Trends in Contaminant Concentrations in Freshwater Fish

Tom Danielson, Ph.D.

Maine Sustainability and Water Conference
March 30, 2023

Benefits of Fishing

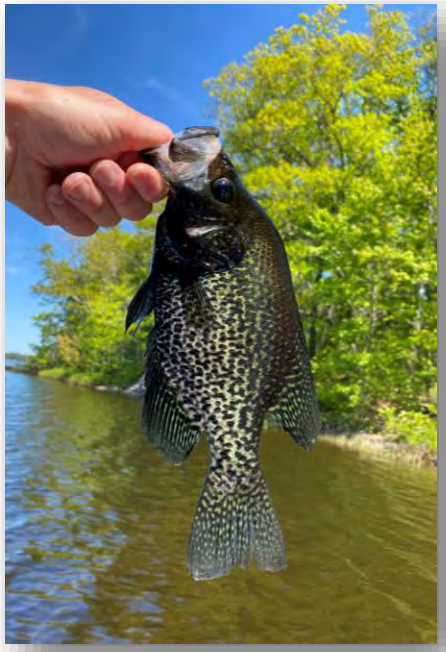
- Social and recreational benefits
  - Exercising, being in nature, relaxing, bonding with family and friends
  - Cultural and spiritual benefits

Benefits of Fishing

- Healthy source of food
  - Low-fat source of protein
  - Vitamins, minerals, omega-3 fatty acids

Benefits of Fishing

- Economically important
  - In 2013, freshwater fishing in Maine had a total economic output of $319 million



Monitoring Contaminants in Fish

MAINE DEPARTMENT OF
Environmental Protection

Aquatic Toxicology Unit

Tom Danielson, Joe Glowa, and Josh Noll

- Coordinate the Surface Water Ambient Toxics (SWAT) monitoring program
- Coordinate with Maine CDC and Maine IF&W

Fish Consumption Advisories

Responsible Agency

Maine Center for Disease Control & Prevention
An Office of the Maine Department of Health and Human Services

Breana Bennett and Andy Smith

Agencies that Provide Input

MAINE DEPARTMENT OF Inland Fisheries & Wildlife

Francis Brautigam, Tegwin Taylor, Michael Abbott

MAINE DEPARTMENT OF Environmental Protection

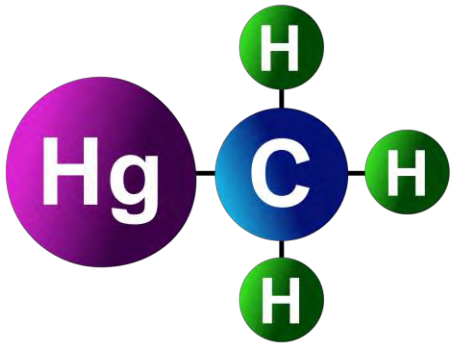
Tom Danielson, Wendy Garland

Safe Eating Guidelines

- Maine CDC issues fish consumption advisories for freshwater and anadromous fish
- Statewide mercury guidelines
- Site specific guidelines for PCBs/Dioxins, DDT, and PFAS for some waterbodies
  - https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/2kfca.htm

Mercury

- An element that occurs naturally
- Human activities can increase the amount of mercury in the environment
- Methyl mercury is the form in the food web



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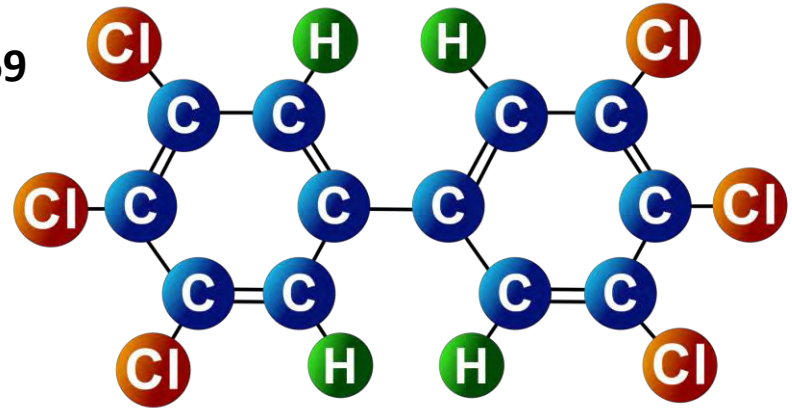
Polychlorinated Biphenyls (PCBs)

- PCBs are a group of industrial chemicals
- Banned production in the U.S. in the 1970s
- Still have some products that contain PCBs
- Legacy pollution

PCB 169



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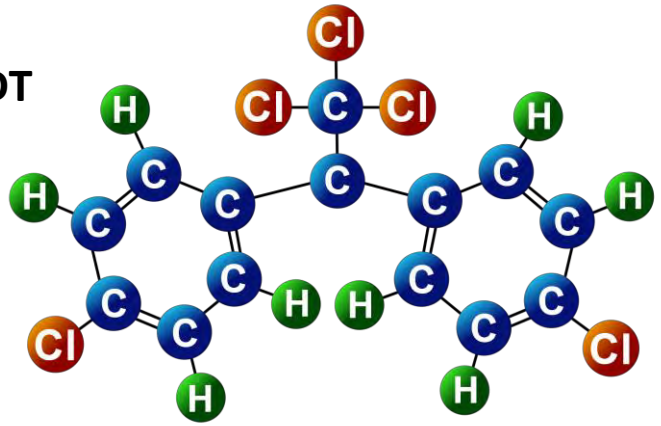
DDT

- Dichloro-diphenyl-trichloroethane (DDT)
- Pesticide for food crops and mosquito control
- Banned in the U.S. in the 1970s but still widely used in some parts of Africa and Asia

4,4'-DDT



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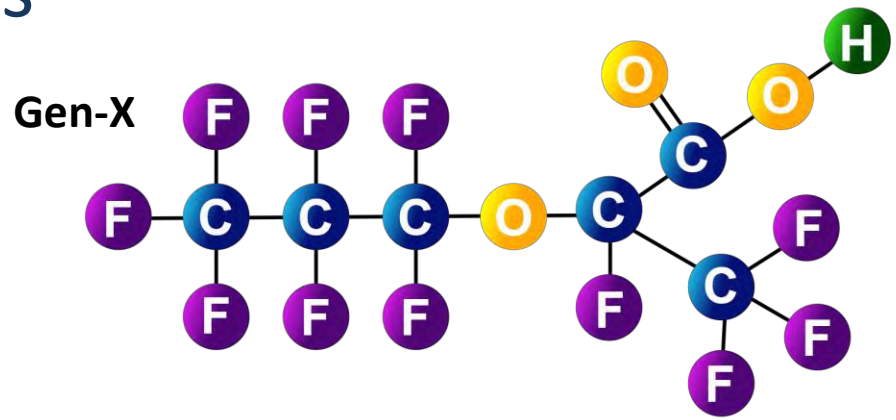
Per- and Polyfluoroalkyl Substances (PFAS)

- A diverse and large group of chemicals used in many consumer products and industrial processes
- “Forever Chemicals”



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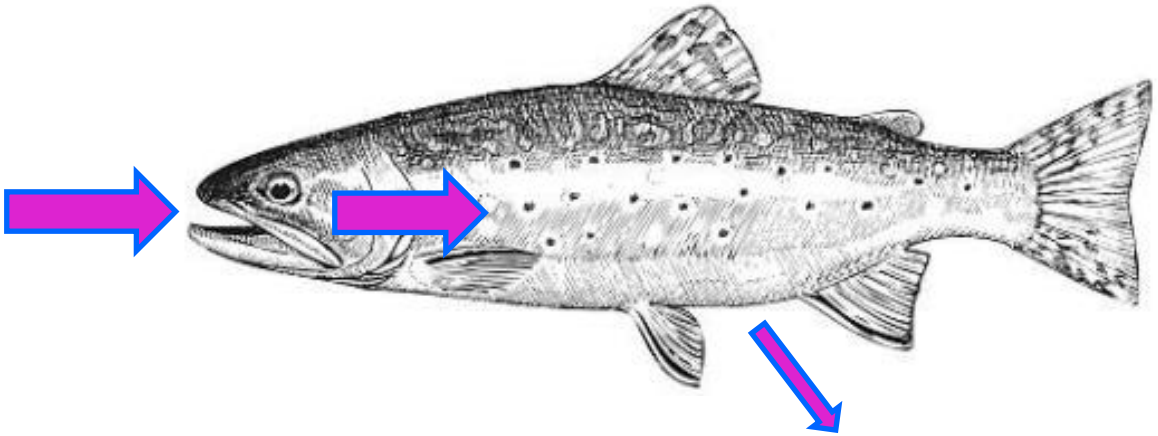
Uptake of Contaminants By Fish

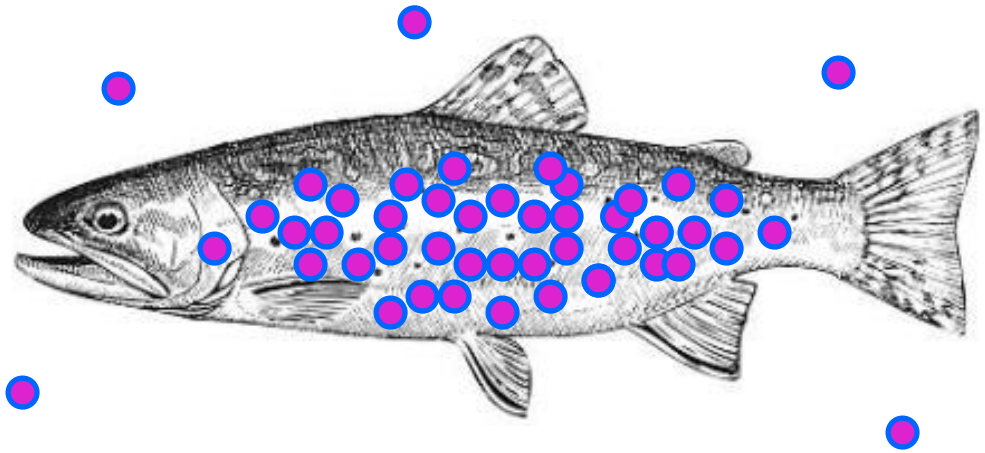
Uptake from eating food or sediment
Uptake from water passing over gills



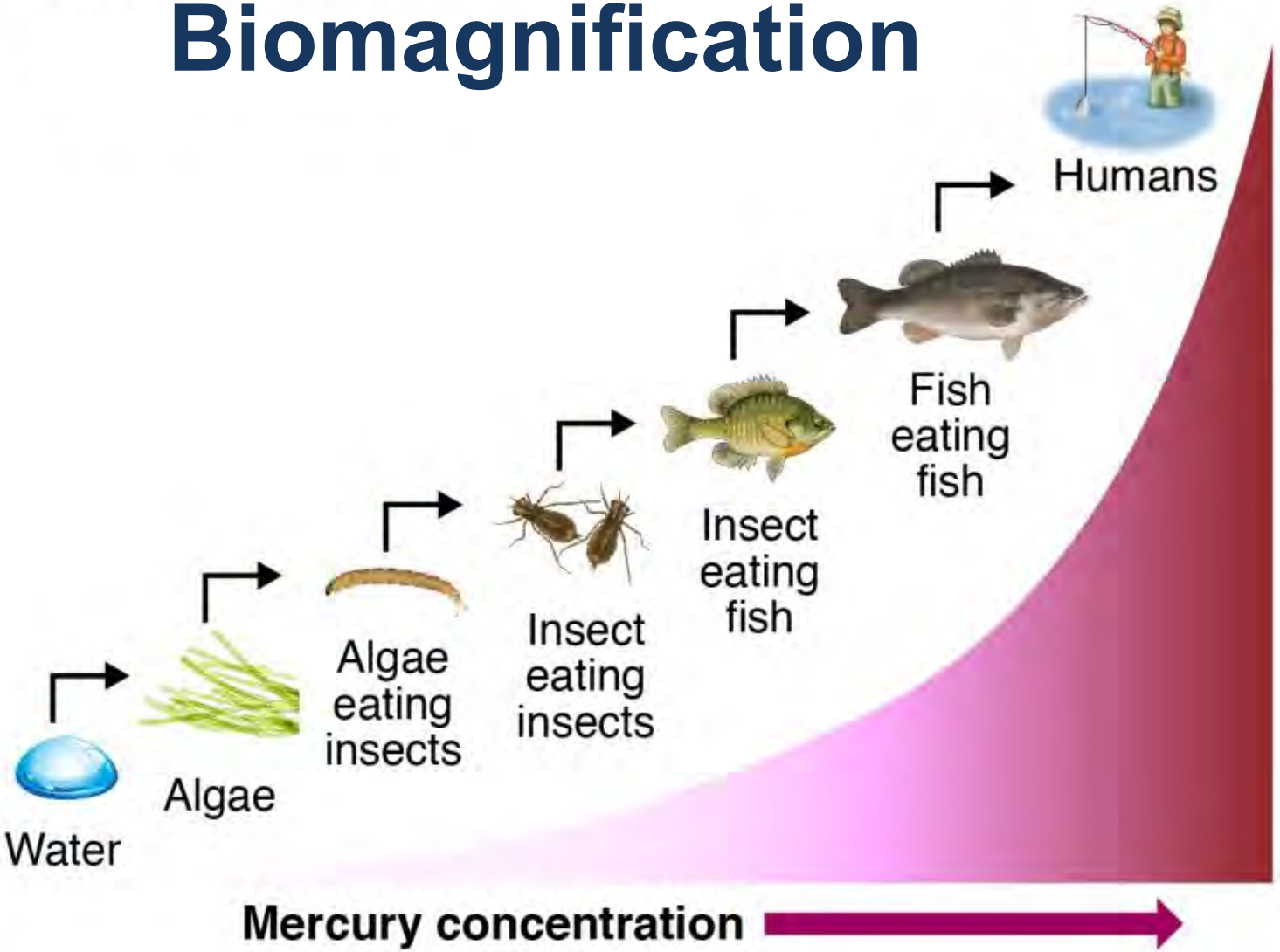
Loss from excretions

Bioaccumulation

Hundreds or thousands times more in the fish



Biomagnification



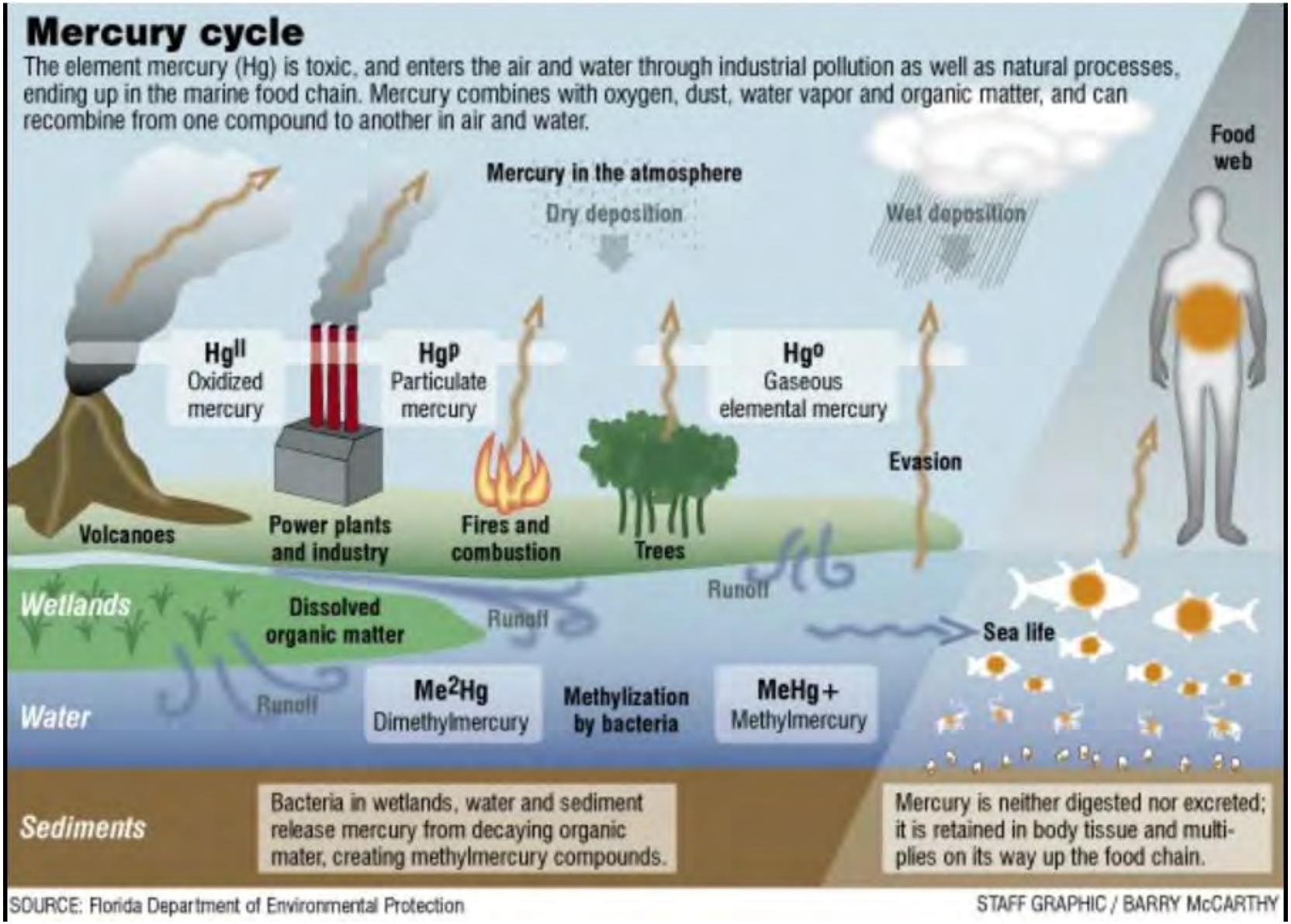
themecurysite.com

Characteristics of Contaminants in Fish

Contaminant	Mercury	DDT	PCBs	PFAS
Concentrates in fats	●	●	●	
Water soluble				●
Binds to certain proteins (e.g., blood albumin)				●
Bioaccumulates	●	●	●	some kinds
Increases with fish age	●	●	●	?
Biomagnifies	●	●	●	?

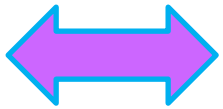
Safe Eating Guidelines for Mercury

Who	Species	Guidelines
• Pregnant and nursing women • Women who may get pregnant • Children under the age of 8	• Brook trout and landlocked salmon	• 1 meal a month
	• Other freshwater fish	• Do Not Eat
• All other adults • Children older than 8	• Brook trout and landlocked salmon	• 1 meal a week
	• Other freshwater fish	• 2 meals a month


Mercury cycle
The element mercury (Hg) is toxic, and enters the air and water through industrial pollution as well as natural processes, ending up in the marine food chain. Mercury combines with oxygen, dust, water vapor and organic matter, and can recombine from one compound to another in air and water.
Mercury in the atmosphere
Dry deposition
Wet deposition
Food web
Hg II Oxidized mercury
Hg P Particulate mercury
Hg 0 Gaseous elemental mercury
Evasion
Volcanoes
Power plants and industry
Fires and combustion
Trees
Runoff
Wetlands
Dissolved organic matter
Runoff
Sea life
Water
Runoff
Me2Hg Dimethylmercury
Methylization by bacteria
MeHg+ Methylmercury
Sediments
Bacteria in wetlands, water and sediment release mercury from decaying organic mater, creating methylmercury compounds.
Mercury is neither digested nor excreted; it is retained in body tissue and multiplies on its way up the food chain.
SOURCE: Florida Department of Environmental Protection
STAFF GRAPHIC / BARRY McCARTHY

National Mercury Trends in Fish

- Generally staying the same or decreasing a little



- Depends on primary sources
  - Local sources of contamination
  - Mercury air pollution in U.S.
  - Global mercury air pollution

Trend Reversal of Mercury in Fish from Minnesota Lakes

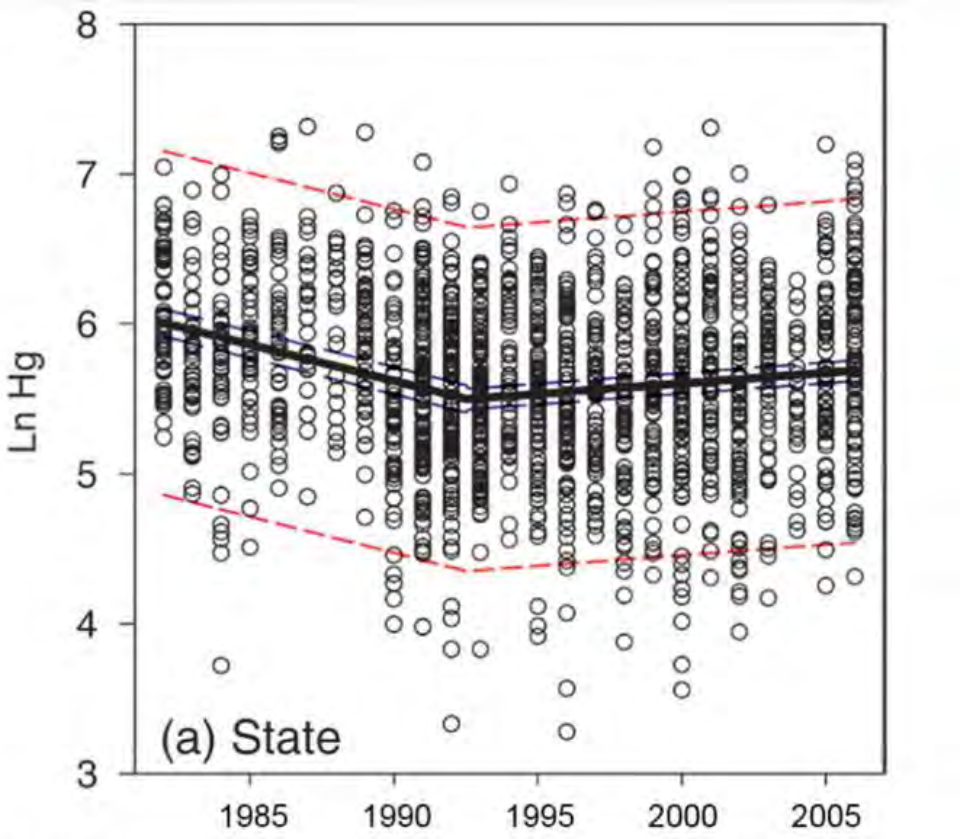
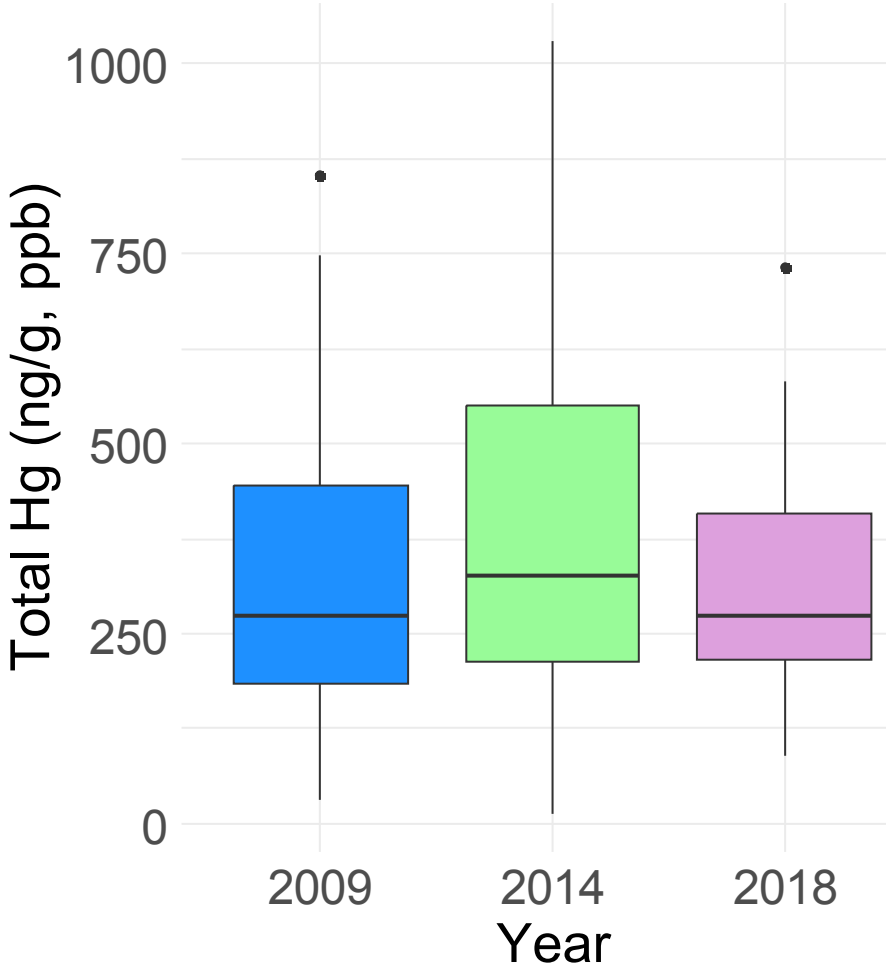


Fig. 6 Regression of natural log-transformed predator fish mercury concentrations from 1982 to 2006, showing a breakpoint in the trend in 1992 (Monson 2009)

Mercury Trends in River Fish
(U.S. EPA National Aquatic Resource Surveys)



Trends in PCBs and DDT

- General decline in these chemicals in the last 50 years

- Only a small number of “hot spots” remain in Maine

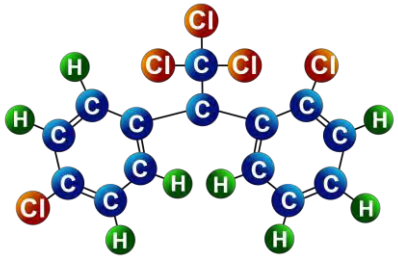
Safe Eating Guidelines for PCBs, Dioxins, and DDT

Region	Portions of the following waterbodies	
Northern Maine	• Green Pond[5] • Greenlaw Brook[5] • Meduxnekeag River[3]	• North Branch Presque Isle River[3] • Prestile Stream[3]
Central Maine	• Kennebec River[3-5] • Little Madawaska River[5]	• Penobscot River[3] • Sebasticook River[3]
Southern Maine	• Androscoggin River[1] • Red Brook[2]	• Salmon Falls River[1]

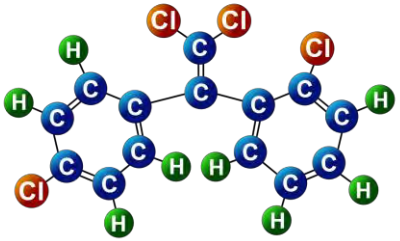
1 No more than 6-12 meals a year
2 No more than 6 meals a year
3 No more than 2 meals a year
4 No more then 1 meal a year
5 Do not eat

DDT and Biproducts

2,4’-DDT



2,4’-DDE



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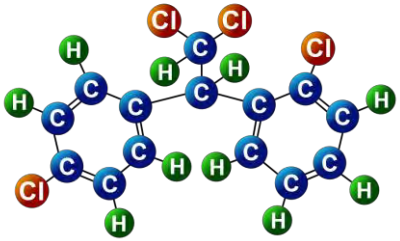
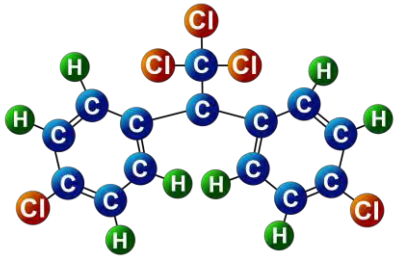
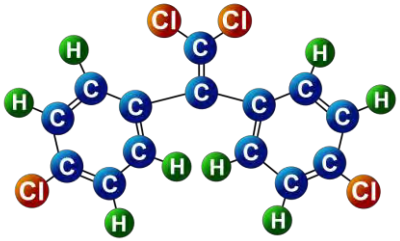


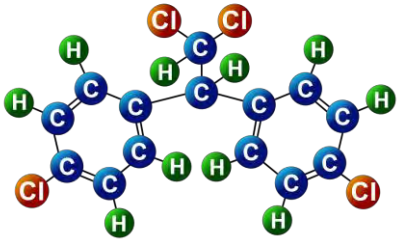
4,4’-DDT



4,4’-DDE



4,4’-DDD



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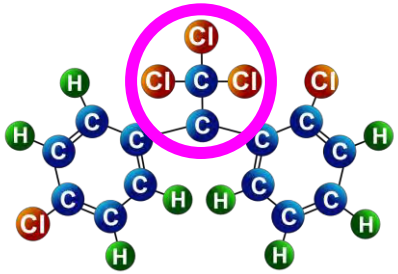
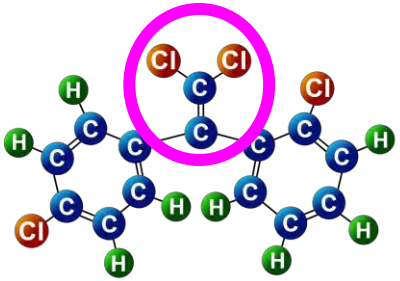
DDT and Biproducts

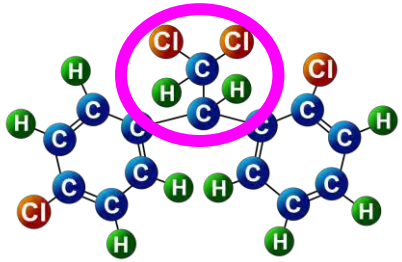
2,4'-**DDT**



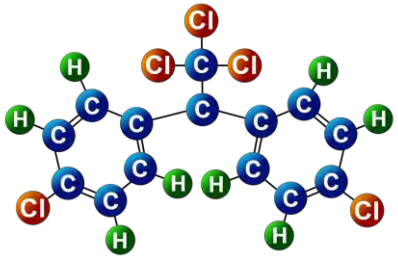
2,4'-**DDE**



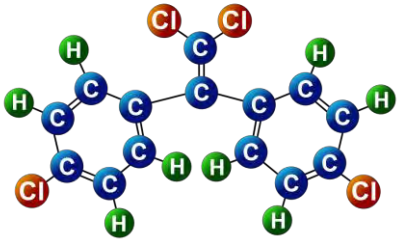
2,4'-**DDD**



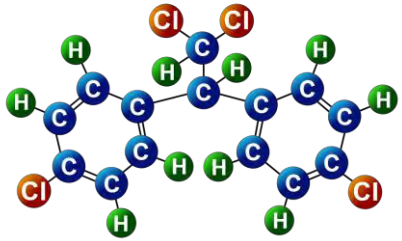
4,4'-DDT



4,4'-DDE



4,4'-DDD



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DDT and Biproducts

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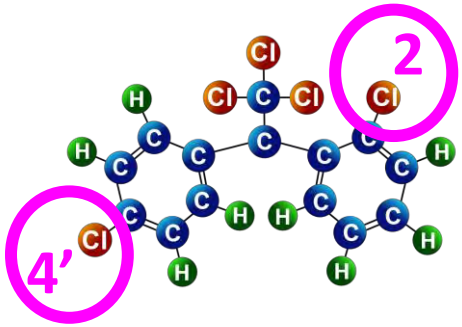
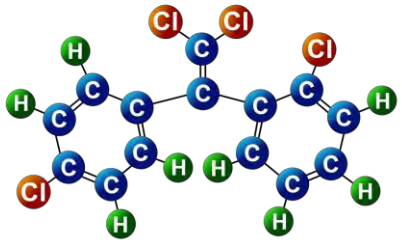
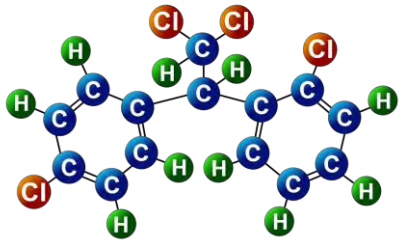


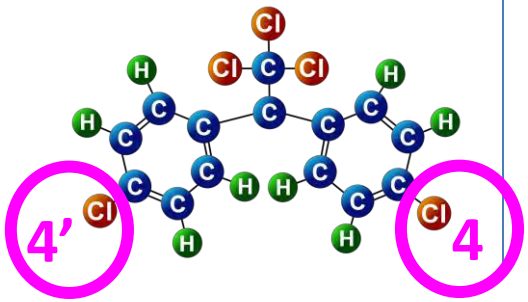
2,4'-DDE



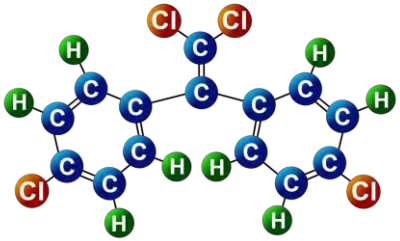
2,4'-DDD



4,4'-DDT



4,4'-DDE



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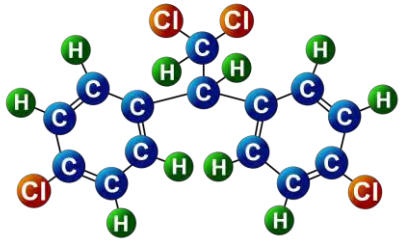

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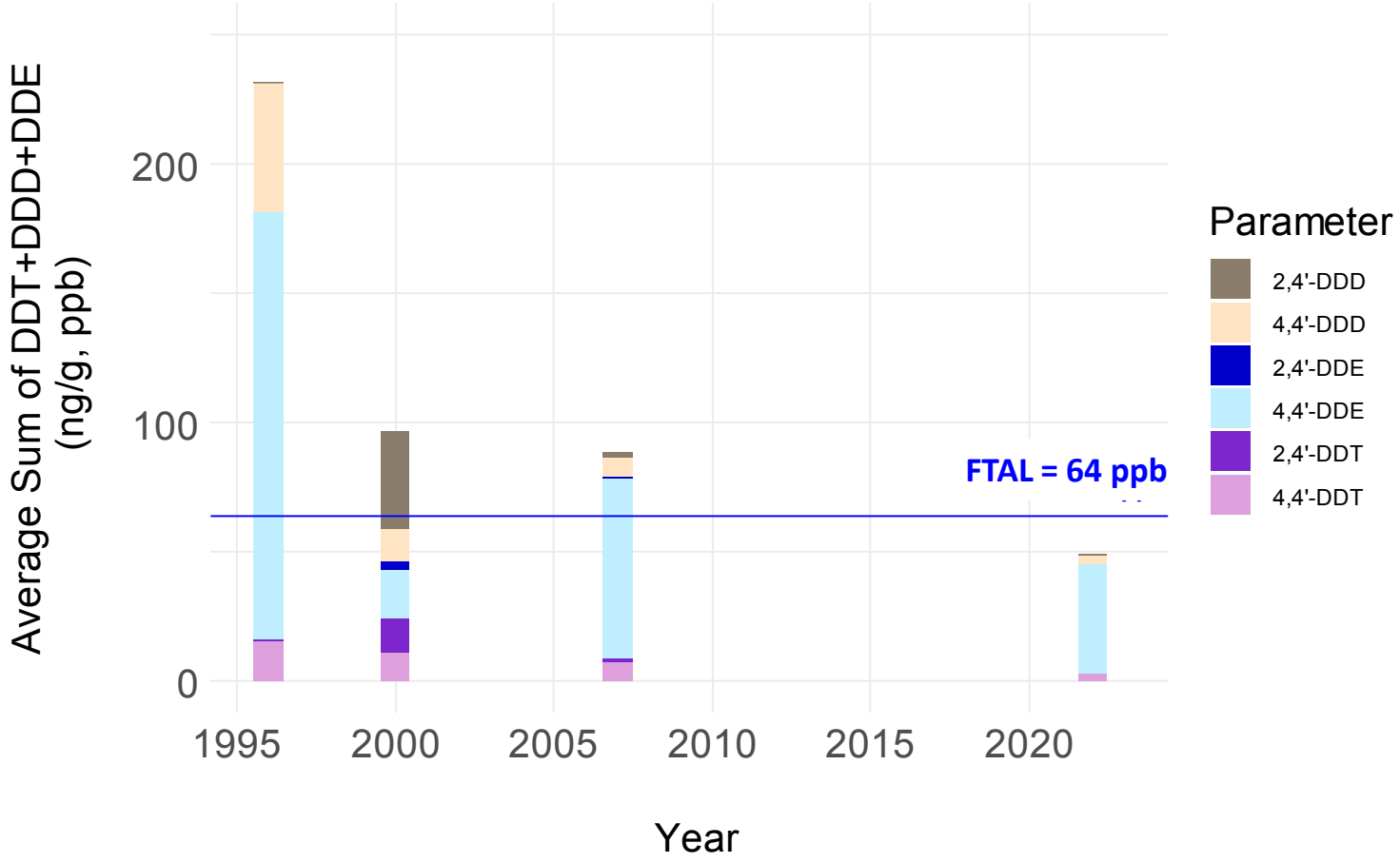
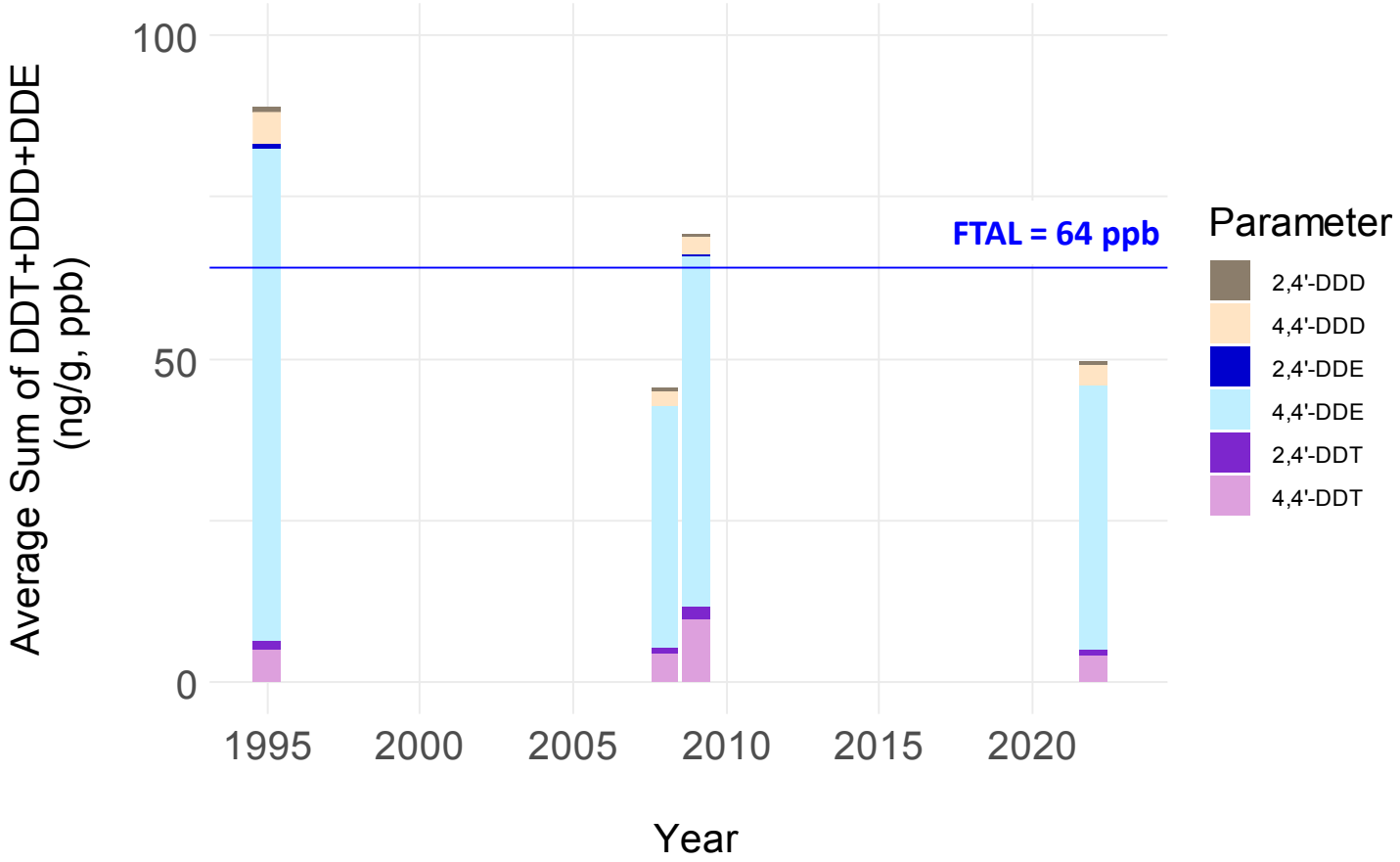
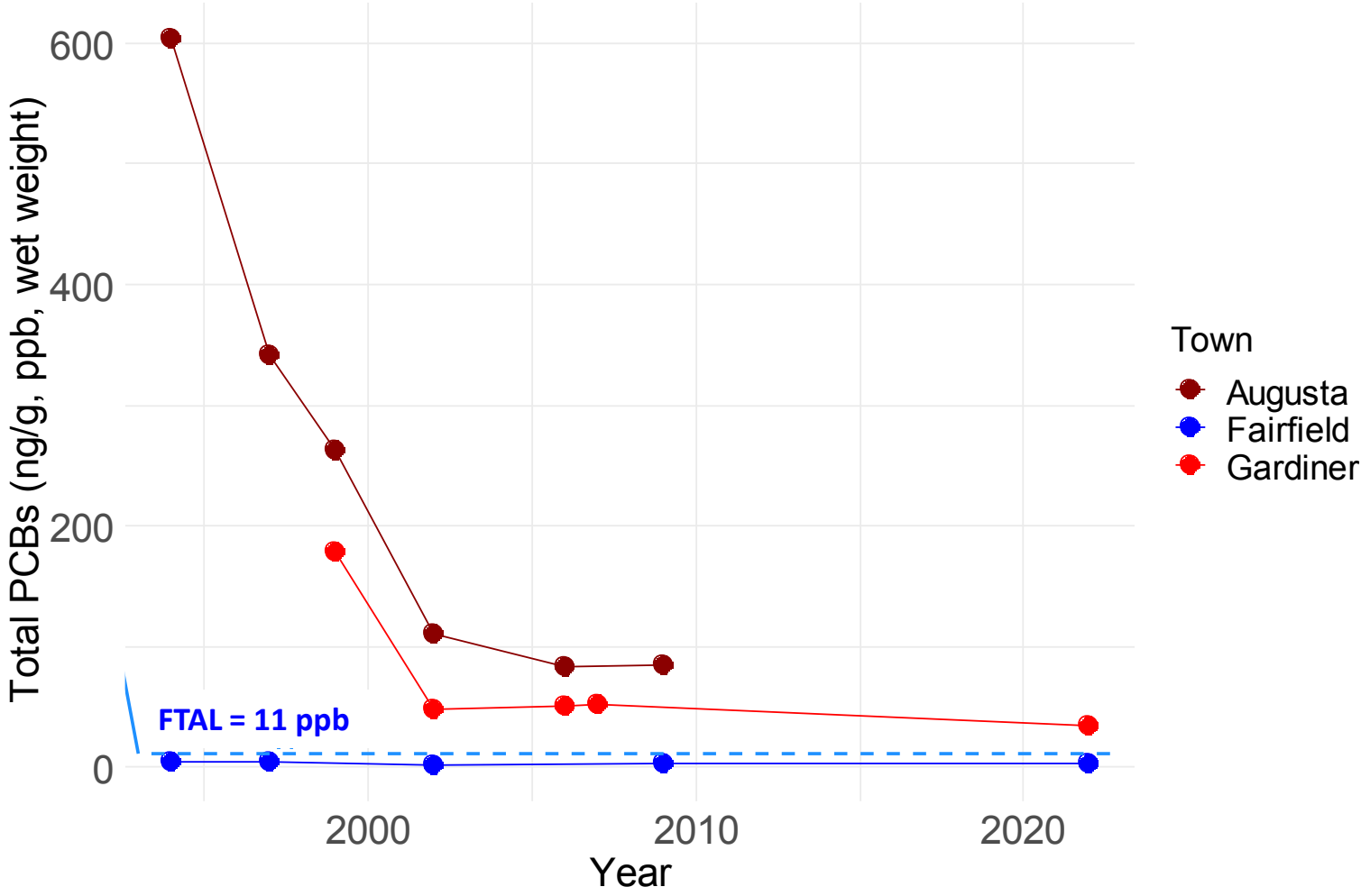
DDT in Meduxnekeag River (Brook Trout)



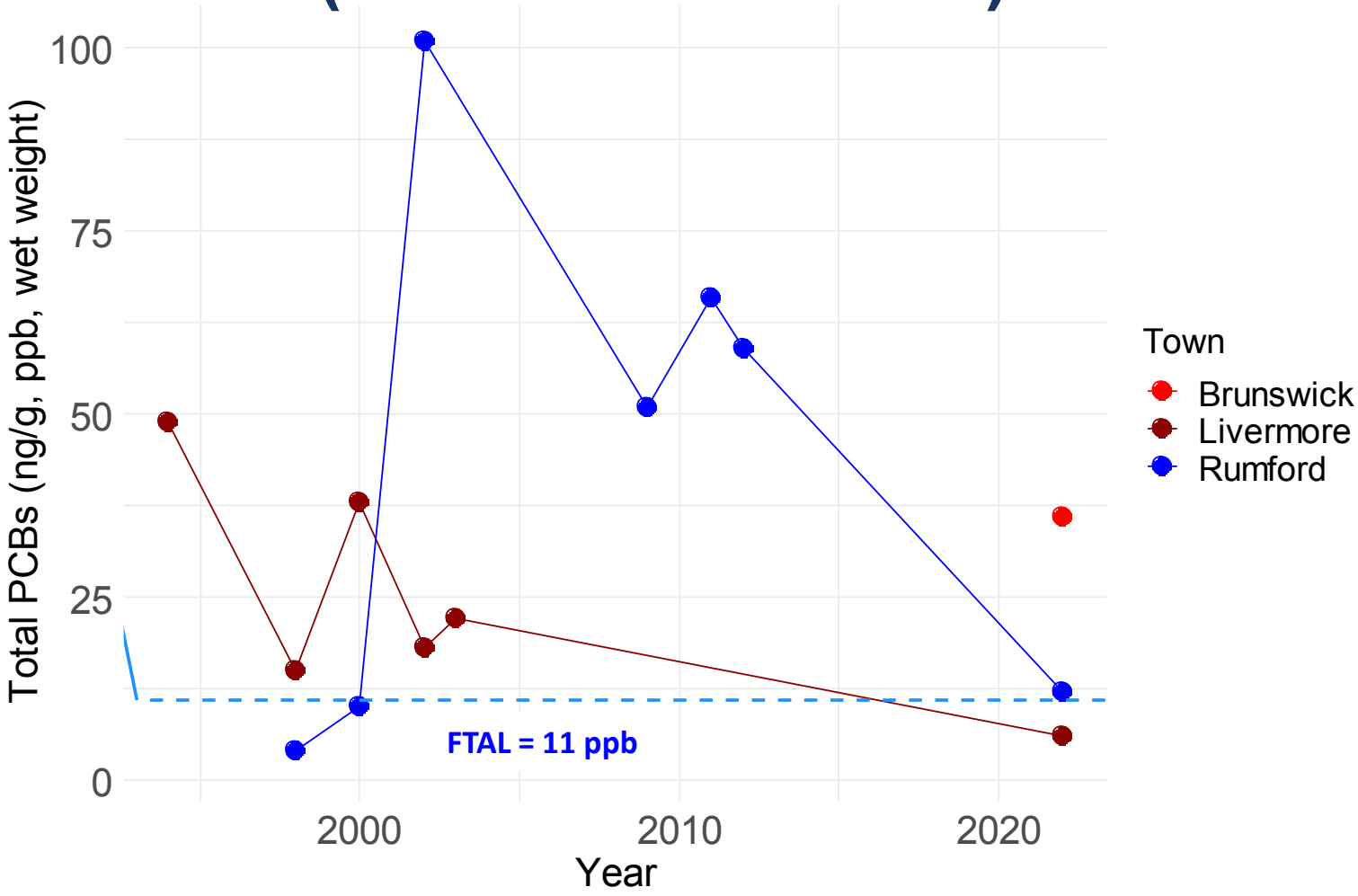
DDT in Prestile Stream (Brook Trout)



Total PCBs in the Kennebec River (Smallmouth Bass)



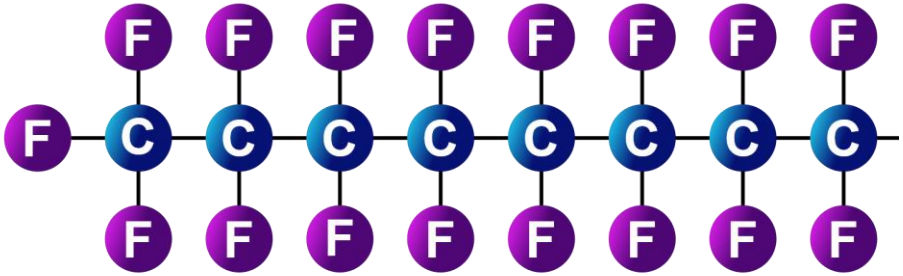
Total PCBs in the Androscoggin River (Smallmouth Bass)



Per- and Polyfluoroalkyl Substances (PFAS)

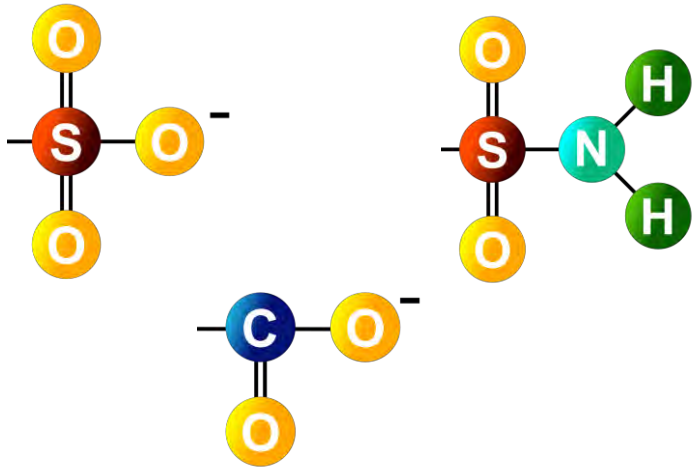
Fluorinated Carbon Chain ("Tail")

repelled from water



Functional Group ("Head")

attracted to water



C Carbon

F Fluorine

O Oxygen

S Sulfur

N Nitrogen

H Hydrogen

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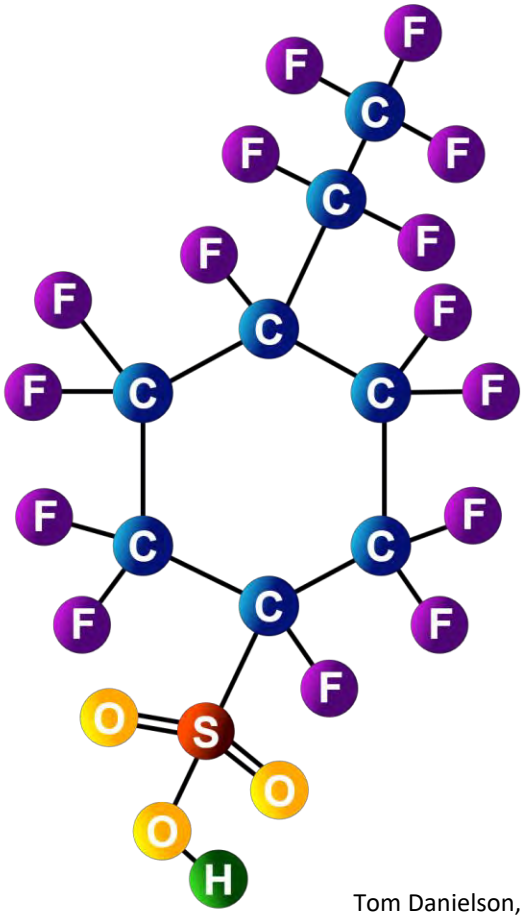
Example of a Complex PFAS



PFECHS

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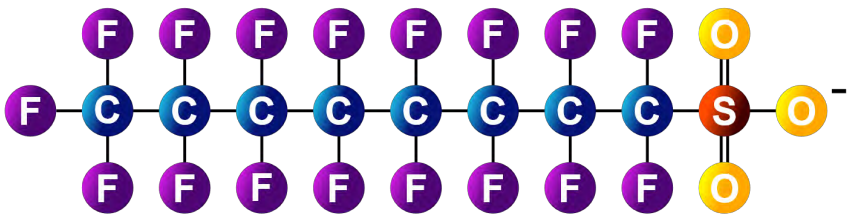
Perfluorinated

All carbons in the “tail” are bonded to fluorines, such as perfluoroalkyl sulfonates

PFOS



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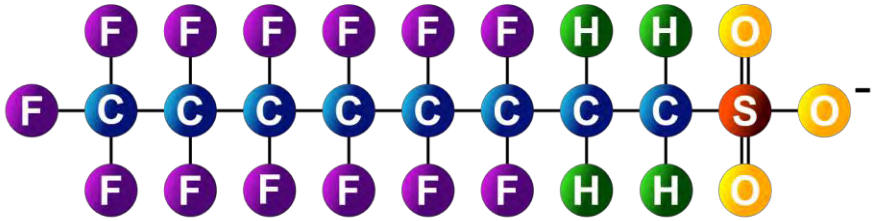
Polyfluorinated

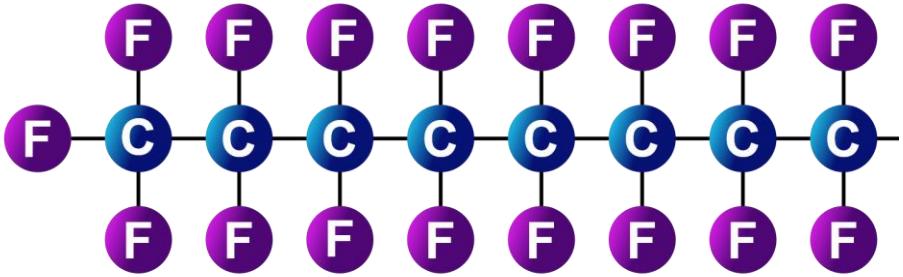
Some (not all) carbons in the “tail” are bonded to fluorines, such as fluorotelomers

6:2 FTS

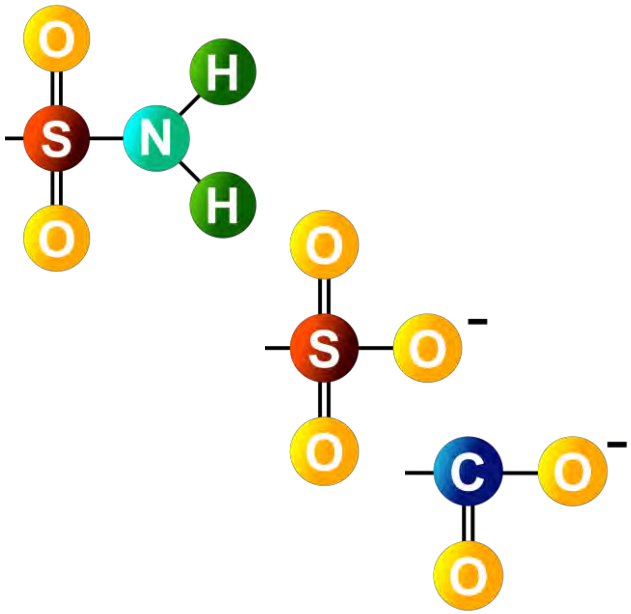


“Forever Chemicals”

Carbon – Flourine bonds in the “tail” are resistant to biogeochemical and thermal degradation



The “heads” can transform, usually to a simpler group of atoms



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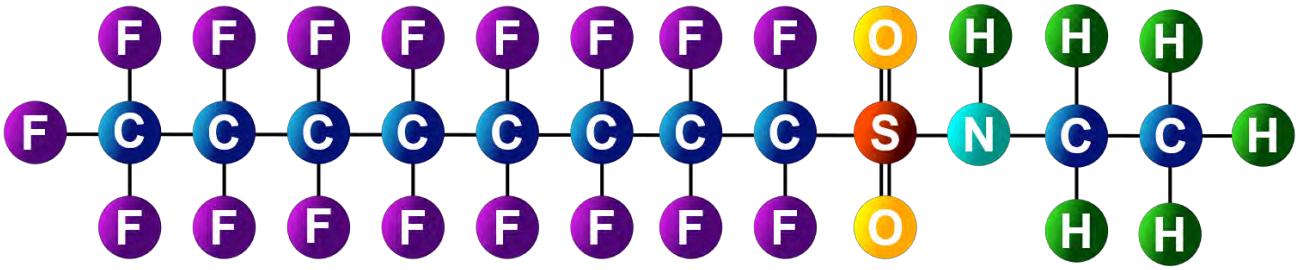
Precursors

- Complex PFAS that can transform to simpler PFAS through biogeochemical processes

N-Ethylperfluorooctanesulfonamide (NEtFOSA)



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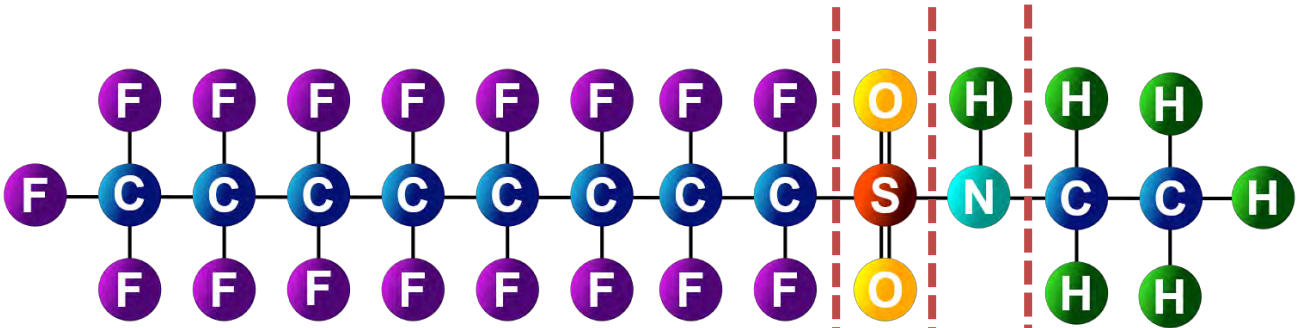
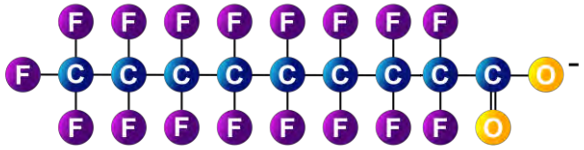
Precursors

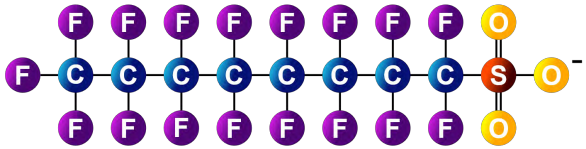
N-Ethylperfluorooctanesulfonamide (NEtFOSA)



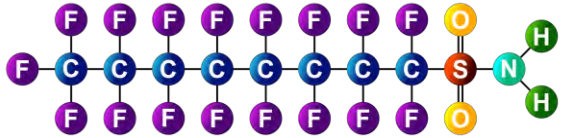
PFNA



PFOS



PFOSA (FOSA)



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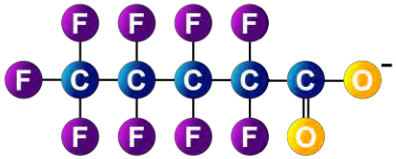
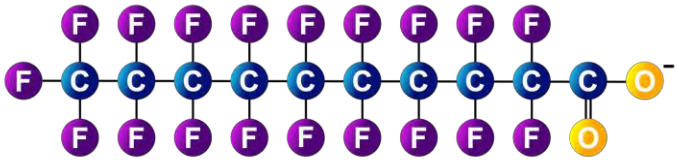
PFAS Characteristics Based on Length

SHORT CHAIN
7 or fewer carbons



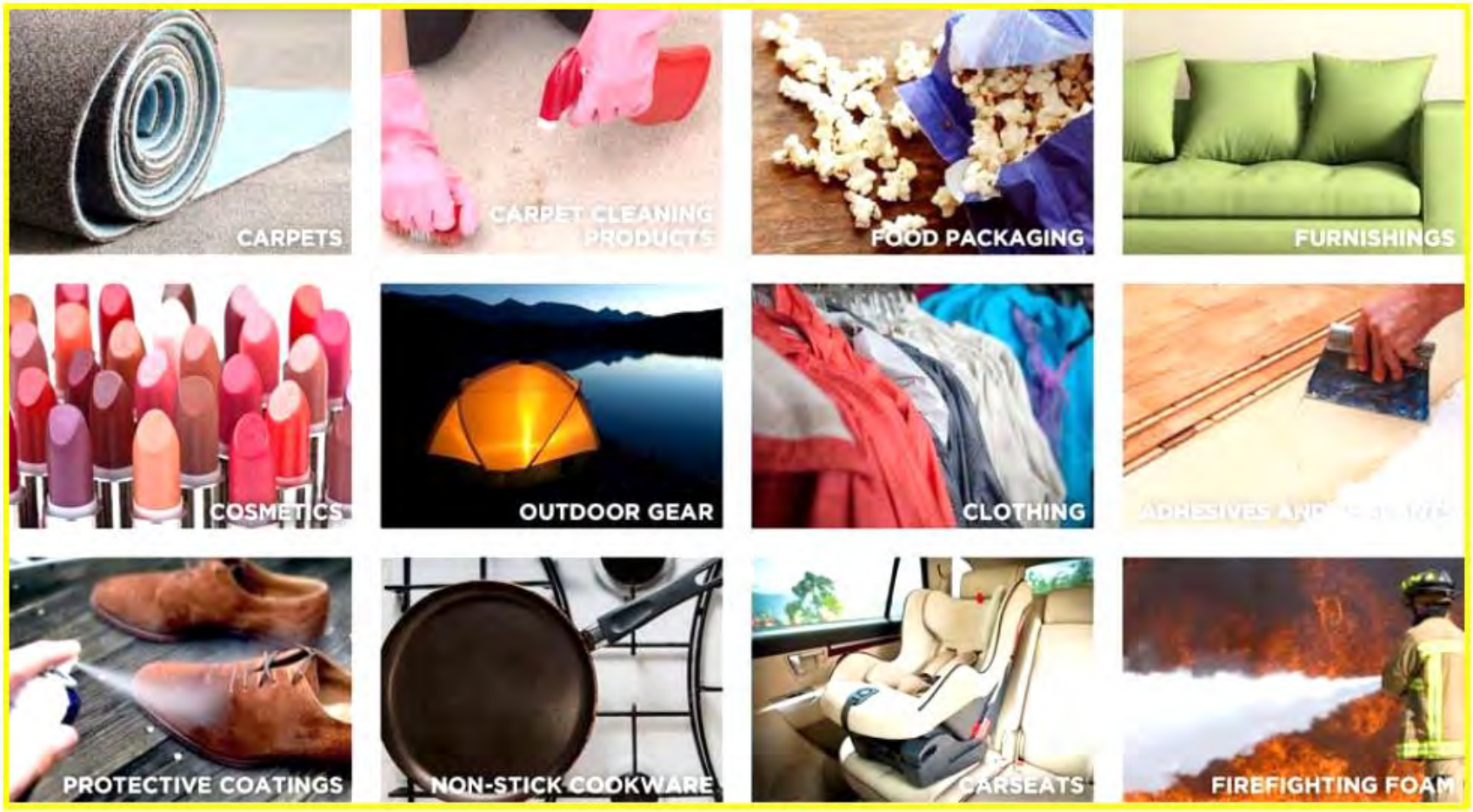
- More soluble in water
- Attracted more to the interface of air and water
- Bioaccumulate less in fish

LONG CHAIN
8 or more carbons



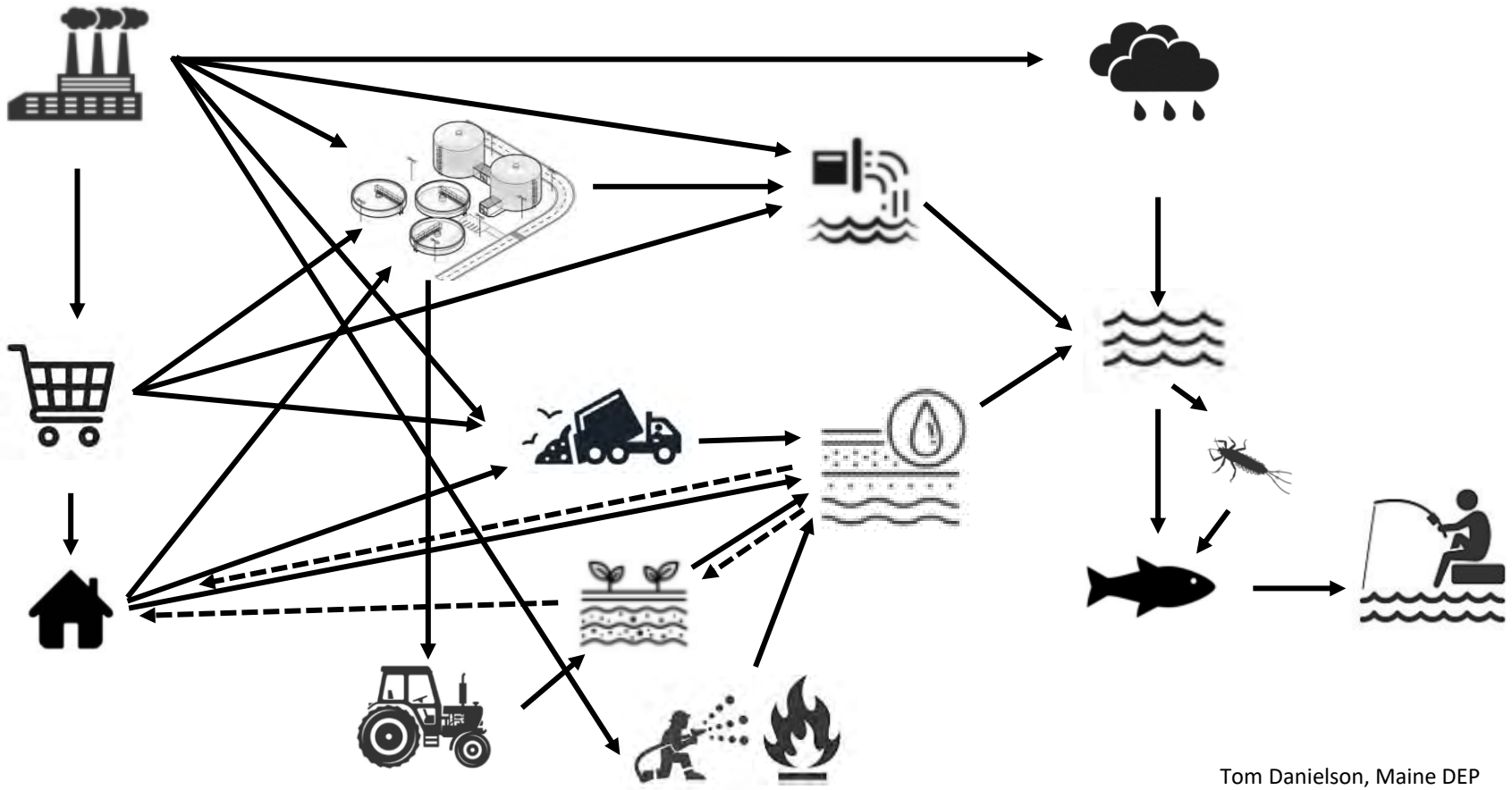
- Less soluble in water
- Bind to sediment and organic matter
- Bioaccumulate more in fish

PFAS in Products



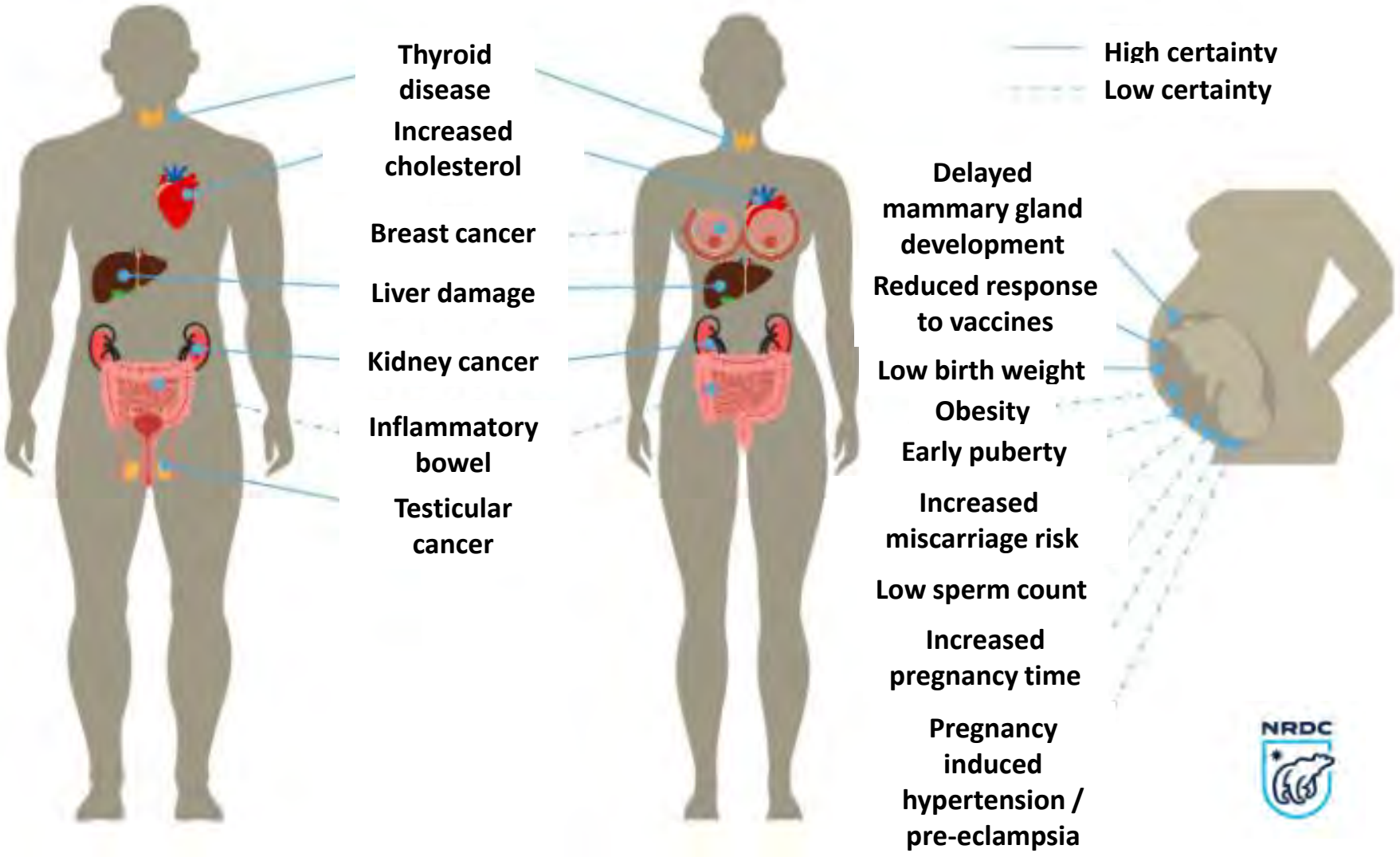
Credit: Green Science Policy Institute

PFAS Pathways from Fish to People

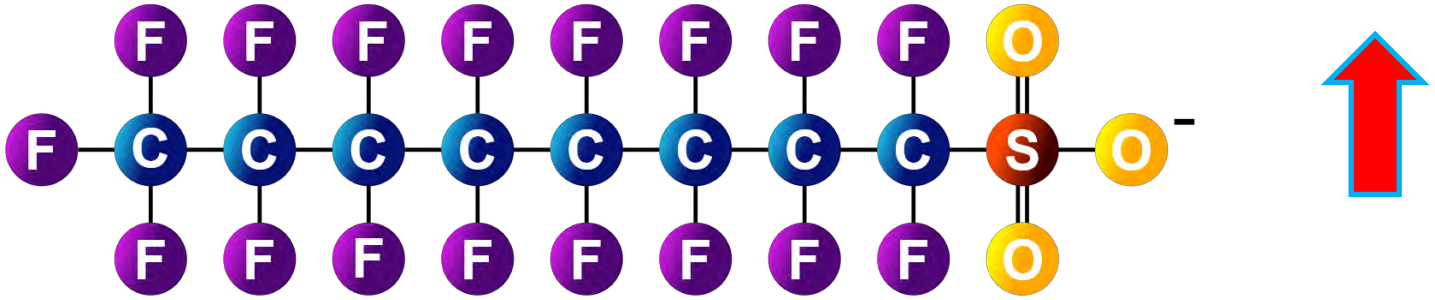


Tom Danielson, Maine DEP

Selected Health Impacts of PFAS



Perfluorooctane sulfonate (PFOS)



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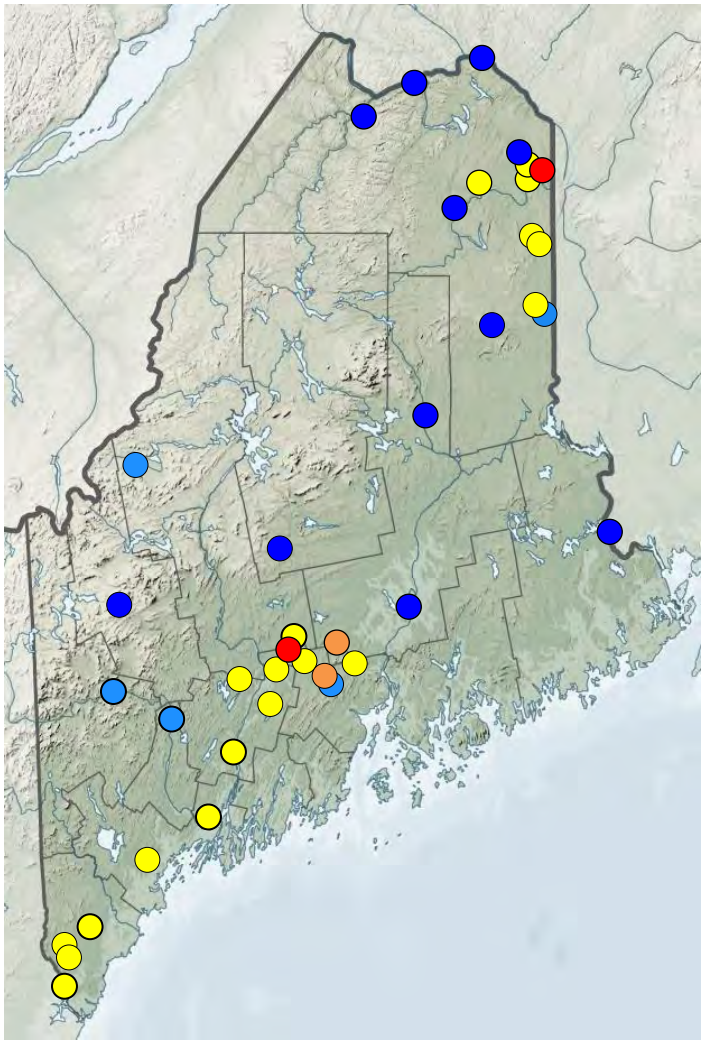
- Maine has a fish tissue action level (FTAL) for PFOS of 3.5 ppb *(ng/g wet weight)*
- Applies to freshwater and anadromous fish

PFOS in Surface Waters (2021-22)

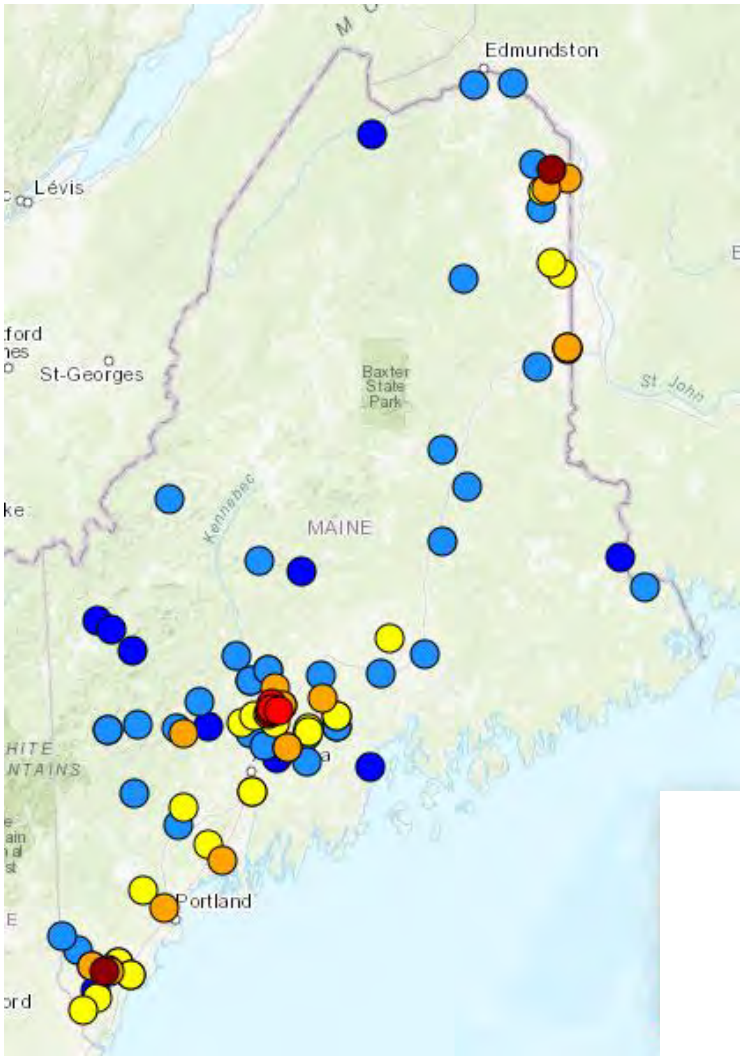


Perfluorooctane sulfonate

ng/L, ppt

- non-detect
- < 1
- 1 - 5
- 6 - 10
- > 10

Mean PFOS in Maine Fish (2014-22)



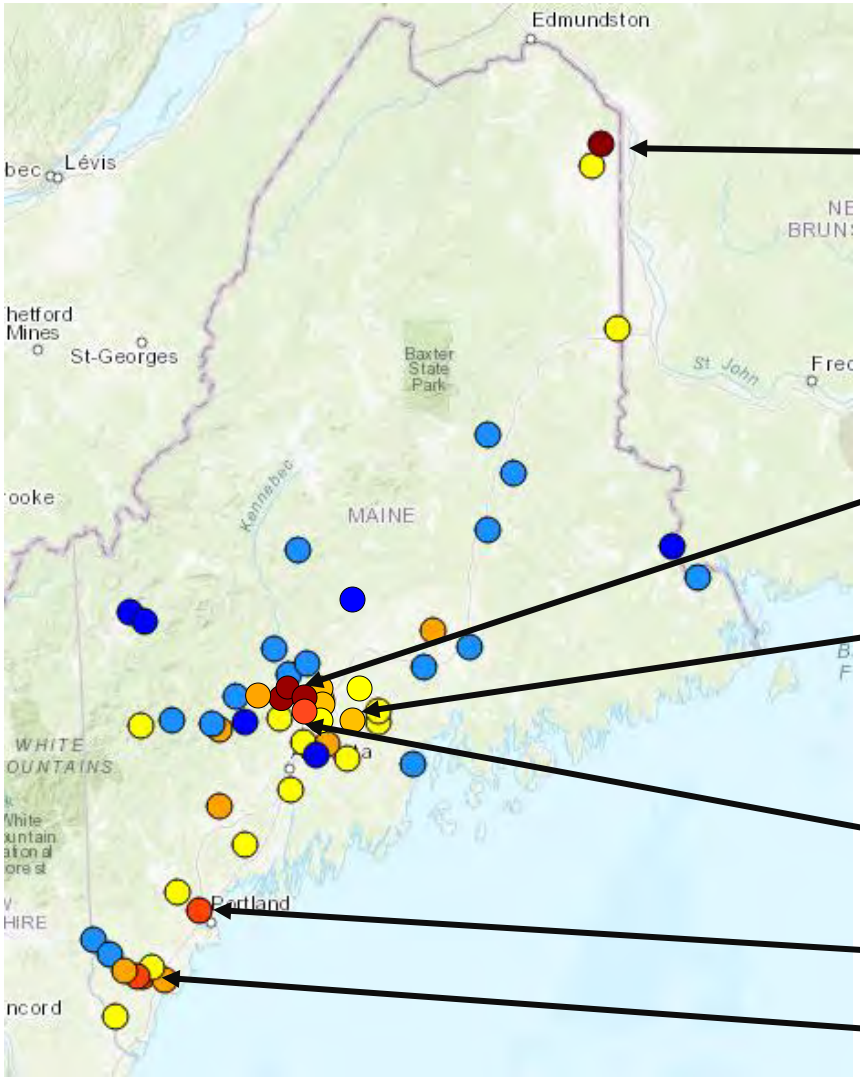
Perfluorooctane sulfonate

ng/g, ppb

- < 1
- 1 – 3.5*
- 3.5* - 10
- 10 - 40
- 40 - 100
- > 100

- Fish tissue action level (FTAL) for PFOS is 3.5 ppb

Fish Consumption Advisories



Durepo Pond & Limestone Stream (3 meals/year)

Fish Brook, Fairfield (Do not eat)
PAL Ponds, Fairfield (Do not eat)

Unity Pond, Unity
(6 meals/year for black crappies and 12 meals/year for others)

Messalonskee Stream (3 meals/year)

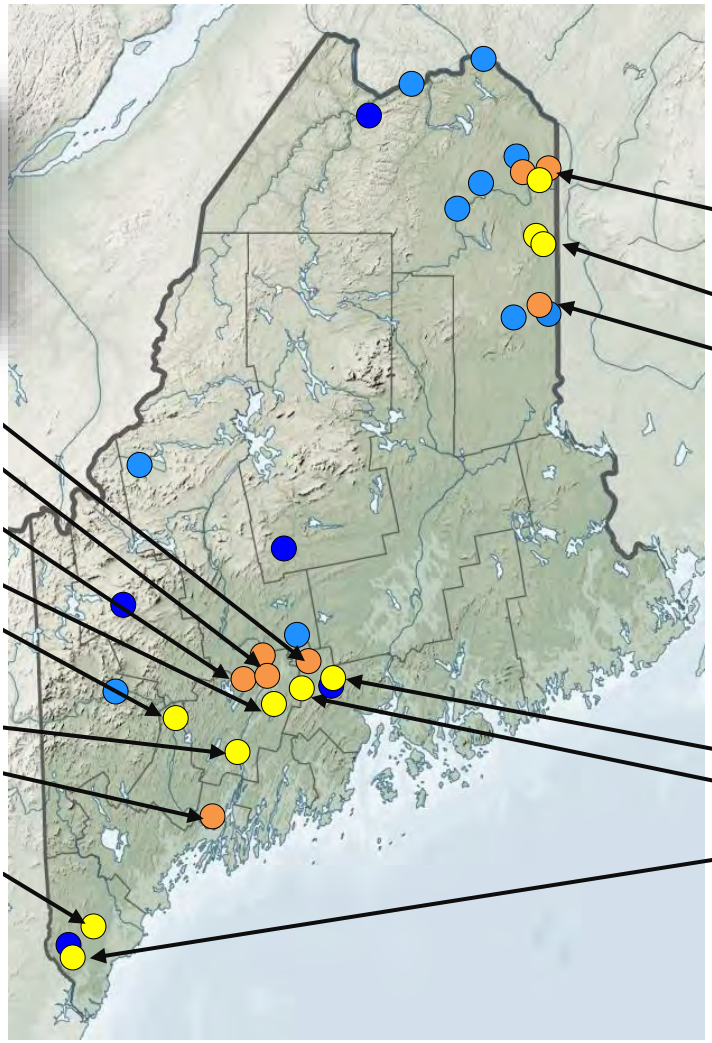
Presumpscot River (4 meals/year)

Mousam River (3 meals/year)

2022 Sites that CDC Might Review

Bass / Crappie / Perch

Unity Pond, Unity
Kennebec River, Fairfield
McGrath Pond, Oakland
China Lake, China
Androscoggin River, Livermore Falls
Kennebec River, Gardiner
Androscoggin River, Brunswick
Number One Pond, Sanford

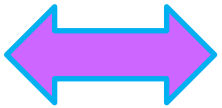
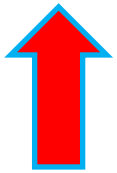


Limestone Stream
Little Madawaska River
Aroostook River, Caribou
Prestile Stream, Mars Hill
Meduxnekeag River, Houlton

Brook Trout

Halfmoon Stream, Thorndike
Fifteenmile Stream, Albion
Great Works River, North Berwick

Summary of Trends

- Mercury 
- DDT and PCBs 
- PFAS 

Next Steps

- Publish a report of the Surface Water Ambient Toxics (SWAT) monitoring program (2021-22) at the end of April
- DEP is planning 2023 monitoring
  - Mostly PFAS with a few DDT and PCB samples
- CDC will continue reviewing data for fish consumption advisories
- IF&W also is doing PFAS monitoring in 2023

SWAT Reports

https://www.maine.gov/dep/water/monitoring/toxics/swat

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