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

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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 still successfully produce an ecological risk assessment.

- We will be using Relative Risk Model (RRM).

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 hypotheses 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 an ecological risk assessment, we need a location rich in relevant data.
- The study site 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 databases such as the California Environmental Data Exchange Network (CEDEN) and California Surface Water (SURF).
San Francisco Bay Region
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

Sutton et al. 2019
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.
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.
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

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<thead>
<tr>
<th>Risk Region</th>
<th>Area (km²)</th>
<th>Area (ha)</th>
<th>Area (mi²)</th>
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</table>

Preliminary risk regions were developed primarily using HUC10 and HUC12 sub-watershed boundaries within 15km of major waterbodies of the study area. Additional risk region boundary discretion was incorporated based on terrain and land use.
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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- California State Coastal Conservancy. 2010. San Francisco Bay Subtidal Habitat Goals Report: Conservation planning for the submerged areas of the Bay.


References