PFAS Associated with AFFF Sites: What we have learned with respect to exposure, ecotoxicity and bioaccumulation?

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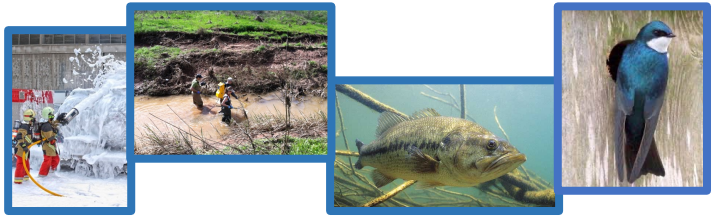
Toxic Contaminant Workgroup
April 10, 2024

TOWSON UNIVERSITY

SERDP
DOD ▪ EPA ▪ DOE

Acknowledgements:



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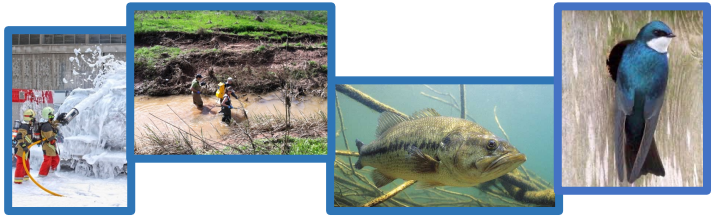
Objectives:



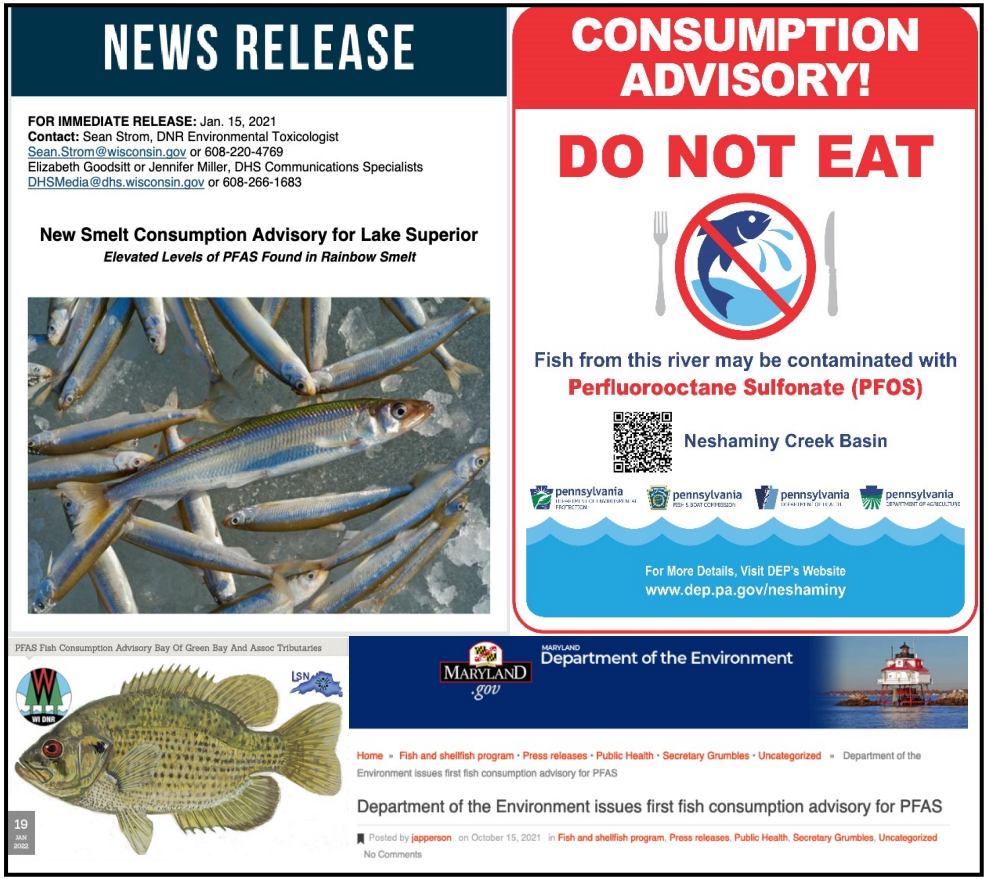
- Overview of research studying environmental impacts of PFAS
  - Field, laboratory, modeling studies
- Highlights:
  - Exposure to aquatic organisms
  - Effects in aquatic organisms
  - Bioaccumulation
- PFAS in Maryland?

Why we need to understand PFAS F&T

There are clear and growing concerns regarding PFAS

Human Health Concerns

Ecological impacts and impacts to Ecosystem Services



NEWS RELEASE

FOR IMMEDIATE RELEASE: Jan. 15, 2021
Contact: Sean Strom, DNR Environmental Toxicologist
Sean.Strom@wisconsin.gov or 608-220-4769
Elizabeth Goodsitt or Jennifer Miller, DHS Communications Specialists
DHSMedia@dhs.wisconsin.gov or 608-266-1683

New Smelt Consumption Advisory for Lake Superior
Elevated Levels of PFAS Found in Rainbow Smelt

CONSUMPTION ADVISORY!

DO NOT EAT

Fish from this river may be contaminated with
Perfluorooctane Sulfonate (PFOS)

Neshaminy Creek Basin

pennsylvania pennsylvania pennsylvania pennsylvania

For More Details, Visit DEP's Website
www.dep.pa.gov/neshaminy

PFAS Fish Consumption Advisory Bay Of Green Bay And Assoc Tributaries

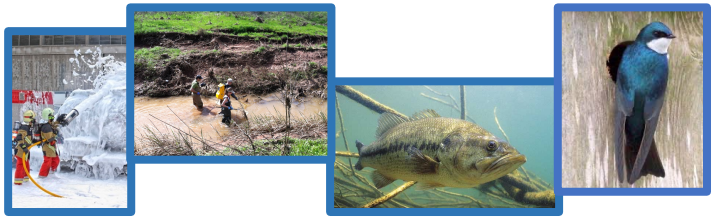
MARYLAND Department of the Environment
MARYLAND .gov

Home » Fish and shellfish program • Press releases • Public Health • Secretary Grumbles • Uncategorized » Department of the Environment issues first fish consumption advisory for PFAS

Department of the Environment issues first fish consumption advisory for PFAS

Posted by japperson on October 15, 2021 in Fish and shellfish program, Press releases, Public Health, Secretary Grumbles, Uncategorized
No Comments

PFAS in the Environment



Generalizations…

Production/Point Source

*Sometimes High Concs.
*Dominated by few PFAS

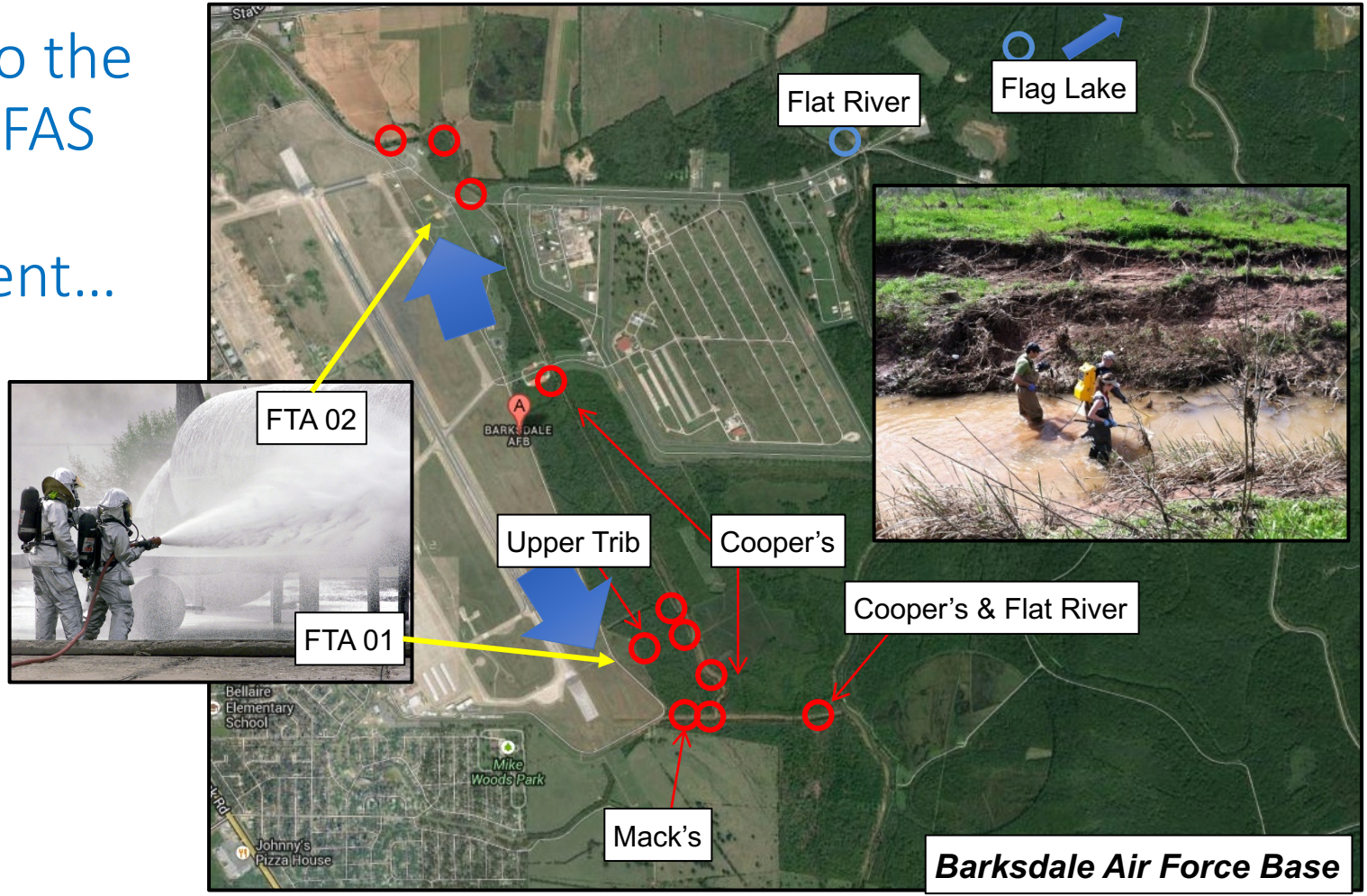
Misc./Urban/ Effluent/Atmos., etc.

*Gen. Lower Concs.
*Various PFAS
*Dominant PFAS varies or well-mixed

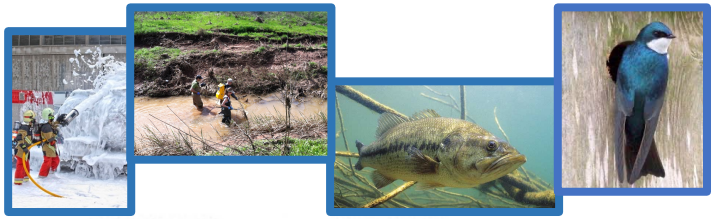
AFFF Use/ Spill

*Relatively High Concs.
*Dominated by few PFAS
*PFOS often dominant

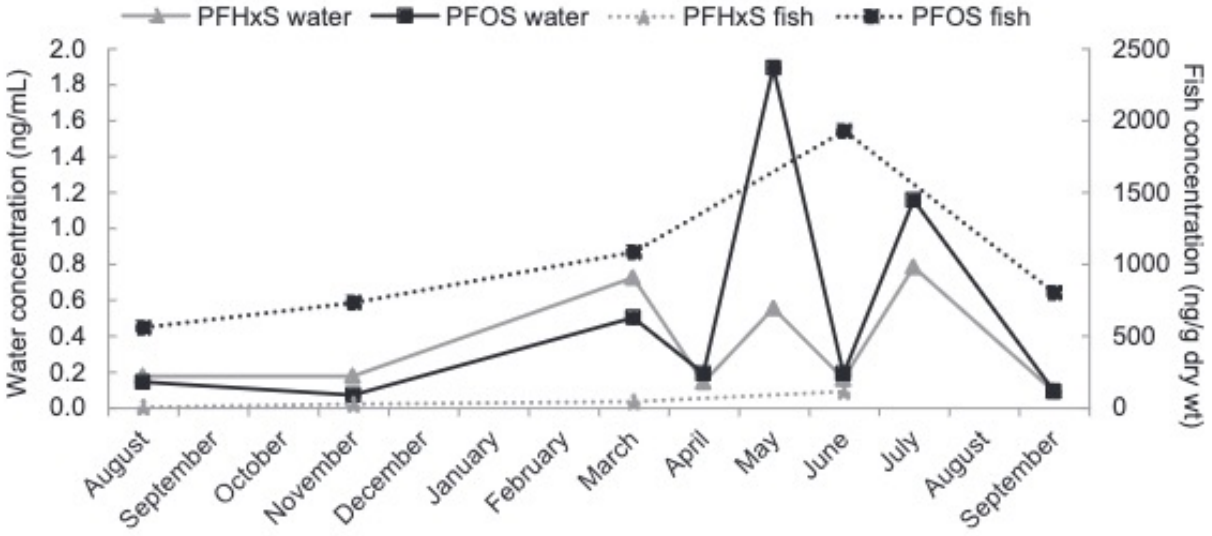
My intro to the world of PFAS in the environment…



PFAS Field Study:



- PFAS vary
  - Spatially
  - Temporally
- Fish track environmental concentrations



Lanza et al. 2017

PFAS vary in space and time

Questions that Surfaced:

- What are representative PFAS at AFFF sites (do they even exist)?
- Do we have toxicity data that matches likely exposure scenarios (PFAS mixtures?)?
- Can we understand factors that improve estimates of bioaccumulation for relevant PFAS?

Air Force AFCED: PFAS at Barksdale AFB

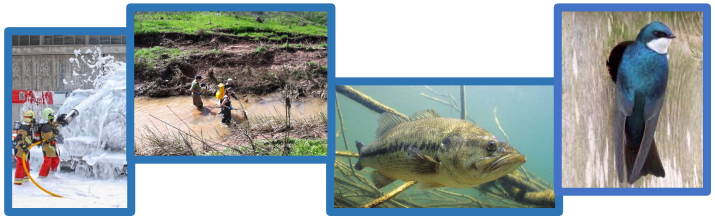
SERDP:

ER-2627 Ecotox of PFAS to wildlife

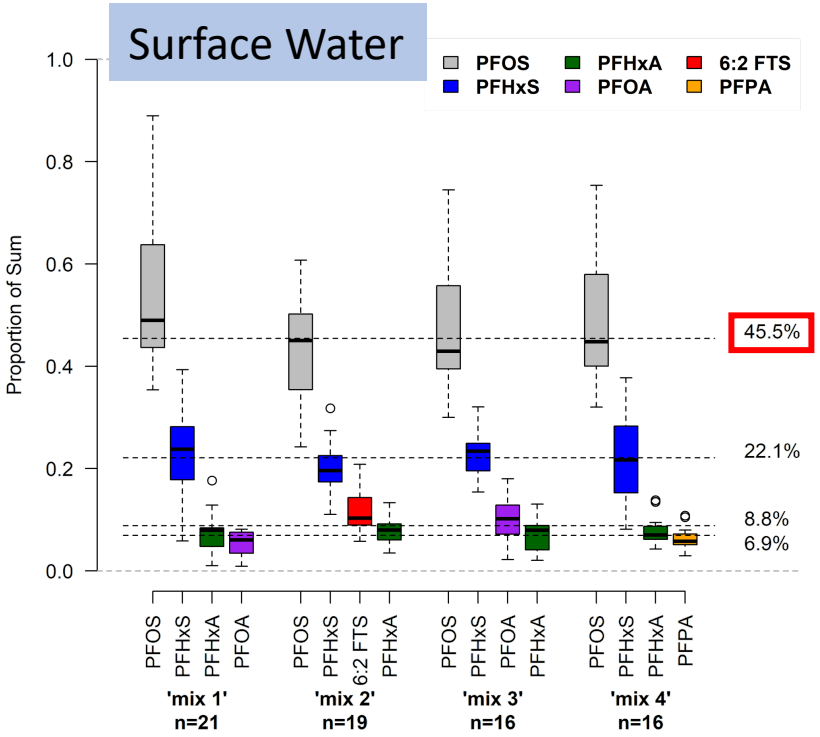
ER19-1193: Bioaccumlation of PFAS in fish

ER18-1626: PFAS risk to threatened and endangered species (avian risk)

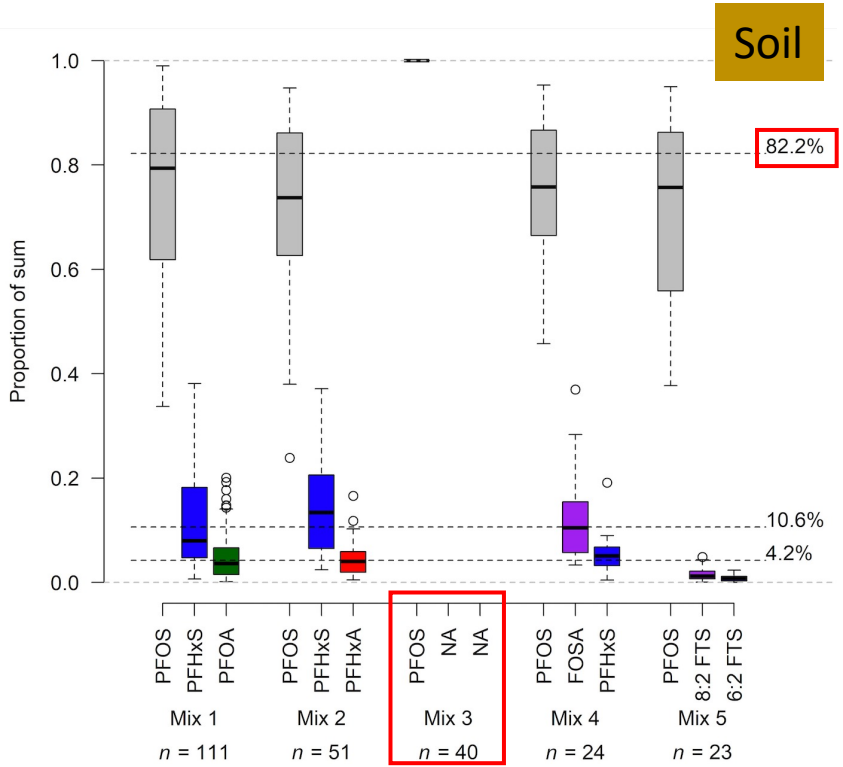
PFAS AFFF Site Generalities?



>200 installations

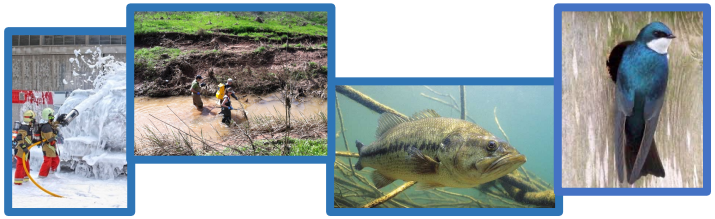


East et al. 2021



East et al. in rev.

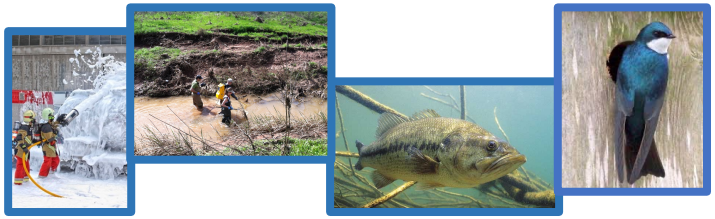
PFAS Ecotox: Insights?



- Analysis of monitoring data:
  - PFOS a dominant PFAS
  - PFHxS equally frequent but lower than PFOS
- Toxicity of PFOS and PFOS + PFHxS would seem a priority

- PFOS and mixture toxicity to:
  - Chironomids (McCarthy et al.)
  - Fathead Minnows (Suski et al.)
  - Lizards (brown anole) (Salice et al.)
  - Bobwhite quail (Dennis et al.)
- Was PFOS + PFHxS more toxic than PFOS alone?

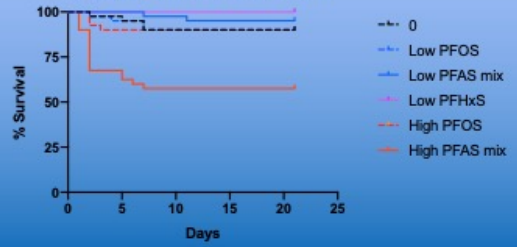
PFAS Ecotoxicity



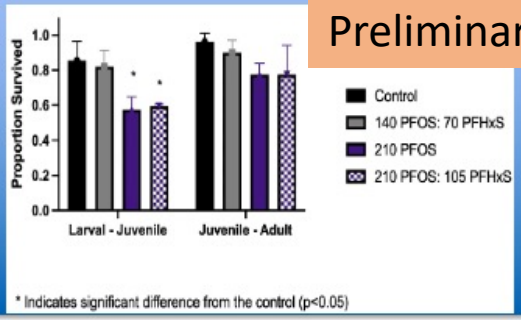
For PFOS and PFHxS:

In fish:

Strong interaction:

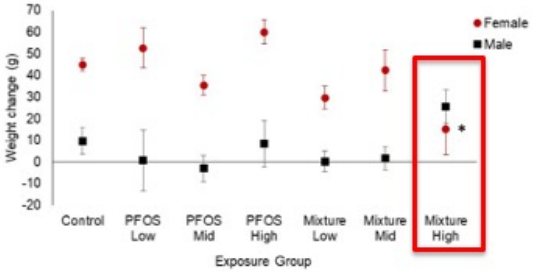


No interaction:



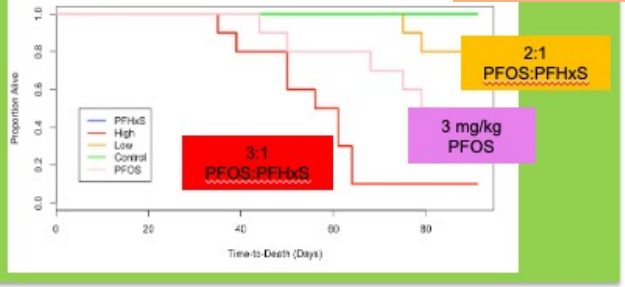
Preliminary

In birds: females, not males



In Reptiles: strong effect

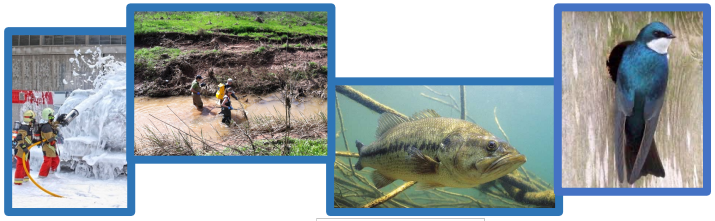
Preliminary

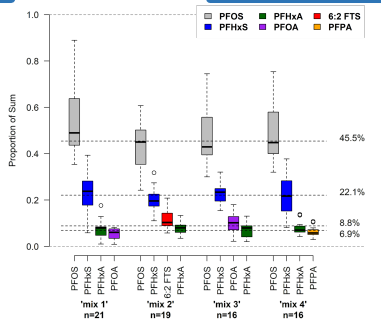


Suski et al. 2021
Dennis et al. 2020

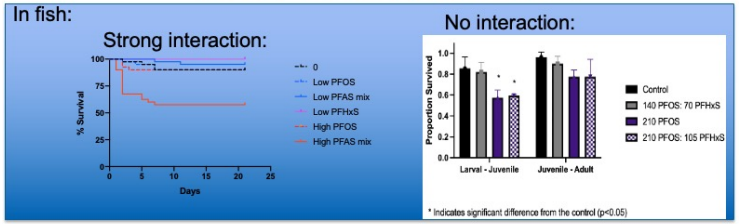
PFAS Ecotox Highlights

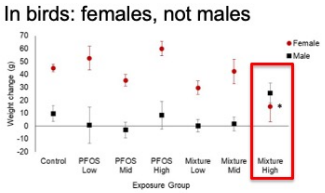
- There are clear and somewhat predictable patterns of PFAS in AFFF-impacted systems
  - PFOS dominant, PFOS + PFHxS always present
- PFOS most toxic single PFAS
- Mixtures yield some synergism but not universal; not easily predicted?

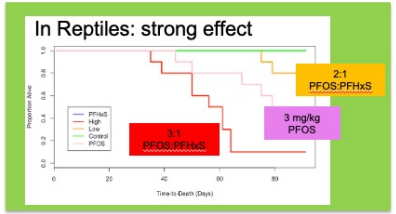




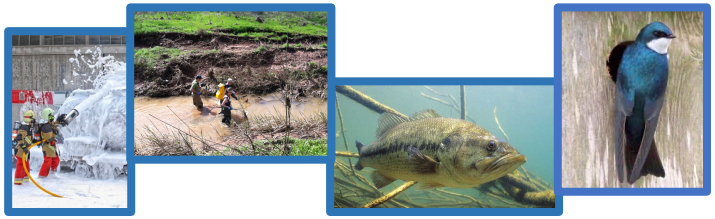
For PFOS and PFHxS:

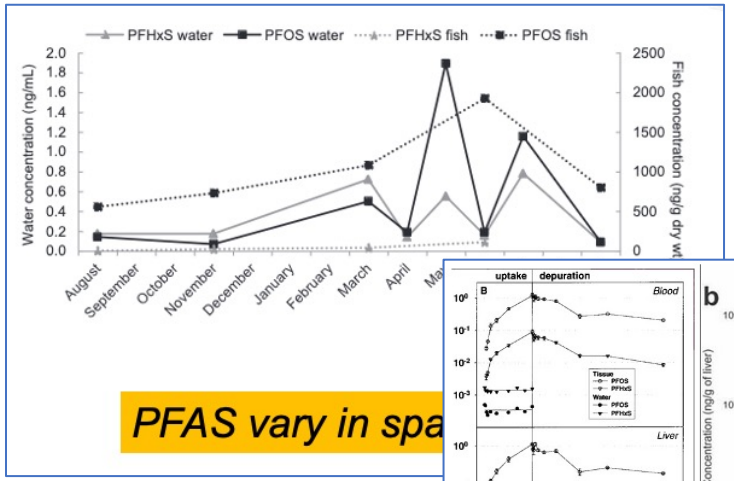




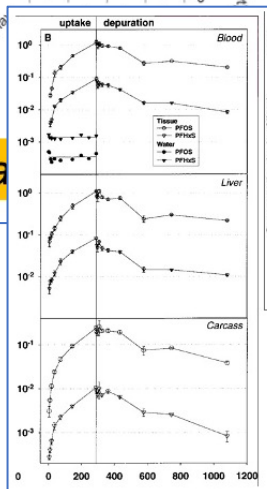


PFAS Bioaccumulation in Fish

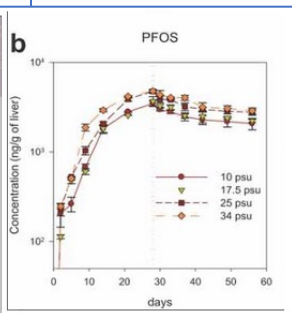




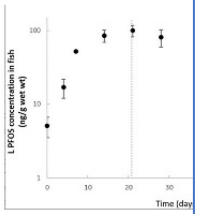
PFAS vary in spa



Martin et al. 2009

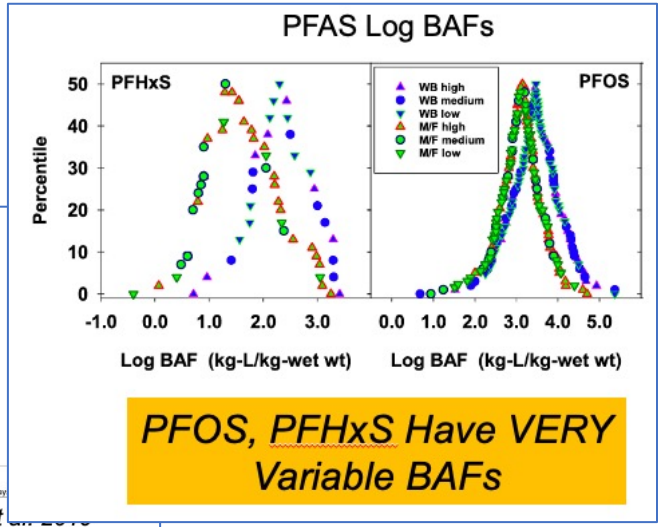


Jeon et al. 2010



Hassel et al.

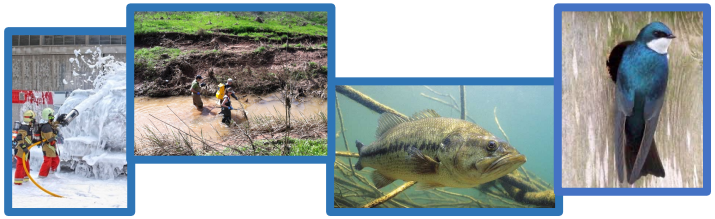
PFAS accumulate quickly

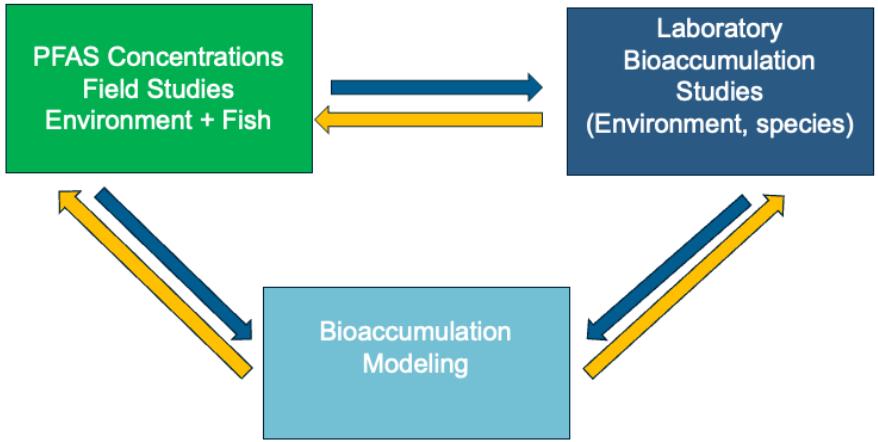


PFOS, PFHxS Have VERY Variable BAFs

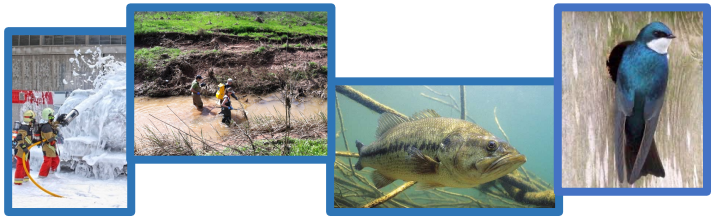
Burkhard 2021

PFAS Bioaccumulation in Fish

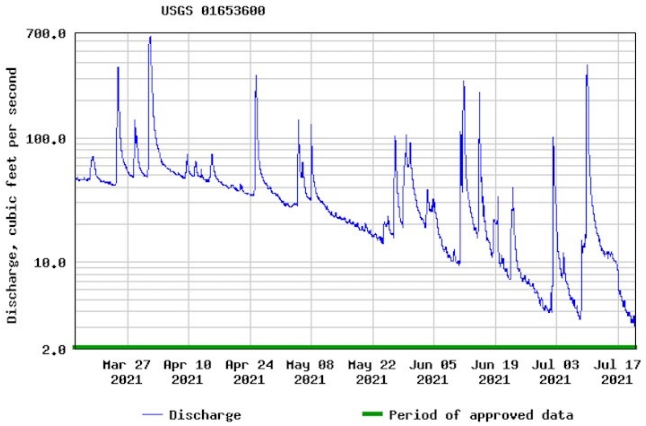


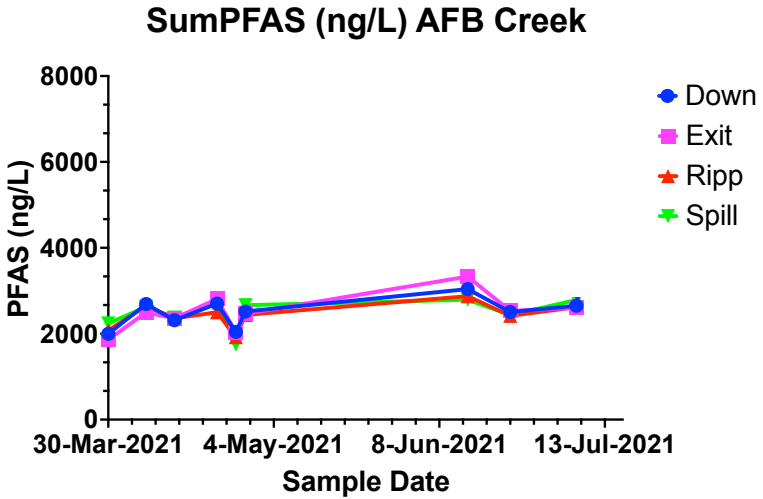


PFAS Bioaccumulation in Fish

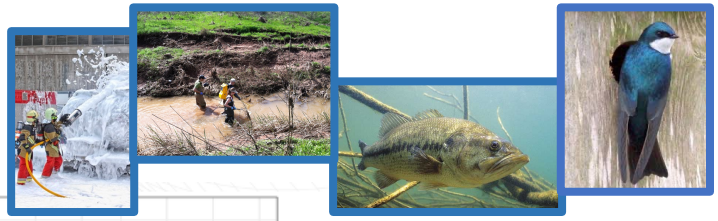


PFAS in surface water from AFB Creek

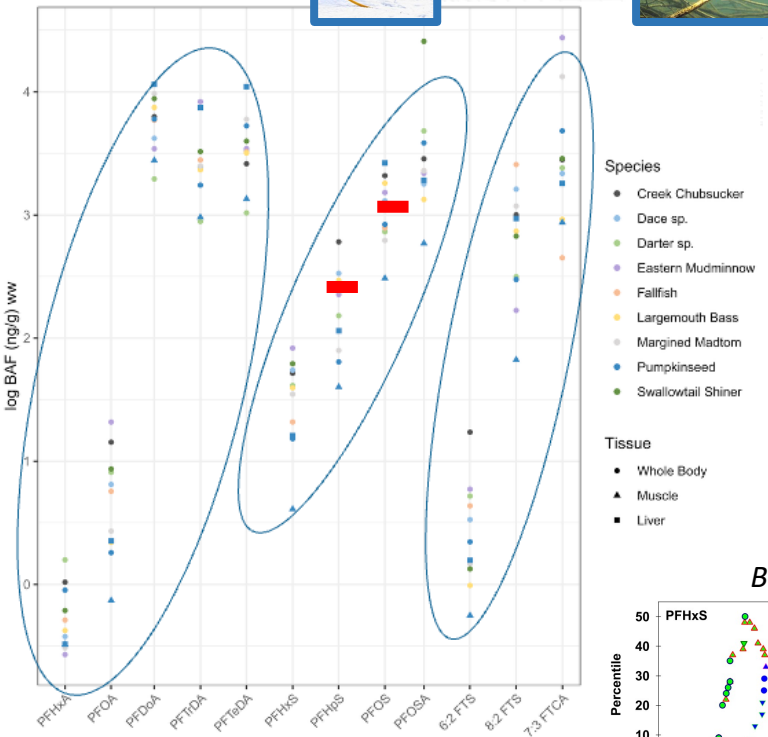




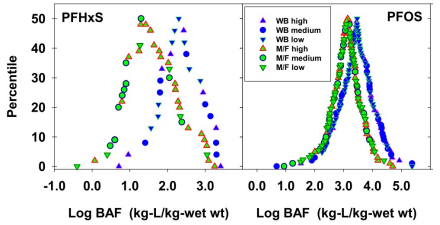
PFAS Bioaccumulation in Fish



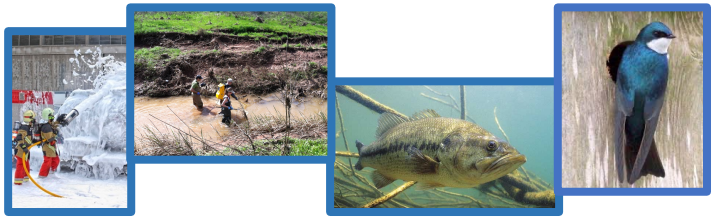
- BAFs in line with published values (Burkhard 2021)
- But, still considerable variability?



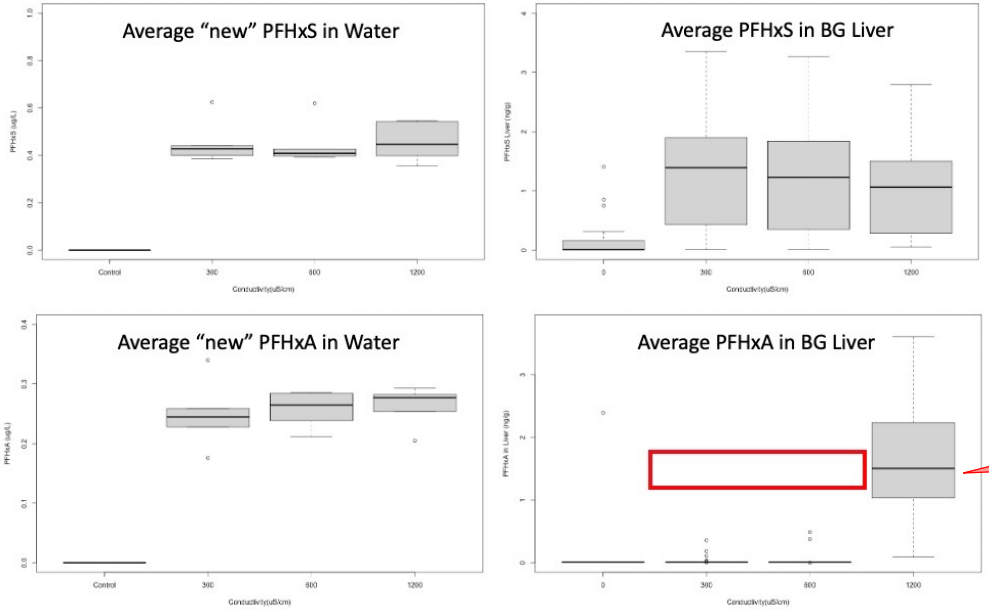
Burkhard 2021



PFAS Bioaccumulation in Fish

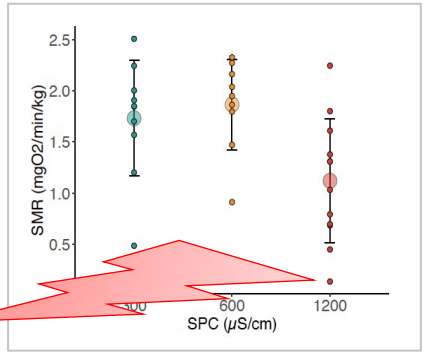


- What factors contribute to PFAS variability in fish?

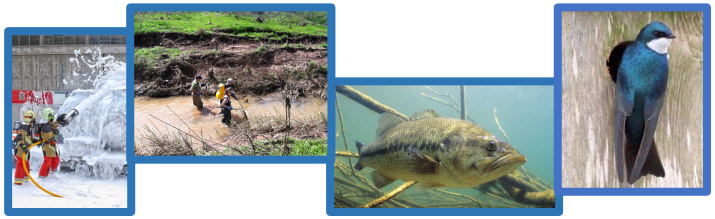


Only fish at high salinity accumulated PFHxS!

BG SMR

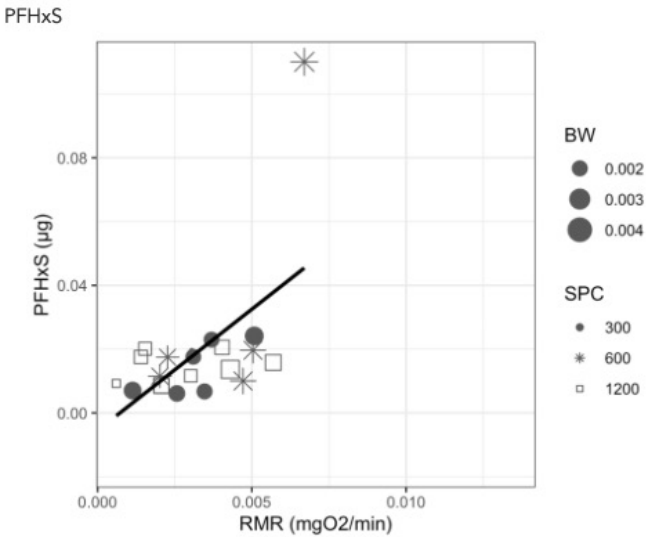


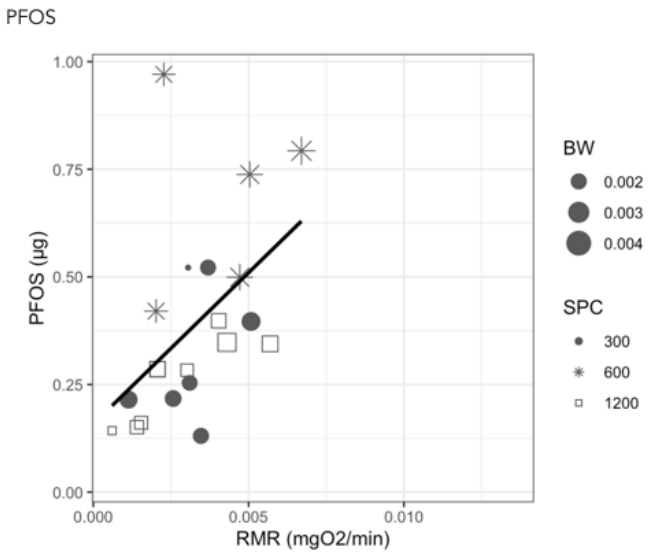
PFAS Bioaccumulation in Fish



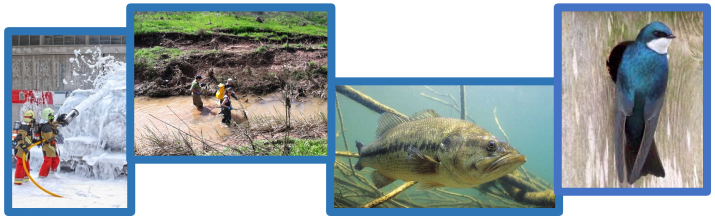
- Does metabolic rate impact PFAS bioaccumulation?

Indeed! It appears To have a positive Effect!



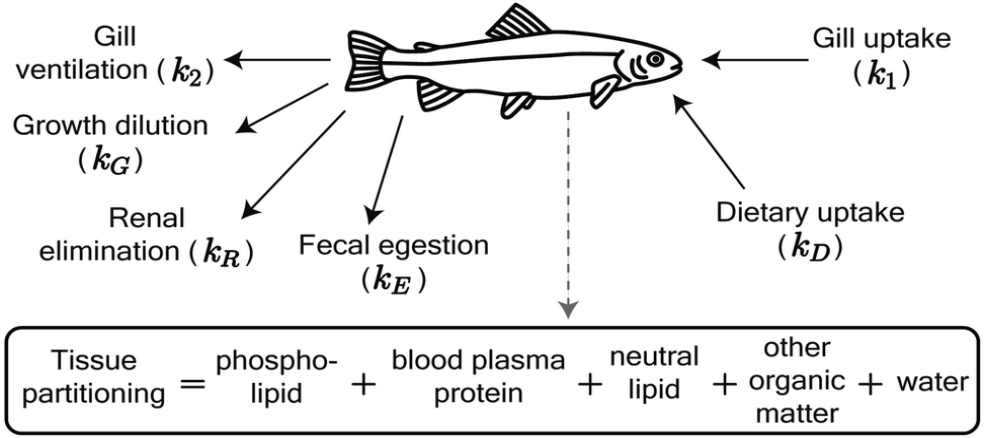


PFAS Fish Bioaccumulation Model

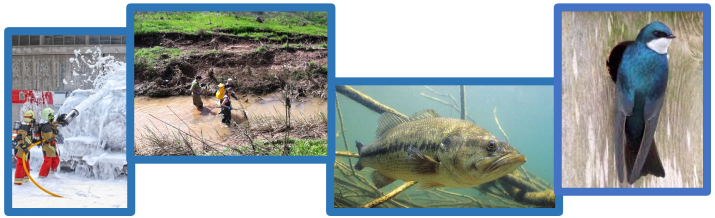


- Implemented two published fish bioaccumulation models (Arnot and Gobas, 2004)
- Sun et al. (2022)*
- Liang et al. (2022)

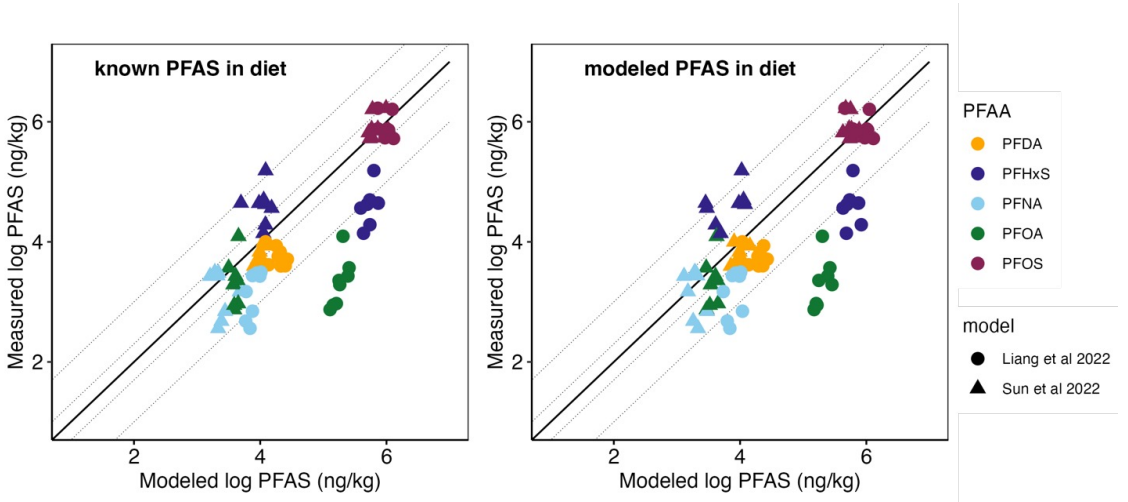
$$C_{fish} = \frac{k_1 C_{water} + k_D C_{diet}}{k_2 + k_E + k_G + k_R}$$



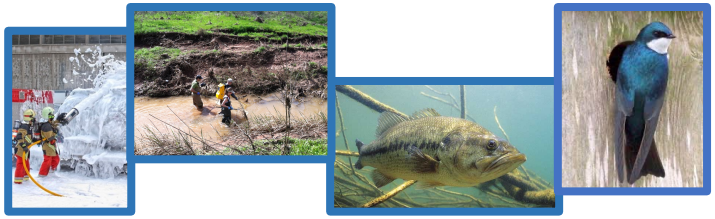
PFAS Fish Bioaccumulation Model



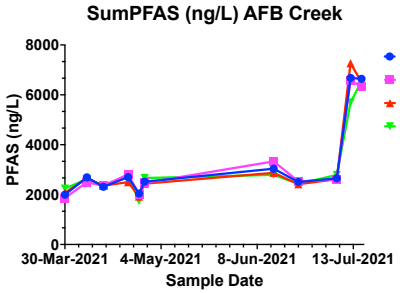
- Sun et al. (2022) generally performed better
  - AFB Creek
  - Navy Rec pond
- Reasonable agreement between modeled and observed data

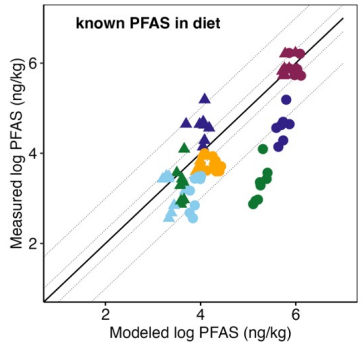


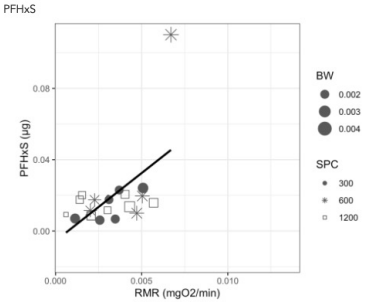
PFAS Bioaccumulation in Fish



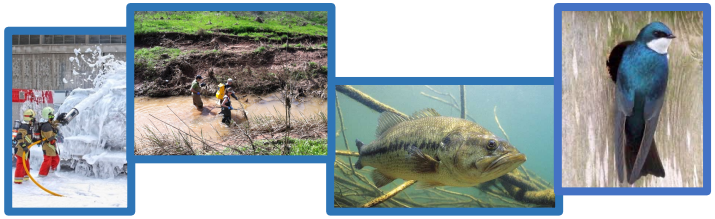
- PFAS vary in space and time
- Physiological and environmental factors can impact PFAS bioaccumulation in fish
- That said, existing bioaccumulation models appear to work reasonably well



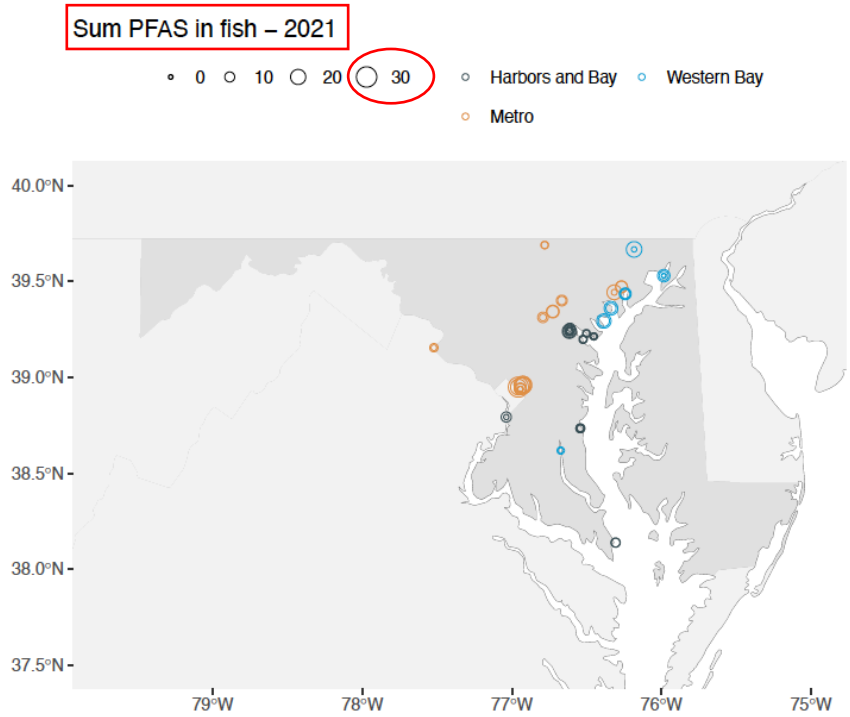




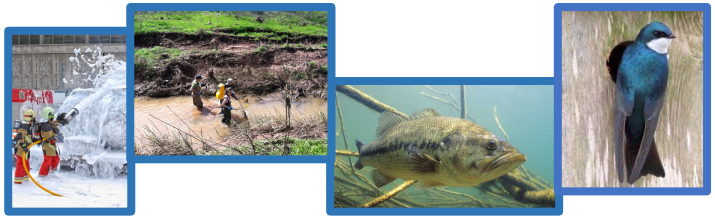
PFAS in MD and Chesapeake?



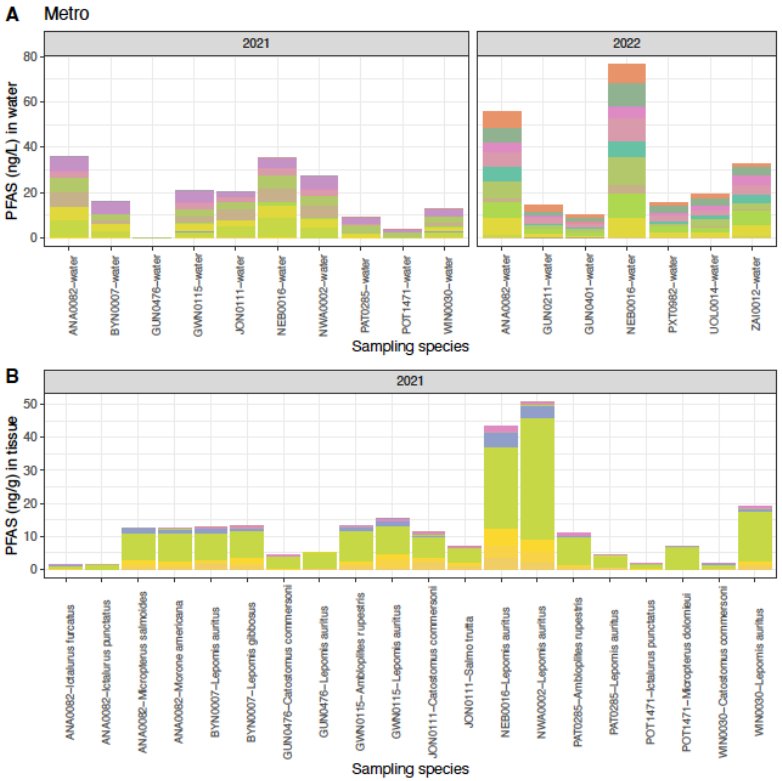
- sumPFAS in fish from 2021 from different water bodies in MD
- Note scale (30 ng/g highest)



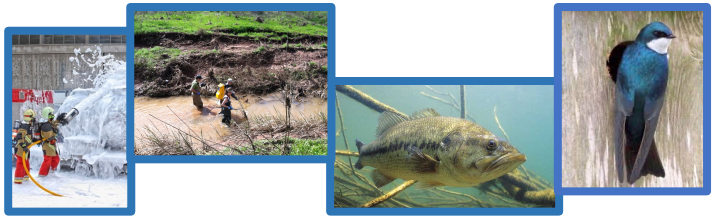
PFAS Bioaccumulation in Fish



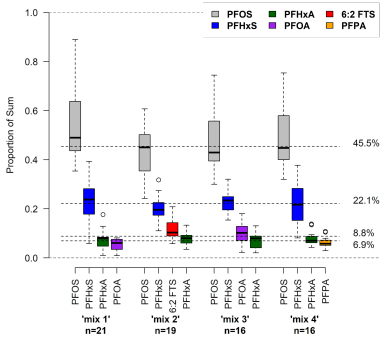
- Apparent ”enrichment” of PFOS in fish tissues
- Despite relatively low concentrations in water?

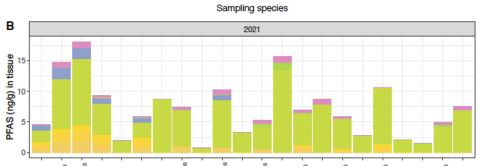


Take-Home Messages

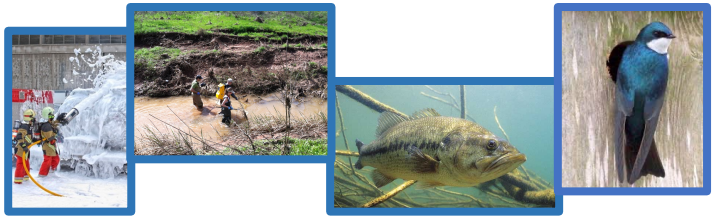


- PFAS are complicated
- PFAS can vary over relatively short timescales and spatial scales
- PFOS is an important PFAS
- PFAS Mixtures are likely relevant
- Existing BAMs appear to work reasonably well
- Environment and physiology can contribute to variation in PFAS bioaccum
- Patterns and sources of PFAS in MD water and fish

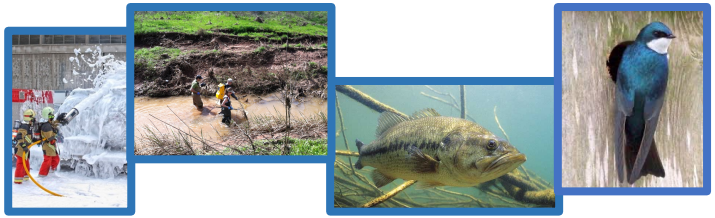




Thanks!



References:



- Lanza et al. 2017 (BAFB fish): ET&C pp. 2022-2029
- Salice et al. 2018 (BAFB risk assessment): ET&C pp. ET&C 2198-2209
- Dennis et al. 2020 (Avian tox): ET&C pp. 1101-1111
- Suski et al. 2021 (Fish Toxicity): ET&C pp. 811-819
- McCarthy et al. 2021 (invert tox): ET&C pp. 2319-2333
- East et al. 2021 (PFAS profile AFFF sites): ET&C pp. 871-882
- Brown et al. 2023 (PFAS in pond): SOTE pp. vol. 880