Long-term monitoring of mercury in fish tissue at Moore and Comerford Reservoirs: 2003

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1. EXECUTIVE SUMMARY

USGen New England, Inc. was tasked to initiate a long-term fish mercury (Hg) monitoring program in 2003. Based on earlier Hg characterization efforts related to the Fifteen Mile Falls Settlement Agreement, two reservoirs, Moore and Comerford, were selected for monitoring purposes. Monitoring efforts include seven fish species representing two size classes. Prey fish (10-20 cm) Hg levels provide a basis for ecological risk assessment while large fish (>25 cm) Hg levels are useful for assessing potential human health risks. Analysis of 92 prey fish indicates a tendency for greater ecological risk in Moore Reservoir than Comerford Reservoir. Prey fish Hg levels for similar sized individuals tend to be more elevated in rock bass, smallmouth bass, and yellow perch and less elevated in fallfish and rainbow trout. Based on analysis of 75 fillets, large fish Hg levels tend to be more elevated for smallmouth bass and yellow perch and less elevated for white sucker.

2. STUDY AREA:

Moore and Comerford reservoirs of the Fifteen Mile Falls Hydroelectric Project were sampled at two sites each; in the north and the south ends (Figure 1). Evers et al. (2003) found significant differences in fish Hg levels within each reservoir, thereby necessitating multiple site-specific sampling efforts.

2.1. Moore Reservoir: Fish sampling locations were selected based on the geographic locality of the site in the reservoir and the presence of suitable fish habitat. Fish were collected from the Roaring Brook area-designated as the "North" site and from Old Waterford Road Cove and Halls Brook Cove in the "South" end of the reservoir (Figure 1). Both sites contained submerged stumps and trees that offered important habitat for fish. Smaller fish prefer the vegetated shallow water present in each site sampled. Small size class fish were typically netted closer to the shore, while large size class fish were collected in the middle of the cove.

2.2. Comerford Reservoir. Fish sites in this reservoir generally lacked submerged stumps. Both – the north and south end sampling sites contained submerged vegetation. The North Site was located downstream from Moore Dam in Comerford Reservoir and the South Site was further down near the Chandler Brook Cove. The shoreline was a mix of sand and cobblestone.

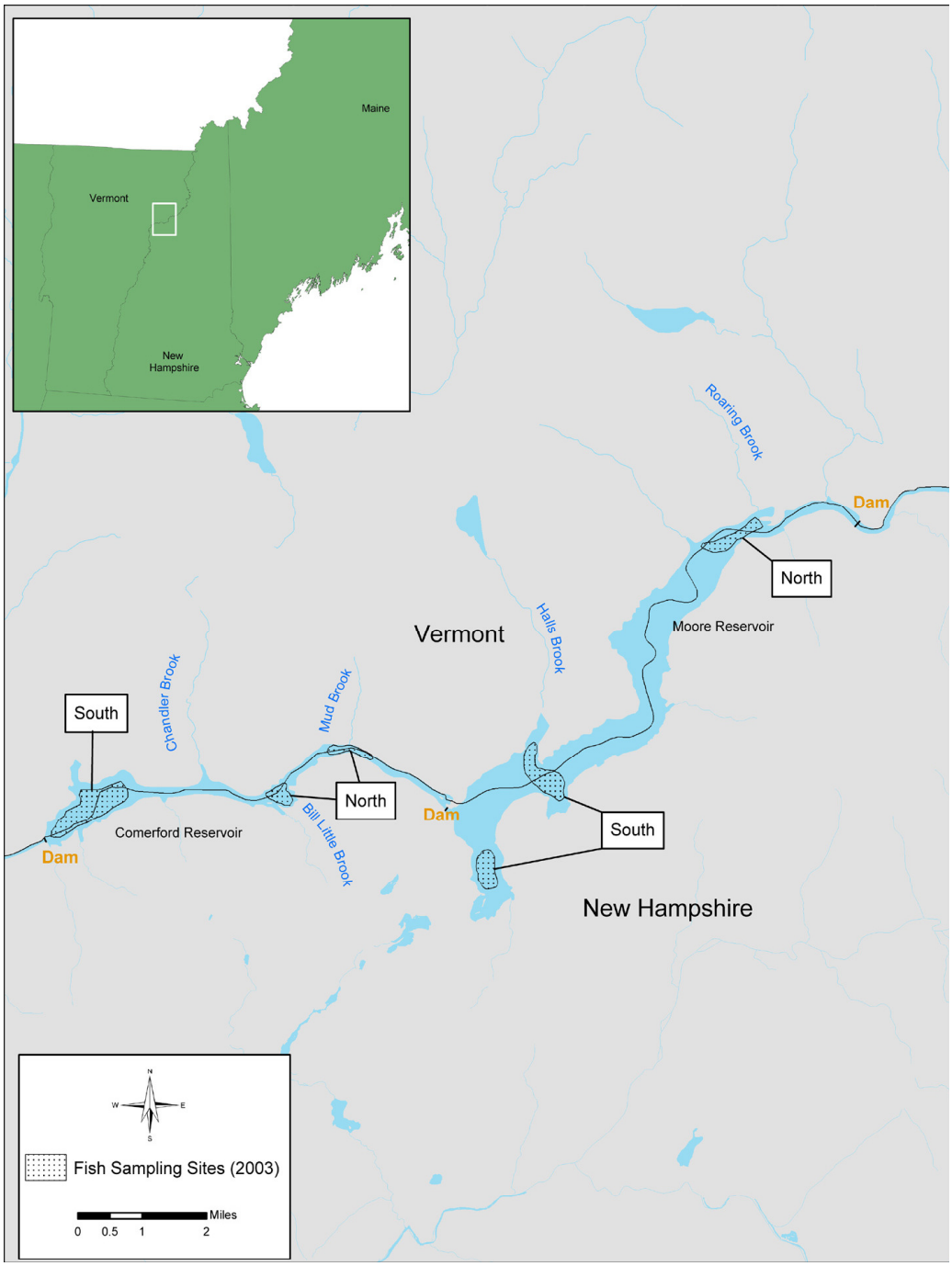
3. METHODS:

3.1 Target species: Two size classes of seven fish species (yellow perch, *Perca flavescens*; rock bass, *Ambloplites rupestris*; smallmouth bass, *Micropterus dolomieu*; white sucker, *Catostomus commersoni*; and fallfish, *Semotilus corporalis*) were targeted. The time of the year severely limited sampling efforts of brown (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*).

3.2 Fish collection and processing: Fisheries biologists from USFWS and NHDES advised and assisted with field efforts. A total of 592 field person-hours were tallied. Fish capture methods included gill and fyke nets, electrofishing and angling. All fish were measured for total length,

weighed, and wrapped in plastic and double-bagged in labeled zip-lock bags. Two fillets were taken from each fish > 25 cm. One fillet was archived in the freezer and the other one was analyzed. Skin was removed from fillets and fillets were frozen immediately thereafter. Scales were taken from all fish, above the pectoral fin and below the midspine for age determination at a later date. Bony structures such as otoliths (bass, perch) and operculae (white suckers) were collected from larger fish. Sex was only determined consistently in mature fish > 25 cm.

Figure 1. Fish sampling sites on Comerford and Moore Reservoirs, 2003.



3.3 Sampling modifications: We modified sampling methodologies because of seasonal time restrictions and the lack of certain species of a required size class. Small white suckers typically spend their first several years in the streams and swim to the lake when sexually mature. Consequently, we were unable to catch suckers under 20 cm in the reservoirs. We used a variety of fish sampling gear to collect target species and sizes. Apparently, several of the target species do not exceed 25 cm in the study area. The largest yellow perch caught was 28 cm and many were between 20-25 cm. We encountered similar trends with fallfish and rock bass. Even though, in optimal growing conditions fallfish can grow up to 50 cm and rock bass up to 40 cm, in the study area all individuals of these species were below 25 cm in length. We modified our methods to accommodate these findings and we used 20-25 cm individuals as our large size class. Trout were not available. According to state and local fishermen there are not many trout in the reservoirs and they are particularly difficult to catch at this time of the year.

3.4 Weather: Fish sampling occurred in late fall, September 13-25 and October 23-24, 2003. Typical weather was characterized by cool mornings (40 °F) and sunny and warm afternoons (60s °F). During the last two sampling days in October the weather conditions were cold (30 °F), windy with blowing snow.

3.5 Sample lab analysis and QA/QC: All fish samples were analyzed at Texas A&M University's Trace Element Research Laboratory (TERL) College Station, Texas. TERL has conducted the analysis for a large-scale, multi-year project through NELSWG for fish fillets and fish whole bodies. Homogenization of fish fillets and fish whole bodies occurred in the laboratory and followed standard USFWS protocols. The cold vapor mercury analyzer used in this laboratory is an LCD Model 1235 uvMonitor equipped with a 30 cm path length absorption cell and operating at the 254 nm wavelength. The instrument is attached to a Houston Instrument Omniscribe chart recorder operating at 10 mV fullscale. All results are reported as total mercury on wet weight (ww) basis in part per million (ppm), which is the same as micrograms per gram (µg/g).

Quality control samples are processed in a manner identical to actual samples. Three method blanks are run with every 35 samples or with every sample set, whichever is more frequent.

Tissue Reference Materials as closely matching the sample set as available are run with each sample set. Two different materials are run to maximize the possible interferences seen. Control charts for these analyses are then established.

Reagent Blanks of digestion reagents (HNO_3, $NH_2OH \cdot HCl$, $KMnO_4$, $K_2S_2O_8$) and laboratory water supplies (both distilled/deionized and distilled/sub-boiling quartz-distilled) are routinely analyzed to identify sources of contamination before samples are processed.

Interferences are investigated by performing *matrix spike* determinations on the samples. A small volume of Hg standard is added to a portion of the sample, which is then analyzed as above. Matrix spike recovery is considered acceptable when it is within 10% of 100%. If the recovery is outside these limits, the analysis is repeated and the reanalysis data is reported if it meets the criterion.

Duplicate Samples are run with every 20 samples or with every sample set. Inhomogeneous samples may result in greater variability between duplicates. Experience has indicated that reference materials are more homogeneous than are samples, and thus comparison of a) reference material duplicate analyses, b) sample duplicate analyses and c) duplicate analyses from single digestion solutions gives an indication of a) total analytical variability (i.e. processing plus instrumental variability), b) the sum of analytical variability and natural sample in homogeneity, and c) instrumental variability.

4. RESULTS

4.1 Project inflow and elevation during monitoring period

On the whole, the sampling period received higher than average inflows. As evident from the charts the discharge out of Moore (Figure 2) was quite high during the last week or so of the sampling period but was generally a two unit operation for a few hours each day and then minimum flows of 320 or so for the remainder. This periodic inflow into Comerford causes that reservoir to fluctuate on a daily basis while Comerford's minimum flow of 818 cfs (until 9/30) and 1145 cfs (10/1 onward) slowly drops the pond unless additional generation is called for which can be seen on the chart. Additional generation at Comerford starting around October 21 (Figure 3) corresponds with the increase in discharge coming out of Moore (due to high Dalton inflows and Moore Reservoir rising).

Figure 2. Moore Development flow and discharge data, 2003

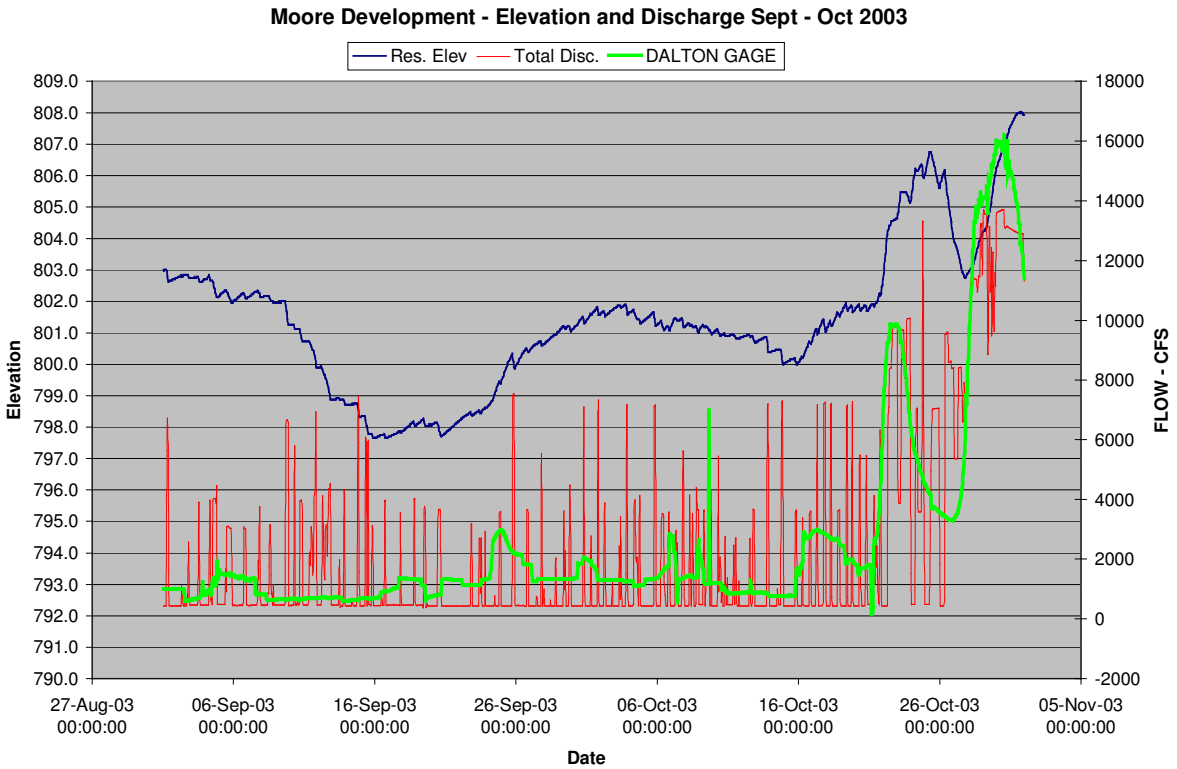
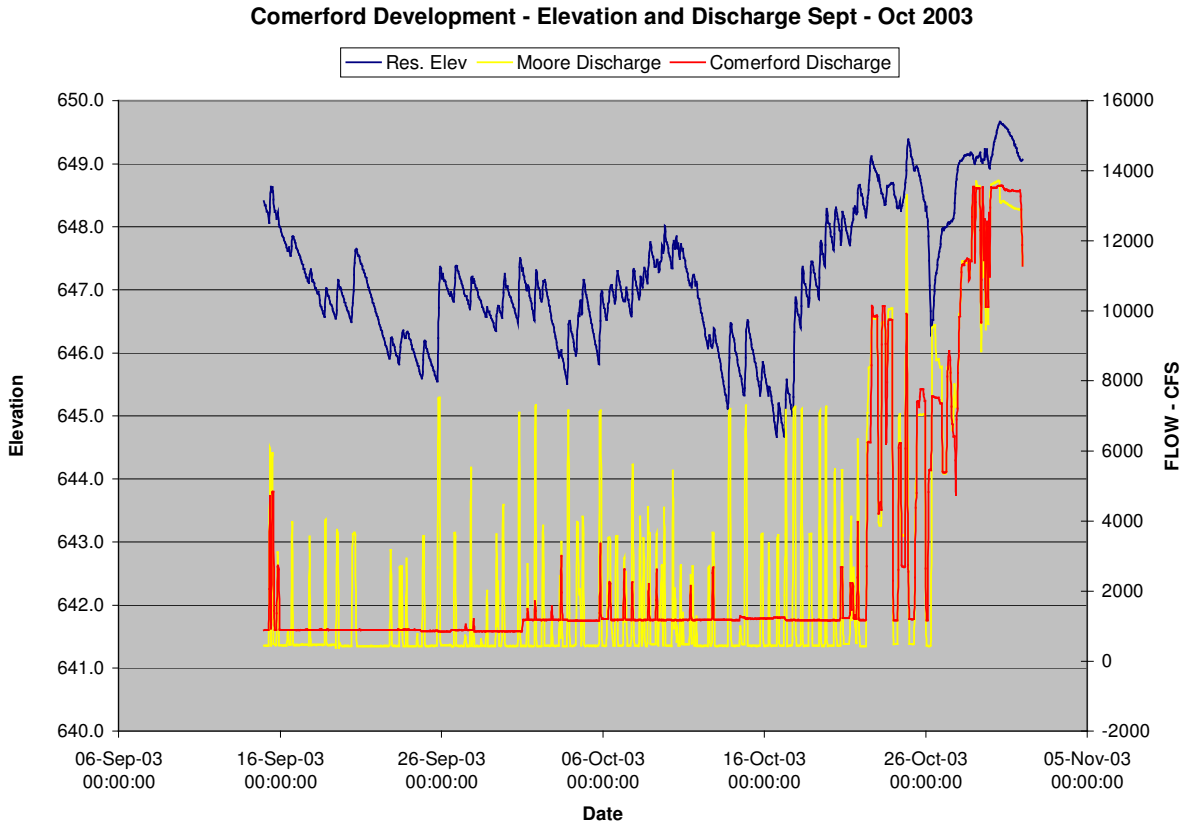


Figure 3. Comerford Development flow and discharge data, 2003.



4.2. Fish Hg concentrations:

Results of large fish fillet Hg levels are shown in Table 1. Smallmouth bass and yellow perch fillet Hg concentrations are more elevated than white sucker levels (Figure 4, Table 1). Bass and perch are predatory fish and feed at a higher trophic level than suckers, which partly explains differences in Hg body burdens.

Table 1. Arithmetic mean and standard deviation of fillet total Hg levels (ppm, ww) from large fish collected in Comerford and Moore Reservoirs, 2003.

	Smallmouth Bass	Yellow Perch	White Sucker
Comerford	1.02 +/- 0.46 (17)	0.95 +/- 0.45 (4)	0.33 +/- 0.22 (20)
Moore	1.09 +/- 0.39 (22)	0.84 +/- 0.24 (3)	0.35 +/- 0.20 (9)

Figure 4. Mean Hg levels in large fish fillets from Comerford and Moore Reservoirs, 2003.

Results of prey fish, whole body Hg levels are shown in Tables 2 and 3. Because fish of the 20-25 cm size class were frequently encountered we processed and analyzed them to increase overall samples size as well as to provide a better understanding for biotic uptake potential to higher trophic level piscivores. Geographic and species patterns in Hg levels found in prey fish were similar to those in large fish. Prey fish Hg levels in Moore Reservoir tended to be more elevated than those in Comerford Reservoir. Prey fish that were 20-25 cm, representing both

Table 2. Arithmetic mean and standard deviation of whole body total Hg levels (ppm, ww) from prey fish (10-20 cm) collected in Comerford and Moore Reservoirs, 2003.

	Smallmouth Bass	**Yellow perch**	**Rock bass**	**Fallfish**	**Rainbow trout**
Comerford	0.09 +/- 0.03 (4)	0.13 +/- 0.05 (15)	N/A	N/A	0.03 +/- 0.003 (2)
Moore	0.23 +/- 0.07 (9)	0.24 +/- 0.18 (10)	0.29 +/- 0.18 (4)	0.12 +/- 0.05 (6)	N/A

N/A = not available

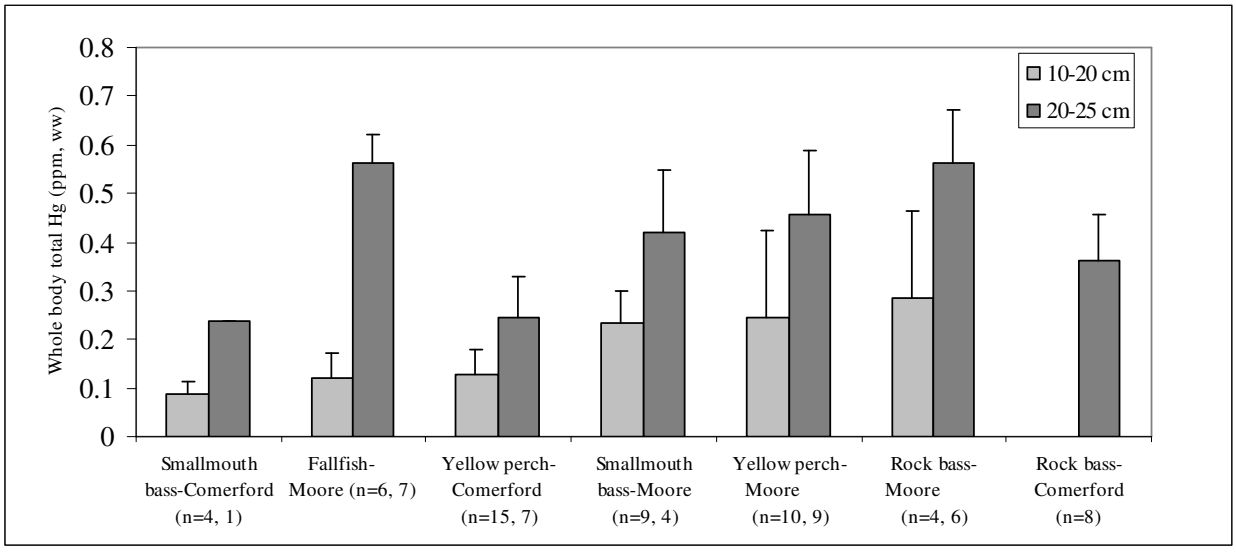
Table 3. Arithmetic mean and standard deviation of whole body total Hg levels (ppm, ww) from prey fish (20-25 cm) collected in Comerford and Moore Reservoirs, 2003.

	Smallmouth Bass	**Yellow perch**	**Rock bass**	**Fallfish**
Comerford	0.236 (1)	0.244+/-0.084 (7)	0.361+/-0.095 (8)	N/A
Moore	0.42+/-0.129 (4)	0.457+/-0.131 (9)	0.563+/-0.109 (6)	0.095+/-0.058 (7)

N/A = not available

reservoirs and all species collected, tended to have Hg levels more elevated than their smaller counterparts (10-20 cm). For many fish species, increases in size relate to (1) forage base changes from primarily insectivorous to piscivorous diets and (2) non-linear increase in age. Therefore, we documented a relatively consistent pattern of Hg biomagnification and bioaccumulation between the two size classes of prey fish (Figure 5).

Figure 5. Mean Hg levels in prey fish from Comerford and Moore Reservoirs, 2003.



Mercury levels and associated metadata are provided for each individual fish in Appendices I-IX.

5. LITERATURE CITED:

Evers, D.C., O. Lane, D. Albano, and C. Pennuto. 2003. Investigation into mercury exposure and risk to wildlife for the 15 Mile Falls Project, 2000. Report BRI 2003-08 submitted to USGen New England, Inc. BioDiversity Research Institute, Falmouth, Maine.

Appendix I. Individual fish fillet total mercury (ppm, wet weight) from Comerford Reservoir, 2003

Comerford Reservoir

Sample #	Species	Length (cm)	Weight (g)	Sex	Fillet TH ppm, ww
COSOSB0503-F	smallmouth bass	33.6	506.4	female	0.993
CONORSB1403-F	smallmouth bass	32.7	478.4	female	0.789
CONORSB1503-F	smallmouth bass	33.5	534.1	female	0.637
COSOSB0603-F	smallmouth bass	40.0	916.6	female	2.16
COSOSB0103-F	smallmouth bass	25.1	203.3	male	0.456
COSOSB0303-F	smallmouth bass	36.5	654.1	male	0.878
CODAMSB0103-F	smallmouth bass	30.0	381.7	male	0.547
CONORSB0203-F	smallmouth bass	31.5	397.6	male	0.606
CONORSB0303-F	smallmouth bass	33.0	475.1	male	0.908
CONORSB0403-F	smallmouth bass	43.0	928.0	male	1.32
CONORSB0503-F	smallmouth bass	34.0	557.5	male	0.819
CONORSB0603-F	smallmouth bass	34.5	541.5	male	1.36
CONORSB1003-F	smallmouth bass	40.0	1152.6	male	1.26
CONORSB1103-F	smallmouth bass	37.0	818.0	male	1.55
CONORSB1303-F	smallmouth bass	38.7	799.9	male	1.48
COSOSB0703-F	smallmouth bass	40.0	822.8	male	1.12
COSOSB0403-F	smallmouth bass	30.5	414.8	male	0.400
CONORWS0403-F	white sucker	39.0	702.2	female	0.283
CONORWS0703-F	white sucker	39.5	818.1	female	0.234
CONORWS0803-F	white sucker	41.5	891.9	female	0.282
CONORWS0903-F	white sucker	41.0	794.2	female	0.170
CONORWS1003-F	white sucker	41.0	794.6	female	0.273
CONORWS1103-F	white sucker	41.0	790.1	female	0.190
CONORWS1203-F	white sucker	41.0	884.4	female	0.141
CONORWS1303-F	white sucker	40.0	783.1	female	0.528
CONORWS1403-F	white sucker	43.5	868.2	female	0.571
CONORWS1603-F	white sucker	41.0	664.8	female	0.396
CONORWS1703-F	white sucker	41.3	968.2	female	0.205
COSOWS0203-F	white sucker	39.5	677.8	female	0.273
CONORWS0103-F	white sucker	42.5	831.3	male	0.209
CONORWS0203-F	white sucker	38.5	638.7	male	0.205
CONORWS0303-F	white sucker	40.5	726.4	male	0.228
CONORWS0503-F	white sucker	42.0	761.0	male	1
CONORWS0603-F	white sucker	42.0	733.4	male	0.732
CONORWS1503-F	white sucker	43.5	886.5	male	0.206
COSOWS0103-F	white sucker	37.5	609.9	male	0.139
COSOWS0303-F	white sucker	38.5	697.3	male	0.273
COSOYP0703-F	yellow perch	25.2	197.8	female	0.521
COSOYP1203-F	yellow perch	28.0	220.1	female	1.18
COSOYP0403-F	yellow perch	25.1	179.1	male	0.637
CONORYP0803-F	yellow perch	27.5	239.0	male	1.47
NPIKE03-F	northern pike	70.6	3016.0	male	0.858

Appendix II. Individual fish fillet total mercury (ppm, wet weight) from Moore Reservoir, 2003					
Moore Reservoir					
Sample #	**Species**	**Length (cm)**	**Weight (g)**	**Sex**	**Fillet TH ppm, ww**
MOHBCSB0303-F	smallmouth bass	27.1	243.7	female	0.523
MOHBCSB0403-F	smallmouth bass	25.5	208.4	male	0.528
MOHBCSB0203-F	smallmouth bass	28.5	292.6	male	0.624
MOHBCSB0703-F	smallmouth bass	25.0	174.7	male	0.723
MORBCSB0503-F	smallmouth bass	29.5	320.2	male	0.902
MORBCSB1503-F	smallmouth bass	30.0	348.1	male	0.944
MORBCSB0203-F	smallmouth bass	29.5	339.3	male	0.984
MOHBCSB0103-F	smallmouth bass	26.6	239.0	female	0.696
MOOWCSB0103-F	smallmouth bass	27.6	283.9	male	0.699
MOHBCSB1303-F	smallmouth bass	37.0	635.4	male	0.89
MORBCSB0103-F	smallmouth bass	28.4	281.7	male	1.02
MOHBCSB1203-F	smallmouth bass	26.6	213.4	male	1.03
MOHBCSB1103-F	smallmouth bass	28.0	268.2	male	1.09
MORBCSB1403-F	smallmouth bass	36.0	562.7	male	1.22
MORBCSB1303-F	smallmouth bass	35.5	614.3	male	1.32
MOOWCSB0203-F	smallmouth bass	35.7	599.0	male	1.36
MOOWCSB0303-F	smallmouth bass	32.6	378.8	male	1.37
MORBCSB1203-F	smallmouth bass	33.5	469.8	female	1.52
MORBCSB0403-F	smallmouth bass	35.3	551.8	male	1.53
MORBCSB1003-F	smallmouth bass	39.0	725.7	male	1.59
MORBCSB1103-F	smallmouth bass	32.0	391.5	male	1.6
MORBCSB1703-F	smallmouth bass	34.5	483.7	male	1.9
MORBCWS0303-F	white sucker	40.5	772.6	female	0.135
MORBCWS0603-F	white sucker	42.0	864.0	female	0.158
MORBCWS0203-F	white sucker	40.0	766.7	female	0.177
MORBCWS0403-F	white sucker	43.0	900.3	female	0.230
MORBCWS0803-F	white sucker	43.0	837.5	male	0.244
MORBCWS0503-F	white sucker	49.5	1362.0	female	0.557
MORBCWS0903-F	white sucker	48.0	1082.0	female	0.588
MORBCWS0103-F	white sucker	47.0	1035.8	male	0.404
MORBCWS0703-F	white sucker	42.0	833.0	male	0.653
MORBCYP1903-F	yellow perch	26.5	212.0	female	0.598
MORBCYP1703-F	yellow perch	25.0	158.6	male	0.842
MORBCYP0203-F	yellow perch	25.3	170.8	male	1.07

Appendix III. Individual whole body total mercury concentrations in fish from Comerford Reservoir, 2003.					
Comerford Reservoir					
Sample #	**Species**	**Size**	**Length (cm)**	**Weight (g)**	**whole body THg (ppm, ww)**
CONORRT0203-W	rainbow trout	l	15.2	37.9	0.023
CONORRT0103-W	rainbow trout	l	15.4	40.4	0.028
COSORB0203-W	rock bass	l	19.0	129.4	0.248
COSORB0303-W	rock bass	l	20.0	177.9	0.297
CONORRB0503-W	rock bass	xl	20.7	177.6	0.294
CONORRB0203-W	rock bass	xl	22.5	285.0	0.300
CONORRB0703-W	rock bass	xl	22.3	247.6	0.343
CONORRB0103-W	rock bass	xl	23.0	262.6	0.419
COSORB0103-W	rock bass	xl	22.5	248.7	0.484
CONORRB0603-W	rock bass	xl	23.4	269.5	0.500
COSOSB0803-W	smallmouth bass	m	14.2	38.3	0.052
CONORSB0803-W	smallmouth bass	m	13.0	30.5	0.079
CONORSB0903-W	smallmouth bass	m	14.0	36.8	0.094
CONORSB0703-W	smallmouth bass	s	9.5	9.5	0.120
COSOSB0203-W	smallmouth bass	xl	23.0	181.4	0.236
CONORYP1003-W	yellow perch	l	15.5	40.6	0.063
CODAMYP0303-W	yellow perch	l	15.0	29.7	0.090
COCBCYP0103-W	yellow perch	l	19.5	73.9	0.103
CODAMYP0103-W	yellow perch	l	16.0	42.6	0.167
CODAMYP0203-W	yellow perch	l	19.5	85.4	0.180
CONORYP1303-w	yellow perch	l	17.0	41.9	0.204
COCBCYP0203-W	yellow perch	l	15.5	28.8	0.205
COSOYP0903-W	yellow perch	m	10.7	13.7	0.052
CONORYP1203-W	yellow perch	m	12.5	19.2	0.080
CODAMYP0503-W	yellow perch	m	13.5	26.7	0.088
COSOYP1003-W	yellow perch	m	14.8	27.3	0.113
CONORYP1403-w	yellow perch	m	10.5	11.7	0.125
CODAMYP0603-W	yellow perch	m	16.5	53.1	0.142
CONORYP1103-w	yellow perch	m	12.0	16.8	0.143
COSOYP1103-W	yellow perch	m	14.0	24.2	0.181
CODAMYP0403-W	yellow perch	xl	21.0	120.7	0.137
CONORYP2003-W	yellow perch	xl	20.8	99.9	0.191
CONORYP0903-W	yellow perch	xl	23.0	148.5	0.206
COSOYP0803-W	yellow perch	xl	24.0	159.7	0.225
CONORYP0703-W	yellow perch	xl	22.0	93.2	0.231
COSOYP0603-W	yellow perch	xl	23.7	162.9	0.353
COSOYP0503-W	yellow perch	xl	23.0	143.6	0.364

Appendix IV. Individual whole body total mercury concentrations in fish from Moore Reservoir, 2003.					
Moore Reservoir					
Sample #	**Species**	**Size**	**Length (cm)**	**Weight (g)**	**Whole body THg (ppm, ww)**
MOHBCFF0403-W	fallfish	l	15.4	31.4	0.049
MORBCFF0403-W	fallfish	l	19.0	61.5	0.145
MORBCFF0503-W	fallfish	l	18.5	51.2	0.192
MORBCFF0203-W	fallfish	m	14.5	25.1	0.095
MORBCFF0303-W	fallfish	m	11.0	10.4	0.117
MORBCFF0103-W	fallfish	m	14.0	23.0	0.131
MOHBCFF0503-W	fallfish	xl	22.4	107.3	0.044
MOHBCFF0203-W	fallfish	xl	22.5	104.1	0.056
MOHBCFF0103-W	fallfish	xl	21.5	102.8	0.063
MOHBCFF0303-W	fallfish	xl	20.8	77.9	0.075
MORBCFF0803-W	fallfish	xl	21.9	88.0	0.105
MORBCFF0603-W	fallfish	xl	23.0	110.9	0.106
MORBCFF0703-W	fallfish	xl	20.4	74.7	0.214
MOSOURB0303-W	rock bass	l	17.3	97.5	0.132
MOSOURB0203-W	rock bass	l	19.4	127.0	0.164
MONORRB1003-W	rock bass	l	20.0	149.4	0.317
MOHBCRB0103-W	rock bass	l	19.2	118.5	0.526
MORBCRB0203-W	rock bass	xl	22.5	237.2	0.374
MORBCRB0503-W	rock bass	xl	22.9	241.7	0.509
MORBCRB0103-W	rock bass	xl	22.0	203.6	0.576
MORBCRB0603-W	rock bass	xl	23.0	226.1	0.609
MORBCRB0403-W	rock bass	xl	23.2	273.0	0.629
MORBCRB0303-W	rock bass	xl	23.7	238.7	0.680
MOHBCSB1003-W	smallmouth bass	l	15.3	45.8	0.171
MOHBCSB0603-W	smallmouth bass	l	20.0	86.8	0.178
MOHBCSB0903-W	smallmouth bass	l	16.0	45.2	0.206
MOHBCSB0803-W	smallmouth bass	l	19.5	84.2	0.218
MOHBCSB0503-W	smallmouth bass	l	17.5	63.7	0.242
MORBCSB1603-W	smallmouth bass	l	19.5	101.0	0.333
MORBCSB1903-W	smallmouth bass	l	18.5	86.2	0.340
MORBCSB0703-W	smallmouth bass	m	10.0	12.6	0.144
MORBCSB0303-W	smallmouth bass	m	13.8	33.3	0.253
MORBCSB0603-W	smallmouth bass	s	9.5	10.9	0.119
MOHBCSB1403-W	smallmouth bass	xl	20.2	99.4	0.235
MORBCSB1803-W	smallmouth bass	xl	24.0	177.5	0.442
MORBCSB0803-W	smallmouth bass	xl	22.0	122.6	0.469
MORBCSB0903-W	smallmouth bass	xl	23.0	165.9	0.533
MORBCYP1603-W	yellow perch	l	19.5	81.4	0.397
MORBCYP0903-W	yellow perch	l	18.5	58.4	0.439
MOHBCYP0203-W	yellow perch	l	19.7	64.1	0.633
MORBCYP1103-W	yellow perch	m	11.5	17.2	0.088
MORBCYP1303-W	yellow perch	m	10.0	9.8	0.102
MORBCYP0103-W	yellow perch	m	14.5	29.5	0.139
MORBCYP1403-W	yellow perch	m	11.5	14.8	0.139
MORBCYP1003-W	yellow perch	m	11.0	12.1	0.141
MORBCYP1203-W	yellow perch	m	12.5	17.6	0.159
MOHBCYP0303-W	yellow perch	m	13.1	16.4	0.194
MORBCYP0603-W	yellow perch	xl	23.0	127.2	0.308
MORBCYP0503-W	yellow perch	xl	23.3	130.6	0.313
MORBCYP0303-W	yellow perch	xl	22.3	132.4	0.328
MORBCYP0703-W	yellow perch	xl	24.5	155.0	0.433
MORBCYP0403-W	yellow perch	xl	23.2	135.9	0.453
MORBCYP0803-W	yellow perch	xl	23.7	130.1	0.453
MORBCYP1803-W	yellow perch	xl	23.9	126.4	0.536
MORBCYP1503-W	yellow perch	xl	22.5	117.0	0.638
MOHBCYP0103-W	yellow perch	xl	23.5	134.9	0.654