Maine CDC Scientific Brief: PFOS Fish Consumption Advisory

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The Maine Center for Disease Control and Prevention (Maine CDC) is responsible for regularly assessing whether any health threats exist for persons consuming freshwater and anadromous fish caught in state waters by noncommercial anglers and issuing a consumption advisory if threats to public health are identified (MRSA 22 § 1696 I). This document discusses recent analyses and recommendations regarding freshwater fish consumption in Maine. Specifically, it describes proposed waterbody-specific advisories based on elevated levels of PFOS in fish tissue.

I. Approach to Fish Consumption Advisories

Maine CDC derives and uses chemical-specific fish tissue action levels (FTALs) as a guide to determine the need to develop a fish consumption advisory. FTALs are concentrations of a contaminant, in this case perfluorooctane sulfonic acid (PFOS)[1], in fish tissue below which there should be negligible risk of toxicity at a set fish consumption rate. Measured concentrations of PFOS in fish tissue are compared to the FTAL and when fish tissue concentrations exceed an FTAL, the development of a fish consumption advisory is considered. Fish consumption advisories are presented as an allowable fish consumption rate that is not expected to exceed the toxicity value of PFOS. Maine CDC recently updated the PFOS FTAL to reflect the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) 2021 toxicity value, which is 10-fold lower than the U.S. Environmental Protection Agency (EPA) toxicity value upon which Maine CDC had previously relied (*see* Appendix B). Using ATSDR's toxicity value and an 8 oz fish meal size for adults, Maine CDC calculates fish tissue PFOS concentrations that correspond to specified meal frequencies (Table 1).

Maine CDC has developed an updated FTAL for PFOS of 3.5 nanograms per gram (ng/g).

Table 1. Levels of PFOS in fish and corresponding 8-ounce meal advice categories.

PFOS in fish (ng/g)	Meal advice
3.5	1 meal per week
7.5	2 meals per month
15	1 meal per month
30	6 meals per year
60	3 meals per year
> 60	Do Not Eat

Maine CDC considers issuing a fish consumption advisory if fish cannot be safely consumed at a rate of at least one meal per week. Thresholds for issuing a Do Not Eat (DNE) advisory are evaluated on a contaminant-specific basis. For PFOS, Maine CDC will issue a DNE advisory when fish cannot be safely consumed at a rate of at least three meals per year because at very low consumption rates (and the associated higher fish tissue levels), the impact on exposure to PFOS of eating just one additional fish meal

[1] For PFAS action levels, Maine CDC follows the PFAS naming convention indicated by ATSDR, which follows the U.S. CDC's PFAS terminology in using the acid form when listing the compounds full name, e.g., perfluorooctane sulfonic acid versus perfluorooctane sulfonate (ATSDR 2021).

per year becomes increasingly large. Additionally, there is still emerging science on the health effects from PFOS exposure and lower toxicity values have been adopted (European Food Safety Authority) or proposed (California and EPA). Maine CDC is aware of other states using 12 meals per year (New Jersey), six meals per year (Michigan), and one meal per year (Massachusetts) as the threshold for a DNE advisory for PFOS.

In considering whether to issue an advisory, Maine CDC also evaluates whether the resulting advisory would be more restrictive than any existing advisories[2], such as the statewide mercury fish consumption advisory (Table 2). The FTAL of 3.5 ng/g for PFOS by itself allows for consumption of 8-ounces per week of any sport caught fish of any species for adults. However, a weekly consumption of recreationally caught fish in Maine waters of up to one meal per week is only recommended for landlocked salmon and brook trout and only by a segment of the population due to the presence of mercury in fish tissue and the associated statewide consumption advisory (Table 2). For all other fish species, the statewide mercury consumption advisory is to eat no more than two fish meals per month. For sensitive populations (children less than 8 years of age and women who are or who may become pregnant), the statewide mercury advisory is much more restrictive and recommends no consumption of freshwater fish from Maine's inland waters except for landlocked salmon and brook trout which can be consumed at a rate of one meal per month. Thus, in determining whether a PFOS-specific advisory needs to be issued, Maine CDC will evaluate whether the concentrations of PFOS in fish tissue warrant an advisory that is more restrictive than the current statewide mercury advisory or any other waterbody-specific advisories.

Table 2. Statewide mercury fish consumption advisory.

Sensitive populations (pregnant and nursing women, women of childbearing age, children under age 8)	
Brook trout and landlocked salmon	One meal per month
All other species	Do Not Eat
General population (all other adults and children aged 8 and older)	
Brook trout and landlocked salmon	One meal per week
All other species	Two meals per month

[2] Current fish consumption advisories can be found under Maine CDC's Freshwater Fish Safe Eating Guidelines (https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/2kfca.htm)

II. Recommended Waterbody-Specific Fish Consumption Advisories

A. Police Athletic League (PAL) Ponds - Fairfield

Area: Both Police Athletic League (PAL) Ponds in Fairfield.

Advisory: Do Not Eat fish of any species.

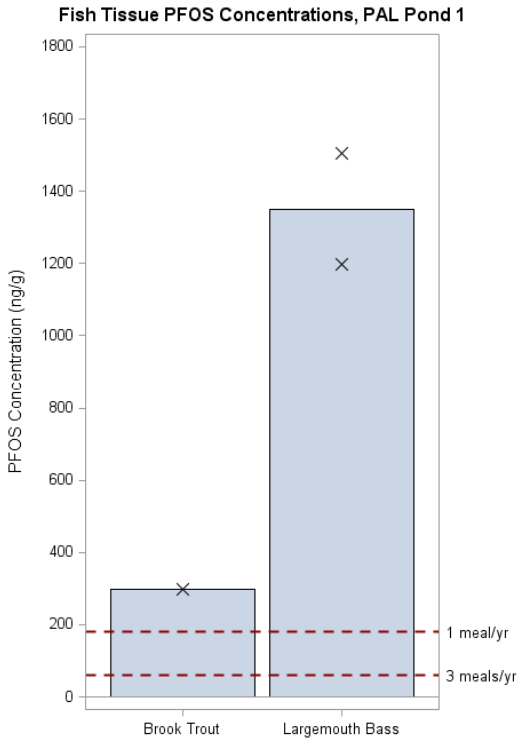

Figure 1. Fish tissue PFOS concentrations in the larger Police Athletic League Pond in Fairfield. *Each bar corresponds to the mean PFOS tissue concentration for a fish species, with the Xs corresponding to PFOS concentrations for each individual fish sample.*

Justification: A Do Not Eat advisory was previously posted at both PAL ponds in October of 2021 due to high surface water concentrations of PFOS. Sampling of fish from the larger pond conducted in September of 2021 revealed PFOS concentrations of 297 ng/g in one brook trout sample and 1,198 to 1,504 ng/g with a mean of 1,351 ng/g in two three-fish composite largemouth bass samples (see Appendix Figure A1). At these concentrations, fish cannot safely be consumed at a rate of even a single meal per year (Figure 1). Trout newly introduced into the PAL ponds in the October of 2021 were found to have PFOS levels above the Do Not Eat threshold level of 60 ng/g when sampled in November (fingerlings) and December (yearlings).

B. Fish Brook Area - Fairfield

Area: Fish Brook, including any tributaries, from the headwaters to the confluence with Messalonskee Stream.

Advisory: Do Not Eat fish of any species.

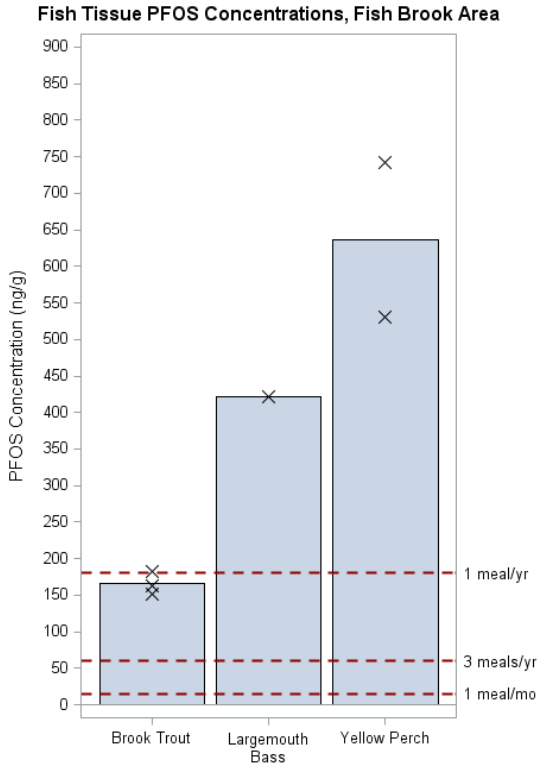

Figure 2. Fish tissue PFOS concentrations in the Fish Brook Area in Fairfield. *Each bar corresponds to the mean PFOS tissue concentration for a fish species, with the Xs corresponding to PFOS concentrations for each individual fish sample.*

Justification: In May and June of 2021 fish were sampled from Fish Brook where it meets Route 139 and from a tributary further upstream at the Ohio Hill Road (see Appendix Figure A2). Two five-fish composite brook trout samples were collected from the tributary of Fish Brook and one single brook trout sample was collected further downstream where Fish Brook meets Route 139. These brook trout had PFOS concentrations ranging from 151 to 183 ng/g (Figure 2). Additionally, one two-fish composite largemouth bass and two five-fish composite yellow perch samples were collected near Route 139 with PFOS concentrations ranging from 421 ng/g (largemouth bass) to 743 ng/g (yellow perch) (Figure 2). Given that all sampled fish had PFOS tissue concentrations above or very close to a level that could not safely be consumed at a rate of even a single meal per year, a Do Not Eat advisory is recommended for the entire waterway.

C. Messalonskee Stream – Oakland/Waterville

Area: Messalonskee Stream from the Rice Rips Dam in Oakland to the Automatic Dam in Waterville.

Advisory: Consume no more than three meals per year of any fish species.

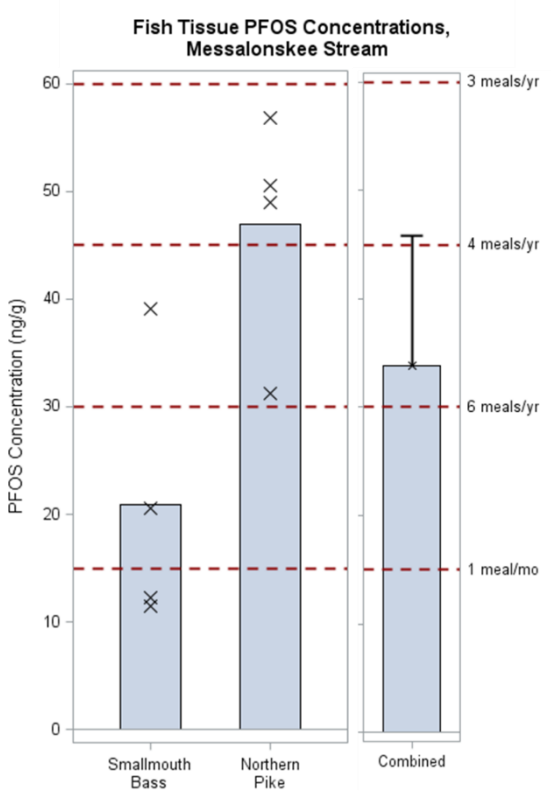

Figure 3. Fish tissue PFOS concentrations in Messalonskee Stream in Oakland and Waterville. *Each bar corresponds to the mean PFOS tissue concentration for a fish species (or both species combined). The Xs correspond to PFOS concentrations for each individual fish sample (smallmouth bass and northern pike), and the cap of the error bar corresponds to upper confidence limit on the mean (all species combined).*

Justification: In the summer and fall of 2021 a total of four five-fish composite smallmouth bass and four five-fish composite northern pike samples were sampled from two locations just upstream and downstream of the confluence of Fish Brook and Messalonskee Stream (see Appendix Figure A3). Since there are no impediments between the Rice Rips and Automatic dams, these fish were considered a part of the same population. Smallmouth bass PFOS tissue concentrations ranged from 11.5 to 39.1 ng/g with a mean of 20.9 ng/g and northern pike PFOS tissue concentrations ranged from 31.2 to 56.9 ng/g with a mean of 46.9 ng/g. Given the small sample sizes and overlapping concentration ranges, and to strive for a simplified advisory, all samples were combined for calculating summary statistics for the available fish species. Combining the northern pike and smallmouth bass samples results in a mean fish PFOS concentration of 34 ng/g and an upper confidence limit on the mean of 46 ng/g (Figure 3). Using the upper confidence limit as a conservative estimate for fish tissue PFOS concentrations results in a corresponding meal frequency of no more than three meals per year. Currently northern pike and smallmouth bass are the only species for which there are PFOS data on this waterbody.

In the absence of data on other fish species and in the interest of simplicity and ease of communication, Maine CDC recommends the above advisory apply to all fish caught in these specific waters.

D. Durepo Pond and Limestone Stream - Limestone

Area: All of Durepo Pond and Limestone Stream from Durepo to the Dam near Route 229 in Limestone.

Advisory: Consume no more than three meals per year of brook trout and Do Not Eat smallmouth bass.

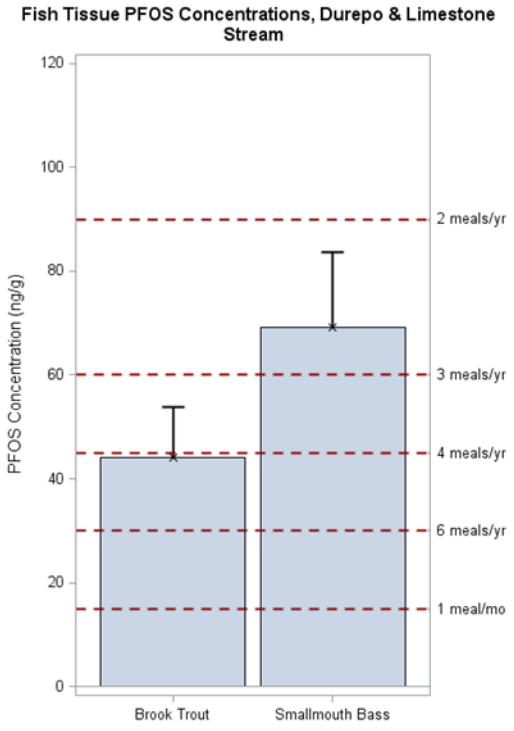

Figure 4. Fish tissue PFOS concentrations in Durepo Pond and Limestone Stream in Limestone. *Each bar corresponds to the mean PFOS tissue concentration for a fish species, with the cap of the error bar corresponding to the upper confidence limit on the mean.*

Justification: Between 2013 and 2017 four three-fish composites, one four-fish composite, and two individual brook trout samples were collected from Durepo Pond (also known as Durepo Reservoir). Additionally, in 2015 and 2016 two four-fish and one five-fish composite brook trout samples were collected from various points along Limestone stream (see Appendix Figure A4). The PFOS concentrations were not notably different between the brook trout collected from Durepo Pond and Limestone Stream, therefore these samples were combined, and the two connected waterbodies were evaluated together. The mean brook trout concentration for Durepo Pond and Limestone Stream, weighted by the number of fish in each sample, was 44 ng/g with an upper confidence limit on the mean of 54 ng/g (Figure 4). Using the upper confidence limit as a conservative estimate of fish tissue PFOS concentrations results in a corresponding consumption rate of no more than three meals per year for brook trout caught in both Durepo Pond and Limestone Stream.

Additionally, in 2015 and 2017 there were two three-fish composite and five individual smallmouth bass samples collected from Durepo Pond. The mean smallmouth bass concentration for Durepo Pond, weighted by the number of fish in each sample, was 69.2 ng/g with an upper confidence limit on the mean of 83.6 ng/g (Figure 4). Using the upper confidence limit as a conservative estimate of fish tissue PFOS concentrations corresponds to a consumption rate of no more than two meals per year, or a Do Not Eat advisory for all populations.

E. Estes Lake & Mousam River – Sanford

Area: The Mousam River from Outlet Dam on Estes Lake to Number One Pond Dam, including all of Estes Lake.

Advisory: Consume no more than three meals per year of any fish species.

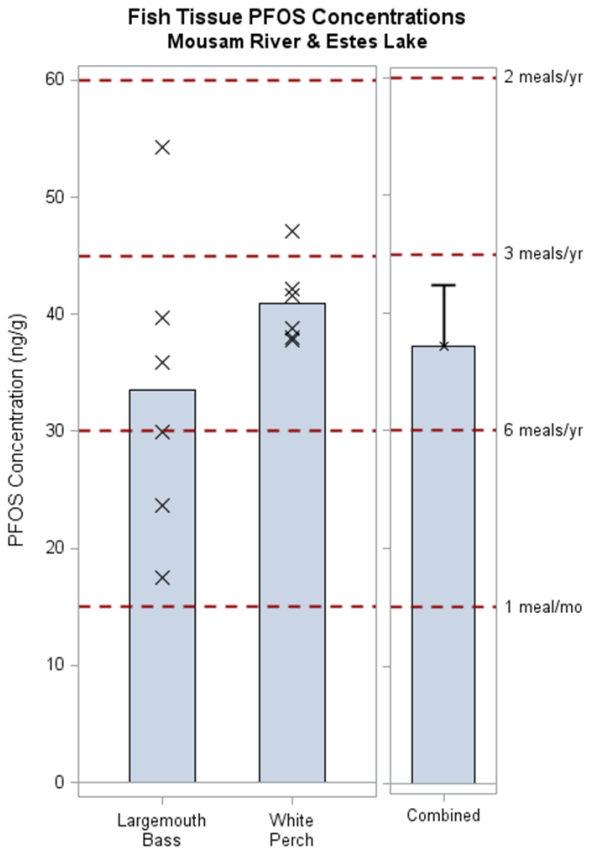

Figure 5. Fish tissue PFOS concentrations in the Mousam River and Estes Lake in Sanford. *Each bar corresponds to the mean PFOS tissue concentration for a fish species (or both species combined). The Xs correspond to PFOS concentrations for each individual fish sample (largemouth bass and white perch) and the cap of the error bar corresponds to the upper confidence limit on the mean (all species combined).*

Justification: In 2015 two five-fish composite white perch samples were collected on the Mousam River near Estes Lake in Sanford (see Appendix Figure A5). Between 2016 and 2021 four five-fish composite white perch and six five-fish composite largemouth bass samples were collected from Estes Lake. Combining the white perch samples from Estes Lake and Mousam River resulted in PFOS concentrations ranging from 37.8 to 47.1 ng/g with a mean concentration of 40.9 ng/g, and the largemouth bass samples collected from Estes Lake had PFOS concentrations ranging from 17.5 to 54.3 ng/g with a mean concentration of 33.5 ng/g. Mean PFOS concentrations in largemouth bass collected upstream from Number One Pond and Mousam Lake were lower at 12.8 and 1.6 ng/g, respectively. Given the overlapping concentrations between largemouth bass and white perch, all samples were combined for analysis, resulting in a mean PFOS concentration of 37.2 ng/g and an upper confidence limit on the mean of 42.3 ng/g (Figure 5). The 42.3 ng/g upper confidence limit PFOS concentration corresponds to a consumption rate of no more than three meals per year.

In the absence of data on other fish species and in the interest of simplicity and ease of communication, Maine CDC recommends the above advisory apply to all fish caught in these specific waters.

F. Presumpscot River - Westbrook

Area: The Presumpscot River from Saccarappa Falls in Westbrook to Presumpscot Falls in Falmouth.

Advisory: Consume no more than four meals per year of any fish species.

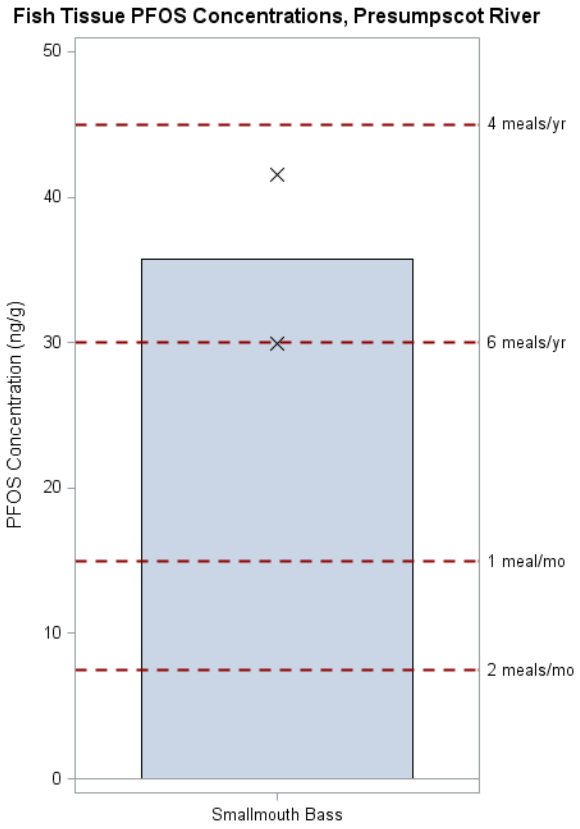

Figure 6. Fish tissue PFOS concentrations in the Presumpscot River in Westbrook. *The bar corresponds to the mean PFOS tissue concentration for smallmouth, with the Xs corresponding to PFOS concentrations for each individual fish sample.*

Justification: In June of 2020 two five-fish composite smallmouth bass samples were collected from the Presumpscot River in Westbrook (see Appendix Figure A6). These samples had PFOS tissue concentrations of 29.9 and 41.6 ng/g with a mean of 35.7 ng/g (Figure 6). Mean PFOS concentrations in smallmouth bass collected upstream in Windham were much lower at 4.2 ng/g. Given the limited data, the maximum detected PFOS concentration of 41.6 ng/g was used as a conservative estimate of fish tissue concentrations. This corresponds to a consumption rate of no more than four meals per year.

In the absence of other fish tissue data, Maine CDC recommends this advisory be applicable to all species caught on this section of the Presumpscot River.

G. Unity Pond - Unity

Area: All of Unity Pond in Unity.

Advisory: Consume no more than six meals per year of black crappie and no more than 12 meals per year for all other fish species.

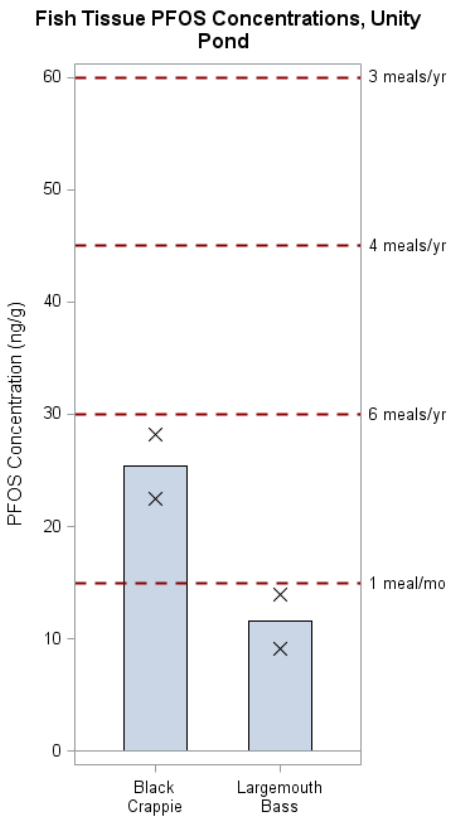

Figure 7. Fish tissue PFOS concentrations in Unity Pond in Unity. *The bars correspond to the mean PFOS tissue concentration for each species, with the Xs corresponding to PFOS concentrations for each individual fish sample.*

Justification: In October of 2021 two five-fish composite black crappie and two five-fish composite largemouth bass samples were collected from Unity Pond in Unity (see Appendix Figure A7). The black crappie had PFOS tissue concentrations of 22.5 and 28.2 ng/g for the two composite samples with a mean of 25.3 ng/g. Given the limited data, the maximum detected PFOS concentration of 28.2 ng/g was used as a conservative estimate of fish tissue concentrations. This corresponds to a consumption rate of no more than six meals per year.

The largemouth bass had PFOS tissue concentrations of 9.2 and 14.0 ng/g for the two composite samples with a mean of 11.6 ng/g. Given the limited data, the maximum detected PFOS concentration of 14 ng/g was used as a conservative estimate of fish tissue concentrations. This corresponds to a consumption rate of 12 meals per year.

In the absence of other data on other fish species, Maine CDC recommends a consumption rate of no more than 12 meals per year (1 meal per month) apply to all fish species, except black crappie for which the advice is to limit consumption to 6 meals per year.

Appendix A: Locations of Fish Sample Collections

Figure A1. Location of fish sampling for PFOS from the Police Athletic League (PAL) Ponds in Fairfield annotated with mean PFOS concentrations in each species sampled.

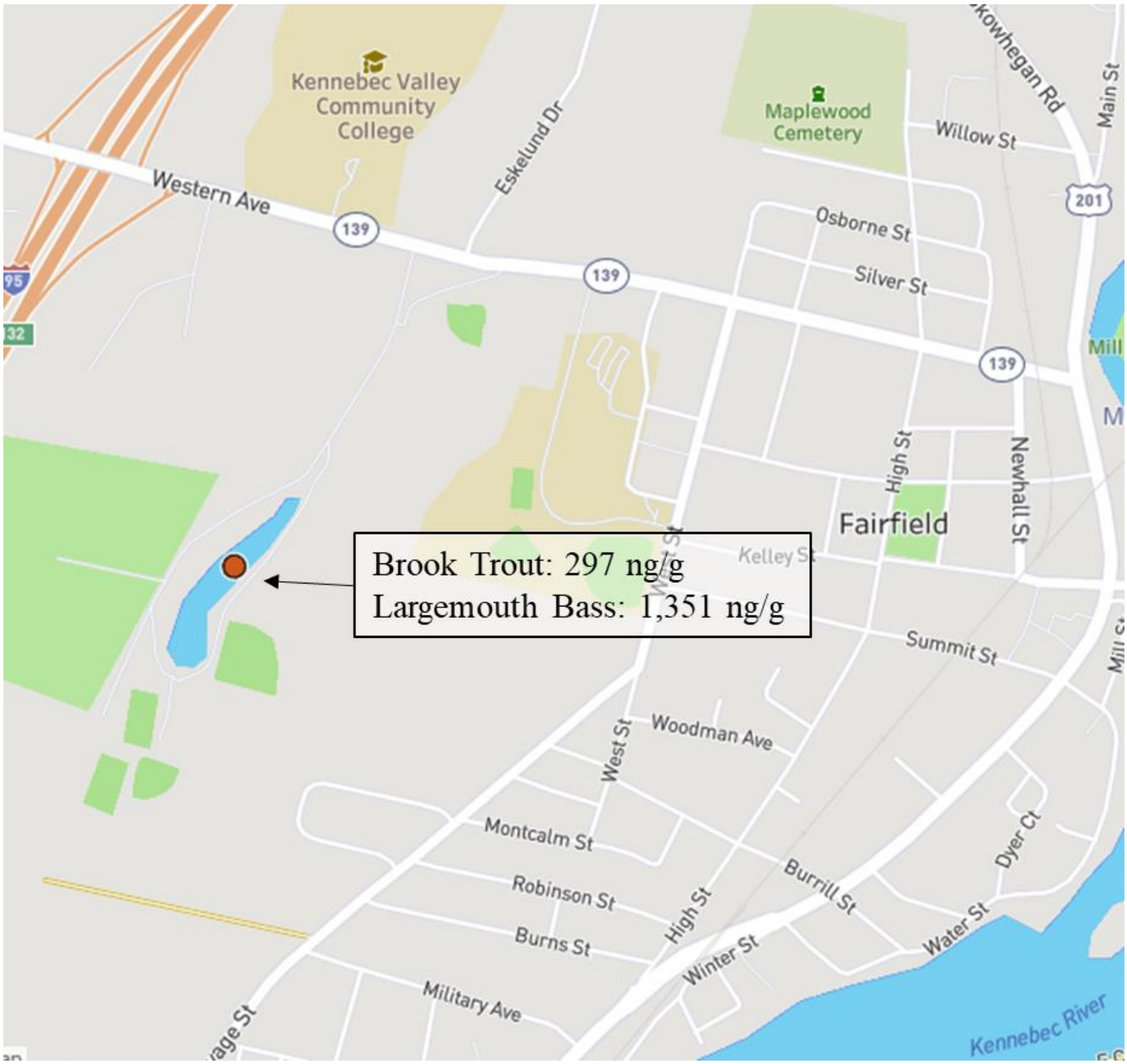

Figure A2. Location of fish sampling for PFOS from the Fish Brook area in Fairfield annotated with mean PFOS concentrations in each species sampled.

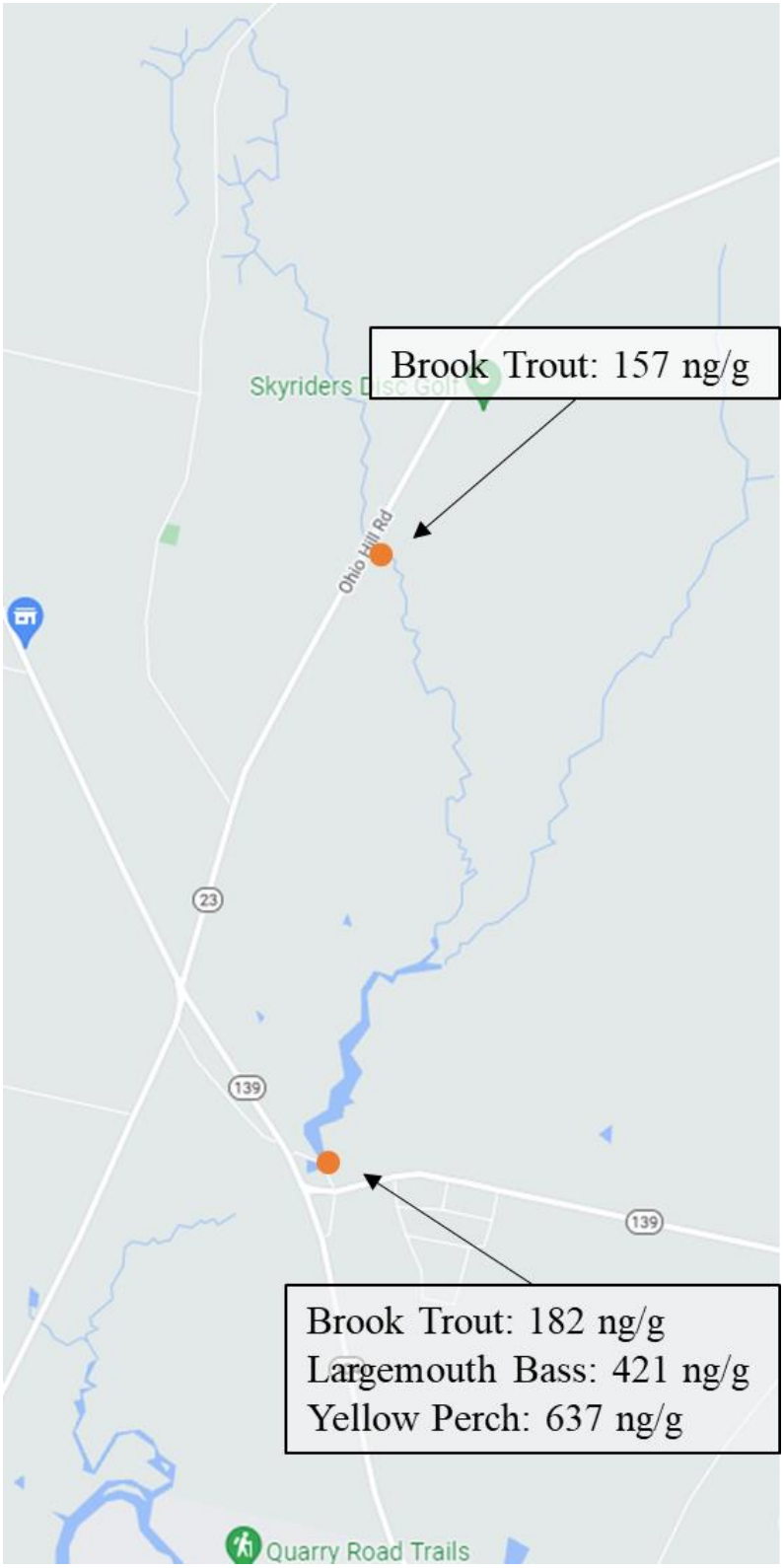

Figure A3. Location of fish sampling for PFOS from Messalonskee Stream in Oakland and Waterville annotated with mean PFOS concentrations in each species sampled.

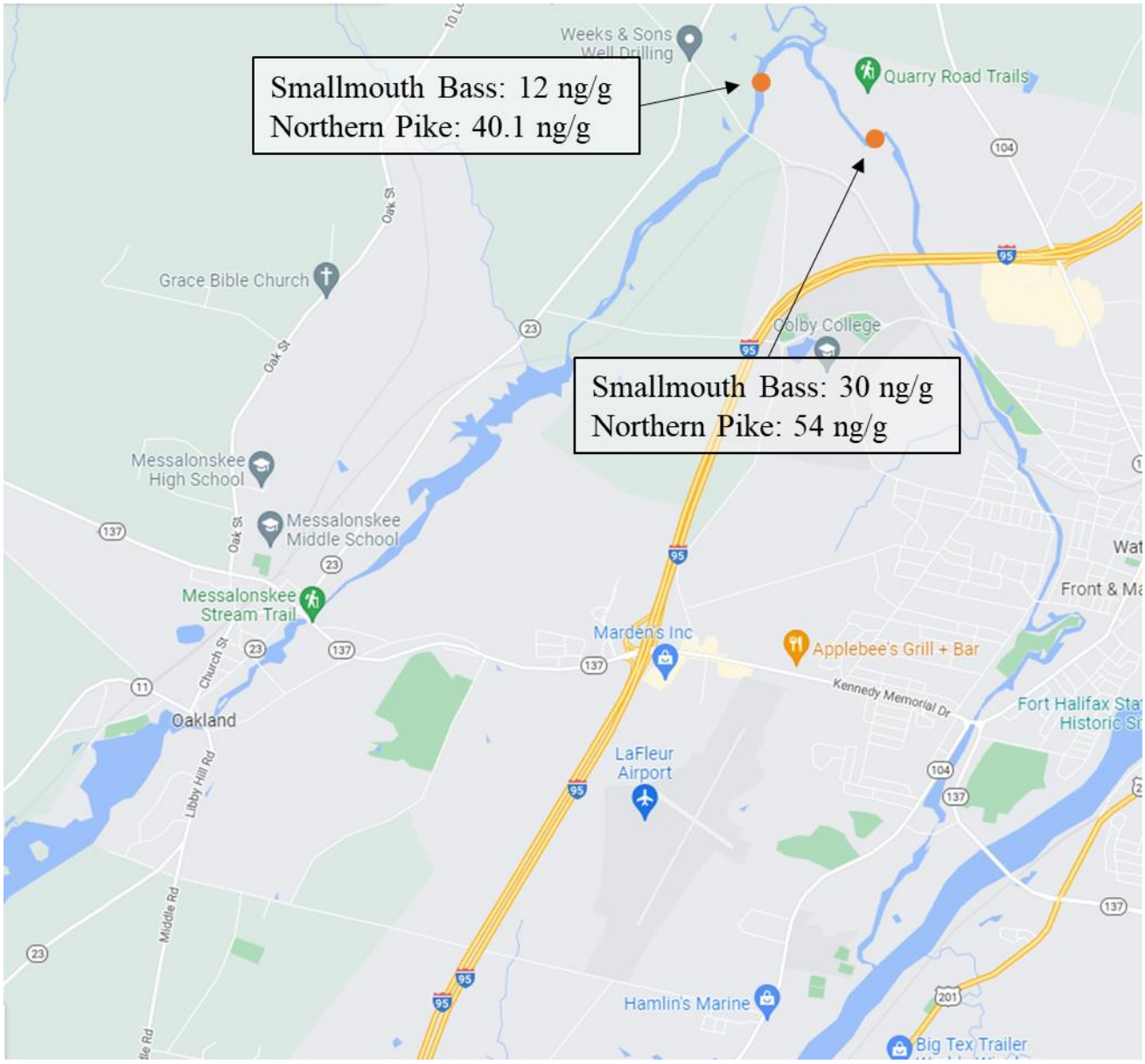

Figure A4. Location of fish sampling for PFOS from Durepo Pond and Limestone Stream in Limestone annotated with mean PFOS concentrations in each species sampled.

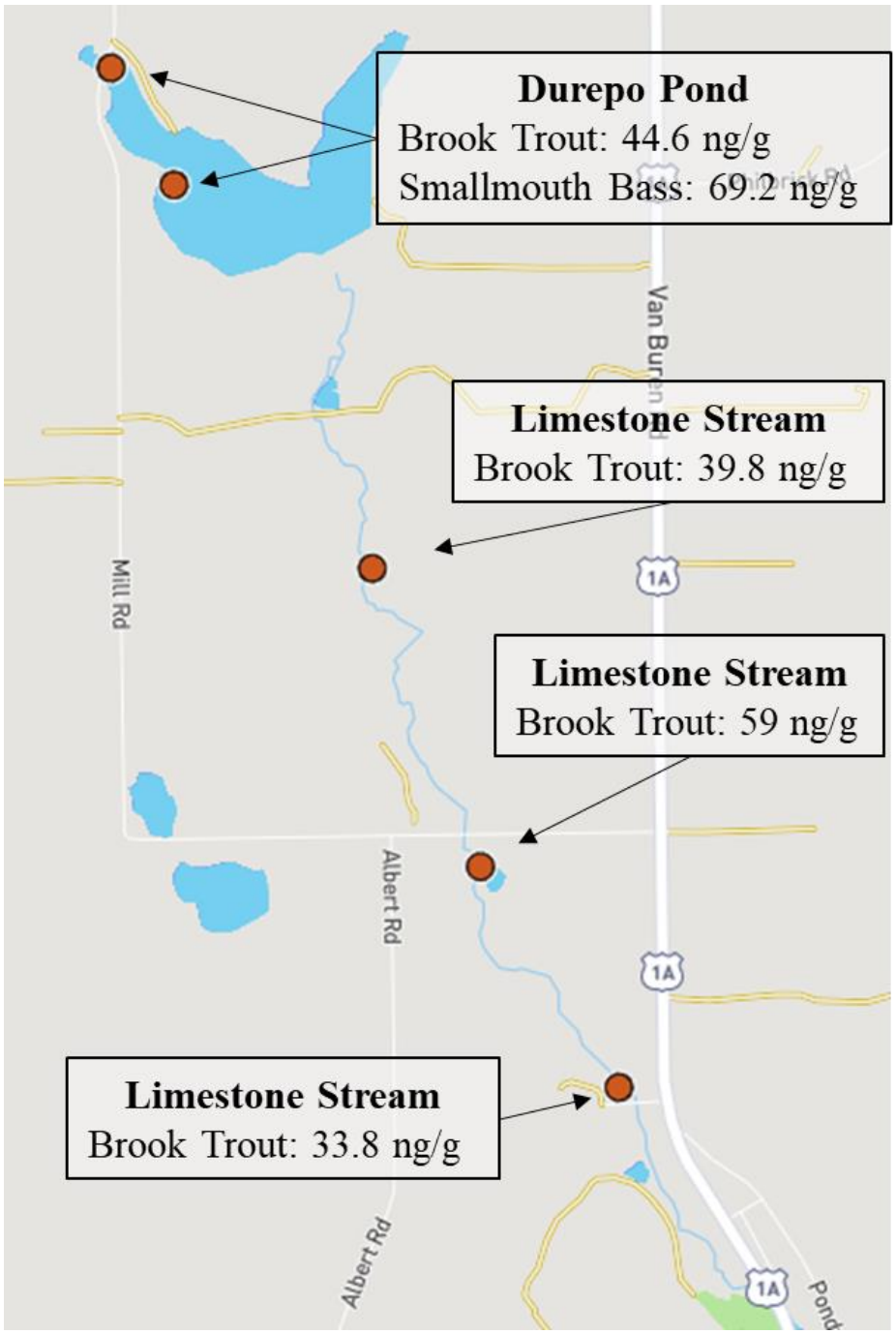

Figure A5. Location of fish sampling for PFOS from Estes Lake and Mousam River in Sanford annotated with mean PFOS concentrations in each species sampled.

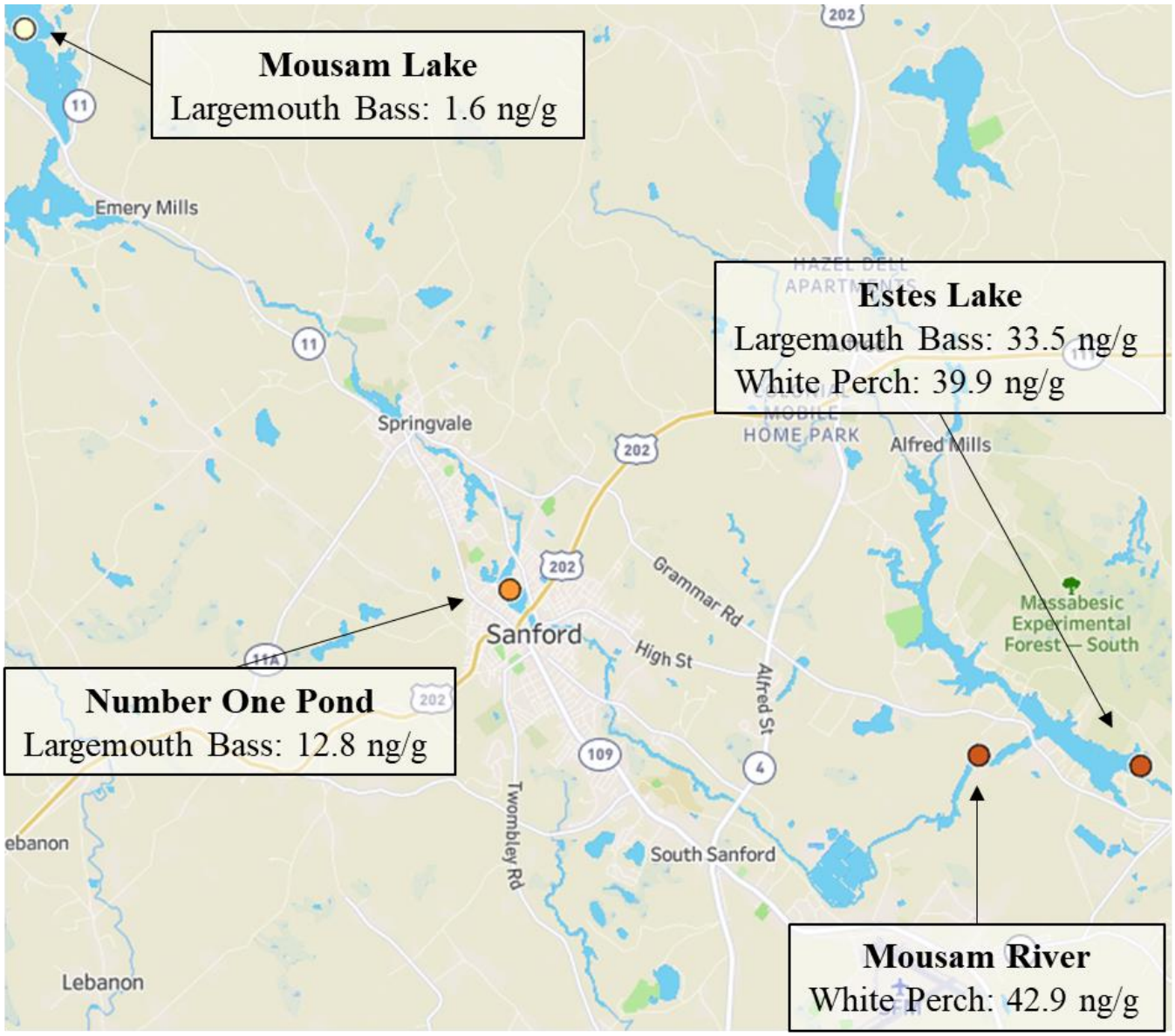

Figure A6. Location of fish sampling for PFOS from the Presumpscot River in Westbrook annotated with mean PFOS concentrations in each species sampled.

Figure A7. Location of fish sampling for PFOS from the Unity Pond in Unity annotated with mean PFOS concentrations in each species sampled.

Appendix B: Derivation of Fish Tissue Action Levels

This Appendix describes the derivation of the updated FTAL for PFOS. As noted above, if conditions exist in which consumption of fish caught in state waters poses a threat to public health, then Maine CDC will issue a corresponding fish consumption advisory. Maine CDC derives and uses fish tissue action levels (FTALs) as a guide to determine the need to develop a fish consumption advisory. Contaminant-specific FTALs in fish are derived following the U.S. Environmental Protection Agency (EPA) Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 1996; EPA 2000a; EPA 2000b). FTALs are concentrations of a contaminant in fish tissue below which there should be negligible risk of toxicity at a set fish consumption rate. Maine CDC typically uses a fish consumption rate of 8-ounces of recreationally caught fish per week. This fish consumption rate is considered protective of most sport fishers. Measured concentrations of contaminants in fish tissue are compared to contaminant specific FTALs. When fish tissue concentrations exceed an FTAL, the development of a fish consumption advisory is considered.

As noted above, Maine CDC has developed an updated FTAL for PFOS of 3.5 nanograms per gram (ng/g).

A. Updating Maine's FTAL based on ATSDR's Toxicity Value for PFOS

In 2018, FTALs for PFOS were developed in response to elevated levels of PFOS detected in fish tissue in an area surrounding the former Loring Air Force Base near Limestone, Maine (Maine CDC 2018). The 2018 PFOS FTALs were 34.1 ng/g for the sensitive population defined as pregnant women, women of childbearing age, and children under the age of 8, and 79 ng/g for the general population of all other adults and children 8 years of age and older. The FTAL for the sensitive population was developed using the EPA Office of Water PFOS reference dose (RfD) of 20 nanograms/kilogram/day (ng/kg/day), based on developmental effects in an animal study (EPA 2016). The general population FTAL was developed using a candidate RfD from the EPA Office of Water for changes in liver and kidney function observed in an adult animal study (EPA 2016). Since this time, several states and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) have derived their own toxicity values for PFOS that range from 1.8 ng/kg/day up to 5 ng/kg/day.

These lower state and ATSDR toxicity values are based on adult animal studies of immune system toxicity as the most sensitive endpoint. The European Food Safety Authority (EFSA) developed a tolerable weekly intake for PFOS and three other PFAS based on human epidemiological studies of reduced vaccine response in 1-year old children that equates to a toxicity value of 0.6 ng/kg/day (EFSA CONTAM Panel 2020). Additionally, in November of 2021 as part of the EPA's process to establish a maximum contaminant level for PFOS in drinking water the EPA proposed a new draft PFOS RfD that is considerably lower than anything previously proposed or adopted. The U.S. Food and Drug Administration (FDA) has reported that it now relies on the ATSDR Minimal Risk Levels (MRLs) for assessments of the safety of exposure to certain PFAS detected in foods (FDA 2021). Based on the growing scientific consensus that PFOS toxicity values lower than the 2016 EPA values are appropriate, and that immune system toxicity is a more sensitive endpoint than developmental toxicity, Maine CDC has updated the PFOS FTAL using the PFOS toxicity value published by ATSDR in May 2021 (ATSDR 2021).

B. Action Level Derivation

Fish consumption advisories based on noncarcinogenic toxicological endpoints are set at a level believed to represent a minimal risk of a deleterious effect from lifetime exposure even for sensitive subpopulations. It is assumed that noncarcinogenic toxicological endpoints have a threshold response (i.e., there is a dose below which toxic effects will not occur). Fish consumption advisories are set such that total exposure from eating on average 8 ounces per week will result in a daily dose below the threshold.

1. Action level equation

Maine CDC derived the PFOS FTAL using EPA's standard for determining action levels for noncancer toxicological endpoints (EPA 2000a). FTALs are calculated using the following equation:

$$FTAL = \frac{(RfD \times BW)}{FC} X\ RSC \qquad (Eq. 1)$$

Where,

FTAL = Fish Tissue Action Level in nanograms per gram (ng/g)

RfD = Reference Dose in nanograms per kilogram body weight per day (ng/kg/day)

BW = Body Weight in kilograms (kg)

FC = Fish Consumption Rate in grams per day (g/day)

RSC = Relative Source Contribution (unitless)

2. Equation inputs

A. Reference dose

A reference dose (RfD) is defined by the EPA as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure level (mg/kg/day) for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 2000a). Reference doses are both chemical and toxicological endpoint specific. The lower the RfD value, the more toxic the substance.

In selecting a RfD, Maine CDC typically relies on toxicity values developed by federal agencies, e.g., the EPA or the ATSDR. In May 2021 ATSDR finalized its toxicity profile for PFAS which included the derivation of MRLs for PFOS, PFOA, PNFA, and PFHxS (ATSDR 2021). Maine CDC is currently utilizing the ATSDR MRL for PFOS to develop food-related action levels.

The ATSDR MRL of 2 ng/kg/day for PFOS was derived from the same developmental toxicity study EPA relied on in 2016 to develop its 20 ng/kg/day RfD. To account for immune effects as a potentially more sensitive endpoint, ATSDR applied a 10-fold modifying factor to the derivation of the MRL based on developmental effects. The addition of the 10-fold modifying factor effectively reduced the developmental endpoint MRL of 20 ng/kg/day to 2 ng/kg/day for the final PFOS MRL. A number of states have developed their own toxicity values for PFOS based on the reported immune system toxicity in adult animal studies with values ranging from 1.8 to 3 ng/kg/day, which is consistent with the 2 ng/kg/day

MRL developed by ATSDR (NJ 2016; MI 2019; MN 2019; NH 2019). ATSDR did not utilize the immunotoxicity studies directly due to a lack of pharmacokinetic model parameters required to estimate a time-weighted average serum level for the mouse strains used and instead applied the 10-fold modifying factor (ATSDR 2021).

Given Maine CDC's preference for relying on toxicity values developed by federal agencies and the general consensus that a toxicity value in the range of 1.8 to 3 ng/kg/day is protective over immune system effects observed in adult laboratory animals, ATSDR's 2 ng/kg/day PFOS MRL has been selected to derive the FTAL for PFOS. Further, given that the observed immune system effects occurred at lower exposures than the observed developmental effects, the 2 ng/kg/day PFOS MRL is protective of exposure to all populations, thus eliminating the need for population specific PFOS FTALs.

B. Body weight

The estimated body weight (BW) of the exposed individual is required in the action level calculation since the RfD is expressed on a "per kilogram body weight" basis. The most recent edition of the EPA's Exposure Factors Handbook (EPA 2011) recommends use of an average body weight of 80 kg for all adults. As noted in the fish consumption rate section below, use of an 80 kg body weight for adults produces a generally protective fish consumption rate on a body weight basis as compared to other age groups and populations.

C. Fish consumption rate

A fish consumption rate (FCR) of 8 ounces (227 grams) per week is used to derive action levels. This consumption rate corresponds to the standard health-based recommendation for fish consumption for adults (AHA 2021; FDA 2021). An 8-ounce per week consumption rate is equivalent to an average daily FCR of 32.4 grams per day (g/day). This consumption rate is considered protective of fish consumption by most individuals who consume recreationally harvested fish and is supported by the following sources:

- EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories (EPA 2000a) recommends a default fish consumption rate of 17.5 g/day. The EPA's default fish consumption rate has since been updated to 22 g/day (EPA 2014), which represents the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the US adult population (≥21 years of age) based on National Health and Nutrition Examination Survey (NHANES) data from 2003-2010.

- A survey of Maine sport fishers (Ebert et al. 1993) reported a 95th percentile consumption of 26 g/day for all inland waters (lakes, ponds, rivers, streams, and brooks), assuming equal consumption of sport caught fish among all household members. If only adults share consumption, the 95th percentile consumption increases to 28 g/day. EPA preferentially recommends the use of local data, the use of data reflecting similar geography or population groups, or the use of data from national surveys over the default consumption rate (EPA 2000a; EPA 2015).

- A recent National survey of high-frequency fish consumers in the U.S. (von Stackelberg et al. 2017) examined rates of overall and self-caught fish consumption among individuals consuming three or more fish meals per week, which corresponds to the 95th percentile of fish

consumption as reported in NHANES. Mean self-caught fish consumption among these high-frequency fish consumers was 30 g/day. The survey further reported regional differences in self-caught fish consumption with the East-South Central and New England regions reporting the lowest consumption rates of self-caught fish (12 to 16 g/day).

Based on these data, it is judged that a fish consumption rate of 32.4 g/day is conservatively representative of an upper-level fish ingestion rate for Maine recreational anglers and is consistent with health-based guidance for recommended fish consumption.

In many dietary risk assessments child intake rates are calculated separately from adults as they may have a higher intake on a body weight basis. However, there is limited available survey data on child consumption of recreationally caught sport fish. In lieu of child-specific sport fish intake rates, Maine CDC compared the usual fish consumption rate estimates for freshwater and estuarine fish for children aged 1 to 6 years and adults, adjusted for body weight (EPA 2014; EPA 2011). The usual fish consumption rates compiled by EPA are based on national dietary recall survey data from the U.S. CDC's NHANES. The usual fish consumption rates are only provided on a g/day basis but can be adjusted to estimate rates on a g/kg body weight/day basis using nationally representative body weight estimates from EPA's Exposure Factors Handbook (EFH).

Table B1. Comparison of body weight-adjusted fish consumption rates (NHANES 2003-2010).

Fish consumption age grouping	90th percentile intake (g/day) (EPA 2014)	Age group mean body weight (kg) (EPA 2011)	Estimated 90th percentile intake (g/kg/day)
1 - <3 years	4.7	12.6	0.37
3 - <6 years	5.8	18.6	0.31
>21 years	22	80	0.28

Using Maine CDC's adult fish consumption rate of 32.4 g/day and the adult mean body weight of 80 kg yields a body weight-adjusted consumption rate of 0.405 g/kg/day. This adult rate 0.405 g/kg/day consumption rate is higher than the young child age groups rates of 0.37 g/kg/day for a 1 to 3-year-old and 0.31 g/kg/day for a 3 to 6-year-old. Thus, the consumption rate for an adult will be protective for these younger consumers.

D. Relative source contribution

EPA's Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories (EPA 2000a, b) encourages states to use available information on other non-fish sources of exposure when possible in setting consumption limits. As noted above, the RfD represents a toxicological threshold below which the risk of a deleterious effect is considered negligible. By using the RfD to set an FTAL, there is an inherent assumption that 100% of the daily intake for a chemical comes from fish consumption. In such a case, any additional "background" exposures via consumption of other foods, drinking water, etc. could result in cumulative exposures that exceed the RfD. EPA's fish advisory guidance (EPA 2000b) recommends states use available exposure information to apportion some fraction of the total allowable daily dose (e.g., 10,

20, or 30 percent) to fish consumption. EPA's guidance specifically references a Relative Source Contribution (RSC) approach that was being developed at the time of publication. A method of evaluating an RSC to account for multiple sources of exposure to pollutants has since been published in the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (EPA 2000c; EPA 2015).

It is clear from U.S. CDC biomonitoring programs that exposure to PFOS is ubiquitous, as it is present in the blood of most individuals tested in recent samplings of Americans 12 years and older (USCDC 2021). The presence of PFOS, as well as several other PFAS, in the general U.S. population is the result of exposure from multiple sources, including dietary sources, house dust, drinking water, and indoor and outdoor air (ATSDR 2021; Egeghy and Lorber 2011; Gebbnik et al. 2015; Trudel et al. 2008). PFOS levels measured in blood may also reflect some contribution of exposure to PFOS precursors that have undergone biotransformation to PFOS within the body (Gebbnik et al. 2015; Vestergren et al. 2008). When there is no known exposure source, e.g., contaminated community drinking water, studies estimating daily PFOS exposures from various media suggest that the largest contributor to overall PFOS exposure is likely diet for adults, and diet and house dust for young children (Egeghy and Lorber 2011; Tittlemier et al. 2007; Trudel et al. 2008). However, the magnitude and relative contribution of these external daily exposure estimates from various individual sources, such as diet, indoor dust or drinking water, are uncertain and may not be entirely representative of current exposures for the general U.S. population.

A measured PFOS serum level in an individual represents a comprehensive exposure metric as serum integrates all external exposures and absorption from diet, water, hand-to-mouth activities, inhalation etc. Measured PFAS serum levels from U.S. CDC National Health and Nutrition Examinations Surveys (NHANES) biomonitoring studies, which are designed to be nationally representative of the general U.S. population, reflect exposure to PFAS, including PFOS, from all sources for the general population. Thus, measured PFAS serum levels from NHANES biomonitoring can be viewed as representative of background exposure for the general U.S. population and utilized to estimate an RSC factor.

To derive a PFOS-specific RSC factor using recent NHANES PFOS serum levels, Maine CDC utilized a one-compartment pharmacokinetic model (Equation 2). This is the same pharmacokinetic model EPA and ATSDR applied in their PFOS RfD and minimum risk level (MRL) derivations, respectively, to convert a dose on a serum level basis to an oral intake dose (EPA 2016; ATSDR 2021). The pharmacokinetic model converts a measured serum to an oral equivalent dose, i.e., the ingested dose on a body weight basis that is required to result in the measured serum level.

$$Background\ exposure\ (ng/kg/day) = Cp \times kp \times Vd \quad (Eq.2)$$

Where,

Cp = PFOS serum concentration in nanograms per milliliter (ng/mL)

kp = first-order elimination rate in per day (1/day or day^{-1})

Vd = volume of distribution in milliliters per kilogram body weight (mL/kg)

For a serum concentration, Maine CDC used the total population geometric mean PFOS serum concentration of 4.25 ng/mL from the 2017-2018 NHANES survey (USCDC 2021), a PFOS elimination rate of 0.00056 day^{-1}, based on a PFOS human half-life of 1241 days (Li et al. 2018), and a volume of distribution of 230 mL/kg-body weight for an adult (Thompson et al. 2010). The calculated background PFOS exposure on a ng/kg/day basis using the geometric mean serum level of 4.25 ng/mL for the total population ages 12 years and older based on the 2017-2018 survey is 0.55 ng/kg/day and is trending downward. The geometric mean was selected to represent the central tendency PFOS serum level, as it is EPA guidance to use central tendencies for RSC intake estimates (EPA 2000c).

Considering this oral equivalent dose to represent average, general background PFOS exposure, the remaining dose which could be allocated to other sources is calculated by subtracting the background exposure from the 2 ng/kg/day PFOS RfD. Here the selected PFOS RfD is the ATSDR PFOS MRL. The RSC is derived by dividing the remaining dose by the PFOS RfD (Equation 3).

$$RSC = \frac{PFOS\ RfD\ (ng/kg/day) - Background\ exposure\ (ng/kg/day)}{PFOS\ RfD\ (ng/kg/day)} \times 100 \quad (Eq.3)$$

Using the 0.55 ng/kg/day background exposure estimate in comparison to the ATSDR PFOS MRL of 2 ng/kg/day produces an RSC of 73%. The rounded value of 70% is used as the RSC for PFOS.

Given that there is also exposure to other PFAS, such as PFOA, PFNA, and PFHxS where there may be a potential for additive toxicities, RSC values were calculated for PFHxS, PFOA, and PFNA based on ATSDR MRLs and NHANES 2017-2018 geometric mean serum levels. Using a toxicity value-weighted approach, the sum of the average daily exposure to PFOS, PFOA, PFNA, and PFHxS results in an RSC of approximately 60%. The 60% RSC is largely dominated by PFOS and PFOA which have higher background serum levels than PFNA and PFHxS. As levels for these four PFAS have continued to decrease based on NHANES biomonitoring from 1999-2018, it's expected that current serum levels are

lower than 2017-2018 years. Lower background serum levels would result in a calculated RSC of greater than 60%. The use of a 70% RSC for PFOS is therefore considered generally protective of potential additive effects of background exposure to other PFAS for which toxicity values and serum data are available.

3. Action level

Using ATSDR's 2 ng/kg/day MRL, the standard 80 kg adult body weight, a conservative upper estimate of 32.4 g/day of sport fish consumption, and a 70% RSC to account for background exposure to PFOS as inputs to Equation 1, Maine CDC calculated a PFOS FTAL of 3.5 ng/g. This updated PFOS FTAL is applicable to both sensitive and general populations. The ATSDR MRL accounts for both developmental effects in animal studies and immune system effects in adult animal studies which occur at lower doses than the developmental effects. Further, the 32.4 g/day fish consumption rate on a body weight basis for adults is not likely to be exceed for young children when accounting for differences in body weight. Thus, the 3.5 ng/g PFOS FTAL is sufficiently protective of both adult and child populations.

4. Action level implementation

In accordance with MRSA 22 § 1696 I, if fish sampled from Maine freshwater have levels of PFOS that exceed the FTAL of 3.5 ng/g, Maine CDC will consider issuing a fish consumption advisory. Fish consumption advisories are presented as an allowable fish consumption rate that is not expected to exceed the toxicity value. Using an 8 oz fish meal size for adults, Equation 1 is used to calculate PFOS concentrations in fish that correspond to specified meal frequencies (e.g., 1 meal per week, 2 meals per month, etc.). Table B2 lists the PFOS fish tissue concentration ranges associated with meal frequencies that are used in assessing the need for consumption advisories. As a matter of policy, Maine CDC will only consider issuing a fish consumption advisory if fish cannot be safely consumed at a rate of at least one meal per week. Thresholds for issuing a Do Not Eat (DNE) advisory are evaluated on a contaminant-specific basis. For PFOS, Maine CDC will issue a DNE advisory when fish cannot be safely consumed at a rate of at least three meals per year because at very low consumption rates and associated higher fish tissue levels the impact of eating just one additional fish meal per year becomes increasingly large. Additionally, there is still emerging science on the health effects from PFOS exposure and the potential health effects from exposure to multiple PFAS.

Table B2. Levels of PFOS in fish and corresponding 8-ounce meal advice categories.

PFOS in fish (ng/g)	Meal advice
3.5	1 meal per week
7.5	2 meals per month
15	1 meal per month
30	6 meals per year
60	3 meals per year
> 60	Do Not Eat

In consideration of whether to issue an advisory, Maine CDC also evaluates whether the resulting advisory would be more restrictive than any exiting advisories[3], such as the statewide fish consumption advisory for mercury (Table B3). The FTAL of 3.5 ng/g for PFOS by itself allows for consumption of 8-ounces per week of any sport caught fish of any species for adults. However, a weekly consumption of recreationally caught fish in Maine waters of up to one meal per week is only recommended for landlocked salmon and brook trout and only by a segment of the population due to the presence of methylmercury in fish tissue and the associated statewide consumption advisory (Table B3). For all other fish species, the statewide methylmercury consumption advisory is to eat no more than two fish meals per month. For sensitive populations (children less than 8 years of age and women who are or who may become pregnant), the statewide mercury advisory is much more restrictive and recommends no consumption of freshwater fish from Maine's inland waters except for landlocked salmon and brook trout which can be consumed at a rate of one meal per month. Thus, in determining whether a PFOS-specific advisory need to be issued, Maine CDC will evaluate whether the concentrations of PFOS is fish tissue warrant an advisory that is more restrictive than the current statewide methylmercury advisory or any other waterbody-specific advisories.

Table B3. Statewide mercury fish consumption advisory.

Sensitive populations (pregnant and nursing women, women of childbearing age, children under age 8)	
Brook trout and landlocked salmon	One meal per month
All other species	Do Not Eat
General population (all other adults and children aged 8 and older)	
Brook trout and landlocked salmon	One meal per week
All other species	Two meals per month

[3] Current fish consumption advisories can be found under Maine CDC's Freshwater Fish Safe Eating Guidelines (https://www.maine.gov/dhhs/mecdc/environmental-health/eohp/fish/2kfca.htm)

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