Modeling PFAS Biomagnification in the Chesapeake Bay, a pilot study

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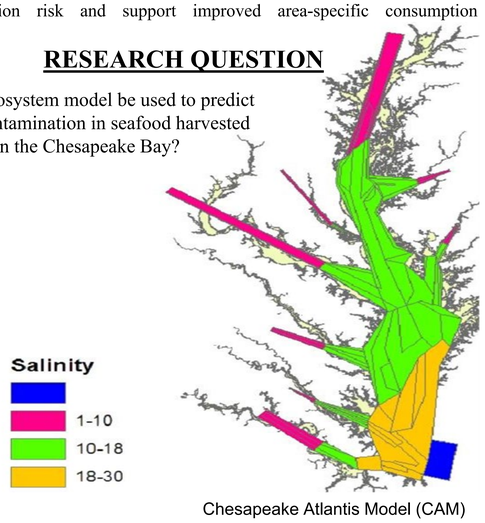
ABSTRACT

Per- and polyfluoroalkyl substances (PFAS) are hazardous, man-made organic chemicals. These chemicals are found in firefighting foams, non-stick cookware, and numerous other products manufactured since the 1940s. PFAS are designed to resist heat and degradation, so they persist in the environment in water, biomagnify in aquatic fauna by binding to proteins, and are consumed by humans through contaminated seafood. PFAS exposure causes many adverse health effects including skeletal deformity, decreased response to vaccines, cancer, low infant birth weight, decreased fertility and increased risk of preeclampsia, and others. PFAS are categorized by the length of their carbon chain backbones as either short- or long-chain PFAS. Reports of environmental concentrations of PFAS are few and haphazard, making it problematic for environmental and human health agencies to develop fish and shellfish consumption advisories. This pilot study aims to apply the spatially-explicit Chesapeake Atlantis Model to estimate PFAS concentrations magnified through the organisms of the Chesapeake Bay food web using Blue Crab (*Callinectes sapidus*) as a test case. The ultimate goal of this work is to establish a validated ecosystem modeling approach that estimates relative concentrations of any biomagnified contaminant in an ecosystem. Such a tool would serve to better inform resource managers and the public of contamination risk and support improved area-specific consumption advisories.

RESEARCH QUESTION

Can an ecosystem model be used to predict PFAS contamination in seafood harvested in the Chesapeake Bay?



Chesapeake Atlantis Model (CAM)

METHOD

- Parameterize existing ecotoxicology module in CAM through literature and data review.
- Use the model to estimate PFAS concentrations spatially for all groups in the model
- Specimen Collection - Collect Blue Crab (*Callinectes sapidus*) from sites with low and high levels of predicted contamination
- Laboratory – Quantify contaminants in muscle tissue of Blue Crab

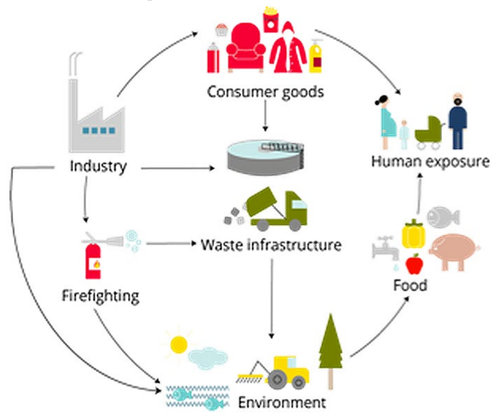
PFAS BACKGROUND

What are PFAS?

- A family of man-made organic chemicals that can repel water, grease, heat, dirt, etc.
- Over 4,000 types of PFAS
- PFAS are differentiated by carbon chain-length (Long-Chain vs Short-Chain)
  - Short-Chain PFAS:
    - Typically have 5 or less carbons
    - Low adsorption potential
    - Relatively difficult to remove from water.
    - Lesser tendency to bioaccumulate.
    - Common Short-Chains are PFHxS, PFHxA, and PFBA
  - Long-Chain PFAS:
    - Perfluoroalkyl sulfonic acids that have ≥ 6 carbons, such as perfluorooctanoic acid (PFOA) and perfluoroalkyl carboxylic acids with ≥ 7 carbons
    - High adsorption potential
    - Relatively easy to remove from water
    - Difficult to assess in laboratory due to "sticky" properties
    - Bioaccumulate to a higher-degree
    - Very persistent!
    - Common Long-Chains are PFOS, PFOA, and PFNA.

Where can PFAS be found?

- PFAS have been used in industry and consumer products since the 1940s
- They are most often found in food packaging, nonstick cookware, stain resistant fabrics, aquatic life, and water.



Typical PFAS exposure pathways. Digital Image. European Environmental Agency. 12 DEC 2019. https://www.eea.europa.eu/themes/human/chemicals/emerging-chemical-risks-in-europe

Why are PFAS cause for concern?

- Bioaccumulative
  - The more the organism comes into contact with the substance the more it can accumulate in its tissues.
- Persistent
  - PFAS can remain in the environment for years after it is released into the environment.

PFAS BACKGROUND CONT'D

Why are PFAS cause for concern?(Cont'd)

- Extremely mobile
  - PFAS are mobile because they bond to water and can travel with the water
- Adverse health effects
  - Increased infant mortality
  - Skeletal alterations and birth defects
  - Decreases in infant birth weight
  - Reduced immune function
  - Neurodevelopmental effects
  - Increased risk of preeclampsia and high blood pressure in pregnant women
  - Increased risk of kidney or testicular cancer
  - Endocrine disruption

PFAS IN THE REGION

How can PFAS in the Chesapeake Bay affect people?

PFAS contaminants runoff into water source → Species from lowest trophic levels bioaccumulate PFAS from water → Species from higher trophic levels biomagnify PFAS by consumption of lower trophic level organisms → People biomagnify PFAS from consumption of fish and shellfish

What concentration levels of PFAS have been observed in the Chesapeake?

- Water Testing* (combined PFOS & PFOA concentrations)
  - Chesapeake Beach: 241,110 ppt
  - Fort Meade: 87,000 ppt
  - Annapolis: 70,000 ppt
  - White Oak: 1, 365 ppt

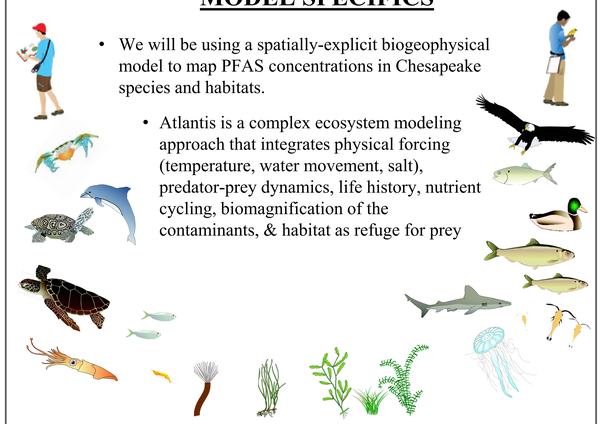
*The US Environmental Protection Agency has a lifetime health advisory of 70 parts per trillion (ppt)

PFAS Regulations for Chesapeake states:

- Maryland law prohibits the use of Class B firefighting foams for testing or training use that intentionally contain PFAS chemicals starting October 1, 2021.
- Virginia law prohibits the use of Class B firefighting foams that intentionally contain added PFAS chemicals for testing or training unless otherwise required by law, in which the testing facility must have implemented appropriate containment, treatment, and disposal measures beginning July 1, 2021

MODEL SPECIFICS

- We will be using a spatially-explicit biogeophysical model to map PFAS concentrations in Chesapeake species and habitats.
  - Atlantis is a complex ecosystem modeling approach that integrates physical forcing (temperature, water movement, salt), predator-prey dynamics, life history, nutrient cycling, biomagnification of the contaminants, & habitat as refuge for prey



TARGETTED OUTCOMES

- This study is a first step to establish the protocols required for the modeling, field collection, and analytical laboratory methods that will be required to validate modeled estimates of PFAS contamination.
- The ultimate goal of this work is to establish a validated ecosystem modeling approach that estimates relative concentrations of any biomagnified contaminants in an ecosystem. Such an approach would serve to better inform resource managers and the public of contamination risk and support improved area-specific consumption advisories.
- Additional benefits include:
  - Improved understanding and public awareness of PFAS present in the Chesapeake Bay's harvested species and the threat it may pose to humans.
  - Improved regulation of these chemicals in the region.

ACKNOWLEDGEMENTS

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