Pacific Northwest
Consortium on Plastics

Risk Assessment of Microplastics in the San Francisco Bay using a Bayesian Network Framework

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Table of Contents

Definition of microplastics

- Currently, there is not a single agreed-upon definition for microplastics, however it is important that a single definition is used for the purposes of this risk assessment.
- We define micro- and nano- plastics in accordance with the San Francisco Estuary Institute's (SFEI) definition developed for their recent microplastic monitoring study in San Francisco Bay (Sutton et al. 2019).
- Microparticles are smaller than 5 millimeters in at least one dimension and nanoparticles must be smaller than 0.1 micrometers.
- In order to confirm whether the micro- or nano- particle is a micro- or nano-plastics, Raman or Fourier Transform Infrared (FTIR) spectroscopy must be used to determine if the composition is a synthetic polymer of anthropological origin.

Ecological Risk Assessment

- Ecological risk assessment is a tool used to organize and evaluate data to help outline relationships between stressors and ecological structures with the goal of using that information to make environmental management decisions (USEPA 1998)
- Developed with the intention of creating a tool that could use data-driven models to help guide decision-makers when making management and regulatory decisions.
- They used scientific data and modeling to calculate the impact on predetermined endpoints.
- Endpoints are derived from cultural and social values that are linked to the ecosystem of interest and connected to regionally specific ecosystem management goals (Landis and Weigers 2005).

Why do we need a risk assessment for microplastics?

- Data on microplastics is growing
- Microplastics are widespread
- Potential exposure related impacts to organisms
- Public awareness and concern about microplastics
- Current risk assessments for microplastics are not adequate for decision making and adaptive management

Overview of Methods

- The large scale and complexity of the SF Bay will require a method that is able to account for multiple sources, habitat types, stressors, and endpoints and can sill successfully produce an ecological risk assessment
- We will be using Relative Risk Model (RRM)
- The RRM has successfully been used as an ecological risk assessment and management tool in a wide variety of applications since its development in 1997 (Landis and Weigers 1997, Hayes and Landis 2004, Colnar and Landis 2007, Anderson and Landis 2012, Ayre and Landis 2012, Landis in press 2021)

Relative Risk Model

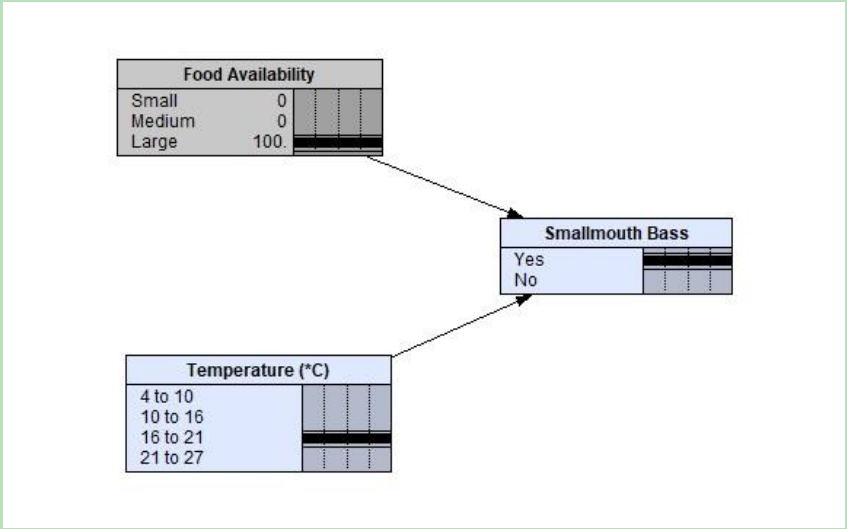
- An important initial step of a relative risk model (RRM) is to break the focus region down into sections called risk regions that are based on natural (e.g. watersheds, habitats) and socially constructed (e.g. management areas, landownership) boundaries.
- Rankings and scalars are used to convert parameters that have units (e.g. temperature, pH, square footage of habitat) into unitless numbers that can be added together to determine an overall relative risk for each region.
- These regions are then ranked using their calculated relative risk.
- The resulting ranking of regions can help derive hypothesizes about which regions, endpoints, and habitats may be most accumulatively affected by the modeled stressors.

Bayesian Networks

- In order to calculate risk we will use Bayesian network models
- Bayesian networks are acyclic graphs made up of nodes linked by probability relationships represented as arrows between the nodes (McCann et al. 2006)
- Bayesian Networks are a uniquely good choice for ecological risk assessments.
  - Different types of information can be included in them, such as expert opinion, without increasing the uncertainty of the model (Ayre and Landis 2012).
  - They allow for the inclusion of new information and data as they become available, increasing their usefulness as a long-term management and decision-making tools
- Due to the causal and hierarchal nature of Bayesian network models, conceptual models can be used as the framework
- In RRM using Bayesian Networks, a single Bayesian Network is created for the site and then parameterized with data from each risk region.

Example: Bayesian Network

Simple Bayesian Network



Complex Bayesian Network

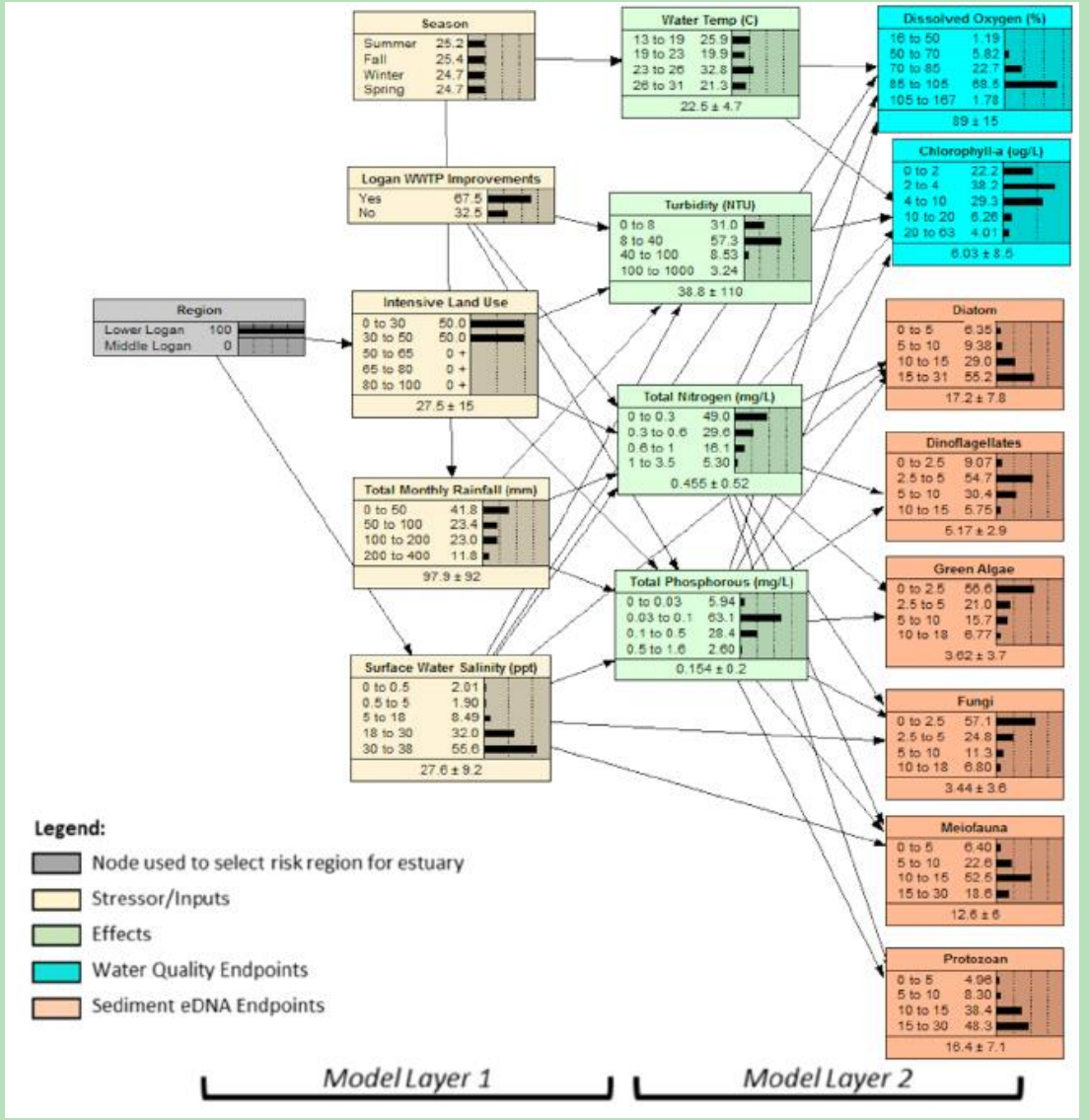
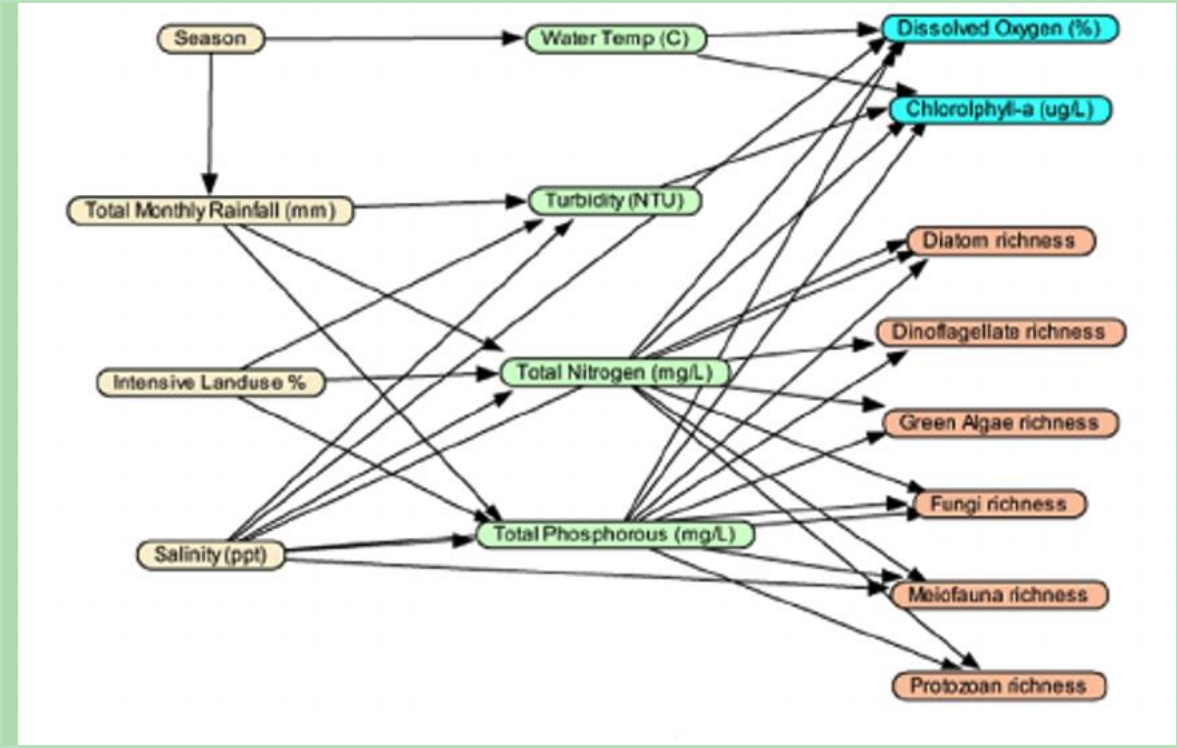


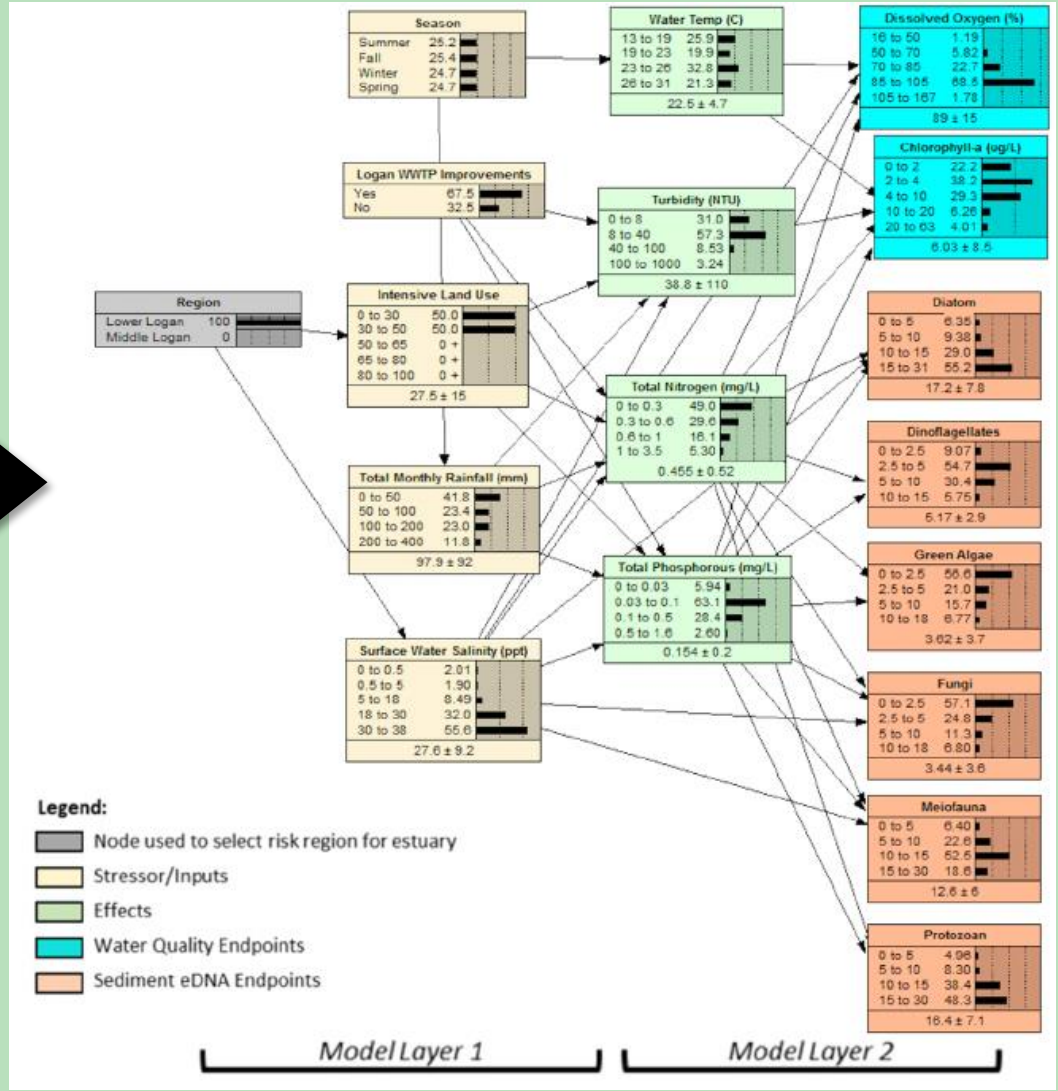
Figure: Graham et al 2019

Example: Bayesian Network to Conceptual Model

Conceptual Model



Bayesian Network



Figures: Graham et al 2019

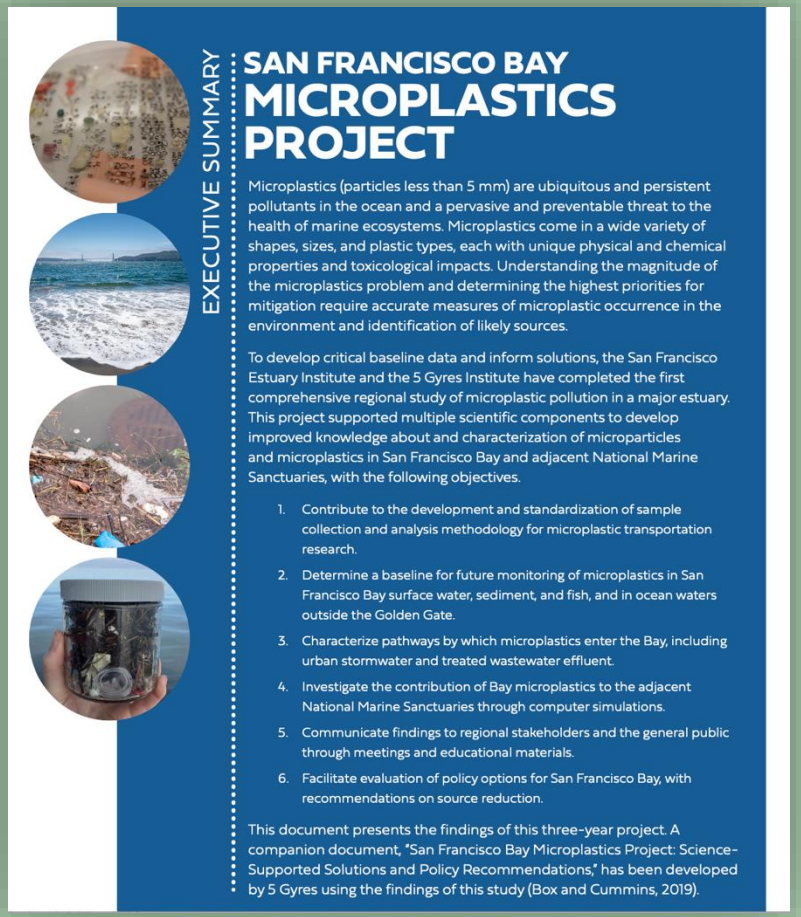
Study Site Selection

- In order to perform and ecological risk assessment we need a location rich in relevant data.
- The study site was selected for this ecological risk assessment is the San Francisco Bay (SF Bay).
- This site was selected because of the availability of microplastic data from recent monitoring studies (Sutton et al. 2019).
- Data on contaminants, water quality, habitat, and species parameters are also prevalent for a large temporal and spatial range for the SF Bay area through data bases such as the California Environmental Data Exchange Network (CEDEN) and California Surface Water (SURF).

San Francisco Bay Region

Sutton et al. 2019

- Microplastic monitoring for San Francisco Bay California by the San Francisco Estuary Institute
- Part of Bay Regional Monitoring Project
- Goal: inform federal, state, and local policymakers in finding solutions
- Monitored for microplastics in stormwater runoff, wastewater effluent, sediment surface water, and prey fish
- They found “Widespread contamination at levels greater than other U.S. water bodies” although this may have been due to better detection and not a higher concentration of microplastics



EXECUTIVE SUMMARY

SAN FRANCISCO BAY
MICROPLASTICS
PROJECT

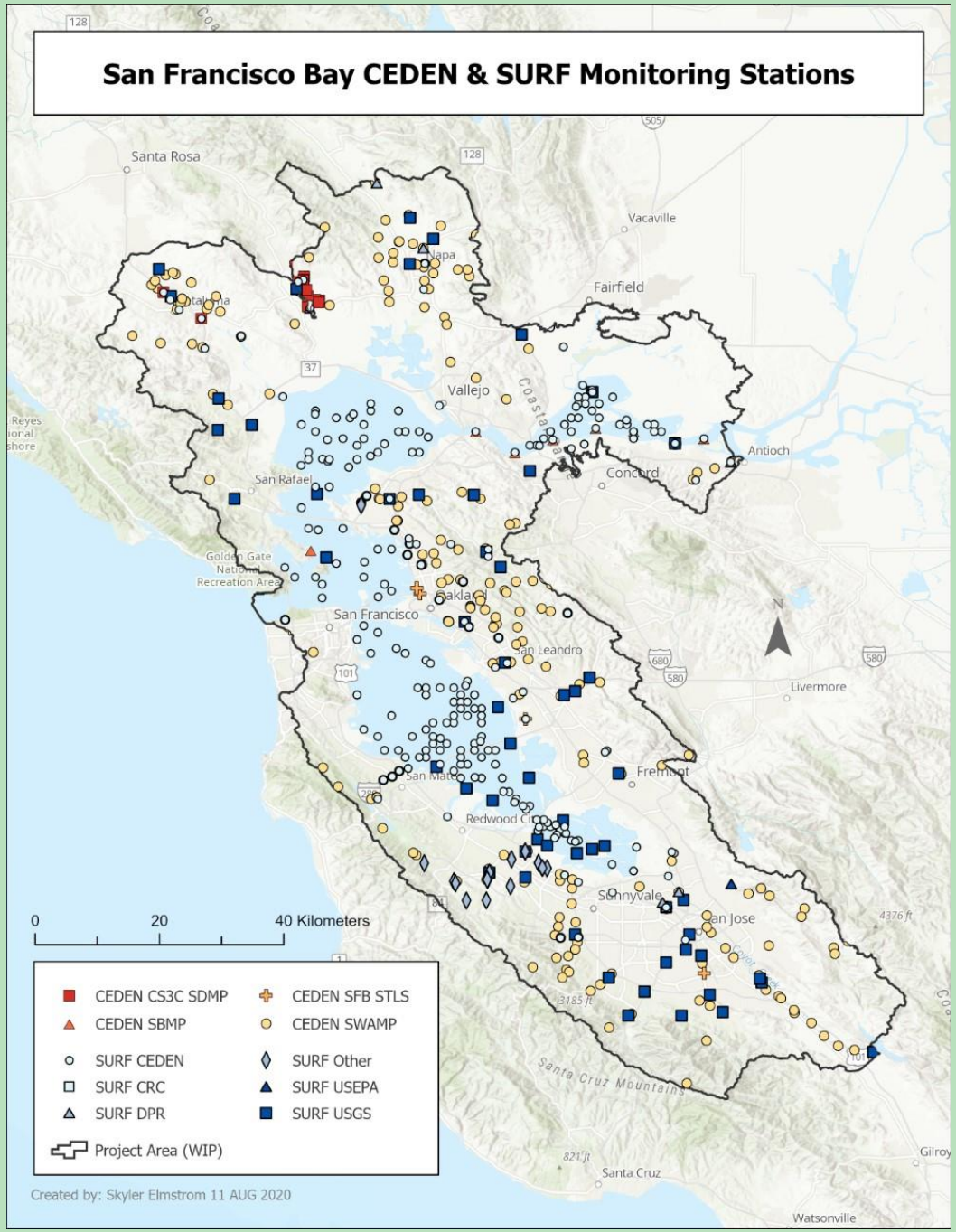
Microplastics (particles less than 5 mm) are ubiquitous and persistent pollutants in the ocean and a pervasive and preventable threat to the health of marine ecosystems. Microplastics come in a wide variety of shapes, sizes, and plastic types, each with unique physical and chemical properties and toxicological impacts. Understanding the magnitude of the microplastics problem and determining the highest priorities for mitigation require accurate measures of microplastic occurrence in the environment and identification of likely sources.

To develop critical baseline data and inform solutions, the San Francisco Estuary Institute and the 5 Gyres Institute have completed the first comprehensive regional study of microplastic pollution in a major estuary. This project supported multiple scientific components to develop improved knowledge about and characterization of microparticles and microplastics in San Francisco Bay and adjacent National Marine Sanctuaries, with the following objectives.

1. Contribute to the development and standardization of sample collection and analysis methodology for microplastic transportation research.
2. Determine a baseline for future monitoring of microplastics in San Francisco Bay surface water, sediment, and fish, and in ocean waters outside the Golden Gate.
3. Characterize pathways by which microplastics enter the Bay, including urban stormwater and treated wastewater effluent.
4. Investigate the contribution of Bay microplastics to the adjacent National Marine Sanctuaries through computer simulations.
5. Communicate findings to regional stakeholders and the general public through meetings and educational materials.
6. Facilitate evaluation of policy options for San Francisco Bay, with recommendations on source reduction.

This document presents the findings of this three-year project. A companion document, “San Francisco Bay Microplastics Project: Science-Supported Solutions and Policy Recommendations,” has been developed by 5 Gyres using the findings of this study (Box and Cummins, 2019).

Sutton et al. 2019 Executive Summary



Other Data Availability

- 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
- Data from these stations are stored and publicly accessible through the **CEDEN** and **SURF** databases
- This represents a selection of the data we will use to parameterize in our model

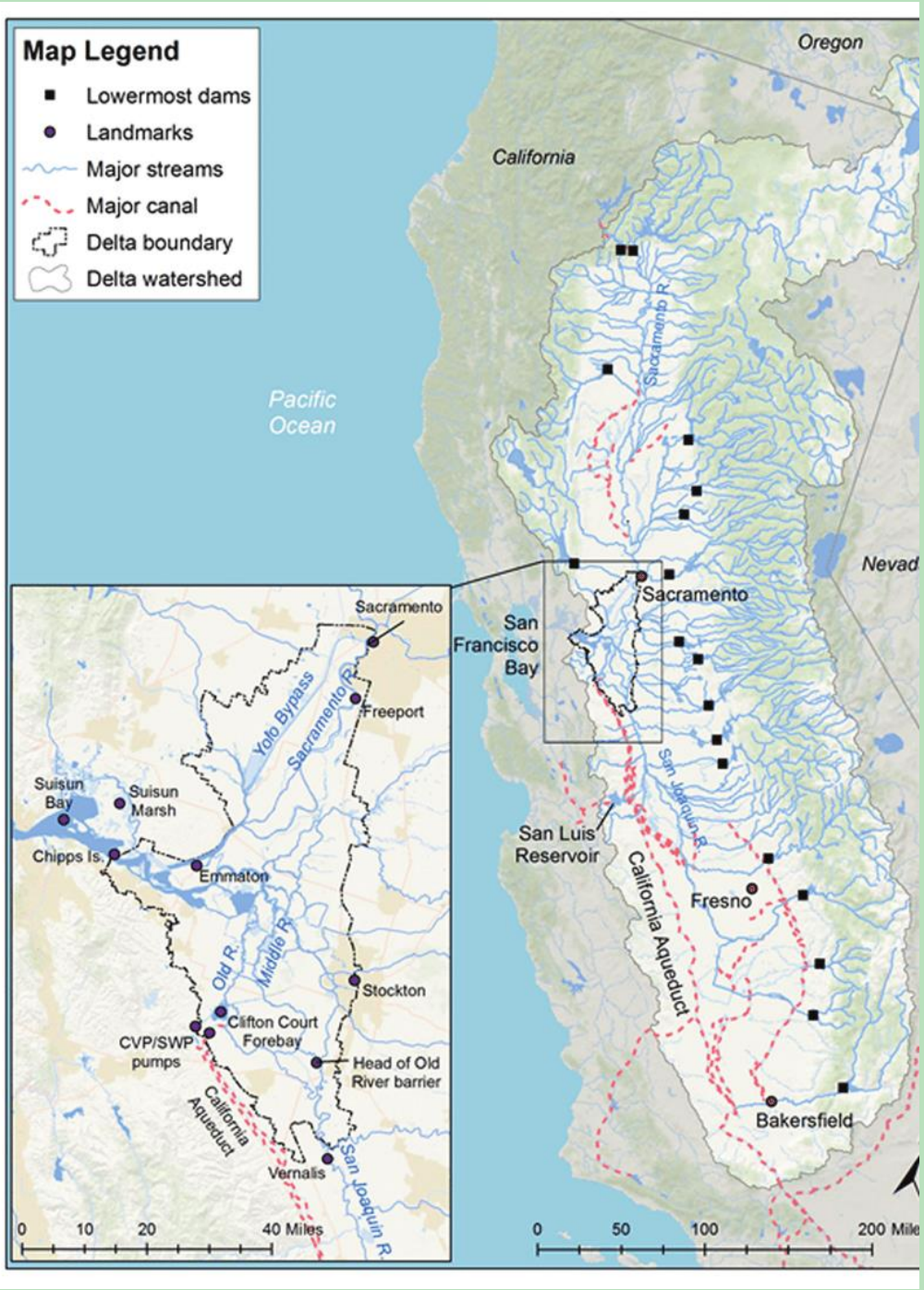
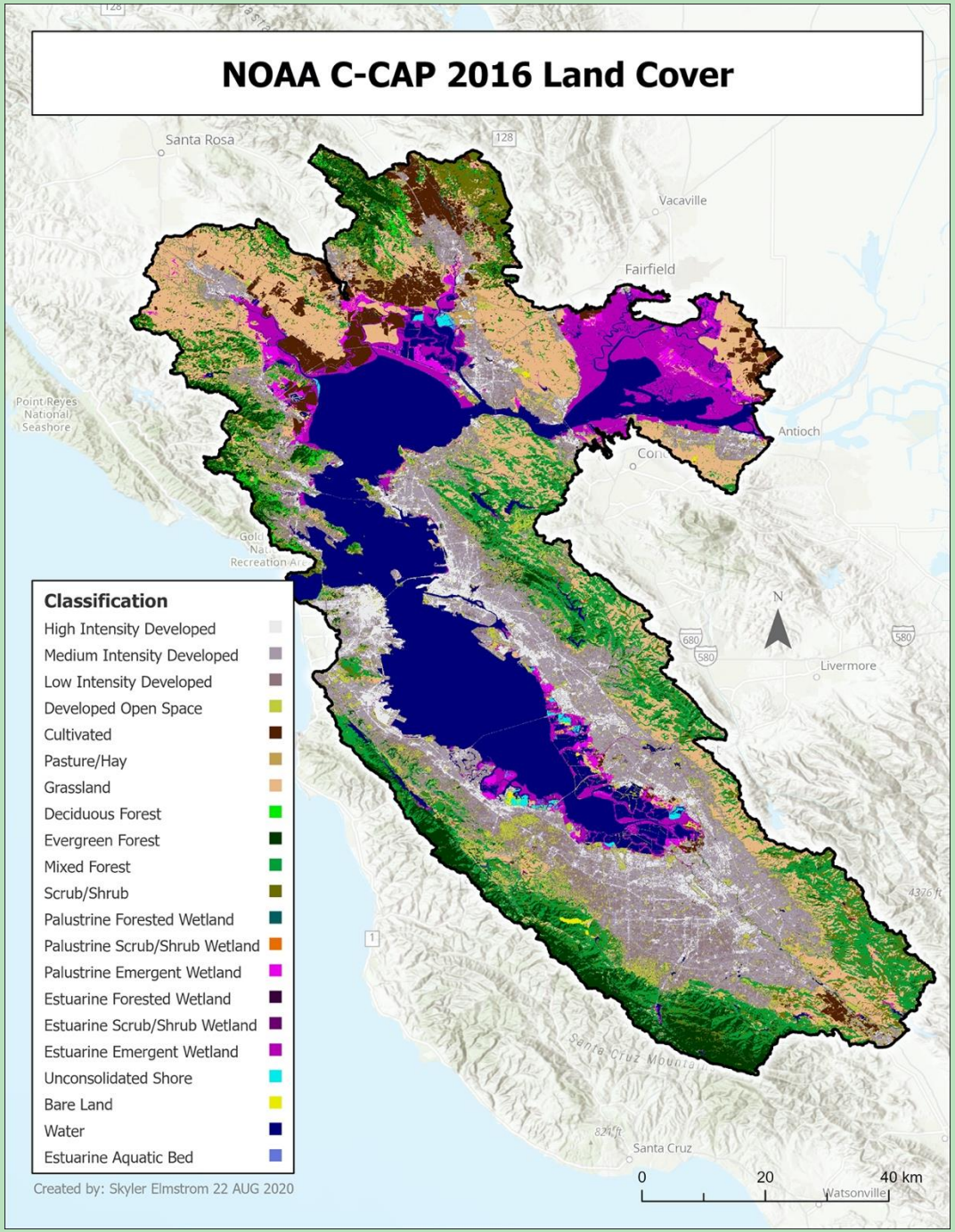


Photo: Reis et al. 2019

Geographical Context

- San Francisco Bay, located just north of central California, is one of the largest estuaries on the west coast of the United States
- Approximately forty percent of the water moving through California goes through the San Francisco Bay, draining from Sierra Nevada mountain range into the Sacramento-San Joaquin River Delta before gathering in the bay Drains primarily through agriculture regions before it reaches San Francisco Bay
- Two-thirds of California's salmon pass through the bay as they migrate to and from their spawning grounds in the creeks and tributaries of the Sacramento-San Joaquin River Delta.



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 in total surround the SF Bay.
- Land use around the bay includes high density and suburban housing, agriculture, public and protected lands, and industrial and commercial infrastructure.
- Ecosystem services provided by SF Bay include food, transportation, jobs, tourism, recreation, education, and cultural interests.
- The complex combination of community, industrial, agricultural, and environmental interests that merge around the SF Bay results in a diverse set of stakeholders and interest groups with converging and diverging goals for the bay.

Development of Endpoints

- The development of endpoints is based on management goals and culturally important resources.
- A successful ecological risk assessment requires the guidance of stakeholders in development of endpoints.
- Endpoints for this case study were developed from information in collaborative reports on area-specific management goals by local, regional and federal government agencies and NGO partnerships.
- The endpoints will be refined as we begin to directly speak with more stakeholders.
- Ideally, a diverse group of stakeholders can be involved in the continued development of these endpoints.

Endpoints:

- Endangered and threatened species
- Native and endemic species
- Fisheries
- Macroinvertebrates
- Prey species
- Habitat quality
- Subsistence fishing
- Tribal interests/rights
- Recreation
- Cultural importance
- Economic importance
- Abiotic resource extraction

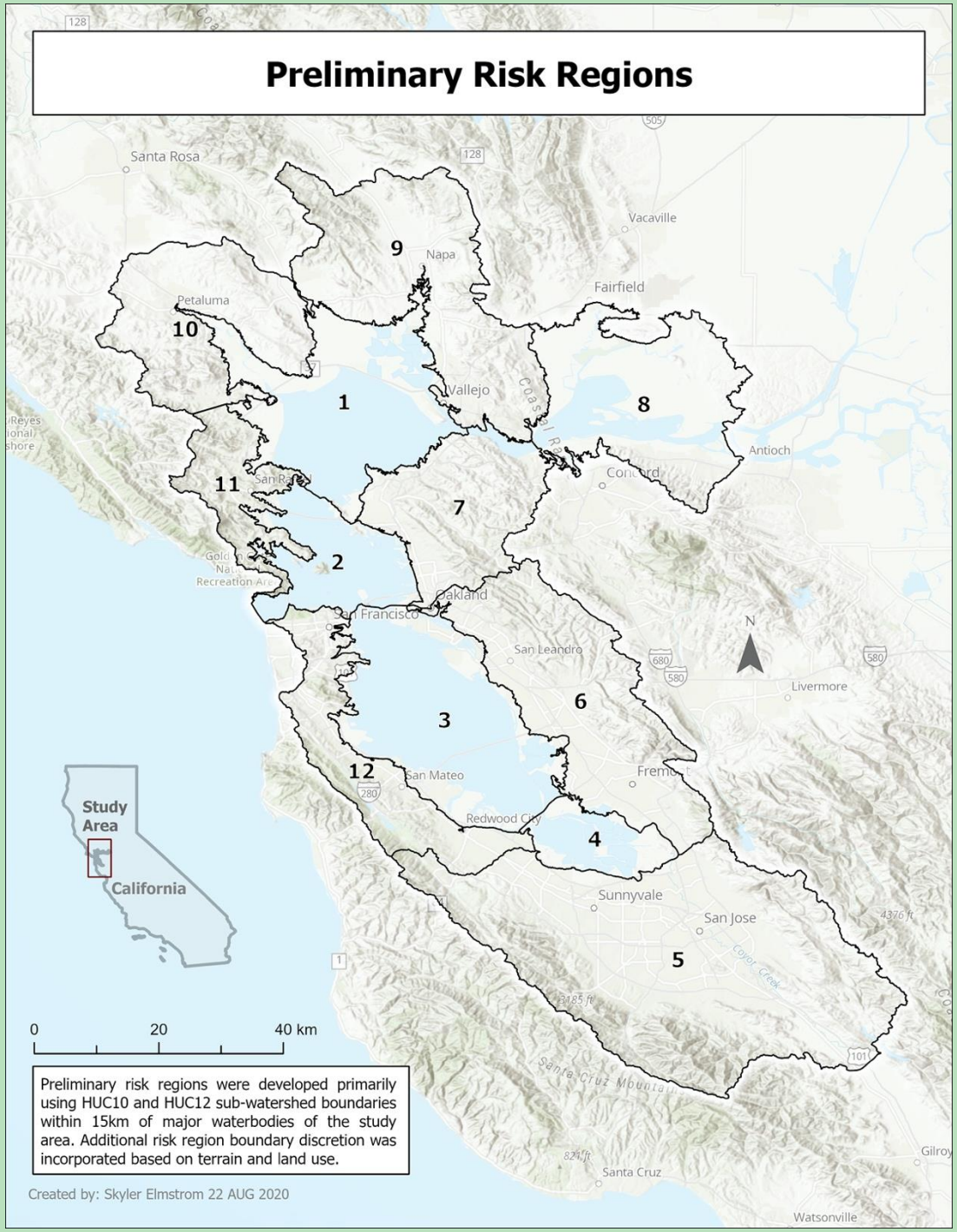
Development of Risk Regions

- This is done based on:
  - Hydrological Units (HUC levels 8, 10, and 12)
  - Land use data
  - Availability of contaminant data that will be required to parameterize the
- These regions will be ranked based on the relative presence of each habitat and likely discharge of stressor for each source type.
- These rankings will then be used in the development of conditional probability tables used in the Bayesian Network model.

Risk Regions

Metrics

Risk Region	Area (km2)	Area (ha)	Area (mi2)
1	594	59367	229
2	281	28118	109
3	662	66216	256
4	159	15928	61
5	1490	148959	575
6	683	68255	264
7	419	41943	162
8	586	58556	226
9	716	71594	276
10	485	48533	187
11	215	21468	83
12	369	36855	142

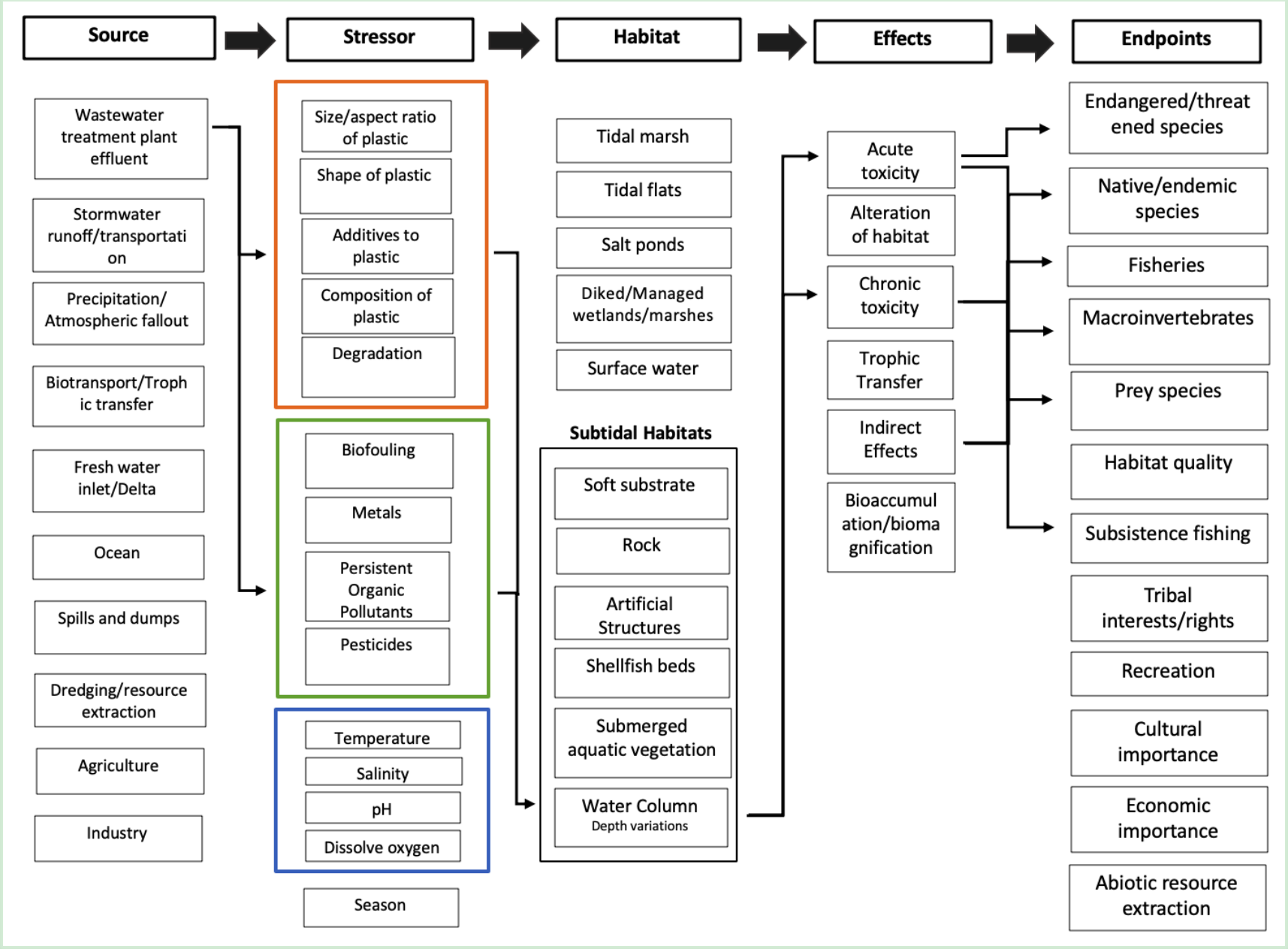


Development of Conceptual Model

- The format of the conceptual model includes sources, stressors, habitat, effects, and endpoints.
- Likely sources of microplastics in SF Bay were concluded from data directly related to monitoring projects as well as more general data about common sources of microplastics into urban water bodies.
- Information about stressors was informed by available toxicity studies on microplastics and contaminants commonly found in SF Bay.
- Information on habitat types was determined from reports of habitat management goals and will need to be refined with the involvement of interested stakeholders.
- Effects are informed by the endpoints and will be adjusted as endpoints change.

Conceptual model for microplastics in San Francisco Bay

- Arrows connecting boxes represent an example of a potential causal pathway.
- The next step will be to use this conceptual model as framework to make a Bayesian network



Next steps

- Continued data collection in the study site area (contaminant concentrations, water quality parameters, organism and species parameters, etc.)
- Stakeholder outreach for input on specific endpoints and conceptual models
- Development of the Bayesian Network
- We are also now scouting out other sites for microplastic risk assessment around the Northwest
- Building a general framework for microplastic risk assessment

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