Photo Credit: Michigan Department of Environmental Quality

PFAS toxicity to aquatic animals and potential firefighting foam replacements

Prepared for:

stac

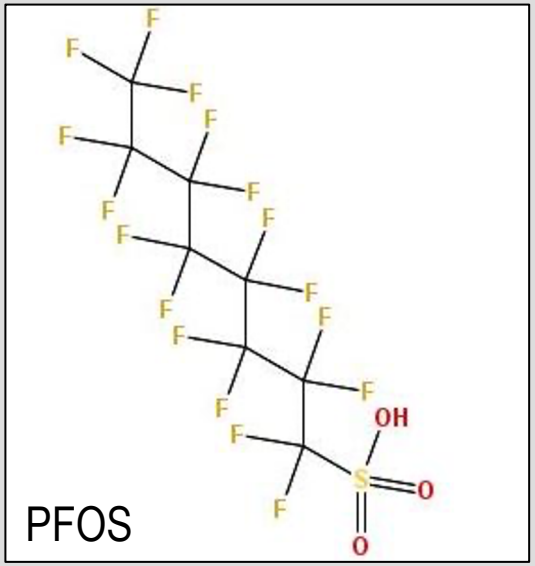
Prepared by:

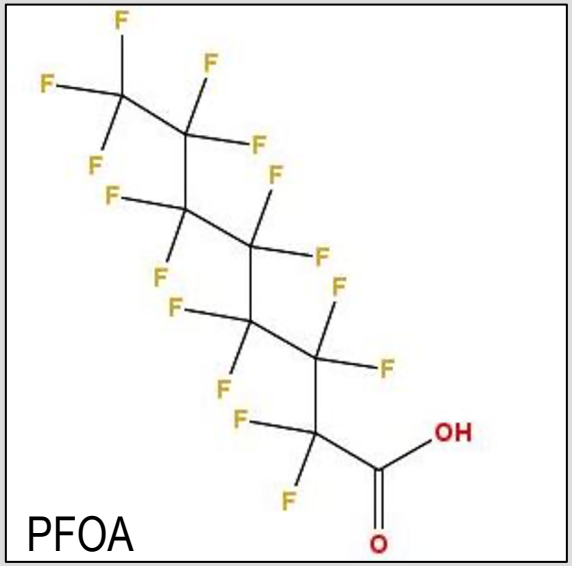
EA Engineering, Science, and Technology, Inc., PBC

Jamie Suski, PhD

17 May 2022

What are PFAS





Per- and Polyfluoroalkyl Substances (PFAS) – thousands of chemicals

- Carbon chain loaded with Fluorine
- Recalcitrant in the environment (does not breakdown)
- Widespread contamination

Example of PFAS Uses

Grease-repellent

Fire Extinguishing

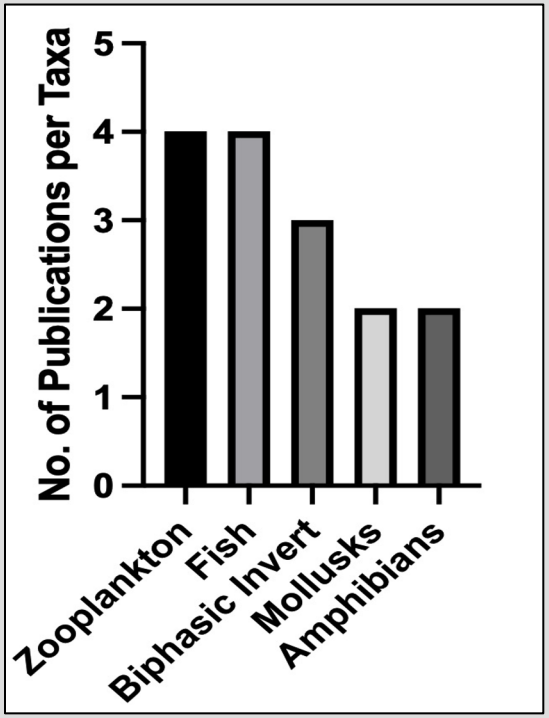
Water/Stain repellent

Non-stick cookware

NARROWING FOCUS TO PFOS

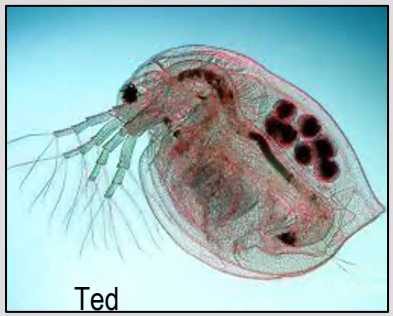
Effects of PFOS to Aquatic Wildlife

Species Sensitivity Distributions (SSDs) – provides a range of sensitivities to PFOS of aquatic animals



Chronic Exposure Studies (as of 2018)


Ho, Hsuan-Ching


Ted Kinsman


Freenatureimages.eu


Pestremovalwarriors.com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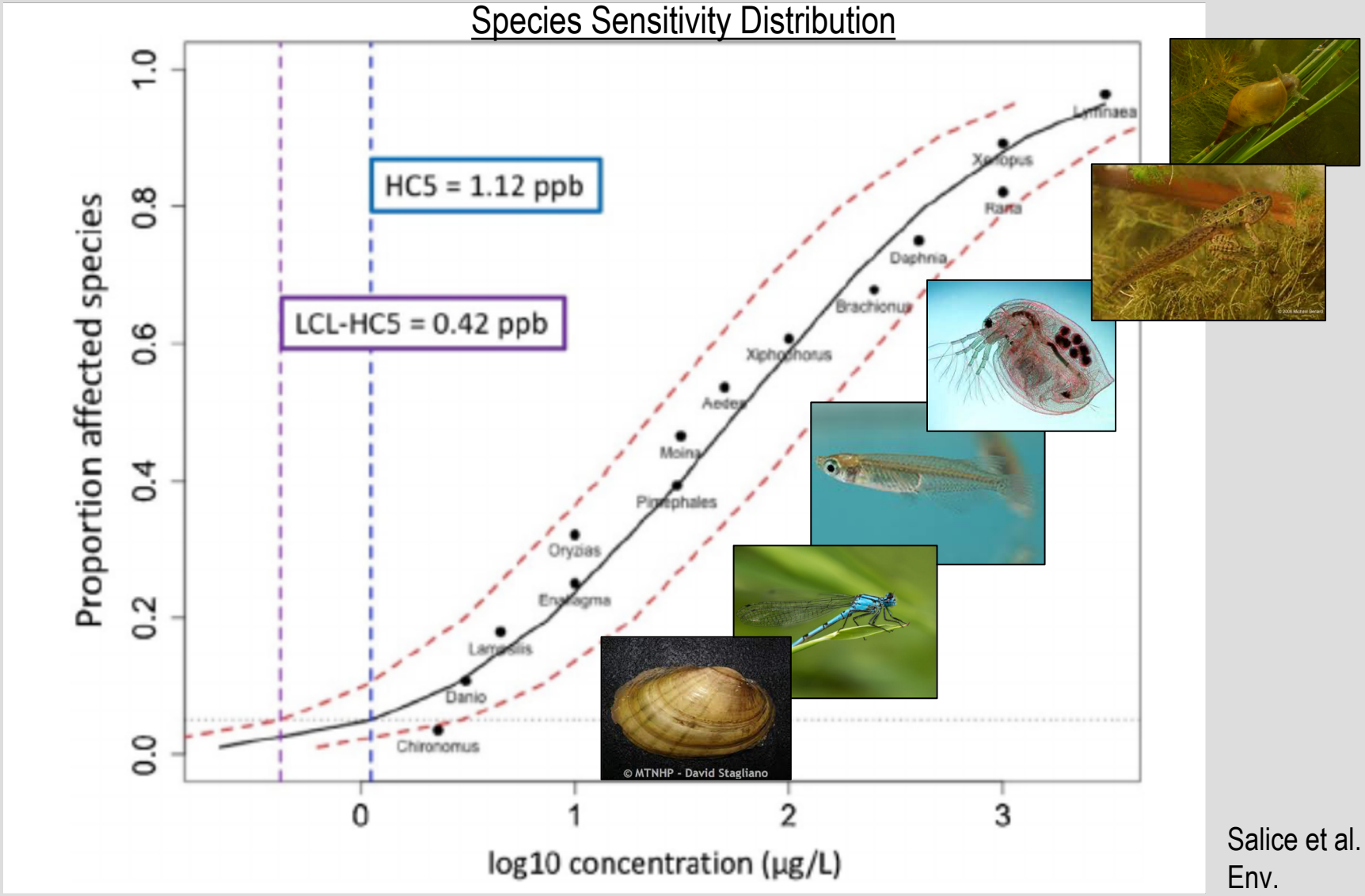
Effects of PFOS to Aquatic Wildlife



Salice et al. 2018 Env. Toxicol.Chem.

Laboratory Toxicity Studies

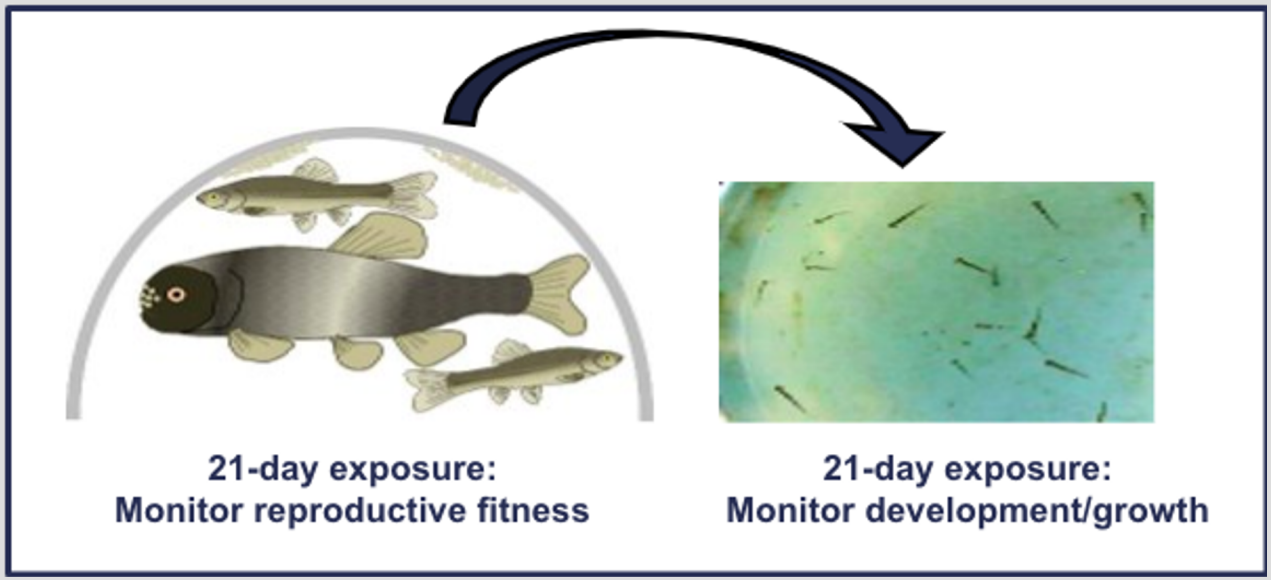
- EA has conducted a number of PFAS studies using the fathead minnow
  - Exposures to
    - PFOS
    - PFHxS
    - PFOS & PFHxS (mixture)
    - PFNA

SERDP
DOD ▪ EPA ▪ DOE

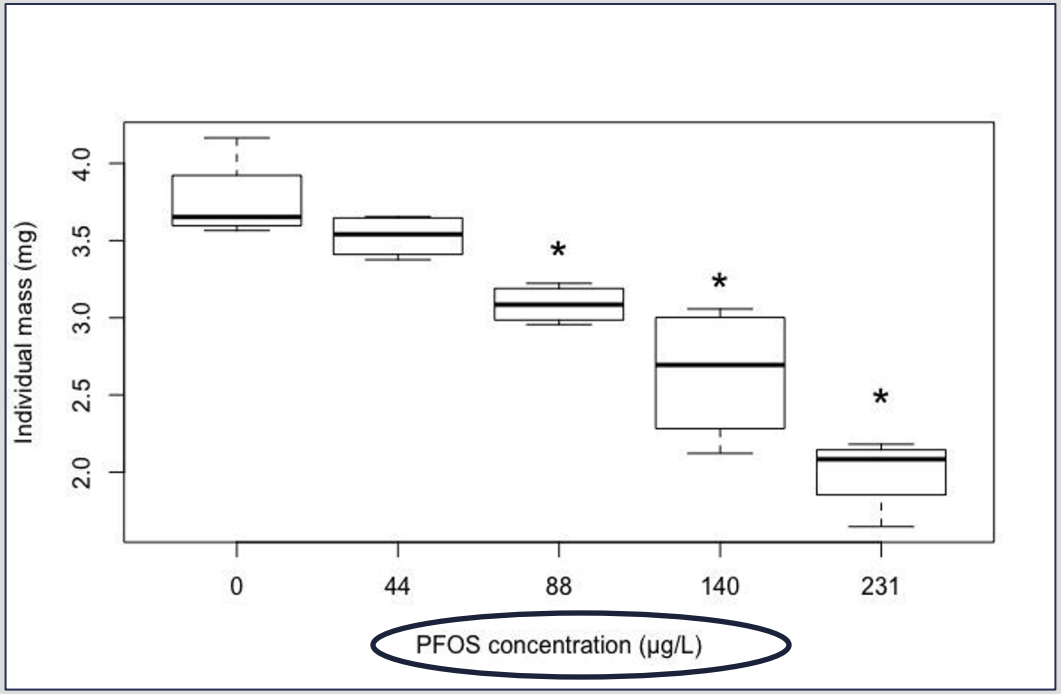
ER-2627 (PI: C. Salice)

Laboratory Toxicity Studies

- Ecotoxicity of PFOS and PFAS mixtures
- Experimental Designs
  - Effects of PFAS over critical life-stages of **reproduction** and **development** (42-d adult exposure; 21-d juvenile exposure)

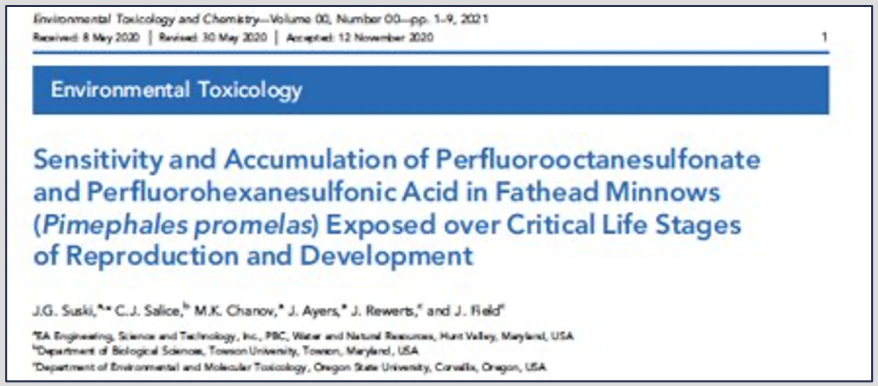


Laboratory Toxicity Studies



Juveniles are most sensitive to PFOS following exposures to 88 µg/L there is reduced growth

- Maternal/Parental Transfer not direct exposure alone



Environmental Toxicology and Chemistry—Volume 00, Number 00—pp. 1–9, 2021
Received: 8 May 2020 | Revised: 30 May 2020 | Accepted: 12 November 2020 1

Environmental Toxicology

Sensitivity and Accumulation of Perfluorooctanesulfonate and Perfluorohexanesulfonic Acid in Fathead Minnows (*Pimephales promelas*) Exposed over Critical Life Stages of Reproduction and Development

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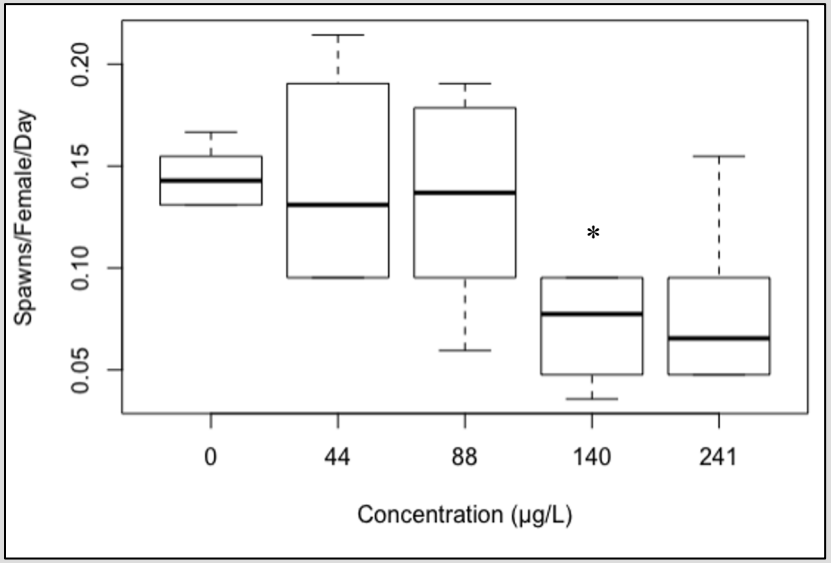
[c]Department of Environmental and Molecular Toxicology, Oregon State University, Corvallis, Oregon, USA

Laboratory Toxicity Studies

Impacts of PFOS to Reproduction



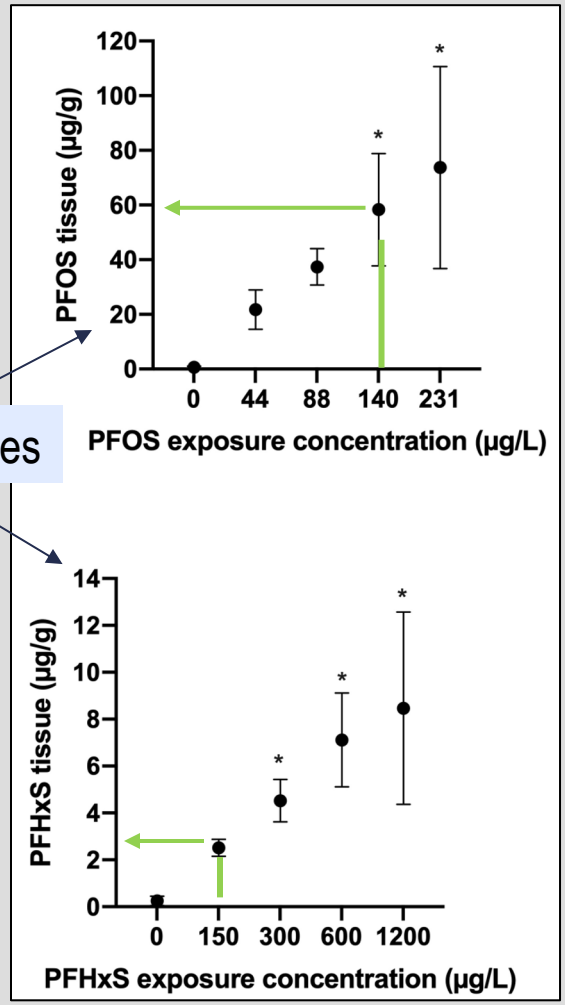
Mean number of Spawning events per female per day over the 42-day study duration. Boxplots are displaying the median (bold cross bar), the interquartile range (IQR) with the 25th and 75th percentile (bottom and top of the box, respectively) and the 1.5*IQR (whiskers).

Ovary Tissue Accumulation

PFOS

different scales

PFHxS

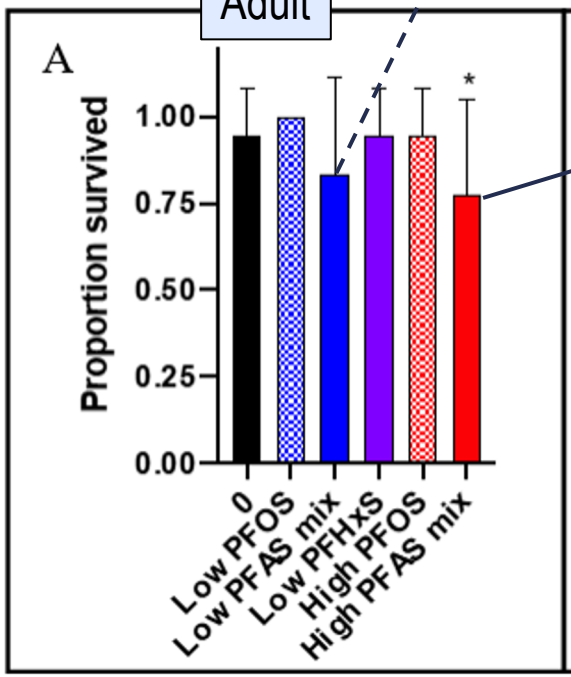


Collaborators: Jennifer Field, OSU

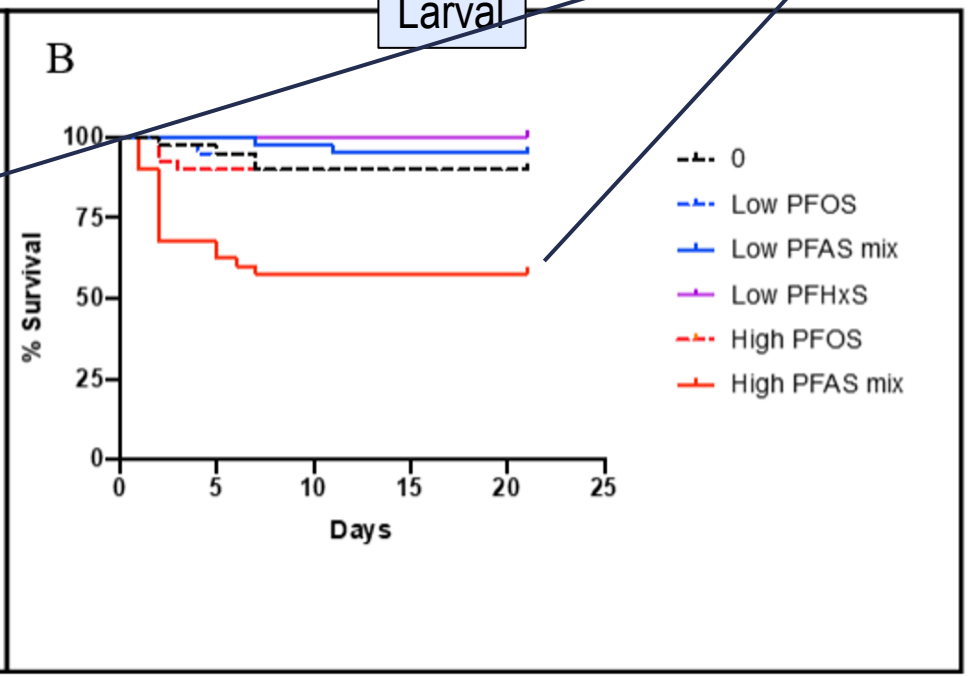
Laboratory Toxicity Studies

1	2	3	4	5
Control	PFOS 150 µg/L	PFOS:150 µg/L PFHxS: 100 µg/L	PFHxS: 200 µg/L	PFOS:300 µg/L	PFOS:300 µg/L PFHxS: 200 µg/L

Adult



Larval



(A) Survival of adult fathead minnows exposed to PFOS, PFHxS and two mixtures. Astericks indicate significant difference ($p<0.05$). (B) Survival analysis of juvenile fathead minnows exposed to PFOS, PFHxS and two mixtures.

Laboratory Toxicity Studies

1 Control

2 PFOS 150 µg/L

3 PFOS:150 µg/L PFHxS: 100 µg/L

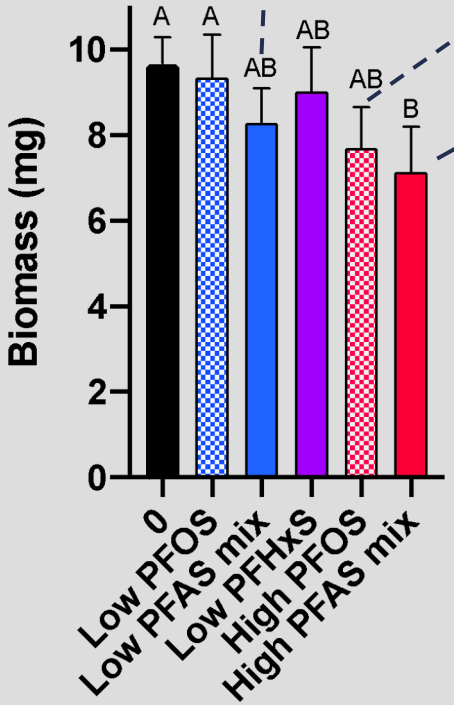
4 PFHxS: 200 µg/L

5 PFOS:300 µg/L

6 PFOS:300 µg/L PFHxS: 200 µg/L

LARVAL STAGE

Growth

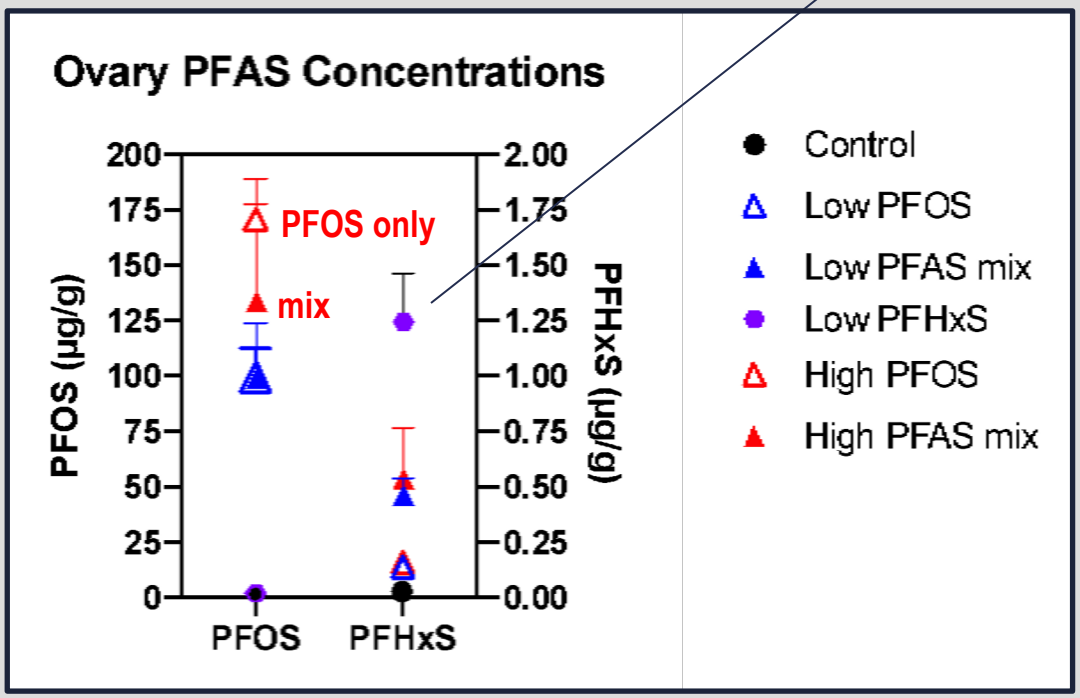


High PFOS alone reduces larval growth in mixture significantly lower than controls

Biomass of juvenile fathead minnows exposed to PFOS, PFHxS and two mixtures. Letters indicate significant differences from exposure treatments ($p<0.05$).

Laboratory Toxicity Studies

	1	2	3	4	5
Control	PFOS 150 µg/L	PFOS:150 µg/L PFHxS: 100 µg/L	PFHxS: 200 µg/L	PFOS:300 µg/L	PFOS:300 µg/L PFHxS: 200 µg/L



As seen before, PFOS accumulation is greater compared to PFHxS

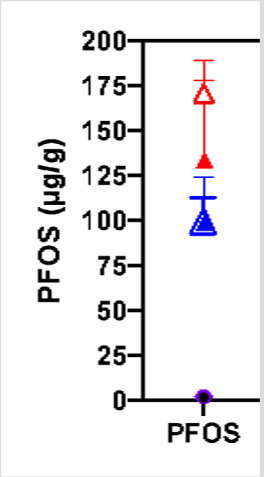
At higher concentrations, PFHxS may reduce PFOS accumulation in gonads through competitive binding?

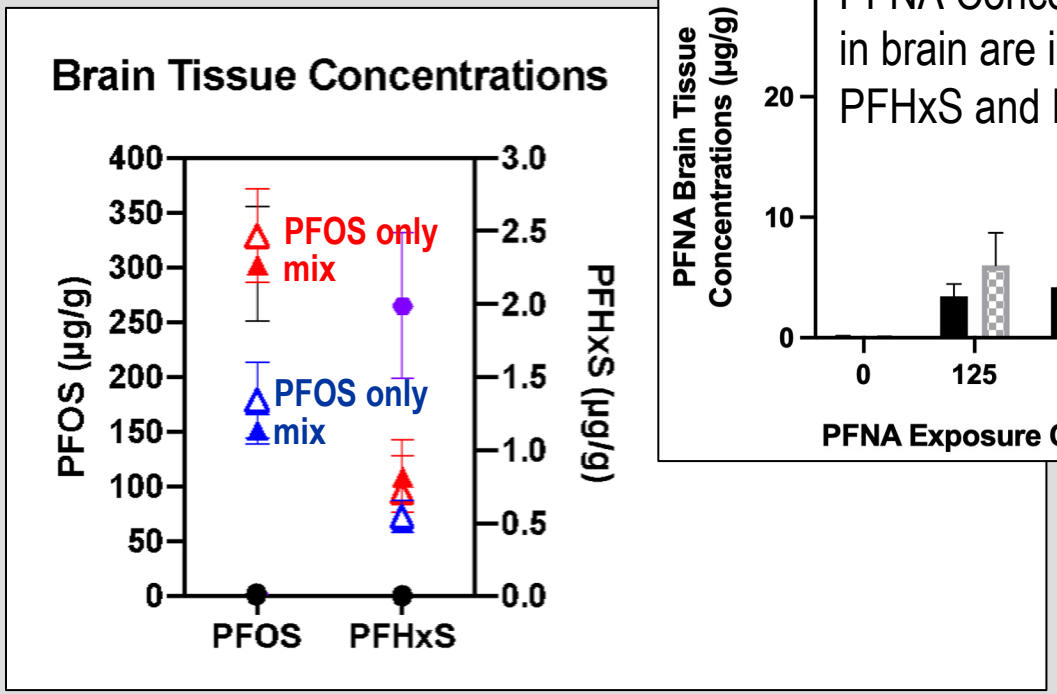
Tissue concentrations of PFAS in adult fathead minnows exposed to PFOS, PFHxS and two mixture concentrations. Letters indicate significant differences from exposure treatments ($p<0.05$).

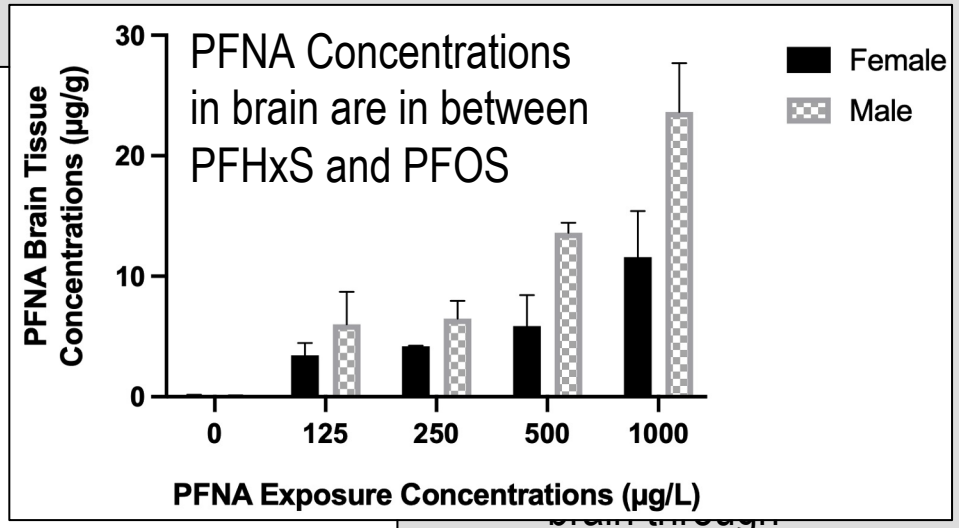
Laboratory Toxicity Studies

1	2	3	4	5
Control	PFOS 150 µg/L	PFOS:150 µg/L PFHxS: 100 µg/L	PFHxS: 200 µg/L	PFOS:300 µg/L	PFOS:300 µg/L PFHxS: 200 µg/L

Ovaries





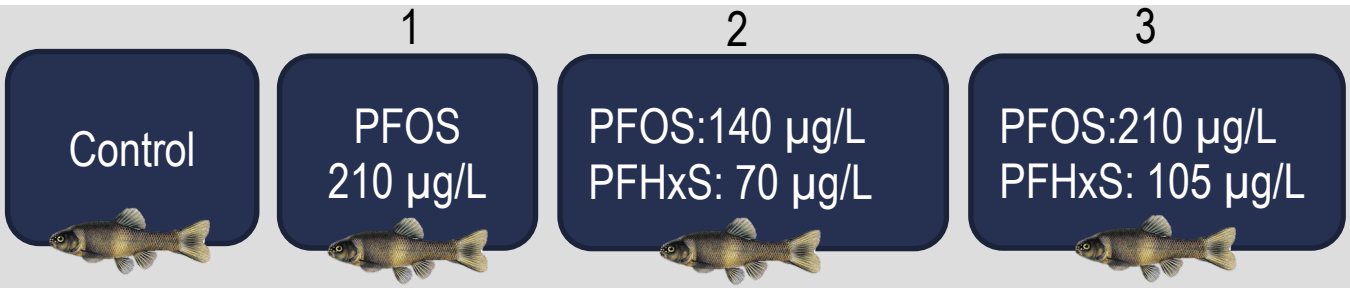


competitive binding?

****Brain tissue concentrations are similar to liver**

Tissue concentrations of PFAS in adult fathead minnows exposed to PFOS, PFHxS and two mixture concentrations. Letters indicate significant differences from exposure treatments ($p<0.05$).

Laboratory Toxicity Studies



Larval to Juvenile life stage
(60-day exposure)

Whole Fish PFAS Analysis

Depuration (Dechlorinated Tap)

Whole Fish PFAS Analysis
10-days Dechlor

Whole Fish PFAS Analysis
20-days Dechlor

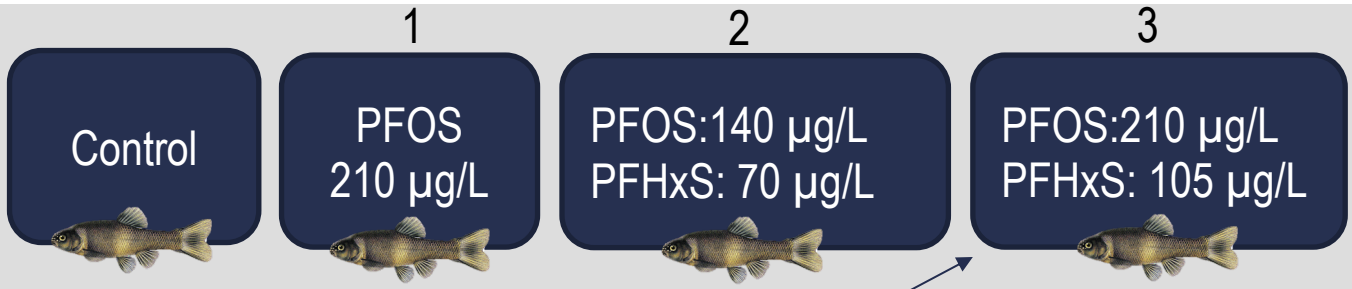
Whole Fish PFAS Analysis
30-days Dechlor

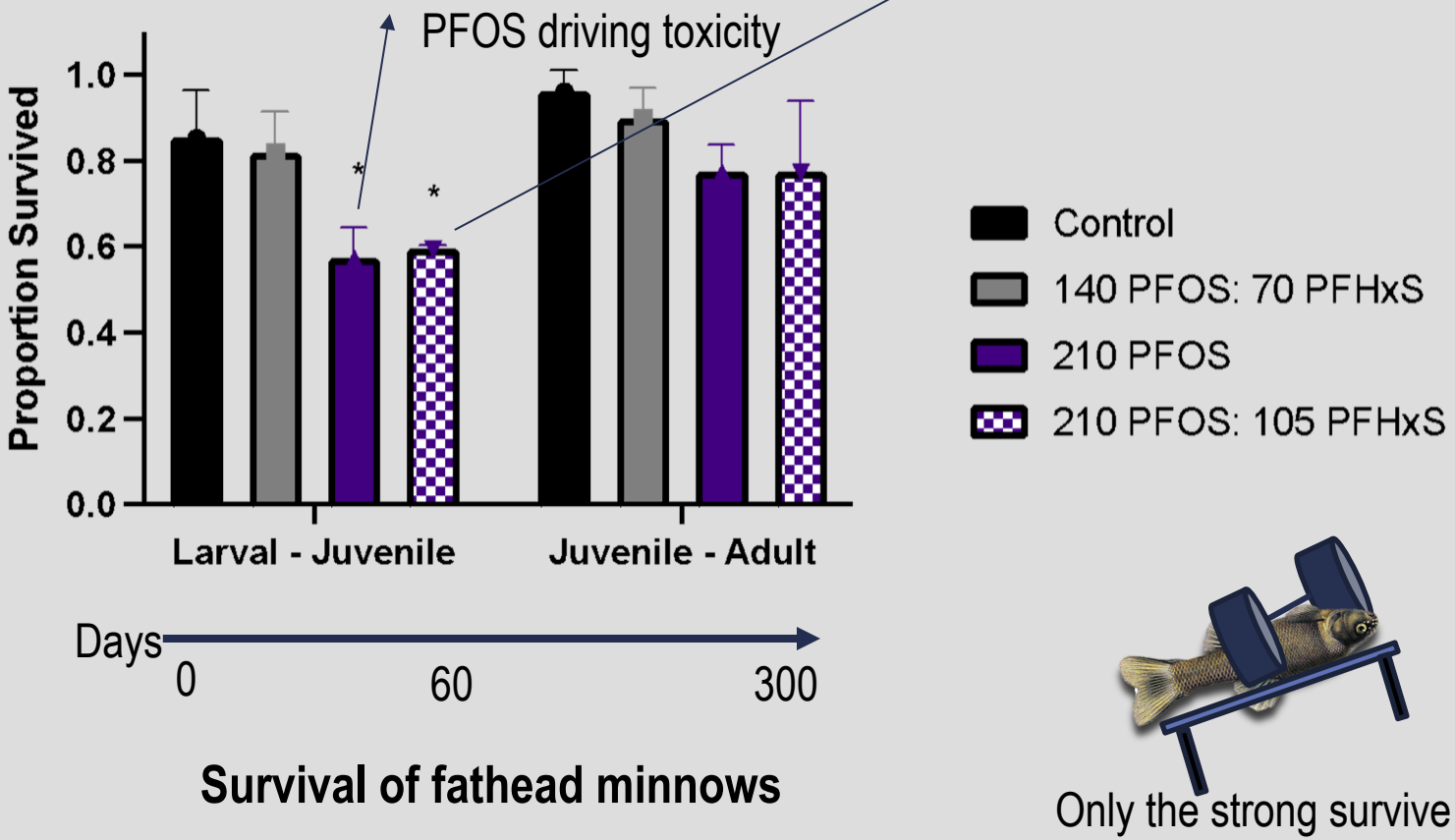
Adult life-stage exposure
(300-day exposure)

Whole Fish PFAS Analysis

* No analytical data yet for tissue yet

Long-term study

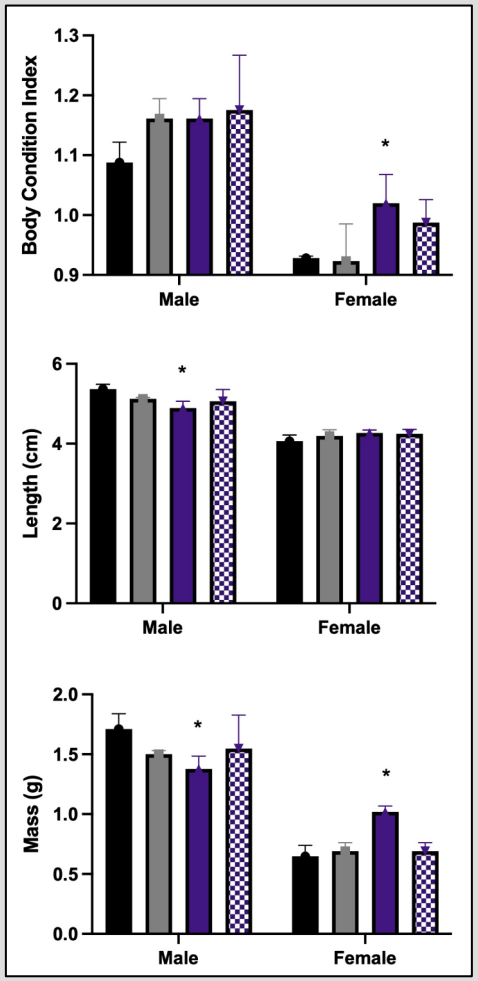


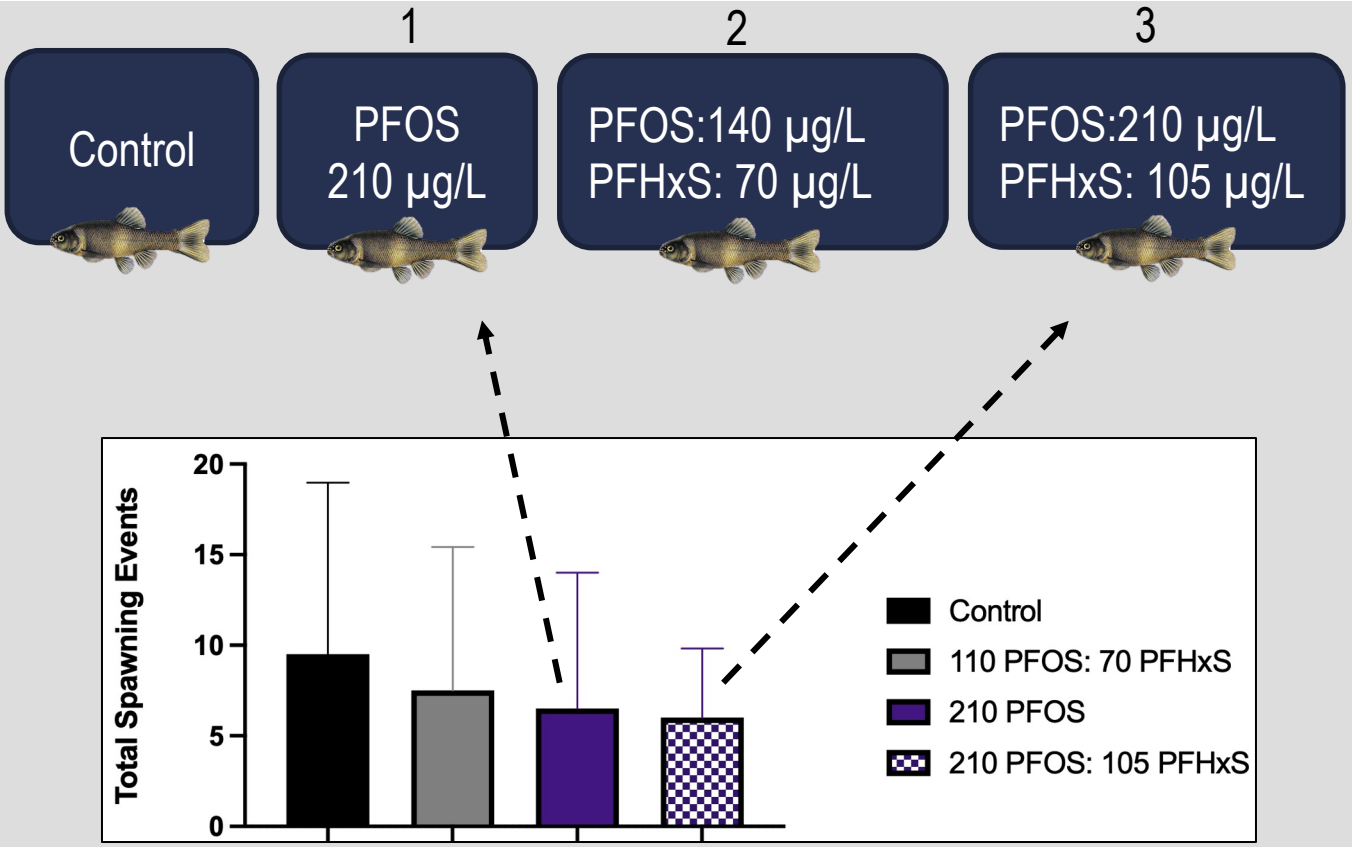


Survival of fathead minnows

Only the strong survive

Long-term study





Reproductive costs of maintaining body condition during PFOS exposures

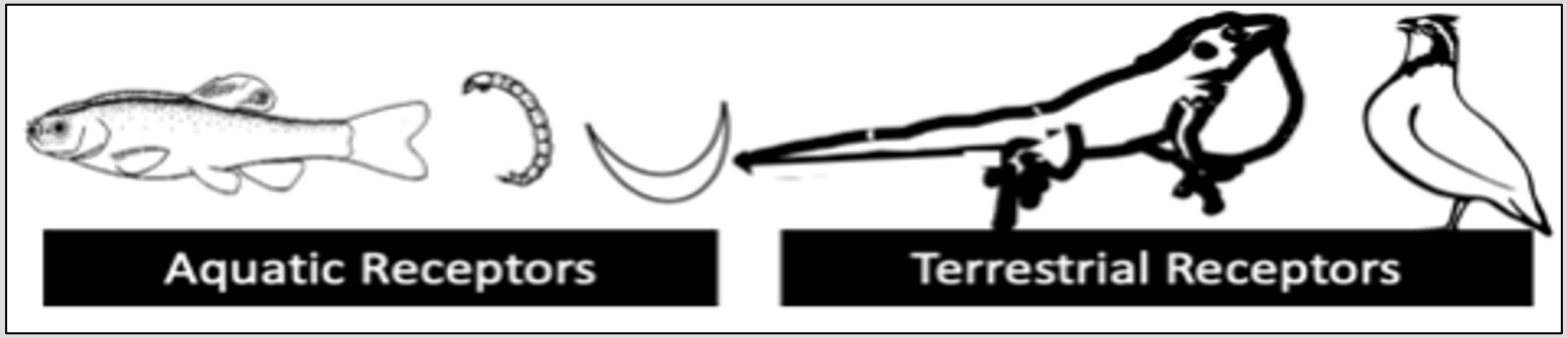
Overall Thresholds –Fathead Minnow

PFAS	Toxicity Value (µg/L)	Biological Endpoint
PFOS	231 LOEC; 140 NOEC	Larval survival
	88 LOEC; 44 NOEC	Larval biomass
PFHxS	1200 NOEC	All endpoints (no observed toxicity)
PFNA	250 LOEC; 125 NOEC	Larval mass
PFOS + PFHxS (42 d)	300 PFOS + 200 PFHxS; LOEC 300 PFOS & 150:100; NOEC	Survival, larval mass
PFOS + PFHxS (300 d)	210 PFOS = 210 PFOS + 105 PFHxS	Larval – juvenile survival

Fire Fighting Foam Replacements

Fire Fighting Foam Replacements

- **Multi-taxa investigation of the toxicity associated with PFAS-Free Foams**



ER20-1531 (PI: J. Suski)

SERDP
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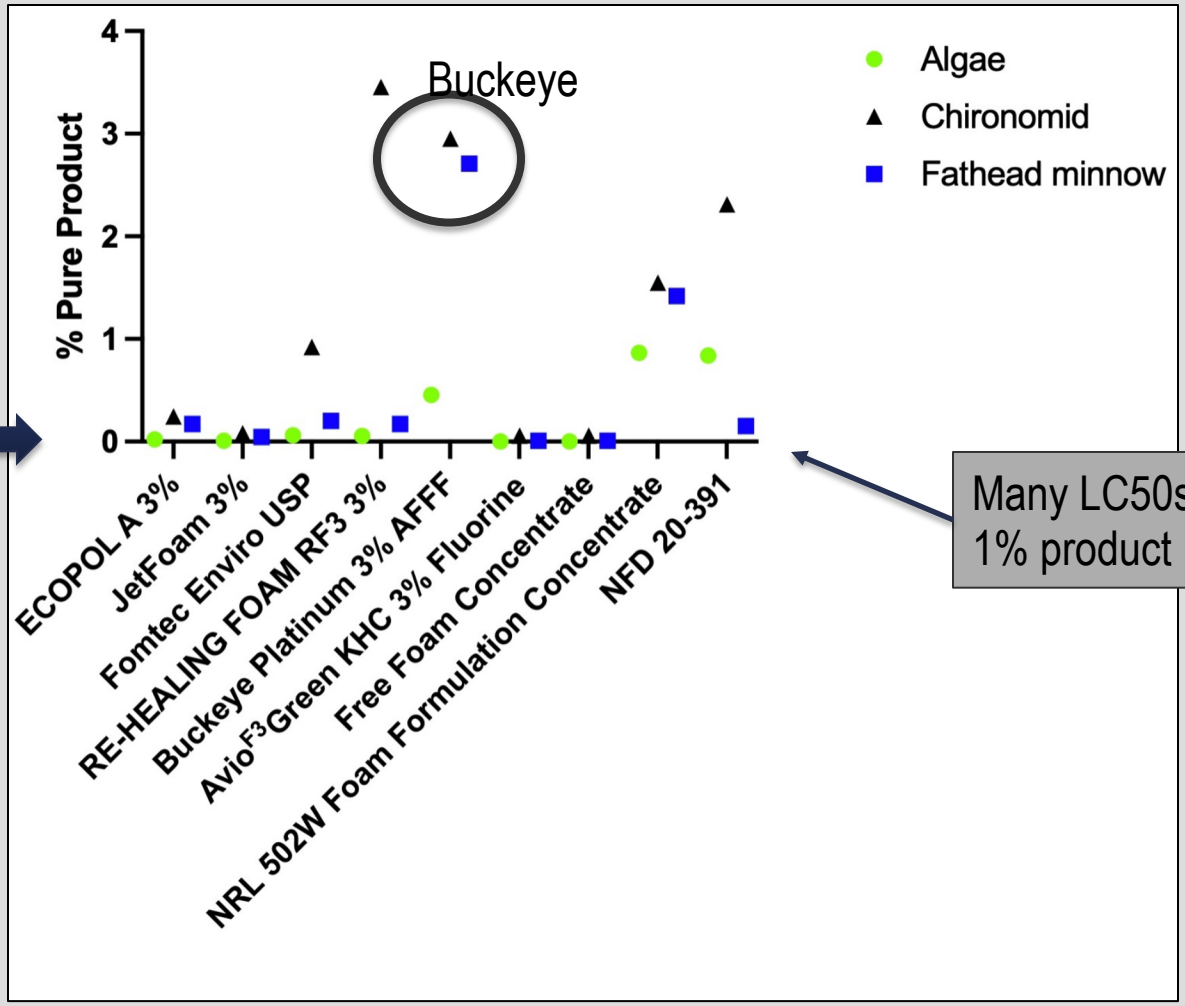
Aquatic Results to Date –LC_{50} Data



Aquatic Results to Date –LC_{50} Data

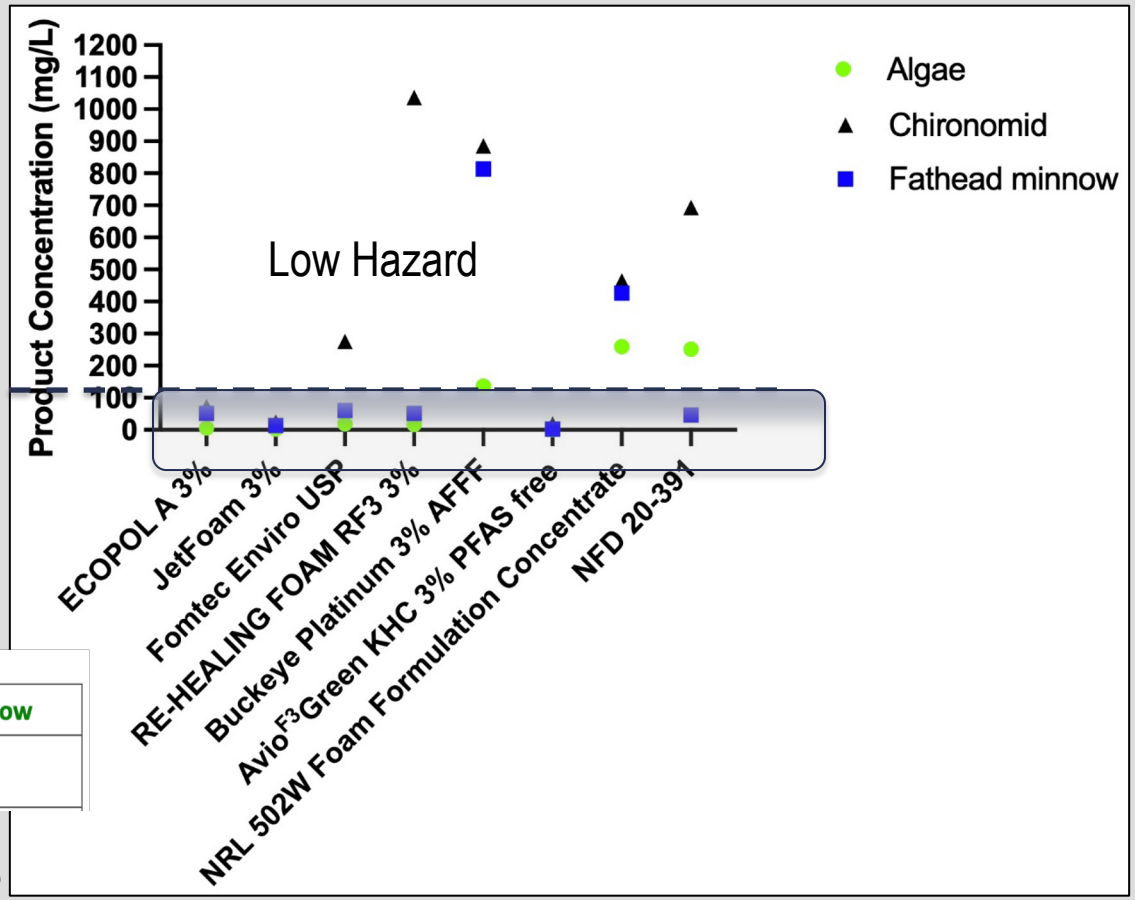


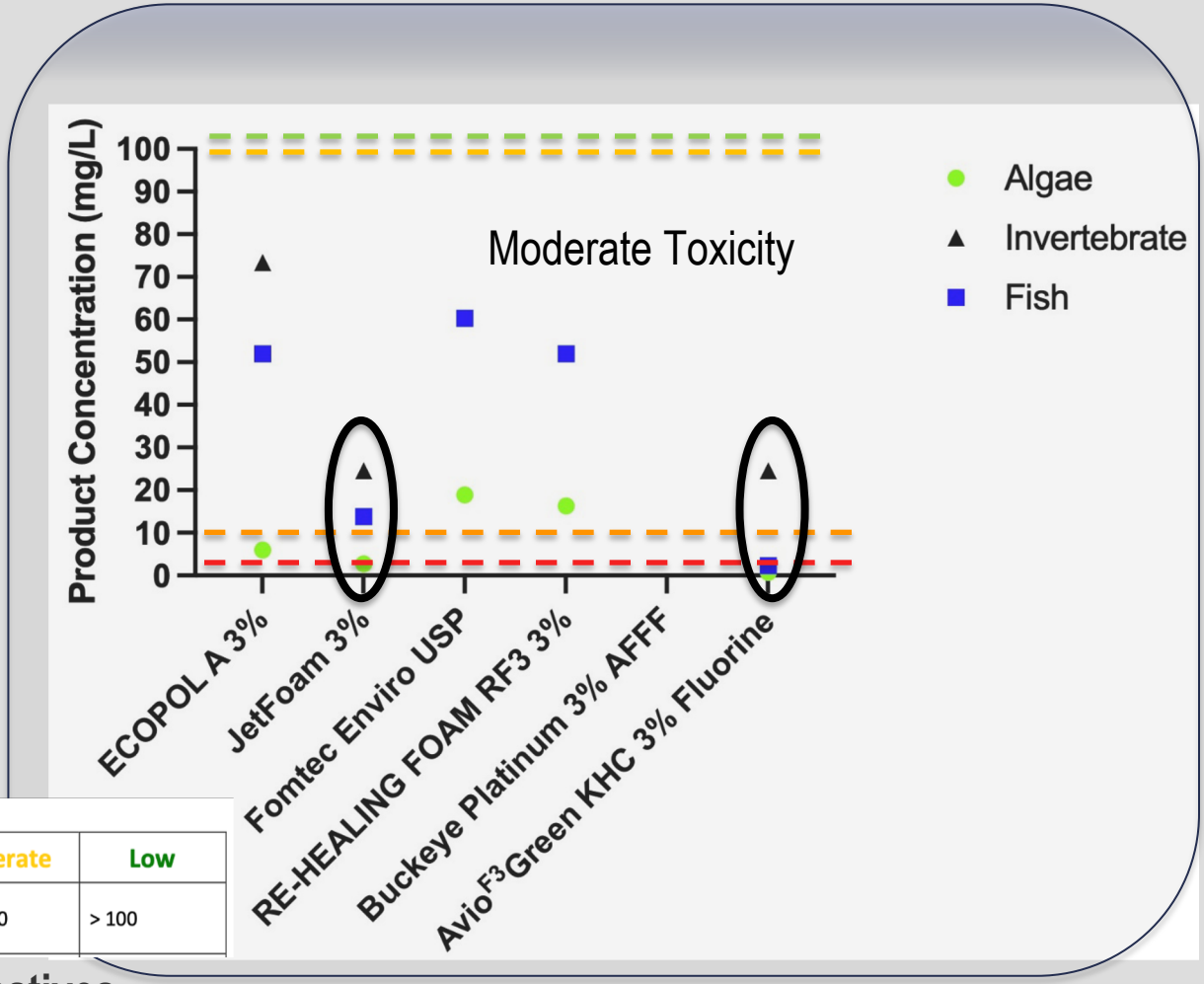
Table 11. Aquatic Toxicity Criteria for Hazard Designations

Aquatic Toxicity	Very High	High	Moderate	Low
Acute Aquatic Toxicity (LC50 or EC50) (mg/L)	< 1.0	1 - 10	> 10 - 100	> 100

Hazard based on U.S. EPA's alternatives assessment criteria

Aquatic Results to Date –LC_{50} Data

Aquatic Toxicity	Acute LC_{50} (mg/L)
Low	> 100
Moderate	> 10 - 100
High	1 - 10
Very High	< 1.0



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Hazard based on U.S. EPA's alternatives assessment criteria

Summary Statements

- PFOS is more Toxic compared to other PFAS tested
- PFOS Accumulates to greater concentrations in measured tissues compared to other PFAS
  - Larval life-stage is more sensitive
- PFAS Free Foams may be acutely toxic to freshwater species but high degree of variability among products (some would be ranked as low acute toxicity)

Thank You!

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