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Surface Water Ambient Toxics Monitoring Program Report 2021-2022

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Introduction

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3. Cyanotoxins in Lakes (*Linda Bacon, Lake Assessment Unit*)
4. Biological Monitoring (*Jeanne DiFranco, Biological Monitoring Unit*)

The full report is available on the DEP website at http://www.maine.gov/dep/water/monitoring/toxics/swat/index.htm

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Acronyms

AFFF	aqueous fire-fighting foam
BKT	brook trout
BRWM	Bureau of Remediation and Waste Management
CDC	Center for Disease Control and Prevention
DEP	Department of Environmental Protection
DMR	Department of Marine Resources
DO	dissolved oxygen
ELISA	enzyme-linked immunosorbent assay
EPA	US Environmental Protection Agency
EPT	sum of mayflies, stoneflies and caddisflies
FTAL	fish tissue action level
HA	health advisory
HAB	harmful algal bloom
LAFB	Loring Airforce Base
LMZ	lobster management zone
MC	microcystin
NA	non-attainment
NCCA	National Coastal Condition Assessment
NPS	nonpoint source pollution
NRSA	National River and Stream Assessment
PCB	polychlorinated biphenyl
PFAS	per- and polyfluoroalkyl substances
PFOS	perfluorooctane sulfonate
PFOSA	perfluorooctane sulfonamide
RAG	remedial action guidelines
RL	reporting limit
SWAT	Surface Water Ambient Toxics
TAG	Technical Advisory Group
TEF	toxic equivalent factor
TEQ	toxic equivalency value
WHO	World Health Organization
WWTP	wastewater treatment plant

Executive Summary

Maine's Surface Water Ambient Toxics (SWAT) monitoring program was established in 1993 (38 MRSA §420-B) and administered by the Department of Environmental Protection (DEP) to determine the nature, scope and severity of toxic contamination in the surface waters and fisheries of the State. The authorizing statute states that the program must be designed to comprehensively monitor the lakes, rivers and streams, and marine and estuarine waters of the State on an ongoing basis. The program must incorporate testing for suspected toxic contamination in biological tissue and sediment; may include testing of the water column; and must include biomonitoring and the monitoring of the health of individual organisms that may serve as indicators of toxic contamination. The program must collect data sufficient to support assessment of the risks to human and ecological health posed by the direct and indirect discharge of toxic contaminants.

The Commissioner of the DEP must prepare a five-year conceptual work plan in addition to annual work plans which are each reviewed by a Technical Advisory Group (TAG). The TAG is composed of 12 individuals, including two representatives with scientific backgrounds representing each of five various interests (business, municipal, conservation, public health and academic), and two legislators.

The SWAT program is divided into four sections: 1) Contaminants in Marine and Estuarine Fish and Shellfish, 2) Contaminants in Freshwater Fish, 3) Cyanotoxins in Lakes, and 4) Biological Monitoring. This biennial report follows the goals of the 2019-2023 five-year conceptual plan, including:

- monitor contaminants in marine and anadromous fish and shellfish and provide information to the Department of Marine Resources (DMR),
- monitor contaminants in freshwater fish and provide data to the Maine Center for Disease Control and Prevention (CDC) for use in revising fish consumption advisories,
- investigate cyanotoxins in lakes, and
- evaluate the condition of aquatic life assemblages in rivers and streams to determine if they attain aquatic life criteria.

This report more specifically presents the findings of the 2021 and 2022 annual work plans recommended by the SWAT Technical Advisory Group. Highlights of the 2021 and 2022 sampling for each of the four sections are provided below.

Contaminants in Marine Fish and Shellfish

- American lobster meat analyzed for per- and polyfluoroalkyl substances (PFAS) compounds from 18 sites across the coast of Maine in 2021. Half of the sites had no detected perfluorooctane sulfonate (PFOS) in lobster meat. The other half, which were collected mostly in the southwestern half of the coast, had very low concentrations of

PFOS that should not pose risk in human consumption of lobster meat. Nine other PFAS compounds were detected in various samples at very low concentrations.

- Softshell clams collected from six sites in 2022 showed low levels of PFAS chemicals in clam tissue. One site, Atkins Bay in the Kennebec River, had a low concentration of PFOS, which was barely above the reporting limit, while the other five sites analyzed had no detectable PFOS in clam tissue. Clam tissue showed low concentrations of nine other PFAS compounds of the 40 compounds for which testing was conducted. PFAS testing of softshell clams, which was requested by Maine DMR, indicates PFAS compound concentrations are low in edible clam tissue and support human consumption without advisories.
- American oyster tissue from one site tested in 2022 contained no PFOS or other PFAS compounds,except for a low concentration of perfluorooctane sulfonamide (PFOSA). This was the first instance of oyster tissue examined by DEP SWAT for PFAS compounds.
- Small, “harbor” pollock and Atlantic silverside, a minnow, were analyzed for PFAS compounds in 2021 from the Piscataqua, Kennebunk, Fore, and Kennebec rivers. PFOS concentrations were higher in the Fore River than in southern Maine rivers and highest in the Kennebec River sample of both species. Ten and five additional PFAS compounds were found in low levels in Atlantic silverside and pollock tissue, respectively.
- Banded killifish and Atlantic silverside tissue analyzed for PFAS in 2022 showed a pattern of PFOS contamination within the Kennebec and Androscoggin rivers, with highest concentrations in the Androscoggin and decreasing in the Kennebec from below Merrymeeting Bay to Phippsburg. Additional work in the tidal portion of the Androscoggin is suggested to follow up on high PFOS levels in these minnow species detected in 2022 SWAT work.
- Striped bass and bluefish tissue sampled for PFAS compounds in 2021-22 showed low PFOS concentrations that will not have an impact on human consumption based on existing consumption advisories for total polychlorinated biphenyl (PCB). As many as eight other PFAS compounds were detected in low concentrations in striped bass fillets. Few bluefish were sampled, but those examined contained little PFOS.
- Striped bass from two sites in the Kennebec River were analyzed for total PCBs, which will be used by Maine CDC to update the existing fish consumption advisory on striped bass based on the toxicity of total PCBs.

Contaminants in Freshwater Fish

- Similar to previous samples, the most common PFAS in freshwater fish collected in 2021 and 2022 was PFOS. Currently, PFOS is the only kind of PFAS that is used by the Maine CDC to determine if fish consumption advisories are necessary for PFAS. The fish tissue action level (FTAL) for PFOS is 3.5 ng/g or parts per billion (ppb).
- In 2021, fish from the following waterbodies had average concentrations of PFOS that **exceeded** the 3.5 ppb FTAL: China Lake (China), Estes Lake (Sanford), Fish Brook (Fairfield), Fairfield PAL Pond (Fairfield), Kennebec River (Hinkley and Fairfield), Kennebunk River (Arundel), Messalonskee Stream (Waterville), Sebasticook River (Winslow), and Unity Pond (Unity).
- In 2021, fish from the following waterbodies had average concentrations of PFOS that were **less than** the 3.5 ppb FTAL: Kennebec River (Norridgewock and Skowhegan), Kennebunk River (Days Mill), Little Androscoggin River (Auburn and Paris), and Messolonskee Lake (Belgrade).
- In 2022, fish from the following waterbodies had average PFOS concentrations that **exceeded** the 3.5 ppb FTAL: Androscoggin River (Livermore and Brunswick), Aroostook River (Caribou), China Lake (China), Fifteenmile Stream (Albion), Great Works River (North Berwick – downstream), Halfmoon Stream (Thorndike), Kennebec River (Hinkley, Fairfield, and Gardiner), Limestone Stream (Limestone), Little Madawaska River (Caribou), McGrath Pond (Oakland), Meduxnekeag River (Houlton), Number One Pond (Sanford), Prestile Stream (Westfield and Mars Hill), and Unity Pond (Unity).
- In 2022, fish from the following waterbodies had average concentrations of PFOS that were **less than** the 3.5 ppb FTAL: Aroostook River (Oxbow Plt and Presque Isle), Halfmoon Stream (Knox), Little Madawaska River (Connor TWP), Meduxnekeag River (New Limerick), Piscataquis River (Abbott), Sandy River (Madrid), Sebasticook River (Burnham), Smith Brook (Houlton), St. John River (Allagash, Frenchville, Grand Isle).
- In 2022, samples of brook trout from the Meduxnekeag River (Houlton) and Prestile Stream (Mars Hill) were analyzed for the pesticide, dichloro-diphenyl-trichloroethane (DDT). Both sites currently have fish consumption advisories for DDT. The FTAL for the sum of 6 forms of DDT and its metabolites is 64 ng/g (ppb). The average concentration of DDT was less than the FTAL in both waterbodies.
- In 2022, samples of smallmouth bass from the Kennebec River (Fairfield and Gardiner) and Androscoggin River (Rumford, Livermore, Brunswick) were analyzed for total PCBs. Both waterbodies have fish consumption advisories for total PCBs. The FTAL for total PCBs is 11 ng/g (ppb). The mean concentration of total PCBs was less than the FTAL in Fairfield but greater than the FTAL in Gardiner. In the Androscoggin River, the average concentration of total PCBs was less than the FTAL in Livermore, just above the FTAL in Rumford, and much greater than the FTAL in Brunswick.

Cyanotoxins in Lakes

- Since 2014, 996 samples have been tested for the cyanotoxin, microcystin, from 316 visits to 142 lakes in populated regions of Maine.
- Maine DEP established the capacity to analyze microcystin using the enzyme-linked immunosorbent assay (ELISA) technique using the plate-reader method (2019) and ELISA strip-test method in 2022.
- The time-series results and results from the probabilistic study suggest that relatively few Maine lakes produce microcystin concentrations that exceed United States Environmental Protection Agency (EPA) Drinking Water Health Advisory guidelines.
- Algal scums that accumulate on downwind shorelines, particularly those on severe, chronic bloomers, may have very high concentrations of microcystin.

Biological Monitoring

- In 2021 the Biological Monitoring Unit sampled macroinvertebrate communities at 40 stations focusing in the Penobscot River basin to determine attainment of Maine's aquatic life use criteria. Twenty-five stations met the aquatic life criteria for their legislatively-assigned water quality class, 14 stations did not attain criteria for their assigned class, and 1 station had an indeterminate result.
- In 2022, the Biological Monitoring Unit focused macroinvertebrate sampling in the Kennebec River basin. A total of 43 stations were sampled. Taxonomic analysis of the 2022 data is still ongoing, and additional results will be added to this report as data are received back from DEP contractors. Results for 15 stations are currently available and are summarized in Table 1b. Of these 15 stations, 5 did not attain criteria for their assigned class.

1. Contaminants in Marine Fish and Shellfish

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1.1 Introduction

Maine's coastline lies within and lends its name to the larger Gulf of Maine, a diverse and productive ecosystem. The Maine coast and the Gulf of Maine provide economic opportunities including commercial fisheries, aquaculture, recreational fisheries, commerce via shipping, and a wide variety of tourism activities. Maine includes the urbanized areas of Portland, Lewiston/Auburn, and Bangor and has experienced growth and increased development in recent years, especially in the southwestern portion of the state's coastline. With development, increases in chemical contaminants discharged to the marine environment may occur. Some contaminants can also become concentrated as they move through the food chain, bioaccumulating at higher trophic levels and potentially impacting the viability of marine species and ecosystem health and causing concern about potential consequences to human health. All these factors suggest that the monitoring of chemical contaminants is an important component of assessing the health of the marine environment in Maine.

This report explores analysis of marine tissue samples for perfluorinated alkylated compounds or chemicals (PFAS), which are organofluorine compounds that have fluorine substituted for all hydrogens where C-H bonds otherwise would occur in organic compounds. PFAS also have a functional group derived from the parent organic compound such that PFAS have properties of both fluorocarbons and the parent compound. The dual properties of PFAS make them useful in water, grease, and stain repellants (paper, fabric, and carpet treatments, notably Scotchgard by 3M), in the semiconductor industry, in firefighting foams, and as paint and other coating additives where flow is critical. Production of perfluorooctonatesulfonyl fluoride related compounds, notably PFOSA (a sulfonamide), was terminated by 3M by 2003 but production overseas has continued or increased. While PFOSA was synthesized for use by industry, it is also created as a degradation byproduct of alkylated-perfluorooctanesulfonamides (which were used to treat paper, carpet, and fabric) through conversion into acetates and eventually to PFOSA.

In addition to PFAS, analysis of total polychlorinated biphenyl (PCBs) was completed in samples of striped bass muscle tissue to update previous work, which supports the fish tissue consumption advisory in place for striped bass in Maine waters.

American Lobster

This report presents data from American lobster (*Homarus americanus*) tissues collected in 2021 from the DMR lobster management zones statewide. Lobsters were collected by DMR via traps and provided to DEP frozen whole for dissection. The DEP SWAT program sampled lobster previously in 2018, with muscle and hepatopancreas (tomalley) analyzed for PCBs, including coplanar PCBs, and dioxins/furans. Previously, SWAT examined lobster tissues as part of EPA's National Coastal Condition Assessment (NCCA), which also provides data on water column parameters, sediment chemistry, and benthic community structure. In most states participating in the NCCA, finfish are collected and used for fish tissue contaminant analysis as part of the program. Some New England states have elected to collect lobster to fulfill the fish tissue portion of the NCCA, as Maine did in the 2010 and prior NCCA sampling efforts. EPA discontinued the use of lobster as a medium for fish tissue contaminant analysis for the 2015 NCCA sampling effort. Lobster analyses funded by SWAT, presented in the 2016 SWAT report, focused on metals in both meat and hepatopancreas tissues, part of a continuing effort to generate new and useful lobster tissue contaminant data. The 2018 PCB/coplanar PCB/dioxins/furans data combined with the 2016 metals data have been useful in confirming low concentrations of contaminants in lobster as seafood, particularly when foreign buyers in emerging markets ask about lobster contaminant concentrations.

Lobster was also analyzed to provide information concerning the quality of the benthic environment and because Maine has a fish consumption advisory on lobster hepatopancreas (tomalley) tissue. As predators and scavengers of benthic infauna and detritus on the sea bottom, lobsters ingest toxic contaminants and bioaccumulate those contaminants in their body tissues. Lobsters are ubiquitous along the Maine coast, allowing collections to take place along the entire coast and facilitating geographic comparisons. The lobster fishery is Maine's premier fishery, with the highest landed value of any commercial fishery in the state. In addition, Maine lobstermen strive to provide the highest quality product and determining and assuring the quality of this product is of importance to the future sustainability of the fishery. This project builds upon early work done by DEP in 1994-1996 on contaminants in lobster tissues, previous sampling of lobster by NCCA in 2005-06 and 2010 at additional locations, 2016 SWAT metals analyses, and 2018 SWAT PCB analyses. Lobster muscle tissue collected in 2021 were analyzed for a suite of 40 PFAS compounds. Hepatopancreas was not analyzed in 2021 since there is already an advisory on human consumption, to allow a more robust sample size of lobster muscle tissue, and to control the overall cost of the study due to the expense of PFAS analysis.

Marine Minnow and Sport Finfish Species

This report presents data from Atlantic silversides (*Menidia menidia*), smaller "harbor" pollock (*Pollachius virens*), striped bass (*Morone saxitilis*), and bluefish (*Pomatomus saltatrix*). Recent PFAS analysis by the SWAT program in blue mussel and softshell clams has shown low concentrations of PFAS in bivalve tissues, prompting interest in examining nearshore finfish to better understand PFAS contaminant concentrations in the Maine marine environment. Freshwater fish show uptake of PFAS compounds and little data exists for marine finfish species on the Maine coast.

Atlantic silverside were chosen for their limited migratory habits and small size, allowing a large composite sample size and a comparison between spatial sites, while minimizing the chance of fish moving large distances from where they took up PFAS contaminants. In 2021, silverside were collected from the lower, seaward portions of the Piscataqua, Kennebunk, Fore (Casco Bay), and Kennebec rivers. In 2022, silverside samples were collected from the lower portions of the Kennebec River.

In 2022, banded killifish (*Fundulus diaphanous*) were collected from the tidal portions of the Kennebec and Androscoggin rivers. Like the silverside, they were chosen for their limited migratory habits and small size, allowing a large composite sample size and a comparison between spatial sites, while minimizing the chance of fish moving large distances from where they took up PFAS contaminants. Banded killifish live in the less saline, upper estuary, allowing them to be used for spatial comparison of PFAS in areas where silverside are not available due to their intolerance for low salinity water.

Pollock - smaller pollock known locally as harbor pollock for their nearshore occurrence – were chosen as another species due to their proximity to shore (at this smaller size) and thus allowing some ability to compare spatial sites sampled. In addition, they are a recreationally-caught finfish with good table quality, hence useful to consider PFAS in relation to human consumption. In 2021, pollock were collected from the lower, seaward portions of the Piscataqua, Kennebunk, Fore (Casco Bay), and Kennebec rivers.

Striped bass are a popular sport fish along the Atlantic coast, and Maine has historically supported a high-quality recreational fishery. They have good table quality and are readily caught by both shore and boat anglers across a wide section of the southwestern Maine coast. This study looked at both sublegal and legal-sized striped bass to understand if there were differences in PFAS accumulation due to size or age. Striped bass were taken from two areas to determine if spatial patterns could be discerned from the data, although the species is highly migratory and questions about where contaminants like PFAS might be taken up by a highly migratory species are problematic. Many striped bass angled on the Maine coast were spawned in the Chesapeake Bay or Hudson River, although a local, reproducing population was documented by DMR in the Kennebec River in 1987. Seasonally, some striped bass move along the Atlantic coast, which makes contaminant uptake even more problematic. Striped bass were collected from Casco Bay and the Kennebec River. Two sites in the Kennebec were sampled in 2021 and three sites were sampled in 2022.

Bluefish are a popular sport fish along the Atlantic coast, although the number of fish migrating to the southwestern Maine coastal waters appears to be highly variable from year to year. Bluefish are frequently caught by recreational anglers when they are abundant along the coast in high summer and are of good table quality. Bluefish were sampled from two areas, Casco Bay and the Kennebec River estuary, to compare if fish from different spatial samples differed in PFAS contaminant concentrations. Their highly migratory behavior makes the determination of where they took up contaminants more problematic, but since they are consumed as food by anglers, the data is of interest from a human health perspective.

Softshell Clam and American Oyster

Softshell clams (*Mya arenaria*) were sampled at six sites in 2022 and analyzed for PFAS compounds as requested by the Maine DMR to document any levels of PFAS compounds of concern for human consumption of softshell clams, which are an important fishery in Maine. DEP staff obtained American or eastern oyster (*Crassostrea virginica*) from one site in 2022 for analysis for PFAS compounds. American oysters have never been analyzed as part of the SWAT program before and were of interest as a species for human consumption.

1.2 Methods

American Lobster

In 2021, lobsters were sampled from 18 areas across the coast of Maine, with samples distributed among the DMR lobster management zones (LMZs), which run east to west from A to G (Figure 1). Three areas from within the highest lobster landing LMZs, A through D, were collected in an eastern, midzone, and western location. In the remaining three LMZs, samples from two areas (east and west) from within each LMZ were collected. Ten lobsters were collected from each area sampled, allowing two composites of five lobsters each to be constructed. Lobsters were trapped by DMR and frozen individually in plastic bags.

In the laboratory, DEP SWAT staff dissected each partially-frozen lobster, removing claw and tail meat to provide a muscle tissue sample. A biopsy punch was used to remove tissue plugs of tail (3 plugs/lobster) and claw meat (2 plugs/lobster). Five lobsters were composited into one replicate sample for each of the two replicates collected from each spatial site sampled. Tissue composites were immediately placed in pre-cleaned glass jars furnished by the lab and capped. Jars were pre-labeled and filled jars were stored at -5^{o} C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Lobster muscle tissue was analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110.

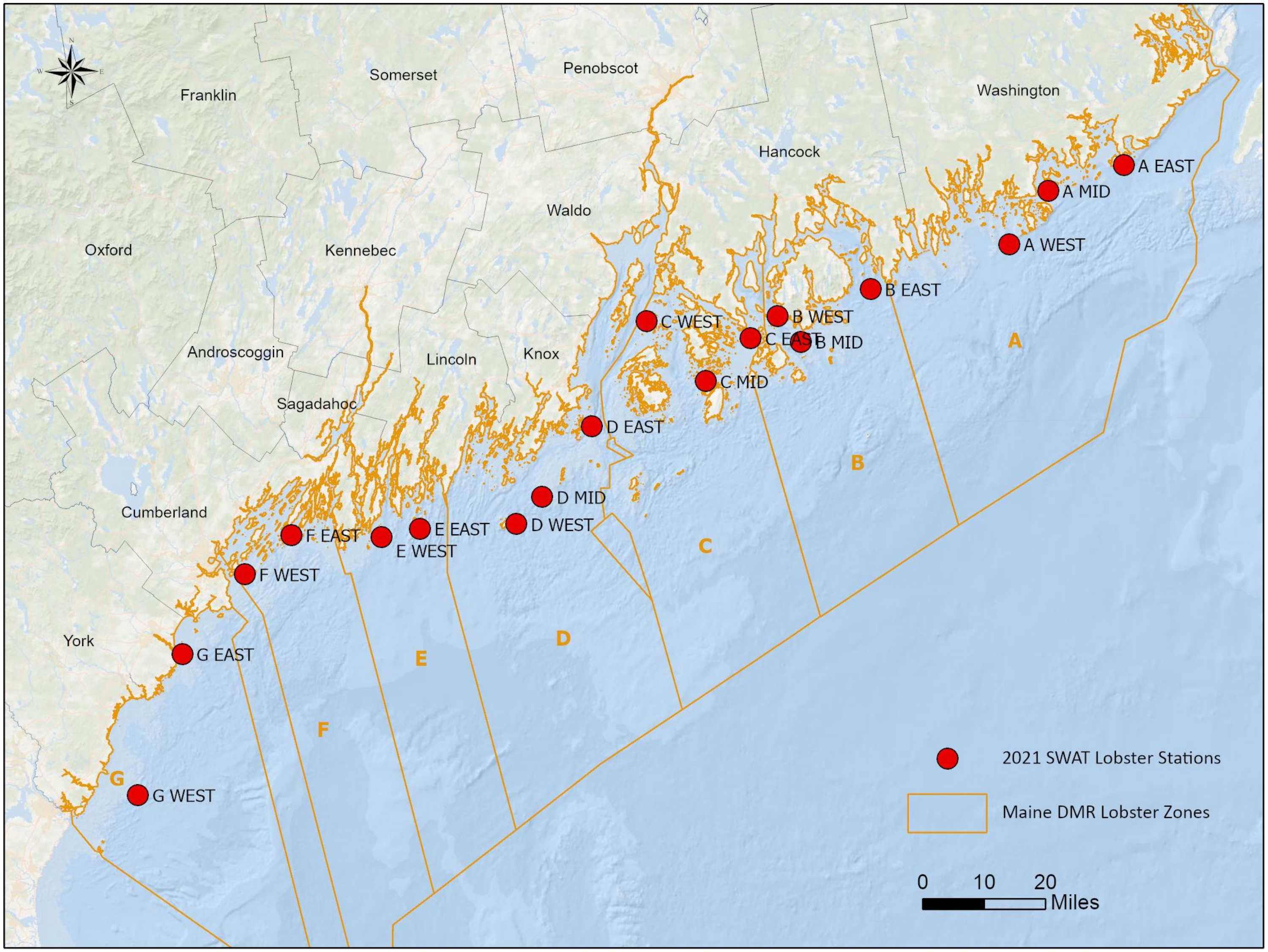


Figure 1. DMR lobster management zones and locations of 2021 SWAT lobster stations

Marine Minnow and Sport Finfish Species

Atlantic silverside and banded killifish were collected by beach seining along shore. In 2021, DEP staff collected silverside from the Piscataqua, Kennebunk, and Fore (Casco Bay) rivers, and DMR provided the sample of silverside from the lower Kennebec River. In 2022, DEP staff accompanied DMR on beach seining trips to acquire both silverside and killifish samples at most sites. DEP seined silverside at Atkins Bay after joint work at other sites was completed. DEP staff processed all minnow samples in the lab, which included removing head/entrails in 2021 and analyzing whole fish samples 2022. Staff created composites of the bodies of 25 fish per replicate with two replicates prepared for each spatial site. Tissue composites were immediately placed in pre-labeled Ziploc bags and filled bags were stored at -5º C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Minnow tissue was analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. See Table 1 and Figure 2.

Pollock were collected by DEP staff by angling in shallow water adjacent to rocky areas near shore. DEP staff collected pollock from the Piscataqua, Kennebunk, Fore (Casco Bay) and Kennebec rivers in 2021. Smaller, "harbor' pollock were targeted and ranged from 244 – 326 mm total length. DEP staff placed five pollock per replicate in Ziploc bags, two replicates per site sampled, and froze the filled bags at -5º C for up to six months until shipping could be completed. Frozen whole fish composites were shipped overnight to the laboratory for analysis. SGS AXYS completed filleting and compositing of the pollock at their facility utilizing equal mass skinless fillet pieces of each of the five pollock in the composite. Pollock skinless fillet composites were analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. See Table 1 and Figure 2.

Striped bass were collected by DEP staff by angling in the targeted areas. DEP collected striped bass, both sublegal (less than 28 inches total length) and legal (equal to or greater than 28 inches and less than 35 inches total length) from Casco Bay and the Kennebec River in 2021. Sampling goals included two replicates of five fish each for both sublegal and legal striped bass from both Casco Bay and the Kennebec River. See Table 1 and Figure 2.

Catching sufficient legal striped bass proved difficult in the Kennebec and to a lesser extent in Casco Bay. Sufficient legal striped bass were collected in Casco Bay to construct a five fish composite (composite 1), while only two additional legal bass were collected to construct the second composite (composite 2). In the Kennebec, only one legal striped bass was collected, which was analyzed alone (composite 1).

Table 1. 2021 marine finfish sites

Atlantic Silversides Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Piscataqua River North of Rte. 1	Kittery	9/21/2021	-70.756137	43.092181	25, 25
Kennebunk River	Kennebunkport	9/23/2021	-70.476651	43.352644	25, 25
Casco Bay Fore River	S. Portland	9/22/2021	-70.268655	43.639219	25, 25
Kennebec River Lee Island	Phippsburg	9/28/2021	-69.80202	43.839348	25, 25

Pollock Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Piscataqua River White Island	Kittery	9/15/2021 9/21/2021	-70.686563	43.059754	5, 5
Kennebunk River	Kennebunkport	9/14/2021 9/14-16/2021	-70.478485	43.343236	5, 5
Casco Bay N.E. Peaks Island	Peaks Island	8/3/2021	-70.179481	43.665334	5, 5
Kennebec River Whaleback Rock	Georgetown	8/9/2021	-69.757829	43.741577	5, 5

Table 1 (continued)

Striped Bass, Sublegal Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Casco Bay W. of Long Is.	Long Island	8/3-4/2021 8/4-11/2021	-70.171570	43.686358	5, 5
Kennebec River Rep 1	Phippsburg	8/9-9/23/2021	-69.808822	43.820200	5
Kennebec River Rep 2	Vassalboro	9/27/2021	-69.722525	44.404731	5

Striped Bass, Legal Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Casco Bay W. of Long Is.	Long Island	8/3-12/2021 8/30-10/14/2021	-70.171570	43.686358	5, 2
Kennebec River Rep 1	Vassalboro	9/30/2021	-69.722525	44.404731	1

Bluefish Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Casco Bay Fort Gorges	Portland	8/23-30/2021	-70.217103	43.663915	2
Kennebec River Fox Island	Phippsburg	8/18/2021	-69.792760	43.729143	1

Table 2. 2022 marine finfish sites

Atlantic Silversides Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Kennebec River Ram Island	Bath	9/15/2022	-69.836421	43.950949	25, 25
Kennebec River Winnegance	Arrowsic	9/1/2022	-69.806216	43.882317	25, 25
Kennebec River Bluff Head	Arrowsic	9/1/2022	-69.792789	43.869174	25, 25
Kennebec River Atkins Bay	Phippsburg	9/28/2022	-69.791411	43.752672	25, 25

Banded Killifish Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Kennebec River Augusta	Augusta	9/12/2022	-69.771581	44.314735	25, 25
Kennebec River Gardiner	Gardiner	9/14/2022	-69.760699	44.224549	25, 25
Kennebec River Gleason's	Dresden	9/14/2022	-69.78354	44.06427	25, 25
Kennebec River Abagadasset Point	Bowdoinham	9/14/2022	-69.82397	44.00308	25, 25
Androscoggin River Topsham	Topsham	9/13/2022	-69.959133	43.92238	25, 25
Androscoggin River Mustard Island	Topsham	9/13/2022	-69.8953	43.94094	25, 25

Striped Bass, Sublegal Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Kennebec River Waterville	Waterville	6/21/2022 - 6/28/2022	-70.171570	43.686358	5, 5
Kennebec River Gardiner	Gardiner	6/22/2022 - 7/21/2022	-69.759775	44.198961	5, 5
Kennebec River Phippsburg	Phippsburg	6/30/2022 - 7/11/2022	-69.808822	43.8202	5, 5

Striped Bass, Legal Site Name	Municipality	Date Sampled	West Longitude	North Latitude	# Fish / Composite
Kennebec River Waterville	Waterville	6/21/2022 -	-70.171570	43.686358	5, 5
Kennebec River Phippsburg	Phippsburg	6/30/2022 - 7/13/2022	-69.808822	43.8202	5, 5

Sub-legal striped bass were more readily available and sufficient fish were collected to fulfill two composites of five fish each at both the Casco Bay and Kennebec River sites. It should be noted that the replicate 1 composite of sublegal Kennebec River striped bass was collected predominantly from the lower Kennebec River in Phippsburg in August (four of five fish), while one fish in the composite came from upriver in the freshwater section in Vassalboro in September. The replicate 2 composite of sublegal Kennebec striped bass came entirely from the freshwater Vassalboro site (all five fish) in late September.

In 2022, additional striped bass sampling was conducted in the Kennebec River at Waterville, Gardiner, and Phippsburg. Sublegal fish were collected at Waterville, Gardiner, and Phippsburg and analyzed for PFAS compounds. Legal striped bass from Waterville and Phippsburg were also analyzed for total PCBs.

DEP staff filleted and skinned portions of striped bass in the laboratory, placed five fillet samples from five fish per replicate in Ziploc bags, two replicates per site sampled, and froze the filled bags at -5^{o} C for up to six months until shipping could be completed. Frozen fillet composites were shipped overnight to the laboratory for analysis. SGS AXYS completed compositing of the striped bass fillets at their facility utilizing equal mass skinless fillet pieces of each of the five bass in the composite. Striped bass skinless fillet composites were analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. SGS AXYS also completed analysis for total PCBs, using Method E1668A. See Tables 1 and 2 and Figure 2.

In 2021, bluefish were collected by DEP staff by angling in the targeted areas. DEP collected bluefish from Casco Bay and the area off the mouth of the Kennebec River. Sampling goals included two replicates of five fish each for both Casco Bay and the Kennebec River.

Catching sufficient bluefish to construct the desired composites proved difficult in Casco Bay and the Kennebec River. With reports of few bluefish on the coast in the summer of 2021, angling was suspended after collecting three bluefish to allow staff to focus on other sampling goals. Two bluefish were collected in Casco Bay and combined into one composite (composite 1), while one bluefish collected off the mouth of the Kennebec River was analyzed as the only sample from the Kennebec (composite 1). Sampling may

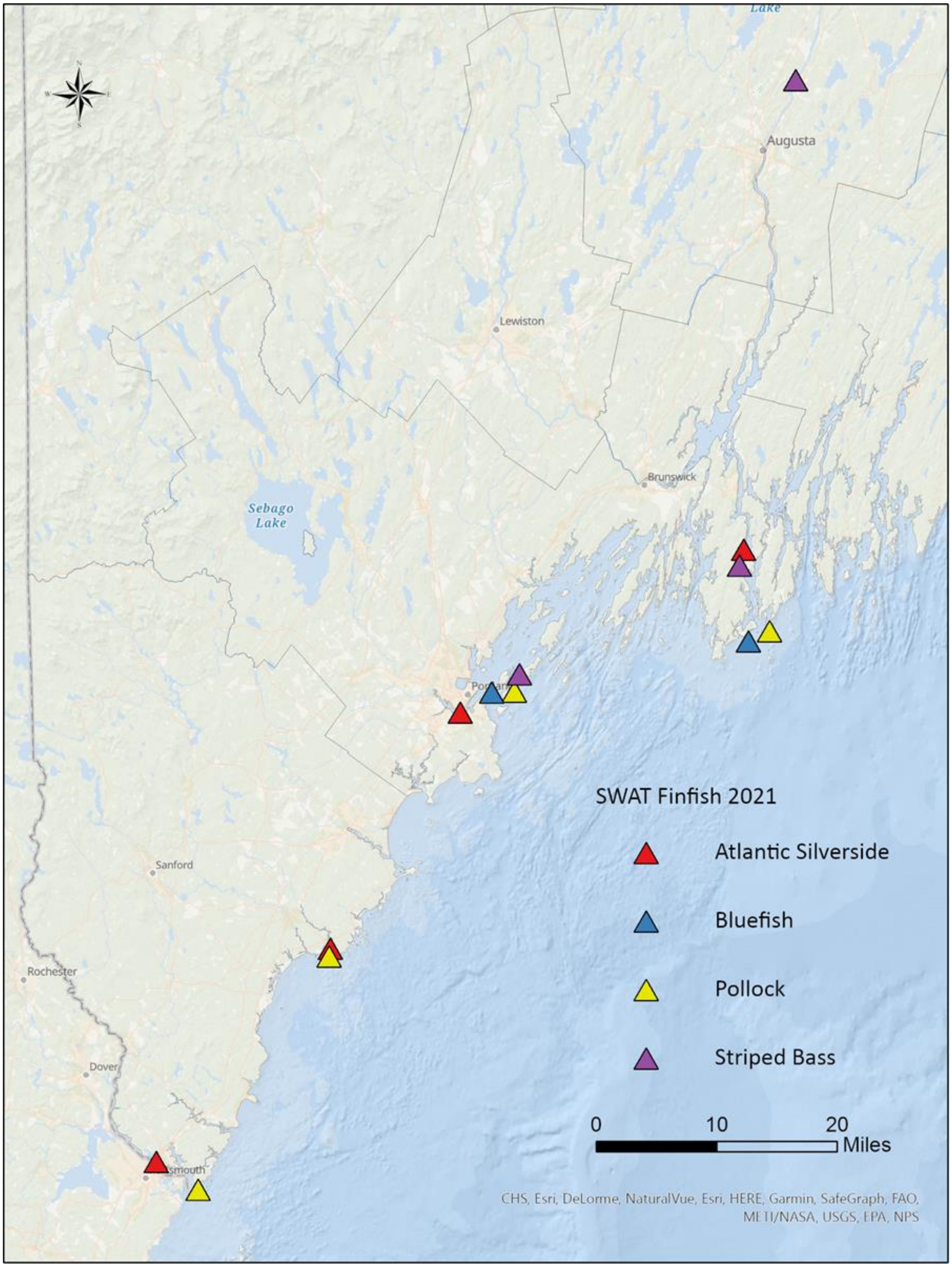


Figure 2. 2021 marine finfish sites

be revisited in future years based on results obtained from these few samples, future interest, and bluefish availability.

DEP staff filleted and skinned portions of bluefish in the laboratory, placed fillet samples from fish in Ziploc bags, and froze the filled bags at -5° C for up to six months until shipping could be completed. Frozen fillet composites were shipped overnight to the laboratory for analysis. SGS AXYS completed compositing of the bluefish fillets utilizing equal mass skinless fillet pieces of each of the fish available for the composite. Bluefish skinless fillet composites were analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. See Table 1 and Figure 2.

Softshell Clam and American Oyster

Softshell clams were collected by digging clams in the intertidal zone along the shore. In 2022, DEP staff collected softshell clams at six sites requested by DMR for analysis for PFAS compounds. Each site was represented by three spatial subsamples, analyzed separately. Each subsample was a composite of ten softshell clams, with the skin or membrane portion of each clam removed. DEP staff separated the "edible" portion from the membrane and edible clam tissue from ten clams was composited into each spatial subsample. Upon dissection, edible tissue composites were immediately placed in pre-cleaned jars provided by the contracted laboratory and were stored at -5° C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Softshell clam edible tissue was analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. See Table 3 and Figure 3.

American oysters were obtained from an aquaculture facility and processed by DEP staff. Three composites of oysters were prepared from the samples obtained, to be analyzed separately. Each replicate sample was a composite of ten American oysters, with all soft parts of the animal included. Upon dissection, tissue composites were immediately placed in pre-cleaned jars provided by the contracted laboratory and were stored at -5° C for up to six months until analyses could be completed. Frozen tissue was shipped overnight to the laboratory for analysis. Oyster tissue was analyzed for a suite of 40 PFAS compounds by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. See Table 3 and Figure 3.

Table 3. 2022 softshell clam and American oyster sites

Softshell Clam Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled
Mast Cove Piscataqua R.	Eliot	PQMCMC	-70.79764	43.117241	8/17/2022
Spruce Creek Piscataqua R.	Kittery	PQSCSC	-70.716722	43.084639	8/17/2022
Presumpscot R. East Side	Falmouth	CBPRES	-70.245092	43.699839	8/22/2022
Royal R. Mouth	Yarmouth	CBRYMT	-70.14574	43.79134	8/23/2022
Atkins Bay Kennebec R.	Phippsburg	MCKNAT	-69.798844	43.742764	9/19/2022
Huntley Creek Holmes Bay	Cutler	ECMCHB	-67.298553	44.702059	8/16/2022

American Oyster Site Name	Municipality	Station Code	West Longitude	North Latitude	Date Sampled
Royal R. Lanes Island	Yarmouth	CBRYLA	-70.125	43.789167	8/24/2022

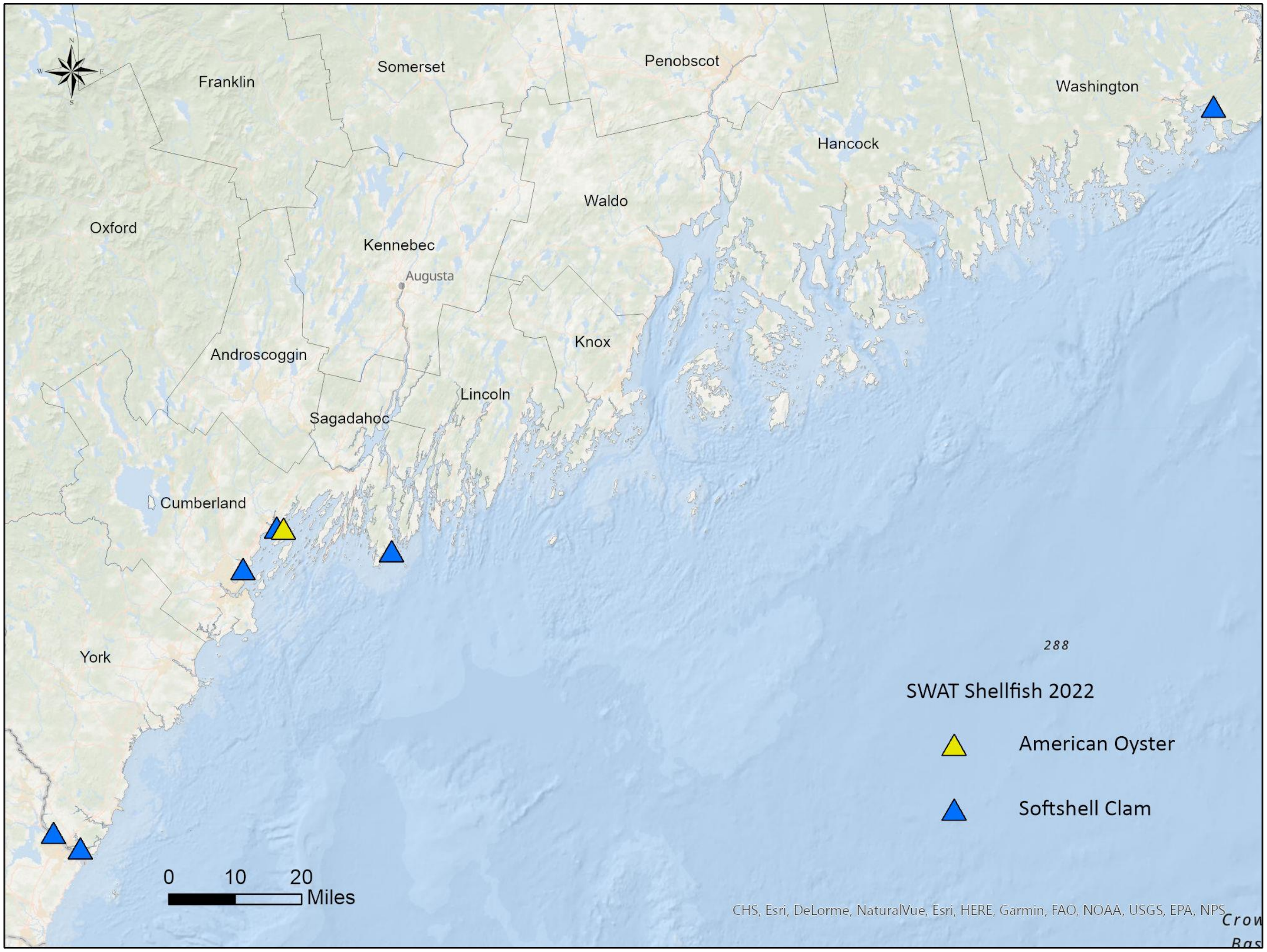


Figure 3. 2022 marine shellfish sites

1.3 American Lobster

Table 4 presents the PFAS compounds for which analysis was completed.

Table 4: SWAT PFAS Compounds (40) – 2021

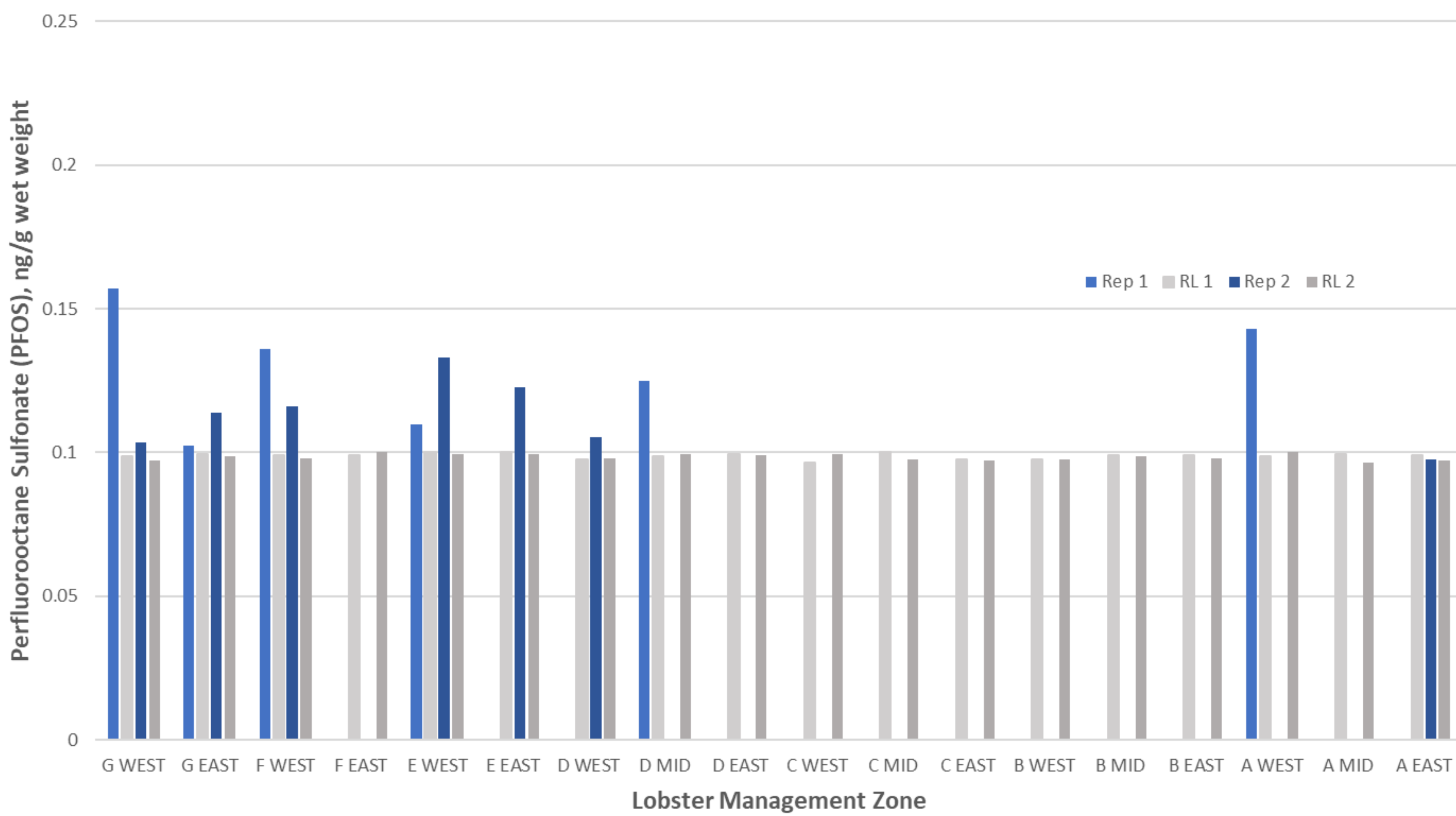
PERFLUOROBUTANOATE
PERFLUOROPENTANOATE
PERFLUOROHEXANOATE
PERFLUOROHEPTANOATE
PERFLUOROOCTANOATE
PERFLUORONONANOATE
PERFLUORODECANOATE
PERFLUOROUNDECANOATE
PERFLUORODODECANOATE
PERFLUOROTRIDECANOATE
PERFLUOROTETRADECANOATE
PERFLUOROBUTANE SULFONATE
PERFLUOROPENTANE SULFONATE
PERFLUOROHEXANE SULFONATE
PERFLUOROHEPTANE SULFONATE
PERFLUOROOCTANE SULFONATE
PERFLUORONONANE SULFONATE
PERFLUORODECANE SULFONATE
PERFLUORODODECANE SULFONATE
4:2 FLUOROTELOMER SULFONATE
6:2 FLUOROTELOMER SULFONATE
8:2 FLUOROTELOMER SULFONATE
PERFLUOROOCTANE SULFONAMIDE
N-METHYL PERFLUOROOCTANE SULFONAMIDE
N-ETHYL PERFLUOROOCTANE SULFONAMIDE
N-METHYL PERFLUOROOCTANE SULFONAMIDOACETIC ACID
N-ETHYL PERFLUOROOCTANE SULFONAMIDOACETIC ACID
N-METHYL PERFLUOROOCTANE SULFONAMIDOETHANOL
N-ETHYL PERFLUOROOCTANE SULFONAMIDOETHANOL
HEXAFLUOROPROPYLENE OXIDE DIMER ACID
4,8-DIOXA-3H-PERFLUORONONANOATE
9-CHOLOROHEXADECAFLUORO-3-OXANONANE-1-SULFONATE
11-CHLOROEICOSAFLUORO-3-OXAUNDECANE-1-SULFONATE
3:3 FTCA
5:3 FTCA
7:3 FTCA
PFEESA
PFMPA
PFMBA
NFDHA

Figure 4 shows the PFOS concentrations in lobster muscle tissue at the 18 lobster stations sampled in 2021. The stations run from left to right in east to west order with station G West located closest to the New Hampshire border and station A East located closest to the New Brunswick border. Each of the 18 sites tested within each lobster management zone was composed of two replicate samples, with the replicate one detected PFOS concentration shown on the left, lighter blue bar and replicate two shown on the right, darker blue bar. If no blue bar is shown, the concentration of PFOS was below the reporting limit for that replicate (non-detect), with the reporting limits given adjacent for comparison. Each replicate's reporting limit concentration is shown by the gray bars, with replicate one shown on the left (lighter, grayed out bar) immediately after the replicate one detected concentration and replicate two reporting limit on the right (darker, grayed out bar) immediately after the replicate two detected concentration.

Some sites showed differences between replicates, a detected concentration vs. a non-detect, including E East, D West, D Mid, A West, and A East. Each of these sites had a detectable PFOS concentration at one of the two replicates analyzed. Four sites showed detectable concentrations of PFOS in both replicates tested: G West, G East, F West, and E West. Nine of the sites tested, one half of the total 18 sites, showed no detectable concentration of PFOS in either of the replicates analyzed: F East, D East, C West, C Mid, C East, B West, B Mid, B East, and A Mid. Most detected concentrations were not much greater than the reporting limit, with the greatest being 159% of the reporting limit, at G West replicate 1.

Most sites with detectable concentrations of PFOS were in the southwestern half of the Maine coast, with zones G through D Mid showing at least one of two replicates with a detectable concentration. These sites correspond with the area from Kittery moving eastward to west of Penobscot Bay. The one exception is the area of east Casco Bay, which showed no detectable PFOS (site F East). Two areas in Zone A, A West and A East, had one of two replicates that exhibited detectable concentrations of PFOS, corresponding with the Hancock/Washington county border and eastern Washington County. The area from Penobscot Bay east to eastern Hancock County did not show detectable concentrations of PFOS in lobster muscle tissue.

The Maine CDC has a FTAL for recreationally-caught freshwater and estuarine finfish for PFOS of 3.5 ng/g wet wt., but that is not directly applicable to lobster consumption. EPA has not released a FTAL for PFOS. Without another point of comparison for human consumption and comparing to the Maine CDC freshwater fish FTAL, the lobster meat PFOS concentrations are well below the FTAL, with the highest at 0.157 ng/g wet wt. at G West being approximately 4.5% of the FTAL for PFOS.



Shown west (left) to east (right); 18 spatial samples with two replicates at each location, each sample concentration represents a five lobster muscle tissue composite; two spatial samples zones E, F, G; three spatial samples zones A - D (higher landing zones); grayed out columns are reporting limit values (below which non-detect); blue columns indicate concentration above reporting limit.

Figure 4. PFOS in 2021 American lobster

Nine other PFAS compounds were detected at various frequencies in lobster muscle tissue, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

Perfluorododecanoate (PFDoDA):	All 36 samples (100%) max. conc. = 0.3786 ng/g wet wt.
Perfluorotetradecanoate (PFTeDA):	All 36 samples (100%) max. conc. = 0.9504 ng/g wet wt.
Perfluorotridecanoate (PFTrDA):	All 36 samples (100%) max. conc. = 1.915 ng/g wet wt.
Perfluoroundecanoate (PFUnDA):	All 36 samples (100%) max. conc. = 0.5425 ng/g wet wt.
Perfluorooctane sulfonamide (PFOSA):	21 of 36 samples (58%) max. conc. = 0.8824 ng/g wet wt.
Perfluorononanoate (PFNA):	16 of 36 samples (44%) max. conc. = 0.2031 ng/g wet wt.
Perfluorodecanoate (PFDA):	6 of 36 samples (17%) max. conc. = 0.1260 ng/g wet wt.
Perfluoropentane sulfonate (PFPeS)	5 of 36 samples (14%) max. conc. = 0.7626 ng/g wet wt.
Perfluorotelomer sulfonate (6:2 FTS):	1 of 36 samples (3%) conc. = 1.649 ng/g wet wt.

Perfluorooctanoate (or perfluorooctanoic acid - PFOA) was not detected in any of the 36 lobster meat samples tested in 2021.

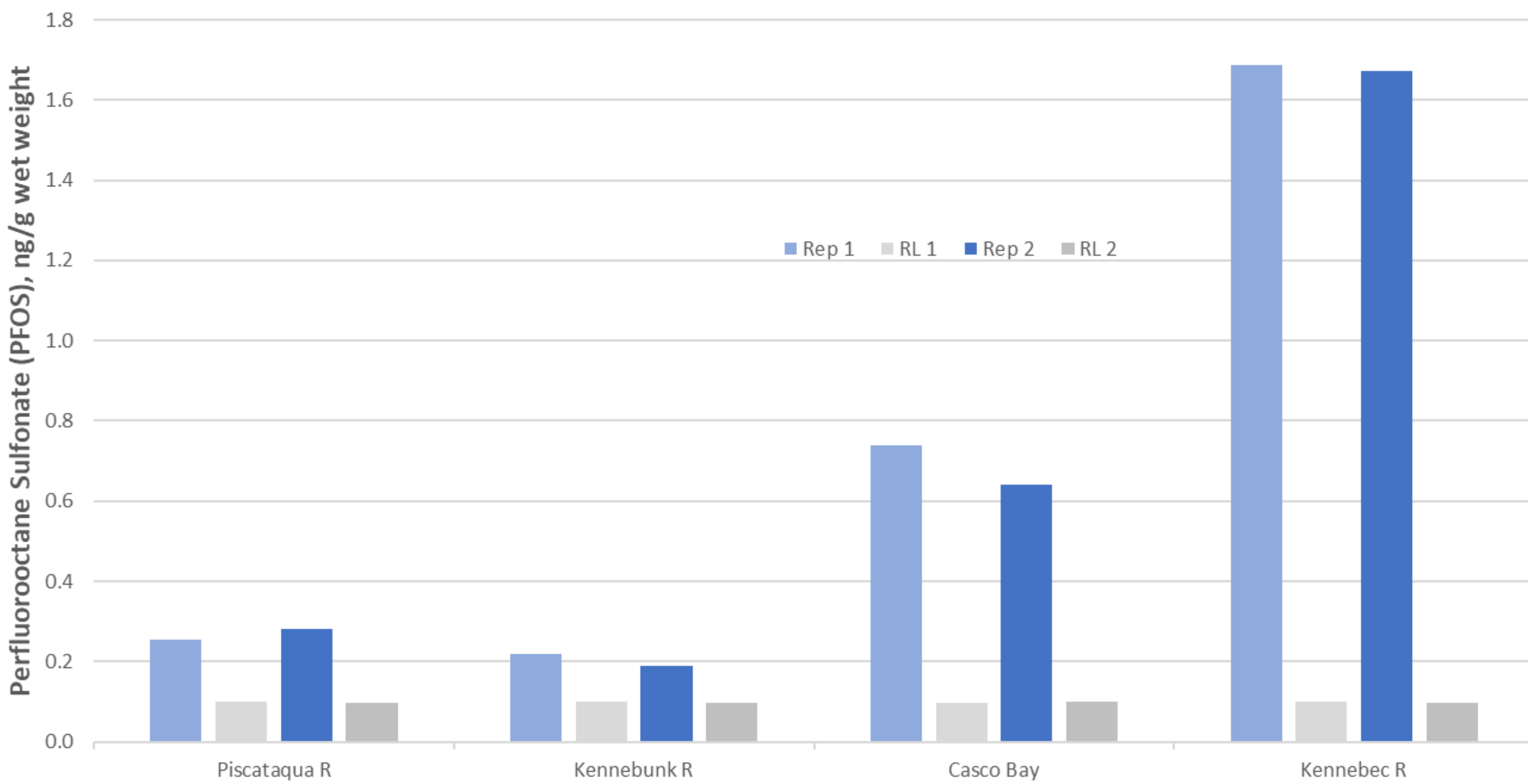
1.4 2021 Marine Minnow and Sport Finfish

Atlantic silverside

Atlantic silverside tissues were analyzed for the same suite of 40 PFAS compounds found earlier in this report in Table 4. Figure 5 shows concentrations of the compound PFOS detected in silverside (body with head and entrails removed) sampled from four sites on the Maine coast. Two replicate samples were composited at each site, for which PFOS concentrations are displayed in the two blue bars. Rep 1 is the left, lighter blue bar while Rep 2 is the right, darker blue bar. For comparison, the two sample specific reporting limits are shown as grayed out bars adjacent to each replicate.

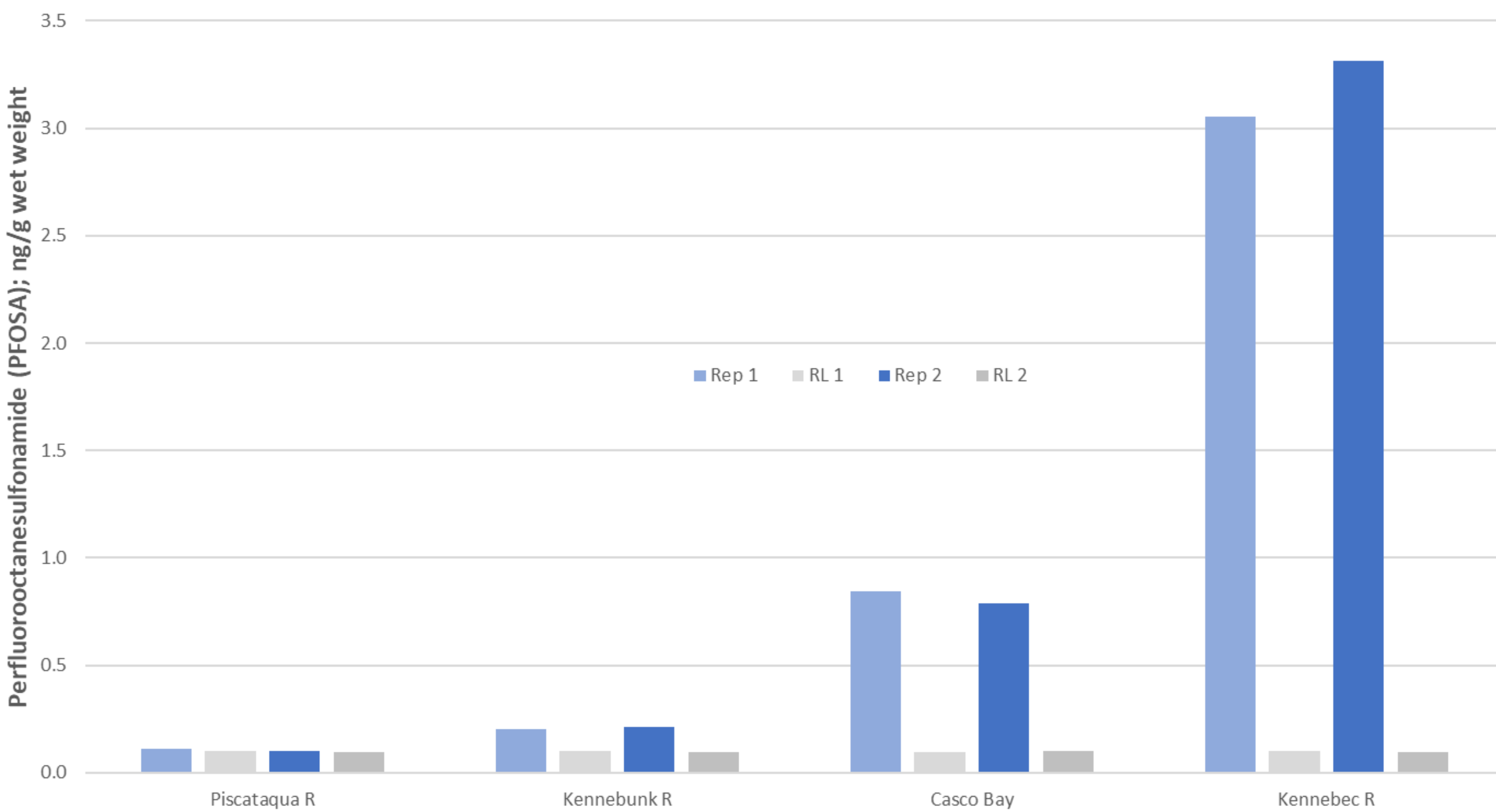
PFOS was detected in all eight replicates of silverside examined, with concentrations in Piscataqua River and Kennebunk River approximately two to three times the reporting limit of 0.1 ng/g wet wt. and not exceeding 0.3 ng/g wet wt. Casco Bay (specifically, Fore River was sampled) and lower Kennebec River concentrations were higher than in the two southern Maine rivers, with Casco Bay concentrations between 0.64 and 0.74 ng/g wet wt. and Kennebec River concentrations between 1.67 and 1.69 ng/g wet wt. The mean of the Kennebec PFOS concentrations is approximately seven times higher than the mean of the combined Piscataqua and Kennebunk concentrations and more than two times the mean of the two Casco Bay concentrations. Lower Kennebec River silverside appear to have much higher concentration of PFOS in their tissue.

Figure 6 shows the concentration of PFOSA detected in the silverside tissue samples from the same four areas. PFOSA was detected in all eight replicates of silverside examined, with concentrations in Piscataqua River barely exceeding reporting limits and Kennebunk River approximately two times the reporting limit of 0.1 ng/g wet wt. and not exceeding 0.21 ng/g wet wt. Casco Bay (specifically, Fore River was sampled) and lower Kennebec River concentrations were higher than in the two southern Maine rivers, with Casco Bay concentrations between 0.79 and 0.84 ng/g wet wt. and Kennebec River concentrations between 3.05 and 3.31 ng/g wet wt. The mean of the Kennebec PFOS concentrations is approximately thirty times higher than the mean of the Piscataqua concentrations and fifteen times higher than the Kennebunk mean and 3.9 times the mean of the two Casco Bay concentrations. Lower Kennebec River silverside appear to have a much higher concentration of PFOSA in their tissue, and the range of PFOSA concentrations is much higher, about two times, across these four sites than the range of PFOS concentrations.



Four spatial samples with two replicates at each location, each replicate represents a 25 fish composite sample (heads and entrails removed; grayed out columns are reporting limit values (below which non-detect); blue columns indicate concentration above reporting limit.

Figure 5. PFOS in 2021 Atlantic silverside



Four spatial samples with two replicates at each location, each replicate concentration represents a 25 fish composite (heads and entrails removed); grayed out columns are reporting limit values (below which non-detect); blue columns indicate concentrations above detection limit.

Figure 6. PFOSA in 2021 Atlantic silverside

Nine other PFAS compounds were detected at various frequencies in Atlantic silverside tissue, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

N-Ethyl Perfluorooctane sulfonamidoacetic acid	4 replicates (50%) max conc. = 1.166 ng/g wet wt.
5:3 Fluorotelomer carboxylic acid (5:3 FTCA)	3 replicates (38%) max conc. = 3.460 ng/g wet wt.
Perfluorodecanoate (PFDA):	2 replicates (25%) max. conc. = 0.1734 ng/g wet wt.
Perfluorododecanoate (PFDoDA):	2 replicates (25%) max. conc. = 0.1206 ng/g wet wt.
Perfluorononanoate (PFNA):	2 replicates (25%) max. conc. = 0.1224 ng/g wet wt.
Perfluoroundecanoate (PFUnDA):	2 replicates (25%) max. conc. = 0.1425 ng/g wet wt.
Perfluoro-4-methoxybutanoic acid (PFMBA):	2 replicates (25%) max. conc. = 0.3124 ng/g wet wt.
Perfluorooctanoate (PFOA):	1 replicate (13%) conc. = 00.1046 ng/g wet wt.
Peerfluorotridecanoate (PFTrDA):	1 replicate (13%) conc. = 0.2491 ng/g wet wt.

It is of interest to note that even though PFOA was not detected in lobster tissue at any site, it was detected in one replicate, Kennebec River rep 2, in Atlantic silversides.

Pollock

Pollock tissues were analyzed for the same suite of 40 PFAS compounds found earlier in this report in Table 4. Figure 7 shows concentrations of the compound PFOS detected in pollock fillet sampled from four sites on the Maine coast. Two replicate samples were composited at each site, for which PFOS concentrations are displayed in the two blue bars. Rep 1 is the left, lighter blue bar while Rep 2 is the right, darker blue bar. For comparison, the two sample specific reporting limits are shown as gray bars adjacent to each replicate.

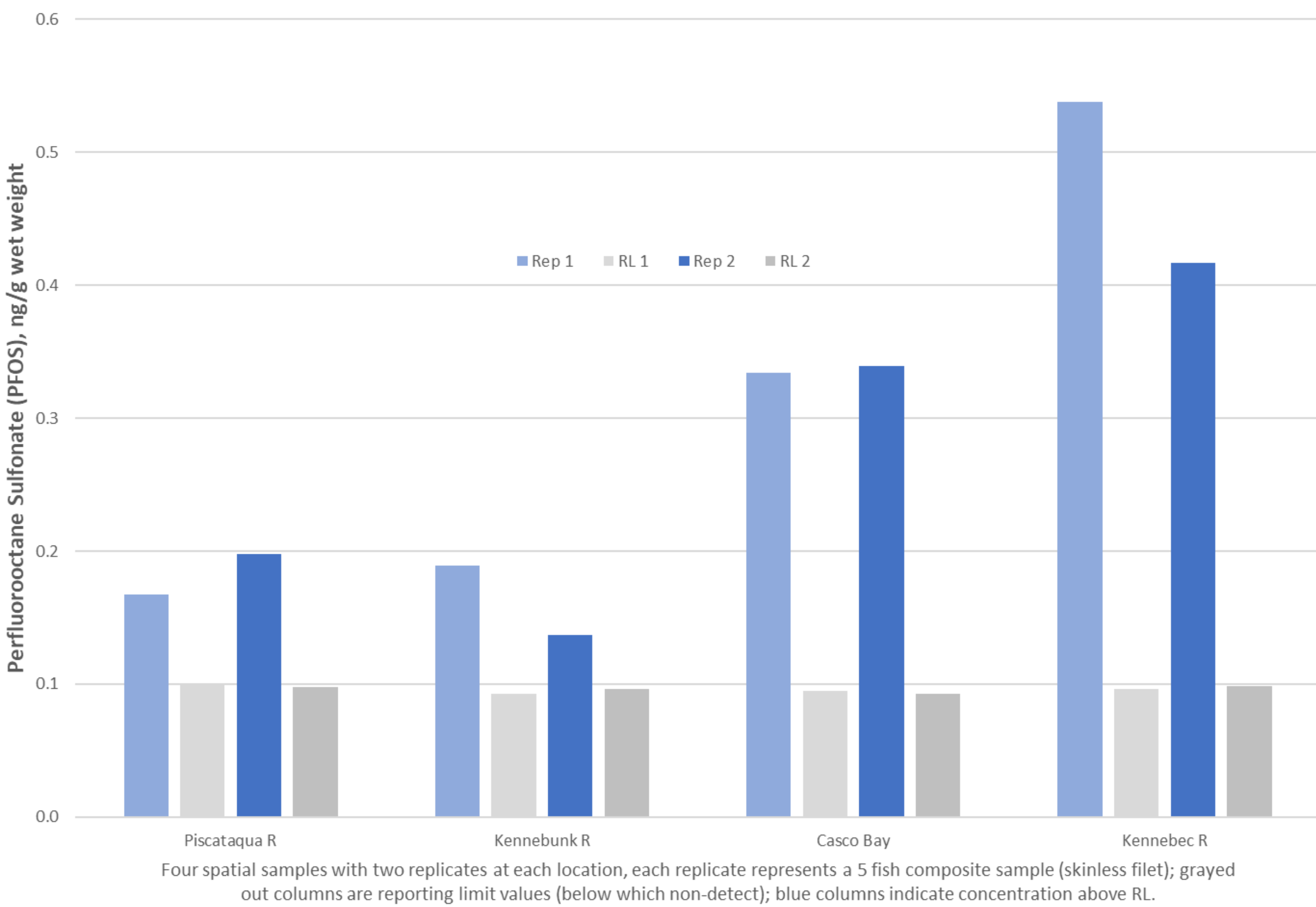


Figure 7. PFOS in 2021 pollock

PFOS was detected in all eight replicates of pollock fillet examined, with concentrations in Casco Bay and lower Kennebec River higher than in the two southern Maine rivers, with Casco Bay concentrations of 0.33 and 0.34 ng/g wet wt. and Kennebec River concentrations of 0.42 and 0.54 ng/g wet wt. The mean of the Kennebec PFOS concentrations is approximately 2.7 times higher than the mean of the combined Piscataqua and Kennebunk concentrations and 1.4 times the mean of the two Casco Bay concentrations. Lower Kennebec River pollock appear to have a higher concentration of PFOS in their tissue than pollock from the other river systems examined.

Figure 8 shows the concentration of PFOSA detected in the pollock fillet samples from the same four areas. PFOSA was detected in all eight replicates of pollock fillet examined, with concentrations in Piscataqua River fillet lowest and Kennebunk River approximately two to three times the reporting limit of 0.1 ng/g wet wt. Casco Bay (specifically, Fore River was sampled) and lower Kennebec River concentrations were higher than in the two southern Maine rivers, with Casco Bay concentrations between 0.50 and 0.53 ng/g wet wt. and Kennebec River concentrations between 0.37 and 0.51 ng/g wet wt. The mean of the Kennebec PFOS concentrations is approximately 1.9 times higher than the mean of the Piscataqua and Kennebunk concentrations and the Casco Bay concentrations are approximately 2.2 times the mean of the Piscataqua and Kennebunk concentrations. Casco Bay and Kennebec River pollock appear to have a higher concentration of PFOSA in their tissue. The general range of pollock PFOSA concentrations (0.1 to 0.5 ng/g wet wt.) are similar to the range of PFOS concentrations.

Four other PFAS compounds were detected at various frequencies in pollock fillet, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

N-Ethyl Perfluorooctane sulfonamidoethanol	5 replicates (63%) max conc. = 2.047 ng/g wet wt.
Perfluoroundecanoate (PFUnDA):	4 replicates (50%) max conc. = 0.1411 ng/g wet wt.
N-Ethyl Perfluorooctane sulfonamidoacetic acid	1 replicate (0.13%) conc. = 0.1387 ng/g wet wt.
Perfluorononanoate (PFNA):	1 replicate (0.13%) conc. = 0.1075 ng/g wet wt.

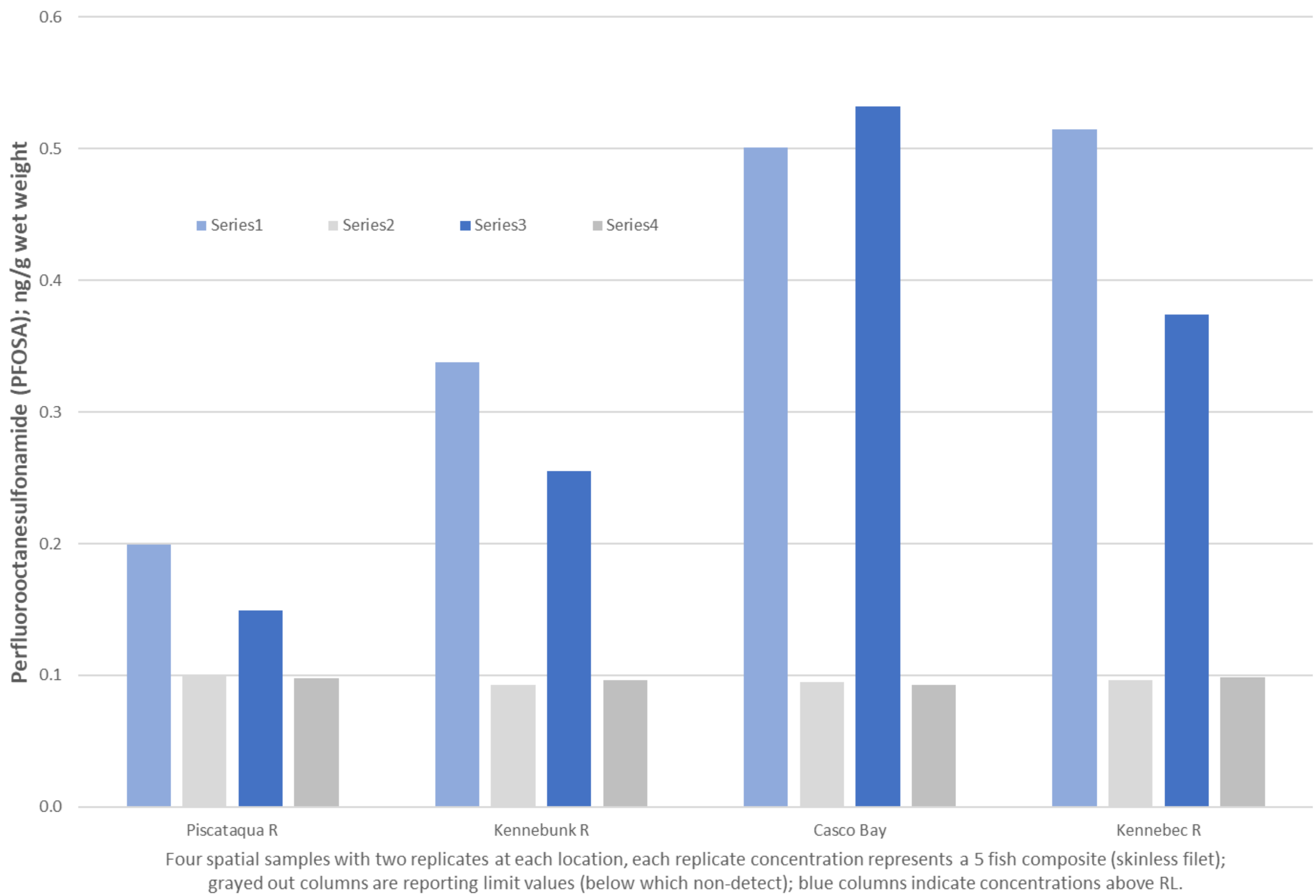


Figure 8. PFOSA in 2021 pollock

Striped Bass and Bluefish

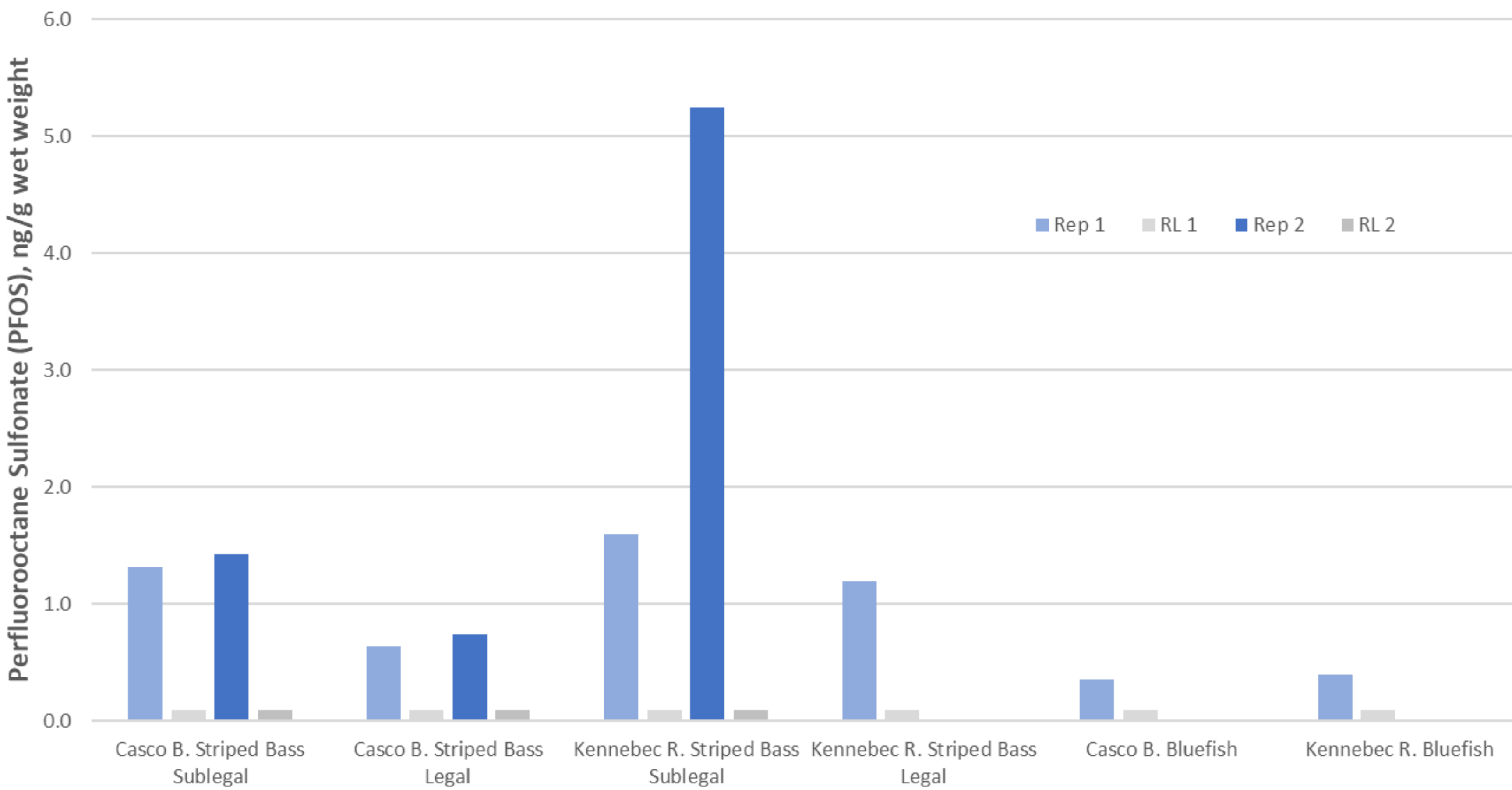
Striped bass and bluefish skinless fillet samples were analyzed for the same suite of 40 PFAS compounds found earlier in this report in Table 4. Figure 9 shows concentrations of the compound PFOS detected in striped bass and bluefish skinless fillet sampled from two sites on the Maine coast, Casco Bay and Kennebec River. Two replicate samples were composited at each site, when available, for which PFOS concentrations are displayed in the two blue bars. Rep 1 is the left, lighter blue bar while Rep 2 is the right, darker blue bar. For comparison, the two sample specific reporting limits are shown as grayed out bars adjacent to each replicate.

As noted in the methods section, striped bass of smaller than legal size and striped bass of legal size were analyzed separately to determine if size range had an impact on PFAS concentration in the tissue. Larger striped bass and bluefish were hard to collect in 2021 and all composites were not constructed of five fish, as was originally planned. Please refer to the methods section of this report (or to the figure caption) for more information about those replicates that had fewer than five fish in a composite.

PFOS was detected in all nine replicates of striped bass and bluefish examined. Concentrations ranged from 6.5 times the reporting limit to 52 times the reporting limit. Concentrations in the smaller, sublegal striped bass were higher than in larger, legal-sized striped bass in the Casco Bay fish, with PFOS concentrations approximately twice as high in sublegal striped bass as in legal fish. The mean of the two sublegal PFOS concentrations was 1.4 ng/g wet wt., while the legal PFOS mean was 0.70 ng/g wet wt. Comparisons in the Kennebec would rely on utilizing only one legal striped bass, represented as replicate 1, which is a small sample size.

In examining the Kennebec sublegal striper PFOS concentrations, the large difference between the two replicates is of interest. Rep 1 had a concentration of 1.6 ng/g wet wt. while rep 2 had a concentration of PFOS of 5.25 ng/g wet wt., over a threefold difference. Rep 1 was constituted of four stripers from the lower Kennebec River in Phippsburg in August and one striper from further upriver in the Vassalboro area taken later in the late summer (mean TL = 572 mm). Rep two was constituted of five stripers from the Vassalboro location, which were all taken in early autumn (mean TL = 466 mm). With only an 11 mm difference in mean length, it may be reasonable to attribute the difference in PFOS concentration to the six-week difference in when the fish were sampled, or more likely the location where they were sampled. The Vassalboro area is a freshwater segment of the river which is above the head of tide and does not have any tidal mixing or dilution present. It may be possible that water concentrations of PFOS are less dilute here in the upper river, perhaps closer to sources, and away from tidal and saltwater mixing. If the striped bass were resident in this section of river for any significant period of time, uptake may be possible from the hypothesized higher water concentration. Further testing of ambient water concentrations of PFOS and other PFAS compounds may further clarify this contrast in PFOS concentration in these two striped bass samples.

The Maine CDC has a FTAL for recreationally-caught freshwater and estuarine finfish for PFOS of 3.5 ng/g wet wt., which may



Each replicate = 5 fish composite, except: Casco B. Striped Bass Legal rep 2 = 2 fish, Kennebec R. Striped Bass Legal rep 1 = 1 fish, Casco B. bluefish rep 1 = 2 fish, Kennebec R. Bluefish rep 1 = 1 fish. Grayed out columns are reporting limit values (below which non-detect); blue columns indicate concentration above reporting limit.

Figure 9. PFOS in 2021 striped bass and bluefish

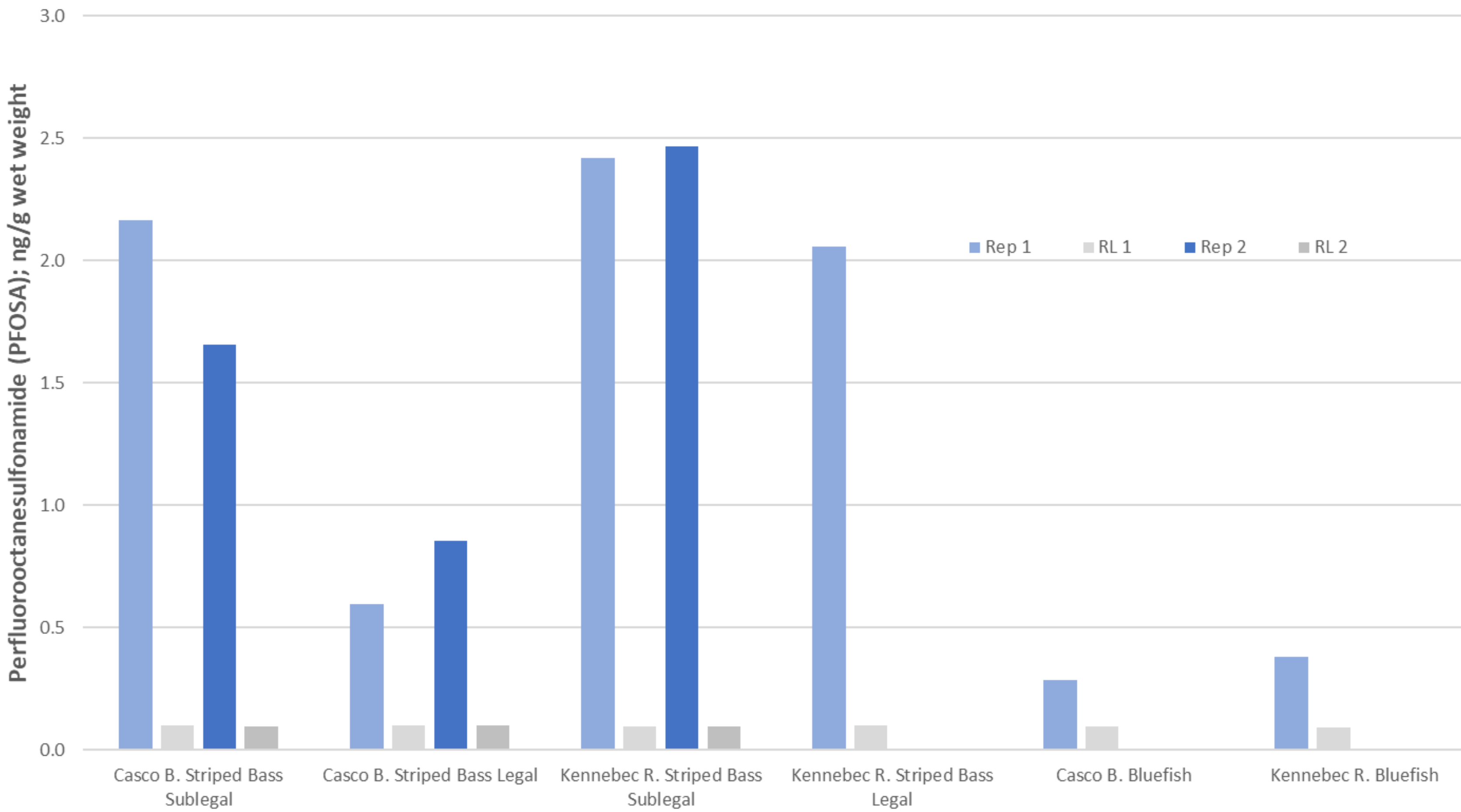
be applicable to striped bass consumption. EPA has not released a FTAL for PFOS. The striped bass skinless fillet PFOS concentrations are well below the FTAL, with the highest legal striper (one fish from the Kennebec) at 1.192 ng/g wet wt., approximately 34% of the current FTAL. The higher PFOS concentration found in Kennebec River sublegal striped bass in rep 2 (5 fish composite, Vassalboro) is approximately 150% of the current FTAL.

Figure 10 shows the concentration of PFOSA detected in the striped bass skinless fillet samples from the same two areas. PFOSA was detected in all nine replicates of striped bass or bluefish examined with concentrations in striped bass ranging from a mean of 0.73 ng/g wet wt. (Casco Bay legal striped bass) to a mean of 2.44 ng/g wet wt. (Kennebec River sublegal striped bass). In Casco Bay, legal striped bass appeared to have somewhat lower PFOSA concentrations than sublegal striped bass. Kennebec River sublegal striped bass had the highest PFOSA concentrations overall. The legal striped bass sample from the Kennebec was composed of one fish, which makes comparison problematic due to the low sample size.

Like PFOS concentrations, PFOSA was higher in sublegal striped bass than in legal fish in Casco Bay. The mean concentration of PFOSA in legal fish was 38% of the mean PFOSA concentration of sublegal fish in Casco Bay. Comparisons in the Kennebec would rely on using one legal fish used as rep 1. Lower Kennebec River sublegal striped bass appeared to have somewhat higher PFOSA concentrations than sublegal Casco Bay fish, although the difference was not as marked as it was in Atlantic silverside concentrations. PFOSA concentrations were in the same approximate range as PFOS concentrations in striped bass.

Seven other PFAS compounds were detected at various frequencies in striped bass tissue, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

Perfluoroundecanoate (PFUnDA):	7 replicates (78%) max. conc. = 0.5757 ng/g wet wt.
Perfluorotridecanoate (PFTrDA):	7 replicates (78%) max. conc. = 0.2959 ng/g wet wt.
Perfluorododecanoate (PFDoDA):	7 replicates (78%) max. conc. = 0.1206 ng/g wet wt.
Perfluorodecanoate (PFDA):	6 replicates (67%) max. conc. = 0.6889 ng/g wet wt.



Each replicate = 5 fish composite, except: Casco B. Striped Bass Legal rep 2 = 2 fish, Kennebec R. Striped Bass Legal rep 1 = 1 fish, Casco B. Bluefish rep 1 = 2 fish, Kennebec R. Bluefish rep 1 = 1 fish. Grayed out columns are reporting limit values (below which non-detect); blue columns indicate concentration above reporting limit.

Figure 10. PFOSA in 2021 striped bass and bluefish

N-Ethyl Perfluorooctane sulfonamidoacetic acid	6 replicates (67%) max conc. = 1.612 ng/g wet wt.
Perfluorotetradecanoate (PFTeDA)	2 replicates (28%) max conc. = 0.2425 ng/g wet wt.
Perfluorononanoate (PFNA):	1 replicate (14%) conc. = 0.1070 ng/g wet wt.

It is of interest to note that PFOA was detected in one replicate, Kennebec River rep 2, in Atlantic silversides as described earlier, but was not detected in lobster or striped bass tissue at any site in any replicate.

Bluefish

Bluefish PFOS concentrations in skinless fillet are also displayed Figure 9 along with the striped bass concentrations (see earlier figure). Limited numbers of bluefish sampled resulted in two bluefish constituting Casco Bay composite 1, while one bluefish taken from the Kennebec River made up composite 1 at that second location. Consequently, limited sample sizes invoke the need of caution in interpreting these data.

PFOS concentrations were relatively low in the two samples, 0.3617 ng/g wet wt. and 0.3942 ng/g wet wt. in Casco Bay and the Kennebec River, respectively, and were approximately four times the sample specific reporting limits. Bluefish PFOS concentrations appeared to be relatively similar in Casco Bay and the Kennebec River. Bluefish PFOS concentrations appeared to be lower than striped bass concentrations. More fish will need to be sampled in future years to determine comparisons in concentrations.

PFOSA concentrations in bluefish in Figure 10 were relatively low in the two samples, 0.2848 and 03788 ng/g wet wt. in Casco Bay and the Kennebec River, respectively, and were approximately three and four times the reporting limits. Bluefish PFOSA concentrations appeared to be relatively similar in Casco Bay and the Kennebec River. Bluefish PFOSA concentrations appeared to be lower than striped bass concentrations, comparable to the PFOS data. More fish will need to be sampled in future years to determine comparisons in concentrations.

Four other PFAS compounds were detected at various frequencies in bluefish tissue, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

Perfluoroundecanoate (PFUnDA):	2 replicates (100%) max. conc. = 0.1788 ng/g wet wt.
Perfluorotridecanoate (PFTrDA):	2 replicates (100) max. conc. = 0.2006 ng/g wet wt.

Perfluorododecanoate (PFDoDA):	1 replicate (50%) conc. = 0.1188 ng/g wet wt.
N-Ethyl Perfluorooctane sulfonamidoacetic acid (N-EtFOSAA):	1 replicate (50%) conc. = 0.1239 ng/g wet wt.

It is of interest to note that PFOA was detected in one replicate, Kennebec River rep 2, in Atlantic silversides as described earlier, but was not detected in lobster, striped bass, or bluefish tissue at any site in any replicate in the 2021 analysis.

1.5 2022 Estuarine Minnow and Marine Sport Finfish

Atlantic Silverside and Banded Killifish

Atlantic silverside and banded killifish tissues were analyzed for the same suite of 40 PFAS compounds found earlier in this report in Table 4. Figure 11 shows concentrations of the compound PFOS detected in silverside and killifish (whole fish in 2022, not body with head and entrails removed as in 2021) sampled from ten sites in the Kennebec and Androscoggin rivers. Killifish were taken from the upriver four Kennebec sites (Augusta, Gardiner, Gleason's, and Abagadasset Point) and the two Androscoggin sites (Topsham and Mustard Island). Further downriver where salinities are higher, silverside were taken from four sites on the lower Kennebec: Ram Island, Winnegance, Bluff Head, and Atkins Bay. Two replicate samples were composited at each site, for which PFOS concentrations are displayed in the two blue bars. Rep 1 is the left, darker blue bar while Rep 2 is the right, lighter blue bar. For comparison, the two sample specific reporting limits are shown as grayed out bars adjacent to each replicate.

PFOS was detected in all ten sites including all twenty replicates of killifish and silverside examined. In Kennebec River killifish, mean concentration ranged from 6.0 ng/g wet wt. (Gardiner) to 9.8 ng/g wet wt. (Augusta). Androcoggin River killifish PFOS mean concentration was higher at Topsham (12 ng/g wet wt.) and much higher at Mustard Island (25.8 ng/g wet wt.). Recent freshwater SWAT work has documented high levels of PFOS in freshwater fish in the Androscoggin further upstream (personal communication, Tom Danielson, DEP). However, this estuarine minnow PFOS data appears to indicate a potential source between Topsham and Mustard Island. Atlantic silverside collected in the lower Kennebec River have lower mean concentrations of PFOS than banded killifish collected further upriver. Of the four sites sampled, mean PFOS concentration decreased moving seaward and downriver from Ram Island (3.0 ng/g wet wt., just below Merrymeeting Bay) to Atkins Bay (0.59 ng/g wet wt., near the mouth of the Kennebec). The Kennebec River silverside sample analyzed in 2021 was collected from the Drummore Bay area, which is located between the 2022 Bluff Head and Atkins Bay sites. It had a mean PFOS concentration of 1.7 ng/g wet wt., which is comparable to the 1.7 ng/g wet wt. Bluff Head mean PFOS concentration despite the 2021 sample differing in tissue composition. The 2021 sample was headed/gutted while all 2022 samples were whole fish. In general, Kennebec baitfish PFOS concentrations suggest an upriver source with decreasing fish tissue levels moving seaward from Augusta, just below head of tide.

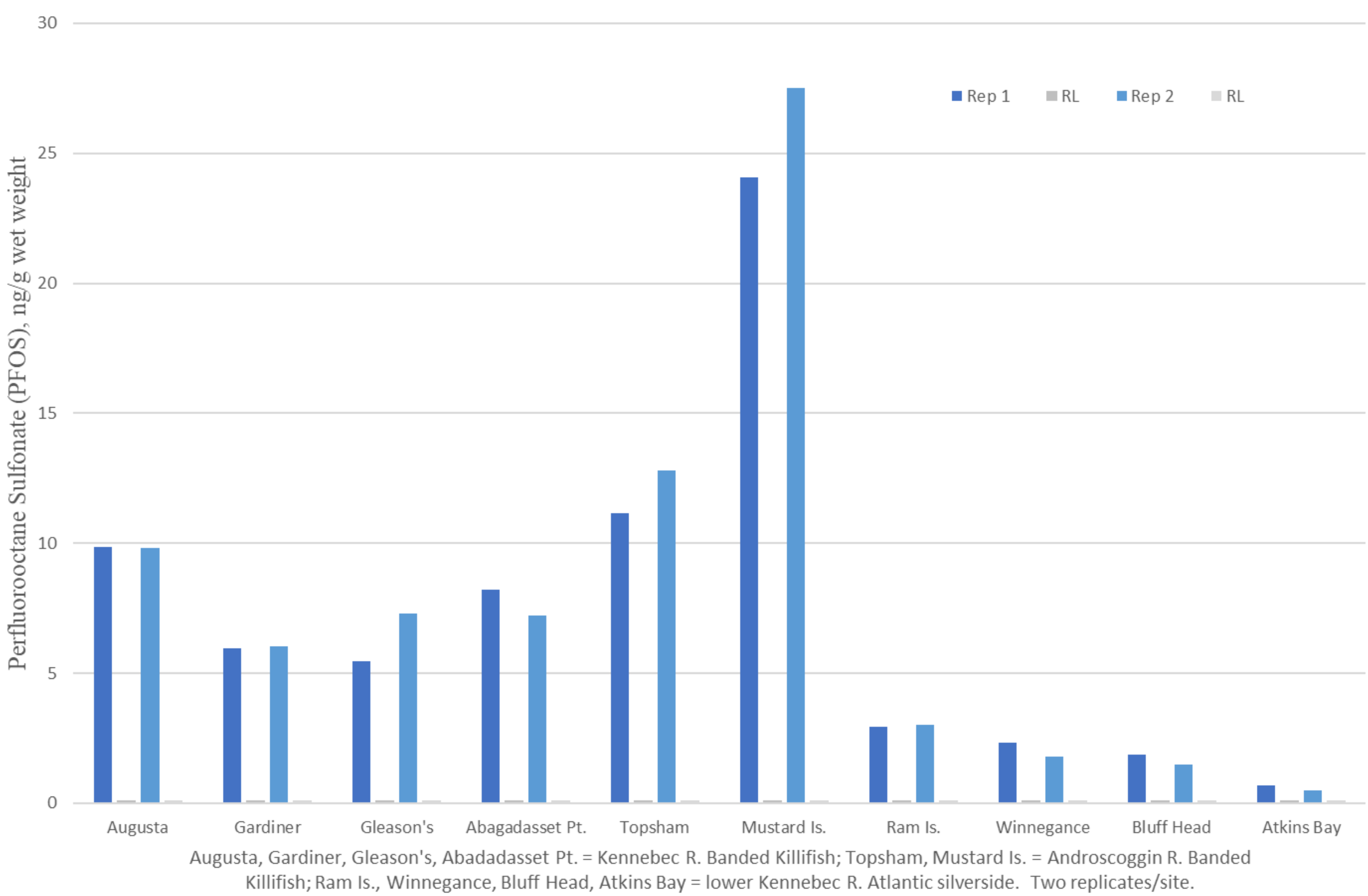


Figure 11. PFOS in 2022 estuarine minnows from the Kennebec and Androscoggin Rivers

Fifteen other PFAS compounds were detected at various frequencies in banded killifish and Atlantic silverside tissue sampled in 2022, although all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

Perfluorooctane sulfonamide (PFOSA)	Killifish - 12 replicates (100%) Silverside - 8 replicates (100%)
N-Ethyl Perfluorooctane sulfonamidoacetic acid (N-EtFOSAA):	Killifish - 12 replicates (100%) Silverside – 8 replicates (100%)
Perfluorodecanoate (PFDA):	Killifish – 12 replicates (100%) Silverside – 7 replicates (88%)
Perfluorododecanoate (PFDoDA):	Killifish - 12 replicates (100%) Silverside – 7 replicates (88%)
Perfluorotetradecanoate (PFTeDA):	Killifish - 12 replicates (100%) Silverside – 4 replicates (50%)
Perfluorotridecanoate (PFTrDA):	Killifish - 12 replicates (100%) Silverside – 3 replicates (38%)
Perfluoroundecanoate (PFUnDA):	Killifish – 12 replicates (100%) Silverside – 7 replicates (88%)
5:3 Fluorotelomer carboxylic acid (5:3 FTCA)	Killifish – 10 replicates (83%) Silverside – 1 replicate (13%)
Perfluorononanoate (PFNA):	Killifish - 9 replicates (75%) Silverside – 6 replicates (75%)
7:3 Fluorotelomer carboxylic acid (7:3 FTCA)	Killifish - 7 replicates (58%) Silverside – 2 replicates (25%)
N-Methyl perfluorooctane sulfonamidoacetic acid (N-MeFOSAA)	Killifish - 7 replicates (58%) Silverside – 1 replicate (13%)
Perfluorodecane sulfonate (PFDS)	Killifish - 5 replicates (42%) Silverside – 0 replicates (0%)
N-Ethyl perfluorooctane sulfonamidoethanol (N-EtFOS)	Killifish – 2 replicates (17%) Silverside – 0 replicates (0%)
Perfluorohexane sulfonate (PFHxS)	Killifish – 1 replicate (8%) Silverside – 0 replicates (0%)

Perfluorooctanoate (PFOA):	Killifish - 0 replicate (0%) Silverside – 4 replicates (50%)

For other PFAS compounds detected, some patterns were of interest.

PFOSA concentrations were highest at the two Androscoggin River sites, Topsham and Mustard Island. This mirrors the PFOS results.

PFOA was detected only in the silverside samples at Ram Island (2 replicates), Winnegance (1 replicate), and Atkins Bay (1 replicate). Concentrations ranged from 0.11 to 0.21 ng/g wet wt., while reporting limits ranged from 0.9 to 1.0 ng/g wet wt. The highest concentration was at Ram Island, just downstream of Merrymeeting Bay and north of Bath.

Striped Bass - PFOS

Striped bass samples were analyzed for the same suite of 40 PFAS compounds found earlier in this report in Table 4. Figure 12 shows concentrations of the compound PFOS detected in striped bass skinless fillet sampled from three sites in the Kennebec River: Waterville, Gardiner, and Phippsburg. Two replicate samples were composited at each site, for which PFOS concentrations are displayed in the two blue bars. Rep 1 is the left, darker blue bar while Rep 2 is the right, lighter blue bar. For comparison, the two sample specific reporting limits are shown as gray bars adjacent to each replicate.

As noted in the methods section, striped bass of smaller than legal size and striped bass of legal size were analyzed separately to determine if size range had an impact on PFAS concentration in the tissue. Sublegal stiped bass were sampled at all three locations, while legal striped bass were sampled at Waterville and Phippsburg. Larger striped bass were available to complete all composites in 2022, which was a problem in 2021 when all composites were not completed with five fish, as was originally planned. All composites analyzed in 2022 were completed with five striped bass each.

PFOS was detected in all ten replicates of striped bass examined. Concentrations ranged from 0.97 ng/g wet wt. to 2.11 ng/g wet wt. across all replicates. Concentrations in the smaller, sublegal striped bass were not as different from those in larger, legal-sized striped bass, at least as compared to 2021 results from Casco Bay. In 2022, Waterville sublegal stripers had mean PFOS concentration 18% higher than the legal sized fish from the same location, while the mean PFOS concentration in Phippsburg was 32% higher in legal stripers compared to sub-legal fish at the same location.

There was a slight difference in Waterville, Gardiner or Phippsburg sublegal striped bass fillet mean PFOS concentrations, which were 1,85, 1.74, and 1.26 ng/g wet wt. While these concentrations are not radically different, there may be some slight decrease in PFOS concentration moving seaward, from Waterville to the north to Phippsburg to the south.

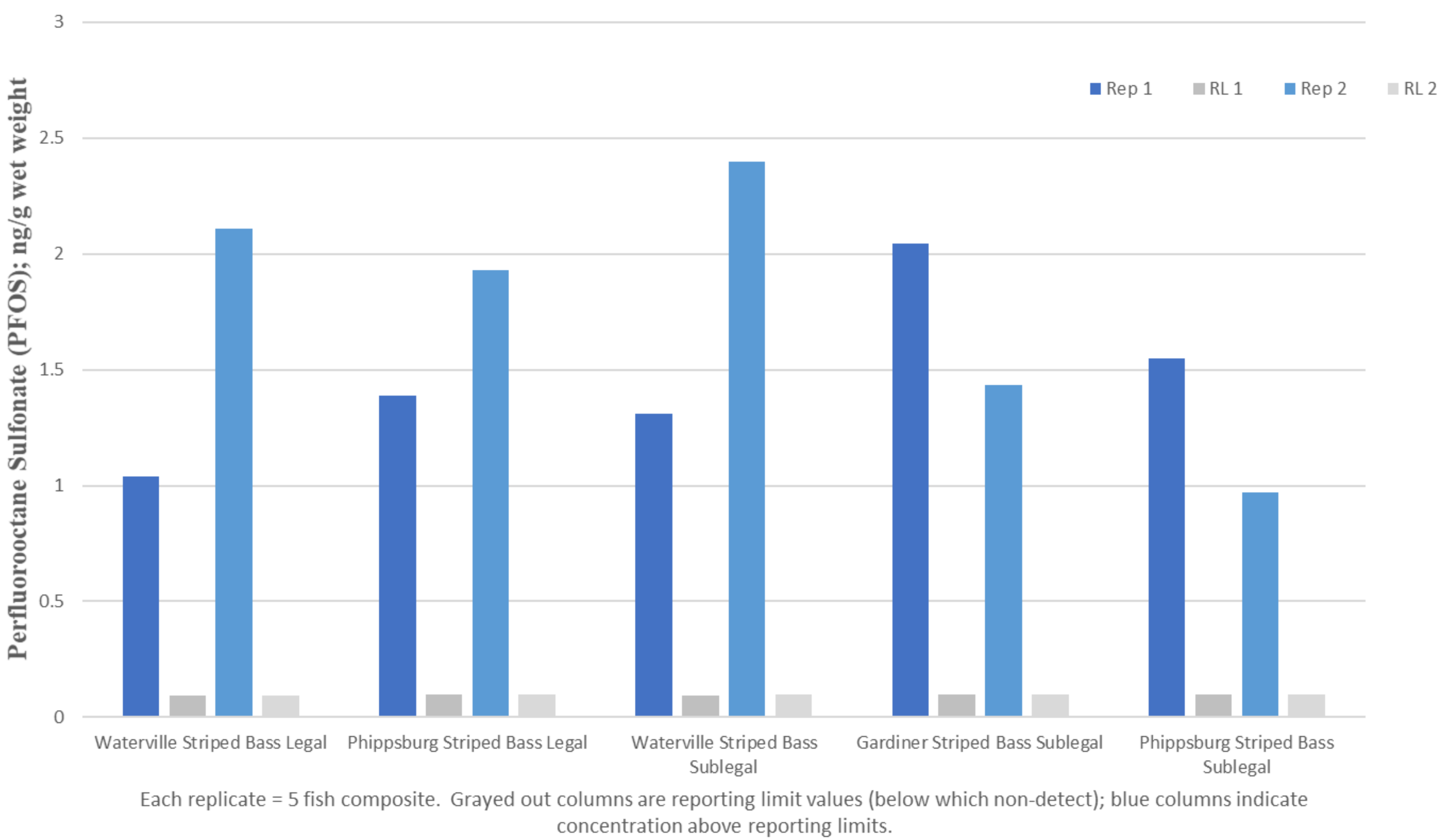


Figure 12. PFOS in 2022 striped bass from the Kennebec River

The Maine CDC has a FTAL for recreationally-caught freshwater and estuarine finfish for PFOS of 3.5 ng/g wet wt., which may be applicable to striped bass consumption. EPA has not released a FTAL for PFOS. The striped bass skinless fillet PFOS concentrations are well below the FTAL, with the highest legal striper composite from Waterville having a concentration of 2.11 ng/g wet wt., with the mean concentration of both replicates was 1.57 ng/g wet wt., which is approximately 45% of the current FTAL. The highest mean legal striped bass PFOS concentration detected (Phippsburg, 1.659 ng/g wet wt.) would still be less than 50% of the lower, more conservative FTAL.

Eight other PFAS compounds were detected at various frequencies in striped bass tissue, although almost all compounds were found at very low concentrations. Compounds detected and their frequency and maximum concentration were:

Perfluorooctane sulfonamide (PFOSA):	10 replicates (100%) max. conc. = 2.413 ng/g wet wt.
Perfluorodecanoate (PFDA):	10 replicates (100%) max. conc. = 0.2490 ng/g wet wt.
Perfluorododecanoate (PFDoDA):	10 replicates (100%) max. conc. = 0.1755 ng/g wet wt.
Perfluorotridecanoate (PFTrDA):	10 replicates (100%) max. conc. = 0.2357 ng/g wet wt.
Perfluoroundecanoate (PFUnDA):	10 replicates (100%) max. conc. = 0.3565 ng/g wet wt.
Perfluorotetradecanoate (PFTeDA)	8 replicates (80%) max conc. = 0.1756 ng/g wet wt.
N-Ethyl Perfluorooctane sulfonamidoacetic acid (N-EtFOSAA):	2 replicates (20%) max conc. = 0.2611 ng/g wet wt.
Nonafluoro-3,6-dioxahaptanoic acid (NFDHA):	1 replicate (10%) conc. = 0.4264

It is of interest to note that PFOA was not detected in any of the striped bass fillet samples. While it was detected in one replicate in Atlantic silversides as described earlier, it was not detected in lobster or striped bass tissue at any site in any replicate.

Striped Bass – Total PCBs

Select striped bass samples collected in 2022 were also analyzed for total PCBs, as requested by Maine CDC to provide additional data in revisiting the current striped bass fish consumption advisory for Maine waters. This existing consumption advisory is based on the toxicity of total PCBs in striped bass skinless fillet. In 2022, striped bass that are legal to harvest in Maine (28-35 inches slot, 711-889 mm) were selected for analysis for total PCBs, since these are the size fish harvested by sport anglers and utilized for recreational human consumption. Samples obtained for PFAS analysis were also utilized for total PCB analysis from two sites, at Waterville and Phippsburg in the Kennebec River. Two replicate samples of five fish were composited for each site and processed as previously described in the striped bass PFAS section of this report. As noted in the methods section, SGS AXYS completed compositing of the striped bass fillets at their facility utilizing equal mass skinless fillet pieces of each of the five bass in the composite. Striped bass skinless fillet composites were analyzed for total PCBs, using Method E1668A by SGS AXYS Analytical Services Ltd. Sidney, British Columbia, Canada, using Method MLA-110. Sampling sites were described in Table 2.

The concentration of each PCB congener from the lab analysis is multiplied by its specific toxic equivalent factor (TEF), which is assigned to each compound and based on its toxicity compared to the toxicity of two of the most toxic compounds. The resulting product, a toxic equivalency value (TEQ), is then summed with the balance of the other PCBs to obtain a total value for all the compounds in this suite. These TEQs are used to assess the toxicity and impact on human consumption of the fish tissue.

Figure 13 shows total PCB TEQ concentrations displayed in three different bars for each site where striped bass were tested. The blue bar represents the TEQ if non-detected PCBs are assigned a concentration of zero. The orange bar represents the TEQ if the non-detected PCBs are assigned a concentration equal to half of the reporting limit (RL). The gray bar represents the TEQ if the non-detected PCBs are assigned a concentration equal to the reporting limit. The two replicates analyzed at each site are shown separately to evaluate variation from composite to composite.

Phippsburg striped bass show less variability between the two replicates, while the Waterville replicates show more variation when compared. The Phippsburg striped bass have lower total PCB TEQs than the upstream, Waterville striped bass, with mean total PCB TEQs of 0.15 and 0.36 pg/g wet wt., respectively (135% higher in Waterville striped bass fillet).

Figure 14 shows the total PCB concentrations detected in legal-sized striped bass at the two locations sampled. The two replicates analyzed at each site are shown separately to evaluate variation from composite to composite. As with the TEQ data, which are calculated from the total PCB concentrations, the Phippsburg striped bass have lower total PCB concentrations than the upstream, Waterville striped bass, with mean total PCB concentrations of 23.6 and 61.95 pg/g wet wt., respectively (163% higher in Waterville striped bass fillet). All replicates exceeded the MCDC total PCB FTAL of 11 ppb, illustrated as the dotted line in Figure 14.

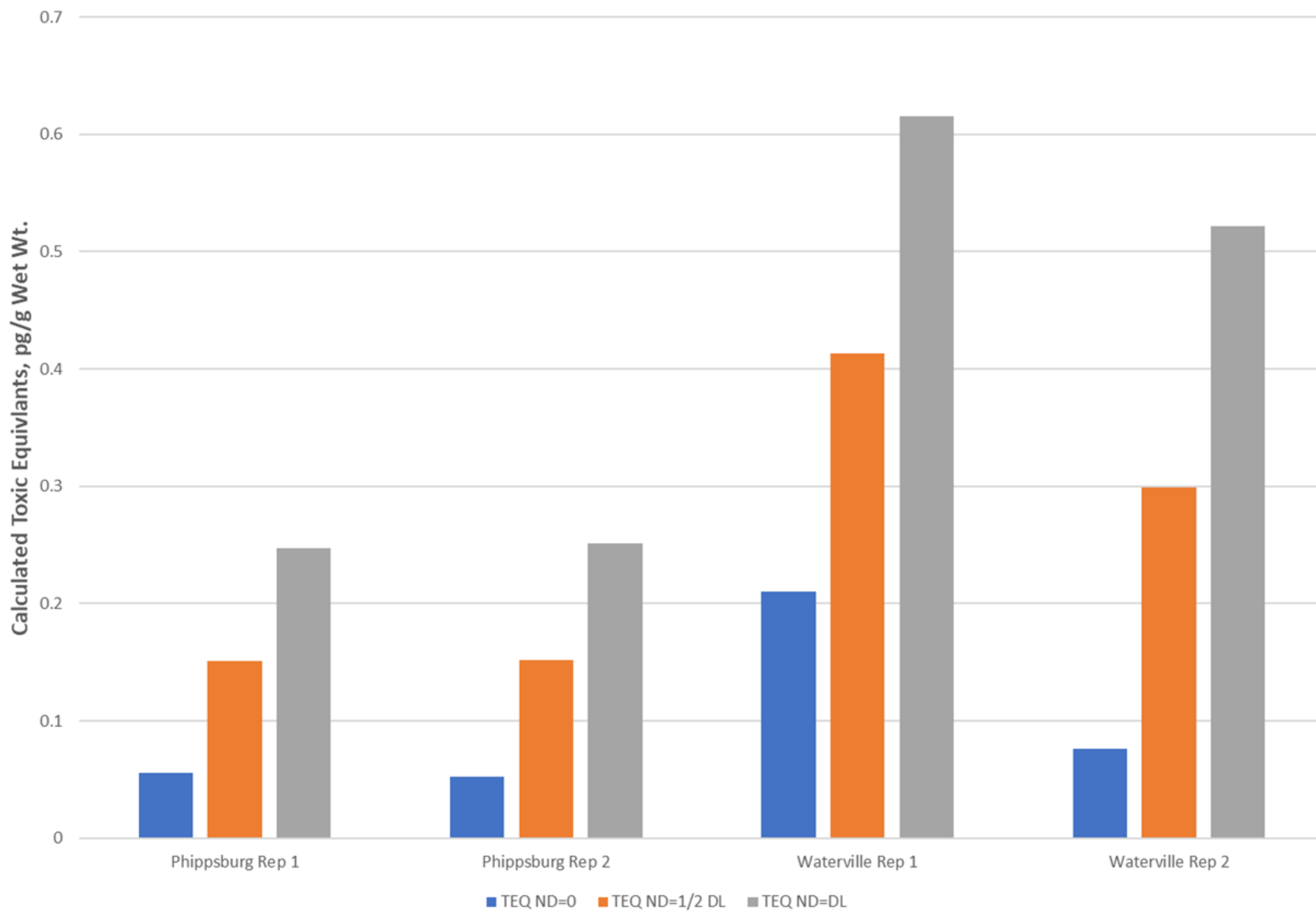


Figure 13. Total PCB TEQs in 2022 legal-sized striped bass

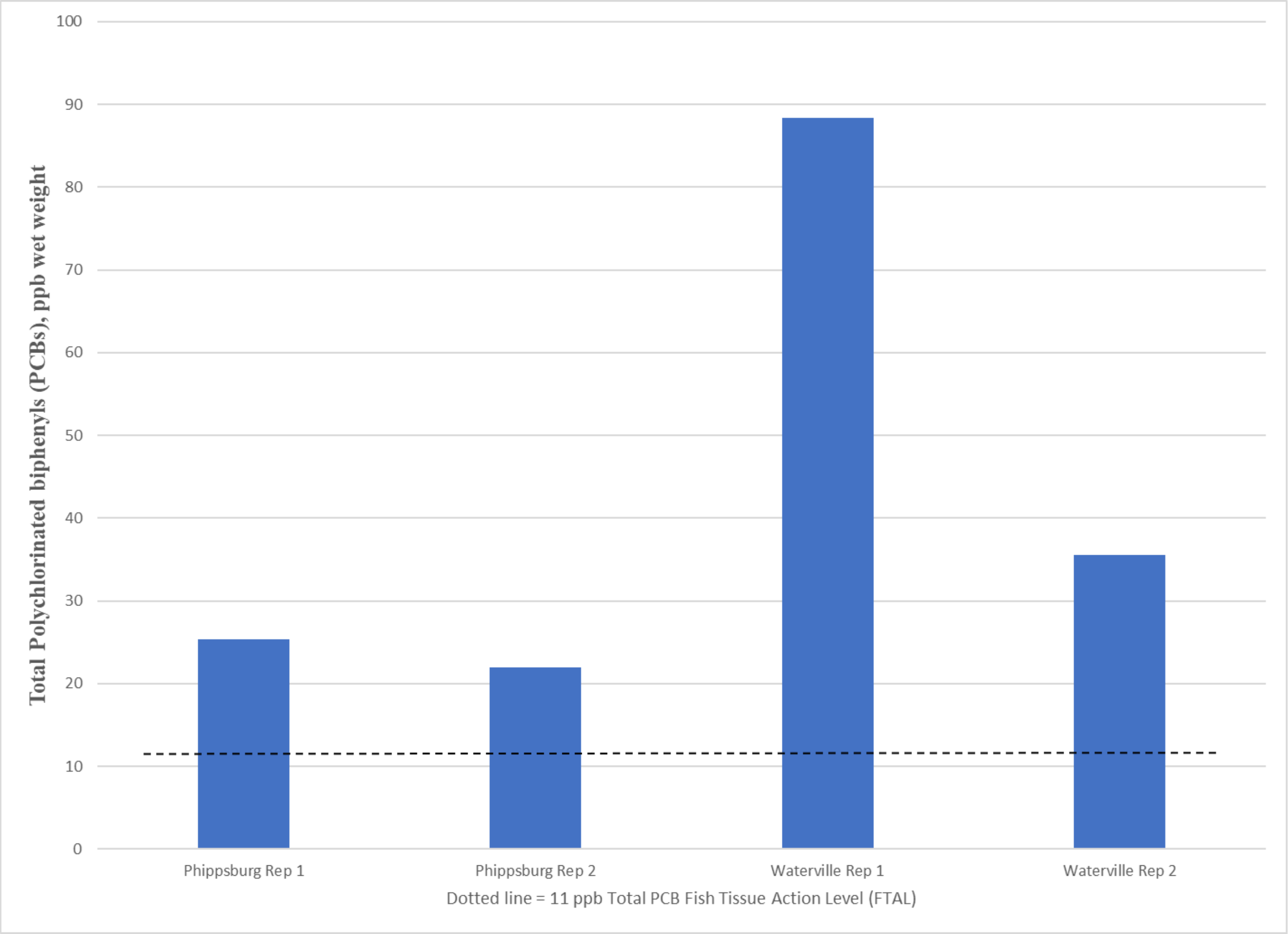


Figure 14. Total PCBs in 2022 legal-sized striped bass

1.6 2022 Softshell Clam and American Oyster

Results for PFAS testing for 40 compounds in softshell clam edible tissue from the six sites sampled in 2022 showed detects for PFOS at only one of the six sites: Atkins Bay in Phippsburg in the Kennebec River. Softshell clam edible tissue at Atkins Bay had detectable concentrations of PFOS in two of three spatial subsamples. This is a first for SWAT clam sites, as no clam site has shown detects for PFOS previously. Detected concentrations in edible tissue ranged from 0.1233 to 0.1240 ng/g wet wt. in the two spatial subsamples, while the third spatial subsample had a high reporting limit value of 0.2451 ng/g wet wt. Some interference in the sample analysis led to the higher reporting limit, which is above the detected concentrations found in the other two spatial subsamples. Reporting limits for the first two spatial subsamples were 0.1010 and 0.0917 ng/g wet wt., which were lower. The PFOS concentration in these clam tissue samples (0.123-0.124 ng/g wet wt.) is orders of magnitude below the FTAL utilized by the Maine CDC for PFOS. Nevertheless, it is interesting that clam tissue from the Kennebec River estuary is the first in SWAT sampling to show PFOS in detectable concentrations. Analysis of American oyster tissue from one site showed no detects for PFOS. PFOS concentrations in edible clam tissue are shown in Figure 15.

PFOSA was detected in softshell clam edible tissue from three of six sites analyzed, Presumpscot River East Side, Royal River (in just one spatial subsample), and Atkins Bay in the Kennebec River. American oyster tissue from Royal River also had detectable concentrations of PFOSA. Three clam sites, Mast Cove and Spruce Creek in the Piscataqua River and Huntley Creek in Cutler had non-detects for PFOSA in all three spatial subsamples at each site. PFOSA in softshell clam edible tissue and American oyster tissue in 2022 samples is shown in Figure 16. Note that oyster tissue showed somewhat higher concentrations of PFOSA than the nearby, but not adjacent, Royal River softshell clam site, where PFOSA was only detected in one of three spatial subsamples.

Additional PFAS compounds detected in softshell clam edible tissue and American oyster tissue are presented in Table 5. Eight additional compounds were detected in at least one spatial subsample across the seven sites, aside from PFOSA (which is shown) and PFOS (which is not shown). Four additional compounds detected in previous sampling, although not in 2022 shellfish samples, are shown as well.

Huntley Creek, Cutler, appears to have limited PFAS contamination as captured in the softshell clam tissue analyzed as part of this project. Maine DEP's Bureau of Remediation and Waste Management (BRWM) had interest in testing this site as PFAS compounds have been identified in the upland near the creek. Sampling sites for the three spatial subsamples were collocated nearby to other sampling in the upland conducted by BRWM. With no PFOS or PFOSA detected in clam tissue from the three samples from the creek, the only PFAS compound detected in this analysis of clam tissue was perfluoropentanoate or perfluoropentanoic acid (PFPeA). PFPeA was found in all three spatial subsamples of clam edible tissue at Huntley Creek and the mean concentration was 0.43 ng/g wet wt., which is 2.2 times the mean reporting limit for these three spatial subsamples.

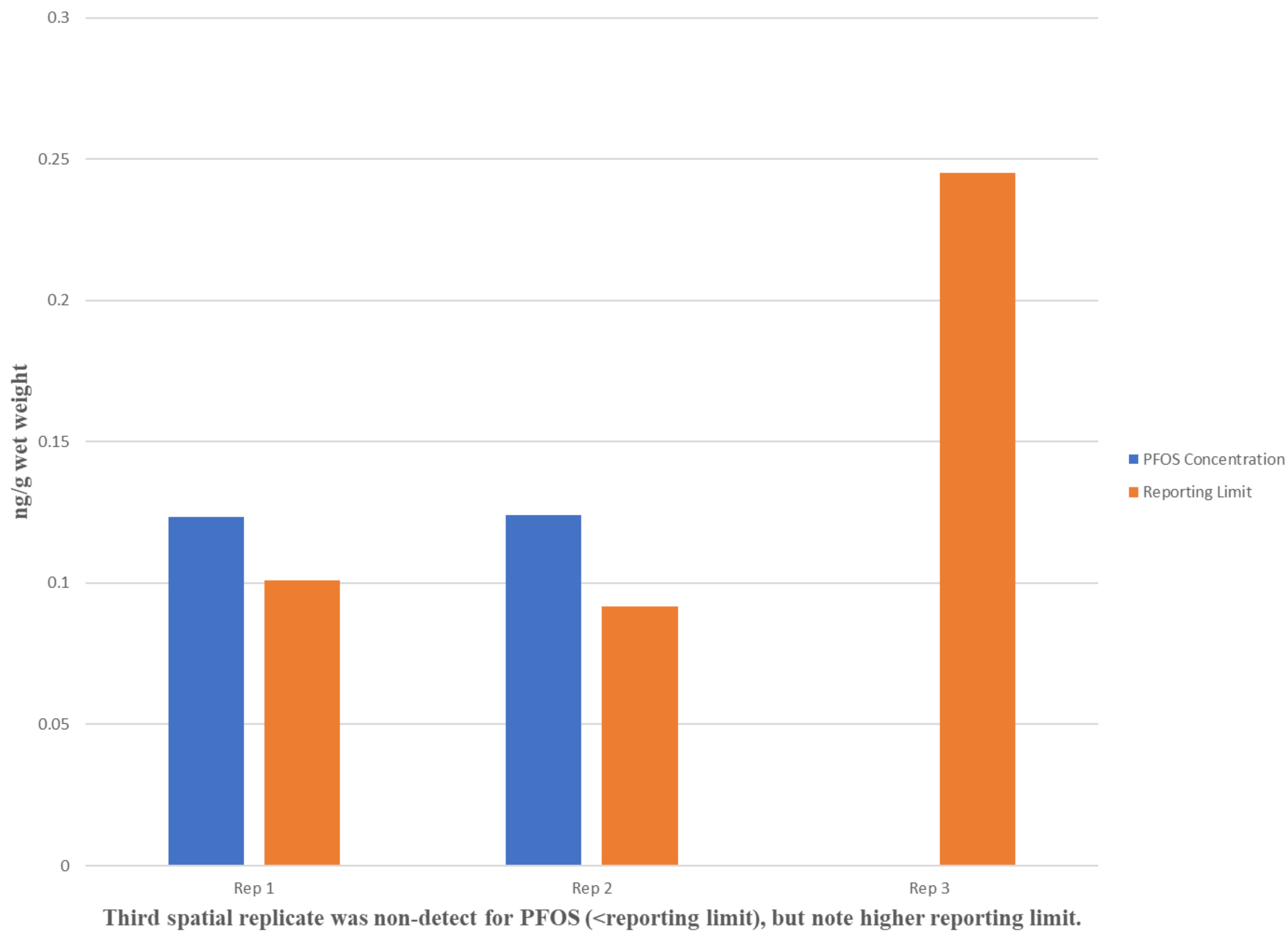
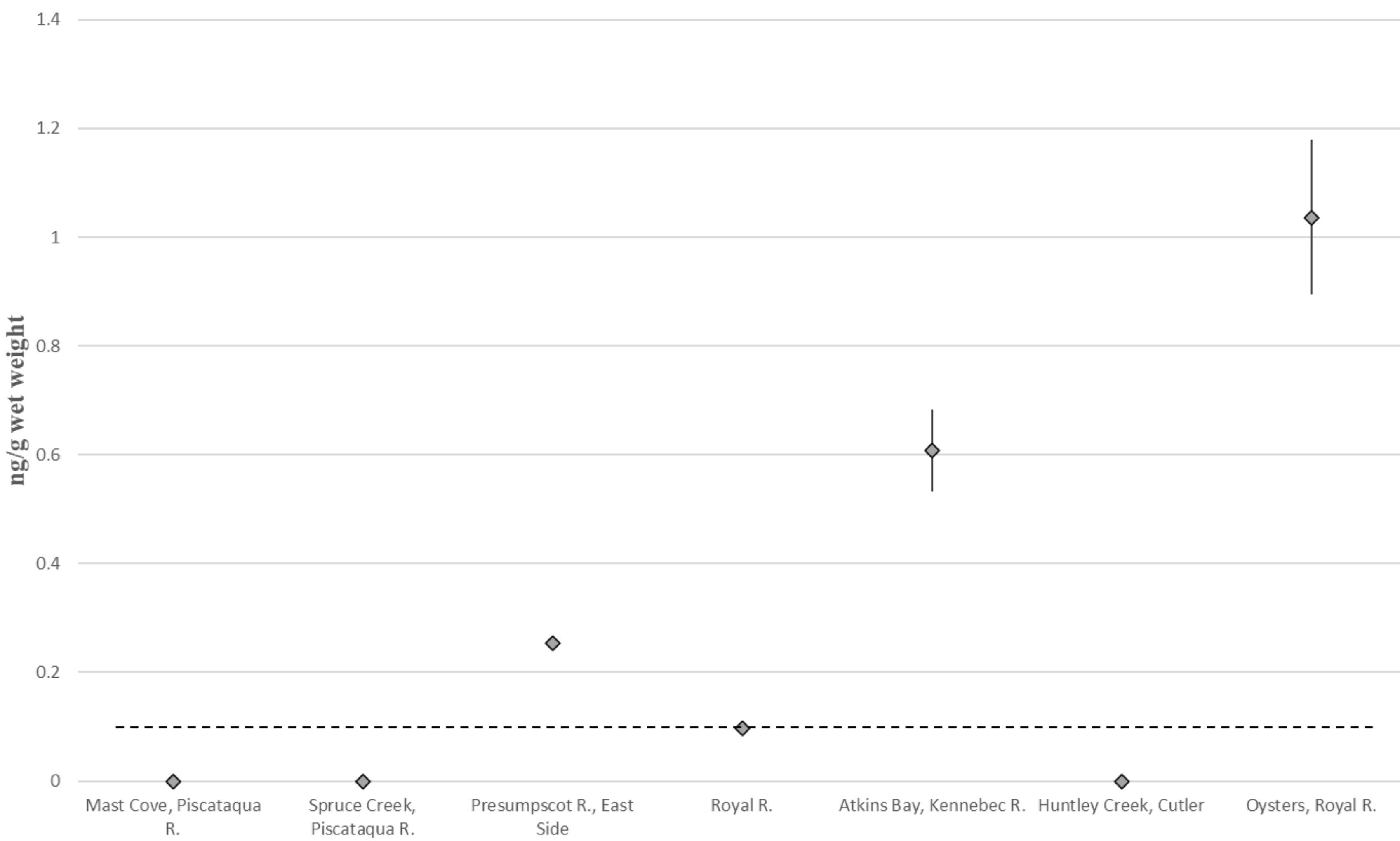


Figure 15. PFOS in 2022 softshell clam in Atkins Bay, Kennebec River



Mean PFOSA concentration +/- standard deviation; dotted line = mean reporting limit for PFOSA; Royal River softshell clam datum is from one individual intra-site sample and not a site mean; non-detects at three sites (=0).

Figure 16. PFOSA in 2022 softshell clam and American oyster tissue

Table 5. PFAS compounds detected in 2022 softshell clam and American oyster tissue

			PFAS Compound Detected												
Clam Site Name	site code	year	PFOSA	PFTrDA	PFTeDA	EtFOSAA	PFDS	PFNA	PFUnDA	N-EtFOSE	PFOS	6:2 FTS	PFPeA	PFDoDA	PFHxS
Mast Cove, Piscataqua R.	PQMCMC	2022			1*,3								2		
Spruce Creek, Piscataqua R.	PQSCSC	2022													
Presumpscot R., East Side	CBPRES	2022	1-3		1*	1-3							1	3*	
Royal R.	CBRYMT	2022	2										2		2*
Atkins Bay, Kennebec R.	MCKNAT	2022	1-3	3	1,2	1,2			1,2		1,2**				
Hunter Creek, Cutler	ECMCHB	2022											1-3		
Oyster Site Name															
Royal R.	CBRYLI	2022	1-3												
							none	none		none		none			

Numbers 1 - 3 represent the number of spatial subsamples at each site with detected concentrations of the PFAS compound (3 replicates per site).

* = EMPC, estimated maximum possible concentration.

** = Detected in two of three replicates, third replicate had higher MDL/RL and was non-detect.

2. Contaminants in Freshwater Fish

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2.1 Background

Sampling in 2021 and 2022 focused primarily on per- and polyfluoroalkyl substances (PFAS) in the fillets of freshwater fish. PFAS are a class of highly persistent and mobile chemicals that have at least one fluorine atom bonded to a carbon atom. There are thousands of different PFAS. The most common PFAS in the environment have linear chains of 4 to 14 carbons that are fully fluorinated, meaning that the carbons are only bonded to fluorine atoms and adjacent carbons (Figure 1). The linear chain of carbon atoms is called the "tail". A functional group (aka, "head"), such as a carboxyl, sulfonate, and sulfonamide group, is attached to one end of the tail. Per- and polyfluoroalkyl substances differ in the proportion of carbons that are bonded to fluorine atoms. In **per**fluoroalkyl substances, all carbons are fully bonded to fluorine atoms and adjacent carbons. Perfluorooctane carboxylate (PFOA), perfluorooctane sulfonate (PFOS), and perfluorooctance sulfonamide (PFOSA) are examples of perfluoroalkyl substances (Figure 2). In contrast, some but not all carbons in the tail of a **poly**fluoroalkyl substance are fully bonded to fluorine atoms. Fluorotelomer acids are examples of polyfluoroalkyl substances because they have one or more carbons in the tail bonded to hydrogen atoms instead of fluorine atoms (Figure 2 and Table 1).

The chemical structure of PFAS give them properties that make them useful in many commercial and industrial products and processes. The carbon-fluorine bonds are very strong and resist

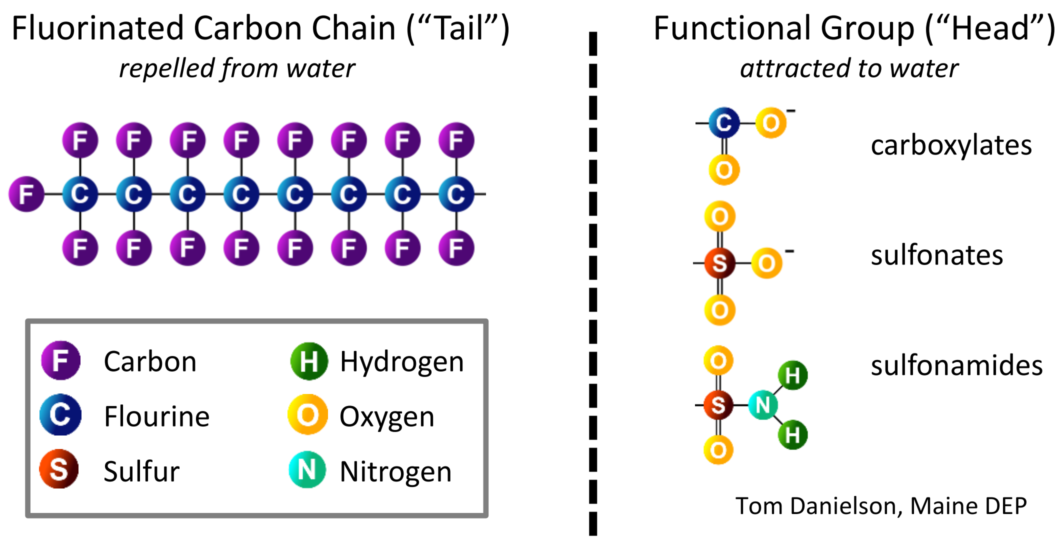

Figure 1. Structure of common linear PFAS included in Table 1, such as perfluoroalkyl carboxylates (PFCAs), perfluoroalkyl sulfonates (PFSAs), and perfluoroalkyl sulfonamides.

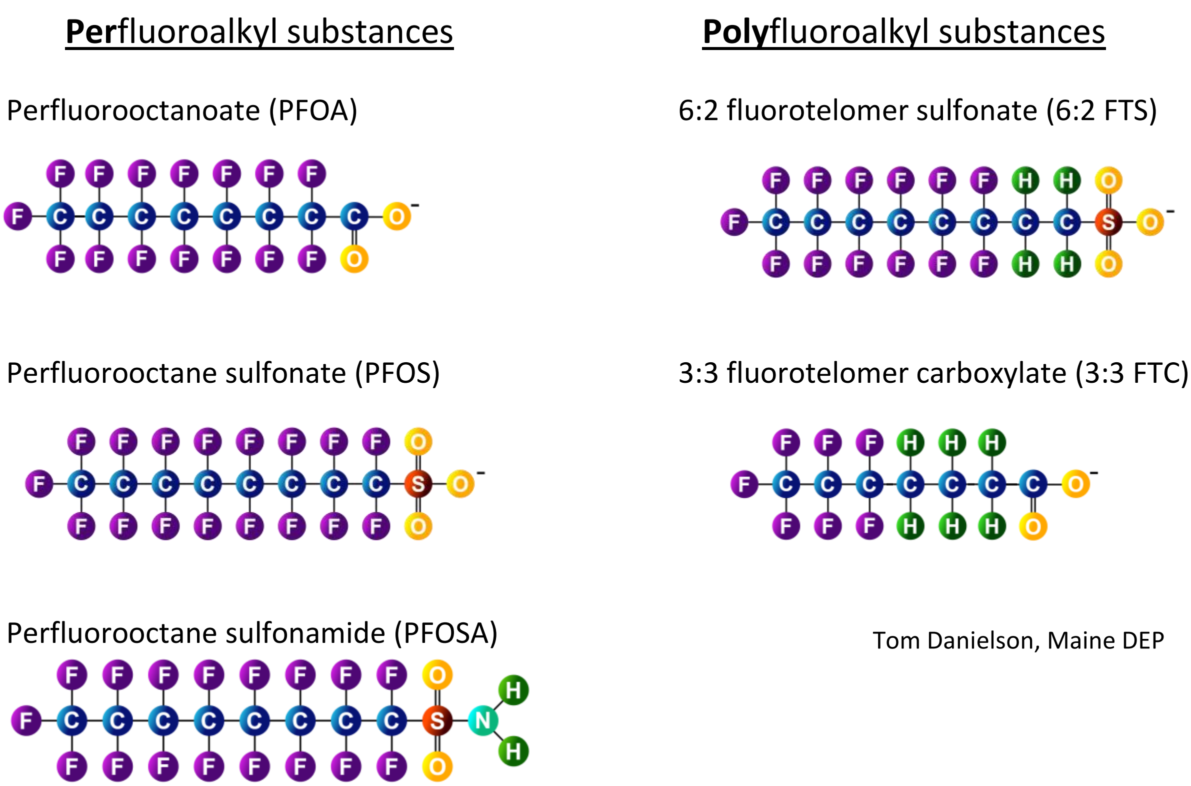

Figure 2. Examples of per- and polyfluoroalkyl substances

degradation from heat and normal biogeochemical processes. Some PFAS are used in aqueous fire-fighting foam (AFFF), industrial lubricants, and heat-resistant products. In addition, PFAS tails often repel water (hydrophobic) and the heads are attracted to water (hydrophilic). As a result, PFAS are used in many fabrics, paper, food wrappers, frying pans, and other products designed to repel water, repel oil, or resist stains. PFAS can persist in the environment for a very long time (thousands of years) because normal biogeochemical processes can't break the carbon-fluorine bonds. Therefore, PFAS have the nickname of "forever chemicals".

Although there are thousands of PFAS, typical lab analysis will include 25-40 varieties of PFAS, often focusing on sulfonates, carboxylates, sulfonamides, and fluorotelomers (Table 1). It is important to point out that naming conventions for sulfonates and carboxylates can be confusing because the carbon in the carboxylate functional group is counted with the carbons in the tail. While perfluoro**octane** sulfonate (PFOS) has 8 fluorinated carbons, perfluoro**octan**oate (PFOA) has only 7 fluorinated carbons (Figure 2). The eighth carbon in PFOA is the carbon in the carboxylate functional group. Some labs report results as acids, such as carboxylic acids instead of carboxylates, meaning they have a hydrogen attached to the functional group instead of having a negative charge. They are essentially the same compounds and are treated interchangeably. For example, pefluorooctane sulfonate, perfluorooctane sulfonic acid, and perfuorooctanesuflonic acid are synonyms for PFOS.

PFAS are emitted into the environment from both point sources (such as industrial or municipal wastewater treatment plants, WWTPs) and nonpoint sources (such as atmospheric deposition; Ahrens and Bundschuh 2014). In a study of sources of PFAS in major rivers of the world, Kimacjeva et al. (2012) found higher levels in industrial areas than in non-industrial areas. PFAS have been found in humans and wildlife all over the world including the artic and deep seas (Yingling 2013), which suggests atmospheric transport (Houde et al. 2011).

PFAS with 8 or more carbons are considered bioaccumulative with sulfonates (e.g. PFOS) having a greater bioaccumulation rate than PFOA and other PFAS, indicating that the functional group is also important (Martin et al., 2013). In some circumstances, people can inadvertently ingest a significant amount of PFOS and other PFAS when eating freshwater fish (Augustsson et al. 2021, Barbo et al. 2023). PFAS have been correlated with increased cancers, thyroid disease, interference with normal growth and development, and endocrine disruption in humans (Yingling 2013, Panieri et al. 2022). There are also reports in the literature of high concentrations in invertebrates, fish, reptiles, and marine mammals worldwide (Houde et al. 2011). PFAS have been linked to many adverse impacts to fish and other aquatic organisms (Lee et al. 2020).

Table 1. PFAS analyzed by the laboratory

Group	# Carbons in the Tail	Abbreviation (Trade Name)	Name	Mean Detection Limit (ng/g, ppb)
Perfluoroalkyl carboxylates (PFCAs)	3	PFBA	Perfluorobutanoate	0.38
	4	PFPeA	Perfluoropentanoate	0.19
	5	PFHxA	Perfluorohexanoate	0.10
	6	PFHpA	Perfluoroheptanoate	0.10
	7	PFOA	Perfluorooctanoate	0.10
	8	PFNA	Perfluorononanoate	0.10
	9	PFDA	Perfluorodecanoate	0.10
	10	PFUnDA	Perfluoroundecanoate	0.10
	11	PFDoDA	Perfluorododecanoate	0.08
	12	PFTrDA	Perfluorotridecanoate	0.10
	13	PFTeDA	Perfluorotetradecanoate	0.10
Perfluoroalkyl sulfonates (PFSAs)	4	PFBS	Perfluorobutane sulfonate	0.10
	5	PFPeS	Perfluoropentane sulfonate	0.10
	6	PFHxS	Perfluorohexane sulfonate	0.10
	7	PFHpS	Perfluoroheptane sulfonate	0.10
	8	PFOS	Perfluorooctane sulfonate	0.10
	9	PFNS	Perfluorononane sulfonate	0.10
	10	PFDS	Perfluorodecane sulfonate	0.10
	12	PFDoDS	Perfluorododecane sulfonate	0.10
Fluorotelomer substances	3 fluorinated & 3 unfluorinated	3:3 FTC	3:3 fluorotelomer carboxylate	0.38
	4 fluorinated & 2 unfluorinated	4:2 FTS	4:2 fluorotelomer sulfonate	0.38
	5 fluorinated & 3 unfluorinated	5:3 FTC	5:3 fluorotelomer carboxylate	2.38
	6 fluorinated & 2 unfluorinated	6:2 FTS	6:2 fluorotelomer sulfonate	0.34
	7 fluorinated & 3 unfluorinated	7:3 FTC	7:3 fluorotelomer carboxylate	2.38
	8 fluorinated & 2 unfluorinated	8:2 FTS	8:2 fluorotelomer sulfonate	0.32

Table 1 (continued)

Group	# Carbons in the Tail	Abbreviation (Trade Name)	Name	Mean Detection Limit (ng/g, ppb)
Perfluoroalkane sulfonamides (PASFs)	8	PFOSA	Perfluorooctane sulfonamide	
	8	N-ETFOSA	N-ethyl perfluorooctane sulfonamide	0.27
	8	N-MEFOSA	N-methyl perfluorooctane sulfonamide	0.10
Perfluorooctane sulfonamido-acetic acids	8	N-EtFOSAA	N-ethyl perfluorooctane sulfonamidoacetic acid	0.10
	8	N-MeFOSAA	N-methyl perfluorooctane sulfonamidoacetic acid	0.10
Pefluorooctane sulfonamide ethanols	8	N-EtFOSE	N-ethyl perfluorooctane sulfonamidoethanol	0.95
	8	N-MEFOSE	N-methyl perfluorooctane sulfonamidoethanol	0.95
Perfluoroether carboxylic acids		ADONA	4,8-dioxa-3h-perfluorononanoate	0.38
		HFPO-DA (Gen-X)	Hexafluoropropylene oxide dimer acid	0.38
	1+2+1 separated by oxygens	PFDHA	Perfluoro-3,6-dioxaheptanoic acid	0.34
	1+3 separated by an oxygen	PFMBA	Perfluoro-4-methoxybutanoic acid	0.10
	1+2 separated by an oxygen	PFMPA	Perfluoro-3-methoxypropanoic acid	0.19
Ether sulfonates	8+2 separated by an oxygen	11CL-PF3OUdS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonate	0.38
	6+2 separated by an oxygen	9CL-PF3ONS (F53-B)	9-cholorohexadecafluoro-3-oxanonane-1-sulfonate	0.38
	2+2 separated by an oxygen	PFEESA	Perfluoro(2-ethoxyethane) sulfonic acid	0.10

The Maine Center for Disease Control and Prevention (CDC) establishes fish tissue action levels (FTAL) for certain toxic chemicals. The FTALs are used to determine if fish are safe to eat. When the concentration of a chemical in a fish sample exceeds the FTAL, then CDC will review the data and determine if a fish consumption advisory is necessary to protect human health. The concentrations of PFAS are measured in nanograms (ng) of a PFAS per gram (g) of wet muscle tissue. The units are commonly expressed as ng/g, wet weight. One ng/g is equivalent to 1 part per billion (ppb). Currently, PFOS is the only kind of PFAS with a FTAL. The FTAL for PFOS is 3.5 ng/g (ppb, wet weight). In 2022, the CDC lowered the FTAL for PFOS from 34.1 ppb for sensitive populations and 79.0 ppb for the general population to the current 3.5 ppb for everyone.

2.2 PFAS in 2021 Fish Samples

Methods

In 2021, sampling focused on the waterbodies listed in Table 2. Several waterbodies were previously sampled, including China Lake, Estes Lake, Kennebec River, and Kennebunk River. The objective at each site was to collect 10 fish per species, except where Maine CDC requested more fish to better inform decisions about fish consumption advisories. In some cases, field crews were unable to catch 10 fish. Most fish were collected by angling. When angling was not practical or productive, fish were collected with seines, nets, or electrofishing gear. Sample collection and preparation followed standard protocols to minimize the potential for contamination. Upon capture, fish were stored in new, clean plastic bags on ice until transfer to DEP. At DEP, the fish were rinsed with PFAS-free water, and then measured and weighed for length and weight. Pieces of skinless fillets were cut from the fish and placed in plastic bags and frozen. The fillets were combined into composite samples of 5 fish whenever possible. In some cases, composite samples consisted of fewer than 5 fish. Samples were shipped overnight to SGS AXYS in British Columbia, Canada for analysis. The lab homogenized the composite samples and analyzed the tissue for 40 kinds of PFAS using Method MLA-110 (Table 1). The lab provided PFAS concentrations based on wet weight and dry weight for each composite sample.

Table 2. 2021 Freshwater Sites

Waterbody	Town	Species[1]	# fish	# composites	Potential contamination[2]
China Lake	China	LMB	10	2	Sludge
China Lake	China	WHP	10	2	Sludge
Estes Lake	Alfred	LMB	15	3	Landfill, WWTP, airport
Fairfield PAL Pond	Fairfield	BKT*	1	1	Landfill, sludge
Fairfield PAL Pond	Fairfield	LMB	6	2	Landfill, sludge
Fish Brook	Fairfield	LMB	2	1	Sludge
Fish Brook	Fairfield	YLP	10	2	Sludge
Fish Brook	Fairfield	BKT*	1	1	Sludge
Fish Brook Tributary	Fairfield	BKT	10	2	Sludge
Kennebec River (Shawmut Impoundment downstream of Rte. 23)	Fairfield	SMB	10	2	Sludge, industry
Kennebec River (Downstream of Shawmut dam)	Fairfield	SMB	10	2	Sludge, industry
Kennebec River	Norridgewock	SMB	10	2	Reference for other Kennebec River sites
Kennebec River	Skowhegan	SMB	10	2	WWTP
Kennebunk River (downstream)	Arundel	EEL	10	2	Sludge
Kennebunk River (downstream)	Arundel	BNT*	1	1	Sludge
Kennebunk River (upstream)	Arundel	BKT	10	2	Sludge
Little Androscoggin River (upstream)	Paris	LMB	10	2	Reference
Little Androscoggin River (downstream)	Auburn	SMB	10	2	Industry
Messalonskee Lake	Belgrade	SMB	10	2	Reference for Messalonskee Stream
Messalonskee Stream	Waterville	PIK	20	4	Sludge
Messalonskee Stream	Waterville	SMB	20	4	Sludge
Sebasticook River	Winslow	SMB	10	2	Sludge
Unity Pond	Unity	BLC	10	2	Sludge
Unity Pond	Unity	LMB	10	2	Sludge

*1 - Fish Codes: BLC = black crappie, BKT = brook trout, BNT = brown trout, EEL = American eel, LMB = largemouth bass, PIK = northern pike, WHP = white perch, YLP = yellow perch, * = stocked*

2 - "WWTP" means wastewater treatment plant and "sludge" means the residual biosolids from a WWTP that were spread on agricultural fields

Data were analyzed with R (version 4.2.2.) and RStudio (version 2022.12.0). Summary statistics were computed for the wet weight concentration of PFAS in composite samples, excluding results below detection limits (Table 3). Average PFAS concentrations were computed for each species at each site. Non-detect values were conservatively set to method detection limits. The distribution of the average PFAS concentrations were displayed as box-and-whisker plots for PFAS detected in at least 5 samples (Figure 3). The average concentration of PFOS from all fish collected at a site were computed and plotted on a map (Figure 5)

Results

Field crews caught 10 fish (2 composites of 5 fish) at most sites (Table 2). Crews caught 15 largemouth bass (3 composites of 5 fish) from Estes Lake at the request of Maine CDC. Crews also caught 20 smallmouth bass (4 composites of 5 fish) and 20 northern pike (4 composites of 5 fish) from Messalonskee Stream. Crews only caught 1 stocked brook trout (composite consisted of the single fish) and 6 largemouth bass (2 composite samples of 3 fish) from the Fairfield Police Athletic League (PAL) Pond. Similarly, only 1 brook trout (composite consisted of the single fish), 2 largemouth bass (1 composite sample of 2 fish), and 10 yellow perch were caught from Fish Brook. Overall, there were 51 composite samples with only a few composites having fewer than 5 fish.

PFOS was detected in all samples and had the highest concentrations in all samples compared to other kinds of PFAS (Figure 3). The other most common PFAS were PFOSA and carboxylic acids with 7-13 fluorinated carbons (PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, and PFTeDA). Like other studies and previous Maine samples, short-chain PFAS with fewer than 8 carbons (e.g., PFBA, PFHxA, PFHxS) had low concentrations in fish tissue. Most fluorotelomer acids had concentrations that were below or just above detection limits. 7:3 FTCA, which is very similar to PFDA but with only 7 of the 10 carbons fluorinated, was found at high concentrations at several sites. The detection limit for 7:3 FTCA is relatively high compared to other PFAS. Detection limits were not consistent among samples because of variations in dilution of tissue samples during processing in the lab.

Many 2021 samples had PFOS concentrations that exceeded the FTAL (3.5 ng/g, ppb, wet weight) (Figures 3 and 4). PFOS concentrations were extremely high in fish collected in Fairfield (Figures 4 and 5). Potential pathways of PFAS contamination to the Fairfield PAL Pond include a closed landfill and adjacent fields with a history of sludge spreading. The concentration of PFOS in largemouth bass from the PAL Pond is the highest concentration recorded in Maine fish to date. The fish in Fish Brook and its tributary also had very high PFOS concentrations. There are several sludge spreading sites and a closed landfill in the Fish Brook watershed. Downstream of Fish Brook, northern pike and smallmouth bass in Messalonskee Stream had high concentrations of PFAS both upstream and downstream of the confluence with Fish Brook (Figure 4). The northern pike had higher concentrations of PFOS than smallmouth bass. In contrast, bass in Messalonskee Lake, which was used as an upstream control site, had low PFOS concentrations. The Messalonskee Lake outlet dam prevents the upstream movement of bass and pike from Messalonskee Stream.

PFOS concentrations in the Kennebec River were low in Norridgewock and Skowhegan but higher in the Shawmut impoundment downstream of the Sappi mill (Figures 3 and 4). PFOS concentrations were also high in the Kennebec River downstream of the Shawmut Dam in Fairfield. Smallmouth bass from the Sebasticook River had PFOS concentrations greater than the FTAL but lower than bass in the Kennebec River in Fairfield. Black crappie and largemouth bass from Unity Pond had PFOS concentrations well above the FTAL, with higher concentrations in black crappie.

Resampling of China Lake and Estes Lake confirmed that fish from those waterbodies had PFOS concentrations greater than the FTAL. Wild brook trout from the upstream location on the Kennebunk River in Days Mill had low PFOS concentrations. In contrast, the downstream site on the Kennebunk River, which is located upstream of Route 1, had high concentrations in eels and low concentrations in the one stocked brown trout that was collected. The immature “yellow” eels that were collected are thought to have small home ranges and high site fidelity. Bass in the Little Androscoggin River had low PFOS concentrations both upstream and downstream of the business that produces plastic products.

Table 3. Summary statistics of PFAS detected in 2021 composite samples (n=51, skinless fillets, wet weight)

PFAS[1]	min	q1	median	mean	q3	max	# of detects	# of non-detects
5:3 FTC	2.76	2.76	2.76	2.76	2.76	2.76	1	50
7:3 FTC	3.88	6.46	9.25	15.76	16.64	49.69	12	39
8:2 FTS	0.68	0.86	1.33	2.17	3.63	4.61	6	45
N-EtFOSAA	0.19	0.84	1.19	3.16	1.57	13.73	9	42
N-MeFOSAA	0.26	0.26	0.26	0.26	0.26	0.26	1	50
PFDA	0.09	0.54	1.46	13.17	5.96	127.1	47	4
PFDoDA	0.14	0.42	0.57	2.93	1.1	49.92	48	3
PFDS	0.13	0.14	0.47	0.61	0.7	2	9	42
PFHpA	0.18	0.25	0.4	0.7	0.85	1.82	4	47
PFHpS	0.09	0.34	0.48	0.6	0.96	1.47	12	39
PFHxA	0.16	0.18	0.2	0.2	0.21	0.23	2	49
PFHxS	0.1	0.13	0.15	0.42	0.71	1.01	5	46
PFNA	0.1	0.34	0.87	2.86	4.08	10.79	23	28
PFNS	0.16	0.21	0.28	1.16	2.43	2.74	5	46
PFOA	0.11	0.23	0.29	1.3	0.99	8.07	13	38
PFOS	1.03	4.06	13.83	113.98	44.08	1504	51	0
PFOSA	0.11	0.19	1.22	2.87	3.19	21.07	31	20
PFTeDA	0.11	0.26	0.36	0.77	0.72	5.89	25	26
PFTrDA	0.14	0.35	0.55	0.98	0.76	12.46	49	2
PFUnDA	0.15	0.68	1.19	10.05	2.94	174.1	49	2

[1] – The following PFAS were not detected in the 51 composite samples processed in 2021: 11CL-PF3OuDS, 3:3 FTC, 4:2 FTS, 6:2 FTC, 9CL-PF3ONS, ADONA, HFPO-DA, N-EtFOSA, N-EtFOSE, N-MeFOSA, N-MeFOSE, PFBA, PFBS, PFDoDS, PFEES, PFMB, PFMP, PFPeA, PFPeS.

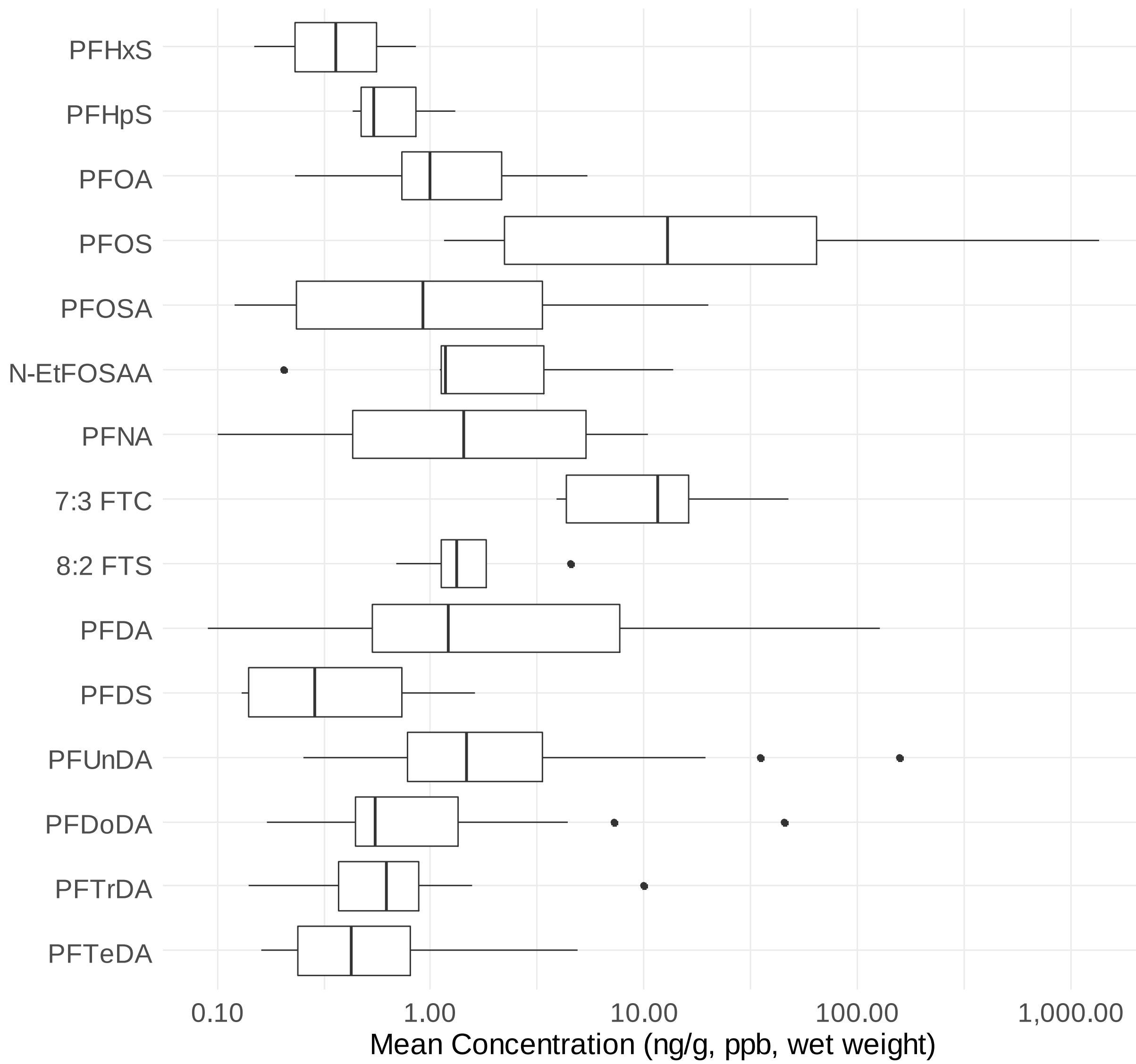

Figure 3. Box-and-whisker plots of mean concentrations of PFAS detected in 5 or more samples in 2021 samples (skinless fillets, wet weight). Non-detect results were excluded.
The boxes show the middle half of the data. Vertical lines inside the boxes show median values. Horizontal lines to the left and right of the boxes show the lowest quarter and highest quarter of concentrations, respectively. Circles indicate unusually high or low values compared to other data.

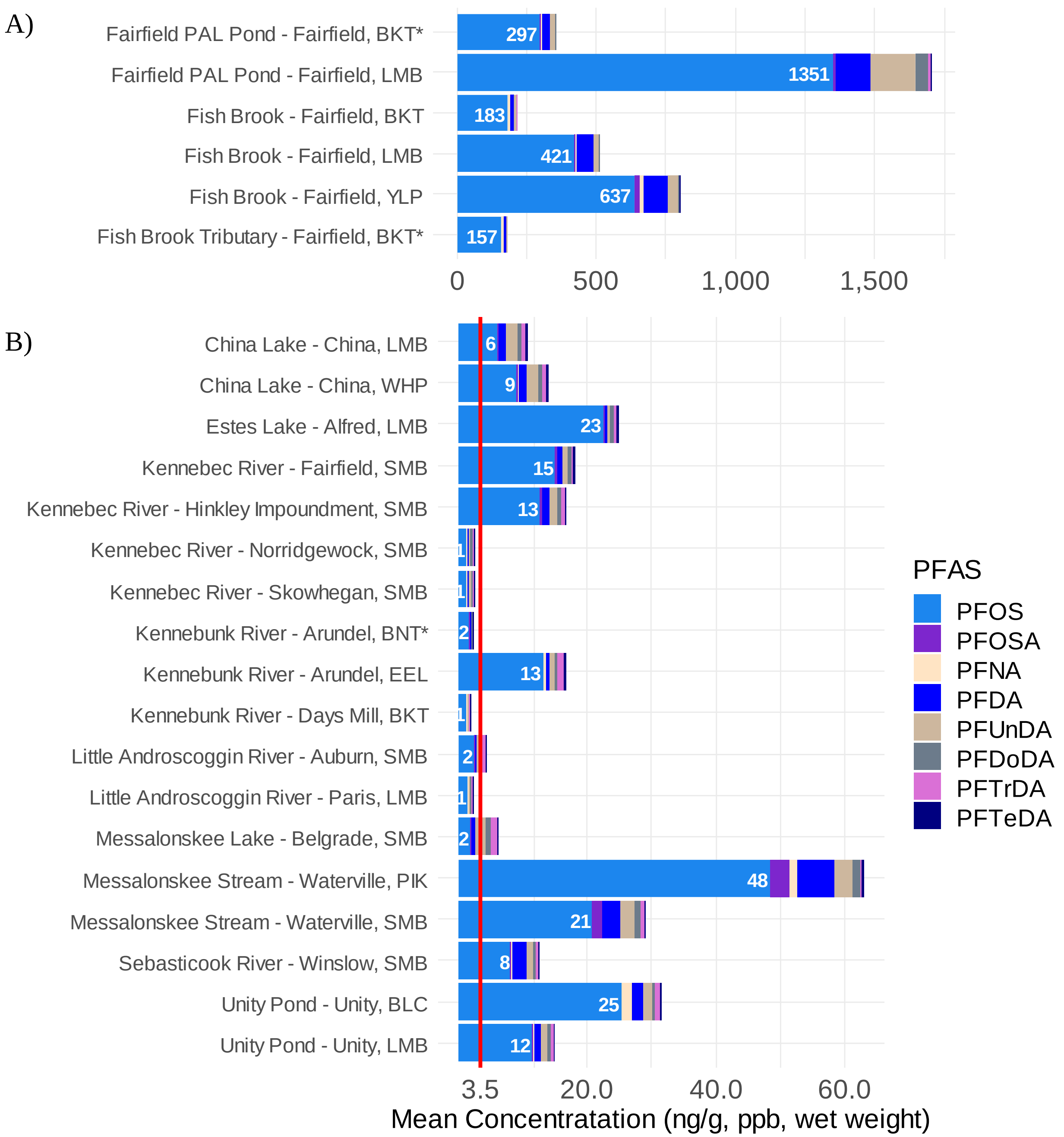

Figure 4. Average concentrations of PFOS and other most common PFAS in 2021 fish tissue samples (skinless fillets, wet weight). *The white numbers are the average PFOS concentrations. Panel A includes samples with high PFOS concentrations and panel B includes samples with low PFOS concentrations. The vertical red line in panel B shows the Fish Tissue Action Level (FTAL) for PFOS, which is 3.5 ppb.*

*Fish Codes: BLC = black crappie, BKT = brook trout, BNT = brown trout, EEL = American eel, LMB = largemouth bass, PIK = northern pike, WHP = white perch, * = stocked*

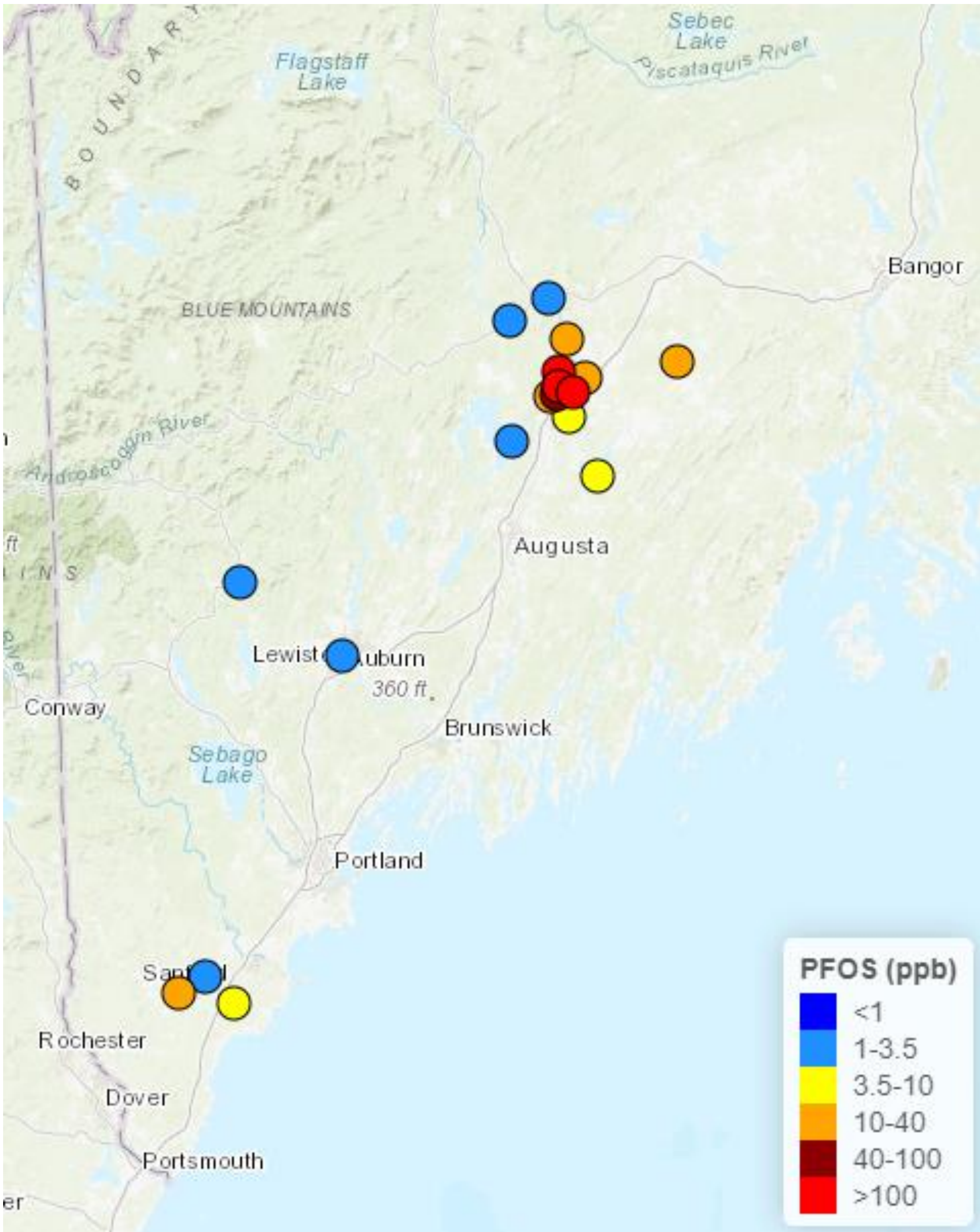

Figure 5. Map of 2022 sample sites with average PFOS concentrations (ng/g, ppb) of skinless fillets of all fish caught at sites.

2.3 PFAS in 2022 Fish Samples

Methods

DEP received grant money from the U.S. EPA to supplement 2022 SWAT funds for freshwater monitoring. As a result, DEP was able to collect more samples than usual. In 2022, the sites listed in Table 4 were targeted for PFAS analysis. Field crews collected single water samples for PFAS analysis from the sites in Table 4 plus some additional sites that were sampled in previous years.

Field crews collected many fish from Aroostook County rivers in 2022 because there were few PFAS samples in previous years. Several sites were selected as reference sites for PFAS in Aroostook County, including the Aroostook River (Oxbow Plt), Little Madawaska River (Connor Twp), Meduxnekeag River (New Limerick), and St John River (Allagash). Brook trout were targeted in downstream segments of Little Madawaska River (Caribou) and Limestone Stream (Limestone) because of PFAS fish consumption advisories in the upstream portions of those rivers. Past use of fire-fighting foam at the former Loring Airforce Base caused severe contamination of the upstream segments of those rivers and Durepo Pond. In addition, the following sites were selected in the County: Aroostook River (Presque Isle), Aroostook River (Caribou), Meduxnekeag River (Houlton), Prestile Stream (Westfield), Prestile Stream (Blaine), Smith Brook (Houlton), St John River (Frenchville), and St John River (Grand Isle).

In Central and Southern Maine, several reference sites were selected, including Moose River (Jackman), Piscataquis River (Abbot), and Sandy River (Madrid Twp). Field crews sampled the following sites because Maine CDC requested additional information to inform the process of determining if fish consumption advisories are necessary: Androscoggin River (Rumford and Livermore Falls), China Lake (China), Halfmoon Stream (Knox and Thorndike), Kennebec River (Hinkley, Fairfield, and Gardiner), Number One Pond (Sanford), and Unity Pond (Unity). The remaining sites were new based on proximity to potential pathways of PFAS contamination: Fifteenmile Stream (Albion), McGrath Pond (Oakland), and Sebasticook River (Burnham). Fifteenmile Stream and Sebasticook River had residual biosolids (sludge) from a wastewater treatment plant spread on agricultural fields. McGrath Pond has a nearby landfill in Oakland.

The standard goal was to collect 10 fish per species per site. In some cases, Maine CDC requested more fish to better inform decisions about fish consumption advisories. In some cases, field crews were unable to catch 10 fish. All fish were collected by angling. Sample collection and preparation followed standard protocols to minimize the potential for contamination. Upon capture, fish were stored in new, clean plastic bags on ice until transfer to DEP. At DEP, the fish were rinsed with PFAS-free water, and then measured and weighed for length and weight. Pieces of skinless fillets were taken from the fish, placed in plastic bags, and frozen. Skin-on fillets were collected from fish at three sites to compare to skinless fillets, including Limestone Stream (Limestone), Meduxnekeag River (Houlton), and Sandy River (Madrid Twp). Samples were shipped overnight to SGS Axys in British Columbia, Canada for analyses. The lab homogenized the composite samples and analyzed the tissue for 40 kinds of PFAS using Method

Table 4. 2022 Freshwater Sites

Waterbody	Town	Species[1]	# fish	# composites	Potential contamination[2]
Androscoggin River	Rumford	SMB	10	2	Industry, WWTP
Androscoggin River	Livermore	SMB	15	3	Industry, WWTP
Androscoggin River	Brunswick	SMB	10	2	Industry, WWTP
Aroostook River	Oxbow Plt	BKT	10	2	Reference
Aroostook River	Presque Isle	BKT	10	2	WWTP
Aroostook River	Caribou	BKT	10	2	Military base
China Lake	China	LMB, SMB, WHP	15, 15, 5	3, 3, 1	Sludge
Fifteenmile Stream	Albion	BKT	25	5	Sludge
Great Works River (upstream)	North Berwick	BKT*	10	2	Reference
Great Works River (downstream)	North Berwick	BKT	10	2	Mix of sources
Halfmoon Stream	Knox	BKT	5	1	Sludge
Halfmoon Stream	Thorndike	BKT	5	1	Sludge
Kennebec River (Shawmut Impoundment downstream of Rte. 23)	Hinkley	SMB	10	2	Industry, sludge
Kennebec River (Shawmut dam)	Fairfield	SMB	10	2	Industry, sludge
Kennebec River	Gardiner	SMB	10	2	Industry, sludge
Limestone Stream	Limestone	BKT	10	4[3]	Military base
Little Madawaska River	Caribou	BKT	10	2	Military base
Little Madawaska River	Connor Twp	BKT	10	2	Reference
Mcgrath Pond	Oakland	SMB, LMB, BLC	10, 5, 10	2, 1, 2	Landfill
Meduxnekeag River	New Limerick	BKT	10	2	Reference
Meduxnekeag River	Houlton	BKT	10	4[3]	Town, sludge
Moose River	Jackman	BKT	10	2	Reference
Number One Pond	Sanford	LMB	10	2	Mix of sources
Piscataquis River	Abbot	BKT*	10	2	Reference
Prestile Stream	Blaine	BKT	10	2	Agriculture
Prestile Stream	Westfield	BKT	10	2	Agriculture
Sandy River	Madrid Twp	BKT	10	4[3]	Reference
Sebasticook River	Burnham	LMB	10	2	Sludge, WWTP
Smith Brook	Houlton	BKT	10	2	Agriculture
St John River	Allagash	BKT	10	2	Reference
St John River	Frenchville	SMB	10	2	Mix of sources

Table 4 (continued)

Waterbody	Town	Species[1]	# fish	# composites	Potential contamination[2]
St John River	Grand Isle	SMB	10	2	Mix of sources
Unity Pond	Unity	BLC, LMB, WHP	15, 15, 25	3, 3, 5	Sludge

*1: Fish Codes: BLC = black crappie, BKT = brook trout, BNT = brown trout, EEL = American eel, LMB = largemouth bass, PIK = northern pike, WHP = white perch, YLP = yellow perch, * = stocked*
2: "WWTP" means wastewater treatment plant and "sludge" means the residual biosolids from a WWTP that were spread on agricultural fields
3: Skin-on fillets were processed along with skinless fillets

MLA-110 (Table 1). The lab provided PFAS concentrations based on wet weight and dry weight for each composite sample. Subsequent analysis focused on average PFAS concentrations for each site based on wet weight.

Data were analyzed with R (version 4.2.2.) and RStudio (version 2022.12.0). Summary statistics were computed for the concentration of PFAS in composite samples, excluding results below detection limits (Table 3). Average PFAS concentrations were computed for each species at each site. For purposes of computing average PFAS concentrations, non-detect values were conservatively set to method detection limits. The distribution of the average PFAS concentrations in skinless fillets were displayed as box-and-whisker plots for PFAS detected in at least 5 samples (Figure 5). Stacked bar plots of the average concentrations of PFOS and other common PFAS were created (Figure 6). The average concentration of PFOS from all fish (skinless fillets) collected at a site were computed and plotted on a map (Figure 7). For streams with paired skinless and skin-on fillet samples, we examined the differences in average concentrations of PFOS and other common PFAS.

Results

Field crews collected 2 composites of 5 fish at most sites (Table 4). At the request of Maine CDC, crews collected more composite samples for one or more species at the Androscoggin River (Livermore), China Lake (China), Fifteenmile Stream (Albion), McGrath Pond (Oakland), and Unity Pond (Unity). Overall, 85 composite skinless fillet samples were collected in 2022. Two composite samples of skin-on fillets were collected from each of the following waterbodies: Limestone Stream (Limestone), Meduxnekeag River (Houlton), and Sandy River (Madrid). Overall, 91 composites samples were collected.

Similar to 2021, PFOS occurred in all samples and had the highest concentrations compared to other kinds of PFAS (Table 3). The other most common PFAS were PFOSA and carboxylic acids with 7-13 fluorinated carbons (PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, and PFTeDA). When compared to 2021, there were fewer highly contaminated sites in 2022 as shown by lower median and maximum concentrations (Figure 5). All sites that were selected as reference sites had PFOS concentrations less than 3.5 ppb.

Fish from Aroostook County varied in PFOS concentrations. Average PFOS concentrations were less than 3.5 ppb in fish collected from the following sites: Aroostook River (Oxbow Plt and Presque Isle), Aroostook River (Presque Isle), Little Madawaska River (Connor Twp), Meduxnekeag River (New Limerick), Smith Brook (Houlton) and St John River (Allagash, Frenchville, and Grand Isle). It was somewhat surprising but encouraging that the fish in the two downstream locations of the St John had low PFOS concentrations. In contrast, PFOS concentrations were greater than 3.5 ppb in fish from the following sites: Aroostook River (Caribou), Limestone Stream (Limestone), Little Madawaska River (Caribou), Meduxnekeag River (Houlton), and Prestile Stream (Westfield and Mars Hill). The trout from the Aroostook River (Presque Isle) were caught at the confluence of Hardwood Brook, and it was not clear if the fish spent more time in Hardwood Brook or the Aroostook River. The trout from Smith Brook (Houlton) had much lower concentrations than trout from the Meduxnekeag River (Houlton), which were caught a short distance downstream from Smith Brook. Smith Brook is a tributary of the Meduxnekeag River, and we assumed that the trout spent some time in the Meduxnekeag River. Given that the concentration of PFOS in the Smith Brook trout was much lower than the concentration of PFOS in the Meduxnekeag River trout (1 ppb vs 15 ppb), it appears that the Smith Brook trout spend most of their time in Smith Brook. Limestone Stream (Limestone) and Little Madawaska River (Caribou) are both downstream of the former Loring Airforce Base, and upstream segments of both rivers have fish consumption advisories in place. Based on the 2022 data collected further downstream, Maine CDC is considering extending the fish consumption advisories further downstream.

Fish from Central and Southern Maine also varied in PFOS concentrations. Average PFOS concentrations from the following sites were less than 3.5 ppb: Androscoggin River (Rumford), Great Works River (North Berwick – upstream), Halfmoon Stream (Knox), Moose River (Jackman), Piscataquis River (Abbott), Sandy River (Madrid), and Sebasticook River (Burnham). The trout from the upstream site on the Great Works River were hatchery fish that were stocked and in the river for only a couple of weeks. In contrast, average PFOS concentrations were greater than 3.5 ppb at the following sites: Androscoggin River (Livermore and Brunswick), China Lake (China), Fifteenmile Stream (Albion), Great Works River (North Berwick – downstream), Halfmoon Stream (Thorndike), Kennebec River (Hinkley, Fairfield, and Gardiner), McGrath Pond (Oakland), Number One Pond (Sanford), and Unity Pond (Unity). Similar to 2021, black crappie samples had higher concentrations of PFOS than bass and white perch collected in the same waterbodies.

Although PFOS was the most common PFAS, PFOSA and long-chain PFCAs were present in the 2022 fish samples. PFOSA was unusually high in the Androscoggin River (Livermore and Brunswick). Long-chain PFCAs made up an unusually high proportion of total PFAS in fish collected from McGrath Pond (Oakland). Long-chain PFAS were abundant in the samples collected from China Lake (China), Kennebec River (Hinkley and Fairfield), and Unity Pond (Unity), as well. In contrast, fish collected from Aroostook County tended to have comparatively low concentrations of long-chain PFCAs.

Table 5. Summary statistics of PFAS detected in 2022 composite samples (n=91, skinless fillets, wet weight)

PFAS[1]	min	q1	median	mean	q3	max	# of detects	# of non-detects
6:2 FTS	1.96	1.96	1.96	1.96	1.96	1.96	1	90
7:3 FTCA	2.67	2.71	2.74	2.74	2.78	2.82	2	89
N-EtFOSAA	0.1	0.21	1.12	3.24	6.79	9.72	9	82
N-EtFOSE	0.88	1.19	1.42	1.82	2.43	4.08	19	72
N-MEFOSA	0.1	0.1	0.1	0.1	0.1	0.1	1	90
N-MeFOSAA	0.1	0.1	0.1	0.1	0.1	0.11	2	89
N-MEFOSE	1.06	1.06	1.06	1.06	1.06	1.06	1	90
PFBA	0.38	0.38	0.38	0.38	0.38	0.38	1	90
PFDA	0.09	0.17	0.31	0.7	1.13	2.58	81	10
PFDoDA	0.08	0.13	0.26	0.36	0.5	1.63	76	15
PFDS	0.1	0.1	0.12	0.17	0.21	0.38	8	83
PFEESA	0.14	0.14	0.14	0.14	0.14	0.14	1	90
PFHpA	0.09	0.1	0.1	0.11	0.11	0.13	3	88
PFHpS	0.1	0.11	0.11	0.11	0.12	0.13	2	89
PFHxS	0.14	0.27	0.37	0.58	0.61	1.72	17	74
PFMBA	0.12	0.12	0.13	0.13	0.13	0.14	4	87
PFNA	0.11	0.16	0.21	0.38	0.44	1.66	49	42
PFNS	0.1	0.1	0.1	0.1	0.1	0.1	1	90
PFOA	0.09	0.14	0.18	0.25	0.24	1.42	30	61
PFOS	0.23	1.54	5.81	8.27	12.07	32.97	91	0
PFOSA	0.09	0.15	0.31	1.15	0.9	4.57	23	68
PFPeS	0.09	0.09	0.09	0.09	0.09	0.09	1	90
PFTeDA	0.09	0.13	0.18	0.24	0.29	0.81	62	29
PFTrDA	0.11	0.21	0.3	0.39	0.52	1.57	84	7
PFUnDA	0.12	0.24	0.4	0.73	1.09	2.78	87	4

[1] – The following PFAS were not detected in the 91 composite samples processed in 2022: 11CL-PF3OuDS, 3:3 FTC, 4:2 FTS, 5:3 FTC, 8:2 FTS, 9CL-PF3ONS, ADONA, HFPO-DA, N-EtFOSA, NFDHA, PFBS, PFDoDS, PFHxA, PFMPA, PFPeA.

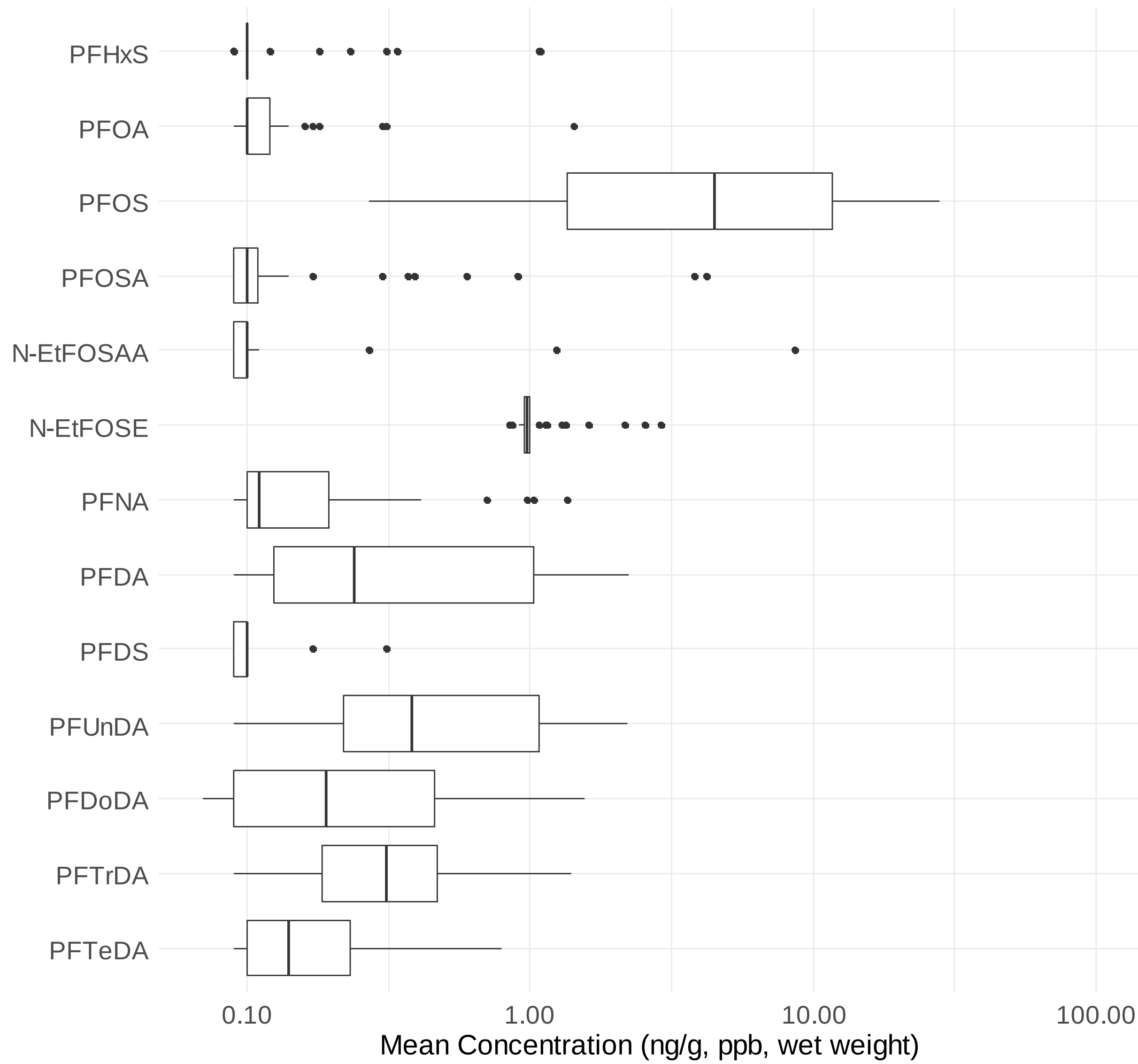

Figure 6. Box-and-whisker plots of concentrations of PFAS in 2022 skinless fillet samples (wet weight). Non-detect results were excluded. The plot includes PFAS that were detected at 5 or more sites.

The boxes show the middle half of the data. Vertical lines inside the boxes show median values. Horizontal lines to the left and right of the boxes show the lowest quarter and highest quarter of concentrations, respectively. Circles indicate unusually high or low values compared to other data.

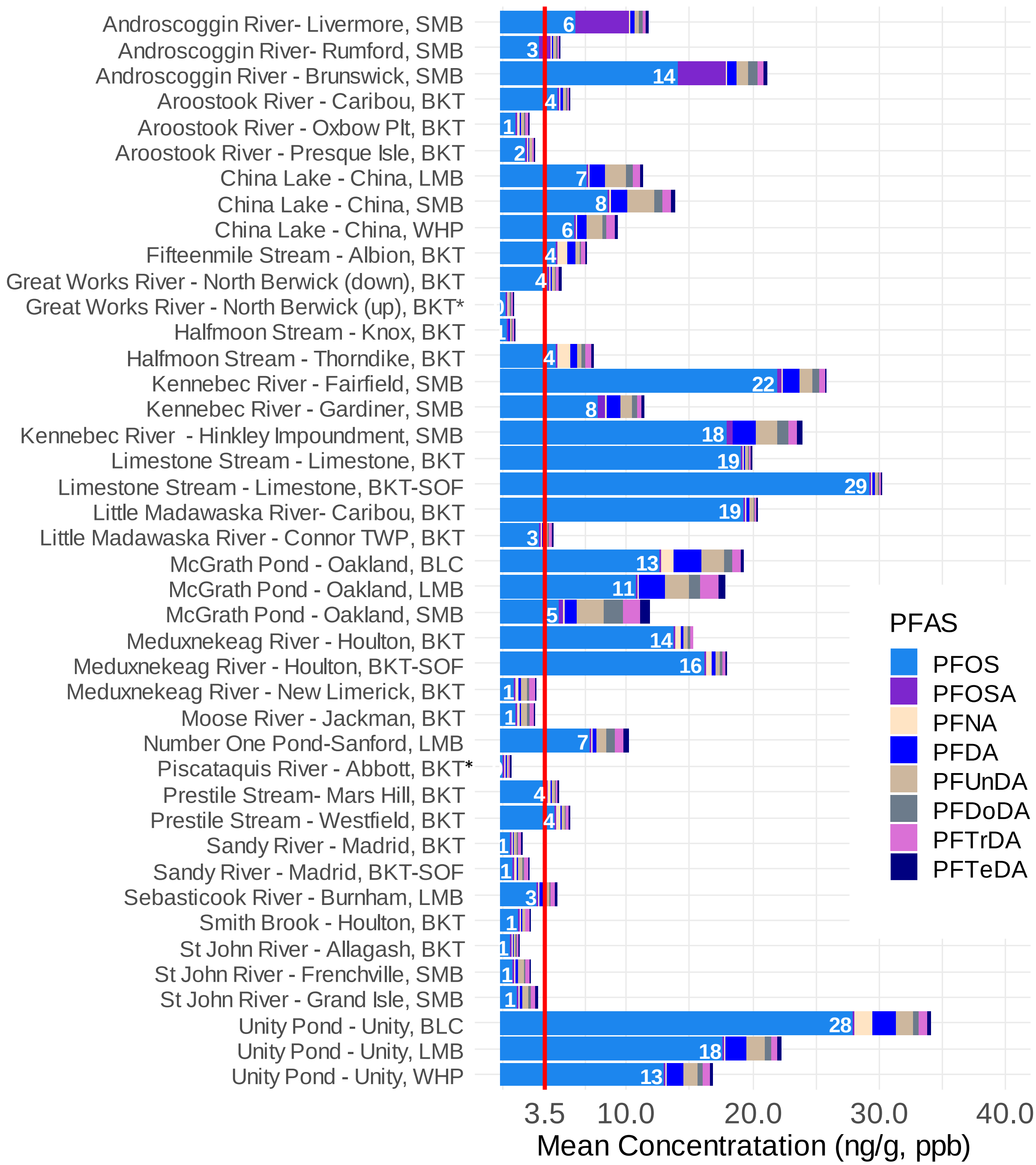

Figure 7. Average concentrations of PFOS and other most common PFAS in 2022 fish tissue samples (wet weight). Most samples were skinless fillets. Samples with SOF in the fish code are skin-on fillets. *The white numbers are the average PFOS concentrations. The vertical red line in panel B shows the Fish Tissue Action Level (FTAL) for PFOS, which is 3.5 ppb.*
*Fish Codes: BLC = black crappie, BKT = brook trout, BKT-SOF = brook trout (skin-on fillet), LMB = largemouth bass, WHP = white perch, * = stocked*

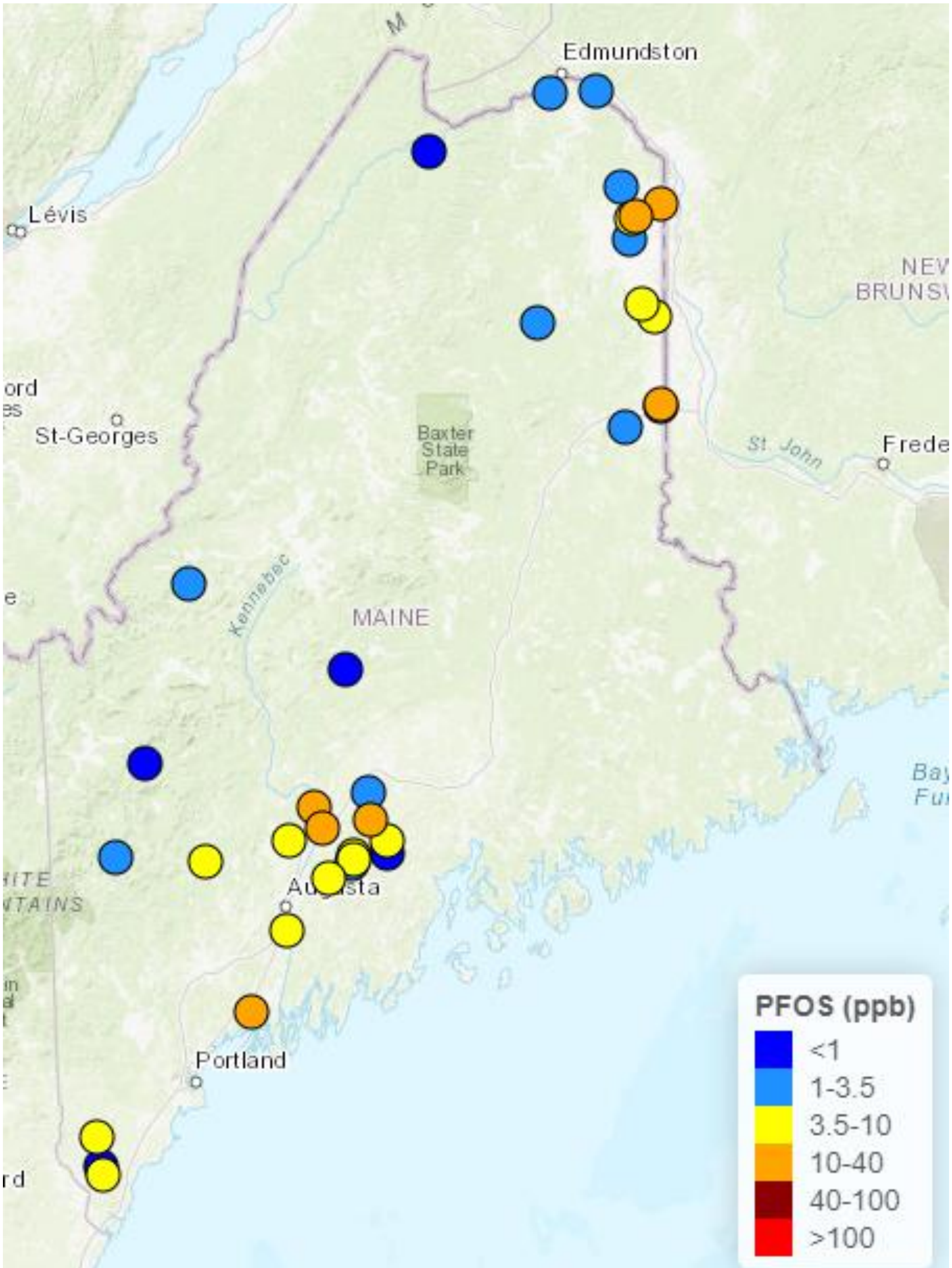

Figure 8. Map of sample sites with average PFOS concentrations (ng/g, ppb, wet weight) of skinless fillets of all fish caught at the site in 2022.

2.4 Overview of PFAS in Fish Samples (2014-2022)

Statewide, most sites with average PFOS concentrations greater than 3.5 ppb in fish tissue are located in densely populated areas of the state, agricultural areas, and near point sources of contamination, such as airports, landfills, and industries. In contrast, most sites in rural, forested parts of the state had low concentrations of PFOS in fish tissue. In some cases, there appears to be single contamination pathways. For example, the likely pathway of contamination to waterbodies near the former Loring Air Force Base (Little Madawaska River, Limestone Stream, and Durepo Pond) appears to be historic use of aqueous fire-fighting foam (AFFF). Past application of residual biosolids from wastewater treatment plants on farm fields appears to be the likely pathway of contamination for some waterbodies in agricultural parts of the state, such as Fifteenmile Stream (Albion), Fish Brook (Fairfield), Halfmoon Stream (Thorndike), Messalonskee Stream (Waterville), and Unity Pond (Unity). In other cases, there are multiple potential pathways of contamination, and it is difficult to determine the primary PFAS source(s). For example, the Mousam River and Estes Lake (Sanford) have a nearby urban area, landfill, airport, and wastewater treatment plant.

2.5 DDT in 2022 Fish Samples

Several rivers in Maine have fish consumption advisories because of high concentrations of the pesticide DDT. A small amount of federal grant money from EPA provided funds to analyze DDT in skinless fillets along with PFAS from trout collected from Prestile Stream (Mars Hill and Westfield, n = 4 composite samples of 5 fish) and Meduxnekeag River (Houlton, n = 2 composite samples of 5 fish). SGS AXYS analyzed the samples with Method MLA-007-E1. The Maine CDC bases fish consumption advisories on the sum of 6 forms of DDT and products of DDT degradation (∑DDT):

- 2,4’ DDT and 4,4’ DDT
- 2,4’ DDD and 4,4’ DDD
- 2,4’ DDE and 4,4’ DDE.

The FTAL for ∑DDT is 64 ppb. SGS Axys analyzed the ∑DDT and individual components and reported results in ng/g (ppb, wet weight). Concentrations of ∑DDT were compared to the FTAL and past samples. The Meduxnekeag River was previously sampled for ∑DDT in 1995, 2008, and 2009. The Prestile Stream was previously sampled for ∑DDT in 1996, 2000, and 2007.

In 2022, the average concentration of ∑DDT in the Meduxnekeag River was 49.5 ppb compared to 89.2 ppb in 1995. The concentration of ∑DDT was lowest in 2008 (45.5 ppb), but sampling the following year had higher concentrations (69.3 ppb). Similar to the Meduxnekeag River, Prestile Stream had the highest concentration of ∑DDT in 1996 (232.3 ppb) and lowest concentration in 2022 (49.2 ppb). It should be pointed out that samples collected before 2022 were analyzed as individual fish (Figure 11). Most of the ∑DDT consists of DDT biproducts, particularly 4,4’-DDE. Although it is encouraging that the ∑DDT concentrations have dropped below 64 ppb, both waterbodies have high concentrations of PFOS, which may prevent changes to fish consumption advisories.

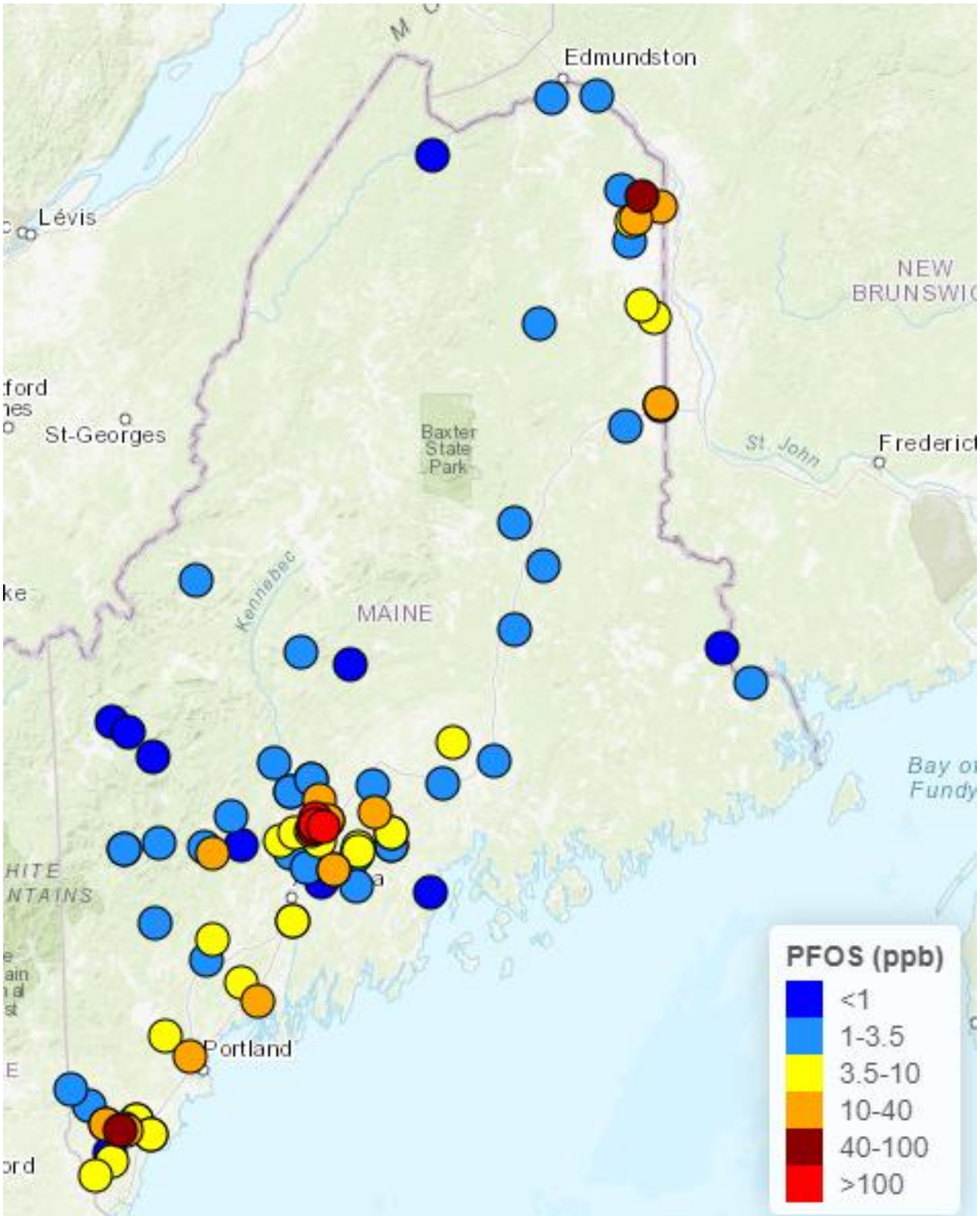

Figure 9. Map of sample sites with average PFOS concentrations (ng/g, ppb, wet weight) of skinless fillets of all fish caught at the site from 2014-2022.

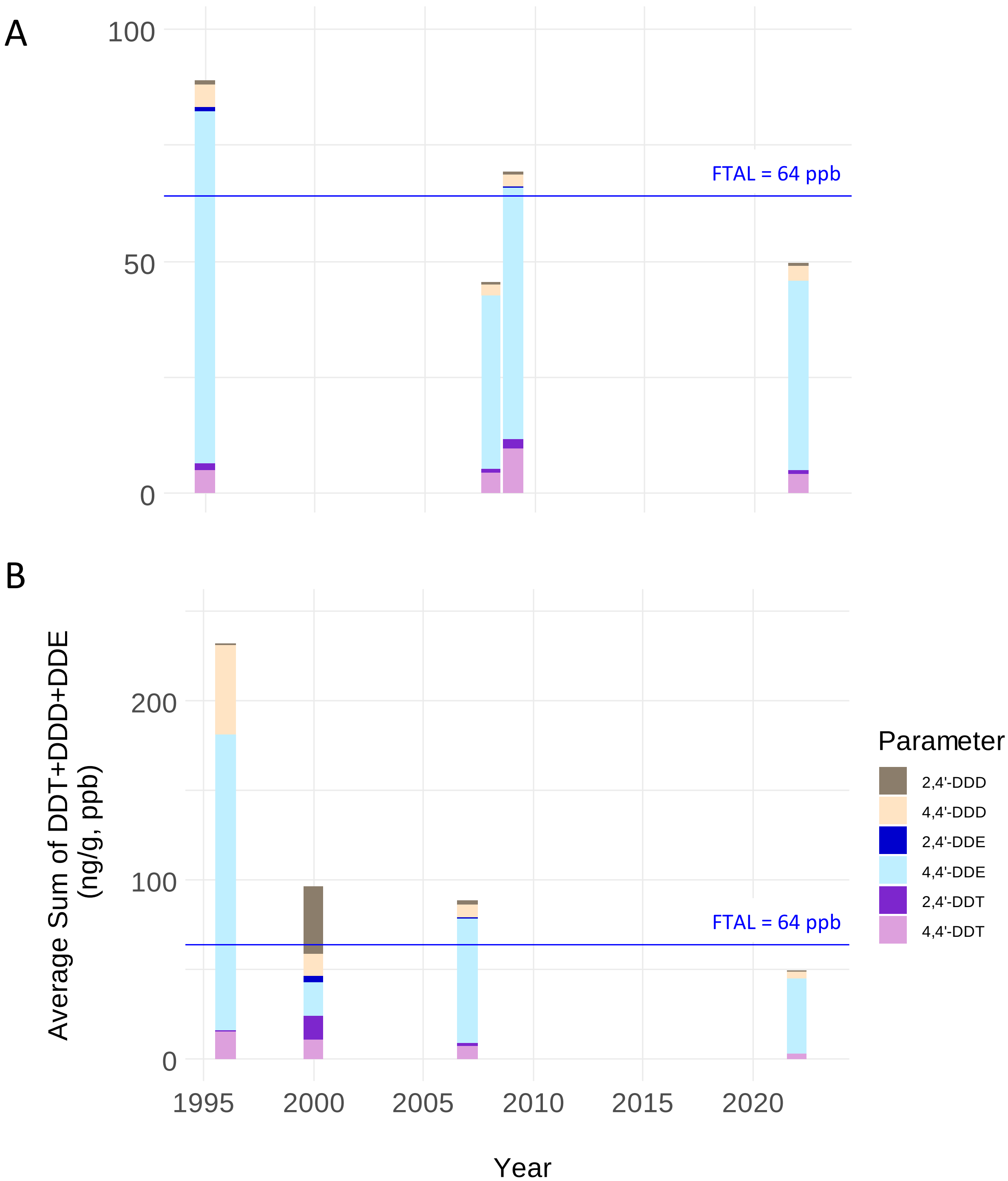

Figure 10. Stacked bar plots of average ∑DDT of skinless fillets (wet weight) from A) Meduxnekeag River (Houlton) and B) Prestile Stream (Westfield and Mars Hill)

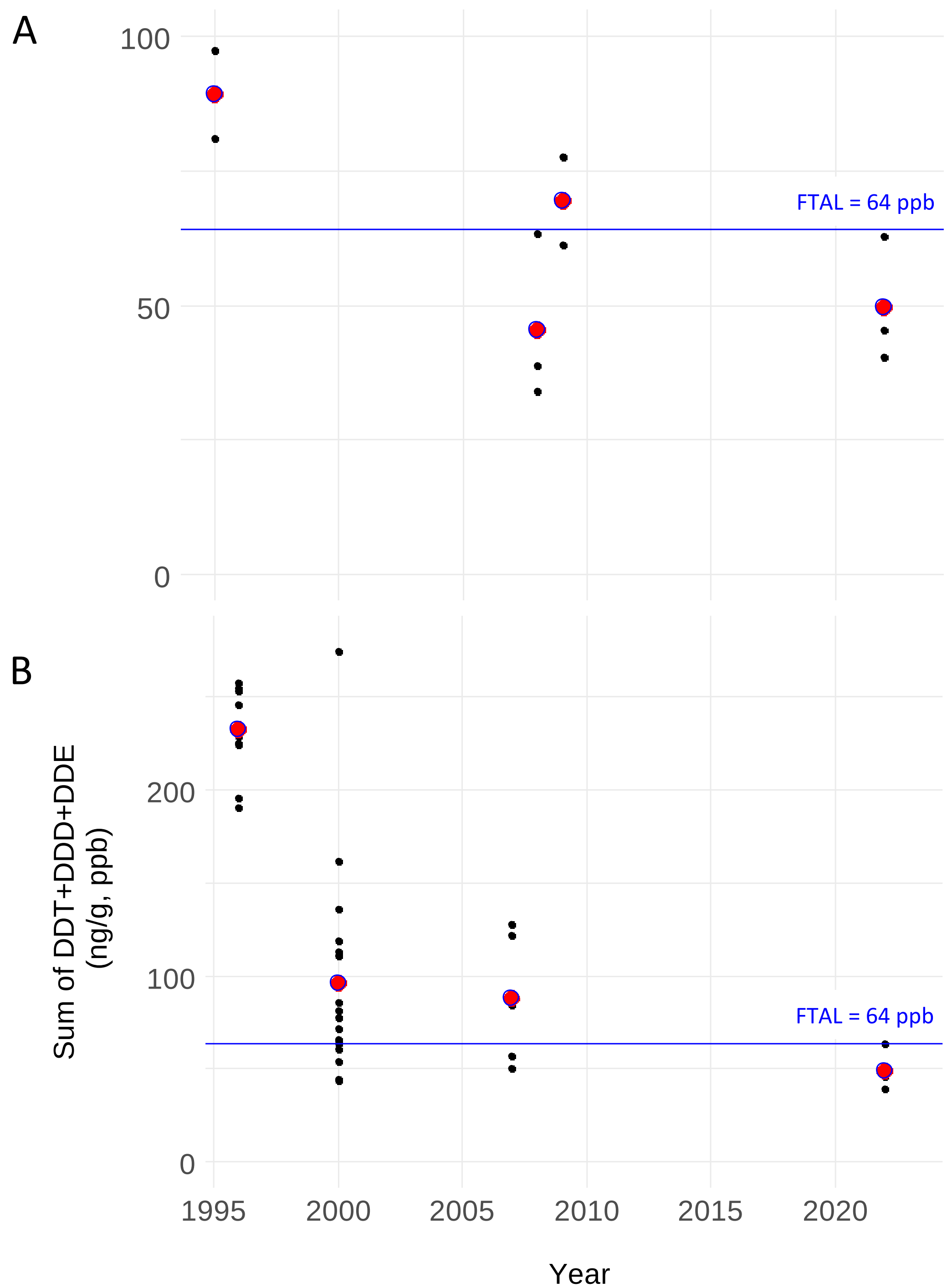

Figure 11. ∑DDT of skinless fillets (wet weight) from A) Meduxnekeag River (Houlton) and B) Prestile Stream (Westfield and Mars Hill). *Black circles are concentrations of individual samples and large, red circles are average concentrations.*

2.6 PCBs in 2022 Fish Samples

Polychlorinated biphenyls (PCBs) are highly carcinogenic chemicals that were formerly used in various industrial and consumer products. Although PCBs were banned in the United States in 1979, several rivers in Maine have fish consumption advisories for total PCBs. Since it has been over 10 years since the SWAT program collected PCB samples in fish, a small amount of federal grant money from EPA was used to analyze PCBs along with PFAS in skinless fillets of smallmouth bass collected from several locations on the Kennebec River (Fairfield and Gardiner) and Androscoggin River (Rumford, Livermore, Brunswick). The analysis was done by SGS AXYS using EPA Method 1668A, SGS AXYS Method MLA-010. Concentrations of total PCBs in the Kennebec River (Fairfield) steadily dropped slightly from 5 ppb in 1994 to 3 ppb in 2022 (Figure 12). In the Kennebec River (Gardiner), concentrations dropped from 179 ppb in 1999 to 48 ppb in 2002. Since 2002, there has been a small decrease in total PCBs, with 35 ppb in 2022. For comparison purposes, a site in Augusta had over 604 ppb in 1994 and 85 ppb in 2009.

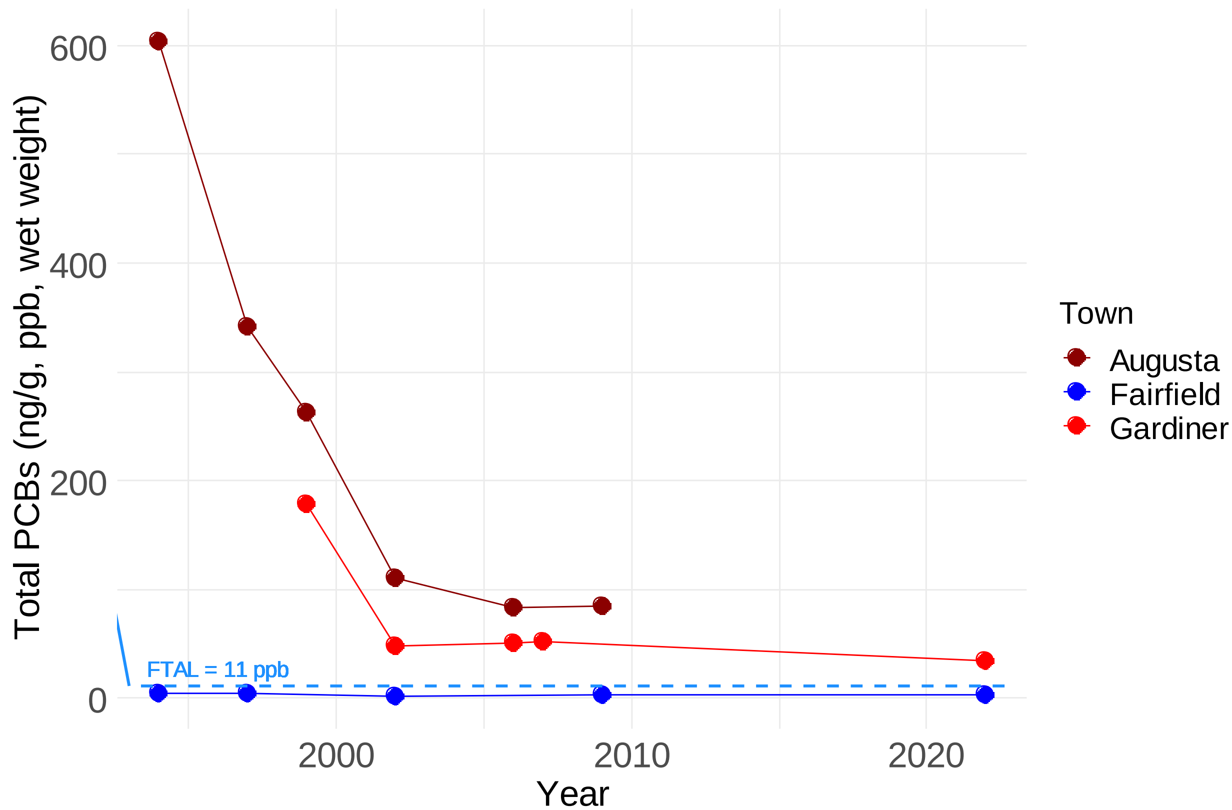

Figure 12. Mean concentrations of total PCBs in small mouth bass collected from the Kennebec River

Concentrations of total PCBs in smallmouth bass collected from the Androscoggin River (Rumford) were lowest in 1998 (4 ppb) and increased to a high of 101 ppb in 2002. Since 2002, concentrations have dropped to 12 ppb in 2022. At the Androscoggin River (Livermore Falls), total PCB concentrations dropped from 49 ppb in 1994 to 6 ppb in 2022. However, total PCBs went up and down at that site during that period of time. The concentration of total PCBs was 36 ppb in the Androscoggin River (Brunswick) in 2022, which was the first total PCB sample at that location. Overall, concentrations of total PCBs were below the FTAL of 11 ppb at the Kennebec River (Fairfield) and Androscoggin River (Brunswick). Total PCBs remain above the FTAL at the other three sites. Unfortunately, high concentrations of PFOS at the Androscoggin River (Livermore) and Kennebec River (Gardiner) may prevent changes to fish consumption advisories at those locations.

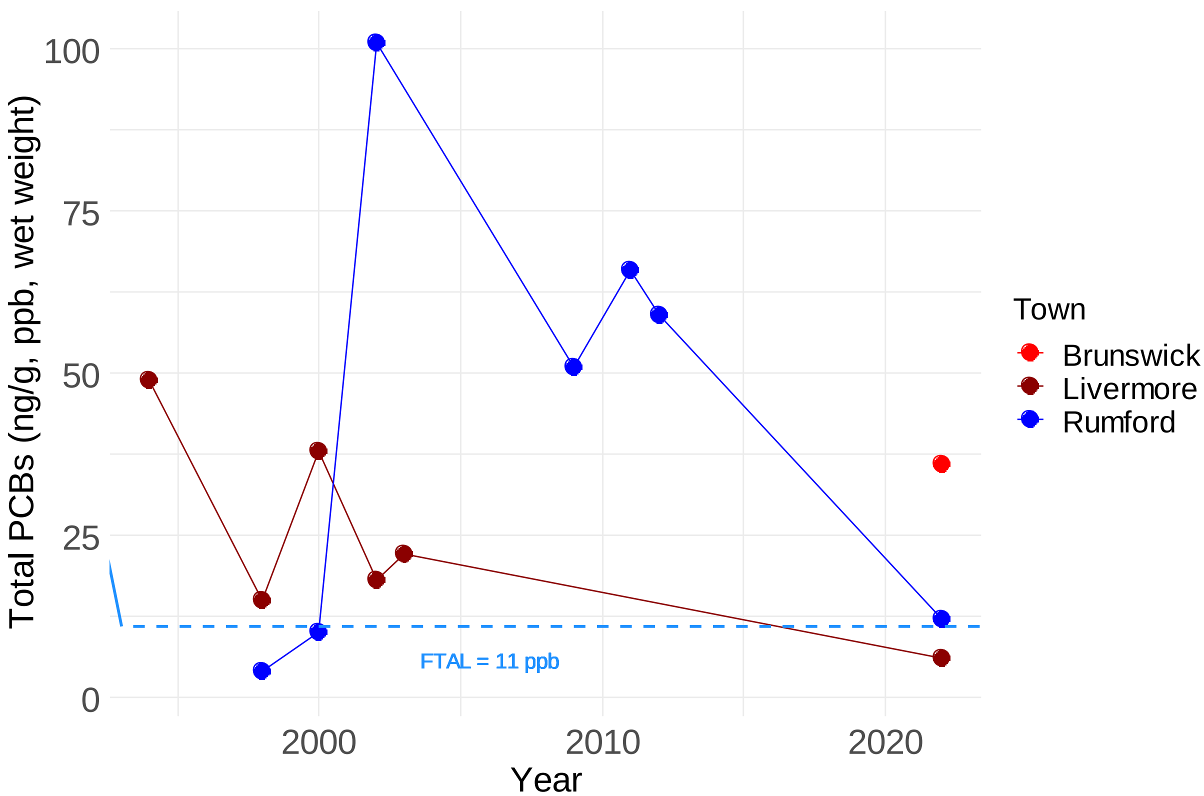

Figure 12. Mean concentrations of total PCBs in smallmouth bass collected from the Androscoggin River

An alternative approach to evaluating the toxicity of PCBs is to compute a toxic equivalency value (TEQ), which is a measure of the overall toxicity many dioxin and dioxin-like compounds. In this case, the TEQ is limited to the PCBs. The lab multiplied the concentration of each PCB by its specific toxic equivalent factor (TEF), which is assigned to each compound and based on its toxicity compared to the toxicity of two of the most toxic compounds. The resulting products were summed to obtain the TEQ. The units of measure are picograms per gram of fish tissue (pg/g wet weight), which is equivalent to parts per trillion (ppt). The historic TEQ threshold for fish tissue was 0.40 ppt. The lab computed three TEQ values for each sampling location based on the following decisions for non-detect values:

- The concentration for non-detects values = 0
- The concentration for non-detect values = ½ of the detection limit
- The concentration for non-detect values = the detection limit

All TEQs were less than the historic threshold of 0.40 ppt (Figure 13), however these calculations were based only on PCBs and did not include dioxins.

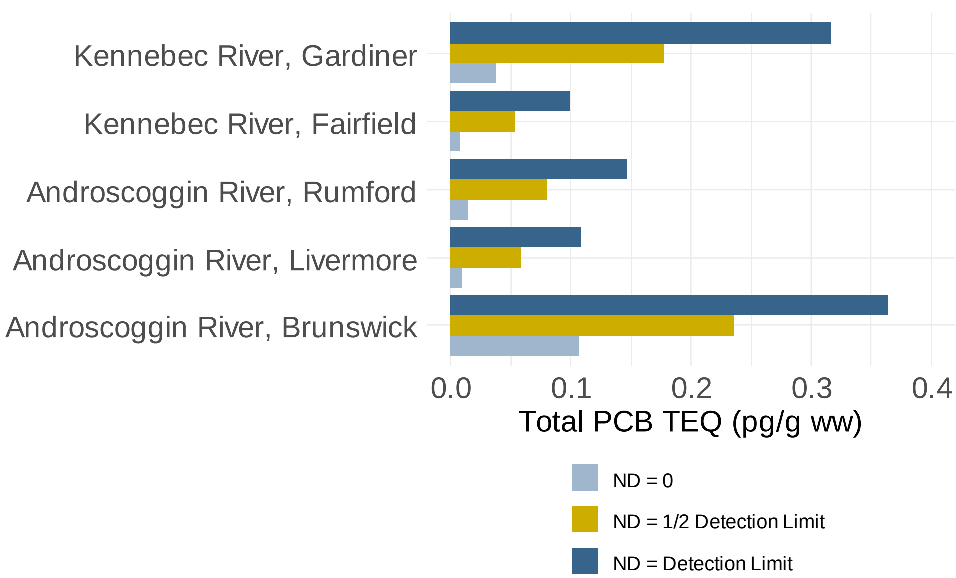

Figure 13. Toxic equivalency values (TEQs) based on PCBs. *The TEQs were computed with three options for including non-detect (ND) values in the computations.*

2.8 References

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3. Cyanotoxins in Lakes

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3.1 Introduction

Harmful Algae Blooms (HABs), dominated by species of cyanobacteria (i.e., blue-green algae) genetically capable of producing toxins, continue to be a problem in for lakes in the United States and Maine. HABs can produce hepatotoxic, neurotoxic and acutely dermatotoxic cyanotoxins such as microcystins, cylindrospermopsins, anatoxins, and saxitoxins among others. Maine has several lakes and ponds that have experienced algal blooms for decades. There have been two known toxic events involving the death of cattle in the 1960s (per Matt Scott, personal communication) prior to enactment of the Clean Water Act, and a few dog deaths for which HABs were suspected but unconfirmed, that may have been attributable to other causes (e.g., THC in edibles, water intoxication, leptospirosis). Nevertheless, there is a growing concern in Maine about the potential for HABs as lake temperatures reach new highs due to extended growing seasons and warmer air temperatures, coupled with an increase in frequency of intense-storms, which deliver nutrient-rich stormwater to lakes.

History of Health Advisory Levels. In 1998, the World Health Organization (WHO) established the following advisory levels for cyanotoxins, which were used in Maine until 2015:

- Drinking water: 1 µg/L,
- Low-risk recreation: 10 µg/L (‘*low-risk’ refers to irritation or allergic reactions, not toxicity*).

In early May of 2015, EPA released 10-day *drinking water* health advisory levels for two populations:

- Bottle-fed infants and pre-school children: > 0.3 µg/L.
- School-age children and adults: > 1.6 µg/L.

In May of 2019, EPA also released *swimming* advisory levels which were finalized in July of 2021:

- 8 µg/L is not to be exceeded on any day.

Because children spend more time in the water and ingest more water per body weight while recreating, conservative criteria were derived based on children’s recreational exposures.

In mid-March of 2021, the WHO released their second edition of ***Toxic Cyanobacteria in Water*** (859 pages), which is available for download at https://www.who.int/publications/m/item/toxic-cyanobacteria-in-water---second-edition.

This edition presents microcystin-LR ingestion guidelines in terms of exposure duration, which are shown in Table 1 and are higher than their previous guidelines as well as current EPA Health Advisory guidelines.

Table 1. WHO 2021 microcystin-LR Provisional Guideline Values

Exposure Duration	Exposure Category	Exposure Level
Chronic (long-term) term	Lifetime Guideline Value	0.96 µg/L (~1 µg/L)
	Tolerable Daily Intake	0.04 µg/kg/day
Short-term	Drinking Water Guideline Value	12 µg/L
	Recreation Guideline Value	24 µg/L

3.2 Results

Complementary to related water quality measurements, samples for microcystin analysis have been collected from Maine lakes using a probability-based approach and a targeted approach. Lakes greater than 150 acres in populated areas of the state were targeted for the probability monitoring (2014 – 2019). Approximately 22 lakes were randomly selected each year, and in 2020, lakes having the highest concentrations of microcystin were revisited. Lakes with a history of algal blooms were targeted for time-series monitoring during the same period, and lakes with reported blooms were sampled opportunistically from 2014-2022. Results from 2015 - 2019 indicated that relatively few probability-draw lakes had elevated microcystin, and as expected, targeted lakes had elevated concentrations. Most lakes that produced actual algal scums had microcystin concentrations in those scums that greatly exceeded EPA health advisory levels. A few ‘scum’ samples were not scums at all but rather collections of detritus; these did not show elevated microcystin.

In 2019, DEP developed the capacity to perform microcystin analysis using the ELISA plate approach (enzyme-linked immunosorbent assay), using SWAT and other funds. Analysis of the backlog of frozen samples (2016-2019) was completed in the fall of 2020. Split samples were run at the University of New Hampshire to validate the method. Samples collected in 2020 were analyzed in 2021. Samples collected in 2021 and 2022 are frozen and will be analyzed by a DEP biologist after they are trained by EPA at their lab in Chelmsford MA in Spring 2023. (A former DEP trained analyst departed for another position.) In addition, staff collected and submitted samples to the EPA Region 1 lab for analysis under EPA’s BloomWatch project between 2020 – 2022. BloomWatch 2020 microcystin results have been received but are pending data review. BloomWatch 2021 and 2022 samples may have the toxin, BMAA, and anatoxin analyses run in addition to microcystin, providing that EPA gets those methods running in a timely manner. Samples collected for phytoplankton taxonomy have also been received but are pending analysis. These outstanding data will be shared in the next SWAT report.

DEP has invested in an Abraxis Strip Reader to obtain more timely toxin results. According to EPA Region 1, these results are comparable to results obtained using ELISA test plates. Rapid tests conducted in 2022, considered a trial year, did not detect microcystin at concentrations approaching EPA's Health Advisories except in scums from one lake. Anatoxin rapid test strips were used as well, and anatoxin was determined to be present in one lake. Advisory levels have yet to be established for anatoxin.

Examination of patterns statewide had to consider that some lakes were visited once, others twice or many times. Any lakes with microcystin detected during the first visit (2014-2019), were visited a second time in 2020. Lakes in the time-series group, may have been visited up to 31 times. Data collected were averaged across lake visits to derive averages for each of the sample types for each lake.

Across-lake averages for each of the four sample types were examined for differences in microcystin concentrations. As illustrated by the box and whisker plot in Figure 1, the three open-water samples were very similar as compared to the scum samples. Thus, results from the two sample types obtained from the deep hole were averaged with the sample obtained from the downwind shore sample to obtain a mean for open-water samples for each lake visit.

Figure 2 illustrates ***average*** concentrations for ***all*** lakes sampled between 2014-2020 geographically across Maine. Open-water samples are colored according to average open-water concentrations in µg/L; colored donuts around the solid circles indicate concentrations in algal scums, if present. Worth noting is that most lakes having higher concentrations are already designated as 'Impaired' due to algal blooms; many of these are located in Kennebec County.

Table 2 summarizes the number of lakes by station type that exceeded EPA Health Advisory guidance for drinking water (2 populations) and swimming (2014-2020). Concentrations of microcystin exceeded EPA's 10-day Drinking Water health advisory value for 'infants and non-school age children' in an average of 7.6% of the open water samples and in 11 of the 17 scum samples (8% of the lakes sampled). This might present a concern for shorefront property owners that draw their drinking water from those lakes, especially those with young children.

Microcystin concentrations exceeded EPA's 10-day Drinking Water health advisory value for 'school-age children and adults' in an average of 3% of the open water samples and in 9 of 17 scum samples (6.5% of the lakes sampled), again potentially of concern to shorefront property owners that draw their drinking water from those lakes. EPA swimming recreational advisory values were exceeded in an average of 0.2% of the open-water samples and 6% of the scum samples - two of which had concentrations more than 2 orders of magnitude greater than the 8 µg/L guidance level.

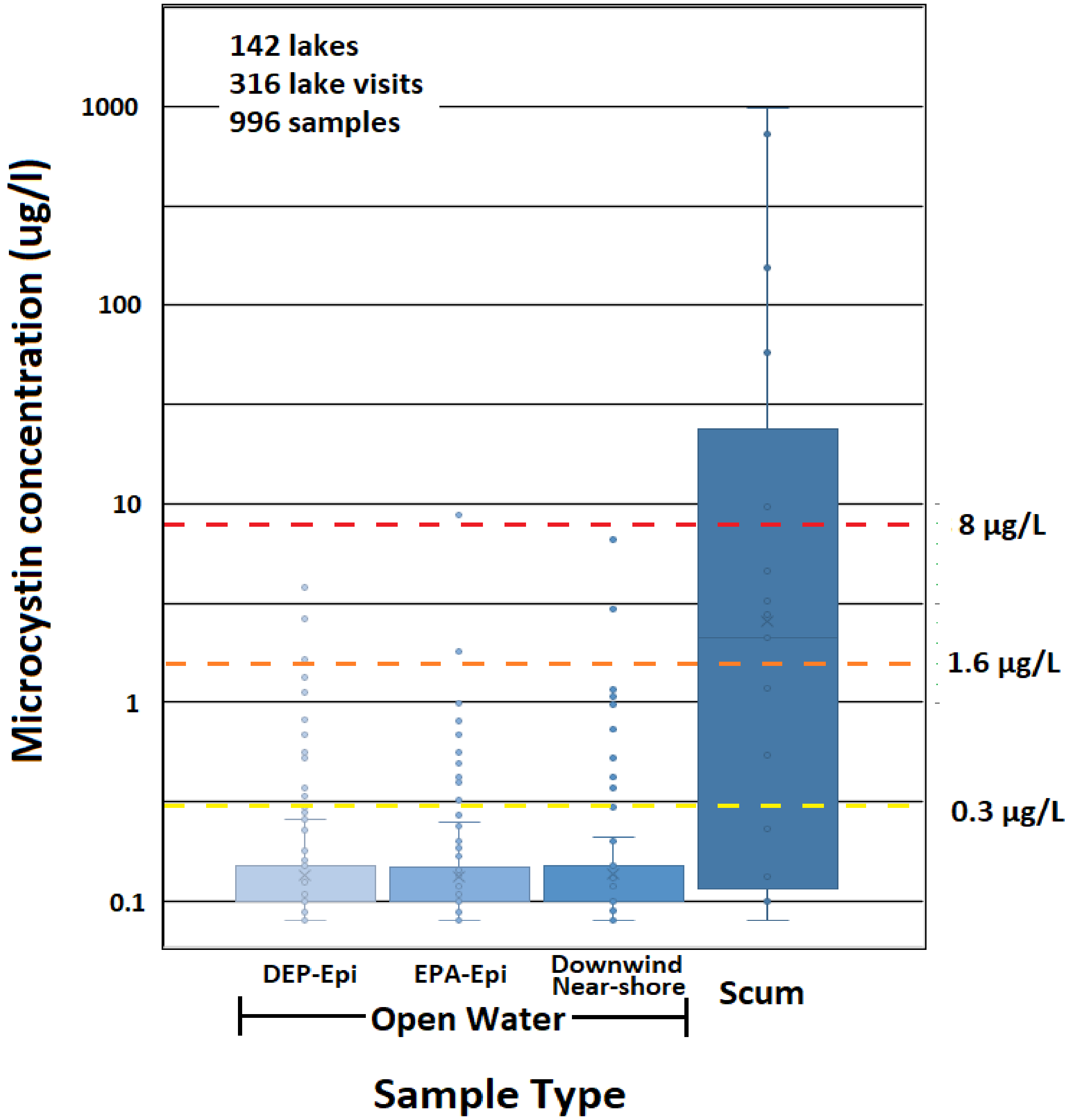

Figure 1. Distribution of microcystin concentrations in µg/L across four sample types (Epi = epilimnetic samples)

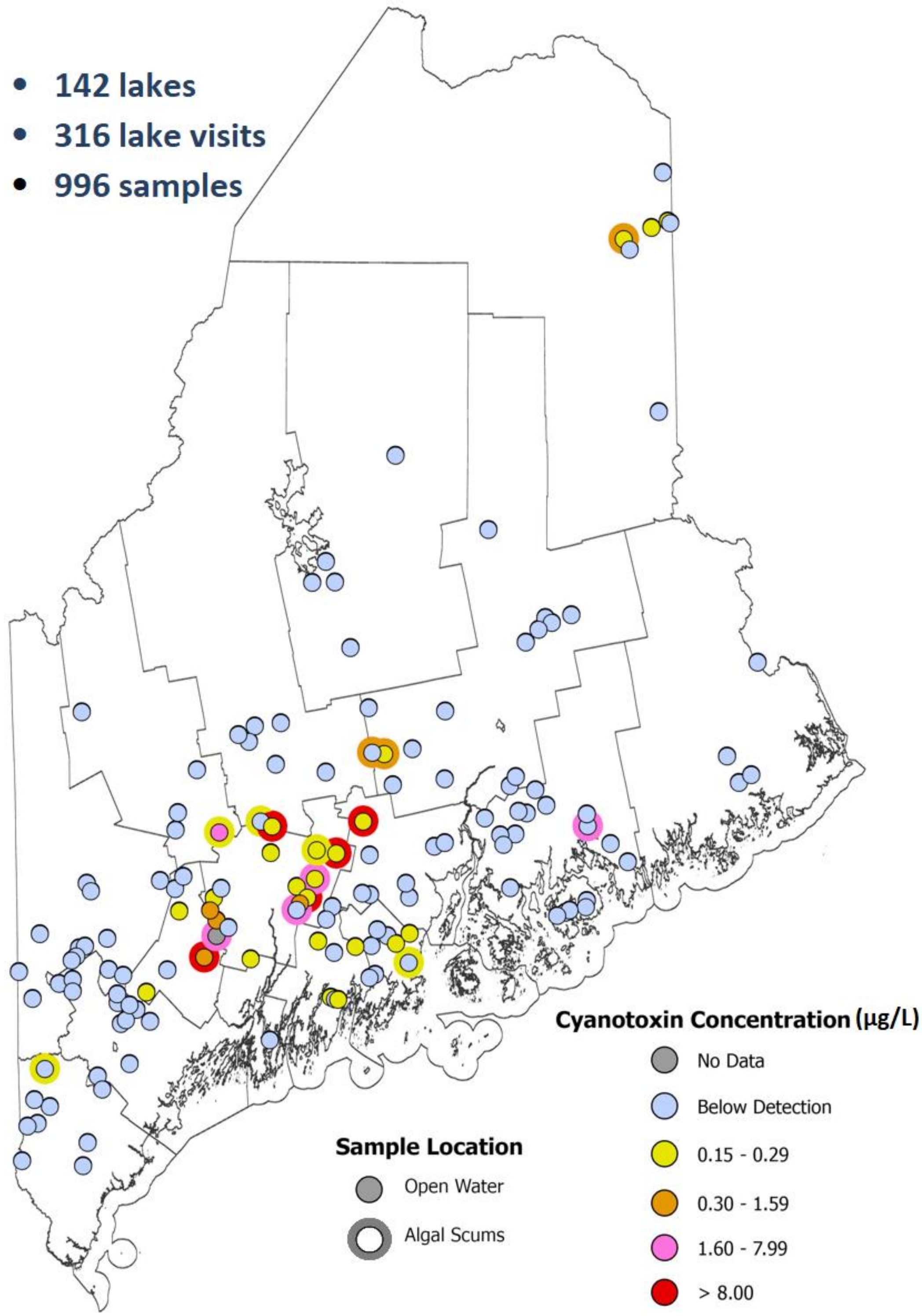

Figure 2. Map of Maine depicting average microcystin concentrations (µg/L) for 142 lakes. Solid circles indicate average concentrations in open-water samples; colored donuts around the solid circles indicate concentrations in algal scums, if present

Table 2. Number and percent of lakes exceeding EPA Microcystin Health Advisories levels for drinking water (DW) and swimming (2014-2020; results averaged across multiple visits)

Sample Location	Deep Station*		Downwind Station	
Microcystin range (µg/L)	Epilimnetic samples (DEP protocol)	Epilimnetic samples (EPA protocol)	Near-shore* samples	Scum Samples
0.3 - 1.6	10 (7.1)	11 (7%)	11 (8%)	2 (1.4%)
1.6 - 8	3 (2.1%)	2 (1.4%)	3 (2.2%)	4 (2.9%)
> 8.0	0	1 (0.7%)	0	5 (3.6%)

*Considered ‘open-water’ samples.

Probabilistic Monitoring Results

The pie charts in Figure 3 depict the distribution of microcystin results obtained under the probability-based sampling component and revisits (2014 – 2020). Again, because there were only minor differences in results obtained from the three open-water sample types, they were averaged. Open-water results from the probability-based monitoring suggest that approximately 12% of Maine lakes having surface areas greater than 150 acres and located in populated regions of the state were producing measurable microcystin concentrations in open water when visited. 5% had concentrations between the reporting level of 0.15 and 0.3 µg/L. Of concern are the 5% that had concentrations between 0.3 – 1.6 µg/L; the 1% that had concentrations between 1.6 – 8.0 µg/L; and the 1% with concentrations >8.0 µg/L. Only 6% of the probability-drawn lakes had near-shore accumulations of material sampled as scums. 2% had concentrations below the reporting level of 0.15 µg/L – and may not have been algal scums but rather detritus. 1% had concentrations between the reporting level of 0.15 and 0.3 µg/L. Of concern are the 1% that had concentrations between 0.3 – 1.6 µg/L; and the 2% that had concentrations >8.0 µg/L. None had average concentrations between 1.6 – 8.0 µg/L, but some samples may have had concentrations within that range that were averaged into a higher or lower mean. It is important to note that higher concentrations derived using ELISA tests may not be as accurate as concentrations closer to the range specified for the kits as the dilution process introduces error into the analysis and quenching of binding sites can occur; nevertheless, one can infer that the actual value is in the same order of magnitude.

Time-series Monitoring Results

Time series data were obtained from a total of 544 samples collected from 162 visits to 12 lakes. The sampling regime was identical to that used in the probability study. Lakes known to be chronic severe bloomers were visited frequently to establish ‘worst-case-scenario’ conditions for the state and examine seasonal fluctuations. Lakes that have bloomed for decades, but not as severely, and lakes that have only recently begun to support blooms were visited less frequently (fewer years). The following table presents averages for open-water samples and bloom samples across visits acquired from 2014-2020. Minimum, median, mean and maximum values can be found in the previous report for samples acquired from 2014-2019.

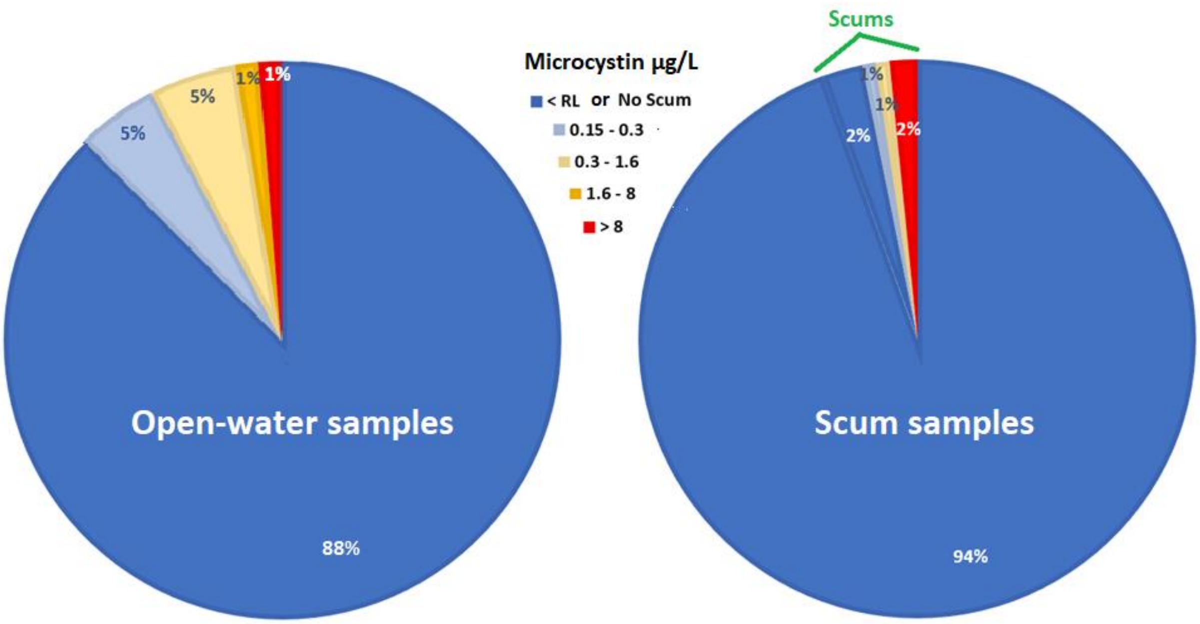

Figure 3. Distribution of microcystin concentration in the averaged open-water samples (n=376) and 6 scum samples from the 126 probability-draw lakes.

Mean concentrations of microcystin do not exceed the drinking water health advisory for adults and school-aged children; however, maximum concentrations exceed the drinking water health advisory in half of the targeted lakes, two of which were high enough to exceed the swimming advisory level. Mean concentrations in scums exceeded the drinking water level in 8 of the 12 lakes; furthermore, 5 of these also exceed the swimming advisory level, with maximum concentrations by as much as 5 orders of magnitude.

Although not illustrated in these tables, microcystin concentrations in open-water tended to peak at the end of August and in early September. Concentrations in scum samples tended to peak in mid to late September. And by November, many samples yielded concentrations below the reporting level. There was considerable variation in microcystin concentrations from year-to-year, likely due to weather-related factors including timing of ice-out, onset of the growing season, and timing of peak algal population density just before waters begin to cool as the daylight period decreases. Note that three of the lakes on this list have had alum treatments to bind the nutrient phosphorus in sediments and thus limit algal growth. East Pond was treated in 2018, Georges Pond was treated in 2020 and 2021, and Long Pond was treated in 2022. Internal recycling of phosphorus from the sediments had been documented as contributing a significant proportion of nutrients each of those lake ecosystems.

Table 3. Microcystin summary results for time series lakes with various bloom characterizations. [MC] = microcystin concentration (µg/L)

[MC] Color Key:	<0.3 µg/L	0.3-1.6 µg/L	1.6-8 µg/L	>8 µg/L

Lake & ID (#visits)	Bloom characterization	[MC] Open Water Samples		[MC] Downwind Scum Samples	
		Mean	Max		
SABATTUS P 3796 (31)	Chronic, severe	1.47	37.84	722	10606
UNITY P 5172 (21)	Chronic, severe	1.03	7.88	58	273
LOVEJOY P 5176 (30)	Chronic, severe	0.46	5.70	976	17696
THREEMILE P 5416 (23)	Chronic, severe	0.82	6.61	155	724
EAST P 5349 (8)	Frequent, not severe	0.74	12.37	10	10
SALMON L (ELLIS P) 5352 (4)	Frequent, not severe	0.43	1.89	No scum	
WEBBER P 5408 (7)	Frequent, not severe	0.17	0.74	No scum	
SEBASTICOOK L 2264 (9)	Frequent, not severe	0.31	1.57	1.18	1.18
LONG P (Parsonsfield) 9701 (8)	Recent	<RL		<RL	
TOGUS P 9931 (6)	Recent	<RL	0.22	2.13	2.13
GEORGES P 4406 (6)	Recent	<RL	0.42	2.78	2.78
NORTH P (Smithfield) 5344 (9)	Recent	<RL		<RL	

The time-series results and results from the probabilistic study suggest that relatively few Maine lakes produce microcystin concentrations, but those few that support severe, chronic algal blooms are very likely to exceed EPA guidelines.

Discussions with Maine CDC Regarding Advisories

Maine CDC toxicologists believe a major impediment to issuing waterbody-specific advisories for microcystins is the current lack of a timely monitoring system of microcystin levels in surface waters. As noted above, levels of microcystin in water can vary substantially over time and are not necessarily consistent from year to year. Maine CDC's review of the available data to date from DEP suggest that most open-water samples collected to date do not approach EPA's drinking water Health Advisory or swimming advisory recommendations for microcystins. Relatively few open-water concentrations approached or slightly exceeded the drinking water health advisory, and Maine CDC already discourages people from drinking any untreated surface waters. Exceedance of swimming advisory recommendations occurs mostly in samples of surface scum; the general HABs advice to avoid scums already speaks to this exposure concern. It is recognized that in a lake-rich state like Maine, managing waterbody-specific advisories would be extremely challenging, especially when coupled with the temporal nature of HABs. Thus, the general HABs guidance, including information about waterbodies that are known bloomers, is a more workable approach. Towns or lake entities have the option to issue their own advisories or post lakes that are blooming and/or are known to have elevated microcystin concentrations from their own monitoring efforts.

4. Biological Monitoring

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4.1 Introduction

As part of the SWAT program, DEP's Biological Monitoring Unit evaluates benthic macroinvertebrate communities of Maine streams, rivers and associated freshwater wetlands to determine if they are potentially impaired by toxic contamination. For reasons of comparability, a small number of unimpaired reference sites are also evaluated. Benthic macroinvertebrates are animals without backbones that can be seen with the naked eye and live on the stream bottom, such as mayflies, stoneflies, caddisflies, crayfish, snails, and leeches. The Biological Monitoring Unit conducts sampling of five major river basins of Maine on a five-year, rotating cycle. Sampling stations in the annual target basin are selected to establish reference conditions, to follow up on previously sampled sites needing additional data, and to target new waterbodies having potential impacts from stressors. A number of stations outside the target basin are also sampled each year, including sites having priority management concerns, those needing timely follow-up data, and long-term reference sites that are sampled annually. In 2021, staff evaluated the condition of 40 sample locations, primarily in the Penobscot River basin. In 2022, staff evaluated the condition of 43 sample locations, primarily in the Kennebec River basin.

Sources of toxic contaminants that negatively impact aquatic life in Maine's surface waters include urban, residential and agricultural runoff, municipal and industrial discharges, acid deposition, and historic in-place contamination from landfills, commercial/industrial facilities, military installations and mining sites. Nonpoint sources (NPS) of toxic pollutants from urbanized areas are among the most common causes of biological impairment in streams, often contributing harmful concentrations of chloride (road salt), pesticides, fertilizers and petroleum products. Increasing levels of impervious cover in a stream watershed, including roads, parking lots, rooftops and lawns, can exacerbate toxic contamination by intensifying runoff and altering stream morphology due to heavy flows. The DEP Biological Monitoring Unit conducted a study focusing on impervious cover in urban and residential areas and its relationship to the health of aquatic communities in Maine streams (Danielson, T. J., L. Tsomides, D. Suitor, J. L. DiFranco, and B. Connors. 2016. Effects of Urbanization on Aquatic Life of Maine Streams. Maine DEP – Augusta, ME.). The study report is available on the DEP Biomonitoring web site at the following link: https://www.maine.gov/dep/water/monitoring/biomonitoring/materials/dep-effects-of-urbanization-on-streams.pdf .

The Biological Monitoring Unit uses a multivariate statistical model to analyze benthic macroinvertebrate samples and predict if waterbodies attain the biological criteria associated with their statutory class (06-096 CMR Chapter 579). If a waterbody does not meet minimum state aquatic life criteria, Class C, then the model class is predicted as Non-Attainment (NA). Classes AA and A are treated the same in the model. The Biological Monitoring Unit uses a separate wetland model to analyze samples collected from shallow, marshy habitats in freshwater wetlands, low-gradient streams, lakes and ponds. For lakes and ponds having an assigned statutory class of GPA, a wetland model result of A is considered to meet GPA aquatic life criteria. Final decisions on aquatic life attainment of a waterbody are made accounting for factors that may allow adjustments to the model outcome. This is called "the final determination."

Tables 1 and 2 summarize the results of biological monitoring activities, sorted by waterbody name, for the 2021 and 2022 SWAT sampling years respectively. Column headings of Table 1 and 2 are described below:

- *Station* – Since waterbodies are sometimes sampled in more than one location, each sampling location is assigned a unique "Station" number.
- *Log* – Each sample event is assigned a unique sample identification number called a "Log" number. The Log number is used to track macroinvertebrate samples and associated data throughout sample processing, data management, data analysis and reporting.
- *Potential sources of pollution*
- *Statutory Class* – The Maine State Legislature has assigned a statutory class, either AA, A, B, or C, to every Maine stream and river. Class AA and A waterbodies shall support a "natural" biological community. Class B waterbodies shall not display "detrimental changes in the resident biological community". Class C waterbodies shall "maintain the structure and function of the resident biological community". "Great ponds" and natural lakes and ponds less than 10 acres in size are assigned a single class, GPA. The habitat of Class GPA waters must be characterized as "natural".
- *Final determination* – The final decision on aquatic life attainment of a waterbody; this decision accounts for factors that may allow adjustments to the model outcome. An 'NA' (Non-attainment) indicates that the sample did not meet the minimum Class C criteria. An 'I' (Indeterminate) indicates that a final decision could not be made based on the aquatic community collected.
- *Attains Class* – "Yes" is given if the final determination is equal to or exceeds the Statutory Class. A Class B stream, for example, would receive a "Yes" if its final determination was

either A or B. "No" is given if a stream does not attain its Statutory Class. A Class B stream, for example, would receive a "No" if its final determination was either C or NA.

- *Probable Cause* – The probable cause column lists potential stressors to benthic macroinvertebrate communities, based on best professional judgment. In some cases, a probable cause may not be related to toxic pollution but instead to other factors.

2021 field and water chemistry data for each sampling event (where available) are presented in Table 2 and 3, respectively. 2022 field and water chemistry data are presented in Tables 6. and 7. Continuous water temperature data were not collected in 2021, however results for 2022 are shown in Figure 1. Data are also summarized in reports for each sampling event, known as Aquatic Life Classification Attainment Reports, which are available in electronic format with the web version of this report. The attainment history of sampling stations prior to 2021 and 2022, where available, is summarized in Tables 4 and 8.

For more information about the Biological Monitoring Program, please visit our web site: www.maine.gov/dep/water/monitoring/biomonitoring/. The Data and Maps page of this website provides access to station information and available data via ArcGIS Online.

4.2 2021 Results

The Biological Monitoring Unit concentrated its sampling in 2021 in the Penobscot River basin. Forty stations were sampled under the SWAT Program (Table 1). Twenty-five of these stations met the aquatic life criteria for their statutory class. One station had an indeterminate result. The following are descriptions of waterbodies not attaining aquatic life criteria for their assigned class in 2021.

Arctic Brook - Bangor Station 313

Arctic Brook is a small first order stream with a water quality goal of Class B. It originates below School Street in Bangor in a watershed encompassing high-intensity urban development. The stream flows south then southwest, crossing Route 15 and Interstate 95 before it flows to Kenduskeag Stream just below Valley Avenue. Station S-313 is located shortly upstream of Valley Avenue. In 2021, the macroinvertebrate sampling result was NA (non-attainment of aquatic life criteria for any water quality class). This is consistent with results in 2014 and 2015. Sensitive taxa were largely absent or present in very low numbers. There were no stoneflies in the sample, and mayfly mean abundance was only 2.5 individuals. The sample was dominated by pollution tolerant taxa, including aquatic worms (Enchytraeidae and Lumbricidae, 41.7%), snails (Physella, 8.89%) and aquatic sowbugs (Caecidotea, 7.16%). The macroinvertebrate community composition indicates a toxic response due to urban runoff, which is supported by very high specific conductance measured at the site in July (1114 uS/cm) and August (1573 uS/cm). Excessive stormwater runoff also contributes to habitat alteration, including unstable stream banks, erosion and sedimentation.

Black Stream – Garland Station W-295

The area evaluated for this assessment is upstream of the damned Bramms Mill Pond, in Garland and has a water quality goal of Class A. In 2021, site W-295 attained Class B aquatic life criteria (0.88) based on the macroinvertebrate sample. A significant proportion of the sample is made up of sensitive organisms (0.48 relative abundance), but the relative abundance and relative richness of mayflies, odonates and caddisflies is low (.038 and 0.139). The top 5 most abundance taxa are snails, amphipods and isopods contributing to non-insects representing 82% of the sample. However, the most abundance taxon is the snail Amnicola which is sensitive to pollution (MTW score of 18.7). The water quality parameters collected or measured in the field seem average except for a slightly elevated dissolved oxygen (DO) % saturation of 100.5. The watershed characteristics of 76.7 % upland woody vegetation and 6.1 % total human altered may indicate forestry activities in the watershed, which are also visible near the stream in recent aerial photos. This site was sampled last in 2016 and also attained Class B.

<u>Bog Stream - T18 MD</u> Station 514

Bog Stream is a third order stream with a water quality goal of Class B. It originates in Deblois and flows north, then east through T18 MD to the Pleasant River. The watershed encompasses wetlands and extensive commercial blueberry fields. Station S-514 is located just downstream of Schoodic Road, above the confluence with the Pleasant River in T18 MD. In 2021, the macroinvertebrate community at Station S-514 met Class C aquatic life criteria, but did not meet criteria for Class B. The community had a relatively high total mean abundance (1,052) and was dominated by net spinning caddisflies (Cheumatopsyche 29.53% and Hydropsyche 18.12%) which are often abundant at sites having elevated inputs of nutrients and/or dissolved organic matter. There were no stoneflies present in the sample and only 2 mayfly genera. Substrate at the site consisted of 90% silt, and poor habitat resulting from siltation along with nutrients and agricultural chemicals are likely causes of macroinvertebrate community impairment. Station S-514 was last sampled in 2001 and also attained Class C at that time. Community composition for the 2 sampling years was similar in many respects, however total generic richness declined from 65 to 46 between 2001 and 2021, and EPT richness (the sum of mayflies, stoneflies and caddisflies) declined from 20 to 15.

<u>Cold Stream - Enfield</u> Station 484

Cold Stream is a second order stream with a water quality goal of Class A which flows south from the outlet of Cold Stream Pond through the towns of Enfield and Passadumkeag to the Passadumkeag River. Station S-484 is located downstream of the Enfield State Fish Hatchery in a watershed with land use including sparse residential development and forestry activity. In 2021, the macroinvertebrate community did not attain aquatic life criteria for Class A, but attained criteria for Class B. The macroinvertebrate community structure showed signs of nutrient enrichment and was substantially different from the community sampled in 2016. Total mean abundance was roughly twice as high in 2021 vs. 2016 (2,359 and 1,211 respectively), and total generic richness declined significantly (39 in 2021, 52 in 2016). Approximately 47 % of the community in 2021 consisted of fairly tolerant midge larvae (Rheotanytarsus and Polypedilum), while the top 2 taxa in 2016 were a mayfly genera (Ephemerella, 19.49 %) and a net spinning caddisfly (Hydropsyche, 11.23 %). While sensitive taxa are still present in the community, the relative abundance of mayflies declined from 0.38 in 2016 to 0.18 in 2021.

Eaton Brook – Brewer Station 973

Eaton Brook is a third order stream with a water quality goal of Class B which flows north through Holden and Brewer to the Penobscot River. Station S-973 is located in the town of Brewer just north (downstream) of Lambert Road. Watershed land use includes agriculture, moderate residential and commercial development and forestry activities. In 2021, the macroinvertebrate community at Station S-973 did not meet aquatic life criteria for Class B but met Class C criteria. Dominant taxa in the sample were mostly midge larvae (Tanytarsus, Rheotanytarsus, Cricotopus, Dicrotendipes, 44.16 % combined). EPT generic richness (sum of mayflies, stoneflies and caddisflies) was quite high (18), however no stoneflies were present. Generic richness was fairly high in 2021 (41), but significantly lower than the last year sampled in 2011 (67). The likely causes of impairment are agricultural and/or urban NPS source runoff.

French Stream – Exeter Station 505

French Stream is a third order stream with a water quality goal of Class B which flows east and north through Exeter, joining Allen Stream before flowing to Kenduskeag Stream in Corinth. Station S-505 is located just north of Crane Road in Exeter. Surrounding land use includes extensive areas of farmland. In 2021, the macroinvertebrate community at Station S-505 did not attain Class B aquatic life criteria, but did attain criteria for Class C. The most abundant taxa in the community belong to a tolerant group of midges (Rheotanytarsus, 27.34 %), and while there were a fair number of mayflies present, they tended to be more tolerant types compared with samples collected in 2016. EPT generic richness (types of mayflies, stoneflies and caddisflies) declined from 21 in 2016 to 12 in 2021, and total generic richness declined from 54 to 41. There were no stoneflies present at all in 2021. Possible causes of impairment include excess nutrient runoff and agricultural chemicals.

Great Falls Branch – Deblois Station 504

Great Falls Branch is a third order stream with a water quality goal of Class AA which flows south through Deblois and joins Schoodic Brook in Cherryfield. Station S-504 is located just downstream of Route 193 in Deblois. The watershed includes extensive commercial blueberry fields, an airstrip, and a fruit processing and shipping facility. In 2021, the macroinvertebrate community attained aquatic life criteria for Class B but did not attain Class A/AA criteria. Total generic richness of macroinvertebrates was fairly high (43), however some sensitive taxa occurred in low numbers. For example, stonefly mean abundance was only 0.33. Possible causes of impairment include agricultural chemicals and NPS source runoff from paved areas. The macroinvertebrate community at station S-504 attained Class A aquatic life criteria in 2016, however the probability for Class A was in Best Professional Judgement range (p = 0.57) and was a borderline result between Class A and Class B. Notably, stream pH measured in July and August at this site were considerably different in 2016 than in 2021 (6.98 and 6.56 in 2016, vs. 5.5 and 5.6 in 2021). Resampling is recommended to confirm attainment status.

Mill Stream (above hatchery) – Embden Station 425

Mill Stream is a third order stream with a water quality goal of Class B which flows from the outlet of Embden Pond south to the Carrabassett River. The watershed includes sparse residential development, farms, and forestry activity. Station S-425 is located in the town of Embden, just downstream of Embden Lake and upstream of the Embden Fish Hatchery. In 2021, the macroinvertebrate community at Station S-425 did not meet aquatic life criteria for Class B, but did meet criteria for Class C (p = 0.65). The most dominant taxa consisted of midge larvae and Oligochaetes (aquatic worms), which are relatively tolerant groups. Total mean abundance was low (75), although generic richness was 39 and fairly high in proportion to the total number of organisms. Stonefly mean abundance was very low, only 0.67. Water quality parameters did not indicate any potential sources of pollution (specific conductance and nutrient levels were all quite low), and it is unclear why the community failed to attain Class B. Resampling is recommended to confirm attainment status.

Mill Stream (below hatchery) – Embden Station 426

Mill Stream is a third order stream with a water quality goal of Class B that flows from the outlet of Embden Pond south to the Carrabassett River. The watershed includes sparse residential development, farms and forestry activity. Station S-426 is located in the town of Embden, downstream of the Embden Fish Hatchery. In 2021, the macroinvertebrate community at Station S-426 did not meet aquatic life criteria for Class B, but did meet criteria for Class C (p = 1.00). Total mean abundance at this site was 27,904 organisms, which is unusually high and indicative of excessive nutrient enrichment. Dominant taxa in the sample included tolerant midge larvae (Rheotanytarsus, 26.15 %, Tvetenia, 16.21%, Eukiefferiella, 7.11 %, Polypedilum, 5.50 %) and net spinning caddisflies (Hydropsyche, 13.61 %). Relative abundance of mayflies was only 0.02 and EPT generic richness (mayflies, stoneflies and caddisflies) was only 8, which are both low considering the excessively high total mean abundance of the community. Total phosphorus at Station S-426 in July was 70 ug/l and orthophosphate was 53 ug/l, compared with 3 ug/l total phosphorus and 1 ug/l orthophosphate at Station S-425 upstream of the hatchery.

Piscataquis River - Dover-Foxcroft Station 152

The Piscataquis River is a 5th order stream with a water quality goal of Class B as it flows east through Dover-Foxcroft to the Penobscot River in Howland. Station S-152 is located in Dover-Foxcroft approximately 1 km below the municipal POTW. The surrounding watershed includes both urban development and agriculture. In 2021, the macroinvertebrate community at Station S-152 attained aquatic life criteria for Class C, but did not attain Class B criteria. Total generic richness was fairly low (23) and EPT generic richness (sum of mayfly, stonefly and caddisfly taxa) was only 5. There was a significant change in the community compared with samples collected in 2014, which had a total generic richness of 47 and EPT generic richness of 27. In 2021, few sensitive taxa were present. Although mayfly relative abundance was 0.19, most individuals were in the genus Caenis, which tends to be more tolerant than other mayfly groups and can be found in habitats having low dissolved oxygen, sedimentation and nutrient enrichment. Dissolved oxygen concentration and saturation values at Station S-152 in July (10.37 mg/l, 130.2 %) and August (10.23 mg/l, 120.9 %) were unusually high ("super-saturated"). This may indicate large diurnal swings from very high to very low dissolved oxygen levels are occurring that adversely affect aquatic life. Toxic effects to the macroinvertebrate community are also evident given low richness and lack of sensitive organisms. Factors likely contributing to non-attainment are nutrient enrichment and toxic runoff from urban and agricultural sources.

<u>Presumpscot River – Standish</u> Station 462

The Presumpscot River in Standish is a fourth order stream with a water quality goal of Class A which flows south from Sebago Lake in Standish then east to Casco Bay in Falmouth. Station S-462 is located in Standish below Eel Wier Dam and above Route 35. Land use in the surrounding watershed includes residential and urban development. In 2021, the macroinvertebrate community at Station S-462 did not meet aquatic life criteria for Class A, and only met criteria for Class C (p = 0.98). Although relative abundance of mayflies was quite high (0.49), there were no stonefly taxa present and generic richness was on the lower side (30) considering that total mean abundance was 794.67. The most common taxa were brush-legged mayflies in the genus Isonychia (33.39%), which feeds mainly on detritus and algae by collecting and filtering food particles using hair-like structures on its legs. Net spinning caddisflies were also fairly abundant in the community and similarly collect food particles using underwater nets. Since this type of community is common below lake outlets and dams, re-sampling is recommended to confirm attainment status and rule out other potential causes of non-attainment.

<u>Sedgeunkedunk Stream – Orrington</u> Station 972

Sedgeunkedunk Stream is a second order stream with a water quality goal of Class B which flows north from the outlet of Fields Pond through Orrington to the Penobscot River in Brewer. Watershed land use includes agriculture and residential and commercial development. Station S-972 is located on the west side of Brewer Lake Road just south of the Pine Hill Golf Course. In 2021, the macroinvertebrate community at Station S-972 did not meet aquatic life criteria for Class B, but met Class C criteria. Total mean abundance (574), generic richness (54) and EPT generic richness (19) were all relatively high, however there were no stoneflies present in the sample. Higher than average abundance and richness values along with loss of the most sensitive taxa may be indicators of nutrient enrichment. In addition, the high proportion of filter-feeding organisms (3 genera of net-spinning caddisflies comprised 53.86 % of the sample) may be partially due to a natural abundance of detritus and algae flowing into the stream from the outlet of Fields Pond ("lake outlet effect"). Although this may be a factor, agricultural and urban runoff are also likely contributing to impairment at Station S-972.

<u>Silver Lake – Bucksport</u> Station W-235

Silver Lake is a 682 acre lake located in the town of Bucksport. The area evaluated for this assessment is a 34.87 acre wetland area on the eastern side of the lake, consisting of shallow, open water and emergent marsh. The lake and the assessed wetland has a water quality goal of GPA. The macroinvertebrate sample collected in 2021, had a relatively high generic richness (36) compared to its relatively low total abundance (84) showing a fairly diverse community. Many sensitive taxa were present, and several are represented in the top five most abundant taxa in the sample, which consists of amphipods, aquatic worms, midges and mites. The model predictions were split across three classes (0.39A, 0.5B, 0.11C), indicating conflicting signals in the macroinvertebrate community. There is no clear indication why the sample did not meet its water quality goal and re-sampling is suggested. At the time of sampling in 2021 (10:45 AM), the dissolved oxygen levels were elevated (10.29 mg/l and 114.9%) possibly indicating diurnal DO swings and nutrient enrichment. The watershed land use is 14.9% human altered and consists of 3.5 % impervious surfaces. The invasive species the *Cipangopaludina chinensis* (Chinese Mystery snail) was observed but was not present in the sample collected.

Silver Lake Outlet Stream – Bucksport Station 285

Silver Lake Outlet Stream is a first order stream with a water quality goal of Class B which originates at the outlet of Silver Lake and flows through Bucksport to the Penobscot River. The flow at the outlet of Silver Lake is regulated by a dam. The direct watershed is characterized by high-density residential development. Station S-285 is located below the Bucks Mill Road bridge. In 2021, the macroinvertebrate community did not meet aquatic life criteria for Class B, and the model result was NA (non-attainment of criteria for any water quality class). Few sensitive taxa were collected. There were no stoneflies present and only one genus of mayfly found in very low numbers (mean abundance = 3.3). Eight different genera of caddisflies were present, but in very low numbers. The dominant taxa were riffle beetles (35.48%), two midge taxa (24.10%), a caddisfly (4.29%), and small freshwater clams (3.22%). Specific conductance was somewhat elevated in July and August (160.8 uS/cm, 156.6 uS/cm) and dissolved oxygen was also on the low side during sampler deployment and retrieval (6.91 mg/L, 6.65 mg/L). In addition to toxic urban runoff, altered hydrology and habitat from high stormwater flows (erosion and sedimentation) is likely contributing to non-attainment at this site.

Table 1. 2021 SWAT Benthic Macroinvertebrate Biomonitoring Results

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class / Final Determination	Attains Class?	Probable Cause
Androscoggin River	Brunswick	955	2877	Municipal/ industrial discharges, Urban NPS	C/C	Y	
Androscoggin River	Brunswick	954	2904	Urban NPS	C/B	Y	
Arctic Brook	Bangor	313	2894	Urban NPS	B/NA	N	NPS toxics/salt, altered hydrology
Black Stream	Garland	W-295	2021-295	Agriculture, forestry	A/B	N	Unclear, possibly influence of forestry activities
Bog Stream	T18 MD	514	2888	Agricultural NPS, Hatchery	A/C	N	Agricultural runoff, nutrients, altered habitat
Burnham Brook	Garland	506	2870	Agricultural NPS	B/I	I	Minimum model provision for Total Mean Abundance not met
Cambolasse Stream	Lincoln	588	2893	Industrial	C/B	Y	
Chase Mills Stream	East Machias	114	2886	Upstream of Hatchery	B/B	Y	
Chase Mills Stream	East Machias	113	2874	Downstream of Hatchery	B/B	Y	
Cold Stream	Enfield	482	2896	Upstream of Hatchery	A/A	Y	
Cold Stream	Enfield	484	2895	Downstream of Hatchery	A/B	N	Nutrient enrichment
Eaton Brook	Brewer	973	2911	NPS	B/C	N	Agricultural and urban toxics, nutrients
French Stream	Exeter	505	2897	Agricultural NPS	B/C	N	Agricultural chemicals, nutrients
Grand Lake Stream	Grand Lake Stream TWP	492	2892	Upstream of Hatchery	A/A	Y	

Table 1 (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class / Final Determination	Attains Class?	Probable Cause
Grand Lake Stream	Grand Lake Stream TWP	493	2891	Downstream of Hatchery	A/A	Y	
Great Falls Branch	Deblois	504	2887	Agricultural NPS	AA/B	N	Agricultural chemicals and NPS toxics
Hothole Brook	Orland	W-288	2021-288	Reference	A/A	Y	
Kenduskeag Stream	Bangor	829	2898	NPS	C/C	Y	
Kenduskeag Stream	Corinth	508	2899	Agricultural NPS	B/A	Y	
Mattanawcook Stream	Lincoln	91	2871	Industrial	C/C	Y	
Mill Stream	Embden	425	2909	Upstream of Hatchery	B/C	N	Uncertain - Resample to verify result
Mill Stream	Embden	426	2910	Downstream of Hatchery	B/C	N	Nutrient enrichment
Mud Pond	Drew PLT	W-123	2021-123	Reference	GPA/A	Y	
Narraguagus River	Beddington	112	2873	Reference	AA/A	Y	
Narraguagus River	Cherryfield	81	2884	NPS	B/A	Y	
Penobscot River	Old Town	62	2900	NPS	B/A	Y	
Piscataquis River	Abbot	83	2914	Reference	A/A	Y	
Piscataquis River	Dover-Foxcroft	152	2915	Municipal discharge, urban and agricultural NPS	B/C	N	NPS toxics and nutrients from urban and agricultural sources
Presumpscot River	Standish	462	2903	Reference	A/C	N	Lake outlet effect
Presumpscot River	Falmouth	802	2906	Municipal/ industrial discharges, Urban NPS	C/C	Y	
Sam Hill Brook	T25 MD BPP	520	2889	Agricultural NPS	A/A	Y	

Table 1 (continued)

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class / Final Determination	Attains Class?	Probable Cause
Sebec River	Milo	827	2901	Urban NPS	B/B	Y	
Sedgeunkedunk Stream	Orrington	972	2912	NPS	B/C	N	Agricultural and urban runoff, lake outlet effect
Sheepscot River	Whitefield	74	2875	Long-term reference	AA/A	Y	
Silver Lake	Bucksport	W-235	2021-235	Agricultural / Forestry NPS	GPA/B	N	Nutrient enrichment
Silver Lake Outlet Stream	Bucksport	285	2913	NPS	B/NA	N	NPS toxics, altered hydrology and habitat
Trout Brook	Columbia	1101	2885	Agricultural NPS	A/A	Y	
West Branch Pleasant River	Katahdin Iron Works Twp	686	2869	Iron mine	AA/A	Y	
Western Little River	Columbia	820	2882	Agricultural NPS	AA/A	Y	
White's Brook	Bucksport	W-236	2021-236	Agricultural NPS and ash spreading	B/A	Y	

NPS = non-point source pollution.

Table 2. 2021 SWAT Field Data

Measurements were obtained using handheld electronic meters.

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Androscoggin River	954	2904	7/13/2021	22.7	8.74	108.9	8.05	8/13/2021	25.7	10.60	90.5	7.20
Androscoggin River	955	2877	--	--	--	--	--	8/25/2021	25.6	8.23	99.3	7.08
Artic Brook	313	2894	7/15/2021	20.2	9.75	1114.0	--	8/12/2021	19.5	10.60	1573.0	8.06
Black Stream	W-295	2021-295	6/22/2021	25.2	8.09	64.0	7.13	--	--	--	--	--
Bog Stream	514	2888	7/26/2021	19.0	9.23	34.7	5.36	8/25/2021	21.5	7.19	34.5	5.18
Burnham Brook	506	2870	7/8/2021	15.1	9.48	207.9	7.32	9/2/2021	16.9	9.17	219.7	7.54
Cambolasee Stream	588	2893	7/19/2021	22.5	--	36.3	6.84	8/18/2021	23.8	9.93	38.9	5.94
Chase Mills Stream	114	2874	7/27/2021	23.7	9.37	33.5	5.63	8/25/2021	26.4	8.96	34.4	5.72
Chase Mills Stream	113	2886	7/27/2021	23.6	9.31	33.4	5.61	8/25/2021	26.8	9.10	33.6	5.88
Cold Stream	482	2895	7/15/2021	20.5	9.66	31.3	6.70	8/12/2021	22.0	9.48	30.7	6.53
Cold Stream	484	2896	7/15/2021	18.4	10.10	34.5	--	8/12/2021	17.6	10.17	34.6	6.41
Eaton Brook	973	2911	7/8/2021	21.8	9.68	--	--	8/5/2021	21.2	9.22	128.6	6.58
French Stream	505	2897	7/13/2021	20.0	10.30	174.1	7.47	8/10/2021	21.6	8.03	265.0	7.67
Grand Lake Stream	492	2891	7/14/2021	19.8	10.16	21.9	7.83	8/16/2021	24.1	9.70	22.9	5.49
Grand Lake Stream	493	2892	7/14/2021	19.9	10.14	22.1	8.16	8/16/2021	23.5	9.80	22.6	6.12
Great Falls Branch	504	2887	7/26/2021	19.1	8.73	40.3	5.50	8/25/2021	23.5	8.00	50.4	5.60
Hothole Brook	W-288	2021-288	6/24/2021	23.3	8.98	39.9	6.40	--	--	--	--	--
Kenduskeag Stream	829	2899	7/13/2021	22.3	9.95	132.4	7.59	8/10/2021	25.5	10.44	252.3	8.57
Mattanawcook Stream	91	2871	8/18/2021	24.2	9.64	67.9	6.17	9/15/2021	18.4	10.27	57.0	6.69
Mill Stream	425	2910	7/12/2021	24.1	9.61	30.6	8.22	8/13/2021	24.7	9.60	30.5	6.42
Mill Stream	426	2909	7/12/2021	17.0	10.05	34.2	7.55	8/13/2021	16.6	10.45	34.3	5.16

Table 2. 2021 SWAT Field Data (Continued)

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Mud Pond	W-123	2021-123	6/29/2021	27.4	8.65	74.0	7.50	--	--	--	--	--
Narraguagus River	112	2873	7/28/2021	21.2	10.04	33.3	6.23	8/26/2021	23.8	9.85	35.9	6.70
Narraguagus River	81	2884	7/26/2021	23.5	9.81	36.4	6.15	8/24/2021	24.9	9.64	40.3	6.15
Penobscot River	62	2900	7/14/2021	22.4	9.37	53.3	7.31	8/11/2021	24.9	9.34	54.7	7.38
Piscataquis River	152	2914	7/7/2021	26.3	10.37	117.8	7.94	8/4/2021	23.7	10.23	107.0	7.74
Piscataquis River	83	2915	7/7/2021	23.1	9.55	54.5	6.86	8/4/2021	24.0	9.91	52.7	6.33
Presumpscot River	462	2903	7/13/2021	22.9	9.95	57.5	8.09	8/13/2021	26.8	119.40	56.9	6.73
Sam Hill Brook	520	2889	7/27/2021	--	--	--	--	8/25/2021	17.9	9.47	28.4	5.56
Sebec River	827	2901	7/15/2021	23.9	9.27	30.6	6.64	8/16/2021	26.1	9.10	31.8	6.60
Sedgeunkedunk River	972	2912	7/8/2021	20.2	9.82	105.4	7.17	8/5/2021	20.9	9.37	57.3	6.28
Sheepscot River	74	2875	8/6/2021	22.3	9.44	83.6	6.38	9/3/2021	20.1	10.35	109.1	7.33
Silver Lake	W-235	2021-235	6/24/2021	22.4	10.29	181.0	6.76	--	--	--	--	--
Silver Lake Outlet Stream	285	2913	7/8/2021	19.9	6.91	160.8	6.51	8/5/2021	20.4	6.65	156.6	5.41
Trout Brook	1101	2885	7/27/2021	19.9	7.45	41.6	5.48	8/24/2021	23.0	7.52	43.5	4.57
W. Br. Pleasant River	686	2869	8/2/2021	15.7	9.85	30.8	5.77	8/30/2021	17.3	9.94	30.5	6.07
Western Little River	820	2882	7/27/2021	18.2	9.02	33.6	5.50	8/24/2021	21.5	9.48	36.9	5.56
White's Brook	W-236	2021-236	6/24/2021	18.0	3.97	224.5	6.73	--	--	--	--	--

Table 3. 2021 SWAT Water Chemistry Data

In 2021, TKN, NO2-NO3-N, Total P, SRP, Chloride and True Color were analyzed by the Health & Environmental Testing Laboratory, Augusta, ME. Alkalinity was analyzed by the Biomonitoring Unit.

Waterbody	**Station**	**Log**	**Sampling Date**	**TKN** *(MG/L)*	**NO2-NO3-N** *(MG/L)*	**Total P** *(MG/L)*	**SRP** *(MG/L)*	**True Color** *(PCU)*	**Alkalinity** *(MG/L)*	**Chloride** *(MG/L)*
Androscoggin River	954	2904	7/13/2021	0.4	0.2	0.024	0.004	--	--	--
Artic Brook	313	2894	7/15/2021	0.4	0.74	0.025	0.009	--	114	--
Black Stream	W-295	2021-295	6/22/2021	0.6	--	0.022	--	65	--	3
Bog Stream	514	2888	7/26/2021	0.3	0.02	0.014	0.002	--	13.5	--
Burnham Brook	506	2870	7/8/2021	0.2	0.14	0.027	0.008	--	--	--
Cambolasse Stream	588	2893	7/19/2021	0.4	0.03	0.013	<0.001	--	10.0	--
Chase Mills Stream	114	2886	7/27/2021	<0.3	0.01	0.006	0.001	--	6.5	--
Chase Mills Stream	113	2874	7/27/2021	<0.3	0.01	0.006	0.001	--	6.0	--
Cold Stream	482	2895	7/15/2021	<0.3	0.01	0.004	0.026	--	7.0	--
Cold Stream	484	2896	7/15/2021	0.5	0.03	0.036	<0.001	--	8.0	--
Eaton Brook	973	2911	7/8/2021	0.7	<0.01	0.025	0.002	--	--	--
French Stream	505	2897	7/13/2021	0.7	0.12	0.042	0.011	--	66.5	--
Grand Lake Stream	492	2891	7/14/2021	0.3	<0.01	0.004	0.001	--	7.5	--
Grand Lake Stream	493	2892	7/14/2021	<0.3	<0.01	0.004	0.001	--	8.0	--
Great Falls Branch	504	2887	7/26/2021	0.6	0.04	0.028	0.002	--	10.0	--
Hothole Brook	W-288	2021-288	6/24/2021	0.3	--	0.014	--	46	--	3
Kenduskeag Stream	508	2898	7/13/2021	0.3	0.24	0.011	0.006	--	59.0	--
Kenduskeag Stream	829	2899	7/13/2021	0.8	0.07	0.04	0.002	--	40.0	--
Mattanawcook Stream	91	2871	8/18/2021	0.4	<0.01	0.016	0.003	--	12.0	--
Mill Stream	425	2909	7/12/2021	<0.3	<0.01	0.003	0.001	--	--	--
Mill Stream	426	2910	7/12/2021	0.6	0.05	0.07	0.053	--	--	--
Mud Pond	W-123	2021-123	6/29/2021	0.6	--	0.015	--	50	--	2

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, SRP = Soluble Reactive Phosphorus (ortho-phosphate), PCU=Platinum-Cobalt Units, "<" = constituent not detected at the reporting limit.

Table 3. 2021 SWAT Water Chemistry Data (continued)

Waterbody	**Station**	**Log**	**Sampling Date**	**TKN** *(MG/L)*	**NO2-NO3-N** *(MG/L)*	**Total P** *(MG/L)*	**SRP** *(MG/L)*	**True Color** *(PCU)*	**Alkalinity** *(MG/L)*	**Chloride** *(MG/L)*
Narraguagus River	112	2873	7/28/2021	0.4	0.01	0.01	0.001	--	10.5	--
Narraguagus River	81	2884	7/26/2021	0.4	0.02	0.024	0.001	--	12.5	--
Penobscot River	62	2900	7/14/2021	0.5	0.03	0.021	0.003	--	--	--
Piscataquis River	152	2914	7/7/2021	0.3	<0.01	0.009	0.001	--	--	--
Piscataquis River	83	2915	7/7/2021	<0.2	0.02	0.005	<0.001	--	--	--
Presumpscot River	462	2903	7/13/2021	<0.3	0.03	0.004	0.001	--	7.5	--
Presumpscot River	802	2906	8/4/2021	0.4	0.08	0.031	0.011	--	16.0	--
Sam Hill Brook	520	2889	7/27/2021	0.3	0.06	0.017	0.002	--	9.5	--
Sebec River	827	2901	7/15/2021	<0.3	0.01	0.007	<0.001	--	11.0	--
Sedgeunkedunk River	972	2912	7/8/2021	0.5	0.01	0.026	0.004	--	--	--
Sheepscot River	74	2875	8/6/2021	0.4	0.02	0.014	0.002	--	18.0	--
Silver Lake	W-235	2021-235	6/24/2021	0.5	--	0.017	--	36	--	38
Silver Lake Outlet Stream	285	2913	7/8/2021	0.4	0.01	0.019	0.002	--	--	--
Trout Brook	1101	2885	7/27/2021	0.7	0.02	0.031	0.001	--	15.5	--
W. Br. Pleasant River	686	2869	8/2/2021	<0.3	0.05	0.004	0.001	--	12.0	--
Western Little River	820	2882	7/27/2021	0.5	0.07	0.026	0.004	--	10.0	--
White's Brook	W-236	2021-236	6/24/2021	0.4	--	0.025	--	50	--	40

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, SRP = Soluble Reactive Phosphorus (ortho-phosphate), PCU=Platinum-Cobalt Units, "<" = constituent not detected at the reporting limit.

Table 4. Past Attainment History of 2021 Sampling Stations

The table below provides the attainment history for 2021 sampling stations that have been sampled in the past.

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Androscoggin River	954	2010, 2018	—	—
Androscoggin River	955	2010	—	—
Arctic Brook	313	—	1997, 2014, 2015	—
Black Stream	W-295	—	2016, 2021	—
Bog Stream	514	—	2001	—
Burnham Brook	506	—	—	2001
Cambolasse Stream	588	2001	2000	—
Chase Mills Stream	114	1987-1989, 2000, 2005	—	—
Chase Mills Stream	113	1987, 2000, 2005	1988, 1989	—
Cold Stream	482	2006, 2011, 2016	2001	—
Cold Stream	484	2006, 2011, 2016	2001	—
Eaton Brook	973	2011	—	—
French Stream	505	2001, 2011, 2016	—	—
Grand Lake Stream	492	2001	1997, 2011	—
Grand Lake Stream	493	2001, 2011	—	—
Great Falls Branch	504	2016	2001, 2006, 2011	—
Hothole Brook	W-288	2016, 2021	—	—
Kenduskeag Stream	508	1988, 2001, 2011, 2016	—	—
Kenduskeag Stream	829	2006, 2011, 2016	—	—
Mattanawcook Stream	91	1985, 1998, 2000, 2001	—	—
Mill Stream	425	2000, 2006, 2011, 2016, 2017	—	—
Mill Stream	426	2006	2000, 2011, 2016, 2017	—
Mud Pond	W-123	2004, 2021	—	—
Narraguagus River	112	2001, 2006, 2011, 2016	1984, 1993	—

Table 4. Past Attainment History of 2021 Sampling Stations (continued)

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Narraguagus River	81	1987, 2006, 2011, 2016	—	—
Penobscot River	62	1984, 1993, 1994, 2006, 2011	—	—
Piscataquis River	152	1984, 1985, 1989, 1996, 2006, 2011	1990	—
Piscataquis River	83	1991, 1993, 1995, 2006, 2011, 2014	—	—
Presumpscot River	462	—	2000	—
Presumpscot River	802	2005	—	—
Sam Hill Brook	520	2000	—	—
Sebec River	827	2006, 2016	—	—
Sedgeunkedunk River	972	2011, 2016	—	—
Sheepscot River	74	1985, 1987,1988-1990, 1992, 1995-1996, 1998-2017, 2019-2020	1984,1986, 1988,1991, 1993-1994, 1997, 2021	—
Silver Lake	W-235	2011	2021	—
Silver Lake Outlet Stream	285	—	1996, 2011	—
Trout Brook	1101	—	2016	—
W. Br. Pleasant River	686	—	2020	—
Western Little River	820	—	2006	—
White's Brook	W-236	2021	2011	—

4.3 2022 Results

The Biological Monitoring Unit concentrated its sampling in 2022 in the Kennebec River basin. Forty-three stations were sampled under the SWAT Program (Table 5). Taxonomic analysis of 2022 data is still ongoing. Results for 15 stations are currently available and are summarized in Table 1b. Of these 15 stations, 5 did not attain criteria for their assigned class. Results for 28 additional stations are not yet available, however they will be added to this report as data are received back from our contractors, and the updated report will be reposted on the DEP webpage.

<u>Fish Brook – Fairfield</u> Station 1038

Fish Brook is a second order stream with a water quality goal of Class B which flows south through Fairfield to Messalonskee Stream. Station S-1038 is located downstream of Route 104 in Fairfield. Surrounding land use includes dense agriculture and moderate levels of urban development. In 2022, the macroinvertebrate community did not attain aquatic life criteria for any water quality class, therefore the final determination was NA. Few sensitive taxa were collected, and the sample was dominated by tolerant organisms including scuds (Hyalella, 33.78 %), sowbugs (Caecidotea, 28.26 %) and various midge larvae. EPT generic richness (sum of mayfly, stonefly and caddisfly taxa) was very low (only 4 genera). No stoneflies were present and only one mayfly genus was represented with very few individuals (mean abundance = 4.33). Water samples collected in July show that total phosphorus concentration was very high (46 ug/l). The pH value measured in July during sampler deployment was also unusually high (8.97), and DO measured in August was extremely low (4.08 mg/l, 47.7 % saturation). Specific conductance values in July (217.8 uS/cm) and August (314.5 uS/cm) were also somewhat elevated, although not extreme. Likely causes of impairment include agricultural chemicals, nutrients and urban NPS toxics.

<u>Red Brook – Scarborough</u> Station 413

Red Brook is a second order stream with a water quality goal of Class C that flows east through Scarborough and South Portland, running parallel to I-295/I-95 for much of its length then joining Long Creek before it reaches Casco Bay. Watershed land use includes dense urban development, in addition to farms in the upper portion of the watershed. Station S-413 is located just downstream of Payne Road in Scarborough. In 2022, the macroinvertebrate community at Station S-413 did not attain aquatic life criteria for any water quality class (NA). Few sensitive taxa were present in the sample. There were no stoneflies and only one mayfly genus (Paraleptophlebia) consisting of one individual organism. Specific conductance at the site was elevated in August (603 uS/cm) and September (342.3 uS/cm), indicating the presence of urban NPS toxics such as road salt. Habitat alteration and sedimentation due to high stormwater flows are also a likely causes of impairment.

<u>Red Brook – Scarborough</u> Station 1218

Red Brook is a second order stream with a water quality goal of Class C that flows east through Scarborough and South Portland, running parallel to I-295 for much of its length then joining Long Creek before it reaches Casco Bay. Watershed land use includes dense urban development, in addition to farms in the upper portion of the watershed. Station S-1218 is located downstream of S-413 in Scarborough, just before Red Brook crosses I-295. In 2022, the macroinvertebrate community at Station S-1218 did not attain aquatic life criteria for any water quality class (NA). Few sensitive taxa were present in the sample. There were no stoneflies and only one mayfly genus (Centroptilum) consisting of one individual organism. Specific conductance was extremely high in August (1016 uS/cm) and still elevated in September (512 uS/cm). Likely causes of impairment are NPS toxics including road salt and habitat alteration due to high stormwater flows and sedimentation.

<u>Red Brook – Scarborough</u> Station 1219

Red Brook is a second order stream with a water quality goal of Class C that flows east through Scarborough and South Portland, running parallel to I-295 for much of its length then joining Long Creek before it reaches Casco Bay. Watershed land use includes dense urban development, in addition to farms in the upper portion of the watershed. Station S-1219 is located upstream of Payne Road and downstream of I-95 in Scarborough. In 2022, Station S-1219 did not attain aquatic life criteria for any water quality class (NA). Few sensitive taxa were present in the sample. There were no stoneflies present, and mayfly relative abundance was only 0.01 (two taxa found in very low numbers). Dominant taxa in the community included a net-spinning caddisfly (Hydropsyche, 41.11 %), tolerant midge larvae (Rheotanytarsus and Procladius), pea clams (Pisidium) and aquatic worms (Lumbriculidae). Specific conductance was elevated in August (462.8 uS/cm) and September (313.1 uS/cm), and there was evidence of heavy sedimentation at the site. Causes of impairment include urban NPS toxics including road salt and habitat alteration due to high stormwater flows.

Stone Brook – Augusta Station 619

Stone Brook is a second order stream with a water quality goal of Class B which flows south through Augusta west of I-95. Stone Brook joins Bond Brook upstream of Bond Brook Road. Watershed land use includes urban development and farmland. Station S-619 is located in Augusta, east of Bond Brook Road just above the confluence with Bond Brook. In 2022, the macroinvertebrate community at Station S-619 met aquatic life criteria for Class C, but did not meet Class B criteria. Total generic richness at the site was quite high (69), however there were few sensitive taxa and those present were found in very low abundance. No stoneflies were collected, and mayfly relative abundance was only 0.02. Specific conductance measured in July and August was very high (1009 uS/cm) indicating the presence of urban runoff containing road salt and other toxics. Altered hydrology and sedimentation due to high stormwater flows likely also impacts the aquatic community.

Stone Brook Augusta Station 944

Stone Brook is a second order stream with a water quality goal of Class B which flows south through Augusta west of I-95. Stone Brook joins Bond Brook upstream of Bond Brook Road. Watershed land use includes urban development and farmland. Station S-944 is located in Augusta upstream of Station S-619 south of Stony Brook Drive. In 2022, the macroinvertebrate community at Station S-944 did not meet aquatic life criteria for any water quality class (NA). Sensitive taxa were mostly absent or found in very low abundance. There were no stoneflies present and only one individual mayfly was collected (Serratella serratoides, mean abundance = 0.33). Specific conductance measured in July and August was very high (1015 uS/cm, 1189uS/cm) indicating the presence of urban runoff containing road salt and other toxics. Altered hydrology and sedimentation due to high stormwater flows likely also impacts the aquatic community.

Table 5. 2022 SWAT Benthic Macroinvertebrate Biomonitoring Results
Some of the 2022 samples have not been processed yet. The table will be updated when the results are available.

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class / Final Determination	Attains Class?	Probable Cause
Alder Brook	Lisbon	1217	2998	NPS			
Alder Brook	Lisbon	1216	2999	NPS	B		
Beaverdam Stream	Wesley	1149	2977	Clam shell project/ Acid rain	AA/A	Y	
Black Brook (Windham)	Windham	W-354	2022 -354	Potential NPS	B / B	Y	
Bull Branch Sunday River	Riley TWP	659	2994	Reference	A/A	Y	
Burnham Brook	Big Moose TWP	869	2996	Reference	A		
Carrying Place Stream	Carrying Place TWP	768	2959	Forestry NPS	A		
China Lake Outlet Stream	Winslow	1208	2964	Agricultural NPS	B		
China Lake Outlet Stream	Winslow	604	2966	Landfill	B/B	Y	
Cobbosseecontee Stream	Gardiner	253	2995	Urban NPS / Nutrients	B		
Creamer Brook	T19 ED BPP	1115	2980	Clam shell project/ Acid rain	AA		
Currier Brook	Skowhegan	1210	2983	Urban NPS	B		
Dresden Bog WMA	Dresden	W-351	2022 -351	Reference	GPA / A	Y	
E. Br. Wesserunsett River	Athens	486	2957	Reference	A		
Fish Brook	Fairfield	1038	2963	Agricultural NPS	B/NA	N	Agricultural runoff and urban toxics
Halfmoon Stream	Thorndike	697	2992	Agricultural NPS	A		
Katahdin Brook	T3 R8 WELS	1212	2960	Reference	AA/A	Y	
Kennedy Brook	Augusta	620	2991	Urban NPS	B		
Lily Bay Brook	Lily Bay TWP	844	2979	Reference	A		
Martin Stream	Dixmont	755	2989	Agricultural NPS	A		
Martin Stream	Dixmont	756	2990	Agricultural NPS	A		

Waterbody	Town	Station	Log	Potential sources of pollution[1]	Statutory Class / Final Determination	Attains Class?	Probable Cause
Moose Brook	Big Moose TWP	1111	2993	Reference	A/A	Y	
North Brook	Lily Bay TWP	841	2978	Reference	A/A	Y	
Perkins Stream	Waterville	977	2997	Urban NPS	B		
Red Brook	Scarborough	413	3000	NPS	C/NA	N	NPS toxics, habitat alteration
Red Brook	Scarborough	1218	3001	NPS	C/NA	N	NPS toxics, habitat alteration
Red Brook	Scarborough	1219	3002	NPS	C/NA	N	NPS toxics, habitat alteration
Richardson Brook	T19 ED BPP	1117	2981	Clam shell project/ Acid rain	A		
Richardson Brook	T19 ED BPP	1116	2982	Clam shell project/Acid rain	A		
Riggs Brook	Augusta	599	2987	Urban NPS	B		
Sheepscot River	N. Whitefield	74	2970	Reference	AA/A	Y	
Sheepscot River	Palermo	393	2988	Below Hatchery	B/C	N	Nutrients
Stone Brook	Augusta	619	2971	Urban NPS	B/C	N	NPS toxics, altered hydrology
Stone Brook	Augusta	944	2972	Urban NPS	B/NA	N	NPS toxics, altered hydrology
Tanning Brook	Manchester	744	2974	Agricultural NPS	BA	Y	
Unnamed Stream (Avon)	Avon	631	2973	Confirm attainment (closed hatchery)	B/A	Y	
Unnamed Stream (Avon)	Avon	632	2975	Confirm attainment	B/A	Y	

				(closed hatchery)			
Waterbody	**Town**	**Station**	**Log**	**Potential sources of pollution[1]**	**Statutory Class / Final Determination**	**Attains Class?**	**Probable Cause**
Vaughan Brook	Hallowell	1209	2956	Agricultural/ Urban NPS	B/NA	N	NPS toxics, altered hydrology
Wassatquoik Stream	T3 R8 WELS	1148	2962	Reference	AA/A	Y	
West Branch Cold Stream	Cornville	W-164	2022-164	Agricultural NPS	B		
Whitney Brook	Augusta	601	2985	Urban NPS	B		
Wild River	Batchelder Grant TWP	674	2967	Reference	A/A	Y	

Table 6. 2022 SWAT Field Data

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Alder Brook	1217	2998	7/21/2022	21.1	6.69	598.0	--	8/18/2022	17.6	8.43	246.9	--
Alder Brook	1216	2999	7/21/2022	18.9	8.20	574.0	--	8/18/2022	17.0	8.62	276.5	--
Beaverdam Stream	1149	2977	7/14/2022	22.6	8.11	55.5	6.75	8/11/2022	21.0	8.48	71.6	6.80
Black Brook (Windham)	W-354	2022-354	6/27/2022	22.2	5.25	315.0	7.10	--	--	--	--	--
Bull Branch Sunday River	659	2994	8/15/2022	19.5	9.88	24.7	6.82	9/13/2022	17.1	10.39	23.3	6.68
Burnham Brook	869	2996	7/26/2022	20.3	8.44	96.8	7.57	8/23/2022	20.7	8.89	77.1	7.05
Carrying Place Stream	768	2959	7/27/2022	18.5	9.90	45.2	7.40	8/24/2022	18.2	10.17	44.5	7.10
China Lake Outlet Stream	1208	2964	7/19/2022	23.4	9.03	176.3	7.83	8/16/2022	23.4	10.45	145.7	8.20
China Lake Outlet Stream	604	2966	7/19/2022	23.9	8.98	162.7	7.77	8/16/2022	20.9	9.83	142.5	7.60
Cobbosseecontee Stream	253	2995	7/20/2022	27.0	9.47	149.9	8.14	8/17/2022	22.9	9.88	154.7	7.86
Creamer Brook	1115	2980	7/14/2022	17.8	10.07	30.5	6.41	8/11/2022	18.1	9.43	31.7	6.18
Currier Brook	1210	2983	7/21/2022	24.5	7.21	473.0	7.42	8/18/2022	15.2	9.13	226.5	6.84
Dresden Bog WMA	W-351	2022-351	6/14/2022	23.1	8.57	39.0	6.38	--	--	--	--	--
E. Br. Wesserunsett River	486	2957	7/27/2022	20.2	9.92	67.6	7.77	8/24/2022	20.1	10.12	100.4	7.70
Fish Brook	1038	2963	7/19/2022	26.5	8.24	217.8	8.97	8/16/2022	23.5	4.08	314.5	7.47
Halfmoon Stream	697	2992	7/20/2022	26.0	10.67	130.4	8.33	8/22/2022	21.9	10.04	175.0	7.58
Katahdin Brook	1212	2960	7/28/2022	22.3	9.60	29.2	7.43	8/25/2022	20.4	10.15	28.0	6.76
Kennedy Brook	620	2991	7/11/2022	17.8	9.92	972.0	8.13	8/8/2022	20.8	9.29	853.0	8.08
Lily Bay Brook	844	2979	7/26/2022	17.8	9.51	29.7	6.99	8/23/2022	15.1	10.52	22.0	6.45
Martin Stream	755	2989	7/20/2022	25.3	9.12	119.6	7.69	8/22/2022	22.2	11.00	136.9	7.63
Martin Stream	756	2990	7/20/2022	24.0	8.98	117.8	7.69	8/22/2022	21.5	11.24	138.2	7.54
Mill Stream	232	2986	7/20/2022	24.3	8.75	124.2	7.54	8/17/2022	21.4	9.91	71.2	7.72

Table 6. 2022 SWAT Field Data (continued)

Site	Station	Log	Sample Deployment					Sample Retrieval				
			Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU	Date	Temperature Deg C	Dissolved Oxygen MG/L	Specific Conductance US/CM	pH STU
Moose Brook	1111	2993	7/26/2022	17.6	9.75	40.0	7.49	8/23/2022	17.0	10.20	35.1	--
North Brook	841	2978	7/26/2022	17.8	9.17	55.9	7.06	8/23/2022	17.1	9.61	34.4	6.33
Perkins Stream	977	2997	7/19/2022	23.4	8.72	828.0	7.90	8/16/2022	18.9	3.77	1695.0	7.25
Red Brook	413	3000	8/5/2022	22.3	6.05	1016.0	--	9/1/2022	18.6	7.93	512.0	--
Red Brook	1218	3001	8/5/2022	21.9	6.72	462.8	--	9/1/2022	18.1	8.55	313.1	--
Red Brook	1219	3002	8/5/2022	21.9	6.63	603.0	--	9/1/2022	18.8	8.27	342.3	--
Richardson Brook	1117	2981	7/14/2022	19.6	9.51	28.6	6.68	8/11/2022	19.2	8.81	33.5	6.71
Richardson Brook	1116	2982	7/14/2022	20.5	8.86	21.9	6.20	8/11/2022	19.2	9.11	25.9	6.00
Riggs Brook	599	2987	7/11/2022	19.0	9.06	412.0	7.88	8/8/2022	23.8	7.52	556.0	7.70
Sheepscot River	74	2970	7/12/2022	24.5	9.22	92.7	7.61	8/9/2022	25.1	7.21	92.4	7.11
Sheepscot River	393	2988	7/19/2022	17.9	9.89	44.9	6.54	8/16/2022	15.4	10.51	46.2	6.27
Stone Brook	619	2971	7/13/2022	19.3	8.07	1009.0	7.72	8/10/2022	19.6	9.06	1109.0	7.92
Stone Brook	944	2972	7/13/2022	21.6	9.17	1015.0	7.96	8/10/2022	20.6	9.43	1189.0	7.90
Tanning Brook	744	2974	8/2/2022	21.6	4.99	218.5	7.18	8/29/2022	18.5	6.10	184.2	6.97
Unnamed Stream (Avon)	631	2973	7/21/2022	20.0	9.35	38.1	6.80	8/18/2022	16.2	10.09	41.4	7.29
Unnamed Stream (Avon)	632	2975	7/21/2022	19.7	9.49	39.3	6.91	8/18/2022	15.8	10.14	23.4	6.60
Vaughan Brook	1209	2956	7/20/2022	25.5	8.84	324.6	7.91	8/17/2022	19.4	9.94	342.9	7.92
Wassataquoik Stream	1148	2962	7/28/2022	23.9	9.42	18.8	7.28	8/25/2022	20.4	10.10	17.0	6.53
West Branch Cold Stream	W-164	2022-164	6/21/2022	21.4	9.18	91.2	7.23	--	--	--	--	--
Whitney Brook	601	2985	7/11/2022	17.7	9.54	800.0	7.75	8/8/2022	22.0	8.78	876.0	7.87
Wild River	674	2967	7/18/2022	21.4	9.65	19.9	7.25	8/15/2022	19.3	10.13	21.1	6.41

Table 7. 2022 SWAT Water Chemistry Data

In 2022, TKN, NO2-NO3-N, Total P, and Chloride were analyzed by the Health & Environmental Testing Laboratory, Augusta, ME. True Color and Alkalinity were analyzed by the Biomonitoring Unit.

Waterbody	Station	Log	Sampling Date	TKN *(MG/L)*	NO2-NO3-N *(MG/L)*	Total P *(MG/L)*	Chloride *(MG/L)*	True Color *(PCU)*	Alkalinity *(MG/L)*
Beaverdam Stream	1149	2977	7/14/2022	0.6	0.03	0.023	8	--	9
Black Brook (Windham)	W-354	2022-354	6/27/2022	0.5	--	0.039	56	34	56
Bull Branch Sunday River	659	2994	8/15/2022	<0.3	0.05	0.008	<1	--	5.5
Burnham Brook	869	2996	7/26/2022	0.5	0.06	0.013	3	--	44
Carrying Place Stream	768	2959	7/27/2022	<0.3	0.1	0.01	<1	--	17
China Lake Outlet Stream	1208	2964	7/19/2022	0.6	--	0.072	20	--	44
China Lake Outlet Stream	1208	2964	8/16/2022	--	<0.01	--	--	--	--
China Lake Outlet Stream	604	2966	7/19/2022	0.6	--	0.075	16	--	43.8
China Lake Outlet Stream	604	2966	8/16/2022	--	0.01	--	--	--	--
Cobbosseecontee Stream	253	2995	7/20/2022	0.4	0.03	0.02	28	--	21.8
Creamer Brook	1115	2980	7/14/2022	0.4	0.07	0.015	2	--	5
Currier Brook	1210	2983	7/21/2022	0.6	0.13	0.042	96	--	62
Dresden Bog WMA	W-351	2022-351	6/14/2022	0.6	--	0.017	7	49	4
Fish Brook	1038	2963	7/19/2022	0.5	--	0.046	16	--	71
Fish Brook	1038	2963	8/26/2022	--	<0.01	--	--	--	--
Halfmoon Stream	697	2992	7/20/2022	0.3	0.28	0.014	10	--	35.3
Katahdin Brook	1212	2960	7/28/2022	<0.3	0.02	0.013	<1	--	11
Kennedy Brook	620	2991	7/11/2022	<0.3	0.5	0.016	200	--	145
Lily Bay Brook	844	2979	7/26/2022	<0.3	0.17	0.008	<1	--	10
Martin Stream (Dixmont)	755	2989	7/20/2022	0.5	0.03	0.023	7	--	40
Martin Stream (Dixmont)	756	2990	7/20/2022	0.5	0.03	0.024	7	--	41.5

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, PCU=Platinum-Cobalt Units, "<" = constituent not detected at the reporting limit.

Table 7. 2022 SWAT Water Chemistry Data (continued)

Waterbody	**Station**	**Log**	**Sampling Date**	**TKN** *(MG/L)*	**NO2-NO3-N** *(MG/L)*	**Total P** *(MG/L)*	**Chloride** *(MG/L)*	**True Color** *(PCU)*	**Alkalinity** *(MG/L)*
Mill Stream	232	2986	7/20/2022	0.3	0.03	0.013	20	--	21.5
Moose Brook	1111	2993	7/26/2022	<0.3	0.09	0.011	<1	--	15
North Brook	841	2978	7/26/2022	0.6	0.19	0.035	1	--	20.5
Perkins Stream	977	2997	7/19/2022	0.4	--	0.053	180	--	93.5
Perkins Stream	977	2997	8/16/2022	--	0.17	--	--	--	--
Richardson Brook	1116	2982	7/14/2022	0.03	0.5	0.016	2	--	7
Richardson Brook	1117	2981	7/14/2022	0.6	0.03	0.017	2	--	4
Riggs Brook	599	2987	7/11/2022	0.7	0.28	0.042	52	--	109
Sheepscot River	393	2988	7/19/2022	0.4	--	0.045	5	--	8
Sheepscot River	393	2988	8/16/2022	--	0.09	--	--	--	--
Sheepscot River	74	2970	7/12/2022	0.4	<0.01	0.013	11	--	20
Stone Brook	619	2971	7/13/2022	0.3	0.07	0.011	250	--	78
Stone Brook	944	2972	7/13/2022	0.4	0.06	0.012	250	--	78.3
Tanning Brook	744	2974	8/2/2022	0.4	0.04	0.037	18	--	71
Unnamed Stream (Avon)	631	2973	7/21/2022	0.5	0.08	0.031	<1	--	13.8
Unnamed Stream (Avon)	632	2975	7/21/2022	0.5	0.06	0.032	<1	--	14
Vaughan Brook	1209	2956	7/20/2022	0.4	0.06	0.035	63	--	46
Wassataquoik Stream	1148	2962	7/28/2022	<0.3	0.02	0.004	<1	--	7.5
West Branch Cold Stream	W-164	2022-164	6/21/2022	0.5	--	0.018	6	54	29.8
Wild River	674	2967	7/18/2022	<0.3	--	0.003	<1	--	4.5
Wild River	674	2967	8/15/2022	--	<0.01	--	--		

TKN = Total Kjeldahl-Nitrogen, NO_2-NO_3-N = Nitrite-Nitrate-Nitrogen, Total P = Total Phosphorus, PCU=Platinum-Cobalt Units, "<" = constituent not detected at the reporting limit

Table 8. Past Attainment History of 2022 Sampling Stations

The table below provides the attainment history for 2022 sampling stations that have been sampled in the past.

Waterbody	Station	Attained Class	Did not Attain Class	Indeterminate Result
Bull Branch Sunday River	659	2020	2021	—
Burnham Brook	869	2012, 2017	2008	—
Carrying Place Stream	768	2004, 2007, 2012, 2017	—	—
China Lake Outlet Stream	604	2002, 2007, 2012	—	—
Cobbosseecontee Stream	253	—	1997, 2007, 2017	—
Creamer Brook	1115	2017, 2018-2020	—	—
East Branch Wesserunsett Stream	486	2001, 2007, 2012-2021	—	—
Fish Brook	1038	—	2014	—
Halfmoon Stream	697	2003, 2007, 2019	2012-2018	—
Kennedy Brook	620	2002	2004, 2007, 2012, 2017	—
Lily Bay Brook	844	2007, 2012, 2017	—	—
Martin Stream (Dixmont)	755	2006, 2017	2004-2005, 2016	2007
Martin Stream (Dixmont)	756	2012	2005-2007, 2016-2017	2004
Mill Stream	232	—	1984, 2004	2010
Moose Brook	1111	2017	—	—
North Brook	841	2012, 2017	—	—
Perkins Stream	977	—	2012, 2014	—
Red Brook	413	2007, 2010	—	1999

Table 8. Past Attainment History of 2022 Sampling Stations (continued)

Waterbody	Station	Attained Class	Did Not Attain Class	Indeterminate Result
Richardson Brook	1116	2017-2018, 2020	—	—
Richardson Brook	1117	2017-2018, 2020	—	—
Riggs Brook	599	—	2007, 2012	—
Sheepscot River	74	1985, 1987,1988-1990, 1992, 1995-1996, 1998-2017, 2019-2020	1984,1986, 1988,1991, 1993-1994, 1997, 2021	—
Sheepscot River	393	2007, 2013	1999, 2006, 2012, 2017	—
Stone Brook	619	—	2002	—
Stone Brook	944	2012	2017	—
Tanning Brook	744	—	2004	—
Unnamed Stream (Avon)	631	2002	—	—
Unnamed Stream (Avon)	632	—	2002	—
Wassataquoik Stream	1148	2018	—	—
West Branch Cold Stream	W-164	2007	—	—
Whitney Brook	601	—	2007, 2012	—
Wild River	674	2021	2020	—

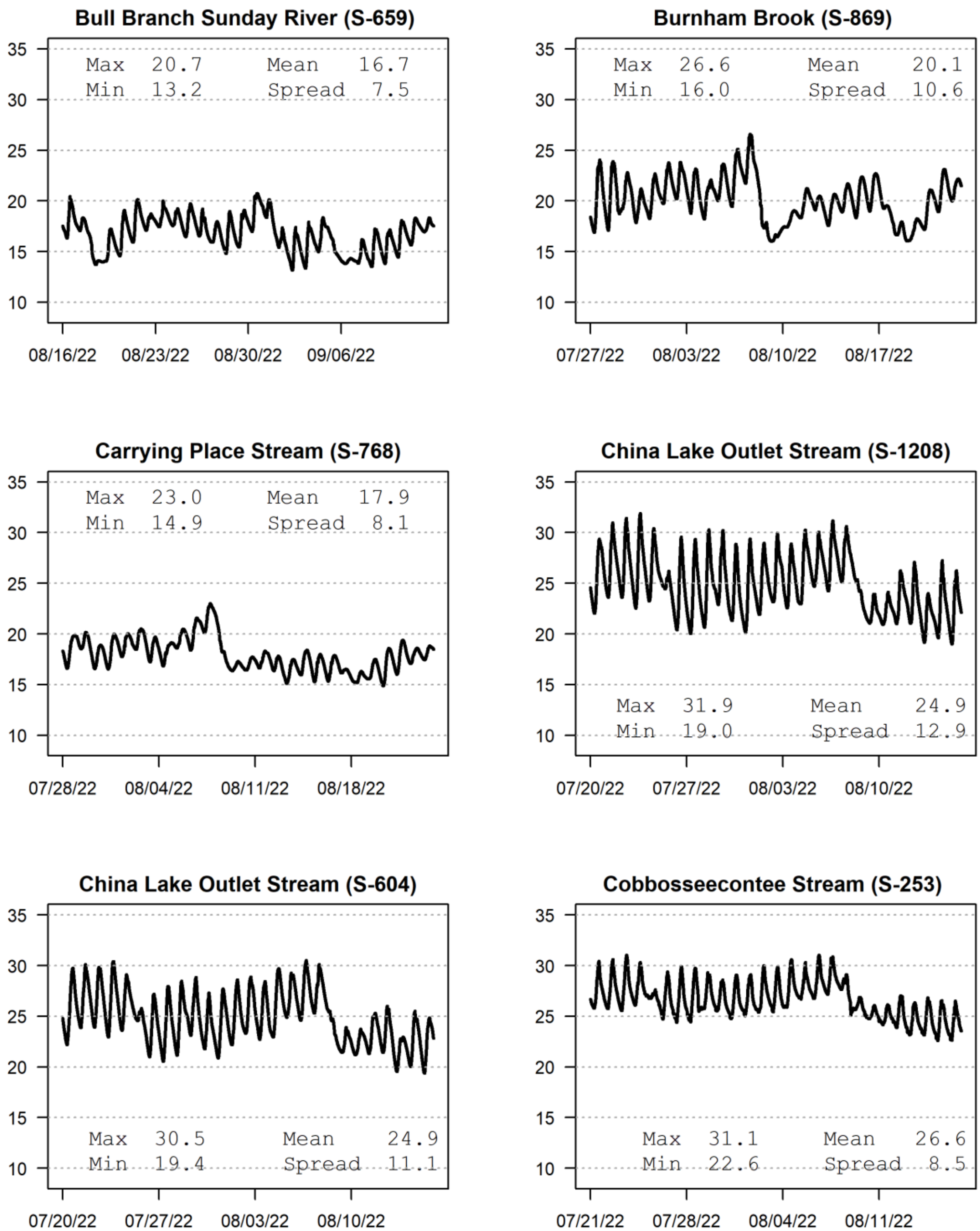


Figure 1. 2022 In-Stream Continuous Temperature Data

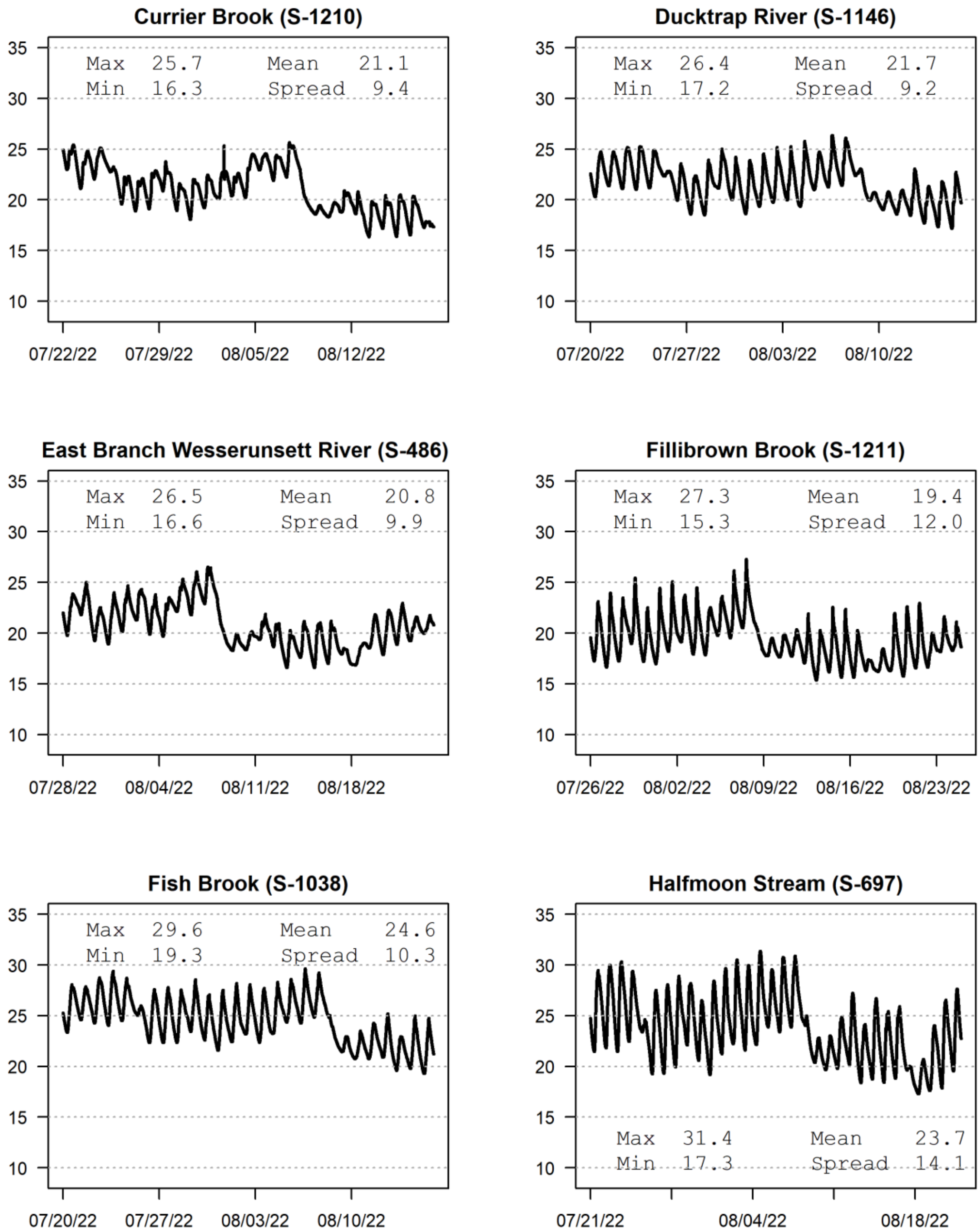


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)

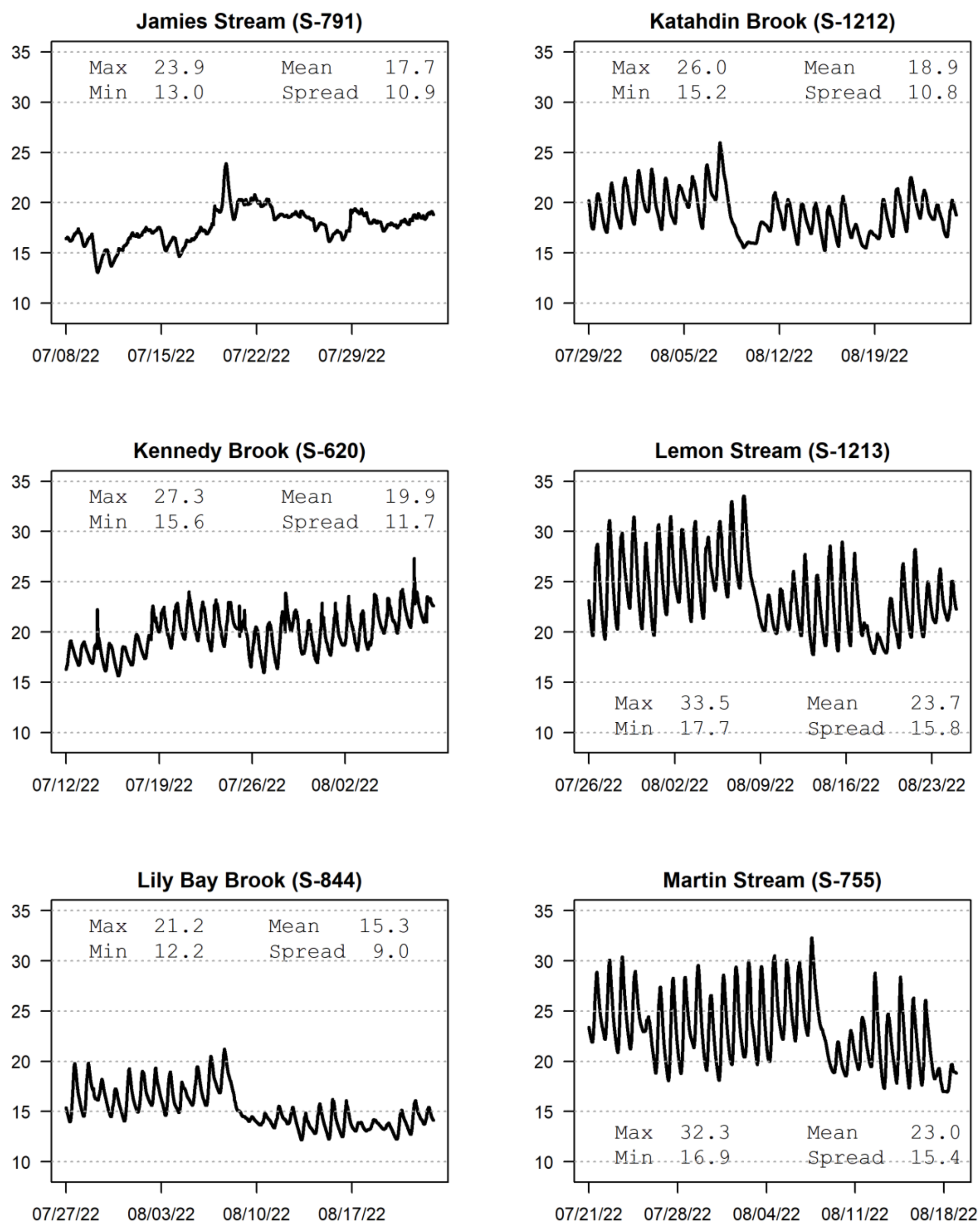


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)

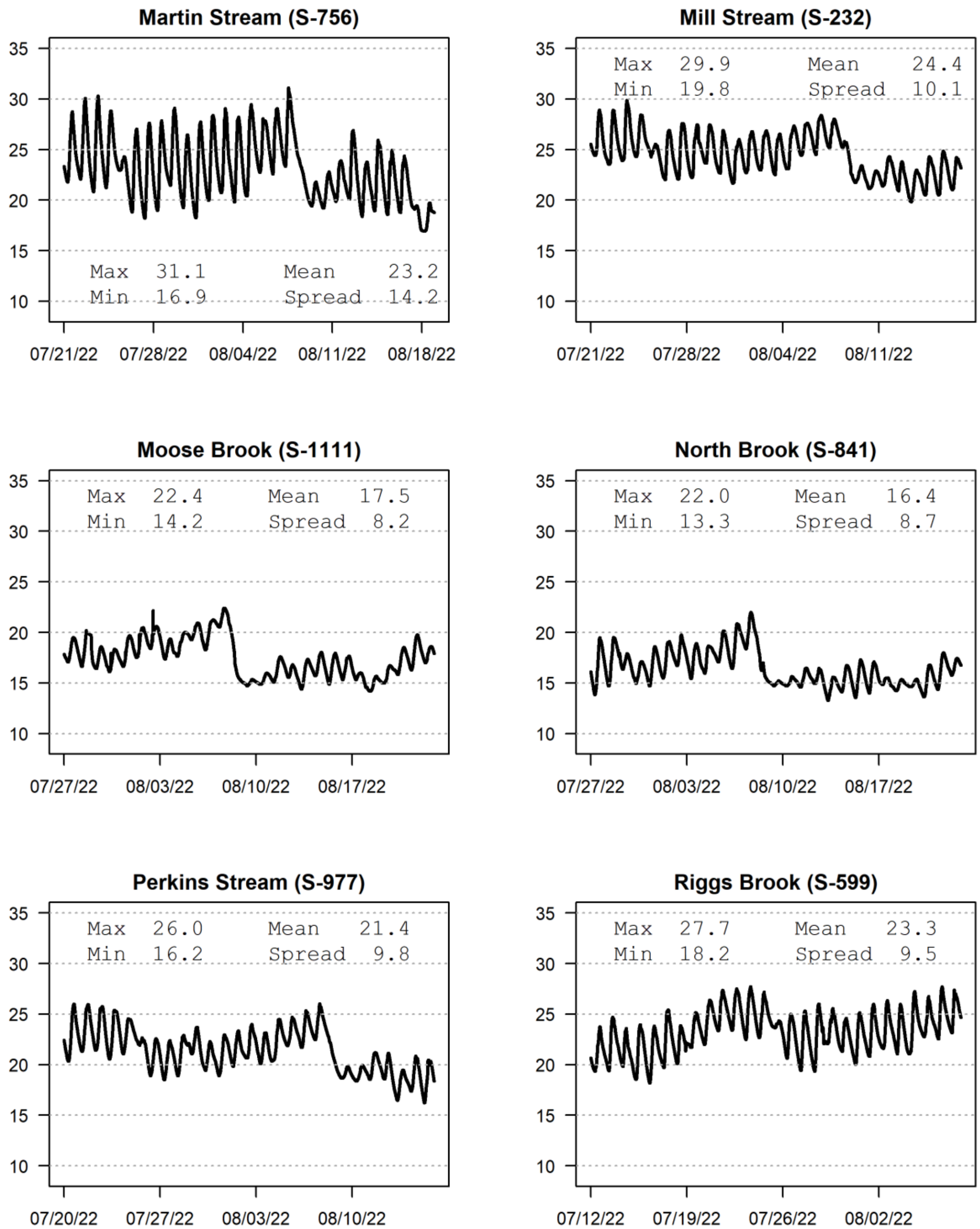


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)

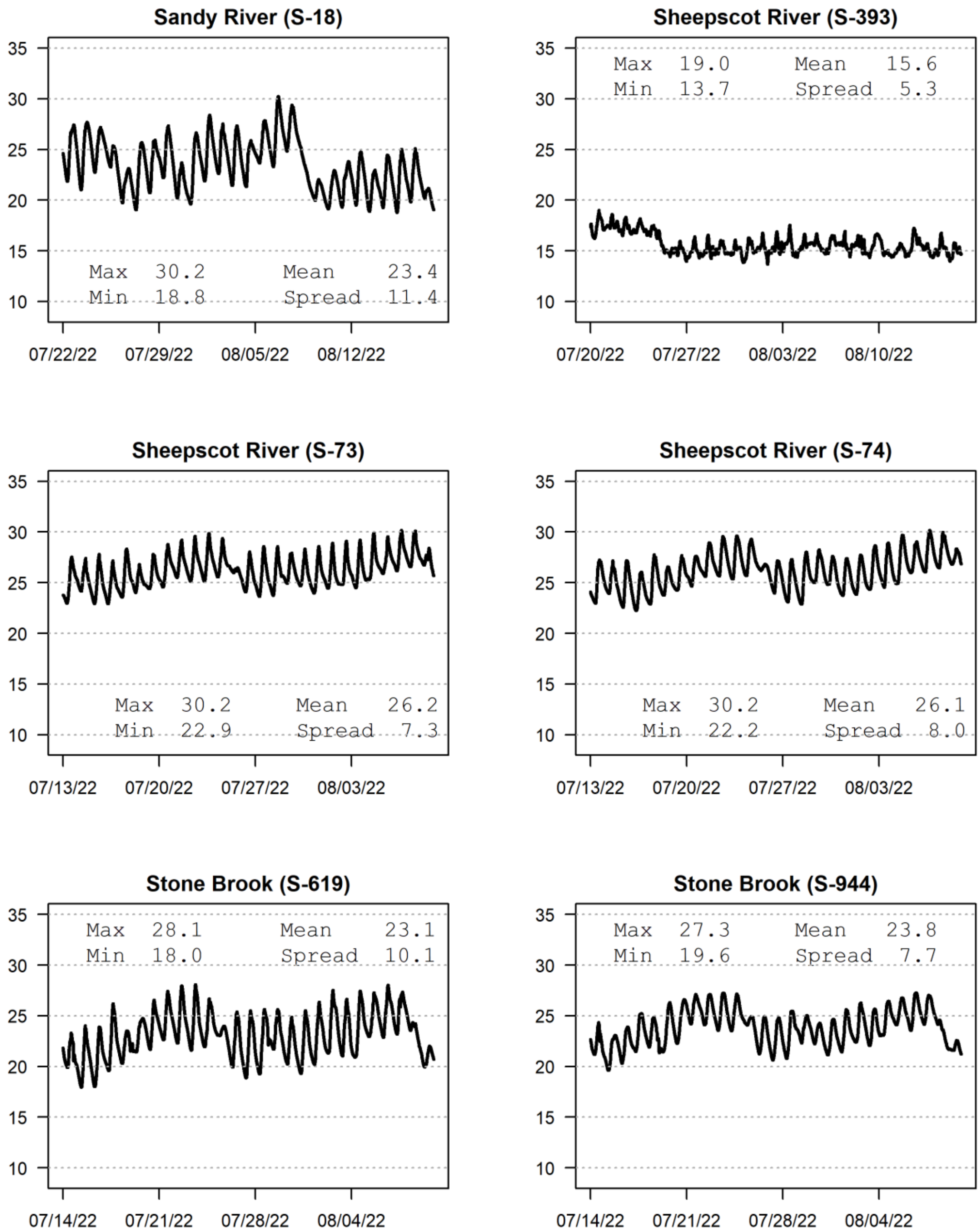


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)

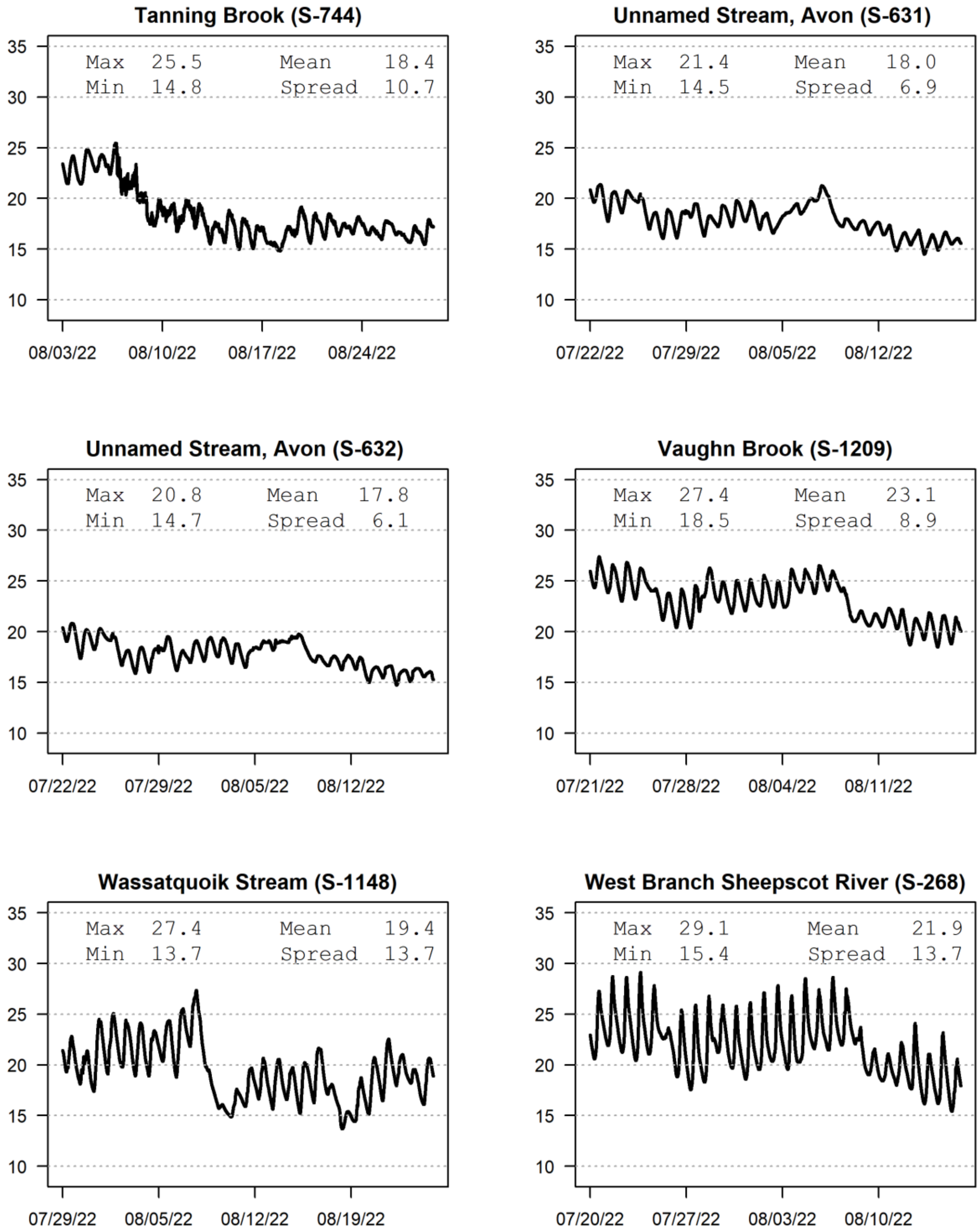
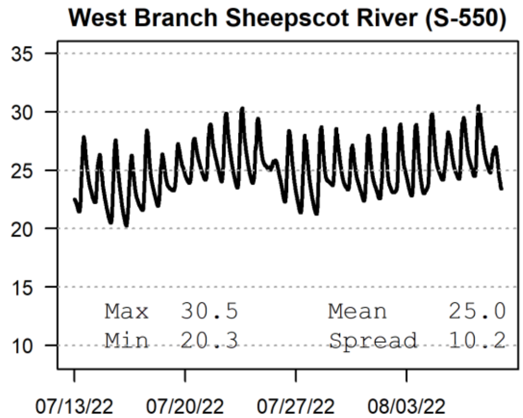
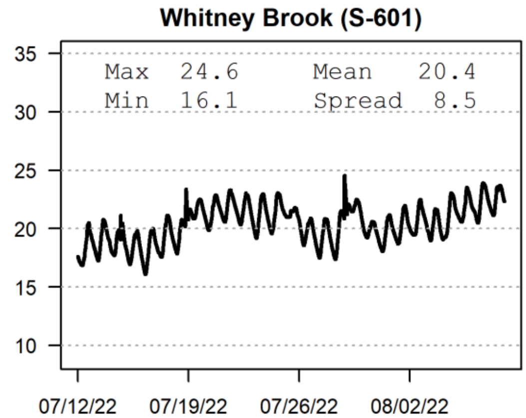


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)





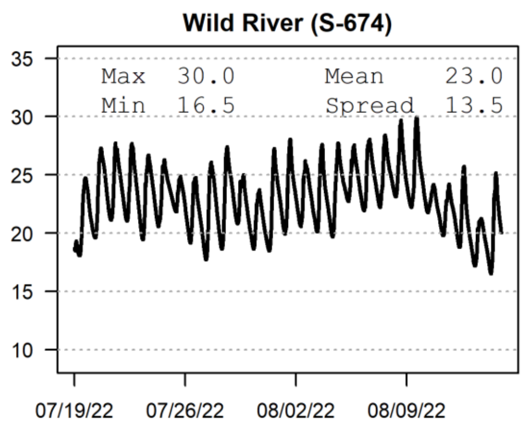


Figure 1. 2022 In-Stream Continuous Temperature Data (continued)