STATE OF NEW HAMPSHIRE

Department of Environmental Services

Environmental Health Program

Inter-Department Communication

To:	David Neils, Chief Aquatic Biologist, Director, Jody Connor Limnology Center, Watershed Management Bureau	**Date:**	April 13, 2020
From:	Jonathan Ali, Ph.D., Toxicologist David Larson, M.P.H., Human Health Risk Assessor	**Cc:**	Patricia North, M.P.H., EHP Administrator Ted Diers, WMB Administrator

RE: *Human Health Risk Assessment of Fish Consumption and Detected PFAS at Squam Lake*

I. Summary

The New Hampshire Department of Environmental Services (NHDES) Environmental Health Program (EHP) has reviewed the *2018 Squam Lake Fish Tissue Results* for per- and polyfluoroalkyl substances (PFAS). Environmental sampling of other biota from Squam Lake have shown the presence of PFAS and other persistent chemical contaminants (e.g. polychlorinated biphenyls (PCBs)). In response to this information, smallmouth bass and yellow perch were sampled from Squam Lake to determine the risks from consuming these fish. NHDES previously recommended restricted fish consumption at Squam Lake due to elevated concentrations of PCBs (NHDES, 2020).

The objective of this document is to evaluate the potential human health risks for individuals consuming fish caught at Squam Lake relative to PFAS exposure. To address this objective, fish tissue concentrations of PFAS in uncooked fillets were compared against EHP's recommended toxicity values (NHDES, 2019a). Screening levels for certain PFAS in fish and game were previously derived by the EHP (NHDES, 2019b). The present assessment calculated acceptable monthly or annual fish consumption rates for certain populations based on uncooked fish tissue and compared this to the recent consumption limits recommended based on PCBs concentrations in fish.

Of the five PFAS that the EHP can calculate consumption limits for, perfluorooctane sulfonic acid (PFOS) raised the most concern due to its potential toxicity and occurrence in sampled fish. Based on high-end (e.g. the 95th percentile) exposure assumptions, the EHP estimated consumption limits at Squam Lake based on PFOS (Table 1).

Table 1. Fish consumption limits (advisories) for Squam Lake based on various contaminants. The PFAS and PCB advisories are the result of fish tissue sampling from Squam Lake in 2018. Methyl mercury advisory is based on state-wide recommendations from prior surveys in NH.

	Adults and children >7 years of age (8 oz. meal)	Women of childbearing age (8 oz. meal)	Children <7 years of age (4 oz. meal)
Recommended consumption limit Polychlorinated Biphenyls (PCBs)	**3 meals per year**	**2 meals per year**	**1 meal per year**
Recommendations for other contaminants Per- and polyfluoroalkyl substances (PFAS)*	48 meals per year (4 meals per month)	36 meals per year (3 meals per moth)	24 meals per year (2 meals per month)
Methyl Mercury (State-wide advisory**)	48 meals per year (4 meals per month)	12 meals per year (1 meal per month)	12 meals per year (1 meal per month)

*Based on concentrations of perfluorooctane sulfonic acid (PFOS) in smallmouth bass.
**Applies to freshwater fish caught in NH. More restrictive advisories, such that at Squam Lake, may exist for some waterbodies. For more information, see: http://www.eregulations.com/newhampshire/fishing/19nhfw/fish-consumption-guidelines/

II. Conclusions & Recommendations

Based on current information, the concentrations of PFAS in smallmouth bass and yellow perch are not high enough to present a significant risk from consumption relative to the existing PCB advisory. Recreational fishers should follow the current guidance with respect to PCBs and limit their fish consumption from Squam Lake. There are no expected risks of PFAS exposure from the catch and release of fish from Squam Lake. The **Approach** and

Uncertainties of this assessment are described on the following pages of this communication. Equations used to calculate screening and consumption levels in fish and the equation inputs are presented in the **Attachment** (**Equations I & II**). Please contact the NHDES Environmental Health Program at (603) 271-6802 with any questions regarding this memo.

III. Approach

Fish tissue concentration of PFAS were assessed by 1) calculation of acceptable consumption frequencies for 8 and 4 oz. servings of uncooked fillet from the sampled species and 2) comparing these values against the recently recommended consumption limits at Squam Lake due to PCBs. Table 2 summarizes the tissue burdens for detected PFAS in smallmouth bass and yellow perch. The arithmetic mean (central tendency) and 95th percentile (high-end estimate) PFAS concentrations in both species were used for developing consumption limits (Table 2).

Table 2. Summary of PFAS concentrations (ng/g or ppb) in smallmouth bass and yellow perch. Values presented as the mean and 95th percentile.

		Smallmouth Bass n = 5 composite samples		Yellow Perch n = 7 composite samples	
Compound Name	**CAS#**	**Mean**	**95th Percen.**	**Mean**	**95th Percen.**
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUDS)	2196242-82-5	-	-	-	-
1H, 1H, 2H, 2H-Perfluorodecane sulfonic acid	481071-78-7	-	-	-	-
1H, 1H, 2H, 2H-Perfluorohexane sulfonic acid (4:2 FTS)	414911-30-1	-	-	-	-
1H, 1H, 2H, 2H-Perfluorooctane sulfonic acid (6:2 FTS)	425670-75-3	-	-	-	-
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	2127366-90-7	-	-	-	-
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS)	1621485-21-9	-	-	-	-
Hexafluoropropylene oxide dimer acid (HFPO-DA)	122499-17-6	-	-	-	-
N-Ethylperfluoro-1-octanesulfonamidoethanol (N-EtFOSE)	1691-99-2	-	-	-	-
N-Ethylperfluorooctanesulfonamide (N-EtFOSA)	4151-50-2	-	-	-	-
N-Ethylperfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	2991-50-6	-	-	-	-
N-Methylperfluoro-1-octanesulfonamidoacetic acid (N-MeFOSAA)	2355-31-9	-	-	-	-
N-Methylperfluoro-1-octanesulfonamidoethanol (N-MeFOSE)	24448-09-7	-	-	-	-
N-Methylperfluorooctanesulfonamide (N-MeFOSA)	31506-32-8	-	-	-	-
Pefluorotetradecanoic acid (PFTeDA)	365971-87-5	0.93	1.16	0.41	0.51
Perfluorobutane sulfonate (PFBS)	45187-15-3	-	-	-	-
Perfluorobutanoate (PFBA)	45048-62-2	-	-	-	-
Perfluorodecanesulfonic acid (PFDS)	126105-34-8	-	-	-	-
Perfluorodecanoate (PFDA)	73829-36-4	0.95	1.57	0.58	0.7
Perfluorododecanesulfonic acid (PFDoS)	343629-43-6	-	-	-	-
Perfluorododecanoate (PFDoA)	171978-95-3	1.7	2.58	0.82	1.08
Perfluoroheptanesulfonic acid (PFHpS)	146689-46-5	-	-	-	-
Perfluoroheptanoate (PFHpA)	120885-29-2	-	-	-	-
Perfluorohexane sulfonate (PFHxS)	108427-53-8	-	-	-	-
Perfluorohexanoate (PFHxA)	92612-52-7	-	-	-	-
Perfluorononanesulfonic acid (PFNS)	474511-07-4	-	-	-	-
Perfluorononanoate (PFNA)	72007-68-2	-	-	0.19	0.23
Perfluorooctane sulfonamide (PFOSA)	754-91-6	0.16*	0.16*	0.18*	0.18*
Perfluorooctanesulfonate (PFOS)	45298-90-6	2.94	5.77	0.96	1.42
Perfluorooctanoate (PFOA)	45285-51-6	-	-	-	-
Perfluoropentanesulfonic acid (PFPeS)	175905-36-9	-	-	-	-
Perfluoropentanoate (PFPeA)	45167-47-3	-	-	-	-
Perfluorotridecanoic acid (PFTrDA)	862374-87-6	4.17	5.64	1.67	2.61
Perfluoroundecanoate (PFUnA)	196859-54-8	4.02	6.71	1.88	2.62

- indicates non-detectable concentrations in fish tissues.
*Indicates only 2/5 bass and 1/7 perch had detectable tissue concentrations.

The EHP assessed the fish tissue based on the non-carcinogenic risk associated with oral exposure to certain PFAS. This approach uses toxicity values known as reference doses (RfDs) to determine threshold where no appreciable health risk is expected (EPA, 2000; EPA, 1993). The RfDs for perfluorooctanoic acid (PFOA, 6.1 ng/kg-d), perfluorooctane sulfonic acid (PFOS, 3.0 ng/kg-d), perfluorononanoic acid (PFNA, 4.3 ng/kg-d), perfluorohexane sulfonic acid (PFHxS, 4.0 ng/kg-d) and perfluorobutane sulfonic acid (PFBS, 10,000 ng/kg-d) are based on previous recommendations made by the EHP as of 2019 (NHDES, 2019a; NHDES, 2019b).

An alternative assessment method is to evaluate carcinogenic risk of specific PFAS using cancer slope factors (CSFs), with an acceptable risk factor of one-in-a-million (10^{-6}) for excess lifetime cancer risk. To date, various CSFs have been generated for PFOA but vary between agencies based on analyses and critical effect studies (CA OEHHA, 2019; NJDWQI, 2017; EPA, 2016). As PFOA was not detected in any fish tissues, this approach was not applied for the risk assessment of fish consumption at Squam Lake.

The RfDs were applied to exposure scenarios to determine risks from fish consumption. Exposures were adjusted using a relative source contribution (RSC) of 80%, indicating that 20% of daily exposure was reserved for other sources of PFAS exposure such as drinking water (EPA, 2000), personal care products and various environmental sources (NHDES, 2019c). The mean and the 95th PFAS concentrations were evaluated for exposure and consumption limits in three groups: adults and children >7 years of age, women of childbearing age, and children <7 years of age. Uncooked fish meal size for adults and women of childbearing age was assumed to be 8 ounces (oz.) while portion size of uncooked fish for children <7 years of age was assumed to be 4 oz. These groups and corresponding fish meal serving sizes reflect previous guidelines for methyl mercury and fish consumption (NHDES, 2016).

Given the limited data that NHDES and other states have regarding PFAS in fish, the EHP compared these results with those from regional sampling data of similar freshwater fish where available. The New Jersey Department of Environmental Protection (NJDEP) sampled fish from 11 water bodies to assess the occurrence of 13 PFAS (NJDEP, 2019). All 13 of the PFAS analyzed by NJDEP were included in the 33 PFAS analyzed by NHDES. Comparing the results for Squam Lake to those reported by the NJDEP, the concentrations of PFAS detected in Squam Lake fish are in the range of those reported across various waterbodies (NJDEP, 2019). Notably, the concentration of PFOS in Squam Lake fish are markedly lower than those reported for fish in waterbodies suspected to have impacts from aqueous film-forming foam (AFFF). Similarly, the PFOS concentrations in Squam Lake fish were lower than those reported at several sites across Michigan which have resulted is stringent fish consumption advisories (MDEQ, 2018). The concentrations of other PFAS including PFDA and PFUnA were higher than those reported for NJ DEP's reference site and some other industrial sites (NJDEP, 2019). However, the potential sources, bioaccumulation and trophic transfer of these PFAS are poorly characterized. In its draft toxicological profile of PFAS, the Agency for Toxic Substances and Disease Registry (ATSDR) found freshwater fish tissue concentrations of PFAS in several U.S. waterbodies were in comparable ranges to those reported above (ATSDR, 2018), but for many of these sites it is unclear if these tissue burdens indicate a specific source of contamination (e.g. AFFF). Overall, this suggest that the PFAS concentrations in Squam Lake fish are the result of bioaccumulation and magnification from various unidentified environmental sources.

IV. Sources of Uncertainty

All risk assessments possess inherent uncertainty. To acknowledge this, the EHP has provided key areas where future studies may reduce uncertainty, improve the site-specific risk assessment and ultimately affect the recommended consumption limits. Several of these points were recently highlighted and discuss by NHDES in its *2019 Plan to Generate Surface Water Quality Standards* for PFAS (NHDES, 2019c). The following are potential sources of uncertainty for the present risk assessment.

- *Mixture effects* – Multiple PFAS were detected in fish tissues from Squam Lake. This is consistent with environmental sampling efforts of biota, water and sediments in NH and nationally (ATSDR, 2018). Certain PFAS were widely used in commerce and are now persistent and wide-spread contaminants due to their mobility and resistance to degradation. The specific risk of all PFAS measured in the present report is currently unknown. Toxicity values for PFOA, PFOS, PFNA, PFHxS and PFBS allow for risk assessment of these compounds, but the remaining PFAS lack sufficient toxicological data to estimate human health risk(s). The presence of PFAS as mixture raises concern for exposure to multiple and in some cases similar chemicals. AT this time, there is a lack of consensus in the scientific community on a quantitative and reliable method to estimate risk for the remaining poorly characterized PFAS. Toxic equivalency factors like those used to assess PCBs (EPA, 2010; Van den Berg, et al., 2006) would be preferable but have not been robustly developed for PFAS. Although some have argued for the summation of all PFAS for estimating risks, there is significant concern for inaccurate risk characterization (NHDES, 2019a; NHDES, 2019c). The EHP continues to monitor the scientific literature for updated methodologies or recommendations from the U.S. EPA.

- *Additional analytes* – Thirty-three PFAS analytes were included in this sampling effort. The broader family of PFAS is estimated to possess >4,000 unique chemicals, although it is possible that only several hundred were used in broad commerce and would be found in the environment (NHDES, 2019c and references therein). Other undetected compounds may act as precursors of PFOA, PFOS, PFHxS, PFNA or PFBS, thereby resulting in underestimation of exposure. However, at this time there is insufficient information to determine that these precusors are present and bioavailable in Squam Lake.
- *Science of PFAS* – The science of PFAS, their health effects and exposure pathways is evolving. This is reflected by the uncertainty factors used to calculate toxicity values and estimates used in exposure assessments. As a part of the 2019 PFAS Action Plan, the EPA has begun the process of evaluating the feasibility of developing RfDs for several PFAS included in the present analyte list (EPA, 2019). As the science evolves, the EHP will adjust its recommendations to reflect current technical information and science policy of NHDES.
- *Fish species sampled* – The current assessment focuses on two fish species, smallmouth bass and yellow perch. The transport of PFAS through aquatic food webs is poorly understood at this time. Thus, the EHP cannot make reliable estimates of the risks associated with consumption of predatory fish, salmonids or bottom-dwelling species. A quantitative risk assessment of these other species would require additional sampling and tissue analyses to determine concentrations of PFAS.

References

ATSDR. (2018). *Toxicological profile for perfluoroalkyls draft for public comment.* Atlanta: U.S. Department of Health and Human Services.

CA OEHHA. (2019). *Office of Environmental Health Hazard Assessment: Risk Assessment* . Retrieved from https://oehha.ca.gov/risk-assessment

EPA. (1993). *Reference Dose (RfD): Description and Use in Health Risk Assessments. Background Documents.* Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments

EPA. (2000). *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health.* Office of Water. Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

EPA. (2010). *Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds.* Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://semspub.epa.gov/work/06/9340611.pdf

EPA. (2011). *Exposure Factors Handbook: 2011 Edition.* Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/expobox/about-exposure-factors-handbook

EPA. (2015). *Human Health Ambient Water Quality Criteria: 2015 Update.* Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/human-health-2015-update-factsheet.pdf

EPA. (2016). *Health Effects Support Document for Perfluorooctanoic Acid (PFOA).* Washington, D.C.: U.S. Environmental Protection Agency, Office of Water. Retrieved from https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_hesd_final_508.pdf

EPA. (2019). *EPA PFAS Action Plan.* Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/pfas/epas-pfas-action-plan

EPA. (2019). *Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3).* Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2018-11/documents/pfbs_public_comment_draft_toxicity_assessment_nov2018-508.pdf

EPA. (2019). *Regional Screening Levels (RSLs) - User's Guide*. (U.S. Environmental Protection Agency) Retrieved from EPA.gov: https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#understanding

MDEQ. (2018). *Reconnaissance sampling of perfluorinated compounds in Michigan suface waters and fish 2010-2014.* Lansing, MI: Michigan Department of Environmental Quality.

NHDES. (2016). *Status and trends of mercury in fish tissue in New Hampshire waterbodies, 1992–2016.* Concord, NH: New Hampshire Department of Environmental Services. Retrieved from https://www.des.nh.gov/organization/commissioner/pip/publications/documents/r-wd-17-22.pdf

NHDES. (2019a). *Technical Background Report for the June 2019 Proposed Maximum Contaminant Levels (MCLs) and Ambient Groundwater Quality Standards (AGQSs) for Perfluorooctane sulfonic Acid (PFOS), Perfluorooctanoic Acid (PFOA), Perfluorononanoic Acid (PFNA), and ...* New Hampshire Department of Environmental Services, Concord, NH.

NHDES. (2019b). *Fish, Shellfish, Recreational Swimming and Wading Screening Levels (SLs) for Five Perfluoroalkyl Substances Including: PFOA, PFOS, PFHxS, PFNA and PFBS.* Environmental Health Program, New Hampshire Department of Environmental Services.

NHDES. (2019c). *Plan to Generate PFAS Surface Water Quality Standards.* Concord, NH: New Hampshire Department of Environmental Services. Retrieved from https://www.des.nh.gov/organization/divisions/water/wmb/wqs/documents/r-wd-19-30.pdf

NHDES. (2020). *Human Health Risk Assessment of Fish Consumption and Detected PCBs at Squam Lake.* Concord, NH: New Hampshire Department of Environmental Services, Environemntal Health Program.

NJDEP. (2019). *Investigation of Levels of Perfluorinated Compounds in New Jersey Fish, Surface Water, and Sediment.* New Jersey Department of Environmental Protection, Division of Science, Research, and Environmental Health. Retrieved from https://www.nj.gov/dep/dsr/publications/Investigation%20of%20Levels%20of%20Perfluorinated%20Compounds%20in%20New%20Jersey%20Fish,%20Surface%20Water,%20and%20Sediment.pdf

NJDWQI. (2017). *Health-Based Maximum Contaminant Level Support Document: Perfluorooctanoic acid (PFOA).* New Jersey Drinking Water Quality Institute.

Van den Berg, M., Birnbaum, L., Denison, M., De Vito, M., Farland, W., Feeley, M., . . . Peterson, R. (2006). The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. *Toxicological Science, 93*(2), 223-241. doi:10.1093/toxsci/kfl055

Attachment: Supplemental information for the Human Health Risk Assessment of Fish Consumption and PFAS at Squam Lake

Equation 1. Estimation of fish consumption rates (ncCR; kg of fish per day) based on non-carcinogenic effects.

$$\text{ncCR (kg/d, wet weight)} = \frac{\text{RfD} \times \text{BW} \times \text{RSC}}{\text{Tissue Concentration}}$$

Equation 2. Estimation of fish consumption rates (cCR; 8 oz. meal per day) based on non-carcinogenic effects.

$$\text{ncCR (8 oz. meal/year)} = \frac{\text{non-carcinogenic CR (kg/d)} \times \frac{365\ \text{d}}{\text{year}} \times \frac{35.27\ \text{oz.}}{\text{kg}}}{\frac{8\ \text{oz.}}{\text{serving}}}$$

Table S1. Variables used by the EHP for Equations 1 and 2 (above). Details about these terms and their supporting information be found in the Regional Screening Levels (RSLs) - User's Guide (EPA, 2019).

Variable	Defined	Units	Value	Justification
BW	body weight	kg	80	Assumption for most adults (EPA, 2011; EPA, 2015).
			61	Assumption for women of childbearing age.
			16.9	Assumption for children <7 years of age.
RSC	Relative source contribution	proportion	0.8	Value used to apportion exposure and account for other potential source of PFAS, e.g. drinking water exposure. (EPA, 2000; NHDES, 2019c)
RfD	Reference dose, PFOA	mg/kg-d	6.1×10^{-6}	NHDES toxicity value based on hepatic toxicity (NHDES, 2019a)
	Reference dose, PFOS	mg/kg-d	3.0×10^{-6}	NHDES toxicity value based on immune system toxicity (NHDES, 2019a)
	Reference dose, PFNA	mg/kg-d	4.3×10^{-6}	NHDES toxicity value based on hepatic toxicity (NHDES, 2019a)
	Reference dose, PFHxS	mg/kg-d	4.0×10^{-6}	NHDES toxicity value based on reproductive toxicity (NHDES, 2019a)
	Reference dose, PFBS	mg/kg-d	1.0×10^{-2}	US. EPA draft toxicity value based on thyroid toxicity (EPA, 2019; NHDES, 2019b)