

Status and trends of mercury in fish tissue in New Hampshire waterbodies, 1992–2016



Clement Pond, Hopkinton



November 2018

Status and trends of mercury in fish tissue in New Hampshire waterbodies, 1992 – 2016

New Hampshire Department of Environmental Services
PO Box 95
Concord, NH 03302-3503
(603) 271-8865

Robert R. Scott
Commissioner

Eugene J. Forbes, PE
Water Division Director

Ted Diers
Watershed Management Bureau Administrator

Prepared by
David Neils, Chief Water Pollution Biologist
and
Kirsten Nelson, Biologist

In conjunction with Scott Ashley and Walter Henderson



November 2018

TABLE OF CONTENTS

1. INTRODUCTION	1
Figure 1 – Anthropogenic mercury emissions in the United States, 1990 – 2010 and projected for 2016. Zheng and Jaegl (2013).....	2
Table 1 – National and State programs that regulate atmospheric mercury emissions	3
Table 2 – Primary New Hampshire atmospheric mercury emission sources, 1997 and 2016, NHDES Air Division	4
Figure 2 – Mercury deposition by precipitation in the northeastern United States, 2005-2013.	5
2. METHODS.....	6
2.1 Data Sources.....	6
2.2 Laboratory Methods	6
Map 1 – New Hampshire waterbodies sampled for mercury in fish tissue, 1992 – 2016.	7
2.3 Data Evaluation	8
Table 3 – Total mercury concentrations for fish species collected New Hampshire waterbodies. Current analysis (1992-2016 data); 2008 analysis (1992-2007 data).....	10
Table 4 – Mercury in tissue concentrations for fish species collected in New Hampshire with a size-specific consumption advisory; 1992-2016 (current analysis) and 1992-2007 (2008 analysis). Data include only individuals between 20.3 cm (8 in.) - 30.5 cm (12 in.) in total length.....	11
Table 5 – Mean total mercury concentration (mg/kg), 95% confidence intervals, and number of specimens analyzed for select freshwater water fish species greater than 30.5cm total length.	13
3.2 Fish tissue concentrations over time	13
Table 6 – Annual mean length-adjusted total mercury concentration (≥ 5 fish/waterbody; mg Hg /kg fish tissue) in largemouth bass tissue, 1994-2015.....	14
Figure 4 – Annual mean (+/-1 se) adjusted total mercury concentration in largemouth bass, 1994-2015.	14
Table 7 – Annual mean length-adjusted total mercury concentration (≥ 5 fish/ waterbody; mg/kg) in yellow perch tissue, 1995-2016.	15
Figure 5 – Annual mean (+/-1 se) adjusted total mercury concentration in yellow perch, 1995 – 2016. Solid line is LOESS smoothed line.....	16
Table 8 – Summary of the number and percent of inter-annual and whole waterbody tendencies for adjusted mean total mercury concentrations in the tissue of largemouth bass.....	16
Table 9 – Summary of the number and percent of inter-annual and whole waterbody tendencies for length-adjusted mean total mercury concentrations in the tissue of yellow perch.....	17
3.3 Geographic patterns	17
Figure 6 – Mean length-adjusted total mercury tissue concentration (+/-1 SE), number of samples, and number of waterbodies sampled by New Hampshire County for yellow perch (a) and largemouth bass (b).	18
Map 2 – Location, number of samples, and mean length-adjusted total mercury tissue category by New Hampshire County in yellow perch, 1992-2016.....	19

Map 3 – Location, number of samples, and mean length-adjusted total mercury tissue category by New Hampshire County in largemouth bass, 1994-2015.....20

4. SUMMARY AND RECOMMENDATIONS 21

Appendix A – New Hampshire fish consumption guidelines for mercury.30

Appendix B – New Hampshire waterbodies with mercury in fish tissue data sampled through structured and opportunistic sampling efforts, 1992 - 2016.....32

Appendix C – Summary of mercury concentrations in largemouth bass for individual waterbodies. (+) indicates an increasing tendency; (-) indicates a decreasing tendency; mean standard error across waterbodies = 0.050. * Applied overall mean standard error to species.43

Appendix D – Summary of mercury concentrations in yellow perch for individual waterbodies. (+) indicates an increasing tendency; (-) indicates a decreasing tendency; mean standard error across waterbodies = 0.052.....44

Appendix E – Formulas and example calculations of risk-based consumption limit used in New Hampshire fish advisory using average fish concentration assumed by NHDES and EPA-recommended water quality criteria.....47

1. INTRODUCTION

The presence of mercury in fish tissue is well documented throughout the United States (Chalmers et al. 2011). High concentrations have been detected in fish that reside in freshwaters of northeastern North America (Kamman et al. 2005). Mercury in fish tissue occurs primarily as methyl-mercury (MeHg), a highly toxic compound to humans. The consumption of fish with high concentrations of methyl-mercury by humans is particularly harmful to the development of the neurological system of unborn and young children, and puts adults at an increased risk of kidney failure, heart attack and compromised immune system (EPA 2010). Thus, monitoring fish to determine the amount of mercury they carry (contaminant burden) is important in assessing the consumptive risk to humans. Mercury also poses a direct threat to the health and long-term survival of aquatic plants and animals (Boeing 2000).

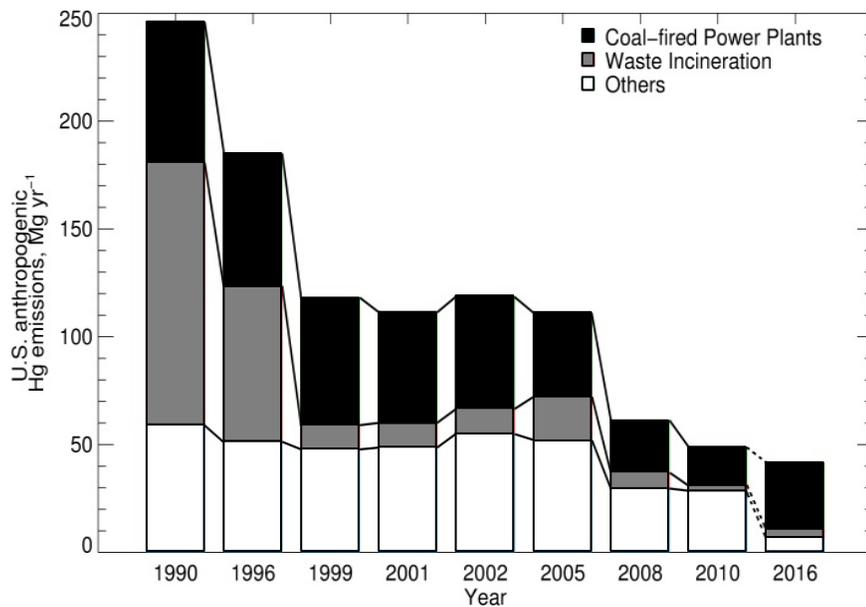
The concentration of mercury in fish tissue is a result of complex processes, but is ultimately controlled by the amount of mercury available globally. Although mercury occurs naturally, human activities have exacerbated its release into the environment. The primary source of human-generated mercury pollution is via emissions into the atmosphere from burning fossil fuels, medical waste and municipal waste. Mercury deposition is influenced by global, regional and local atmospheric sources, with the highest deposition areas a result of proximity to the emission source(s) as well as the prevailing wind currents. Thus, mercury is found in all precipitation and air samples, even those collected in remote locations. Additionally, mercury persists in the environment for long periods by cycling back and forth between the air and soil surface, all the while changing chemical forms. Atmospheric lifetimes of elemental mercury are estimated to be up to two years, and methyl-mercury is estimated to persist in the soils for decades. Mercury is never removed from the environment; it is just moved to other locations and eventually buried under soils and sediments.

Once deposited on the landscape, mercury can be transported to surface waters where it becomes available for assimilation by aquatic organisms (e.g., plants, animals, bacteria). This inorganic mercury is biologically transformed to the more toxic methyl-mercury form via microbial activity that is dependent, in part, on water chemistry, the abundance of wetlands, soil properties and water level management. Methyl-mercury is incorporated into the bodies of aquatic organisms by a process known as bioaccumulation, which is the accumulation of the toxin in the tissues of aquatic organisms as they feed and grow over their lifetimes. As organisms are consumed by predators, the methyl-mercury is transferred, resulting in even higher concentrations for the predators. The end result is that predatory animals at the top of the food chain, in particular popular sport fish, are typically observed to have the highest concentrations of mercury (Kamman et al. 2005, Wentz et al. 2014, Chalmers et al. 2011).

In the United States, mercury emissions were estimated to have peaked in the 1970s and have since declined (Driscoll et al. 2007). In the last 25 years, significant progress has been made to reduce non-natural sources of mercury in the environment in an effort to reduce risks to human health and wildlife. Since 1990, atmospheric emissions of mercury in the United States have decreased by about 80% (Figure 1, Zheng and Jaeglé 2013). Several national and state initiatives have been enacted to control the release of mercury into the air (Table 1). In New Hampshire, specifically, estimated atmospheric emissions of mercury were reduced from 1,109 lbs/yr in 1997 to 11.3 lbs/yr in 2016 (Table 2). The reduction in

atmospheric emissions of mercury since 1997 in New Hampshire is attributed, in large part, to the cessation of medical waste incineration, the closure of nine out of 10 small solid waste incinerators, and the fact that only one large municipal waste combustion facility remains in operation. In addition, in 2000, the state’s largest source of atmospheric mercury, the Wheelabrator Concord incinerator, installed and made operational a stack-scrubber that reduced mercury emissions of the facility by more than 300 lbs/yr. Lastly, non-atmospheric controls of mercury sources in New Hampshire have included banning the sale of most consumer products containing mercury (e.g., novelty items, thermostats and switches), restricting the disposal of products known to contain mercury, and requiring dental facilities to install amalgam separators.

Figure 1 – Anthropogenic mercury emissions in the United States, 1990 – 2010 and projected for 2016. Zheng and Jaegl (2013)



Mercury deposition is measured by a national atmospheric deposition program called the Mercury Deposition Network (MDN). MDN samples are analyzed for total mercury concentration, while a subset of the samples is analyzed for the more toxic methyl-mercury. Researchers use MDN data to evaluate the role of precipitation as a source of mercury in waterbodies of interest. MDN estimates of mercury deposition by precipitation in the Northeast from 2005 through 2013 indicated that deposition rates ranged between 2-18 $\mu\text{g}/\text{m}^2$ (Figure 2).

In 2010 the US Environmental Protection Agency recommended a water quality criterion of 0.30 milligrams of methyl-mercury per kilogram fish tissue (mg/kg) to minimize human health risks (EPA 2010). As a result, fish consumption advisories have been issued in all 50 states, including many that are statewide, regardless of species or waterbody (Wentz et al. 2014). When considered collectively, these advisories cover 16.4 million lake acres and 1.1 million river miles (EPA 2011). In New Hampshire, a statewide fish consumption advisory has been in place since 1994, with revisions in 2001 and 2008

(NHDES 2008). The advisory places recommended limits on the number of meals per month that should be consumed and includes statewide guidelines for pregnant and nursing woman, children and adults as well as species- and waterbody-specific restrictions (See Appendix A for full details). The consumption limits are based on a total mercury tissue benchmark concentration of 0.70 mg/kg. Essentially, this assumes that the total mercury concentration of the fish for each meal consumed is 0.70 mg/kg. The end result of using 0.70 mg/kg as a benchmark concentration is that fewer meals are recommended for consumption on a monthly basis than if the EPA criterion were used. Thus, the New Hampshire advisory is conservative and errs on the side of providing ample protection to public health.

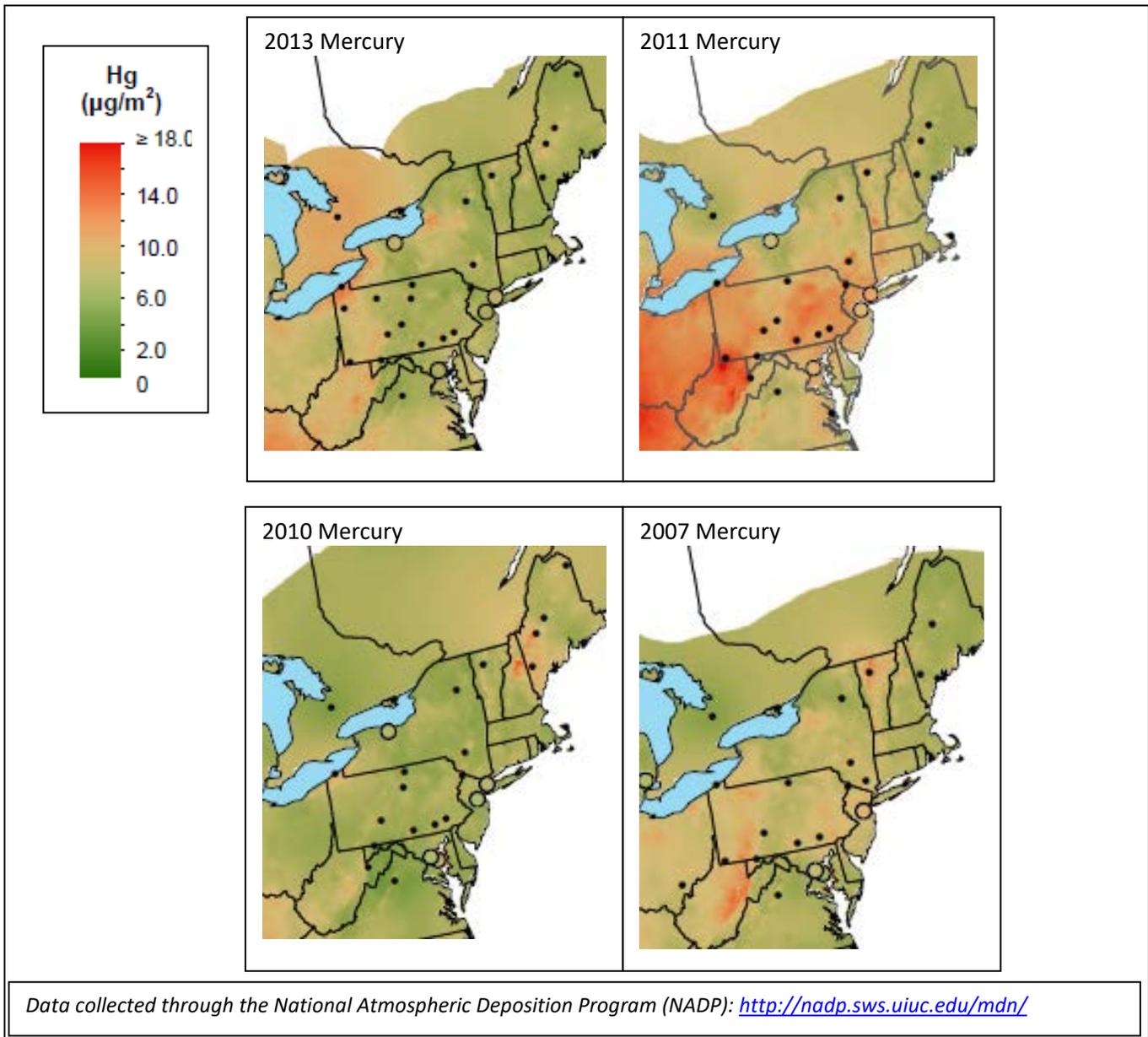
Table 1 – National and State programs that regulate atmospheric mercury emissions

Date	Goal	Sources Effected
1990-present Federal Acid Rain Program	--	Program designed to reduce sulfur and nitrogen emissions from large point sources like power plants. Certain sulfur emission controls also removed a significant amount of mercury from emissions as a co-benefit.
1998-2003 NH 125-C (NH Mercury Reduction Strategy)	50%	Incineration of municipal solid waste and medical waste, and from the combustion of fossil fuels, such as coal and oil.
2011-2013 NH 125-O (NH Clean Power Act)	80%	Coal burning power plants in New Hampshire. Also mandates that a scrubber be installed at Merrimack Station in Bow.
2011-2015 Federal MATS rule	90%	Oil and coal-fired power plants nationally.
2014-2016 Federal Boiler MACT	Varies	Nationally targets toxic emissions from large (major) industrial, commercial, and institutional boilers and process heaters and small (area) industrial, commercial, and institutional boilers; and commercial and industrial solid waste incineration (CISWI) units.

Table 2 – Primary New Hampshire atmospheric mercury emission sources, 1997 and 2016, NHDES Air Division

Town	Facility	1997 Mercury Emissions (Est. Lbs/Yr)	2016 Mercury Emissions (Est. Lbs/Yr)
Large Municipal Waste Combustors			
Claremont	Wheelabrator Claremont Co., L.P.	154.9	Closed
Concord	Wheelabrator Concord Co., L.P.	401.6	1.69
Total		556.5	1.69
Small Solid Waste Incinerators			
Auburn	Town of Auburn Incinerator	5.7	Closed
Bridgewater	Hebron-Bridgewater SWD	5.5	0.0045
Candia	Town of Candia Incinerator	6.7	Closed
Lincoln	Lincoln/Woodstock SWD	15.0	Closed
Litchfield	Town of Litchfield Incinerator	4.0	Closed
Nottingham	Town of Nottingham Incinerator	1.8	Closed
Ossipee	Town of Ossipee Incinerator	10.9	Closed
Pelham	Town of Pelham Incinerator	9.3	Closed
Sutton	Town of Sutton Incinerator	3.4	Closed
Wilton	Town of Wilton Incinerator	3.2	Closed
Total		65.5	0.0045
Medical Waste Incinerators			
Berlin	Androscoggin Valley Hospital	1.2	Closed
Concord	Concord Hospital	35.2	Closed
Derry	HCA Parkland Medical Center	7.4	Closed
Exeter	Exeter Hospital	5.2	Closed
Hanover	Dartmouth Medical School	0.6	Closed
Keene	The Cheshire Medical Hospital	4.6	Closed
Laconia	Lakes Region General Hospital	4.0	Closed
Lancaster	Weeks Memorial Hospital	1.2	Closed
Littleton	Littleton Regional Hospital	2.1	Closed
Manchester	Catholic Medical Center	14.4	Closed
	Elliot Hospital	39.5	Closed
	Veterans Affairs Medical Center	1.9	Closed
Portsmouth	HCA Portsmouth Regional Hospital	23.8	Closed
Total		141.1	0.0
Sewage Sludge Incinerators			
Manchester		14.3	0.027
Total		14.3	0.027
Coal Fired Power Plants			
Bow	Merrimack Station	259.4	2.21
Portsmouth	Schiller Station	67.6	3.33
Total		327.0	5.54
Fuel Oil			
#2 Fuel Oil Residential Use		2.7	2.4
#2 Fuel Oil Commercial/Industrial Use		1.0	1.0
#6 Fuel oil Commercial/Industrial Use		1.0	0.6
Total		4.7	4.0
TOTAL EMISSIONS FROM MERCURY SOURCES		1109.1	11.26

Figure 2 – Mercury deposition by precipitation in the northeastern United States, 2005-2013.



Data collected through the National Atmospheric Deposition Program (NADP): <http://nadp.sws.uiuc.edu/mdn/>

Until recent years, the Northeastern United States has not seen indications of reduced mercury deposition. Instead, mercury deposition fluctuates from year to year as a function of weather patterns. Given recent state and federal mercury emission regulations and current economics making natural gas combustion a more attractive energy source than mercury-containing coal and oil, mercury emissions and deposition are beginning to decrease. Unfortunately, worldwide emissions of mercury are increasing and some of those emissions are making their way into the United States, including to New Hampshire. The effect of this could slow improvements in our region.

In order to evaluate the extent of mercury contamination in freshwater fish species from New Hampshire and, in turn, human health risks, this report examines data from fish tissue collected from 1992-2016 as part of the New Hampshire Department of Environmental Services' (NHDES) fish tissue mercury monitoring program (FTMMP). The specific objectives of the analyses were to: 1) summarize the data and examine concentrations of individual species with respect to those reported in the 2008 statewide fish advisory technical report; 2) determine the extent of changes in tissue concentrations over time; 3) report on geographic patterns; and 4) make recommendations for modifications to the sampling program.

2. METHODS

2.1 Data Sources

Specimens analyzed for the FTMMP were obtained from two primary sources. First, starting in 1992, fish specimens captured primarily by angling were submitted directly to NHDES by citizens. Prior to submission, interested citizens were provided with specific instructions on handling specimens to maintain sample integrity. Once received, samples were frozen until needed for preparation of tissue content analysis. In total, these submissions included 3,262 specimens from 227 waterbodies and 26 fish species.

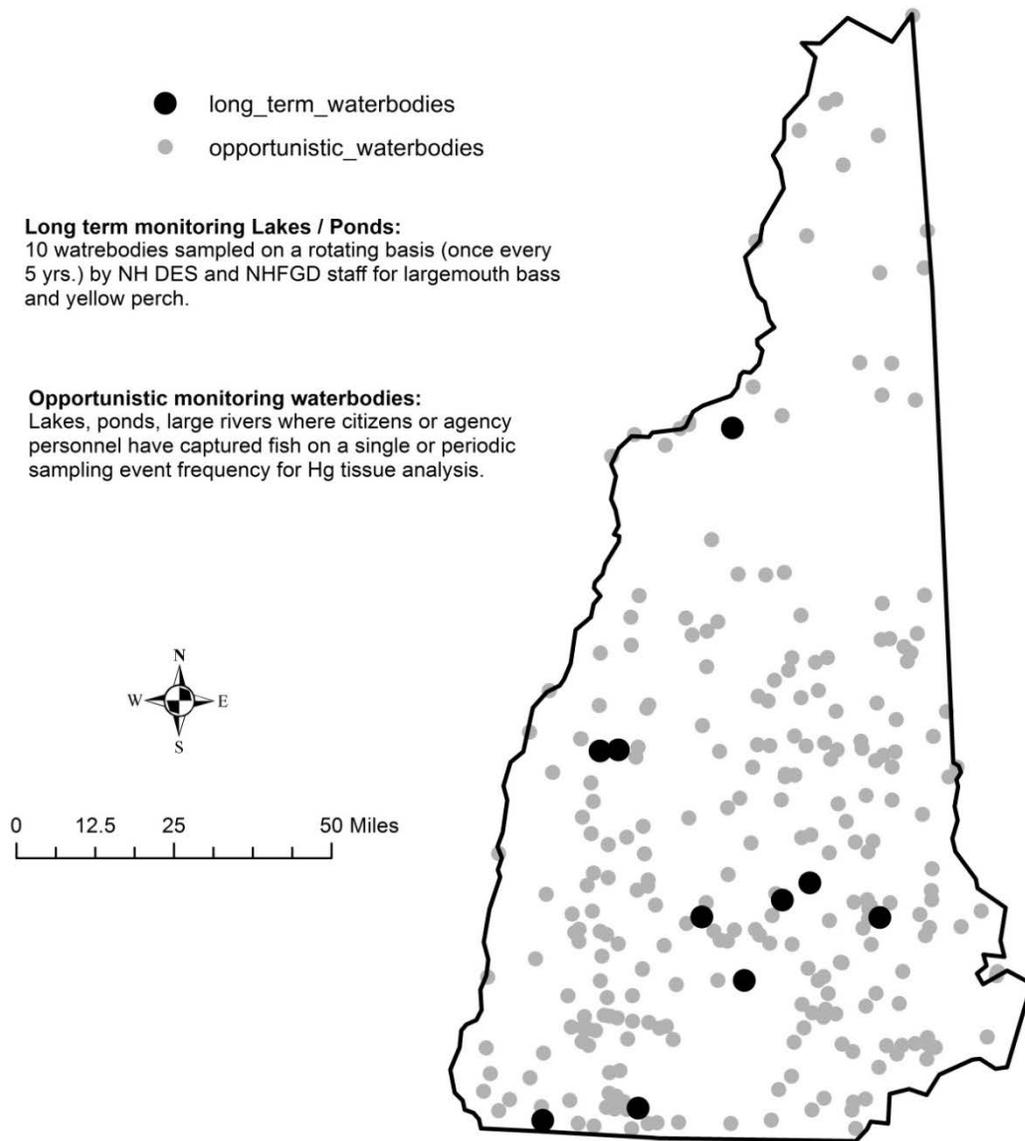
A second, structured sampling effort began in 1998 and included 10 lakes. In each year, two lakes were scheduled for sampling, such that each waterbody was to be sampled twice in a 10-year timeframe. Lakes were selected based on their acidity, water clarity and dissolved oxygen concentrations, as those parameters can influence the amount of methyl-mercury assimilated into fish tissue (Driscoll et al. 2007). For waterbodies included in the structured sampling program, NHDES or New Hampshire Fish and Game Department (NHFG) staff collected fish during night electrofishing surveys that were frozen for later analysis. In total, these sample submissions included 414 individuals that were either largemouth bass (*Micropterus salmoides*) or yellow perch (*Perca flavescens*).

Overall, the two sources of specimens for analysis provided reasonable distribution of sample points from waterbodies within New Hampshire (Map 1, see Appendix B for list of waterbodies sampled).

2.2 Laboratory Methods

Fish were analyzed in the State of New Hampshire Department of Health and Human Services Public Health Laboratory (DHHS-PHL) from 1992-2005 and in the NHDES Jody Connor Limnology Center (JCLC) from 2006-2016. For each individual, fish total length (cm) and weight (g) was recorded and a small section of muscle tissue was removed from above the lateral line in front of the dorsal fin using a clean, stainless steel knife. A tissue sample between 0.1-0.2 g was targeted with the exact weight determined to the nearest 0.001 g.

Map 1 – New Hampshire waterbodies sampled for mercury in fish tissue, 1992 – 2016.



Mercury cold vapor atomic absorption (EPA method #245.1) was used for all samples with a detection limit of 0.01 mg Hg / kg of fish tissue. Samples processed through the DHHS-PHL utilized a Perkin Elmer Flow Injection Mercury (FIMS) analyzer. Samples processed through the JCLC utilized a Milestone Direct Mercury Analyzer (DMA-80). Sample results were reported as mg Hg / kg of fish tissue wet weight (mg/kg).

2.3 Data Evaluation

The concentration of total mercury in individual fish species was evaluated using basic statistical summaries that included the calculation of mean and 95% confidence limits (CL). These data were compared to species-specific mercury concentrations included in a 2008 NHDES report on the New Hampshire statewide fish consumption advisory (NHDES 2008). The comparison of the current results versus the results included in the 2008 report was made for two primary reasons; first, to evaluate if the statewide consumption advisory was still warranted and second, to determine if new advisories for individual species were needed. Comparisons of upper 95% CLs (UCLs) were particularly important since they were used as the basis for determining if a revised statewide advisory was necessary and to identify species in need of size restricted consumption limits. (See 2008 report for full explanation of risk-based consumption limits.)

Largemouth bass and yellow perch were selected as target species because they are common, distributed statewide and popular for human consumption. For each species, data were inspected for outliers and \log_e -transformed to improve normality of the data's distribution. Data were examined for changes in mercury concentration by year (i.e., time series analysis) and for differences among New Hampshire counties (i.e., geographic pattern analysis). The time series analysis did not include fish data from waterbodies containing fewer than five individual fish per waterbody per year to preserve degrees of freedom and reduce variation; however, the geographic pattern analysis included all data minus outliers.

For the time series analysis, total mercury concentrations by year were length-adjusted by an analysis of covariance (ANCOVA) using fish length and an interaction between fish length and year as covariates (SAS; Proc Mixed). Waterbody and an interaction between waterbody and year were considered random variables. The final model was:

$$\text{Transformed Mercury}_{ijkl} = \mu + \text{Year}_i + \text{Length}_j + \text{Year}_i * \text{Length}_j + \text{Waterbody}_k + \text{Year}_i * \text{Waterbody}_k + \epsilon_{ijkl}$$

Annual, a two-year sum, and a three-year sum of precipitation were investigated as random variables; however, these variables accounted for no error and were removed from the final model. An "LSMEANS" statement was used in SAS to acquire the length-adjusted mercury means and their standard error (+/- 1 se) for each year. Two-way nonparametric Mann-Kendall tests (MKT) were conducted for the length-adjusted mercury means in SYSTAT 13 to determine if a significant trend was present ($p < 0.05$). A LOESS (LOcally weighted regrESSion) smoothing curve was added to provide a year-by-year visual estimate of total length-adjusted mercury tissue concentrations.

For the geographic pattern analyses, total mercury concentrations by county were length-adjusted by an analysis of covariance (ANCOVA) using fish length and an interaction between fish length and year as covariates (SAS; Proc Mixed). Year, waterbody, and an interaction between waterbody and year were considered random variables. The final model was:

$$\text{Transformed Mercury}_{ijklm} = \mu + \text{County}_i + \text{Length}_j + \text{Year}_k * \text{Length}_j + \text{Year}_k + \text{Waterbody}_l + \text{Year}_k * \text{Waterbody}_l + \epsilon_{ijklm}$$

An “LSMEANS” statement was used in SAS to acquire the length-adjusted mercury means and their standard error (+/- 1 se) for each county. For county-by-county comparisons, length-adjusted mercury concentration means of yellow perch and largemouth bass were plotted by county using simple bar plots. No formal statistical comparisons between counties were made due to the unbalanced nature of the sample collection points (i.e., number of data points per county). The data analysis for geographical patterns represented a gross qualitative assessment and was used to identify broad geographic patterns and data gaps.

For waterbodies sampled as part of the NHDES/NHFG structured sampling effort, tendencies of total mercury concentrations in largemouth bass and yellow perch over time for each waterbody were evaluated using year-to-year (inter-year) comparisons of mean length-adjusted annual mercury concentrations. Although this sampling effort began in 1998, there have been only two to three sampling events on each lake. As a result, a formal trend analysis for each lake was not completed. Instead, inter-year differences in mean length-adjusted total mercury concentrations were tallied either as increasing (+), decreasing (-) or equal (=). Inter-year comparisons were completed for all year-to-year combinations of mean length-adjusted mercury concentrations. For example, if fish tissue samples were collected from an individual lake in 1998, 2003 and 2008, three inter-year comparisons were made (i.e., 1998 to 2003, 1998 to 2008, 2003 to 2008). Inter-year differences of mean length-adjusted mercury concentrations were assigned to one of three levels of severity: 1) greater than or equal to the laboratory detection limit (minimal); 2) greater than or equal to 1 standard error (moderate); 3) greater than or equal to 2 standard errors (large). For the purposes of consistency, a mean standard error for each species was computed from the standard errors of individual waterbodies from each year of sampling. The mean standard error for each respective species was then used to identify the severity of the difference in total mercury concentrations between years. Lastly, an overall waterbody tendency in total mercury concentration was determined as increasing [all inter-year differences positive (+)], decreasing [all inter-year differences negative (-)] or mixed [inter-year differences (+) and (-)]. The determination of the overall waterbody tendency was based on the threshold established for the “minimal” level of severity of inter-year differences (e.g., lab detection limit).

3. RESULTS

3.1 Fish consumption guidelines

A total of 4,100 individuals from 26 freshwater fish species were included in the current analysis of total mercury in fish tissue. The combined mean total mercury concentration across all fish species was 0.36 mg/kg (95% CL +/-0.09) with mean concentrations for individual species ranging from 0.07 to 0.67 mg/kg (Table 3). Of those species where a direct comparison between the current analysis and the 2008 report was possible, five had higher and seven had lower mean concentrations. Species observed to have concentration increases greater than 0.10 mg/kg were northern pike, walleye and lake trout. Only yellow bullhead was observed to have decreased in mean concentration greater than 0.10 mg/kg.

Table 3 – Total mercury concentrations for fish species collected New Hampshire waterbodies. Current analysis (1992-2016 data); 2008 analysis (1992-2007 data)

Species	Common Name	Current vs. 2008 mean	Current analysis				2008 analysis			
			Mean Hg (mg/kg)	Mean Length (cm)	Hg 95% UCL	N	Mean Hg (mg/kg)	Mean Length (cm)	Upper 95% CI	N
<i>Alosa pseudoharengus</i>	Alewife	=	0.20	27.0	N/A	3	0.2	27.9	-----	3
<i>Ambloplites rupestris</i>	Rock bass	-	0.34	20.6	0.41	21	0.32	20.3	0.39	12
<i>Ameiurus natalis</i>*	Yellow bullhead	-	0.43	23.2	0.73	10	0.54	22.9	-----	7
<i>Ameiurus nebulosus</i>	Brown bullhead	-	0.15	22.0	0.18	152	0.23	25.4	0.27	65
<i>Catostomus commersonii</i>	White sucker	-	0.23	41.1	0.28	52	0.31	40.6	0.35	55
<i>Coregonus clupeaformis</i>	Lake whitefish	N/A	0.10	44.0	N/A	1	NS			
<i>Esox lucius</i>	Northern pike	+	0.60	79.8	N/A	2	0.5	78.7	-----	4
<i>Esox niger</i> ^{##}	Eastern chain pickerel	N/A	0.64	42.1	0.70	253	See Table 4			
<i>Lepomis sp.</i>	Sunfish	-	0.19	17.9	0.26	13	0.27	20.3	-----	5
<i>Lepomis gibbosus</i>	Pumpkinseed	=	0.27	18.4	0.32	57	0.27	17.8	0.33	15
<i>Lepomis macrochirus</i>	Bluegill	-	0.29	19.9	0.34	29	0.3	17.8	0.38	13
<i>Lota lota</i>	Cusk	-	0.31	62.7	0.35	29	0.35	61	0.42	22
<i>Micropterus dolomieu</i> ^{##}	Smallmouth bass	N/A	0.67	31.4	0.71	411	See Table 4			
<i>Micropterus salmoides</i> [#]	Largemouth bass	N/A	0.56	31.8	0.59	632	See Table 4			
<i>Morone americana</i> [#]	White perch	N/A	0.49	26.2	0.53	210	See Table 4			
<i>Notemigonus crysoleucas</i>	Golden shiner	N/A	0.15	21.5	N/A	1	NS			
<i>Oncorhynchus mykiss</i>	Rainbow trout	N/A	0.08	35.0	0.09	300	NS			
<i>Osmerus mordax</i>	smelt	N/A	0.17	10.5	N/A	1	NS			
<i>Perca flavescens</i> [#]	Yellow perch	N/A	0.35	20.9	0.36	1659	See Table 4			
<i>Pomoxis nigromaculatus</i>	Black crappie	+	0.44	28.5	0.50	59	0.4	25.4	0.48	42
<i>Salmo salar</i>	Atlantic salmon	N/A	0.23	42.9	0.27	28	NS			
<i>Salmo trutta</i>	Brown trout	N/A	0.11	27.5	N/A	8	NS			
<i>Salvelinus fontinalis</i>	Brook trout	N/A	0.07	24.0	0.10	91	NS			
<i>Salvelinus namaycush</i>	Lake trout	+	0.44	56.6	0.63	40	0.3	53.3	0.36	18
<i>Sander vitreus</i> *	Walleye	+	0.66	39.3	0.86	11	0.48	35.6	-----	5
<i>Semotilus corporalis</i>	Fallfish	+	0.36	24.6	0.43	27	0.33	22.9	0.38	24
All Species			0.33	32.3	0.43	4,100				
Commonly Consumed Species			0.36	33.0	0.44	3,995				

Commonly consumed species are emboldened; * species with 95% UCL = /> 0.70 mg / kg; # species-specific consumption advisory applies; NS = no sample.

The New Hampshire statewide freshwater fish consumption advisory, as reported in the 2008 report, is 1 meal (8 oz.) per month for sensitive individuals (woman who are, or may become, pregnant and children under age 7) and 4 meals (total 28 oz.) for adults (Appendix A). The number of meals recommended for

consumption on a monthly basis in the 2008 advisory corresponds to a fish tissue total mercury concentration of 0.70 mg/kg (benchmark concentration). In the 2008 report, individual species with an upper 95% CL below 0.70 mg/kg of fish tissue were used to indicate that the current statewide advisory would still be protective of human health, while species with 95% UCL concentrations above this level would indicate a potential need for revision. By definition, individual species with a 95% UCL lower than 0.70 mg/kg provides a 95% assurance that the mean total mercury concentration of repeated samples would be below the benchmark concentration, and thus, within current guidelines for freshwater fish consumption. Conversely, 95% UCLs greater than 0.70 mg/kg for individual species indicates that there is a greater than 5% chance that the mean of repeated samples is above the benchmark concentration, and thus, there is a potential for the ingestion of an amount of mercury that is not protective of human health.

Of the 26 species reported included in the current analysis, four (yellow bullhead, eastern chain pickerel, smallmouth bass and walleye) had mean tissue concentrations of total mercury with 95% UCLs above or equal to 0.70 mg/kg (Table 3). In addition, two other species (lake trout and largemouth bass) had 95% UCLs of their respective means that were near 0.70 mg/kg (0.63 and 0.59 mg/kg respectively). Yellow bullhead, walleye and lake trout are not currently covered under species-specific consumption advisories and should be considered further (see below). For the remainder of the species, the current statewide advisory would still be protective of human health.

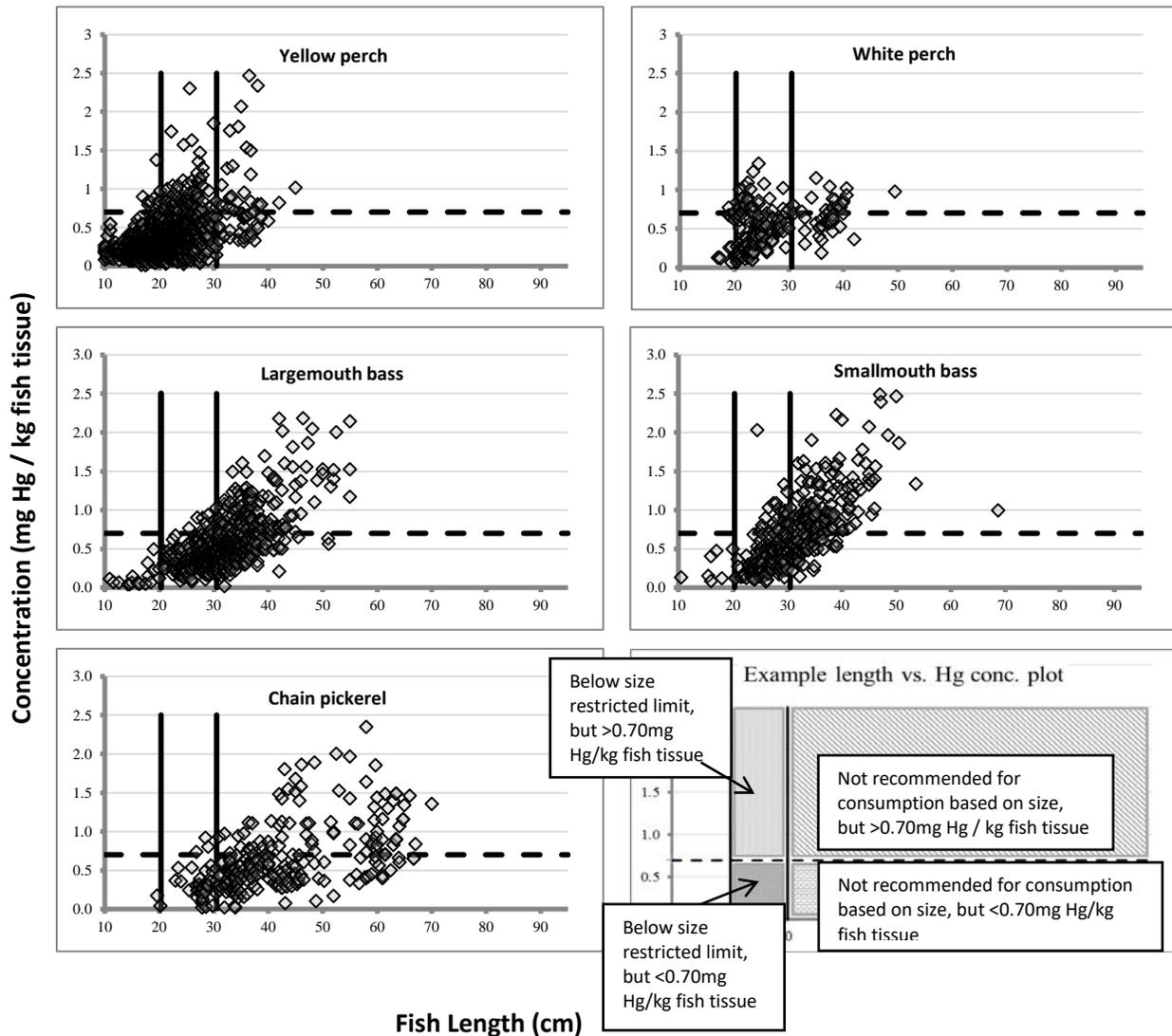
Statewide species-specific consumptive advisories are currently in effect for smallmouth bass, largemouth bass, eastern chain pickerel, yellow perch and white perch. The advisories recommend that only individuals less than 30.5cm (12in.) in length be consumed at a rate consistent with the statewide guidelines for all other freshwater species. For comparison to the 2008 report, total mercury concentrations for individuals from 20.3cm (8in.)-30.5cm (12in.) in length were summarized for each of the size-restricted species (Table 4). All five species had mercury concentrations similar to those reported in 2008. More importantly, the 95% UCL of the mean total mercury concentration for each species remained well below 0.70 mg/kg. Thus, the current statewide advisory would still be protective of human health as long as individuals of these species are consumed within the recommended size range.

Table 4 – Mercury in tissue concentrations for fish species collected in New Hampshire with a size-specific consumption advisory; 1992-2016 (current analysis) and 1992-2007 (2008 analysis). Data include only individuals between 20.3 cm (8 in.) - 30.5 cm (12 in.) in total length.

Species	Common Name	Current Analysis				2008 Analysis		
		Mean	95% LCL	95% UCL	N	Mean	95% UCL	N
<i>Morone americana</i>	White Perch	0.45	0.40	0.49	151	0.51	0.57	64
<i>Micropterus dolomieu</i>	Smallmouth bass	0.43	0.39	0.47	186	0.43	0.48	89
<i>Esox niger</i>	Eastern Chain pickerel	0.33	0.26	0.39	39	0.32	0.49	29
<i>Micropterus salmoides</i>	Largemouth bass	0.39	0.37	0.42	245	0.38	0.41	121
<i>Perca flavescens</i>	Yellow perch	0.41	0.39	0.42	814	0.42	0.47	466

For species where consumption of fish less than 30.5 cm (12 in.) is recommended, plots of fish length vs. mercury concentration were helpful in visualizing the frequency of occurrence of individuals with total mercury concentrations above and below the benchmark concentration (0.70 mg/kg) (Figure 3). The percentage of individuals with total mercury concentrations below the benchmark concentration and between 20.3 cm (8 in.) to 30.5 cm (12 in.) in total length was 97% for largemouth, 92% for chain pickerel, 90% for yellow perch, 86% for smallmouth bass and 79% for white perch. These percentages represent the frequency of fish available for consumption (based on the size restriction) and that had total mercury concentrations below the benchmark concentration.

Figure 3 – Total mercury concentration versus total length for size-restricted species. Vertical solid line is 20.3-30.5 cm (8-12 in.) size range*; long dashed line is 0.70 mg/kg benchmark concentration.* Represents edible size range and is consistent with NHDES (2008).



The fish length versus total mercury concentration plots (Figure 3) were also useful in evaluating the percentage of individuals with mercury concentrations greater than 0.70 mg/kg and greater than 30.5 cm (12 in.). In effect, this is a validation of the need for size-restricted limit consumption advisories. For these individuals in excess of 30.5 cm (12 in.), 61% of smallmouth bass, 47% of yellow perch, 41% of white perch, and 39% of largemouth bass and chain pickerel had concentrations of total mercury greater than 0.70 mg/kg.

The mean and 95% confidence limits of individuals over 30.5 cm (12 in.) was computed for 12 select species (Table 5). Of these species, six had 95% UCLs greater than 0.70 mg/kg and of these, five are already covered by the current fish consumption advisory. Only walleye are not covered. However, walleye sample size was limited (n=11). Larger individuals (>30.5 cm) of brown bullhead, burbot and black crappie had 95% UCLs below 0.70 mg/kg and can be consumed using the guidelines of the current fish advisory, regardless of size. Lake trout had an upper 95% confidence interval near the benchmark concentration. Northern pike were not evaluated because this species is not widespread in New Hampshire and only two individuals have been analyzed.

Table 5 – Mean total mercury concentration (mg/kg), 95% confidence intervals, and number of specimens analyzed for select freshwater water fish species greater than 30.5cm total length.

Species	Common name	All			
		Mean	Lower 95% CL	Upper 95% CL	N
<i>Ameiurus natalis</i>	Yellow bullhead	None over 30.5 cm			
<i>Ameiurus nebulosus</i>	Brown bullhead	0.37	0.26	0.47	13
<i>Esox lucius</i>	Northern pike	N=2; not enough data			
<i>Esox niger</i>[#]	Chain pickerel	0.71	0.65	0.77	211
<i>Lota lota</i>	Burbot	0.39	0.34	0.43	43
<i>Micropterus dolomieu</i>[#]	Smallmouth bass	0.90	0.84	0.96	211
<i>Micropterus salmoides</i>[#]	Largemouth bass	0.70	0.66	0.74	366
<i>Morone americana</i>[#]	White perch	0.67	0.61	0.73	44
<i>Perca flavescens</i>[#]	Yellow perch	0.91	0.72	1.10	60
<i>Pomoxis nigromaculatus</i>	Black crappie	0.52	0.40	0.63	19
<i>Salvelinus namaycush</i>	Lake trout	0.49	0.29	0.68	37
<i>Sander vitreus</i>	Walleye	0.66	0.45	0.86	11

Emboldened species had upper 95% confidence intervals above 0.70 mg Hg / kg fish tissue; [#] indicates size restricted consumption limit already in place.

3.2 Fish tissue concentrations over time

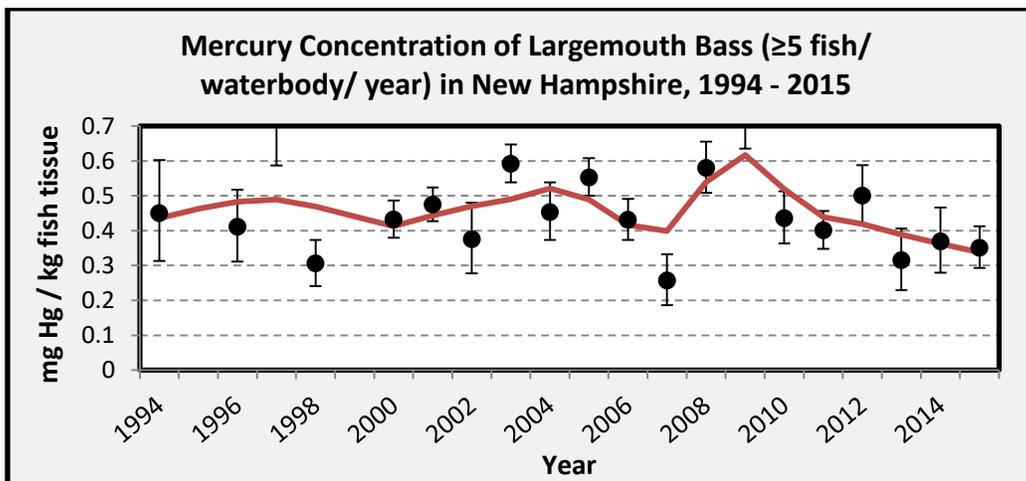
The mean statewide length-adjusted concentration of total mercury in fish tissue for largemouth bass ranged from 0.26 mg/kg in 2007 to 0.76 mg/kg in 2009 (Table 6). In general, the LOESS trend line indicated that annual mean length-adjusted concentrations of total mercury in tissue were variable over time with a recent tendency (2009-2015) towards lower concentrations (Figure 4). Given the lack of a consistent tendency over the entire period of observation, a significant trend in the annual mean length-adjusted

mercury concentrations in the tissue of largemouth bass was not detected from 1994 through 2015 (MKT, p = 0.35).

Table 6 – Annual mean length-adjusted total mercury concentration (≥ 5 fish/waterbody; mg Hg /kg fish tissue) in largemouth bass tissue, 1994-2015.

Year	# individuals	# of waterbodies	Mean	Std. Error
1994	10	1	0.45	0.14
1995	0	0	n/a	n/a
1996	13	2	0.41	0.10
1997	6	1	0.76	0.18
1998	10	2	0.31	0.07
1999	0	0	n/a	n/a
2000	41	6	0.43	0.05
2001	30	6	0.47	0.05
2002	10	2	0.38	0.10
2003	60	7	0.59	0.05
2004	11	2	0.45	0.08
2005	51	7	0.55	0.05
2006	21	4	0.43	0.06
2007	40	3	0.26	0.07
2008	15	3	0.58	0.07
2009	10	2	0.76	0.13
2010	10	2	0.44	0.07
2011	29	4	0.40	0.05
2012	15	2	0.50	0.09
2013	5	1	0.32	0.09
2014	5	1	0.37	0.09
2015	15	3	0.35	0.06

Figure 4 – Annual mean (± 1 se) adjusted total mercury concentration in largemouth bass, 1994-2015.



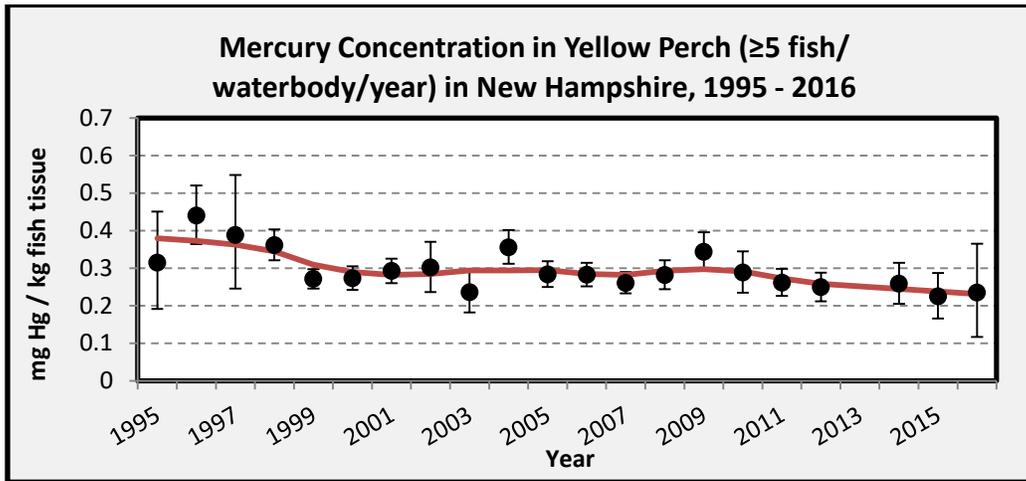
Solid line is LOESS smoothed line.

Annual mean yellow perch length-adjusted total mercury tissue concentrations varied from a low of 0.23 mg/kg in 2015 to a high of 0.44 mg/kg in 1996 (Table 7). Length-adjusted mercury concentration in yellow perch significantly declined from 1995 to 2016 (Figure 5; MKT: $p < 0.001$).

Table 7 – Annual mean length-adjusted total mercury concentration (≥ 5 fish/ waterbody; mg/kg) in yellow perch tissue, 1995-2016.

Year	# of individuals	# of waterbodies	Mean	Std. Error
1995	5	1	0.31	0.13
1996	24	3	0.44	0.08
1997	5	1	0.39	0.15
1998	99	8	0.36	0.04
1999	115	23	0.27	0.03
2000	122	14	0.27	0.03
2001	85	17	0.29	0.03
2002	15	3	0.30	0.07
2003	59	4	0.24	0.05
2004	57	8	0.36	0.04
2005	90	13	0.28	0.03
2006	100	14	0.28	0.03
2007	134	18	0.26	0.03
2008	213	9	0.28	0.04
2009	41	5	0.34	0.05
2010	24	4	0.29	0.06
2011	79	10	0.26	0.04
2012	115	8	0.25	0.04
2013	0	0	n/a	n/a
2014	26	4	0.26	0.05
2015	17	3	0.23	0.06
2016	5	1	0.24	0.12

Figure 5 – Annual mean (+/-1 se) adjusted total mercury concentration in yellow perch, 1995 – 2016. Solid line is LOESS smoothed line.



The direction of length-adjusted total mercury concentrations was evaluated in repeatedly sampled lakes and ponds for largemouth bass and yellow perch. For largemouth bass, a total of 33 inter-year comparisons were made across all lakes (Table 8). Overall, nearly 48% of the changes fell into the large category (increases and decreases combined), 33% in the moderate category, and 15% in the small category. A majority of the lake-wide tendencies for largemouth bass were mixed (60%), 10% increased, and 10% decreased. Appendix C includes a full summary of the results in largemouth bass from each waterbody.

Table 8 – Summary of the number and percent of inter-annual and whole waterbody tendencies for adjusted mean total mercury concentrations in the tissue of largemouth bass.

Severity of Change	Number	Percent
<i>Inter-annual comparisons</i>		
Minimal Increases (difference > 0.01)	4	12%
Minimal Decreases (difference < -0.01)	1	3%
Moderate Increases (difference > 0.056)	5	15%
Moderate Decreases (difference < -0.056)	6	18%
Large Increases (difference > 0.112)	8	24%
Large Decrease (differences < -0.112)	8	24%
No Change (Difference -0.01 < X < 0.01)	1	3%
Total number inter-annual comparisons	33	100%
<i>Structured Sampling Program Waterbody Tendencies</i>		
Increasing Lakes	1	10%
Decreasing Lakes	1	10%
Mixed Lakes	6	60%
No Data	2	20%
Total number of waterbodies	10	100%

A total of 76 inter-year comparisons were made to evaluate the tendency of total adjusted mercury concentrations in yellow perch (Table 9). Of these comparisons, 41% indicated a large change, 31% a moderate change, and 17% a minimal change. Lake-wide tendencies for yellow perch were possible from 34 waterbodies with 29% of all waterbodies demonstrating an increasing tendency, 32% a decreasing tendency, 32% a mixed tendency and 6% with no change. A majority (50%) of the waterbodies sampled through the structured sampling program had mixed response. Appendix D includes a full summary of the results in yellow perch from each waterbody.

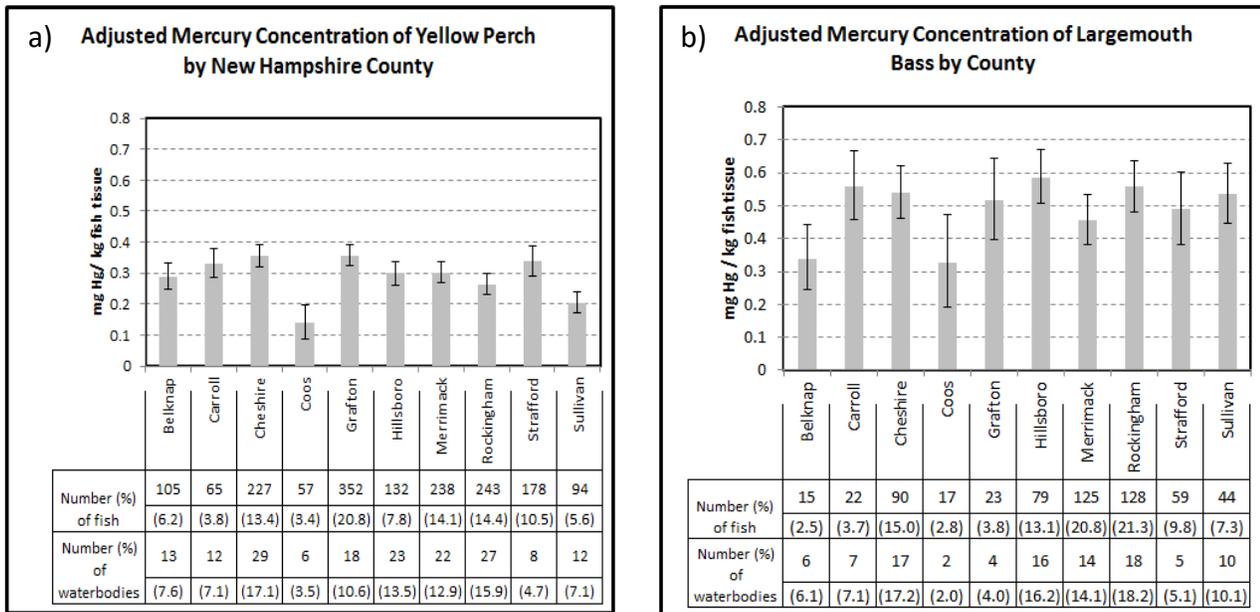
Table 9 – Summary of the number and percent of inter-annual and whole waterbody tendencies for length-adjusted mean total mercury concentrations in the tissue of yellow perch.

Severity of Change	All Waterbodies		Long-term Waterbodies	
	Number	Percent	Number	Percent
<i>Inter-annual comparisons</i>				
Minimal Increases (difference > 0.01)	12	16%	2	7%
Minimal Decreases (difference < -0.01)	6	8%	3	10%
Moderate Increases (difference > 0.056)	7	9%	3	10%
Moderate Decreases (difference < -0.056)	15	20%	6	21%
Large Increases (difference > 0.112)	12	16%	5	17%
Large Decrease (differences < -0.112)	18	24%	7	24%
No Change (Difference -0.01 < X < 0.01)	6	8%	3	10%
Total number inter-annual comparisons	76	100%	29	100%
<i>Waterbody Tendencies</i>				
Increasing Lakes	10	29%	1	10%
Decreasing Lakes	11	32%	2	20%
Mixed Lakes	11	32%	5	50%
No Change (Difference -0.01 < X < 0.01)	2	6%	1	10%
No Data	0	0%	1	10%
Total number of waterbodies	34	100%	10	100%

3.3 Geographic patterns

Largemouth bass and yellow perch results were summarized by county in order to provide a common understanding of the data's spatial distribution and the mean length-adjusted concentrations of total mercury in fish tissue across the state. For yellow perch, Grafton county had the greatest number of tissue samples [n=352 (20.8%)] while Rockingham had the greatest number of waterbodies sampled [n= 27 (15.9%)] (Figure 6a). The fewest number of yellow perch tissue samples [n=57 (3.4%)] and waterbodies sampled [n=6 (3.5%)] came from Coos County. For largemouth bass, Rockingham County had the highest number of tissue samples [n=128 (21.3%)] and greatest number of waterbodies sampled [n=18 (18.2%)] (Figure 6b). In contrast, Belknap County had the fewest tissue samples [n=15 (2.5%)] while Coos County had the fewest waterbodies sampled [n=2 (2.0%)].

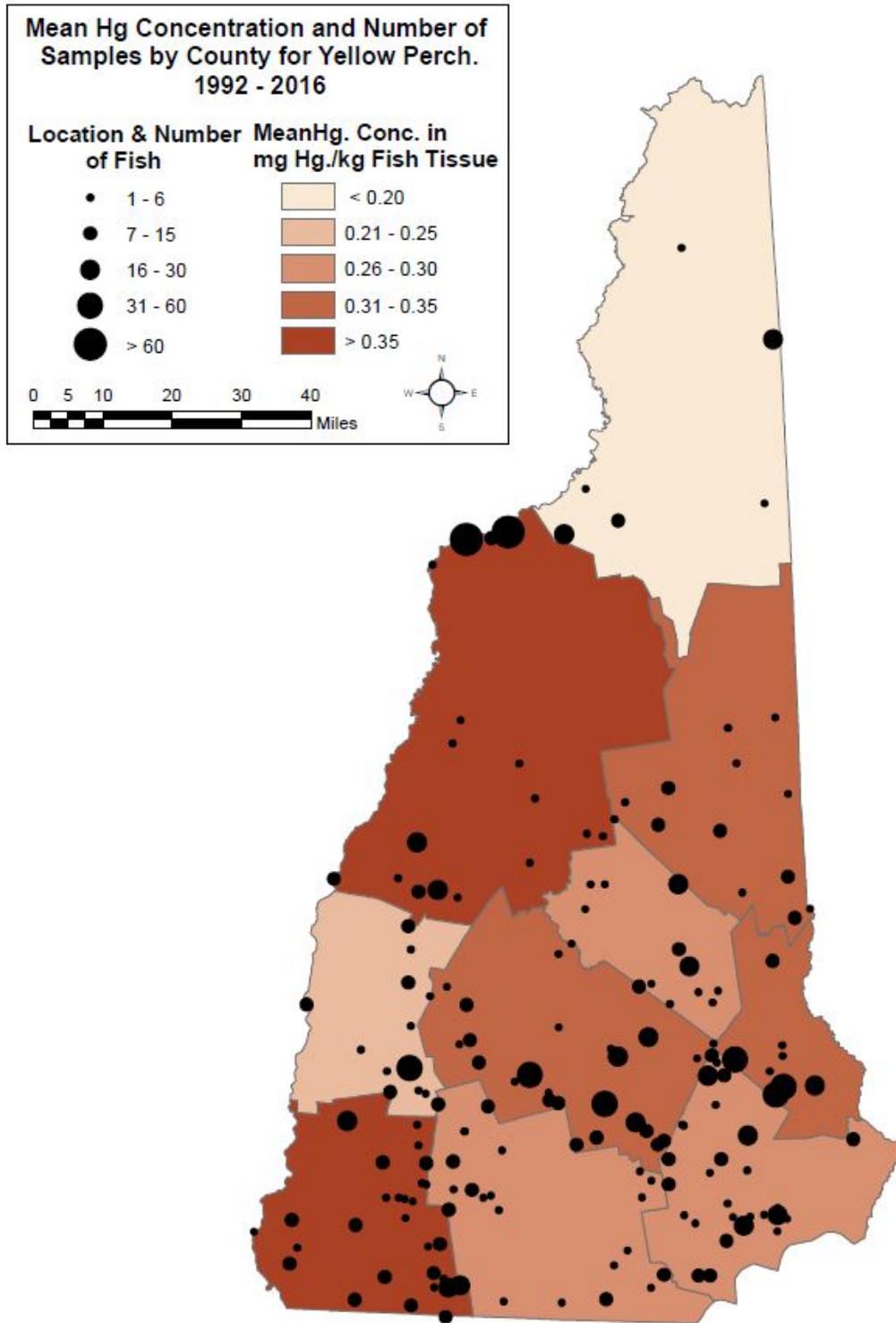
Figure 6 – Mean length-adjusted total mercury tissue concentration (+/-1 SE), number of samples, and number of waterbodies sampled by New Hampshire County for yellow perch (a) and largemouth bass (b).



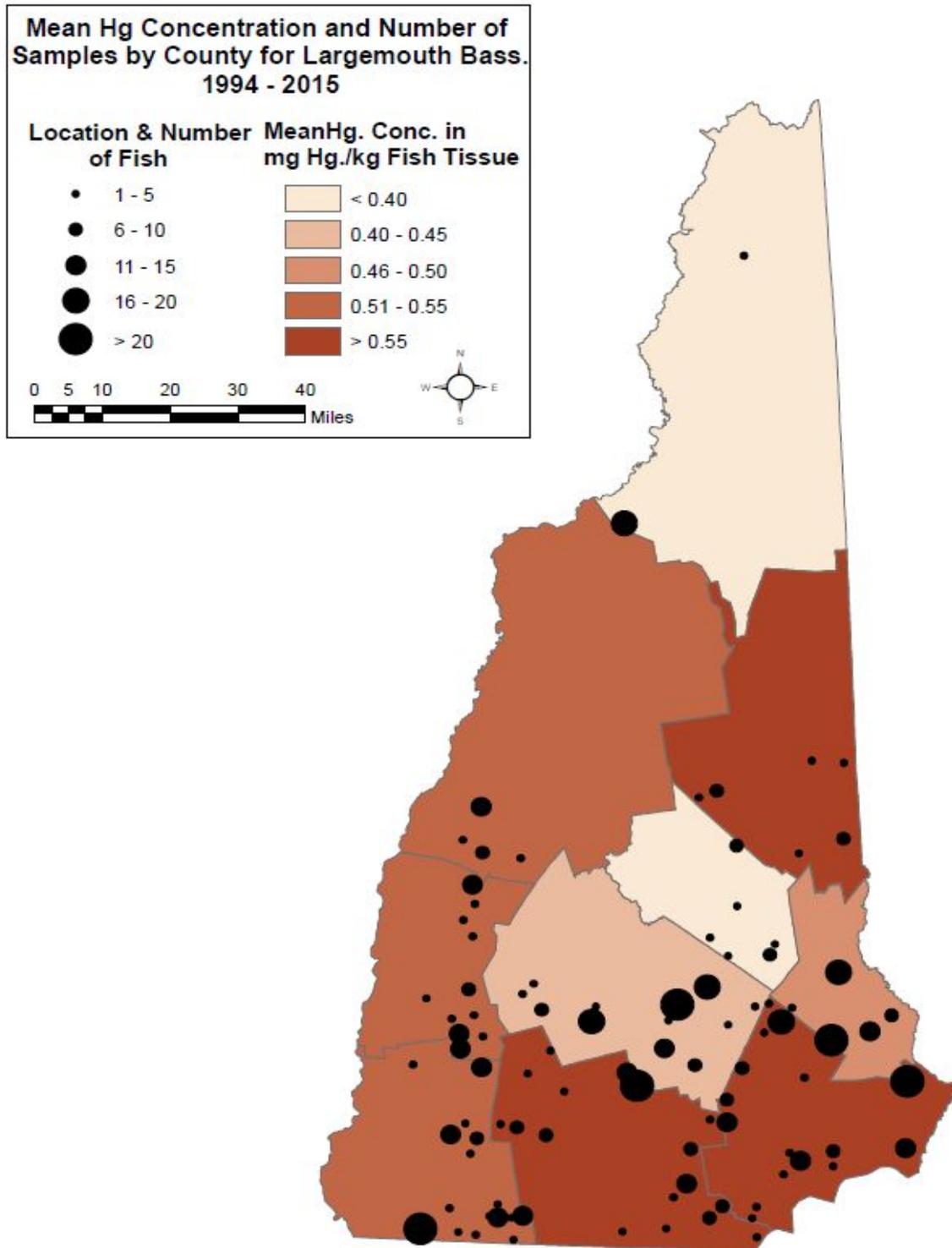
Mean length-adjusted total mercury concentrations for yellow perch were relatively consistent statewide and ranged from 0.14 mg/kg in Coos County to 0.36 mg/kg in Grafton County (Figure 6a). Mean length-adjusted total mercury concentrations for largemouth bass were highest in Hillsborough (0.59 mg/kg) and Carroll Counties (0.56 mg/kg) (Figure 6b). The lowest mean length-adjusted total mercury concentrations for largemouth bass were observed in Coos County (0.33 mg/kg) and Belknap County (0.34 mg/kg).

Overall, the patterns in mean length-adjusted total mercury concentrations by county were dissimilar between yellow perch and largemouth bass. For yellow perch, Grafton and Cheshire counties in western New Hampshire had the highest mean length-adjusted total mercury concentrations (Map 2), whereas for largemouth bass concentrations tended to be highest in the southeastern counties (Hillsborough and Rockingham) (Map 3). Fewer waterbodies were sampled from Coos County than all other New Hampshire counties. These concentration differences documented between yellow perch and largemouth bass may be regional, but also could be due to the variation in the number of individual fish and waterbodies that were sampled.

Map 2 – Location, number of samples, and mean length-adjusted total mercury tissue category by New Hampshire County in yellow perch, 1992-2016.



Map 3 – Location, number of samples, and mean length-adjusted total mercury tissue category by New Hampshire County in largemouth bass, 1994-2015.



4. SUMMARY AND RECOMMENDATIONS

The overall mean concentration of total mercury in tissue for all species (0.33 mg/kg) and those that are commonly consumed (0.36 mg/kg) were well below the benchmark concentration (0.70 mg/kg) used in establishing New Hampshire's freshwater fish consumption guidelines. The statewide mean of all species and commonly consumed species, however, is above the EPA-recommended water quality criteria of 0.30 mg/kg for methyl-mercury. In order to adequately protect human health, NHDES assumes total mercury and methyl-mercury concentrations are equivalent. In general, this is relatively accurate for piscivorous fish, but methyl-mercury may be about 80% of total mercury for planktonic fish (Driscoll et al. 2007).

The NHDES statewide fish consumption guidelines represent a risk-based consumption limit (RBCL) that is computed using a toxicological reference dose (RfD) and a fish tissue benchmark concentration. Along with an assumed human body weight, this defines the total amount of fish that can be safely consumed over a defined period of time. RBCLs for the statewide fish consumption advisory were computed and expressed as the number of meals per month using a meal size of 0.227 kg (8 oz). Based on the formula for computation of the RBCL, the statewide consumption guidelines that use a benchmark concentration equal to 0.70 mg/kg are more protective (e.g., less fish consumption allowed) than if the guideline were established using a benchmark concentration based on the EPA-recommended water quality criteria (0.30 mg/kg). For example, the current statewide fish consumption advisory for mercury in New Hampshire is 4 meals per month for adults and children over age 7 (non-sensitive individuals) and 1 meal per month for women of childbearing age and children under age 7 (sensitive individuals). (See Appendix E for formula and example calculations.) If the EPA-recommended water quality criteria (0.30 mg/kg) were used as the benchmark concentration to compute a consumption limit using the same RfD and body weights, the resultant guidelines would be 9 meals per month for non-sensitive individuals and 3 meals per month for sensitive individuals. As a result, NHDES has elected to retain its current fish advisory that is based on 0.70mg/kg as a benchmark concentration to evaluate the human health risks with respect to total mercury concentrations in fish tissue.

Of the 14 species where comparisons between the 2008 (NHDES 2008) and the current analysis were made, seven had minimal increases or decreases in total mercury (≤ 0.05 mg/kg). Lake trout, walleye and northern pike had tissue concentrations of total mercury equal to or greater than 0.10 mg/kg higher in the current analysis than in 2008 while concentrations of mercury in tissue of yellow bullhead decreased by at least 0.11 mg/kg. For many of these species, the inclusion of additional individuals in the current analysis provides a better estimate of the statewide mean, and thus, more confidence in making determinations of the risk for consumption than in 2008. In particular, the inclusion and analysis of popular sport fish species that are regularly consumed, such as walleye and lake trout, is critically important to establishing accurate species-specific estimates of mercury concentration. The current analysis includes 40 individuals of lake trout and 11 walleye, an increase of 22 and six individuals, respectively. Similarly, the current analysis includes only two northern pike. Future sampling should target these species since they are top predators and likely to have higher mercury concentrations than fish species that are lower on the food chain.

As an added measure of human health safety, NHDES uses the 95% UCL of the mean tissue concentration as a comparison to the benchmark concentration. On average the 95% UCL was 22% higher than the

overall mean for all species (Table 3). The current fish advisory, based on the 2008 NHDES report, includes size-restricted consumption limits for species whose 95% UCL were above the benchmark concentration including a recommendation that only individuals less than 30.5cm (12 in.) in total length be consumed. A comparison of the 95% UCL of mean total mercury concentrations in tissue indicated the current size restricted consumption limits are still protective (i.e., 95% UCLs < 0.70mg/kg) for largemouth bass, smallmouth bass, chain pickerel, yellow perch and white perch less than 30.5 cm (12 in.) in total length (Table 4). Further substantiating these size restrictive consumption limits, the data also indicated that individuals for each of these species that were greater than 30.5 cm (12 in.) in total length had mean total mercury concentrations near or above the benchmark (Table 5). In particular, based on the available data, 61% of smallmouth bass, 47% of yellow perch, 41% of white perch, 39% of largemouth bass, and 39% of chain pickerel greater than 30.5 cm (12 in.) in total length had total mercury concentrations that were in excess of 0.70 mg/kg (Figure 3). Therefore, it is recommended that consumption of these species continue to be restricted to individuals less than 30.5 cm (12 in.) in total length for the protection of human health. Additionally, the use of the 95% UCL of the mean for individual species provides a high level of certainty that repeated samples of fish (e.g. catches) will have a mean total mercury concentration lower than the benchmark concentration and reasonable assurance that the RBCL will not be exceeded. The continued use of this method is also recommended to assess the need for size restricted consumption limits.

Yellow bullhead, walleye and lake trout are not included in the size restricted consumption limits; however, these species all had 95% UCLs above or near the benchmark concentration, either for individuals greater than 30.5 cm (12 in.) in length (lake trout and walleye, Table 5) or for all samples (yellow bullhead, Table 3). As a result, these species are being considered for further inclusion into the current size restricted consumption limits; however, additional sampling is necessary.

Yellow bullhead are bottom dwelling, opportunistic feeders that primarily consume invertebrates and plant material as food. Kamman et al. (2005) previously reported concentrations of total mercury in the tissue of brown bullhead, a species with similar habitat requirements and feeding habits, from northeastern North America of 0.17 mg/kg for 410 individuals. Currently, the FTMMMP database includes only 10 individuals of all lengths. The statewide mean of all individuals was 0.43 mg/kg with a 95% UCL of 0.73 mg/kg. Given the small sample size and the discrepancy between mercury concentrations reported here to those reported by Kamman et al. (2005) for brown bullhead, future sampling that targets yellow bullhead is recommended prior to issuing a size-restricted consumption advisory. The inclusion of additional individuals in the FTMMMP database will allow for an estimate of the mean and range of statewide mercury concentrations for this species with a higher level of confidence.

Walleye are exclusively top predators that consume smaller fish. Since methyl-mercury is the most common form of mercury in top predators and is known to bioaccumulate, it is not surprising that this species was found to have the high concentrations of mercury. Further, these results are consistent with the high concentrations of total mercury in tissue that were observed in New Hampshire for other fish species that are exclusively top predators (e.g. smallmouth bass, largemouth bass, Eastern chain pickerel). Kamman et al. (2005) reported a mean total mercury concentration for walleye from northeastern North America of 0.76 mg/kg (n=1,273) and that this species had among the highest concentrations observed for 40 freshwater fish species. Data from FTMMMP for walleye were restricted to 11 individuals and all

individuals included in the analysis were over 30.5 cm (12 in.) in length with a mean total mercury concentration of 0.66 mg/kg (95% UCL = 0.86). Despite the low number of individuals included in the FTMMP, it is recommended that size-restricted consumption limits be added for this species in New Hampshire because data from the FTMMP is corroborated by their position at the top of the food web and the high mean concentrations reported by Kamman et al. (2005).

The data also indicated that lake trout had mean total mercury concentrations higher than most species (0.49 mg/kg) with a 95% UCL concentration of 0.68 mg/kg based on 37 individuals greater than 30.5 cm in length. Kamman et al. (2005) reported a mean concentration for lake trout of 0.61 mg/kg for 1,076 individuals. Since the 95% UCL of individuals from the FTMMP nearly meets the benchmark concentration, lake trout are top predators, and the high mean concentration reported by Kamman et al. (2005) it is recommended that a size-restricted consumption limits be considered for this species as well.

Last, although only two northern pike have been analyzed in the FTMMP, their mean total mercury concentration (0.60 mg/kg) ranks fourth among all the species tested in New Hampshire. Kamman et al. (2005) reported a mean total mercury concentration for northern pike of 0.63 mg/kg for 1,328 individuals. As top predators, northern pike bioaccumulate mercury and represent a likely health risk to humans and wildlife. In New Hampshire, northern pike inhabit a limited number of waterbodies, primarily on the western edge of the state, so there is a lower likelihood of capture and widespread consumption and, in turn, health risk due to mercury contamination. Nonetheless, it is recommended that this species be considered for size-restricted consumption limits.

The collection and processing of additional individuals for walleye, lake trout and northern pike should be targeted in the future to increase the level of certainty in the total mercury concentrations.

Issuing size-restricted consumption advisories for walleye, northern pike and lake trout needs to be considered in conjunction with the fishing regulations issued by NHFG. In 2017, the minimum length limits for walleye and lake trout were 46 cm (18 in.) and 72 cm (28 in.) for northern pike. Therefore, simply adding the current size-restricted consumption limit that recommends no fish over 30.5 cm (12 in.) can be consumed presents a conflict (i.e., establishment of a catch-and-release fishery in which no fish could be consumed). All three of these species are popular sport fish and maintaining some level of consumption that is safe with respect to mercury, if possible, is highly desirable. Future efforts to better understand mercury concentrations in these species should include an analysis across a range of lengths with a minimum number of individuals in multiple size categories. A robust dataset for each species that meets these objectives will allow for the computation of RBCLs within each size category to determine if there is a safe level of consumption within a given size range that fits within the current NHFG minimum length limit.

Annual mean length-adjusted total mercury concentrations in the tissue of yellow perch decreased significantly from 1995-2016 (MKT; $p < 0.05$). In contrast, trends of annual mean adjusted total mercury concentrations in the tissue of largemouth bass were inconclusive (MKT; $p > 0.05$) from 1994-2015. Data from recent years (2009-15) suggest a tendency toward decreasing concentrations; however, additional years of data are needed to confirm if this observation continues.

Differences in inter-annual comparisons from waterbodies included in the structured sampling program indicated that most (48%) waterbodies had large change (>2 standard error) in length-adjusted mercury concentrations for largemouth bass. Similarly, comparisons of lake-wide tendencies for yellow perch indicated that the majority (40%) fell into the large change (i.e., ≥ 2 standard errors) narrative category. Large inter-annual differences in total mercury concentrations may be an artifact of the gaps in the number of years between sample collections at individual waterbodies, or in the number of fish captured and analyzed. For the opportunistic sampling program, repeated collections at individual waterbodies were not common, and when they did occur, the number of years separating the sample collection was completely random. The number of fish submitted for processing and analysis was also random. The structured sampling program had a five-year scheduled data gap between collections. Without consistent annual samples, it appears as though mercury concentrations in fish tissue are highly variable across timeframes (5+ years) within individual waterbodies for individual species.

Observations of lake-wide tendencies from the structured sampling program were limited. For largemouth bass, six of 10 waterbodies experienced a mixture of inter-annual increases and decreases in adjusted mercury concentrations (i.e., mixed tendency). Lake-wide tendencies for yellow perch had a similar frequency of waterbodies with decreased (n=11; 32%), increased (n=10; 29%), and mixed (n=11; 32%) inter-annual comparisons. Overall, the analysis of time series data from the repetitively sampled lakes did not provide a clear indication of either increasing or decreasing trend of the concentration of mercury in fish tissue.

Similar to yellow perch in New Hampshire, a study of 23 lakes and ponds in Massachusetts, Hutchinson et al. (2014) documented significant declines in the mercury concentrations in the tissue of yellow perch and largemouth bass between two distinct time periods (1998-2002 vs. 2003-2011). The same research indicated the greatest declines were documented in lakes and ponds located near local atmospheric sources and that the reductions in fish tissue concentrations were likely linked to reduced atmospheric emissions of local sources. National trends in freshwater fish tissue mercury concentrations reported by Chalmers et al. (2011) indicated that 57% of the sites sampled showed no change between 1969 and 2005 and 37% of sites had a declining trend. Chalmers et al. (2011) also reported declining trends in six out of seven Northeast waterbodies sampled from 1969 through 1987. Results from Great Lakes walleye and lake trout tissue indicated consistent downward trends over time in most cases for the period 1970 through 2007 (Bhavsar 2010).

The documentation of improvement is an obvious goal when an environmental pollutant source is reduced or removed. With respect to mercury, significant national (Figure 1) and statewide (Tables 1 and 2) reductions in atmospheric emissions have occurred in recent years. The ability to detect corresponding improvements in the fish data available through the FTMMPP was restricted to yellow perch (Figure 5). The inability to detect trends for largemouth bass that correspond to reductions in atmospheric emissions is, in part, attributed to the unstructured nature of the sampling design of the FTMMPP. A majority of the annual data included in the largemouth bass trend analysis came from less than 30 individuals (17 of 22 years) and less than five waterbodies (18 of 22 years). In contrast, for yellow perch, 18 of 22 years

included 30 or more individuals and came from five or more waterbodies in 12 of 22 years. A consistently robust annual dataset was important to detecting long-term trends.

In addition, because mercury is a persistent environmental contaminant that is sequestered in bottom sediments, an unknown load of mercury is continuously available for delivery to waterbodies for an extended period (e.g., >100 years) until the source is depleted. Coupled with continued mercury deposition from local and global sources, the ability to detect statewide reductions in mercury concentrations in fish tissues will continue to be challenging. Finally, delayed responses of mercury concentrations in fish tissue to atmospheric emission reductions are possible (Chalmers et al. 2011). These confounding factors are important to consider when judging the effectiveness of reductions in atmospheric mercury with respect to concentrations in fish tissue.

Overall, 90% of the fish specimens submitted for inclusion into the FTMPP were submitted to NHDES through a statewide request to citizens. The resultant data, in most cases, represent single sampling events from waterbodies across the state without concern for spatial distribution, nearness to local emission sources, modeled mercury deposition patterns, or in-lake water chemistry. The remaining 10% of the data came from the 10-lake structured sampling effort, where each lake is sampled once every five years, and although this program was started in 1998, these waterbodies have only two to three data points. Collectively, while the FTMPP data provides accurate estimates of statewide mercury concentrations in the tissue for the most commonly consumed freshwater fish, a more rigorous sampling design is needed to track trends in mercury concentrations in fish tissue over time, especially given the complex nature of the factors that control the supply and availability of mercury in the environment.

A revised sampling program capable of detecting trends should include annual sampling of specific fish species from a consistent roster of waterbodies statewide. A subset of these repetitively sampled waterbodies should be focused in areas of southeastern New Hampshire as previous research has shown this area is subjected to higher mercury deposition rates than the rest of New Hampshire (Evers et al. 2007, Lombard et al. 2011). Additional “trend” waterbodies should be scattered across the state to provide adequate geographic distribution including areas that are known or suspected of having low mercury deposition rates. Basic water quality parameters such as pH, dissolved organic carbon, acid neutralizing capacity and total phosphorus should be taken into consideration when selecting lakes as they contribute to a waterbody’s mercury sensitivity (Driscoll et al. 2007). The revised program should include up to 20 waterbodies and take into consideration waterbodies with previous mercury in fish tissue data. Many of the waterbodies from the current structured sampling program could be included in the revised program as they were originally selected based on the water chemistry parameters noted above. Mason et al. (2005) provides specific and more detailed suggestions for the establishment of a structured mercury monitoring framework that includes fish.

Since 2011, a municipal waste incinerator in the Town of Claremont and the PSNH coal-fired power plant in the Town of Bow collectively reduced statewide atmospheric sources of mercury by approximately 180 kg/yr (~36% of statewide reduction) and contributed significantly to the documented reductions in statewide atmospheric reductions since 1997 (Table 1). The recent significant declining trend observed in tissue concentrations of total mercury for yellow perch and recent tendency toward lower total mercury

concentrations in largemouth bass may be related to these atmospheric reductions. Hutchinson et al. (2014) observed similar rapid reductions in mercury concentrations of fish tissue in concert with the reduction of localized mercury emission sources. Evers et al. (2007) reported that mercury concentrations declined 64% in loons (blood and eggs) over a three-year period, and, that these declines coincided with a 45% reduction in upwind atmospheric mercury sources in southern New Hampshire. While these studies provide examples of the potential for rapid declines in mercury concentrations in animals associated with the removal of nearby atmospheric sources, response times depend on a variety of factors including the form(s) of mercury (particulate, gaseous, elemental) removed, coincident changes in regional or global emission rates, the amount of mercury historically deposited across the landscape, climatic conditions and watershed characteristics. The inclusion of future years of data to track trends of mercury in fish tissue concentrations through the FTMPP will confirm whether the current tendency continues and represents a significant reduction over time. Ultimately, if done correctly, coupling fish tissue with emission or deposition data could be used to make associations between the potential supply (availability) and the observed contaminant load in aquatic resources.

Total mercury concentrations in fish tissue by New Hampshire County were relatively consistent across the state with largemouth bass typically near or in excess of 0.50 mg/kg and yellow perch near or in excess 0.30 mg/kg (Maps 2 & 3). Coos County had lower total mercury concentrations for both largemouth bass and yellow perch; however, these data consisted of fewer individuals from fewer waterbodies than other counties. Evers et al. (2007) identified “hotspots” of mercury concentrations in fish tissue in southeastern New Hampshire and northeastern Massachusetts. These results were further confirmed in a study of Massachusetts fish tissue by Hutchinson et al. (2014). For the FTMPP, the largest variation in length-adjusted mean total mercury concentrations in fish tissue between counties was observed in largemouth bass with concentrations of fish from two southern New Hampshire counties, Hillsborough and Rockingham, nearly two times higher than fish collected from waterbodies in New Hampshire’s northernmost county, Coos County. Many waterbodies sampled within Hillsborough and Rockingham counties were located downwind or within approximately 50 miles of two of the historically largest atmospheric emission sources in New Hampshire (Merrimack station, Bow, New Hampshire; Schiller Station, Portsmouth, New Hampshire). Yellow perch had less variation across the landscape when mean length-adjusted total mercury concentrations were compared by county and were highest in western New Hampshire counties, yet still indicated that tissue concentrations in fish collected from Coos County (0.16 mg/kg) were lowest and approximately half of the total mercury concentrations observed in eight of the nine remaining New Hampshire counties. Although these observations of county-wide mercury concentrations in fish tissue were based on a non-statistical comparison of means, and for some counties rely on a limited number of samples, they are consistent with observed atmospheric mercury deposition patterns in the northeast reported by Vanarsdale et al. (2005) and modeled for New Hampshire and MA by Evers et al. (2007).

The county-wide summaries, especially with respect to largemouth bass, provide some guidance to the public regarding the geographic areas where there exists the greatest potential of catching, and potentially consuming, fish with high mercury concentrations. The current New Hampshire fish consumption advisory includes waterbody-specific advisories on eight waterbodies: three in Grafton County, one in Belknap County, two in Sullivan County, one in Merrimack County, one of Hillsborough

County and one in Rockingham County. (See Appendix A for waterbody names and towns.) Future sampling should also include the collection of additional fish tissue samples from northern areas of New Hampshire in order to increase the sample size in an effort to confirm the apparent broader north-to-south patterns reported here and elsewhere. The current dataset is underrepresented with respect to the percentage of fish and waterbodies in Coos County, the largest county in New Hampshire. Additional data are needed for largemouth bass from Belknap, Carroll and Grafton Counties. For yellow perch, more data could be used from Strafford and Belknap Counties.

In summary, the FTMMP has provided valuable long-term statewide data on the concentrations of total mercury in the tissue of the most commonly encountered and consumed freshwater fish in New Hampshire. The data are important for evaluating the need for revisions to the statewide fish consumption advisory and an evaluation of mercury concentrations in fish tissue over time and across the state. These data were, in large part, contributed to NHDES by volunteers and ultimately provides a rich dataset by which to analyze mercury in fish tissue data. There are indications that statewide mercury concentrations are declining in fish tissue, especially for yellow perch. The recent tendency in fish tissue concentrations of mercury coincides with reductions of in-state atmospheric emissions of mercury, however, additional fish and emissions data is required to confirm this association. County-wide comparisons of mercury in fish tissue concentrations indicate that southern areas of New Hampshire had fish with higher concentrations than that New Hampshire's northern-most county, Coos. The data also correspond to known patterns of atmospheric mercury deposition across the New Hampshire landscape. It is recommended that the FTMMP be continued, with some modification, as it serves as an important resource in evaluating the risk to humans from a highly toxic chemical and its persistence in aquatic ecosystems. Since its inception in 1992, the FTMMP has amassed one of the largest and longest running statewide datasets in the country with respect to the content of mercury in fish tissue.

5. REFERENCES

- Boening, D.W. 2000. Ecological effects, transport, and fate of mercury: a general review. *Chemosphere* 40: 1335-1351.
- Chalmers, A.T., D.M. Argue, D.A. Gay, M.E. Brigham, C.J. Schmitt, D.L. Lorenz. 2011. Mercury trends in fish from rivers and lakes in the United States, 1969-2005. *Environmental Monitoring and Assessment* 175:175-191.
- Bhavsar, S.P., S.B. Gewurtz, D.J. McGoldrick, M.J. Keir, S.M. Backus. 2010. Changes in mercury levels in Great Lakes fish between 1970s and 2007. *Environmental Science and Technology* 44:3273-3279.
- Driscoll, C.T., Y. Han, C.Y. Chen, D.C. Evers, K. Fallon Lambert. Mercury contamination in forest and freshwater ecosystems in the northeastern United States. *Bioscience* 57: 17-28.
- EPA. 2010. Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion. EPA 823-R-10-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.
- EPA. 2011. Biennial national listing of fish advisories. EPA-820-F-11-014. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C.
- Evers, D., Y. Han, C.T. Driscoll, N.C. Kamman, W.W. Goodale, K.F. Lambert, T.M. Holsen, C.Y. Chen, T.A. Clair, T. Butler. 2007. Biological mercury hotspots in northeastern United States and southwestern Canada. *Bioscience* 57:29-43.
- Hutchinson, M.S., C.M. Smith, J. Rose, C. Batdorf, O. Pancorbo, C. Rowen West, J. Strube, C. Francis. 2014. Temporal and spatial trends in freshwater fish tissue mercury concentrations associated with mercury emissions reductions. *Environmental Science and Technology* 48:2193-2202.
- Kamman, N.C., N.M. Burgess, C.T. Driscoll, H.A. Simonin, W. Goodale, J. Linehan, R. Estabrook, M. Hutchinson, A. Major, A.M. Scheuhammer, D.A. Scruton. 2005. Mercury in freshwater fish of northeast North America – A geographic perspective based on fish tissue monitoring databases. *Ecotoxicology* 14: 163-180.
- Lombard, M. A. S., J. G. Bryce, H. Mao, R. Talbot. 2011. Mercury deposition in southern New Hampshire, 2006-2009. *Atmospheric Chemistry and Physics*. 11:7657-7668.
- Mason, R.P., M.L. Abbott, R.A. Bodaly, O.R. Russell Bullock, Jr., C.T. Driscoll, D. Evers, S. E. Lindberg, M. Murray, E.B. Swain. 2005. Monitoring the response to changing mercury deposition. *Environmental Science and Technology* 39:14A-22A.

NHDES. 2008. Technical background for the 2008 update to the New Hampshire statewide mercury fish consumption advisory. New Hampshire Department of Environmental Services, Concord, New Hampshire. Publication #R-ARD-08-01. 19pp.

NESCAUM. 2007. Tracking progress in reducing mercury in air emissions. Northeast States for Coordinated Air Use Management. 6pp.

Vanarsdale, Alan, J. Weiss, G. Keeler, E. Miller, G. Boulet, R. Brulotte, L. Poissant. 2005. Patterns of mercury deposition and concentration in northeastern North America 1996-2002. *Ecotoxicology* 14:37-52.

Wentz, D.A., Brigham, M.E., Chasar, L.C., Lutz, M.A., and Krabbenhoft, D.P., 2014, Mercury in the Nation's streams — Levels, trends, and implications: U.S. Geological Survey Circular 1395, 90 p., <http://dx.doi.org/10.3133/cir1395> .

Zheng, Yanxu and L. Jaeglé. 2013. Decreases in mercury wet deposition over the United States during 2004-2010: Roles of domestic and global background emission reductions. *Atmosphere* 4:113-131.

New Hampshire Fish Consumption Guidelines

Fish and shellfish are an important part of a healthy diet. They are a good source of low fat protein and contain nutrients like omega-3 fatty acids, a key nutrient for brain development. However, nearly all fish and shellfish have traces of mercury. Small amounts of mercury can damage a brain starting to form or grow. That is why babies and young children are at most risk. Risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. You can eat fish and be healthy. Following these guidelines will help.

Freshwater Fish

For all freshwater fish, except stocked trout, follow these fish consumption guidelines:

- Pregnant and nursing women, and women who may become pregnant **can safely eat ONE**, 8-ounce meal of freshwater fish per month.
- Children under age 7 **can safely eat ONE**, 4-ounce meal of freshwater fish per month.
- All other adults and children age 7 and older **can safely eat FOUR**, 8-ounce meals of freshwater fish per month.
- When eating bass, pickerel, white perch or yellow perch, limit consumption to fish 12 inches or less in length while following the above guidelines.

Stocked trout contains relatively low levels of mercury. For *rainbow* and *brown trout*, women of childbearing age and children can safely eat ONE meal per week; others can eat SIX meals per week. *Brook trout* could be either stocked or from a native population, and therefore should be consumed at the rate of the general freshwater advisory above.

Fish from several waterbodies in New Hampshire have been shown to have higher than average mercury concentrations. For the waterbodies identified below, *women of childbearing age and young children should **not** consume any fish*; others may consume TWO meals per month.

- Ashuelot Pond, Washington
- Comerford and Moore Reservoirs on the Connecticut River
- Crystal Lake, Gilmanton
- Dubes Pond, Hooksett
- Mascoma Lake, Enfield
- May Pond, Washington
- Tower Hill Pond, Candia

In addition, NO fish should be consumed from the Androscoggin River from Berlin to the Maine border due to potential dioxin contamination.

Saltwater Fish, Shellfish and Commercially Available Fish

For all saltwater fish, shellfish and commercially available fish please follow these consumption guidelines:

BEST CHOICES: Catfish, Cod, Flounder, Haddock, Herring, Light Tuna (canned), Pollack, Sole, Salmon, Tilapia and Shellfish (Oysters, Shrimp, Crab, Clams, Scallops, Lobster)

- Pregnant and nursing women, women who may become pregnant, and young children **can safely eat** TWO meals per week. For all others, no limit as part of a balanced diet.

GOOD CHOICES: Halibut, Red Snapper, Tuna Steak and White Tuna (canned)

- Pregnant and nursing women, women who may become pregnant, and young children **can safely eat** ONE meal per week. For all others, no limit as part of a balanced diet.

CAUTION: King Mackerel, Swordfish, Shark and Tilefish

- Pregnant and nursing women, women who may become pregnant, and young children **should avoid consumption.** For all others, TWO meals per month.

All dietary sources of fish should be considered together. For example, a pregnant woman may have one meal of freshwater fish but is advised not to consume any additional mercury containing freshwater or saltwater fish that month. **Remember:** “meal” sizes are 4 oz. for children under age 7 and 8 oz. for older children and adults.

Appendix B – New Hampshire waterbodies with mercury in fish tissue data sampled through structured and opportunistic sampling efforts, 1992 - 2016.

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
ADDER POND	NHLAK700030403-01	ANDOVER	MERRIMACK	BAKUORF-GEN	Opportunistic
ANDROSCOGGIN RIVER	NHRIV400010605-09	BERLIN	COOS	CRYGLM-GEN	Opportunistic
ANDROSCOGGIN RIVER	NHRIV400010606-10	GORHAM	COOS	CUBLDVL-GEN	Opportunistic
ANDROSCOGGIN RIVER	NHRIV400020103-06	SHELBURNE	COOS	BATWOL-GEN	Opportunistic
ANGLE POND	NHLAK700061403-01-01	SANDOWN	ROCKINGHAM	BAXFAR-GEN	Opportunistic
ARMINGTON LAKE	NHLAK801040201-01	PIERMONT	GRAFTON	DANMFRE-GEN	Opportunistic
ASHEULOT RIVER	NHRIV802010403-07	WINCHESTER	CHESHIRE	BEADEE-GEN	Opportunistic
ASHUELOT POND	NHLAK802010101-01	WASHINGTON	SULLIVAN	BEADER-GEN	Opportunistic
AYERS ISLAND DAM POND	NHIMP700010801-08	NEW HAMPTON	BELKNAP	BEASWH-GEN	Opportunistic
AYERS POND	NHLAK600030607-01	BARRINGTON	STRAFFORD	DEEDRG-GEN	Opportunistic
BATSON POND	NHLAK700020101-01	WOLFEBORO	CARROLL	DERCAN-GEN	Opportunistic
BAXTER LAKE	NHLAK600030602-01	FARMINGTON	STRAFFORD	BELMBY-GEN	Opportunistic
BEARCAMP POND	NHLAK600020601-01-01	SANDWICH	CARROLL	DIASTE-GEN	Opportunistic
BEAVER LAKE	NHLAK700061203-02-01	DERRY	ROCKINGHAM	DINSWH-GEN	Opportunistic
BEAVER POND	NHIMP600030702-01	DEERFIELD	ROCKINGHAM	DODLEM-GEN	Opportunistic
BELLAMY RESERVOIR	NHLAK600030903-02	MADBURY	STRAFFORD	BLASUT-GEN	Opportunistic
BIG ISLAND POND	NHLAK700061101-01-01	DERRY	ROCKINGHAM	BOGLIN-GEN	Opportunistic
BIG TURKEY POND	NHLAK700060301-02-01	CONCORD	MERRIMACK	BOLSUL-GEN	Opportunistic
BLAISDELL LAKE	NHLAK700030302-02	SUTTON	MERRIMACK	BOWSFF-GEN	Opportunistic
BOG POND	NHLAK700010201-01	LINCOLN	GRAFTON	BRIBRN-GEN	Opportunistic
BOLSTER POND	NHLAK802010201-01	SULLIVAN	CHESHIRE	BRYDOR-GEN	Opportunistic
BOW LAKE	NHLAK600030604-01-01	STRAFFORD	STRAFFORD	CANWIN-GEN	Opportunistic
BRINDLE POND	NHLAK700060402-01	BARNSTEAD	BELKNAP	CHEEPS-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
BRYANT POND	NHLAK700010304-01	CANAAN	GRAFTON	CHEJEF-GEN	Opportunistic
CANOBIE LAKE	NHLAK700061102-02	WINDHAM	ROCKINGHAM	CHIHAR-GEN	Opportunistic
CENTER POND	NHLAK802010201-02	NELSON	CHESHIRE	CLAHOK-GEN	Opportunistic
CHERRY POND	NHLAK801030102-04	JEFFERSON	COOS	COBWINS	Opportunistic
CHESTNUT POND	NHLAK700060502-03	EPSOM	MERRIMACK	ADDAND-GEN	Opportunistic
CHILDS BOG	NHLAK802010202-02	HARRISVILLE	CHESHIRE	ANGSDN-GEN	Opportunistic
CLAY POND	NHLAK700060701-02	HOOKSETT	MERRIMACK	ARMPLE-GEN	Opportunistic
COBBETTS POND	NHLAK700061204-01-01	WINDHAM	ROCKINGHAM	COMMON-GEN	Opportunistic
COMERFORD RESERVOIR	NHIMP801030203-01	MONROE	GRAFTON	CONCNW-GEN	Opportunistic
CONNECTICUT RIVER	NHRIV801060702-12	CLAREMONT	SULLIVAN	CONJAF-GEN	Opportunistic
CONNECTICUT RIVER	NHRIV801010203-07	CLARKSVILLE	COOS	ASHWAS-GEN	Opportunistic
CONNECTICUT RIVER	NHLAK801040402-03	HANOVER	GRAFTON	AYEBAR-GEN	Opportunistic
CONNECTICUT RIVER	NHRIV801060302-01	LEBANON	GRAFTON	AYEBRI-GEN	Opportunistic
CONNECTICUT RIVER	NHLAK801030202-01	LITTLETON	GRAFTON	COUKIN-GEN	Opportunistic
CONNECTICUT RIVER	NHRIV801070501-10-02	WALPOLE	CHESHIRE	CRACLM-GEN	Opportunistic
CONNECTICUT RIVER AT LYMAN FALLS	NHRIV801010405-03	COLUMBIA	COOS	CREACW-GEN	Opportunistic
CONTOOCOOK LAKE	NHLAK700030101-03-01	RINDGE	CHESHIRE	CREWOL-GEN	Opportunistic
CONWAY LAKE	NHLAK600020304-01-01	EATON	CARROLL	LONDVL-GEN	Opportunistic
COUNTRY POND	NHLAK700061403-03-01	KINGSTON	ROCKINGHAM	LONHEN-GEN	Opportunistic
CRANBERRY BOG POND	NHLAK801010403-01	COLUMBIA	COOS	LONLEM-GEN	Opportunistic
CRESCENT LAKE	NHLAK801070201-01	ACWORTH	SULLIVAN	ONWRAY-GEN	Opportunistic
CRESCENT LAKE	NHLAK700020101-04	WOLFEBORO	CARROLL	OPELAC-GEN	Opportunistic
CRYSTAL LAKE	NHLAK700060401-02-01	GILMANTON	BELKNAP	RUSWOL-GEN	Opportunistic
DEERING RESERVOIR	NHLAK700060601-01	DEERING	HILLSBOROUGH	RUSWOO-GEN	Opportunistic
DERBY POND	NHLAK700010304-02	ORANGE	GRAFTON	GRTKIN-GEN	Opportunistic
DIAMOND POND	NHLAK400010403-01	STEWARTSTOWN	COOS	GUNGOS-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
DINSMORE POND	NHLAK700020103-02	SANDWICH	CARROLL	LONNOR-GEN	Opportunistic
DODGE POND	NHLAK801070201-02	LEMPSTER	SULLIVAN	LOOFMT-GEN	Opportunistic
DORRS POND	NHLAK700060802-01	MANCHESTER	HILLSBOROUGH	OTTGRE-GEN	Opportunistic
DREW LAKE	NHLAK700030503-02	HOPKINTON	MERRIMACK	OTTHUD-GEN	Opportunistic
DUBES POND	NHLAK700060701-03	HOOKSETT	MERRIMACK	SANMLW-GEN	Opportunistic
DUCK POND	NHLAK600020804-03	FREEDOM	CARROLL	HALALT-GEN	Opportunistic
DURGIN POND	NHIMP700060502-01	NORTHWOOD	ROCKINGHAM	HALHAN-GEN	Opportunistic
EAST POND	NHLAK700010204-01	LIVERMORE	GRAFTON	LOOPLY-GEN	Opportunistic
EASTMAN POND	NHLAK801060401-06	GRANTHAM	SULLIVAN	LOVWAK1D	Opportunistic
ELLSWORTH POND	NHLAK700010206-01	ELLSWORTH	GRAFTON	PARLTL-GEN	Opportunistic
ELM BROOK POOL	NHIMP700030503-01-01	HOPKINTON	MERRIMACK	HALWAS-GEN	Opportunistic
FLAT MOUNTAIN POND	NHLAK600020602-02	WATERVILLE VALLEY	GRAFTON	MANGLM-GEN	Opportunistic
FLINTS POND	NHLAK700040402-01	HOLLIS	HILLSBOROUGH	MARLAN-GEN	Opportunistic
FOREST LAKE	NHLAK802010401-01-01	WINCHESTER	CHESHIRE	MASaub1D	Opportunistic
FRANKLIN PIERCE LAKE	NHLAK700030202-03-01	HILLSBOROUGH	HILLSBOROUGH	MASaub2D	Opportunistic
FROST POND	NHLAK700030102-02	JAFFREY	CHESHIRE	MASaub3D	Opportunistic
FULLAM POND	NHLAK802010403-02	CHESTERFIELD	CHESHIRE	PAWNOT-GEN	Opportunistic
GILES POND	NHLAK700010802-02	SANBORNTON	BELKNAP	SEBBED-GEN	Opportunistic
GILMORE POND	NHLAK700030101-05	JAFFREY	CHESHIRE	SESDUM-GEN	Opportunistic
GOOSE POND	NHLAK801060103-01	CANAAN	GRAFTON	SHEGLM-GEN	Opportunistic
GOULD POND	NHLAK700030501-01	HILLSBOROUGH	HILLSBOROUGH	HARHAR-GEN	Opportunistic
GRASSY POND	NHLAK700030101-08	RINDGE	CHESHIRE	MASBRA-GEN	Opportunistic
GREAT POND	NHLAK700061403-06-01	KINGSTON	ROCKINGHAM	MASENF1D	Opportunistic
GREENWOOD POND	NHLAK700061403-07	KINGSTON	ROCKINGHAM	MASENF-GEN	Opportunistic
GREGG LAKE	NHLAK700030108-02-01	ANTRIM	HILLSBOROUGH	PEARIN-GEN	Opportunistic
GUNNERSON LAKE	NHLAK801060403-02	GOSHEN	SULLIVAN	PEATHO-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
HALFMOON LAKE	NHLAK700060402-03	ALTON	BELKNAP	PEMMER-GEN	Opportunistic
HALFMOON POND	NHLAK700030103-04	HANCOCK	HILLSBOROUGH	HARPIT-GEN	Opportunistic
HALFMOON POND	NHLAK700030201-02	WASHINGTON	SULLIVAN	HERSAN-GEN	Opportunistic
HARRIS POND	NHLAK801010202-01	PITTSBURG	COOS	MAYWAS-GEN	Opportunistic
HARRISVILLE POND	NHLAK700030103-05-01	HARRISVILLE	CHESHIRE	PERSUN-GEN	Opportunistic
HERMIT LAKE	NHLAK700010802-03-01	SANBORNTON	BELKNAP	PHISDN-GEN	Opportunistic
HIGHLAND LAKE	NHLAK700030201-03	STODDARD	CHESHIRE	DORMAN-GEN	Opportunistic
HORN POND	NHLAK600030403-02	WAKEFIELD	CARROLL	DREHOP-GEN	Opportunistic
HORSESHOE POND	NHLAK700060302-02	CONCORD	MERRIMACK	DUBHOK-GEN	Opportunistic
HORSESHOE POND	NHLAK700061002-03	MERRIMACK	HILLSBOROUGH	DUCFRE-GEN	Opportunistic
HOWE RESERVOIR	NHLAK802010202-06	DUBLIN	CHESHIRE	HIGSTDND	Opportunistic
HUNTS POND	NHLAK700030106-01	HANCOCK	HILLSBOROUGH	MCIMON-GEN	Opportunistic
ISLAND POND	NHLAK802020103-05	NEW IPSWICH	HILLSBOROUGH	PINWAK-GEN	Opportunistic
ISLAND POND	NHLAK700030202-02-01	STODDARD	CHESHIRE	DURNOR-GEN	Opportunistic
ISLAND POND	NHLAK700030204-03	WASHINGTON	SULLIVAN	MELTUF-GEN	Opportunistic
JACKMAN RESERVOIR	NHLAK700030202-03-01	ANTRIM	HILLSBOROUGH	MENBAR-GEN	Opportunistic
JACQUITH POND	NHLAK801010103-04	PITTSBURG	COOS	MERNWD-GEN	Opportunistic
JENNESS POND	NHLAK700060502-06	NORTHWOOD	ROCKINGHAM	MESNWL-GEN	Opportunistic
JERICO LAKE	NHLAK400010606-01	BERLIN	COOS	PISWCHD	Opportunistic
JUDD POND	NHLAK400010402-01	CLARKSVILLE	COOS	PLEDEE-GEN	Opportunistic
KEZAR LAKE	NHLAK700030303-03-01	SUTTON	MERRIMACK	EASGTM-GEN	Opportunistic
KILTON POND	NHLAK700010701-02-01	GRAFTON	GRAFTON	EASLIV-GEN	Opportunistic
KIMBALL POND	NHIMP700030507-01-01	HOPKINTON	MERRIMACK	HORCON-GEN	Opportunistic
KUSUMPE POND	NHLAK700010501-03	SANDWICH	CARROLL	HORMMK-GEN	Opportunistic
LAKE KANASATKA	NHLAK700020105-02	MOULTONBOROUGH	CARROLL	HORWAK-GEN	Opportunistic
LAKE MASSASECUM	NHLAK700030302-04-01	BRADFORD	MERRIMACK	HOWDUB-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
LAKE MONOMONAC	NHLAK802020103-06	RINDGE	CHESHIRE	MIRTUF-GEN	Opportunistic
LAKE SOLITUDE	NHLAK700030301-01	NEWBURY	MERRIMACK	PLENWL-GEN	Opportunistic
LAKE UMBAGOG	NHLAK400010602-04	ERROL	COOS	POORIN-GEN	Opportunistic
LAKE UMBAGOG	NHLAK400010602-04	ERROL	COOS	ELLELL-GEN	Opportunistic
LAKE WENTWORTH	NHLAK700020101-05-01	WOLFEBORO	CARROLL	ELMHOP-GEN	Opportunistic
LAKE WINNIPESAUKEE, ALTON BAY	NHLAK700020110-02-19	ALTON	BELKNAP	HUNHAN-GEN	Opportunistic
LAKE WINNIPESAUKEE, BROADS	NHLAK700020110-02-19	GILFORD	BELKNAP	ISLDER-GEN	Opportunistic
LAKE WINNIPESAUKEE, GOV ISLAND	NHLAK700020110-02-19	GILFORD	BELKNAP	MONRINAD	Opportunistic
LAKE WINNIPESAUKEE, MEREDITH BAY	NHLAK700020110-02-19	MEREDITH	BELKNAP	POTBRL-GEN	Opportunistic
LAKE WINNIPESAUKEE, MEREDITH BAY	NHLAK700020110-02-19	GILFORD	BELKNAP	FLAWTV-GEN	Opportunistic
LAKE WINNIPESAUKEE, MOULT. BAY	NHLAK700020110-02-19	MOULTONBOROUGH	CARROLL	FLIHLS-GEN	Opportunistic
LAKE WINNIPESAUKEE, SMITH COVE	NHLAK700020110-02-19	GILFORD	BELKNAP	ISLPEL-GEN	Opportunistic
LAKE WINNIPESAUKEE, WNT HBR	NHLAK700020110-02-19	WOLFEBORO	CARROLL	ISLNWI-GEN	Opportunistic
LAKE WINNIPESAUKEE, WOLFE. BAY	NHLAK700020110-02-19	WOLFEBORO	CARROLL	ISLSTD-GEN	Opportunistic
LAKE WINNISQUAM	NHLAK700020201-05-01	LACONIA	BELKNAP	ISLWAS-GEN	Opportunistic
LAKE WINNISQUAM MOHAWK ISL	NHLAK700020201-05-01	BELMONT	BELKNAP	MOOLTLAD	Opportunistic
LAKE WINNISQUAM POT ISLAND	NHLAK700020201-05-01	LACONIA	BELKNAP	MOOLTL-GEN	Opportunistic
LAKINS POND	NHLAK700060802-02	HOOKSETT	MERRIMACK	MOOTAM-GEN	Opportunistic
LAUREL LAKE	NHLAK802020202-02-01	FITZWILLIAM	CHESHIRE	POWHAN-GEN	Opportunistic
LEES POND	NHLAK700020103-05	MOULTONBOROUGH	CARROLL	POWKIN-GEN	Opportunistic
LITTLE CUB POND	NHLAK700061403-05	DANVILLE	ROCKINGHAM	PRANWID	Opportunistic
LITTLE ISLAND POND	NHLAK700061204-02	PELHAM	HILLSBOROUGH	FORWCH-GEN	Opportunistic
LITTLE SQUAM LAKE	NHLAK700010502-01-01	HOLDERNESS	GRAFTON	JACHSB-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
LITTLE TURKEY POND	NHLAK700060301-02-02	CONCORD	MERRIMACK	JACPIT-GEN	Opportunistic
LONG POND	NHLAK700061403-09	DANVILLE	ROCKINGHAM	JENNOR-GEN	Opportunistic
LONG POND	NHLAK700030502-01	HENNIKER	MERRIMACK	JERBER-GEN	Opportunistic
LONG POND	NHLAK802010101-04	LEMPSTER	SULLIVAN	MOUJAF-GEN	Opportunistic
LONG POND	NHLAK700060502-07	NORTHWOOD	ROCKINGHAM	PROEFF-GEN	Opportunistic
LOON LAKE	NHLAK700010307-01	PLYMOUTH	GRAFTON	PUREAT-GEN	Opportunistic
LOON POND	NHLAK600030703-02	FREMONT	ROCKINGHAM	RAIDER-GEN	Opportunistic
LOVELL LAKE	NHLAK600030401-01-01	WAKEFIELD	CARROLL	RANGOS-GEN	Opportunistic
LOWER FREESES POND	NHLAK600030701-02	DEERFIELD	ROCKINGHAM	FRAHSBD	Opportunistic
LOWER PEVERLY POND	NHIMP600030904-05	NEWINGTON	ROCKINGHAM	FRELDEE-GEN	Opportunistic
MANNING LAKE	NHLAK700060401-06	GILMANTON	BELKNAP	JUDCLK-GEN	Opportunistic
MARTIN MEADOW POND	NHLAK801030102-02	LANCASTER	COOS	KANMOU-GEN	Opportunistic
MASCOMA LAKE	NHLAK801060105-04-01	ENFIELD	GRAFTON	KEZSUT-GEN	Opportunistic
MASCOMA LAKE	NHLAK801060105-04-01	ENFIELD	GRAFTON	MOUWEA-GEN	Opportunistic
MASSABESIC LAKE	NHLAK700060702-03	AUBURN	ROCKINGHAM	REDSWH-GEN	Opportunistic
MASSABESIC LAKE	NHLAK700060702-03	AUBURN	ROCKINGHAM	RHUPIT-GEN	Opportunistic
MASSABESIC LAKE	NHLAK700060702-03	MANCHESTER	HILLSBOROUGH	RICRIC-GEN	Opportunistic
MAY POND	NHLAK802010101-05	WASHINGTON	SULLIVAN	FROJAF-GEN	Opportunistic
MCINDOE RESERVOIR	NHIMP801030205-02	MONROE	GRAFTON	FULCHE-GEN	Opportunistic
MELVIN POND	NHLAK700020104-01	TUFTONBORO	CARROLL	GILJAF-GEN	Opportunistic
MENDUMS POND	NHLAK600030707-01	BARRINGTON	STRAFFORD	GILSAN-GEN	Opportunistic
MERRIMACK RIVER	NHRIV700060302-25-02	BOW	MERRIMACK	KILGRA-GEN	Opportunistic
MERRYMEETING LAKE	NHLAK700020102-03	NEW DURHAM	STRAFFORD	NATMMK-GEN	Opportunistic
MESSER POND	NHLAK700030303-04	NEW LONDON	MERRIMACK	NEWBRI-GEN	Opportunistic
MIDDLE DANFORTH POND	NHLAK600020803-01-02	FREEDOM	CARROLL	ROBHUD-GEN	Opportunistic
MIRROR LAKE	NHLAK700020106-02-01	TUFTONBORO	CARROLL	ROBSTD-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
MOORE RESERVOIR	NHLAK801030202-01	LITTLETON	GRAFTON	ROCCRO-GEN	Opportunistic
MOORE RESERVOIR	NHLAK801030202-01	LITTLETON	GRAFTON	GOOCAN-GEN	Opportunistic
MOORES POND	NHLAK600020604-03	TAMWORTH	CARROLL	KUSSWH-GEN	Opportunistic
MOUNT WILLIAM POND	NHLAK700060602-02	WEARE	HILLSBOROUGH	LAKHOK-GEN	Opportunistic
MOUNTAIN BROOK RESERVOIR	NHLAK700030101-11	JAFFREY	CHESHIRE	NIPBAR-GEN	Opportunistic
NATICOOK LAKE	NHLAK700061002-04-01	MERRIMACK	HILLSBOROUGH	NORHAN-GEN	Opportunistic
NEWFOUND LAKE	NHLAK700010603-02-01	BRISTOL	GRAFTON	ROCFIT-GEN	Opportunistic
NIPPO POND	NHLAK600030605-01	BARRINGTON	STRAFFORD	ROCGLM-GEN	Opportunistic
NORTHWOOD LAKE	NHLAK700060502-08-01	NORTHWOOD	ROCKINGHAM	ROCWEN-GEN	Opportunistic
NORTON POND	NHLAK600030801-01	RAYMOND	ROCKINGHAM	ROCWIN-GEN	Opportunistic
NORWAY POND	NHLAK700030107-02-01	HANCOCK	HILLSBOROUGH	ROLGLM-GEN	Opportunistic
NUBANUSIT LAKE	NHLAK700030103-07	HANCOCK	HILLSBOROUGH	GOUHSB-GEN	Opportunistic
NUTT POND	NHLAK700060803-01	MANCHESTER	HILLSBOROUGH	LAUFIT-GEN	Opportunistic
ONWAY LAKE	NHLAK600030703-03-01	RAYMOND	ROCKINGHAM	LEEMOU-GEN	Opportunistic
OPECHEE BAY	NHLAK700020201-06-01	LACONIA	BELKNAP	NORRAY-GEN	Opportunistic
OTTER LAKE	NHLAK700030105-02-01	GREENFIELD	HILLSBOROUGH	NUBNEL-GEN	Opportunistic
OTTERNICK POND	NHLAK700061206-02	HUDSON	HILLSBOROUGH	NUTMAN-GEN	Opportunistic
PARTRIDGE LAKE	NHLAK801030502-03	LITTLETON	GRAFTON	ROUBAR-GEN	Opportunistic
PAWTUCKAWAY LAKE	NHLAK600030704-02-01	NOTTINGHAM	ROCKINGHAM	RUSHAR-GEN	Opportunistic
PEAKED HILL POND	NHLAK700010205-02	THORNTON	GRAFTON	RUSSUT-GEN	Opportunistic
PEARLY LAKE	NHLAK802020103-08	RINDGE	CHESHIRE	GRARIN-GEN	Opportunistic
PEMIGEWASSET LAKE	NHLAK700010801-01	MEREDITH	BELKNAP	GREANT-GEN	Opportunistic
PERKINS POND	NHLAK801060405-03	SUNAPEE	SULLIVAN	GREKIN-GEN	Opportunistic
PHILLIPS POND	NHLAK600030802-03-01	SANDOWN	ROCKINGHAM	GRELIV-GEN	Opportunistic
PINE RIVER POND	NHLAK600020703-03	WAKEFIELD	CARROLL	SWASWA-GEN	Opportunistic
PISGAH RESERVOIR	NHLAK802010403-05	WINCHESTER	CHESHIRE	TAYHAM-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
PLEASANT LAKE	NHLAK700060502-09-01	DEERFIELD	ROCKINGHAM	TEWGRA-GEN	Opportunistic
PLEASANT LAKE	NHLAK700030402-02-01	NEW LONDON	MERRIMACK	THOJAF-GEN	Opportunistic
POOL POND	NHLAK700030101-12	RINDGE	CHESHIRE	THRUWRR-GEN	Opportunistic
POTANIPO POND	NHLAK700040401-02-01	BROOKLINE	HILLSBOROUGH	TODNBY-GEN	Opportunistic
POWDER MILL POND	NHLAK700030107-03	HANCOCK	HILLSBOROUGH	TOMWRN-GEN	Opportunistic
POWWOW POND	NHIMP700061403-04	KINGSTON	ROCKINGHAM	TOWCND-GEN	Opportunistic
PRATT POND	NHLAK700060901-03	NEW IPSWICH	HILLSBOROUGH	TROFRE-GEN	Opportunistic
PROVINCE LAKE	NHLAK600020902-01	WAKEFIELD	CARROLL	TROLYM-GEN	Opportunistic
PURITY LAKE	NHLAK600020803-06	EATON	CARROLL	TURBCON-GEN	Opportunistic
RAINBOW LAKE	NHLAK700061203-05	DERRY	ROCKINGHAM	TURBOW-GEN	Opportunistic
RAND POND	NHLAK801060403-04-01	GOSHEN	SULLIVAN	TURLCON-GEN	Opportunistic
RED HILL POND	NHLAK700020103-08	SANDWICH	CARROLL	UMBERR1D	Opportunistic
RHUBARB POND	NHLAK400010202-02	PITTSBURG	COOS	SUNSUN2D	Opportunistic
RICE BROOK	NHRIV802010302-01	RICHMOND	CHESHIRE	SIPFIT-GEN	Opportunistic
ROBB RESERVOIR	NHIMP700030202-02	STODDARD	CHESHIRE	UMBERR4D	Opportunistic
ROBINSON POND	NHLAK700061203-06-01	HUDSON	HILLSBOROUGH	SMIWAS-GEN	Opportunistic
ROCK POND	NHLAK700061204-03	WINDHAM	ROCKINGHAM	SNOCON-GEN	Opportunistic
ROCKWOOD POND	NHLAK802010303-04	FITZWILLIAM	CHESHIRE	SOLNBY-GEN	Opportunistic
ROCKY POND	NHLAK700060201-04	LOUDON	MERRIMACK	SONNFD-GEN	Opportunistic
ROCKY POND	NHLAK700010304-06	WENTWORTH	GRAFTON	WALBOS-GEN	Opportunistic
ROCKYBOUND POND	NHLAK801060404-01	CROYDON	SULLIVAN	WARALS-GEN	Opportunistic
ROLLINS POND	NHLAK700060501-05	GILMANTON	BELKNAP	SPOCHE-GEN	Opportunistic
ROUND POND	NHLAK600030606-03-02	BARRINGTON	STRAFFORD	WATNWI-GEN	Opportunistic
ROUND POND	NHLAK700060503-05	EPSOM	MERRIMACK	SPONEL-GEN	Opportunistic
RUSSELL POND	NHLAK700010203-02	WOODSTOCK	GRAFTON	SPRDEE-GEN	Opportunistic
RUSSELL POND	NHLAK700030302-05	SUTTON	MERRIMACK	SQUHOL2D	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
RUSSELL RESERVOIR	NHLAK802010202-07	HARRISVILLE	CHESHIRE	WEBFRK-GEN	Opportunistic
RUST POND	NHLAK700020101-07-01	WOLFEBORO	CARROLL	WENWOL-GEN	Opportunistic
SAND POND	NHLAK802010101-08	MARLOW	CHESHIRE	STEMAN-GEN	Opportunistic
SEBBINS POND	NHLAK700060804-02	BEDFORD	HILLSBOROUGH	STIRUM-GEN	Opportunistic
SESSIONS POND	NHLAK400010602-13	DUMMER	COOS	WHIALB-GEN	Opportunistic
SHELLCAMP POND	NHLAK700060201-05	GILMANTON	BELKNAP	STOGTM-GEN	Opportunistic
SILVER LAKE	NHLAK802010202-09	HARRISVILLE	CHESHIRE	STUHOP-GEN	Opportunistic
SILVER LAKE	NHLAK600020801-06-01	MADISON	CARROLL	WHIHOL-GEN	Opportunistic
SIP POND	NHLAK802020103-10	FITZWILLIAM	CHESHIRE	WICMER-GEN	Opportunistic
SMITH POND	NHLAK700030203-02	WASHINGTON	SULLIVAN	SUNGRE-GEN	Opportunistic
SNOW POND	NHLAK700060302-07	CONCORD	MERRIMACK	WILSOM-GEN	Opportunistic
SONDOGARDY POND	NHLAK700060101-02-01	NORTHFIELD	MERRIMACK	WILSWA-GEN	Opportunistic
SPOFFORD LAKE	NHLAK801070503-01-01	CHESTERFIELD	CHESHIRE	WINALT-GEN	Opportunistic
SPOONWOOD LAKE	NHLAK700030103-09	NELSON	CHESHIRE	SUNMID-GEN	Opportunistic
SPRUCE POND	NHLAK600030702-02-01	DEERFIELD	ROCKINGHAM	WINMBEL-GEN	Opportunistic
SQUAM LAKE	NHLAK700010501-04-01	HOLDERNESS	GRAFTON	WINBGIL-GEN	Opportunistic
STEVENS POND	NHLAK700060803-02	MANCHESTER	HILLSBOROUGH	WINBWOL-GEN	Opportunistic
STINSON LAKE	NHLAK700010306-01	RUMNEY	GRAFTON	WINGGIL-GEN	Opportunistic
STOCKER POND	NHLAK801060401-02	GRANTHAM	SULLIVAN	WINHWOL-GEN	Opportunistic
STUBBS POND	NHLAK600030904-01	NEWINGTON	ROCKINGHAM	WINLAC-GEN	Opportunistic
STUMPFIELD-MUDGETT MARSH	NHIMP700030503-04	HOPKINTON	MERRIMACK	WINMERD	Opportunistic
SUNAPEE LAKE	NHLAK801060402-05-01	SUNAPEE	SULLIVAN	WINMER-GEN	Opportunistic
SUNRISE LAKE	NHLAK600030601-05-01	MIDDLETON	STRAFFORD	WINMOU-GEN	Opportunistic
SUNSET LAKE	NHLAK700030105-03-01	GREENFIELD	HILLSBOROUGH	WINPLAC-GEN	Opportunistic
SWAINS LAKE	NHLAK600030903-03	BARRINGTON	STRAFFORD	WINSGIL-GEN	Opportunistic
SWANZEY LAKE	NHLAK802010302-01-01	SWANZEY	CHESHIRE	WOOROX-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
TAYLOR RIVER REFUGE POND	NHLAK600031003-02	HAMPTON FALLS	ROCKINGHAM	ZEPGRE-GEN	Opportunistic
TEWKSBURY POND	NHLAK700010701-04	GRAFTON	GRAFTON	SUNUBRN-GEN	Opportunistic
THORNDIKE POND	NHLAK700030102-01-01	JAFFREY	CHESHIRE	SWABARAD	Opportunistic
TODD LAKE	NHLAK700030301-02	NEWBURY	MERRIMACK	CENNEL-GEN	Opportunistic
TOM POND	NHLAK700030304-05	WARNER	MERRIMACK	SILHAR-GEN	Opportunistic
TOWER HILL POND	NHLAK700060701-04	CANDIA	ROCKINGHAM	SILMADSD	Opportunistic
TROUT FARM		PLAINFIELD	SULLIVAN	LSQ11EL	Opportunistic
TROUT POND	NHLAK600020803-09	FREEDOM	CARROLL	NORNORST1	Opportunistic
TROUT POND	NHLAK801040203-02	LYME	GRAFTON	KIMHOP-GEN	Opportunistic
TUREE POND	NHLAK700060301-01	BOW	MERRIMACK	ROUEPS-GEN	Opportunistic
UPPER BAKER POND	NHLAK700010303-02	ORFORD	GRAFTON	PEVUNEW-GEN	Opportunistic
UPPER GREELEY POND	NHLAK700010401-04	LIVERMORE	GRAFTON	PEVLNEW-GEN	Opportunistic
UPPER PEVERLY POND	NHIMP600030904-04	NEWINGTON	ROCKINGHAM	STUNEW-GEN	Opportunistic
UPPER SUNCOOK POND	NHLAK700060402-10-02	BARNSTEAD	BELKNAP	ANDBER-GEN	Opportunistic
UPPER THREE PONDS	NHLAK700010306-03	WARREN	GRAFTON	ANDGOR-GEN	Opportunistic
WALKER POND	NHLAK700030506-02	BOSCAWEN	MERRIMACK	ANDSHE-GEN	Opportunistic
WARREN LAKE	NHLAK801070203-01	ALSTEAD	CHESHIRE	ASHWIN-GEN	Opportunistic
WATER LOOM POND	NHLAK700060901-01	NEW IPSWICH	HILLSBOROUGH	CONCOL-GEN	Opportunistic
WEBSTER LAKE	NHLAK700010804-02-01	FRANKLIN	MERRIMACK	CONCLA-GEN	Opportunistic
WHITE OAK POND	NHLAK700010501-05	HOLDERNESS	GRAFTON	CONCLK-GEN	Opportunistic
WHITTON POND	NHLAK600020303-09	ALBANY	CARROLL	CONHAN-GEN	Opportunistic
WICWAS LAKE	NHLAK700020201-04	MEREDITH	BELKNAP	CONLEB-GEN	Opportunistic
WILLAND POND	NHLAK600030405-03	SOMERSWORTH	STRAFFORD	CONLIT-GEN	Opportunistic
WILSON POND	NHLAK802010303-10	SWANZEY	CHESHIRE	CONWAL-GEN	Opportunistic
WOODWARD POND	NHIMP802010202-05	ROXBURY	CHESHIRE	MERBOW-GEN	Opportunistic
ZEPHYR LAKE	NHLAK700030105-01-01	GREENFIELD	HILLSBOROUGH	TROPLA-GEN	Opportunistic

Waterbody Name	Waterbody ID	Town	County	Station ID	Program
CASS POND	NHLAK802020203-01	RICHMOND	CHESHIRE	CASRIC-GEN	Structured
CLEMENT POND	NHLAK700030505-01	HOPKINTON	MERRIMACK	CLEHOP-GEN	Structured
CROOKED POND	NHLAK700060202-04	LOUDON	MERRIMACK	CROLOU-GEN	Structured
CRYSTAL LAKE	NHLAK801060104-01	ENFIELD	GRAFTON	CRYENF-GEN	Structured
HARVEY LAKE	NHLAK700060502-05	NORTHWOOD	ROCKINGHAM	HARNOR-GEN	Structured
HUBBARD POND	NHLAK700030101-10	RINDGE	CHESHIRE	HUBRIN-GEN	Structured
FOREST LAKE	NHLAK801030101-02-01	DALTON	COOS	FORDAL-GEN	Structured
GORHAM POND	NHLAK700060603-01	DUNBARTON	MERRIMACK	GORDUN-GEN	Structured
TURTLE POND	NHLAK700060302-08	CONCORD	MERRIMACK	TURCON-GEN	Structured
SPECTACLE POND	NHLAK801060102-03	ENFIELD	GRAFTON	SPEENF-GEN	Structured

Appendix C – Summary of mercury concentrations in largemouth bass for individual waterbodies. (+) indicates an increasing tendency; (-) indicates a decreasing tendency; mean standard error across waterbodies = 0.050. * Applied overall mean standard error to species.

Waterbody	Program Type	Year	Adjusted Mean Concentration (mg Hg/kg fish tissue)	Standard Error	Number of Fish	Mean length (cm)	Lake Tendency
Ashuelot Pond	Opportunistic	2001	0.70	0.06	5	31.2	Increasing
		2003	0.83	0.05	8	29.1	
Cass Pond	Structured	2001	0.60	0.05	5	31.1	Mixed
		2004	0.66	0.04	6	32.3	
		2009	0.75	0.06	5	33.5	
		2014	0.44	0.04	5	32.5	
Clement Pond	Structured	1998	0.25	0.05	5	34.0	Mixed
		2003	0.39	0.03	8	29.1	
		2008	0.40	0.04	5	30.7	
Crooked Pond	Structured	2000	0.47	0.04	5	32.6	Decreasing
		2010	0.39	0.04	5	32.4	
		2015	0.32	0.04	5	34.5	
Forest Lake	Structured	2001	0.29	0.05	5	31.6	Mixed
		2006	0.31	0.05	5	32.1	
		2011	0.22	0.05	5	28.9	
Harvey Lake	Structured	2001	0.39	0.11	5	29.2	Mixed
		2006	0.47	0.04	5	29.8	
		2011	0.41	0.04	5	35.3	
Hubbard Pond	Structured	2004	0.95	0.16	5	31.1	Decreasing
		2009	0.89	0.13	5	34.3	
Gorham Pond	Structured	1998	0.32	0.05	5	31.2	Mixed
		2003	0.71	0.03	10	28.3	
		2008	0.78	0.05	5	28.9	
		2013	0.41	0.04	5	27.1	
Mendums Lake	Opportunistic	2011	0.51	0.03	14	33.0	Increasing
		2012	0.68	0.05	10	27.4	
Turtle Pond	Structured	2000	0.51	0.05*	5	31.8	Mixed
		2005	0.80	0.05*	5	32.5	
		2010	0.50	0.05*	5	36.8	
		2015	0.52	0.05*	5	30.2	

Appendix D – Summary of mercury concentrations in yellow perch for individual waterbodies. (+) indicates an increasing tendency; (-) indicates a decreasing tendency; mean standard error across waterbodies = 0.052.

Waterbody	Program Type	Year	Adjusted Mean Concentration (mg Hg/kg fish tissue)	Standard Error	Number of Fish	Mean length (cm)	Lake Tendency
Angle Pond	Opportunistic	2002	0.38	0.04	5	26.1	Increasing
		2006	0.39	0.03	7	28.6	
Bellemey Reservoir	Opportunistic	1997	0.53	0.04	5	22.4	Decreasing
		2000	0.38	0.02	10	23.0	
Dan Hole Pond	Opportunistic	2014	0.25	0.05	5	15.6	Decreasing
		2016	0.24	0.06	5	23.2	
Bow Lake	Opportunistic	2000	0.34	0.04	5	15.9	Mixed
		2011	0.20	0.02	10	16.7	
		2012	0.24	0.01	20	16.1	
Canobie Lake	Opportunistic	2000	0.28	0.02	5	24.0	Decreasing
		2006	0.17	0.03	6	18.8	
Clement Pond	Structured	1998	0.20	0.10	5	16.1	Mixed
		2008	0.18	0.11	5	16.2	
		2009	0.26	0.03	10	21.5	
		2014	0.18	0.02	10	20.1	
Comeford Reservoir	Opportunistic	1998	0.43	0.05	16	23.2	Mixed
		2003	0.20	0.02	24	17.9	
		2008	0.23	0.01	91	17.5	
Crooked Pond	Structured	2002	0.24	0.04	5	21.0	Mixed
		2007	0.15	0.04	5	21.7	
		2012	0.29	0.09	6	19.3	
Crystal Lake, Enfield	Structured	2002	0.24	0.05	5	21.7	Mixed
		2007	0.15	0.04	5	18.4	
		2012	0.29	0.05	5	18.6	
Crystal Lake, Gilmanton	Opportunistic	1998	0.29	0.04	9	26.0	Increasing
		2004	0.50	0.05	6	20.6	
		2005	0.54	0.14	7	17.0	
Dubes Pond	Opportunistic	2001	0.54	0.06	5	20.1	Increasing
		2006	0.80	0.07	5	19.7	
Eastman Lake	Opportunistic	2014	0.14	0.01	5	19.3	Increasing
		2015	0.17	0.01	6	20.6	

Waterbody	Program Type	Year	Adjusted Mean Concentration (mg Hg/kg fish tissue)	Standard Error	Number of Fish	Mean length (cm)	Lake Tendency
Forest Lake	Structured	2001	0.36	0.12	5	24.6	Mixed
		2006	0.13	0.04	5	17.9	
		2011	0.14	0.02	6	20.3	
Goose Pond	Opportunistic	2009	0.47	0.06	6	20.0	Decreasing
		2010	0.34	0.08	7	16.0	
Gorham Pond	Structured	1998	0.25	0.02	5	20.2	No change
		2008	0.26	0.02	5	21.7	
Grassy Pond	Opportunistic	2007	0.50	0.04	10	20.1	Increasing
		2009	0.52	0.04	10	22.4	
Great Pond, Kingston	Opportunistic	2006	0.24	0.03	5	20.4	No change
		2007	0.25	0.03	5	20.2	
Harvey Lake	Structured	2001	0.29	0.04	5	19.5	Decreasing
		2006	0.20	0.03	5	21.6	
Hubbard Pond	Structured	2000	0.25	0.05	7	23.2	Increasing
		2004	0.33	0.03	8	21.9	
		2009	0.54	0.06	5	21.1	
Jeness Pond	Opportunistic	1999	0.20	0.02	5	18.0	Increasing
		2000	0.31	0.02	5	17.2	
Lakins Pond	Opportunistic	2001	0.49	0.04	5	21.3	Decreasing
		2006	0.39	0.03	5	22.9	
May Pond	Opportunistic	1995	0.52	0.14	5	21.2	Mixed
		1996	0.67	0.04	12	19.3	
		2004	0.53	0.05	8	20.2	
		2007	0.55	0.04	11	18.0	
Mendums Pond	Opportunistic	2000	0.39	0.04	5	21.6	Mixed
		2011	0.24	0.03	10	16.0	
		2012	0.30	0.02	20	17.5	
Moore Reservoir	Opportunistic	1998	0.08	0.07	11	23.8	Mixed
		2003	0.31	0.02	22	19.5	
		2008	0.27	0.01	70	15.4	
Northwood Lake	Opportunistic	1998	0.22	0.04	21	11.9	Decreasing
		2000	0.14	0.11	5	23.5	
Pawtuckaway Lake	Opportunistic	1999	0.10	0.09	5	24.1	Increasing
		2012	0.20	0.02	20	18.2	
Robb Reservoir	Opportunistic	1999	0.52	0.05	5	21.4	Decreasing

Waterbody	Program Type	Year	Adjusted Mean Concentration (mg Hg/kg fish tissue)	Standard Error	Number of Fish	Mean length (cm)	Lake Tendency
		2006	0.45	0.06	5	24.5	
Spectacle Pond	Structured	2002	0.34	0.03	5	18.0	Decreasing
		2007	0.21	0.03	5	19.4	
		2012	0.16	0.02	11	18.5	
Sunrise Lake	Opportunistic	1999	0.16	0.02	5	17.3	Increasing
		2008	0.22	0.01	10	17.3	
Swains Lake	Opportunistic	1998	0.34	0.04	26	11.2	Decreasing
		2011	0.19	0.02	10	16.5	
		2012	0.13	0.03	20	21.1	
Turee Pond	Opportunistic	2001	0.40	0.10	5	22.4	Mixed
		2010	0.33	0.05	6	24.0	
		2011	0.24	0.08	5	24.8	
		2014	0.41	0.05	6	23.2	
Turtle Pond	Structured	2000	0.43	0.14	5	23.5	Mixed
		2005	0.71	0.08	5	22.7	
		2010	0.37	0.06	6	22.9	
		2015	0.31	0.11	5	19.4	
Warren Lake	Opportunistic	2008	0.38	0.04	6	22.5	Decreasing
		2009	0.36	0.03	10	22.0	
Wilson Pond	Opportunistic	1999	0.11	0.01	5	17.6	Increasing
		2006	0.12	0.01	10	17.0	

Appendix E – Formulas and example calculations of risk-based consumption limit used in New Hampshire fish advisory using average fish concentration assumed by NHDES and EPA-recommended water quality criteria.

Formulas:

$$CR = \frac{RfD \times BW}{C_{fish}}$$

Where:

CR = Maximum allowable consumption rate (kg / day)

RfD = toxicological reference dose for methylmercury (MeHg)

(0.0003 mg / kg / day for children 7 years or older and other adults)

(0.0001 mg / kg / day for woman of childbearing age and children under 7 years of age)

BW = Body weight

(70 kg; weight of average adult males and females in US population)

(61 kg; weight of average adult females in US population)

C_{fish} = Reference concentration of fish used to set advisory

(0.70 mg / kg; average concentration assumed by NHDES)

(0.30 mg / kg; EPA recommended water quality criteria)

$$RBCL = \frac{CR \times \text{days per month}}{\text{Portion Size}}$$

Where:

Days per month = 30.4

Portion size = 8 ounces (0.227kg)

Examples (using RfD of 0.0003 mg / kg and body weight of 70kg):

NHDES reference concentration

$$CR = \frac{0.0003 \text{ mg Hg /kg BW/day} \times 70\text{kg BW}}{0.70 \text{ mg Hg/kg fish}}$$

$$CR = 0.030 \text{ kg fish/day}$$

$$RBCL = \frac{0.030 \text{ kg fish/day} \times 30.4 \text{ days/month}}{0.227 \text{ kg /meal}}$$

$$RBCL = 4 \text{ meals/month}$$

EPA reference concentration

$$CR = \frac{0.0003 \text{ mg Hg /kg BW/day} \times 70\text{kg BW}}{0.30 \text{ mg Hg/kg fish}}$$

$$CR = 0.070 \text{ kg fish/day}$$

$$RBCL = \frac{0.070 \text{ kg fish/day} \times 30.4 \text{ days/month}}{0.227 \text{ kg /meal}}$$

$$RBCL = 9 \text{ meals/month}$$