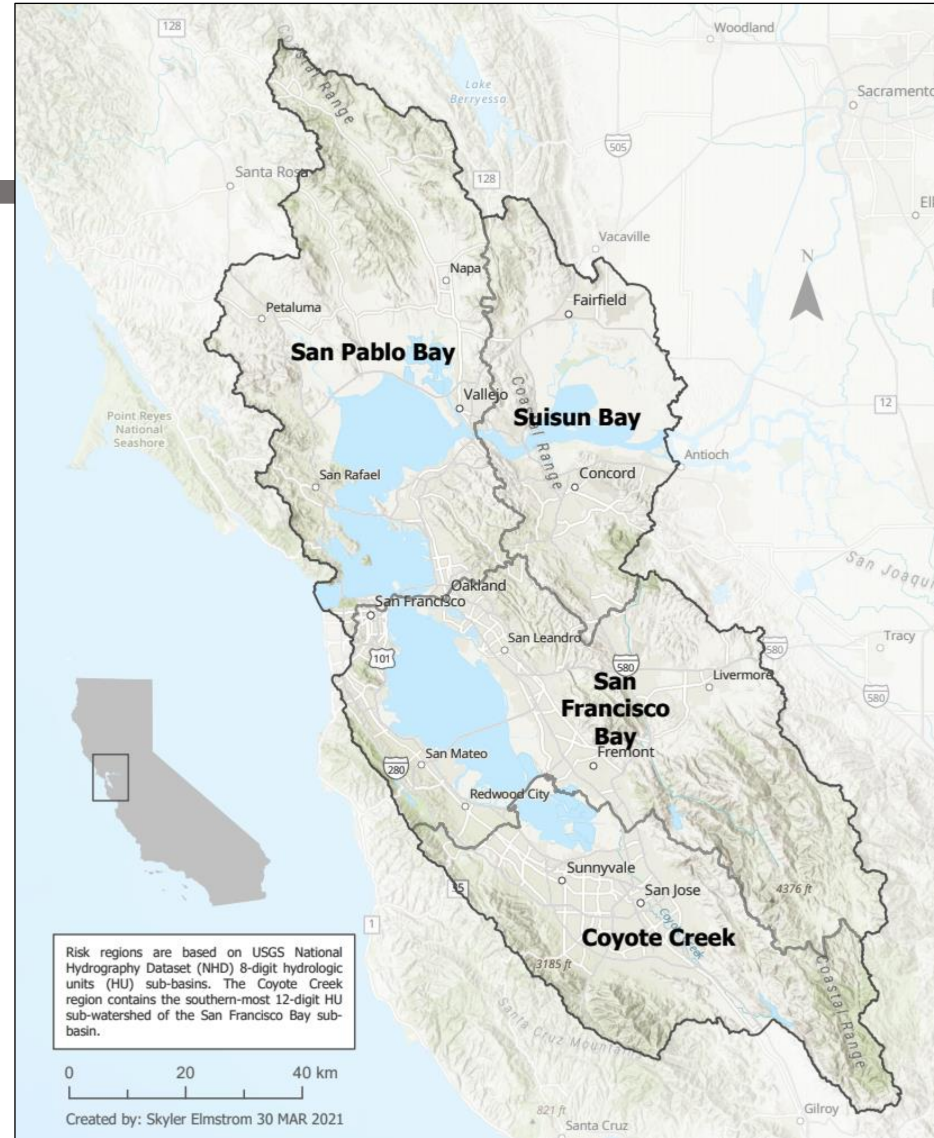


Sutton, R.; Lin, D.; Sedlak, M.; Box, C.; Gilbreath, A.; Holleman, R.; Miller, L.; Wong, A.; Munno, K.; Zhu, X.; et al. 2019. **Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region.** SFEI Contribution No. 950. San Francisco Estuary Institute: Richmond, CA.

Study Area divided into regions

Four risk regions

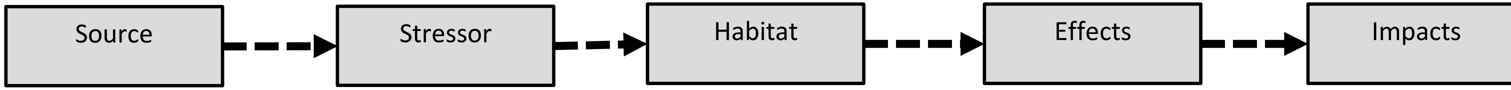
Now we can compare how different parts of the Bay compare.



This is the backbone of the risk assessment approach

This is a diagram of the basic risk assessment approach, the boxes are nodes, and the arrows are the cause-effect interactions. The functions describe how the probability distributions for each node interact and result in an estimate of risk to valued ecological services (impacts).

Should look familiar????



Source → Stressor → Habitat → Effect → Endpoint

Source

Wastewater treatment plants
effluent, sludge, etc.

Transportation
roadways, bikes, etc.

Stormwater runoff
storm drains, etc.

Industry
spills, dumps, runoff, etc.

Agriculture
sewage sludge, slow-release fertilizers, films, etc.

Atmospheric deposition
precipitation, ambient particulates

Freshwater tributaries
creeks, rivers, delta

Spills/dumps
fishing nets, primary plastics, etc.

Trophic Transfer
bio transport, biomagnification

Ocean

Stressor

Microplastics
0.1 μm - 5 mm

Nanoplastics
$<$ 0.1 μm

Tire Wear Particles
Chemical composition matching or resembling tires

Particle Characteristics
- Size
- Shape
- Composition
- Degradation
- Biofouling

Sorbed Contaminants
- Metals
- POPs
- Pesticides

Water Quality
- Salinity
- pH
- Temperature
- Dissolved O_2

Habitat

Water Column
depth profile

Habitats of Endpoints

Effect

Acute toxicity
short-term exposure

Chronic toxicity
longer-term exposure

Alteration of habitat
changes to critical habitat

Trophic transfer
transfer along the food web

Bioaccumulation/ biomagnification
accumulation within organism

Indirect Effects
reduction in food source, etc.

Endpoint

Pacific Herring
Clupea pallasii

Chinook Salmon
Oncorhynchus tshawytscha

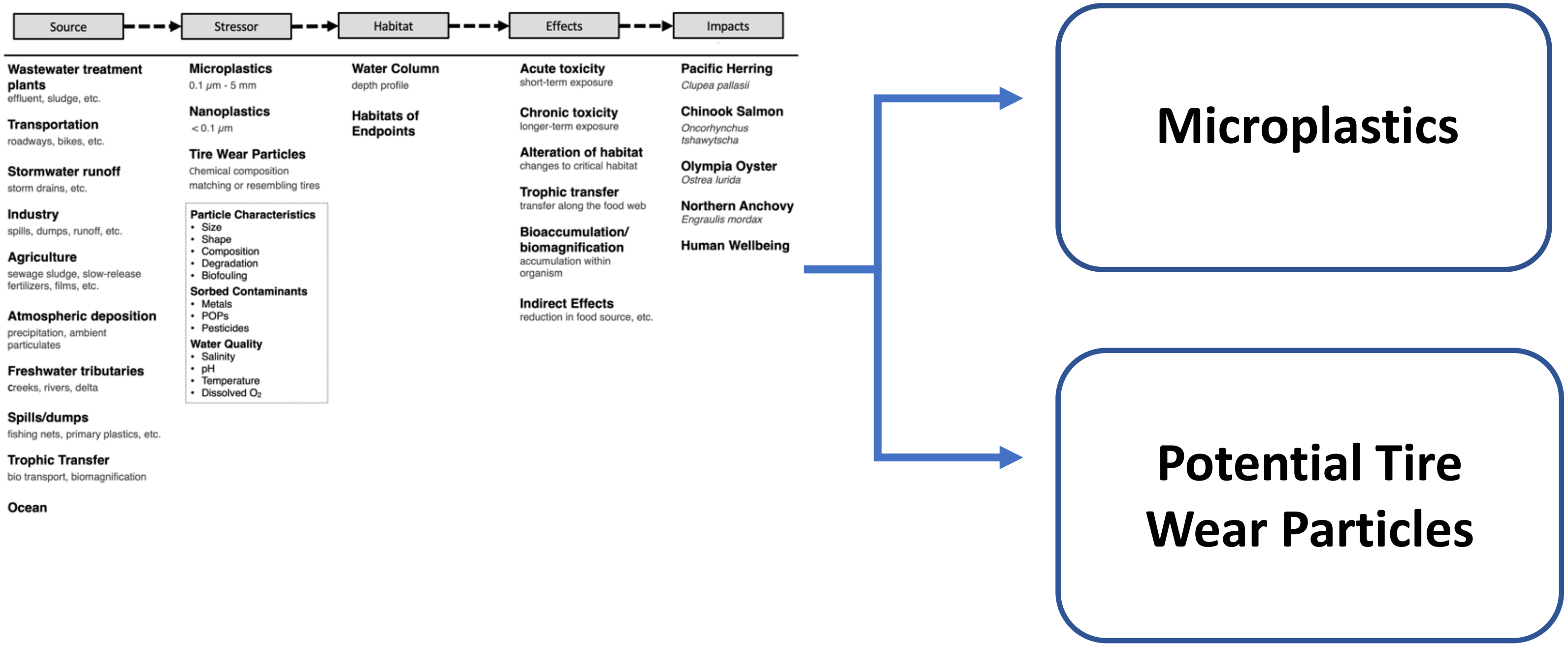
Olympia Oyster
Ostrea lurida

Northern Anchovy
Engraulis mordax

Human Wellbeing

Conceptual Model to Bayesian Net

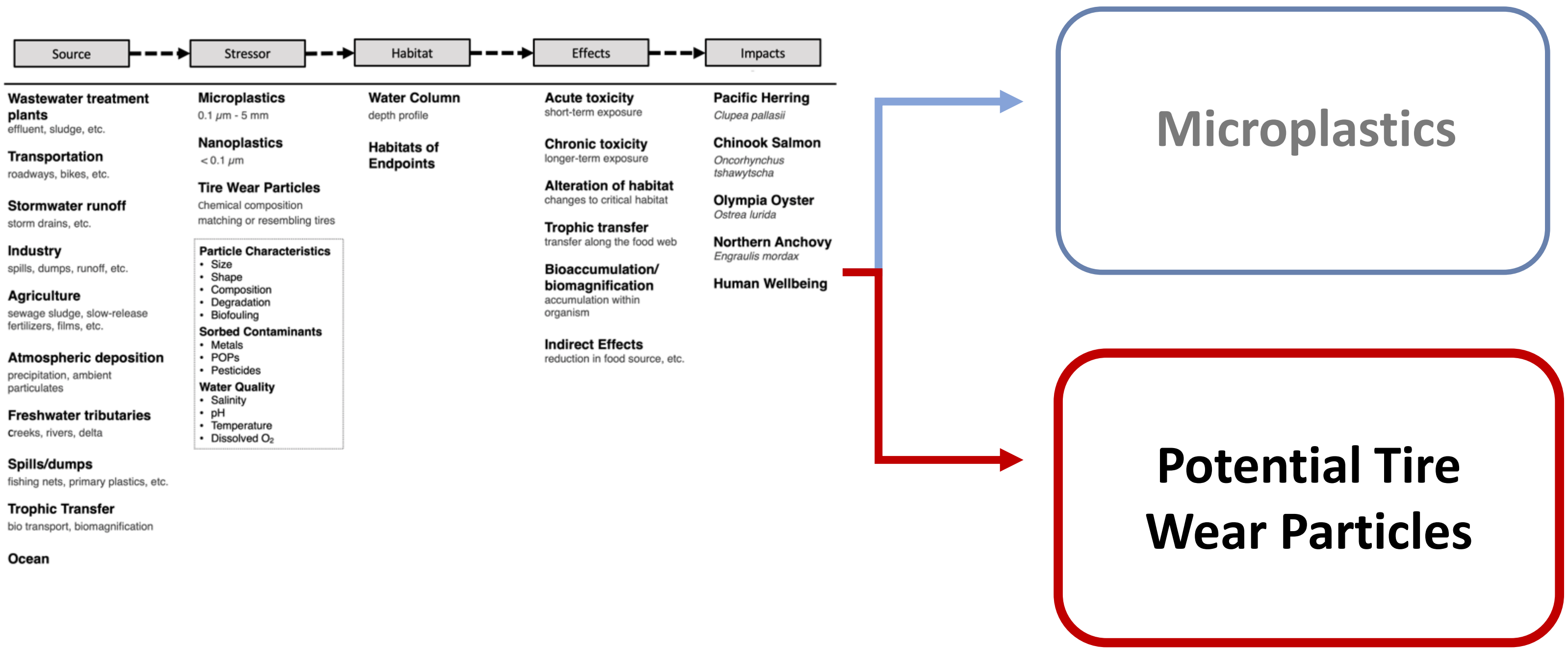
Conceptual Model to Bayesian Net



Plastics not categorized as rubber or potentially rubber

Rubber and potentially rubber

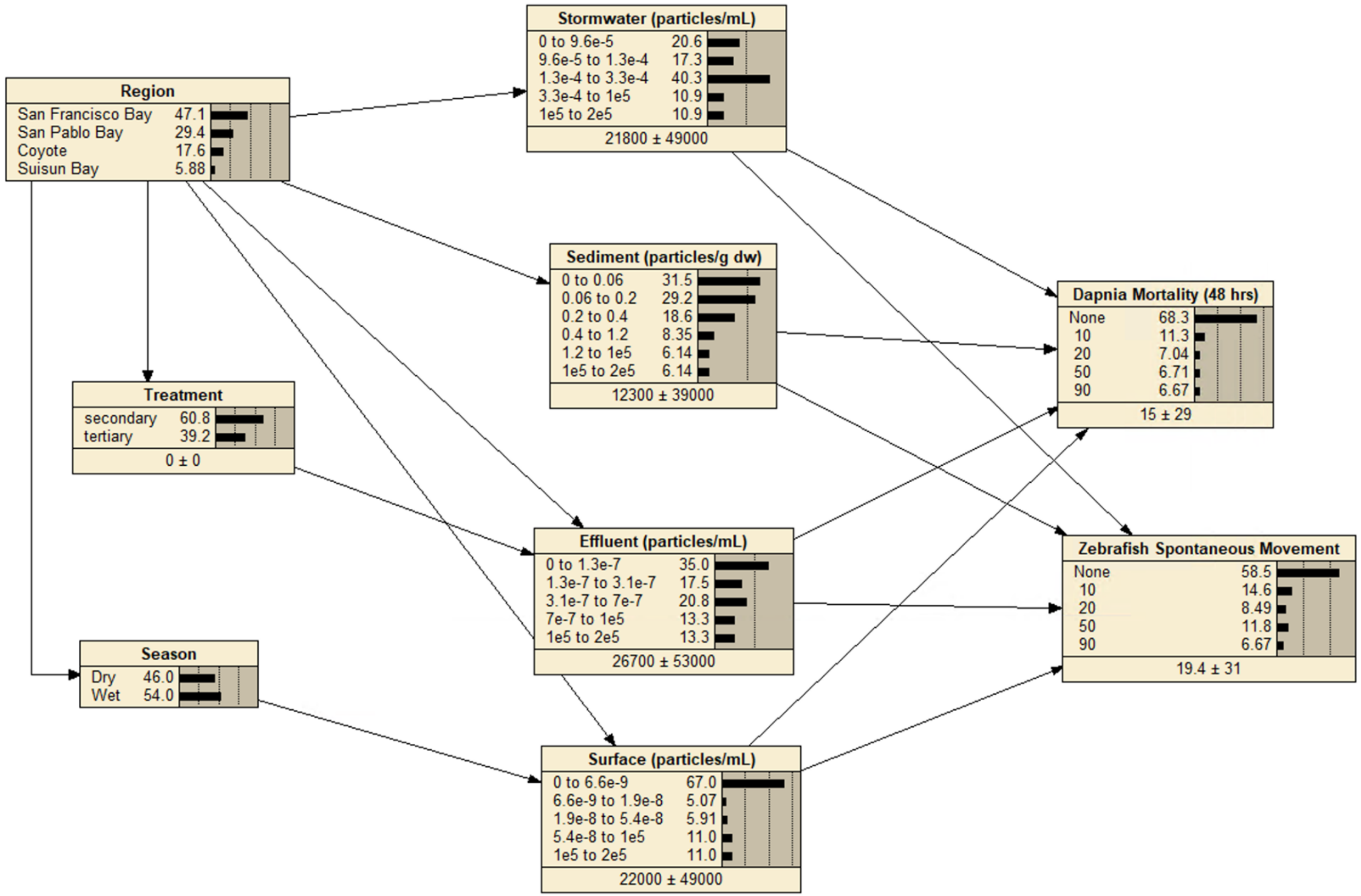
Conceptual Model to Bayesian Net



Plastics not categorized as rubber or potentially rubber

Rubber and potentially rubber

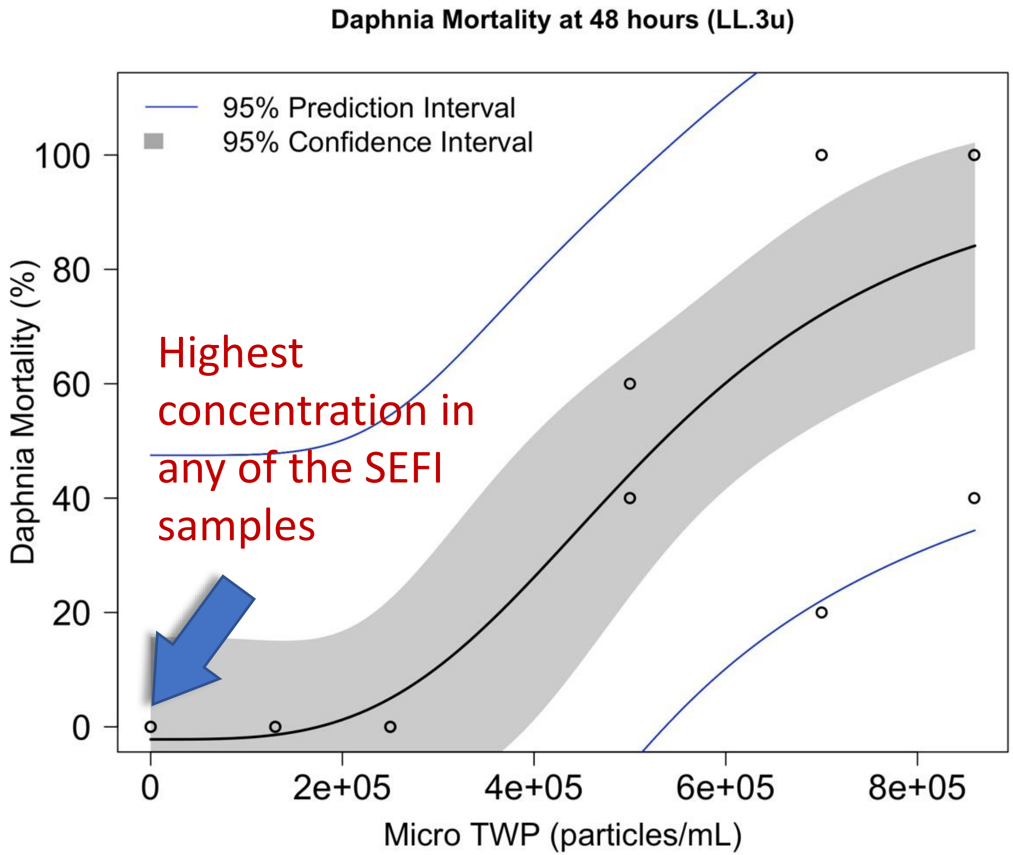
Current Tire Wear Particles Bayesian Network



Dose-Response Daphnia 48 hr.

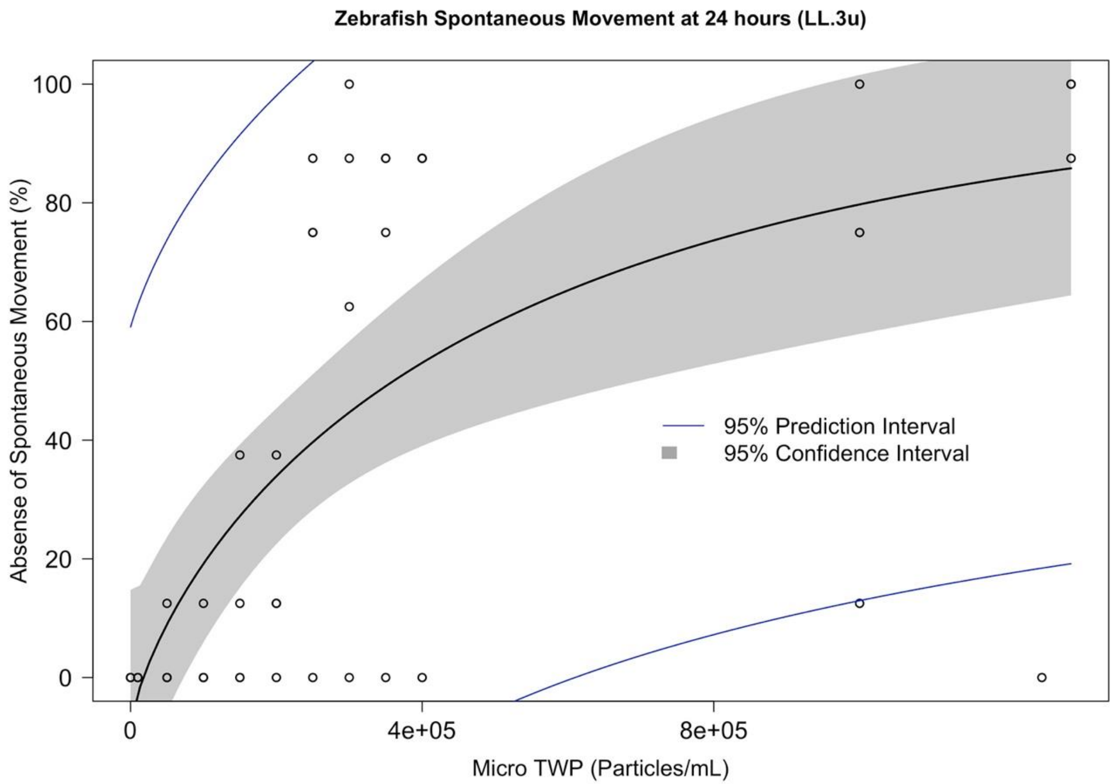
- Harper Lab toxicity data
- 6 concentrations
- 3 replicates

- The equation for the regression are used to build the conditional probability table for the BN.

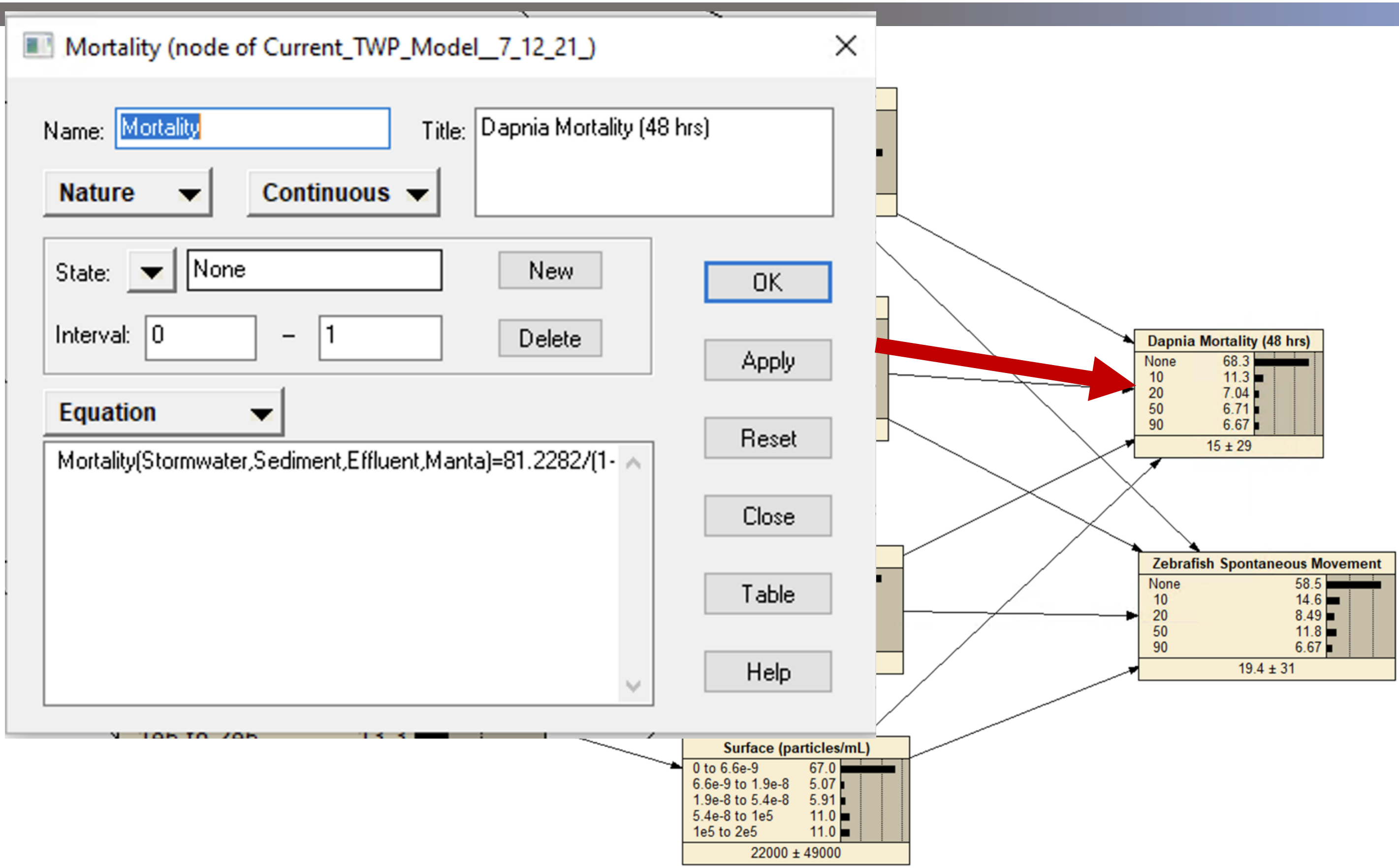


Zebrafish toxicity test

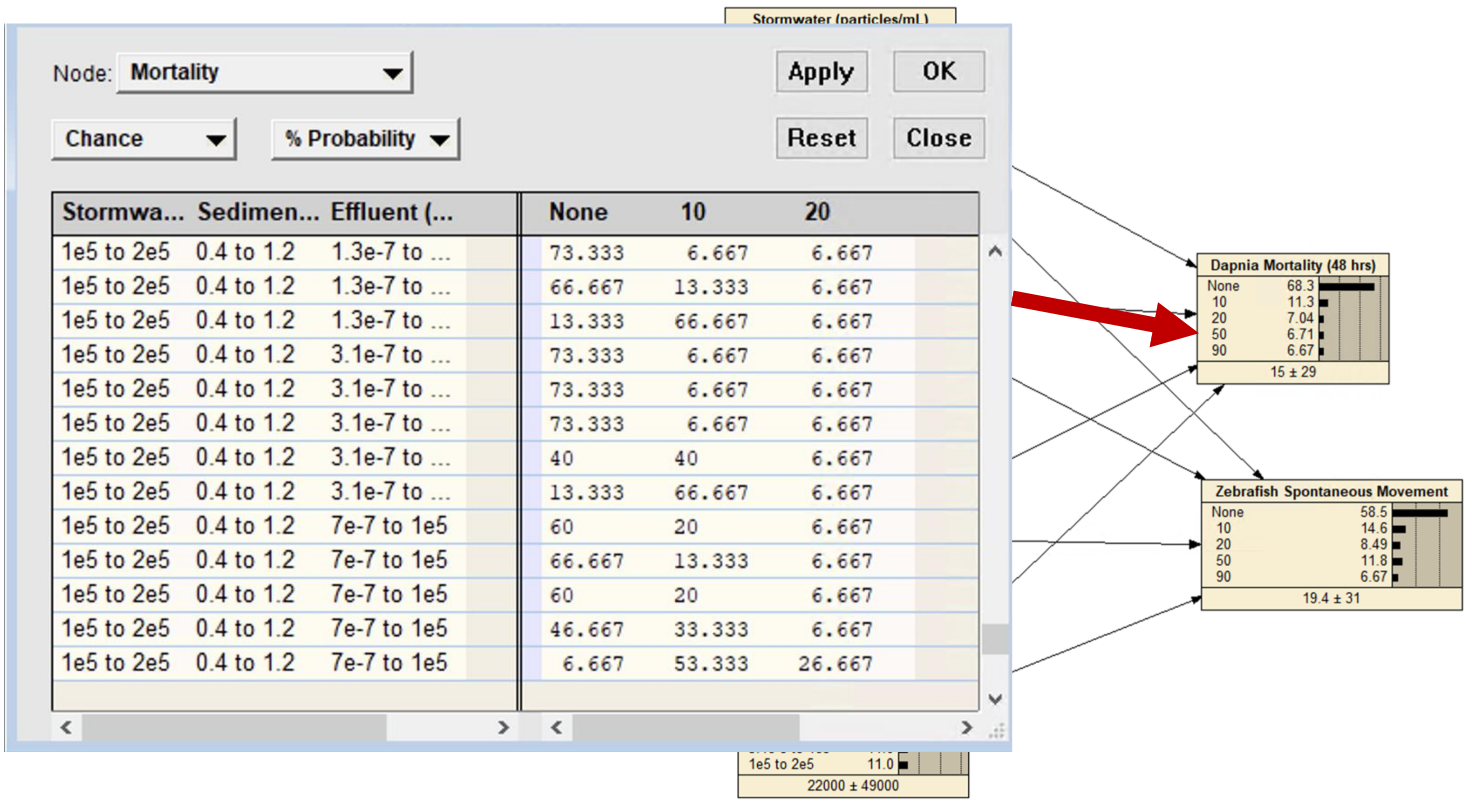
Zebrafish Spontaneous movement-exposure-response curve



The equation describes the interactions-1

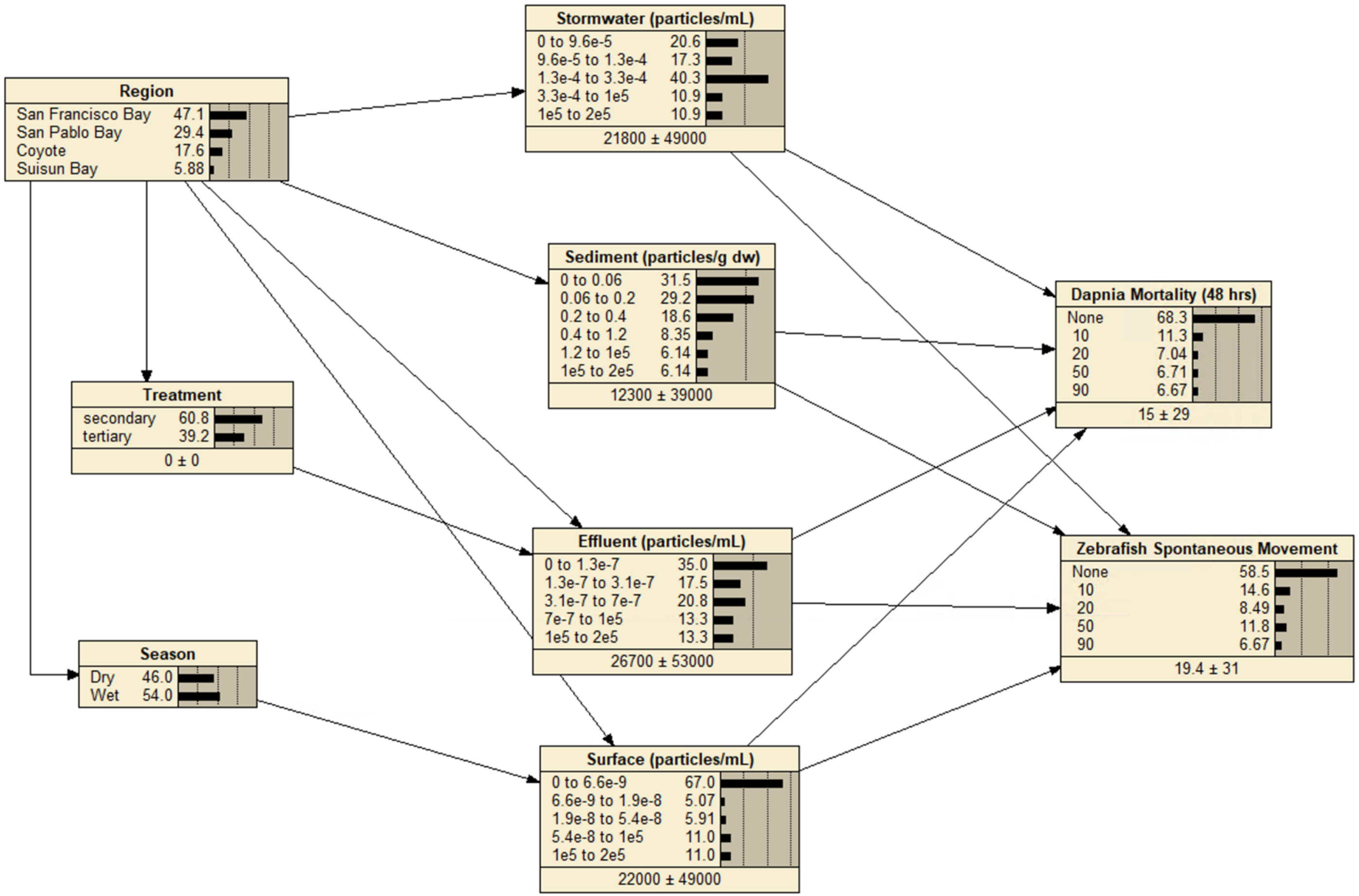


The conditional probability table describes the interactions-2

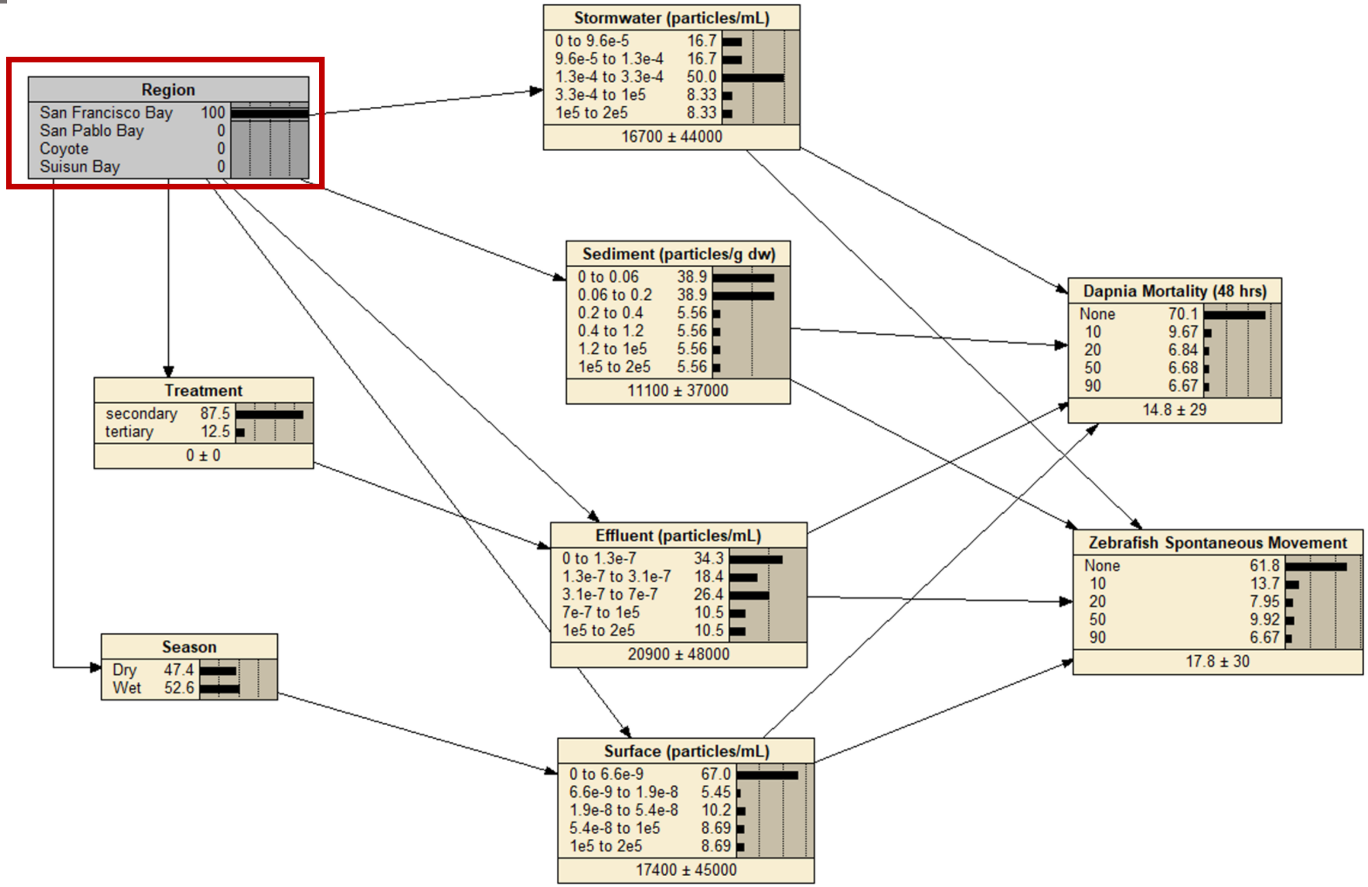


Stormwa...	Sedimen...	Effluent (...	None	10	20
1e5 to 2e5	0.4 to 1.2	1.3e-7 to ...	73.333	6.667	6.667
1e5 to 2e5	0.4 to 1.2	1.3e-7 to ...	66.667	13.333	6.667
1e5 to 2e5	0.4 to 1.2	1.3e-7 to ...	13.333	66.667	6.667
1e5 to 2e5	0.4 to 1.2	3.1e-7 to ...	73.333	6.667	6.667
1e5 to 2e5	0.4 to 1.2	3.1e-7 to ...	73.333	6.667	6.667
1e5 to 2e5	0.4 to 1.2	3.1e-7 to ...	73.333	6.667	6.667
1e5 to 2e5	0.4 to 1.2	3.1e-7 to ...	40	40	6.667
1e5 to 2e5	0.4 to 1.2	3.1e-7 to ...	13.333	66.667	6.667
1e5 to 2e5	0.4 to 1.2	7e-7 to 1e5	60	20	6.667
1e5 to 2e5	0.4 to 1.2	7e-7 to 1e5	66.667	13.333	6.667
1e5 to 2e5	0.4 to 1.2	7e-7 to 1e5	60	20	6.667
1e5 to 2e5	0.4 to 1.2	7e-7 to 1e5	46.667	33.333	6.667
1e5 to 2e5	0.4 to 1.2	7e-7 to 1e5	6.667	53.333	26.667

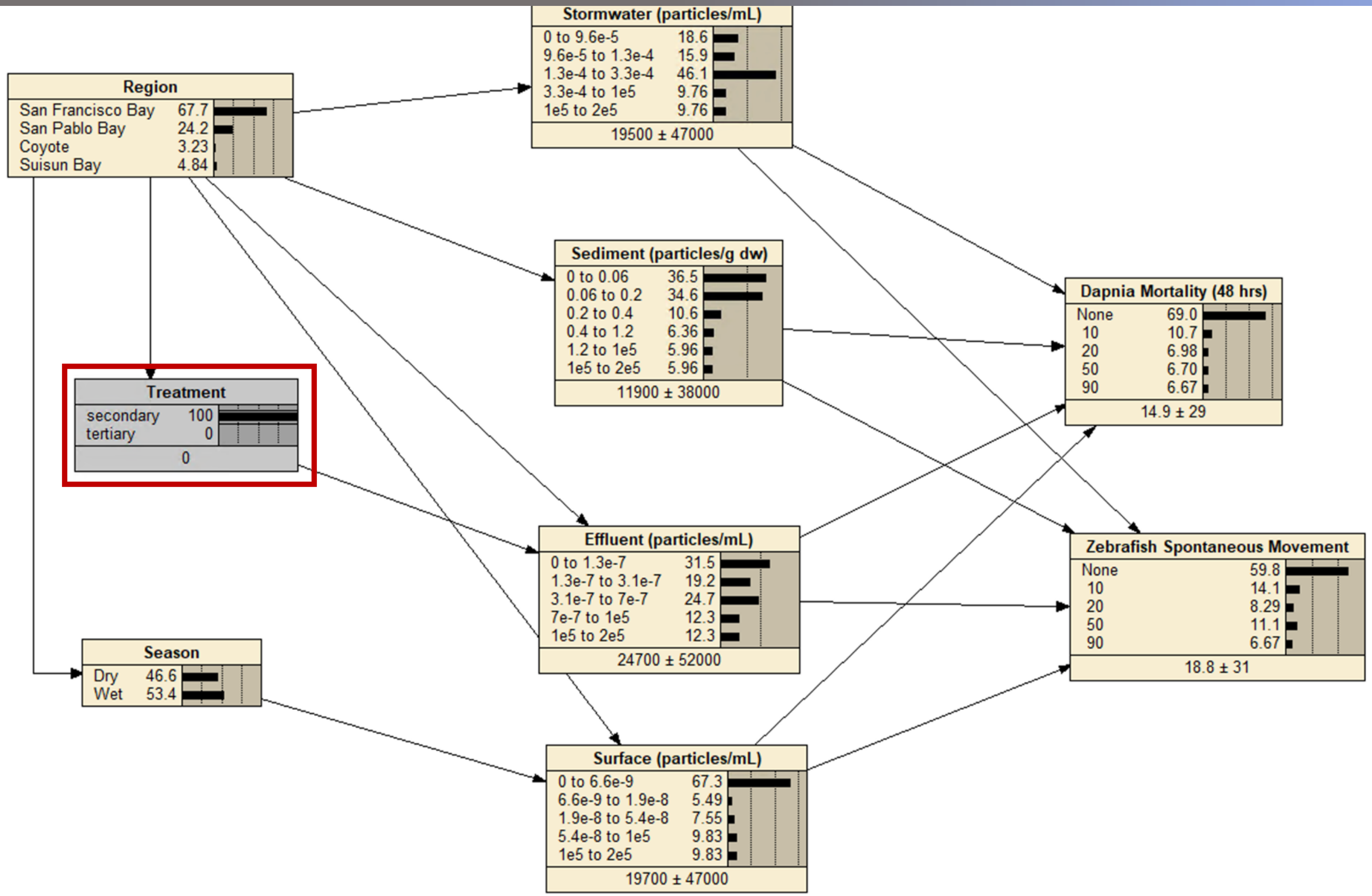
Current Tire Wear Particles Bayesian Network



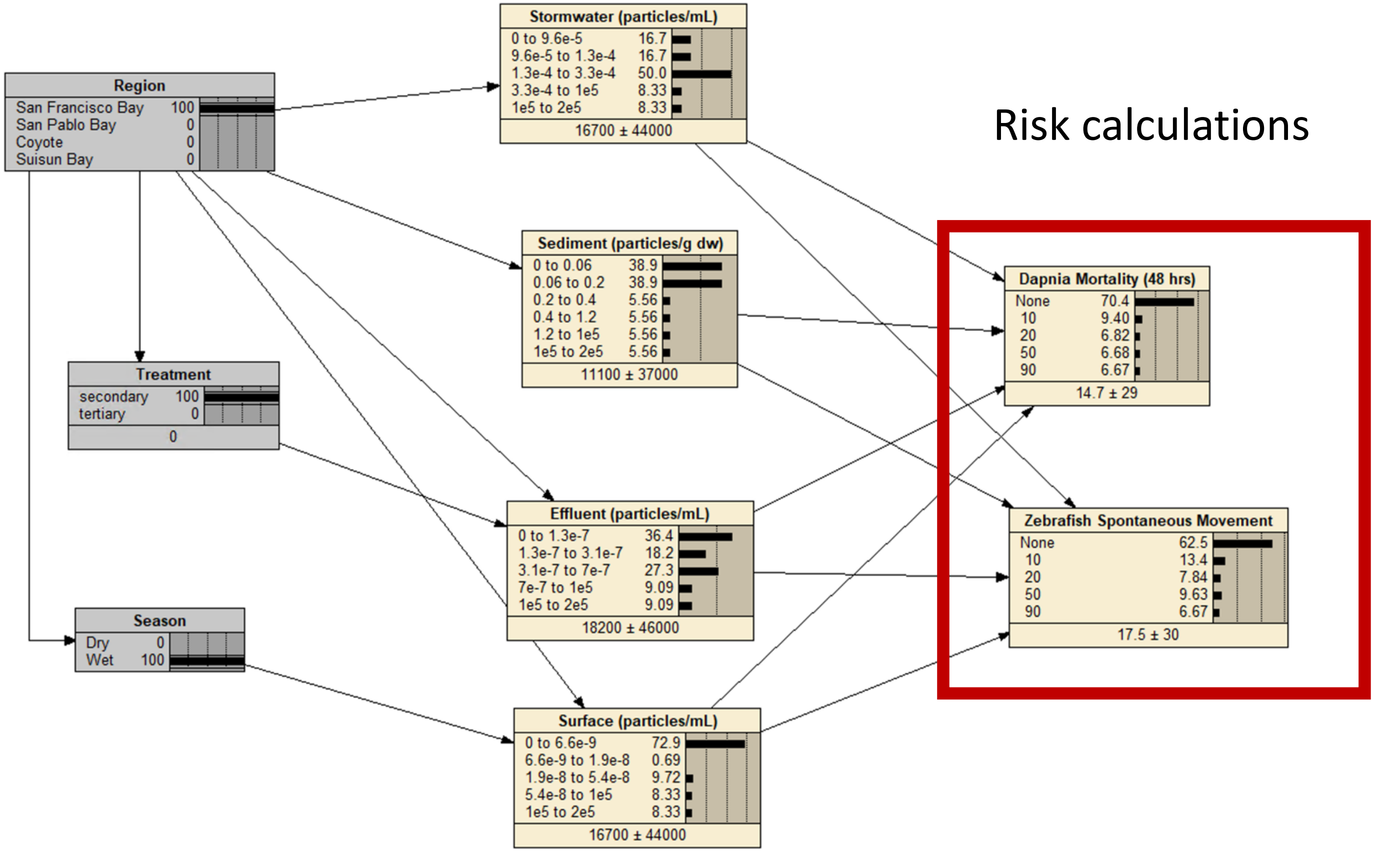
We now chose the parameters-region



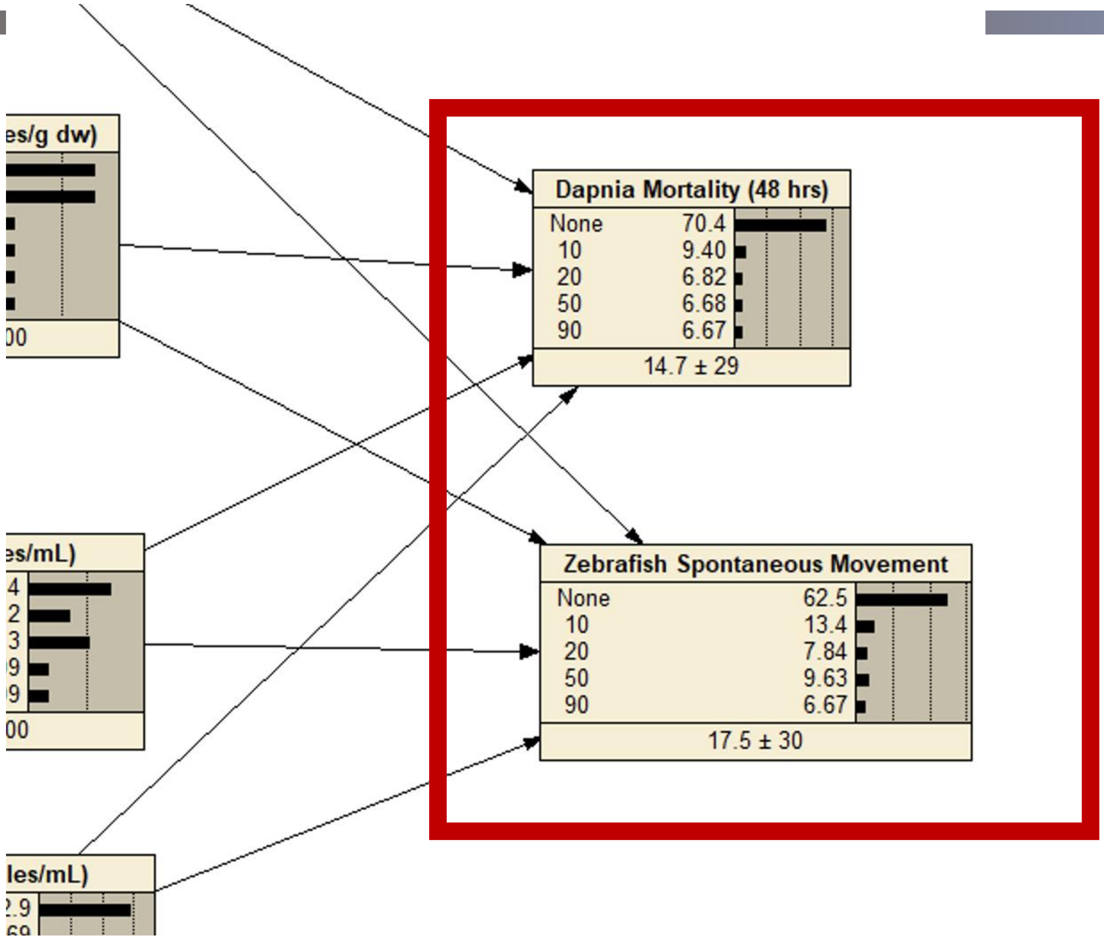
We now chose the parameters-water treatment



We now chose the parameters-season



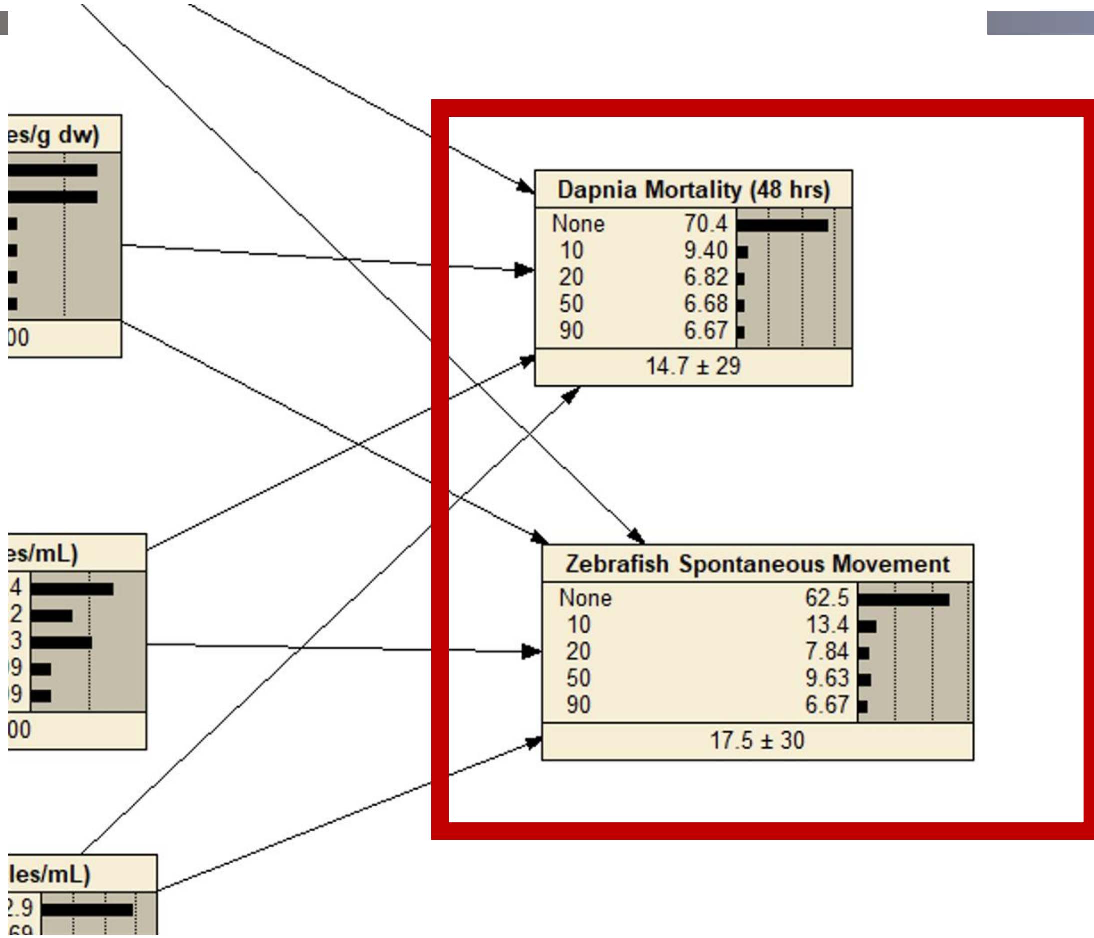
Risk distributions



The risk is in the None category with residuals in the other categories.

The uncertainty in the data are driving the higher risk values.

Confirmation of previous research



The exposure is low compared to levels that are in rising segment of the exposure-response curve.

Discussion and Conclusions

The importance of measuring exposure-SFEI 2021

The use of risk assessment to plan the research

The use of the original RRM to build a research plan.

The importance of measuring exposure-

Environmental Management (2018) 61:1–8
DOI 10.1007/s00267-017-0947-8

FORUM

Are We Underestimating Microplastic Contamination in Aquatic Environments?

Jeremy L. Conkle[1] · Christian D. Báez Del Valle[2] · Jeffrey W. Turner[3]

Cooke et al 2018

Today my bet would be that we are underestimating exposure and uptake. That could change…

Integrated Environmental Assessment and Management — Volume 17, Number 1—pp. 282–291
282 Received: 18 January 2020 | Returned for Revision: 6 July 2020 | Accepted: 5 August 2020

Environmental Management

Methods Matter: Methods for Sampling Microplastic and Other Anthropogenic Particles and Their Implications for Monitoring and Ecological Risk Assessment

Charlotte Hung,† Natasha Klasios,† Xia Zhu,† Meg Sedlak,‡ Rebecca Sutton,‡ and Chelsea M Rochman†*
†Department of Ecology and Evolutionary Biology, University of Toronto, Toronto, Ontario, Canada
‡San Francisco Estuary Institute, Richmond, California, USA

ABSTRACT
To inform mitigation strategies and understand how microplastics affect wildlife, research is focused on understanding the sources, pathways, and occurrence of microplastics in the environment and in wildlife. Microplastics research entails counting and characterizing microplastics in nature, which is a labor-intensive process, particularly given the range of particle sizes and morphologies present within this diverse class of contaminants. Thus, it is crucial to determine appropriate sampling methods that best capture the types and quantities of microplastics relevant to inform the questions and objectives at hand. It is also critical to follow protocols with strict quality assurance and quality control (QA/QC) measures so that results reflect accurate estimates of microplastic contamination. Here, we assess different sampling procedures and QA/QC strategies to inform best practices for future environmental monitoring and assessments of exposure. We compare microplastic abundance and characteristics in surface-water samples collected using different methods (i.e., manta and bulk water) at the same sites, as well as duplicate samples for each method taken at the same site and approximate time. Samples were collected from 9 sampling sites within San Francisco Bay, California, USA, using 3 different sampling methods: 1) manta trawl (manta), 2) 1-L grab (grab), and 3) 10-L bulk water filtered in situ (pump). Bulk water sampling methods (both grab and pump) captured more microplastics within the smaller size range (<335 μm), most of which were fibers. Manta samples captured a greater diversity of morphologies but underestimated smaller-sized particles. Inspection of pump samples revealed high numbers of particles from procedural contamination, stressing the need for robust QA/QC, including sampling and analyzing laboratory blanks, field blanks, and duplicates. Choosing the appropriate sampling method, combined with rigorous, standardized QA/QC practices, is essential for the future of microplastics research in marine and freshwater ecosystems. *Integr Environ Assess Manag* 2021;17:282–291. © 2020 SETAC

Keywords: Microplastics Sampling methods Monitoring Quality assurance and quality control Exposure assessment

INTRODUCTION

Ubiquitous microplastic pollution (plastic particles <5 mm in size) in aquatic ecosystems is a growing concern globally, …

Hung et al 2021
SFEI

… deep sea (Thompson 2015). Microplastics are diverse, and they include many morphologies, sizes, colors, and polymer types (Rochman et al. 2019). This diversity is a result of the many plastic products used in society that enter the environment from a myriad of pathways, including agricultural and urban runoff and effluent discharge from wastewater …

… from the weathering of a plastic bottle cap. The size, morphology, and polymer type of microplastics in environmental samples can help inform identification of the potential sources to aquatic ecosystems (Helm 2017).

Not only are microplastics ubiquitous in the environment, but they are also ubiquitous in animals (Chae and An 2017). Exposure to microplastics can be hazardous to aquatic animals. Microplastic uptake can cause physical effects

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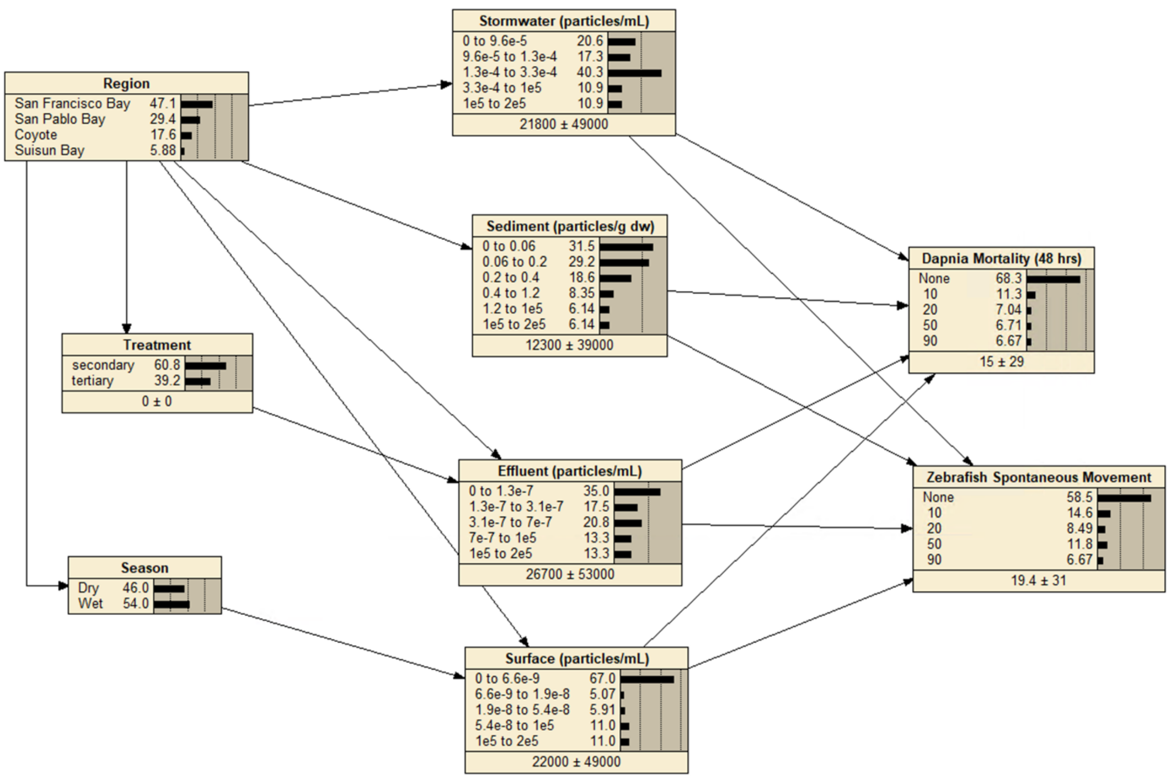
The use of risk assessment to provide a research plan for the future.



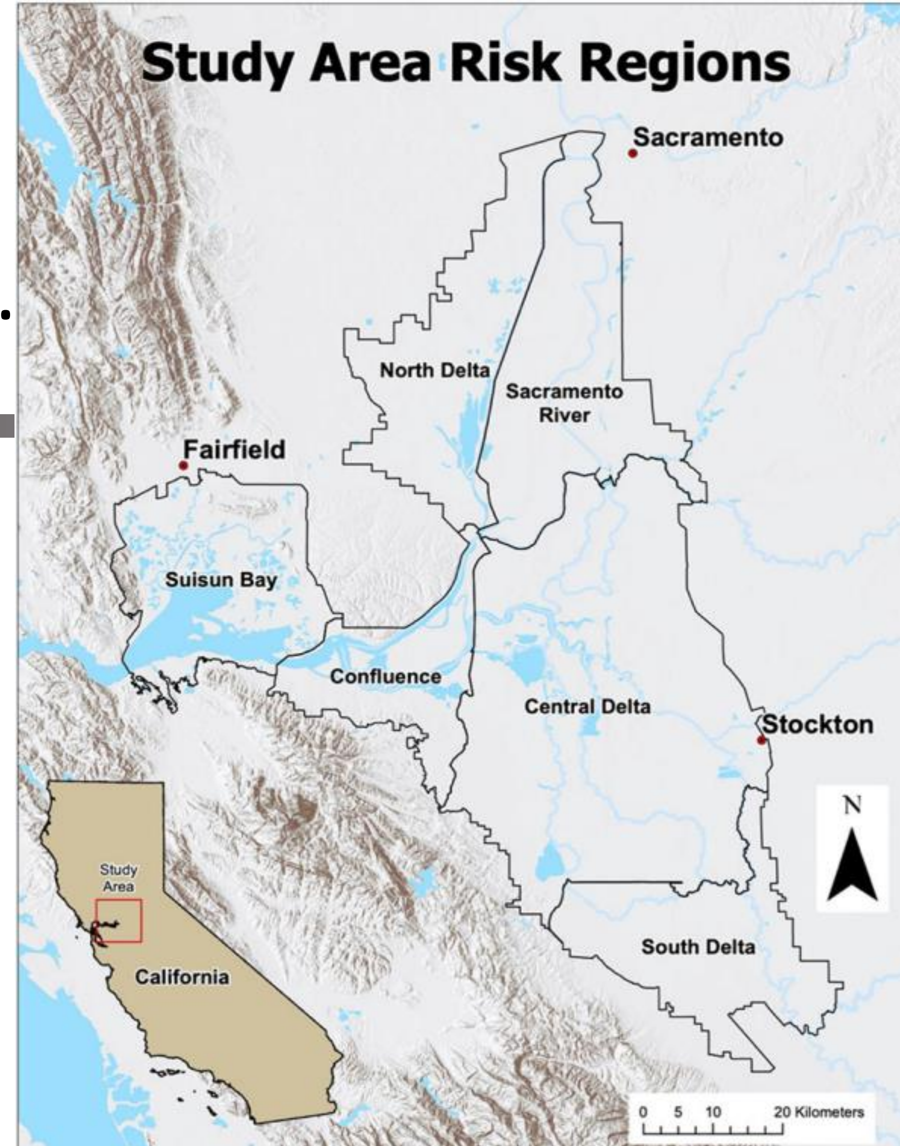
Here is a list of what we know and what we need to learn more about to build a robust risk assessment.

The uncertainty and sensitivity analysis will teach you more.

The use of the risk assessment to put microplastics into a context.

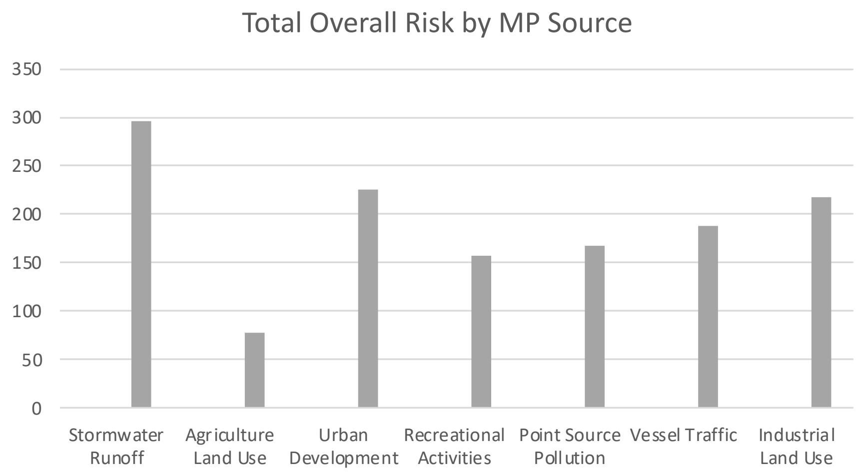
We have already done a screening level relative risk model for the Delta.

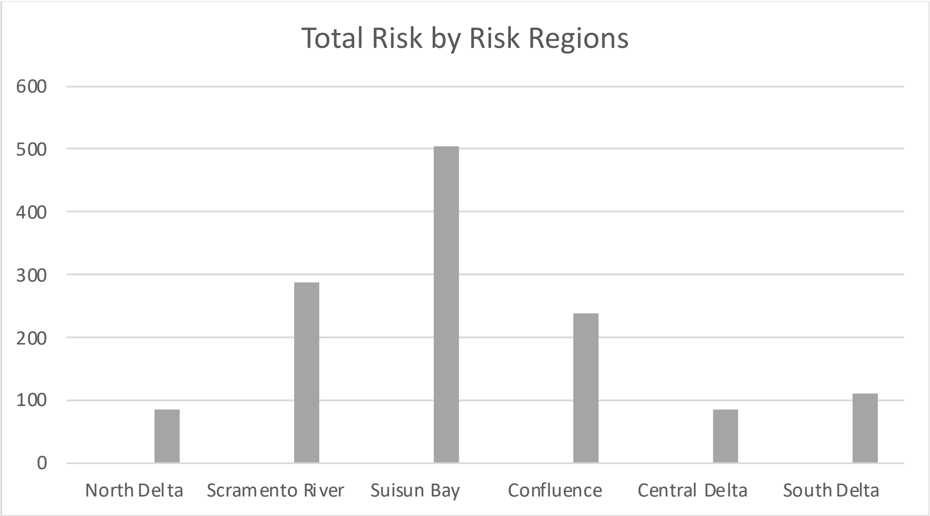
We are already working in the region.



The use of the risk assessment to put microplastics into a context.

Even with a basic RRM risk assumptions you can let you start thinking about the sources and spatial context-USFE RRM assessment.

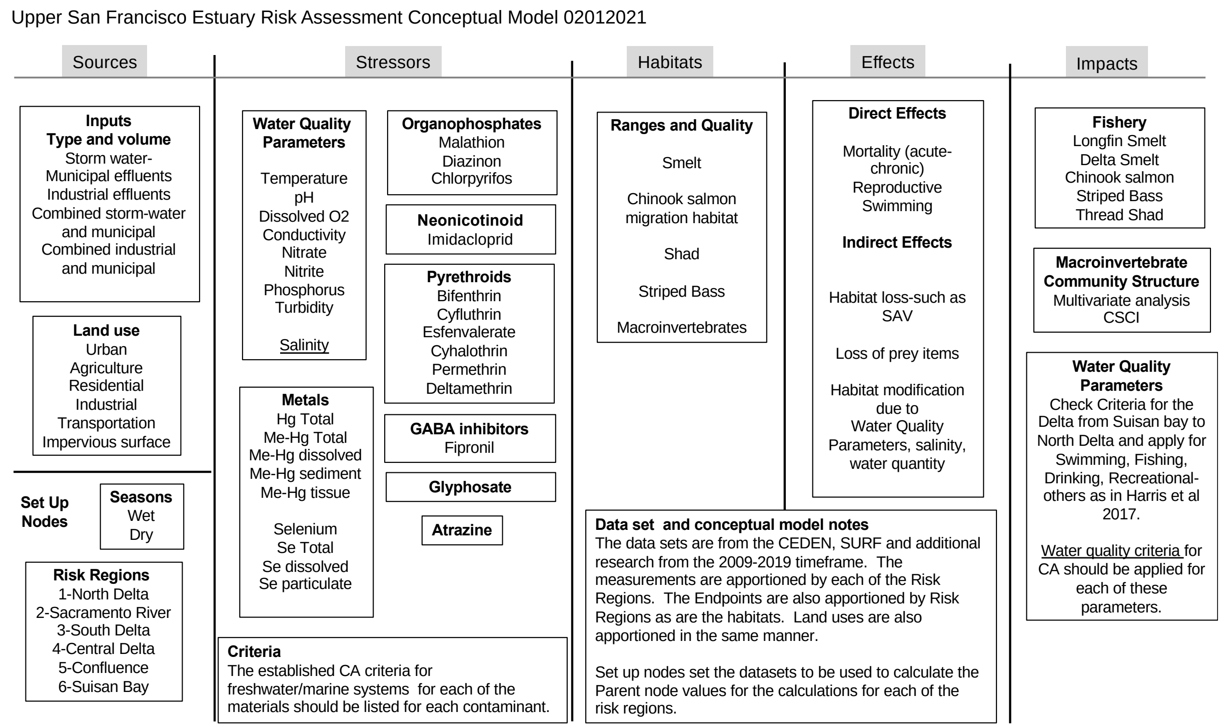




Congratulations to M. Bowers and C. Kuhn for building the model.

The use of the risk assessment to put microplastics into a context.

I have heard that there are other chemicals and water quality stressors in the region. Here is the conceptual model for the USFE



Things to think about….

Start first with a basic conceptual model of the cause-effect pathway as used in a modern risk assessment. What do you know and not know.

Do the best science you can and start with the basics-exposure response experimental design and analysis, measure what is in the environment.

Consider the context of how a decision-usually regulatory-is going to be made. The frameworks of the regulation already exist.

Things to think about….

Source → Stressor → Habitat → Effect → Endpoint

Source

Wastewater treatment plants
effluent, sludge, etc.

Transportation
roadways, bikes, etc.

Stormwater runoff
storm drains, etc.

Industry
spills, dumps, runoff, etc.

Agriculture
sewage sludge, slow-release fertilizers, films, etc.

Atmospheric deposition
precipitation, ambient particulates

Freshwater tributaries
creeks, rivers, delta

Spills/dumps
fishing nets, primary plastics, etc.

Trophic Transfer
bio transport, biomagnification

Ocean

Stressor

Microplastics
0.1 μm - 5 mm

Nanoplastics
$< 0.1\ \mu m$

Tire Wear Particles
Chemical composition matching or resembling tires

Particle Characteristics
- Size
- Shape
- Composition
- Degradation
- Biofouling

Sorbed Contaminants
- Metals
- POPs
- Pesticides

Water Quality
- Salinity
- pH
- Temperature
- Dissolved O_2

Habitat

Water Column
depth profile

Habitats of Endpoints

Effect

Acute toxicity
short-term exposure

Chronic toxicity
longer-term exposure

Alteration of habitat
changes to critical habitat

Trophic transfer
transfer along the food web

Bioaccumulation/ biomagnification
accumulation within organism

Indirect Effects
reduction in food source, etc.

Endpoint

Pacific Herring
Clupea pallasii

Chinook Salmon
Oncorhynchus tshawytscha

Olympia Oyster
Ostrea lurida

Northern Anchovy
Engraulis mordax

Human Wellbeing

I would suggest starting here first- thinking about causality and how decisions are going to be made rather than doing it last.

How much of risk do micro/nano plastics have on the environment

I maintain that until we have done the hard work to build a cause-effect pathway, fill in the nodes and do the calculations that the uncertainty will be putting long tails on the risk distribution…..

I can translate that if you want me to.

The good news is that we know how to do a much better job.


Thanks for your time……