PFAS - Aquatic Toxicology Data Overview

Presentation to the Santa Ana River Emerging Contaminants Task Force

January 22, 2024

Chris Stransky
Environmental Scientist, Aquatic Sciences & Toxicology Group
WSP USA, San Diego, CA
chris.stransky@wsp.com
858-775-5547

Outline

1. Overview of Ecotoxicity of PFAS
2. USEPA 2022 Draft Ambient Water Quality Criteria for PFOS and PFOA
3. Tissue Monitoring Programs and Objectives for Ecological and Human Health Risk
4. SoCal Regional Bight Monitoring

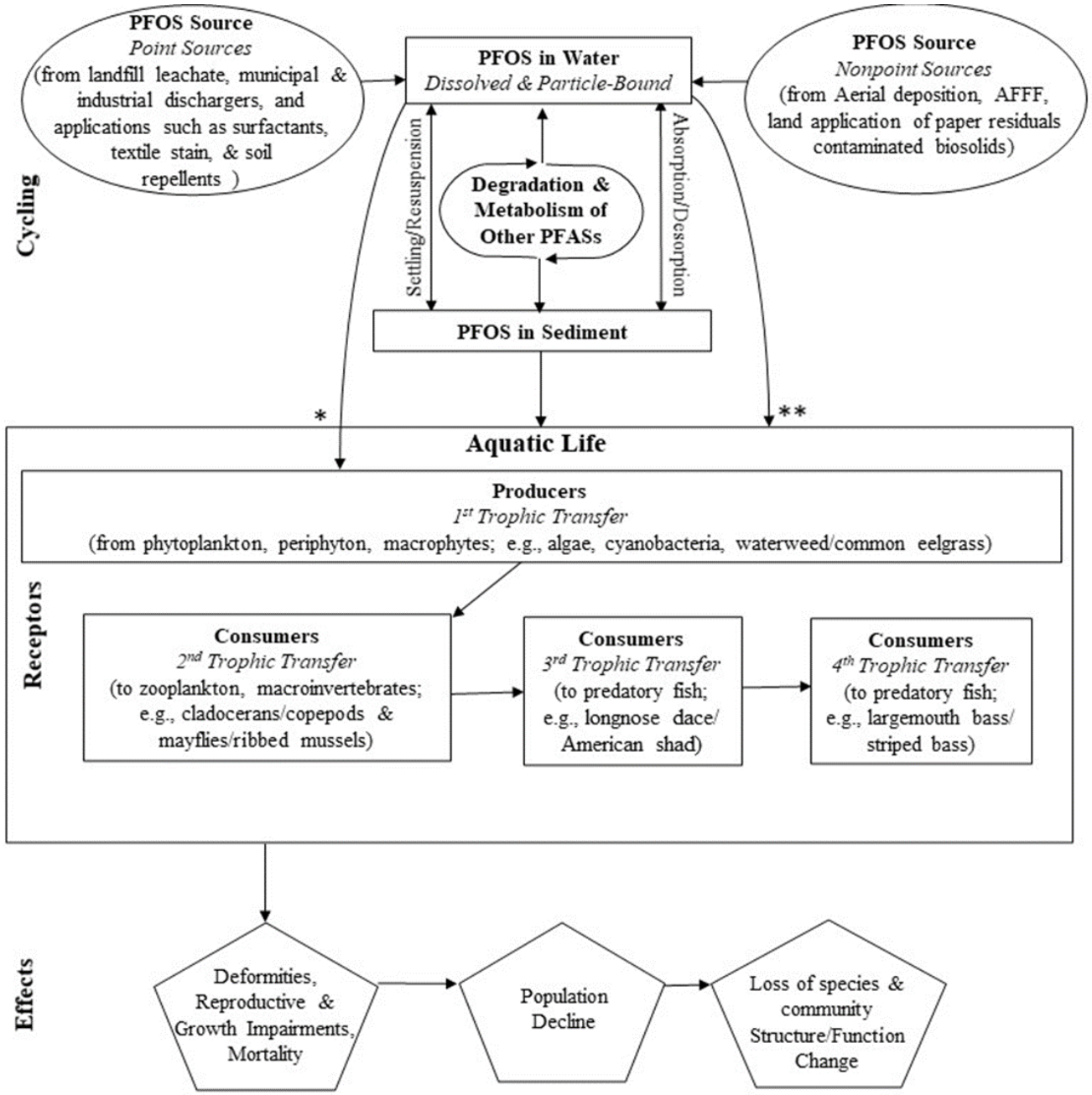
Introduction – PFAS Effects

- Over 3,000 PFAS compounds on the global market.
- PFOS and PFOA (breakdown chemicals from precursors) among the most studied due to their prevalence and toxicity.
- Underlying mechanisms of PFOA toxicity to aquatic animals, and fish in particular, appear to be related to oxidative stress, apoptosis, thyroid disruption, and development-related gene expression
- Causing reproductive failure, effects on growth, developmental toxicity; androgen, estrogen and thyroid hormone disruption; immune system disruption; and neuronal and developmental damage.

Conceptual Model

Conceptual Model Diagram of Sources, Compartmental Partitioning, and Trophic Transfer Pathways of PFOA and PFOS in the Aquatic Environment and its Bioaccumulation and Effects in Aquatic Life and Aquatic-dependent Wildlife

From EPA 2022
EPA-842-D-22-002



Summary of Assessment Endpoints and Measures of Effect Used in the Criteria Derivation for Aquatic Life

Assessment Endpoints for the Aquatic Community	Measures of Effect
Aquatic Life: Survival, growth, and reproduction of freshwater and estuarine/marine aquatic life (i.e., fish, amphibians, aquatic invertebrates)	For effects from **Acute exposure (short term)**: 1. LC50, EC50, or IC50 concentrations in water 2. NOEC and LOEC concentrations in water For effects from **Chronic exposure (longer term, sublethal)**: 1. EC10 concentrations in water 2. NOEC and LOEC concentrations in water; *Only used when an EC10 could not be calculated for a genus.*

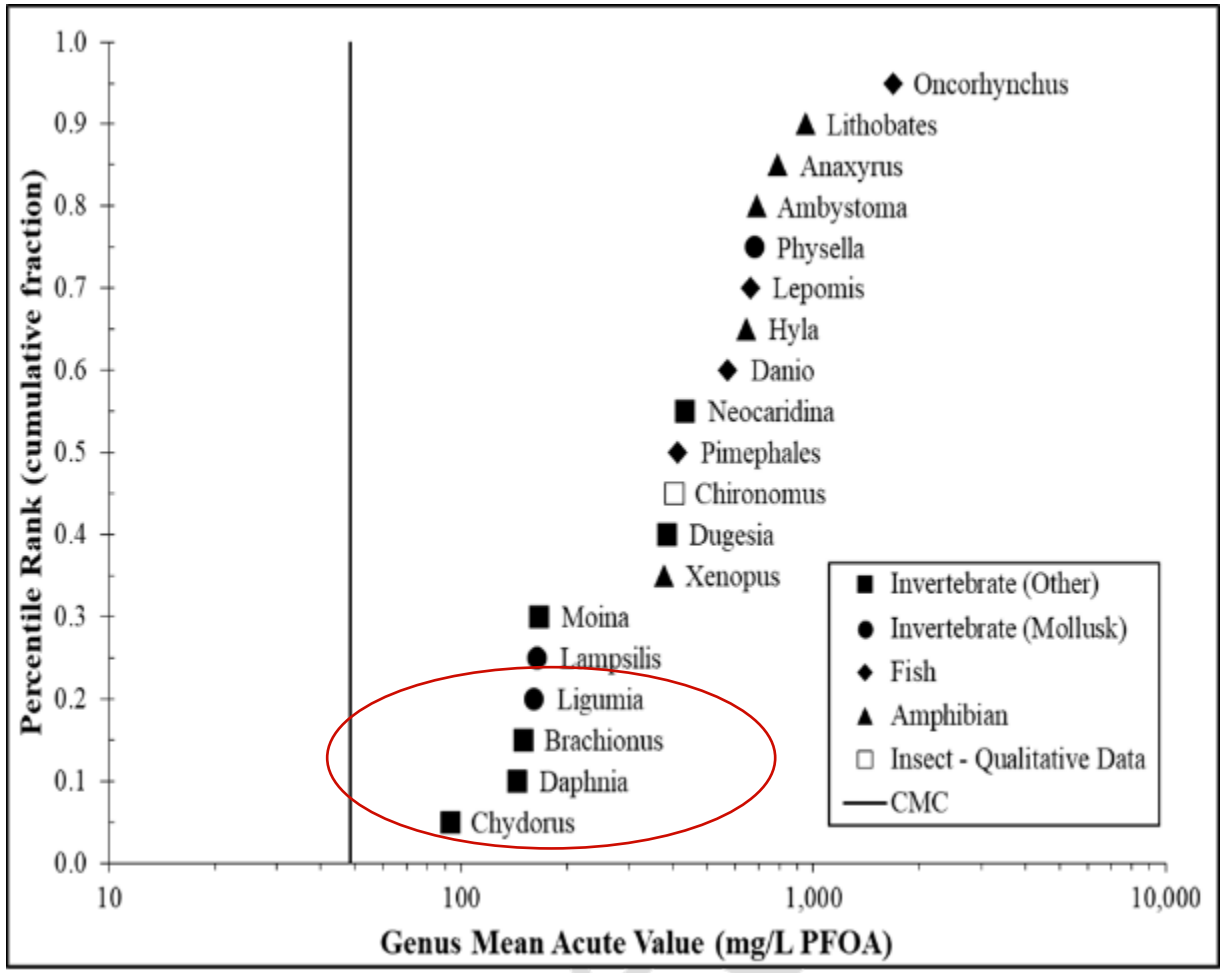
NOEC = No observed effect concentration, LOEC = Lowest observed effect concentration
LC, EC, or IC50 = Median lethal, effect, or inhibition concentration.
EC_{10} = 10% Effect Concentration

Most Sensitive Freshwater Species to PFOA - Acute

The Four Most Sensitive Genera used to Calc. the Acute Freshwater Criterion (PFOA)

Rank	Genus	Species	GMAV (mg/L)
1	*Chydorus*	Cladoceran (*Chydorus sphaericus*)	93.2
2	*Daphnia*	Cladoceran (*Daphnia carinata*)	144
		Cladoceran (*Daphnia magna*)	
		Cladoceran (*Daphnia pulicaria*)	
3	*Brachionus*	Rotifer (*Brachionus calyciflorus*)	150
4	*Ligumia*	Black sandshell mussel (*Ligumia recta*)	161



Photos 1-3. Univ of New Hampshire Image-Based Key To The Zooplankton of North America. http://cfb.unh.edu/cfbkey/html/index.html
Photo 4 Montana Field Guide - https://fieldguide.mt.gov/speciesDetail.aspx?elcode=IMBIV26020

Most Sensitive Freshwater Species to PFOA - Chronic

The Four Most Sensitive Genera Used to Calc. the Chronic Freshwater Criterion (PFOA)

Rank	Genus	Species	GMCV (mg/L)
1	*Hyalella*	Amphipod (*Hyalella azteca*)	0.147
2	*Lithobates*	American bullfrog (*Lithobates catesbeiana*)	0.288
3	*Daphnia*	Cladoceran (*Daphnia carinata*)	0.370
		Cladoceran (*Daphnia magna*)	
4	*Brachionus*	Rotifer (*Brachionus calyciflorus*)	0.765



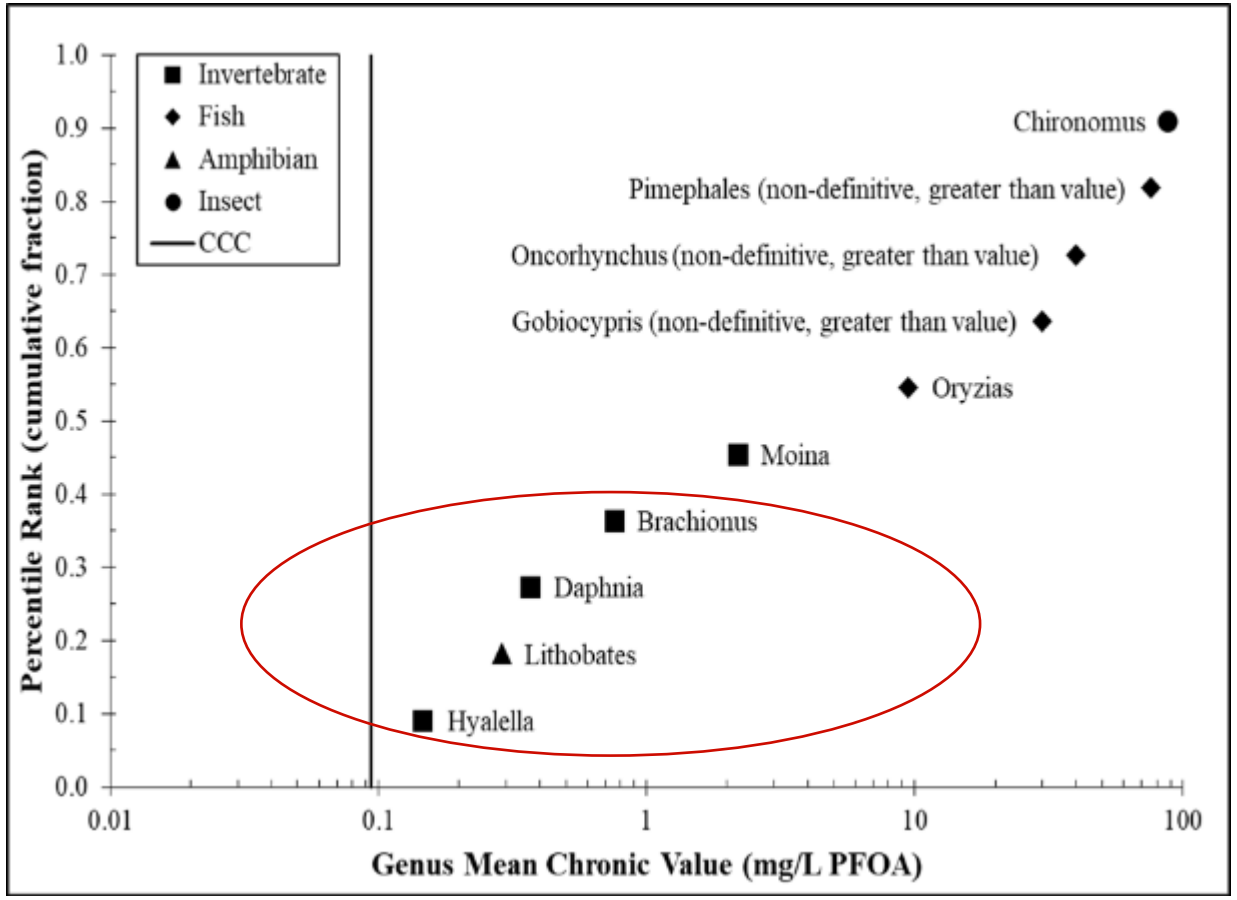



Photo 1. Field Guide to Freshwater Invertebrates of North America, 2011. J.H. Thorp and D.C. Rogers. https://www.sciencedirect.com/book/9780123814265/field-guide-to-freshwater-invertebrates-of-north-america
Photo 2.. i-Naturalist. Photo 13302641, (c) eggimann.com. https://www.inaturalist.org/photos/13302641
Photos 3-4. Univ of New Hampshire Image-Based Key To The Zooplankton of North America. http://cfb.unh.edu/cfbkey/html/index.html

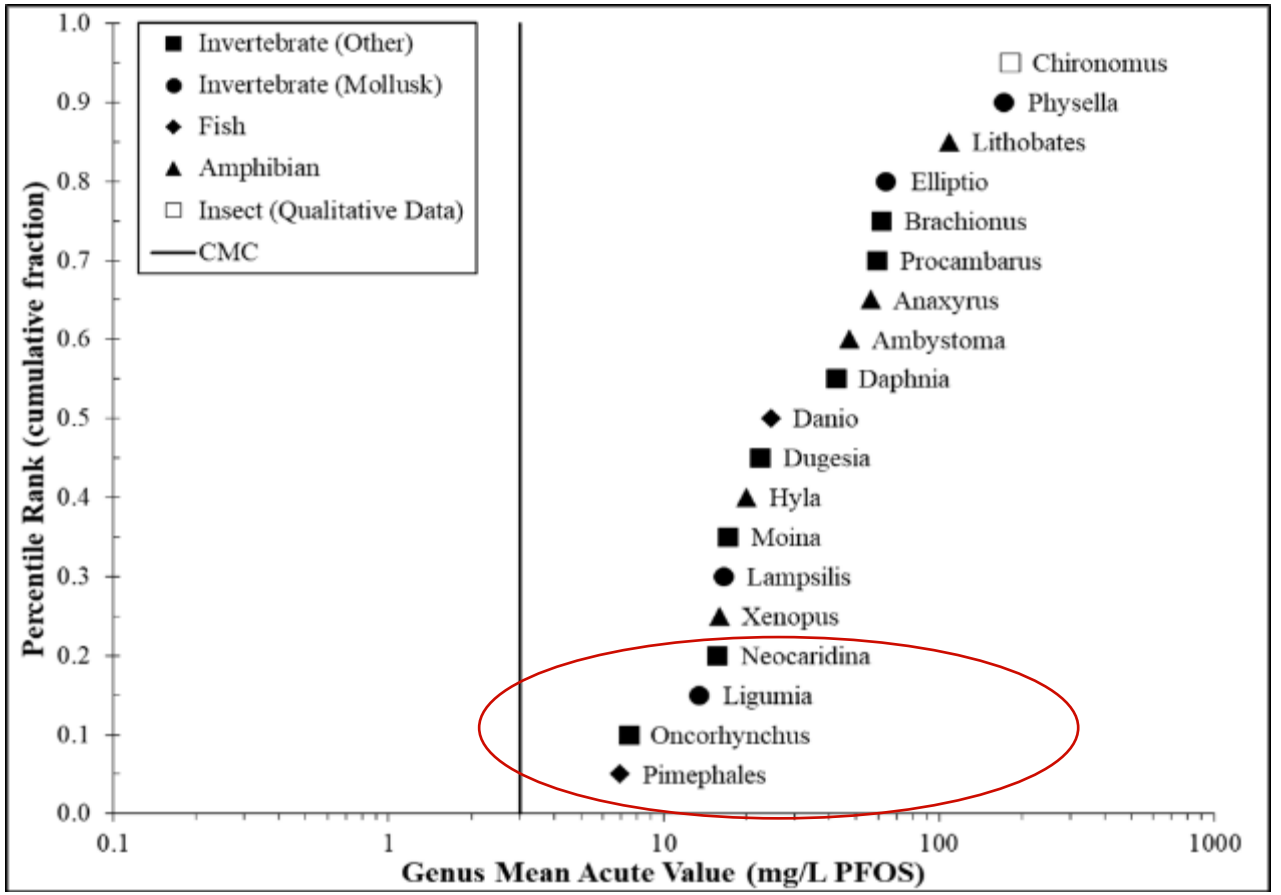
Most Sensitive Freshwater Species to PFOS - Acute

The Five Most Sensitive Genera used to Calc the Acute Freshwater Criterion (PFOS)

Rank	Genus	Species	GMAV (mg/L)[1]
1	*Pimephales*	Fathead minnow, *P. promelas*	6.95
2	*Oncorhynchus*	Rainbow trout, *O. mykiss*	7.52
3	*Ligumia*	Black sandshell mussel (*Ligumia recta*)	13.5
4	*Neocaridina*	Japanese swamp shrimp, *N. denticulata*	15.6
5	*Xenopus*	African clawed frog, *X. laevis*	16.0







Photos 1 and 2. Jacobs, R. P., O'Donnell, E. B., and Connecticut DEEP. (2009). A Pictorial Guide to Freshwater Fishes of Connecticut. Hartford, CT. *https://portal.ct.gov/DEEP/Fishing/Freshwater/Freshwater-Fishes-of-Connecticut/Fathead-Minnow*

Photo 3. Montana Field Guide - https://fieldguide.mt.gov/speciesDetail.aspx?elcode=IMBIV26020

Photo 4. i-Naturalist. http://commons.wikimedia.org/wiki/File:Neocaridina_denticulata_denticulata(Hamamatsu,Shizuoka,Japan,2007).jpg

Photo 5. WA Dept of Fish and Wildlife. Photo by Brian Gratwick. https://wdfw.wa.gov/species-habitats/invasive/xenopus-laevis

Most Sensitive Freshwater Species to PFOS - Chronic

The Four Most Sensitive Genera used to Calc the Chronic Freshwater Criterion (PFOS)

Rank	Genus	Species	GMCV (mg/L PFOS)[1]	GMCV (µg/L PFOS)[1]
1	*Chironomus*	Midge, *Chironomus dilutus*	0.00968	9.68
2	*Lampsilis*	Fatmucket, *Lampsilis siliquoidea*	0.01768	17.68
3	*Enallagma*	Blue damselfly, *Enallagma cyathigerum*	0.03162	31.62
4	*Danio*	Zebrafish, *Danio rerio*	0.03217	32.17

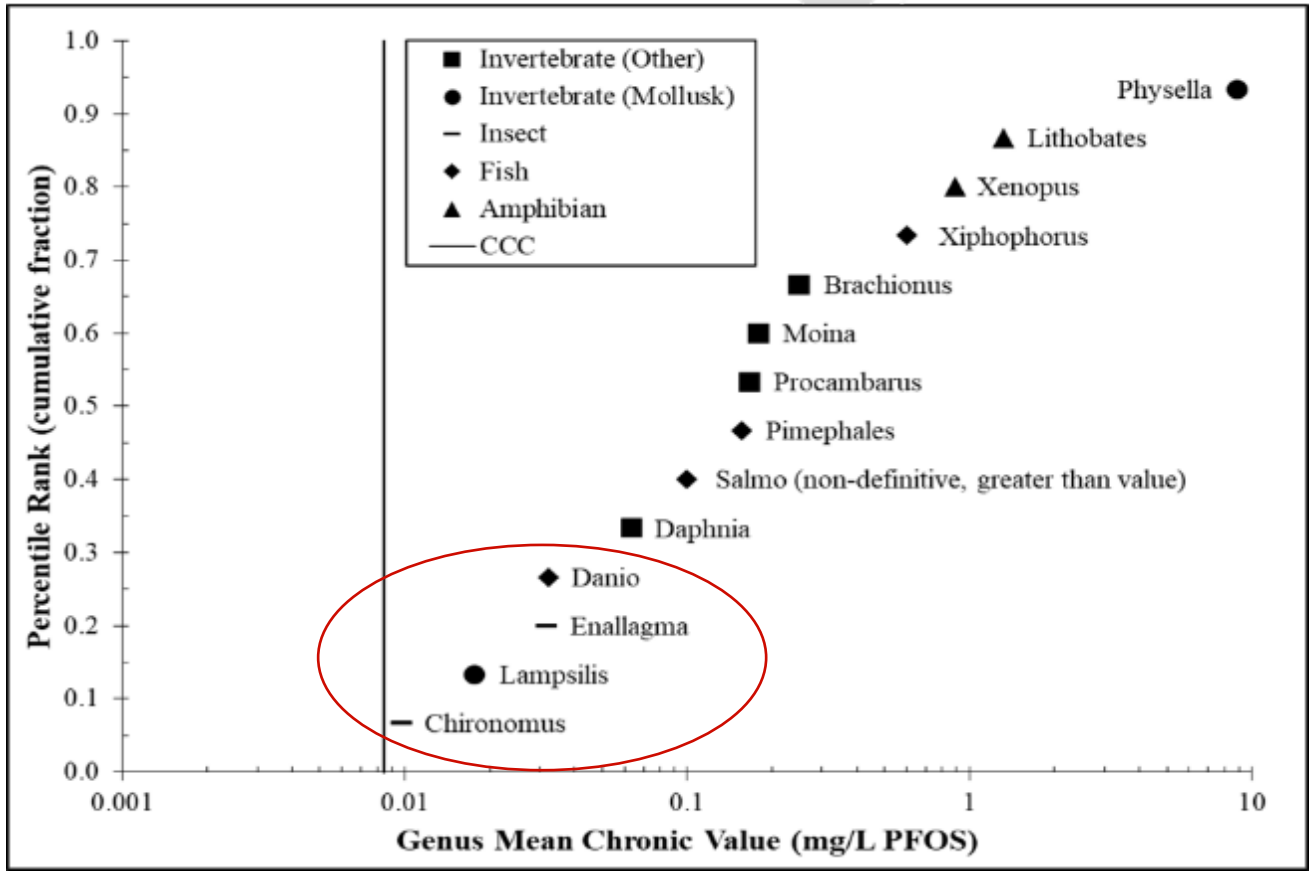


Photo 1. N. Carolina State Univ. Extension. https://content.ces.ncsu.edu/biology-and-control-of-non-biting-aquatic-midges Photo by B. Shoenmakers.
Photo 2. i-Naturalist. Photo by Jesse Weinzinger. https://inaturalist.ca/taxa/125545-Lampsilis-siliquoidea
Photo 3. i-Naturalist. Photo by Fabrice Prugnaud. https://inaturalist.ca/photos/79614657
Photo 4. i-Naturalist. Photo by Tohru Murakami. https://inaturalist.ca/taxa/49977-Danio-rerio

Most Sensitive Marine Species to PFOA - Acute

The Four Most Sensitive Estuarine/ Marine Genera – Acute Endpoints (PFOA)

Rank	Genus	Species	GMAV (mg/L)
1	*Siriella*	Mysid (*Siriella armata*)	15.5
2	*Mytilus*	Mediterranean mussel (*Mytilus galloprovincialis*)	17.6
3	*Strongylocentrotus*	Purple sea urchin (*Strongylocentrotus purpuratus*)	20.6
4	*Americamysis*	Mysid (*Americamysis bahia*)	24.0

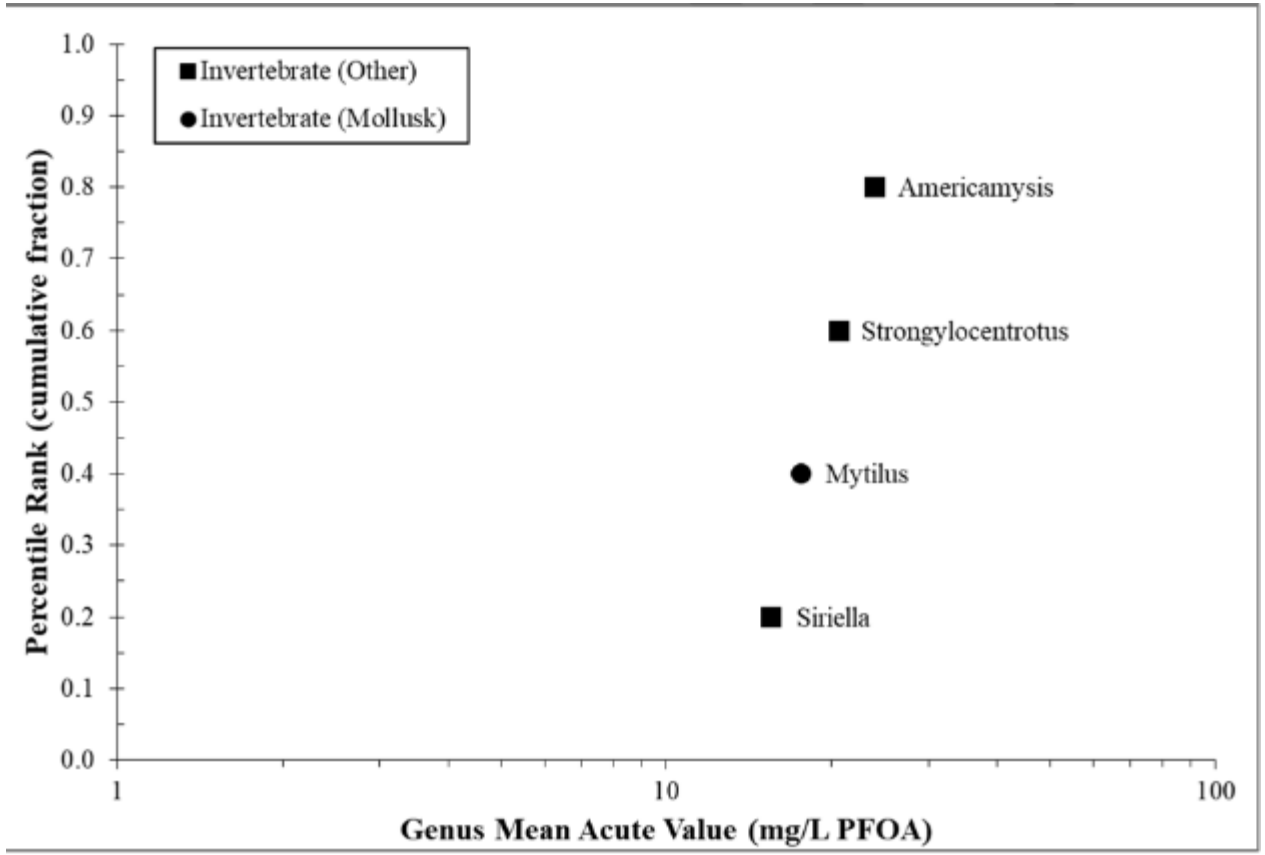


Photo 1. i-Naturalist. Photo by Przese. https://inaturalist.ca/photos/113992514
Photos 2 and 3. Chris Stransky, WSP USA
Photo 4. US EPA. https://www.epa.gov/sites/default/files/2017-01/documents/sop-for-mysid-analysis-201502-24pp.pdf

Most Sensitive Marine Species to PFOS - Acute

The Four Most Sensitive Estuarine/ Marine Genera – Acute Endpoints (PFOS)

Rank	Genus	Species	GMAV (mg/L PFOS)
1	*Mytilus*	Mediterranean mussel, *M. galloprovincialis*	1.1
2	*Strongylocentrotus*	Purple sea urchin, *S. purpuratus*	1.7
3	*Paracentrotus*	Sea urchin, *P. lividus*	1.80
4	*Americamysis*	Mysid, *A. bahia*	4.91



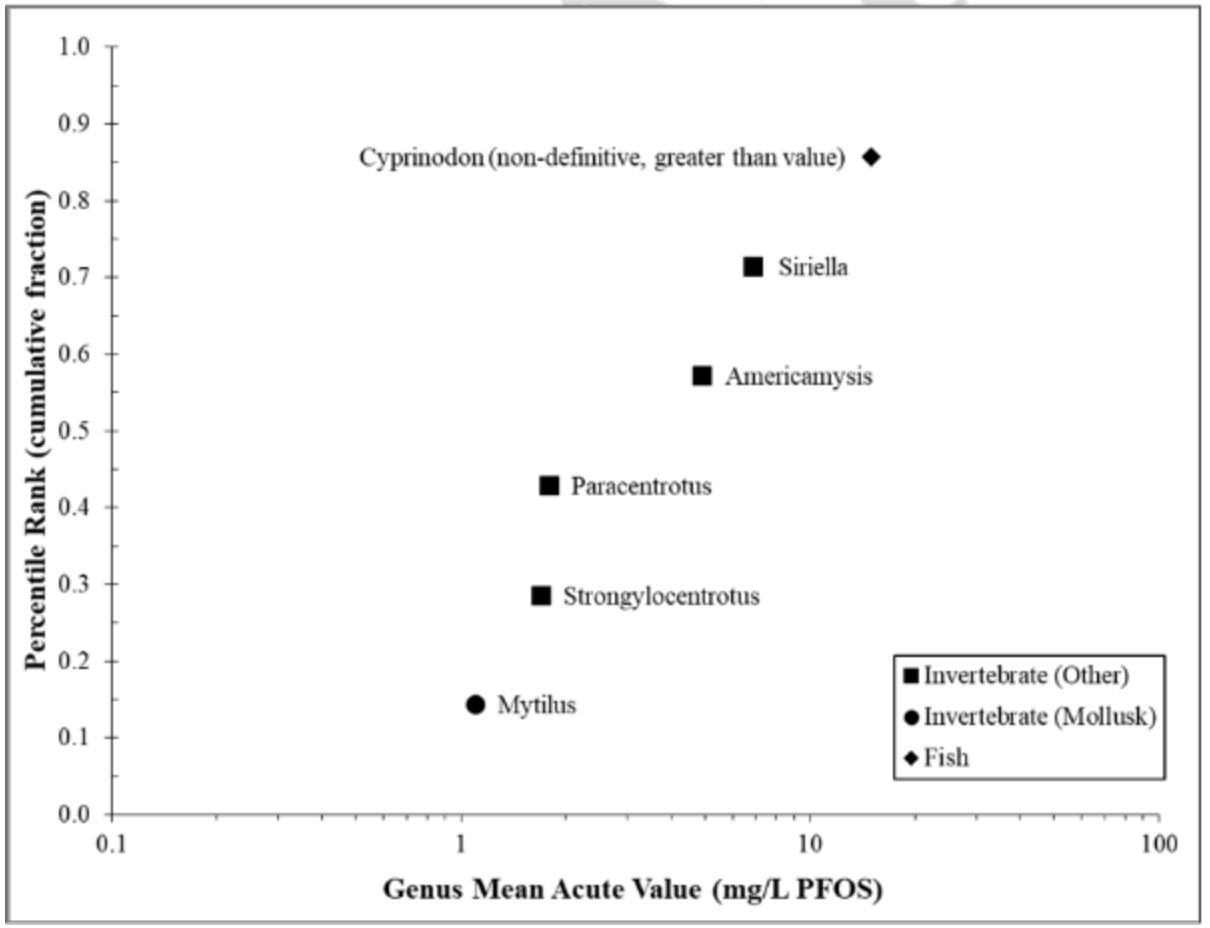



Photo 1 and 2. **Photos 2 and 3**. Chris Stransky, WSP USA
Photo 3. i-Naturalist. Photo by Emanuele Santarelli. https://www.inaturalist.org/taxa/48032-Paracentrotus-lividus
Photo 4. US EPA. https://www.epa.gov/sites/default/files/2017-01/documents/sop-for-mysid-analysis-201502-24pp.pdf

Most Sensitive Marine Species to PFOS - Chronic

The Three Most Sensitive Estuarine/ Marine Genera – Chronic Endpoints (PFOS)

Rank	Genus	Species	GMCV (mg/L PFOS)	GMCV (µg/L PFOS)
1	*Perna*	Asian green mussel, *Perna viridis*	0.0033	3.3
2	*Americamysis*	Mysid, *Americamysis bahia*	0.3708	371
3	*Tigriopus*	Copepod, *Tigriopus japonicus*	0.7071	707

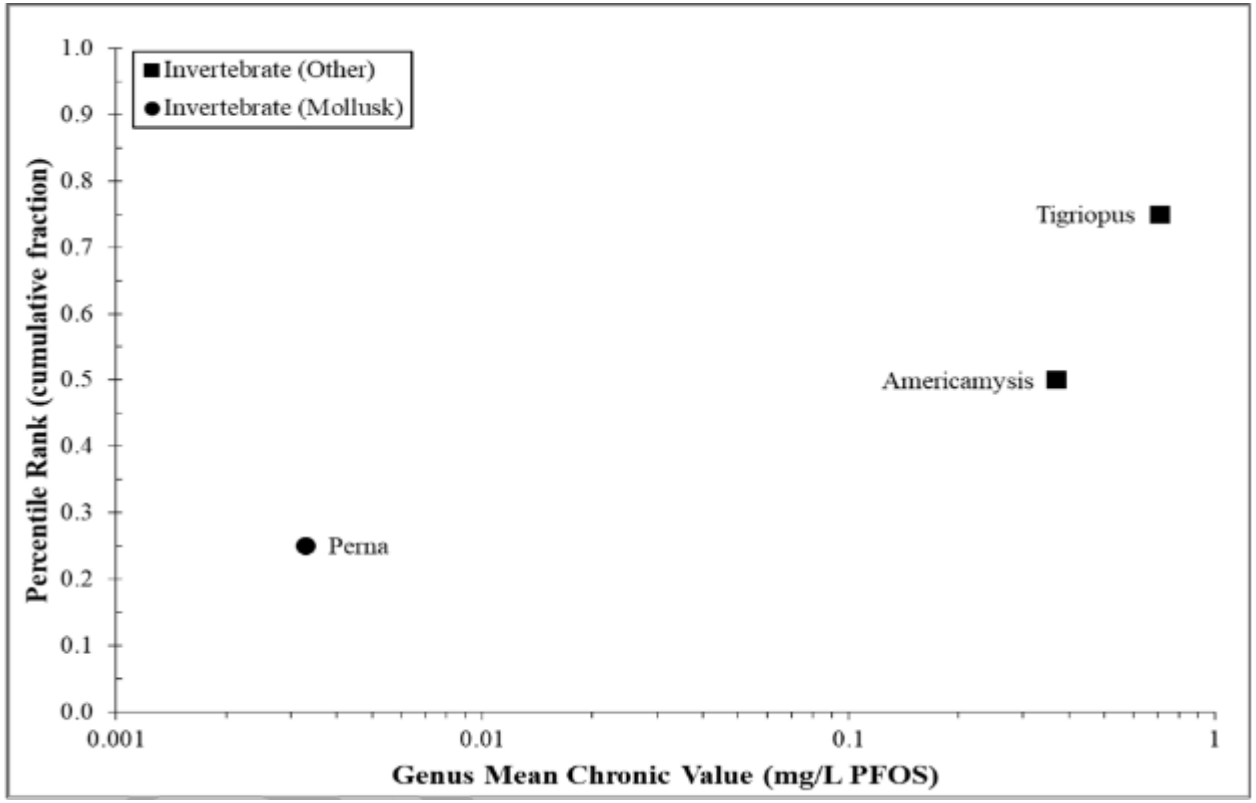


Photo 1. i-Naturalist. Photo by: khuemer. https://www.inaturalist.org/taxa/199358-Perna-viridis/browse_photos
Photo 2. US EPA. https://www.epa.gov/sites/default/files/2017-01/documents/sop-for-mysid-analysis-201502-24pp.pdf
Photo 3. Wikipedia open source photo. https://en.m.wikipedia.org/wiki/File:Tigriopus_sp_japonicus_pair.jpg

US EPA Draft Recommended Freshwater Aquatic Life Water Quality Criteria for PFOA and PFOS (April 2022)

Criteria Component	Acute Water Column (CMC)[1]	Chronic Water Column (CCC)[2]	Invertebrate Whole-Body	Fish Whole-Body	Fish Muscle
PFOA Magnitude	49,000 µg/L	94 µg/L	1.11 mg/kg ww	6.10 mg/kg ww	0.125 mg/kg ww
PFOS Magnitude	3,000 µg/L	8.4 µg/L	0.937 mg/kg ww	6.75 mg/kg ww	2.91 mg/kg ww
Duration	1-hour average	4-day average	Instantaneous[3]		
Frequency	Not to be exceeded more than once in three years, on average	Not to be exceeded more than once in three years, on average	Not to be exceeded more than once in ten years, on average		

[1] Criterion Maximum Concentration. [2] Criterion Continuous Concentration.

[3] Tissue data provide instantaneous point measurements that reflect integrative accumulation of PFOA or PFOS over time and space in aquatic life population(s) at a given site.

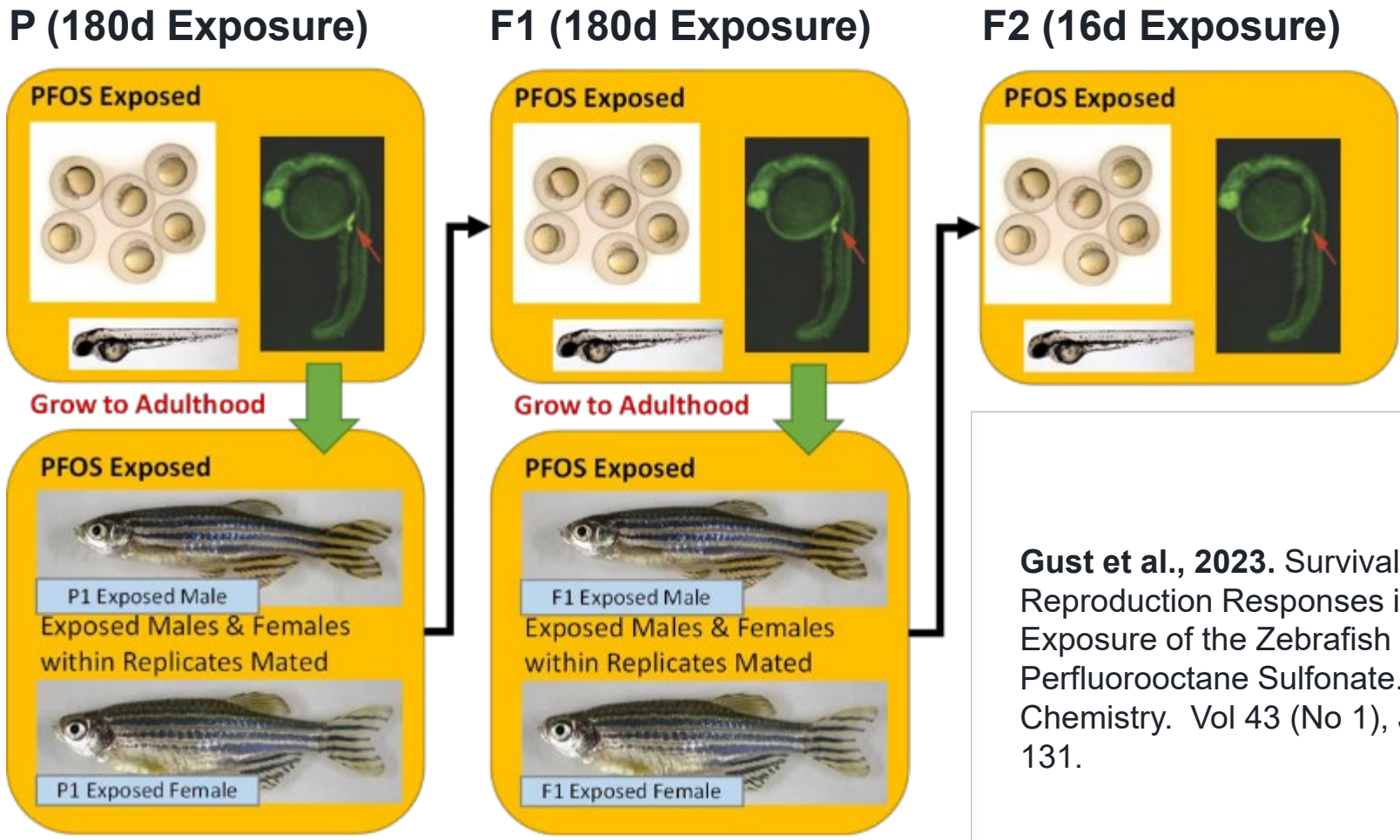
*EPA's Proposed drinking water Maximum Contaminant Level (MCL) = 4.0 parts per trillion (ng/L) or 0.004 µg/L. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

A Multigenerational Zebrafish PFOS Exposure-Response Study (Gust et al., 2023)

- Study performed in follow up to a prior publication by Keiter et. al. (2012) that reported reduced growth of zebrafish at 0.734 µg/L (ppb) from 30 to 180 days post fertilization.
- Another study reported a no observed effect concentration (NOEC) of 50 µg/L for reproduction (Wang et al 2012).
- This 1 paper led to EPA in Victoria, Australia to apply the 0.734 µg/L value to derive ambient water quality criteria for PFOS. US EPA did not use this value due to limitations in the study design and lack of dose-response relationships.
- The study was thus repeated by Gust et al., with a more robust design.

Gust et al., 2023. Survival, Growth, and Reproduction Responses in a Three-Generation Exposure of the Zebrafish (Danio rerio) to Perfluorooctane Sulfonate. Environ. Toxicol. and Chemistry. Vol 43 (No 1), January 2024, Pp 115-131.

A Multigenerational Zebrafish PFOS Exposure-Response Study Conceptual Overview



Gust et al., 2023. Survival, Growth, and Reproduction Responses in a Three-Generation Exposure of the Zebrafish (Danio rerio) to Perfluorooctane Sulfonate. Environ. Toxicol. and Chemistry. Vol 43 (No 1), January 2024, Pp 115-131.

Results from a Multigenerational Zebrafish PFOS Exposure-Response Study

(Gust et al., 2023)

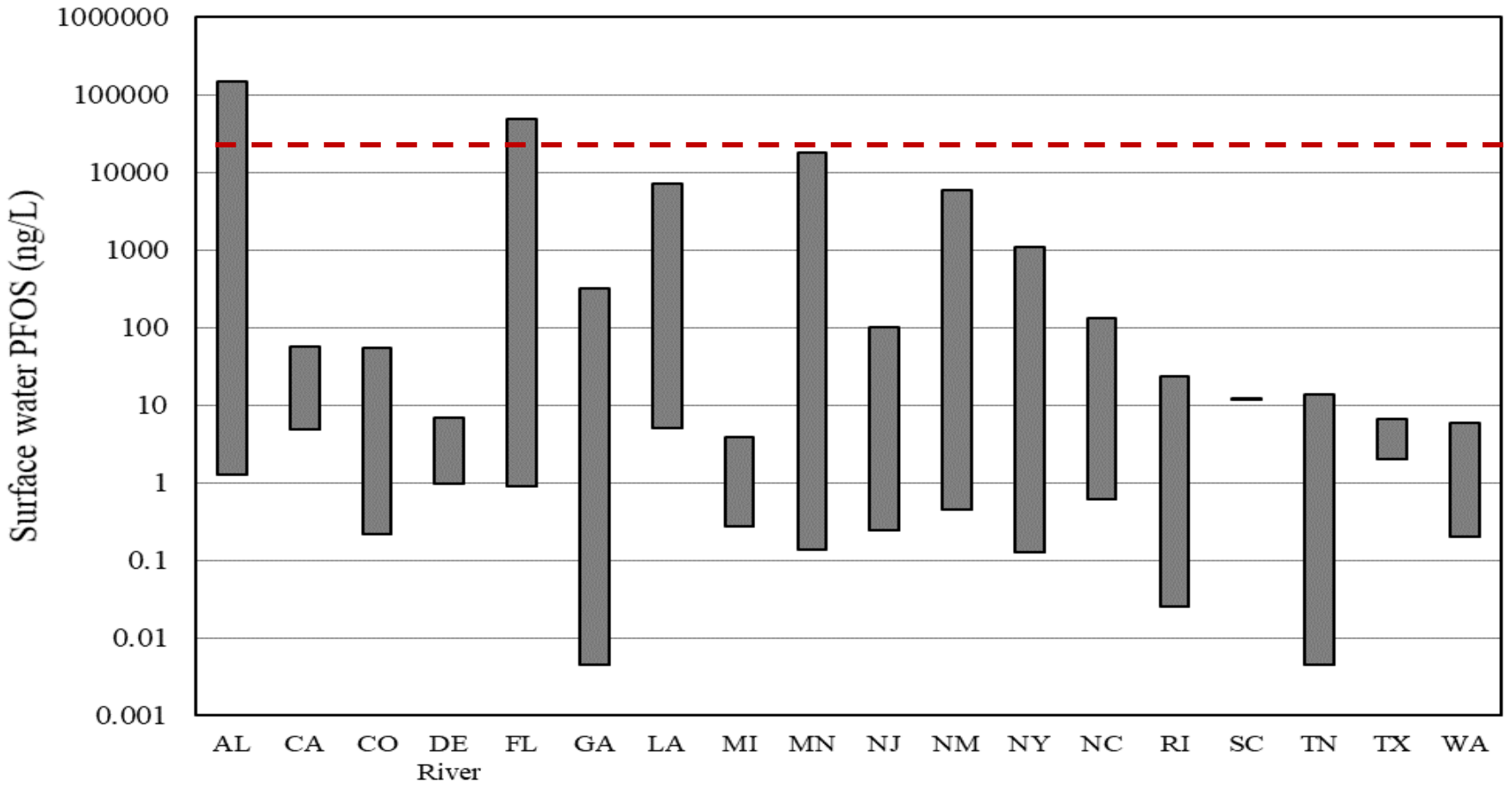
- Survival reduced on days 10-15 at 100 µg/L in P generation and at day 16 in the F2 generation, but not statistically significant
- Some indication of reduced growth at 100 µg/L (LOEC), but no effects 20 ppb and lower, contrary to growth reductions at 0.6 µg/L reported in Keiter et al. (2012).
- No statistically significant effect on either egg production or viability relative to controls through 8 reproductive trials
- No indication of vitellogenin (VTG) production in male fish
- Ecologically relevant adverse effects threshold for zebrafish = 117 µg/L for survival and 47 µg/L for all endpoints evaluated. (using EPA water quality development guidelines to derive a Species Mean Chronic Value (SPCV)

Environmental Concentrations of PFOS in Surface Waters

- Data review of 90% of sites in the U.S. (impacted and unimpacted) have PFOS values of < 0.2 µg/L (ppb), with a range of 0.00016 to 8,970 µg/L. Median = 0.0055 µg/L (Jarvis et al., 2021)
- Survey of water quality concentrations associated with U.S. Air Force bases with a history of using fire-fighting foams containing PFOS (256 sites across 85 installation) report a mean concentration on 0.25 µg/L with 75th and 95th percentiles of 1.2 and 12.9 µg/L (East et al., 2021)

Concentrations of PFOS Measured in U.S. Surface Waters

(US EPA 2022 Draft Aquatic Life Ambient WQO Document)

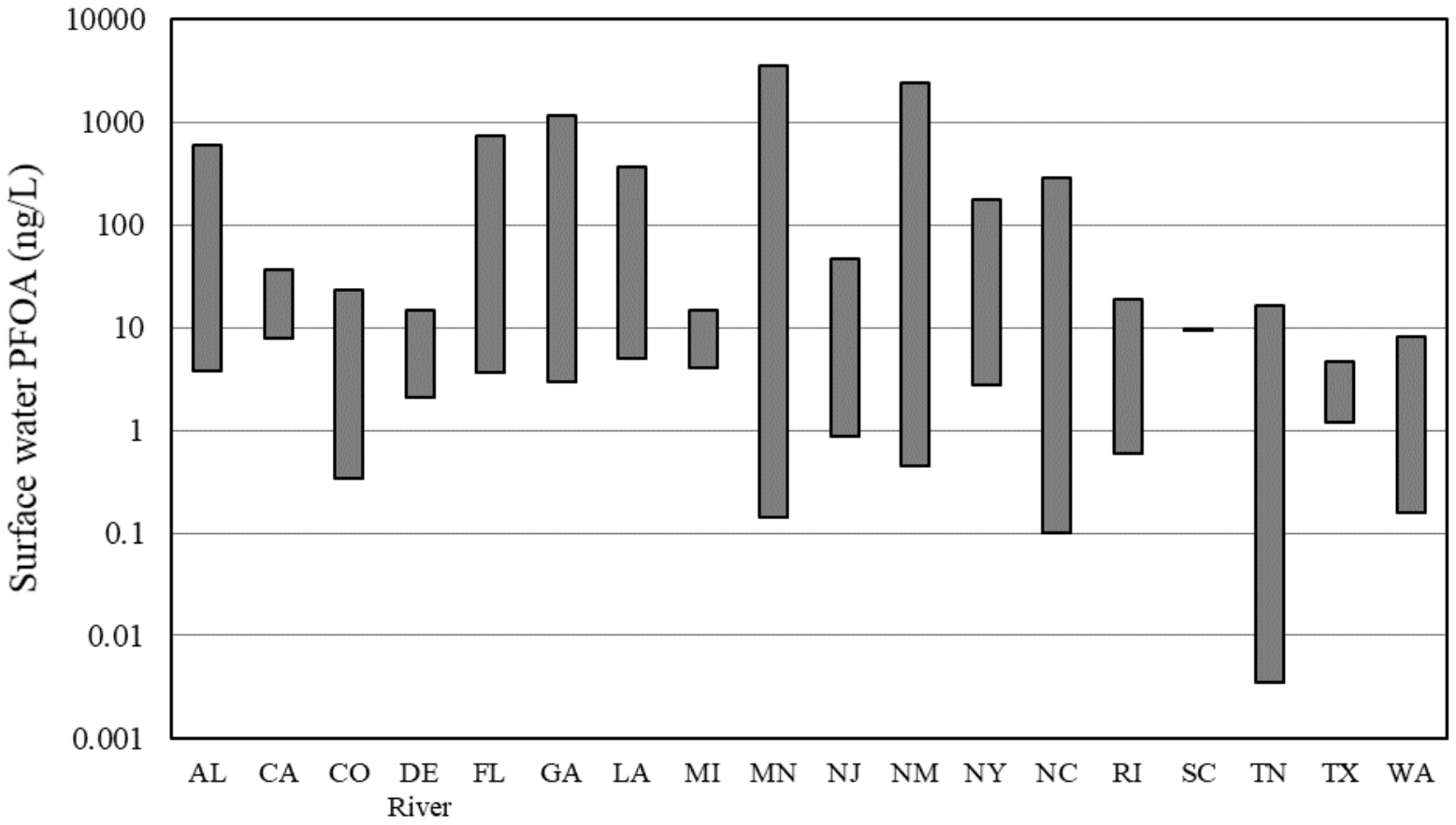


Proposed US EPA Freshwater Chronic Water Quality Objective (CCC) = 8,400 ng/L

Minimum and Maximum Concentrations (ng/L)

Concentrations of PFOA Measured in U.S. Surface Waters

(US EPA 2022 Draft Aquatic Life Ambient WQO Document)



Proposed US EPA Freshwater Chronic Water Quality Objective (CCC) = 94,000 ng/L

Human Health Fish Tissue Guidelines for PFAS

- Currently 8 states have developed consumption risk guidelines for PFAS with New Jersey and Minnesota having the most conservative values.
- No State of CA guidance for the consumption of fish based on PFAS
- State thresholds vary because they may include not only an analysis of risk from the contaminant, but often also a risk-benefit analysis balancing toxicity of the contaminant with the known benefits of consuming fish. Thresholds may also vary because they evaluate different studies and endpoints or use different factors and assumptions (e.g., body weight and consumption rate).
- USEPA human health fish tissue benchmark of 68 ppb ww PFOS

Human Health Fish Tissue Guidelines – New Jersey

New Jersey developed fish consumption triggers using the **Reference Doses** for previously developed for use in drinking water and ground water standards.

PFOA (2 ng/kg/day; NJDWQI, 2017),

PFOS (1.8 ng/kg/day; NJDWQI, 2018), and

PFNA (0.74 ng/kg/day; NJDEP, 2017)

	General Population (ng/g; ppb)		
	PFOA	**PFNA**	**PFOS**
Unlimited	≤ 0.62	≤ 0.23	≤ 0.56
Weekly	≤ 4.3	≤ 1.6	≤ 3.9
Monthly	≤ 18.6	≤ 6.9	≤ 17
Once/3 months	≤ 57	≤ 21	≤ 51
Yearly	≤ 226	≤ 84	≤ 204
Do Not Eat	**>226**	**> 84**	**> 204**

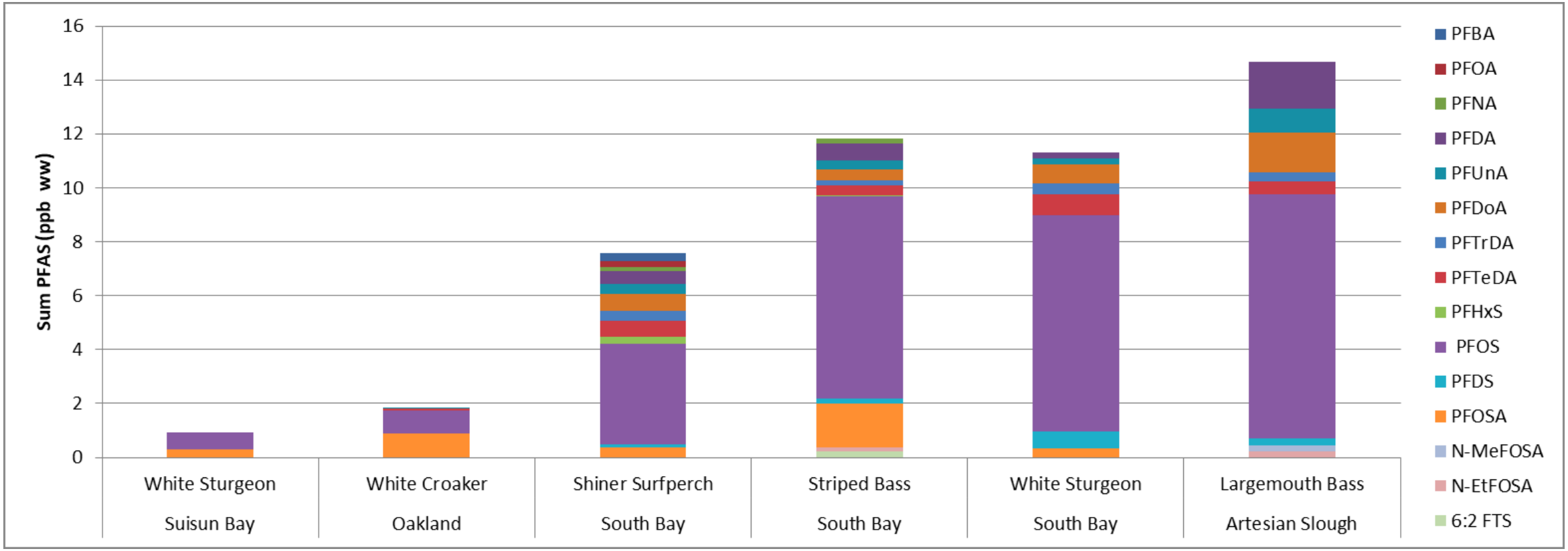
$$\text{Daily trigger concentration } \left(\frac{\text{ng}}{\text{g}}\right) = \frac{\text{RfD } (ng/kg/day) \text{x Body Weight (kg)}}{\text{Meal size (g)}}$$

- Where body weight= 70 kg and meal size is 227 g
- For consumption triggers that are less than daily, the triggers are multiplied by the appropriate timeframe

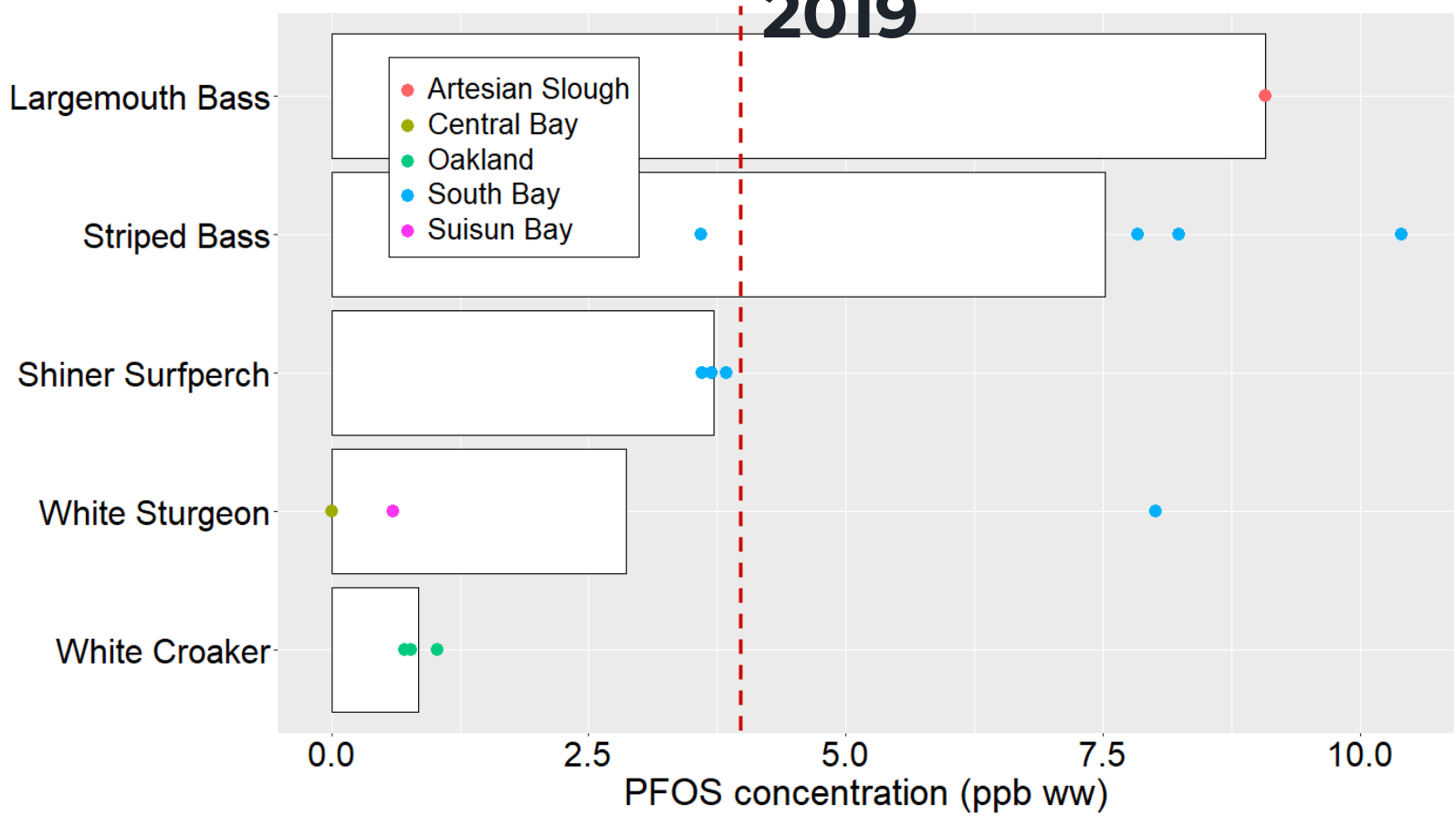
Human Health Fish Tissue Guidelines -Minnesota

Meal Frequency	PFOS (ng/g; ppb)
Unlimited	≤ 10
2 meals per wk	10-20
1 meal per wk	20-50
1 meal per month	50-200
Do Not Eat	>200

Sum of PFAS Concentrations and Analyte Contributions in San Francisco Bay Fish, 2019



PFOS Concentrations in San Francisco Bay Fish, 2019



Human Health Guidance: Threshold shown is from New Jersey: general population, one serving/week - 3.9 ppb ww. USEPA 2020 fish tissue benchmark = 68 ppb ww

EcoRisk Guidance (USEPA 2022 Proposed): 2,910 ppb ww (filet), 6,750 ppb ww (whole body)

PFAS Concentrations in Freshwater Lakes and Streams
USEPA National Condition Assessment Program (2018 –2019)

- 501 composite samples comprising 1,968 individual fish representing 44 species total.
- Most frequent species:
  - Channel catfish (*Ictalurus punctatus*),
  - Smallmouth bass (*Micropterus dolomieu*),
  - Largemouth bass (*Micropterus salmoides*),
  - Yellow perch (*Perca flavescens*), and
  - Walleye (*Sander vitreus*)
- Median summed PFAS in U.S streams and rivers – 9.5 ppb. 74% is PFOS (6.6 ppb).
- Median summed PFAS in Great Lakes fish = 17.8 ppb. PFOS = 12.35 ppb

The Southern CA Bight Regional Monitoring Program

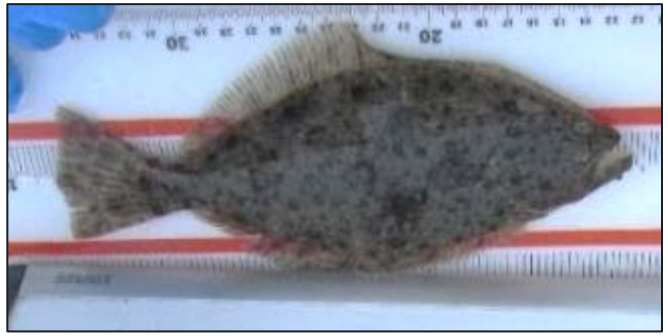
Regional Monitoring Program every 5 years starting in 1993 managed by the Southern California Coastal Water Research Project (SCCWRP). Planning efforts currently underway for 2023.

1. What is the extent and magnitude of sediment quality impacts in the southern California Bight?
2. How does the extent and magnitude of sediment quality impacts vary over time in the southern California Bight?
3. What is the extent and magnitude of bioaccumulation of select contaminants in seafood in the southern California Bight?

Southern CA Regional Bight Monitoring Program – Bight ‘23

- Sediment samples collected at ~166 locations offshore and within bays and estuaries are undergoing analysis of PFAS compounds.
- Fish tissues analysis of PFAS compounds in ~50 samples from the San Diego Regional Harbor Monitoring Program.

Yellowfin Croaker

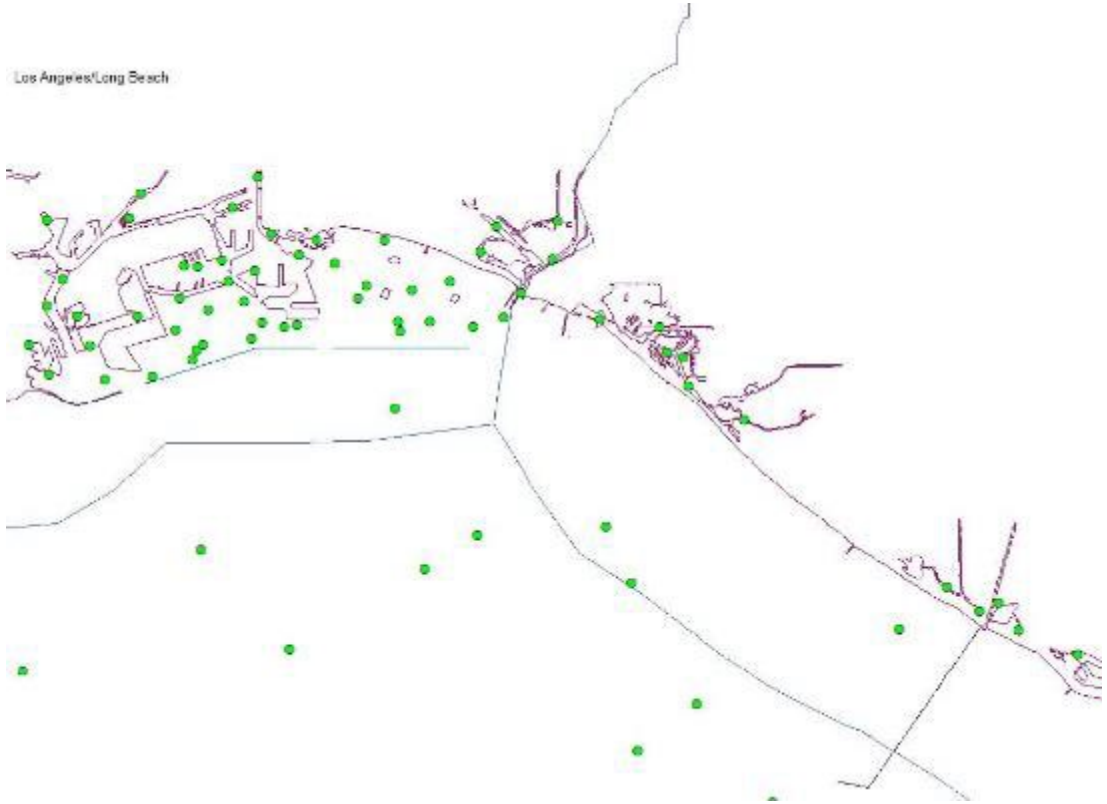


California halibut

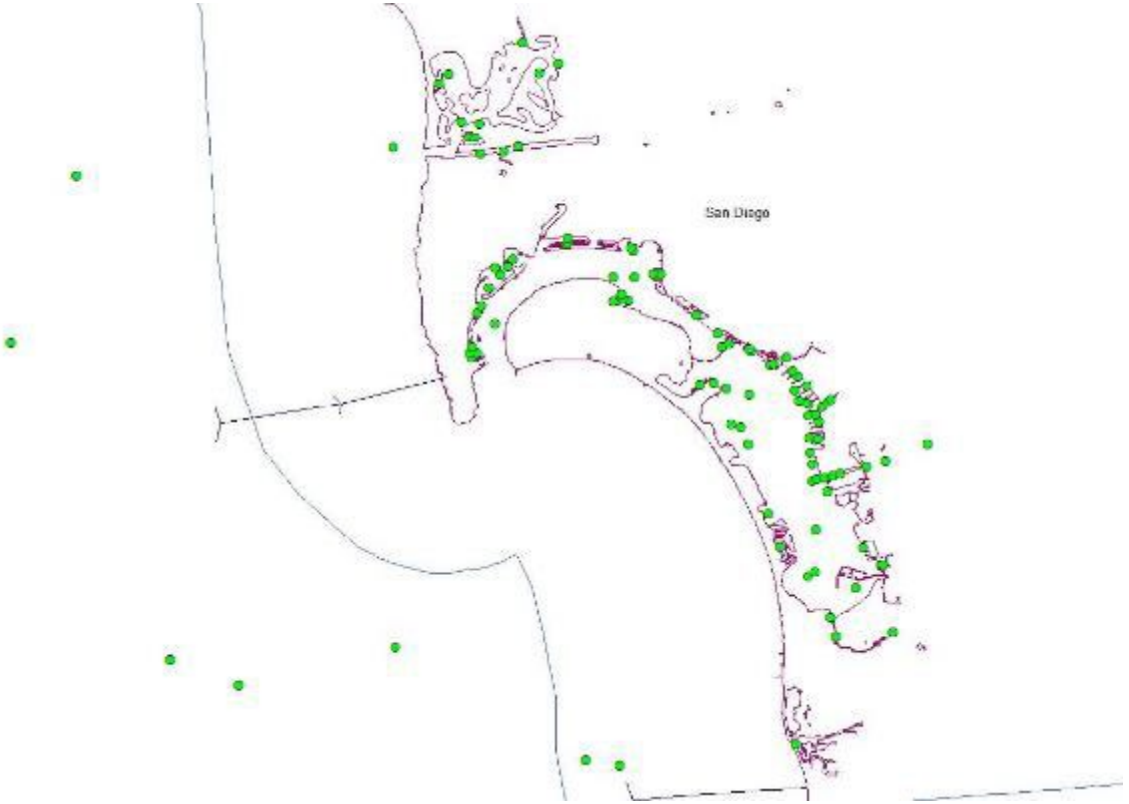
Bight ‘23 Sediment Sampling Locations

Bight ‘23 Sediment Sampling Locations

LA and Long Beach Region



San Diego Region



A Few Good Resources

- ITRC Website: https://pfas-1.itrcweb.org/
- US EPA Guidance Docs: https://www.epa.gov/wqc/aquatic-life-criteria-perfluorooctanoic-acid-pfoa
- SERDP/ESTCP: https://serdp-estcp.mil/focusareas/9db2c9ed-2086-490a-8bc0-f51da299c737
- USEPA Ecotox Database: https://cfpub.epa.gov/ecotox/

Discussion/ Questions

Chris Stransky
Environmental Scientist, Aquatic Sciences & Toxicology Group
WSP USA, San Diego, CA
chris.stransky@wsp.com
858-775-5547