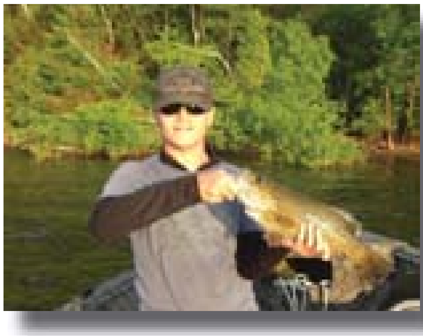
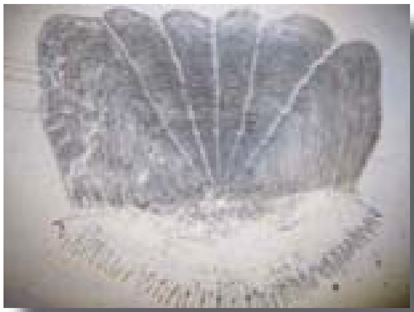
TECHNICAL REPORT NO. 66

A Synoptic Assessment of Mercury and Re-evaluation of PCB's in Lake Champlain Fishes





August 2012

Final Report

Prepared by Ian Johnson
Biodiversity Research Institute

for
The Lake Champlain Basin Program

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Biodiversity Research Institute

A Synoptic Assessment of Mercury and Re-evaluation of PCBs in Lake Champlain Fishes

Final Report

The mission of Biodiversity Research Institute is to assess emerging threats to wildlife and ecosystems through collaborative research, and to use scientific findings to advance environmental awareness and inform decision makers.

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Lake Champlain Basin Program

Final Report
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Lake-wide mercury levels by species (ppm, expressed as mean ± standard deviation) were 0.222 ± 0.16 ppm in white perch (n = 79), 0.011 ± 0.07 ppm in yellow perch (n = 103), 0.373 ± 0.15 ppm in lake trout (n =27) and 0.533 ± 0.31 ppm in smallmouth bass(n = 69).

Comparison of plug samples and their partner whole fish samples revealed that plug samples gathered in this study are an excellent indicator of Hg concentration within the entire fillet. Our results show a reduction in Hg levels in most of the target species when compared to data from 2003 – 2004. PCB results with lipid normalization found a reduction in PCB levels compared to historical data. Data from this study can be used to assess the Wilcox Dock remediation. Results of this study will be made publicly accessible through production of an easy-to-understand, two-page fact sheet that can be distributed at public events or via the web.

INTRODUCTION

Lake Champlain is one of the largest lakes of the northeastern United States; it provides drinking water and recreational activities such as swimming and fishing to hundreds of thousands of people (Comprehensive Wildlife Strategy Plan 2005). It is located along the border of New York and Vermont and extends up into Quebec. The lake is nearly 120 miles long (Figure 1: Sampling segments of Lake Champlain). Commercial fishing, agriculture, industrialization and other human impacts have exposed some regions of the lake to pollutants for more than 150 years (Appleby et al. 2000). Mercury (Hg) has been an increasing concern of the Environmental Protection Agency (EPA), state, and local governments as a harmful heavy metal that affects fish and humans (epa.gov; Pfeiffer et al. 2005). Hg may enter aquatic systems through atmospheric deposition and point source contamination. Poly-chlorinated biphenyls (PCBs) are another concern for the watershed, and often enter aquatic environments through runoff from industrial sites and roadways (Driscoll et al. 2007). In 2003 the Lake Champlain Basin Program (LCBP) Management Plan identified Hg and PCB management as its highest priority over all other toxins and heavy metals.

Documenting the presence of Hg in lakes is critical because of its negative effects on wildlife and humans. Humans are often exposed to Hg by eating predacious fish that have had time to bio-accumulate Hg in fatty tissues. Liver Hg concentrations can become elevated in high trophic level fish, which can be harmful to both fish populations and the humans which consume them (Transande et al. 2005;Sonesten 2001; Back et al. 1998). Currently the state of Vermont does not recommend consumption of more than one 25-inch lake trout per month from Lake Champlain; New York state advises that no more than one 19-inch walleye be eaten per month. Women of childbearing age are advised not to eat fish from Lake Champlain (LCBP website).

PCBs are characterized by two connected rings of six carbons, to which chlorines are attached. The number and arrangement of chlorine atoms the PCB is considered a different congener; there are 209 congeners (Earth Tech 2007). PCBs are a pollutant of concern in many lakes that have, or did have, industrial plants along their shores. Often these contaminants are created at industrial sites and are either dumped into lakes and rivers or leach into the ecosystem; they do not readily break down (Robertson 2001). PCBs have many effects on human and wildlife growth and development, and are a probable carcinogen (Robertson 2001).

Poly-chlorinated biphenyls are well documented in Lake Champlain. Assessment of sediments in 1994 showed relatively high concentrations of Hg, as well as localized pockets of PCB (McIntosh 1994). In 1997 a Phase 2 re-assessment of the sediments found heavy PCB concentrations in the Wilcox Dock area (McIntosh et al. 1997). These authors went on to say that based on limited information there appeared to be PCBs in the water column at the range of less than 0.1ng/L to 0.3 ng/L; these PCBs are mostly Aroclor 1242 (Pg A-19). PCBs are often grouped by their commercial purpose and when grouped this way are called Aroclors. Of all the PCB Aroclors, Aroclor 1242 is the contaminant of concern at the Cumberland Bay site. Areas of the highest PCB concentrations were removed during the Cumberland Bay Wilcox Dock remediation. The expected result of this removal is to reduce the lipid normalized PCB concentration in fish around the Wilcox Dock area. PCB hotspots and contamination of sediments are well understood thanks to studies completed by McIntosh in 1997. Based on these results, the Wilcox Dock remediation in 1999 was aimed at removing a large source of PCB containing sediments that polluted the surrounding waters. The cleanup involved removal of approximately 150,000 cubic yards of sediment, sludge and debris, as well as 38,000 cubic yards of sediment from the shoreline (Cleland 2000). The completion of the Wilcox Dock remediation prompted the need to evaluate its effectiveness at removing PCBs from the water. One of the goals of sampling was to quantitatively analyze PCBs in fish tissues and compare these results with earlier, pre-remediation levels.

The Northeast Hg Total Maximum Daily Load (TMDL), set by the EPA in 1997, is a continuing evaluation of Hg loads in northeastern lakes, ponds and streams. The Phase I assessment of this TMDL occurred in 2003 and had a goal of reducing the Hg load by 50% between 1998 and 2003. Phase II re-assessment included the following goals:

> "Phase II, from 2003 to 2010, sets a goal of 75 percent reduction. This leaves 20 kg/yr for in-region reductions necessary to meet this target. In 2010, Hg emissions, deposition, and fish tissue concentration data will be re-evaluated in order to assess progress and set a timeline and goal for Phase III to make remaining necessary reductions to meet water quality standards. Not enough data are currently available to accurately assess reductions achieved by out-of-region sources". (EPA 2007)

All of the fish tissues for the EPA TMDL are to be measured in wet weight. This is to ensure that the end product creates results that are comparable to previous surveys. In summary, this research falls directly under Priority Action #5 of the LCBP Management Plan by quantifying toxins in fish so that a more accurate risk assessment can be created. The results of the study can set the stage for further remediation of PCB hotspots throughout the lake, and guide best catch policies for anglers in the lake based on found Hg concentrations. Subsequently the results of this study will fulfill the need for re-assessment as outlined in the EPA's Northeast TDML.

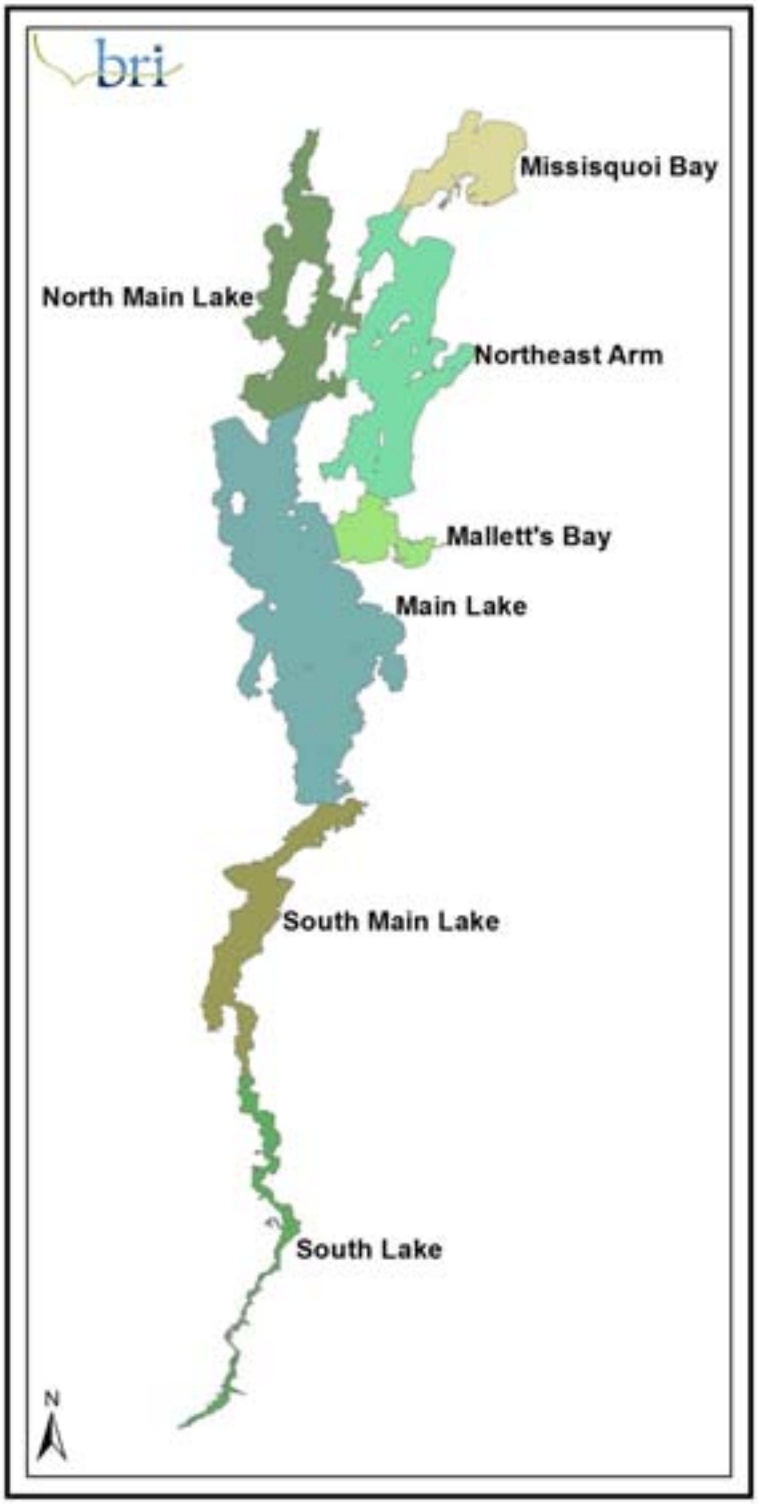

FIGURE 1: SAMPLING SEGMENTS OF LAKE CHAMPLAIN

METHODS

FIELD METHODS

Approximately half of the 300 samples were collected during early June 2011 prior to the Lake Champlain International fishing derby. Fish were sampled from seven distinct sections of Lake Champlain as delineated by the LCBP (Figure 1). When a fish was captured its length, weight and capture location was recorded. Scales were taken from the fish and a 5mm biopsy plug was removed from just below the dorsal fin. This plug was stored in a pre-weighed, air-tight vial and placed on dry ice. Blood was taken from each species. Up to eight fish had blood drawn from them for each segment; if a fish was evidently stressed blood was not taken. Blood was not drawn from dead fish. All blood was drawn from the caudal artery with a 22 gauge hypodermic. Blood was put into tubes coated in heparin and placed on dry ice. If a whole fish was collected it was wrapped in tinfoil and then placed inside two air-tight plastic bags. At the conclusion of the sampling the vials were checked into BRI freezers and inventoried. To collect a sample for PCB analysis the specimen was wrapped in tinfoil and then wrapped tightly within a plastic garbage bag; a garbage bag was necessary due to the large size of the lake trout. The wrapped fish was wrapped within another garbage bag and labeled on the outside with the sample code, species and date of collection. PCB samples were shipped to B&B Laboratories for analysis at the conclusion of sampling; chain of custody (COC) forms were filled out for each shipment.

The other half of the 300 fish samples collected were obtained through the Annual Father's Day Fishing Derby and in collaboration with Lake Champlain International (LCI). BRI pre-contacted anglers through social media outlets through coordination with LCI to educate people about the sampling effort before the derby. It was hoped that these anglers would participate in the sampling during the derby. Each of the anglers that were pre-contacted was shipped a packet of information explaining why this effort was taking place and how they could help during the derby. Through collaboration with the Father's Day Fishing Derby we were able to collect approximately 150 samples over the course of three days; collecting samples at the derby also enabled BRI teams to conduct outreach by explaining to contributing anglers and observers the objectives for this study. Their firsthand look at the sample collection method and subsequent release of the fish was an invaluable teaching tool. During data collection at the Father's Day Fishing Derby five teams of two were placed throughout the derby weigh stations. When a fish came in BRI teams would approach the angler and ask if it was alright to take a non-lethal sample of the fish. Samples were only taken from fish if the angler could point on a map where they captured the specimen. The weight of each specimen was taken from weigh station scales. All other processing steps of the fish were done by the team of technicians at the weigh station. All samples were placed immediately on dry ice. At the end of each sampling day our samples were transported to University of Vermont (UVM) for storage. Access to their -20C freezers enabled high sample integrity during the study.

LABORATORY METHODS AND SCALE AGING

Whole fishes that were collected were filleted with an acid rinsed knife. BRI prepared samples for analysis by homogenizing them in an industrial blender. Once the fillet had been homogenized to a slurry two different aliquots were taken from the slurry and placed into a pre-weighed vial. The blender was washed with tap water to remove all pieces of fillet, then it was rinsed thoroughly with 7% HCl acid, and finally it was rinsed two times with distilled water.

During analysis of the biopsy plugs the weights of each vial were known which allowed us to weigh the vial and entire sample to determine the wet weight. There were 15 samples where the wet weight was not known before it was analyzed, so a conversion factor was necessary. One study reported the fish sample percentage moisture as 75.7% ± 2.36% (Eagles-Smith et al. 2008). Our data supported these findings and samples contained a percentage moisture of 78.9% ± 5.9%. Based on these results, the samples where the wet weight was not know prior to analysis were converted as [wet weight = dry weight ppm * 0.20pm] to achieve an approximate wet weight concentration.

Hg analysis of the whole fish aliquots and the plug samples followed the same protocol and was completed at the BRI lab. Samples were placed into nickel sample boats, weighed, and analyzed for total Hg using thermal decomposition technique with an automated direct Hg analyzer (DMA 80, Milestone Incorporated, USA) using the US EPA Method 7473 (US EPA 2007). Before and after every set of 30 samples the lab included one sample each of two standard reference materials (Dorm-3 and Dolt-4), two methods blanks, and one sample blank. Every 20 samples a duplicate was run. All results are reported as total Hg on wet weight basis in parts per million (ppm), which is the same as micrograms per gram (µg/g).

Scales were collected from each specimen to use in aging the fish. The scales were pressed onto an acrylic slide to make an impression. The acrylic slide was projected onto a wall and the scales were projected. All of the work was completed at the Inland Fisheries and Wildlife office in Gray, ME.

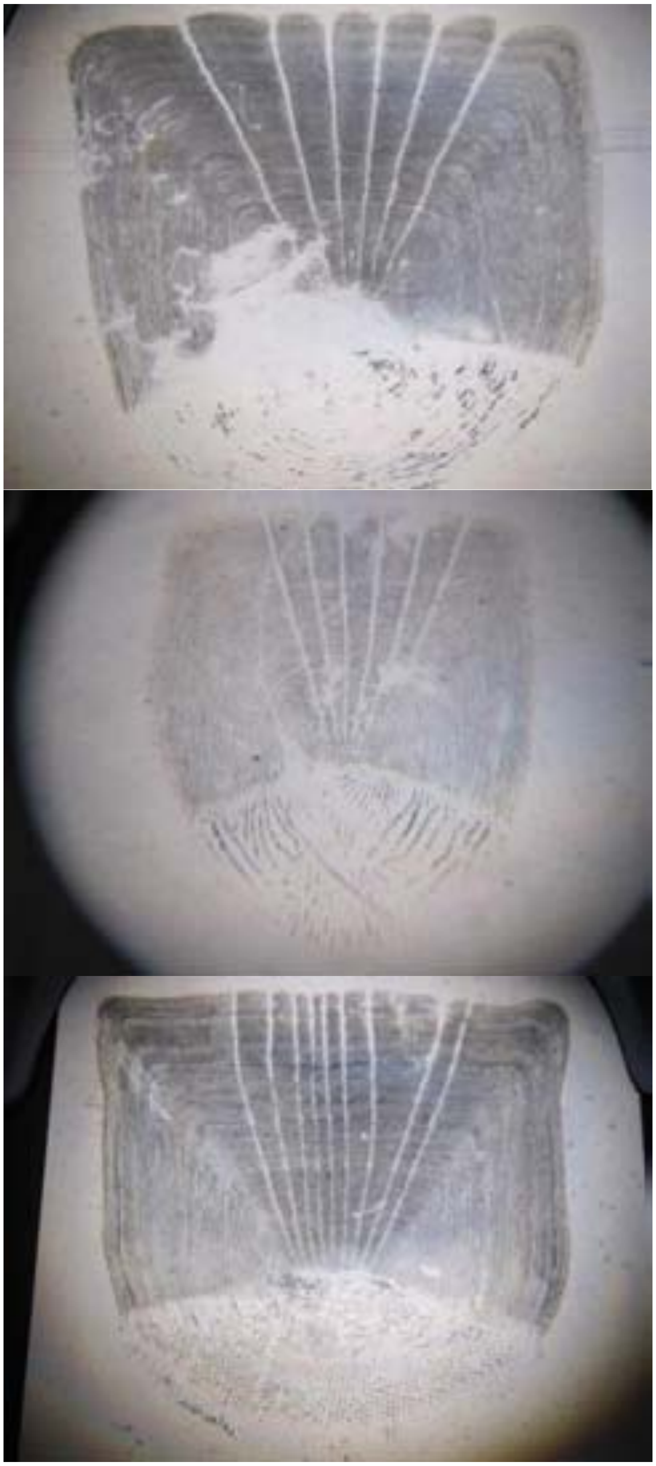

FIGURE 2: EXAMPLES OF PROJECTED FISH SCALED USED IN AGING.

COMPARISONS OF HG INDICES

An assumption of this work was that the biopsy Hg concentrations would be strongly correlated with fillet concentrations, thus making it possible to use biopsy data instead of fillets to assess human exposure to Hg throughout the lake; other studies have reported close correlations between biopsy and whole fish or fillet Hg concentrations (Peterson et al. 2005, Baker et al. 2004). There was no evidence of a difference between biopsy and whole fish Hg concentrations in lake trout, yellow perch and walleye(paired t-test, $t = 1.07$, $df=20$, $p = 0.147$). Levels of Hg found in biopsy plugs were a strong predictor of whole fish fillet Hg levels ($F=206.64$, $p<0.0001$, $r^2=0.916$;Figure 3). The individual results of the fish data can be found in Appendix II.

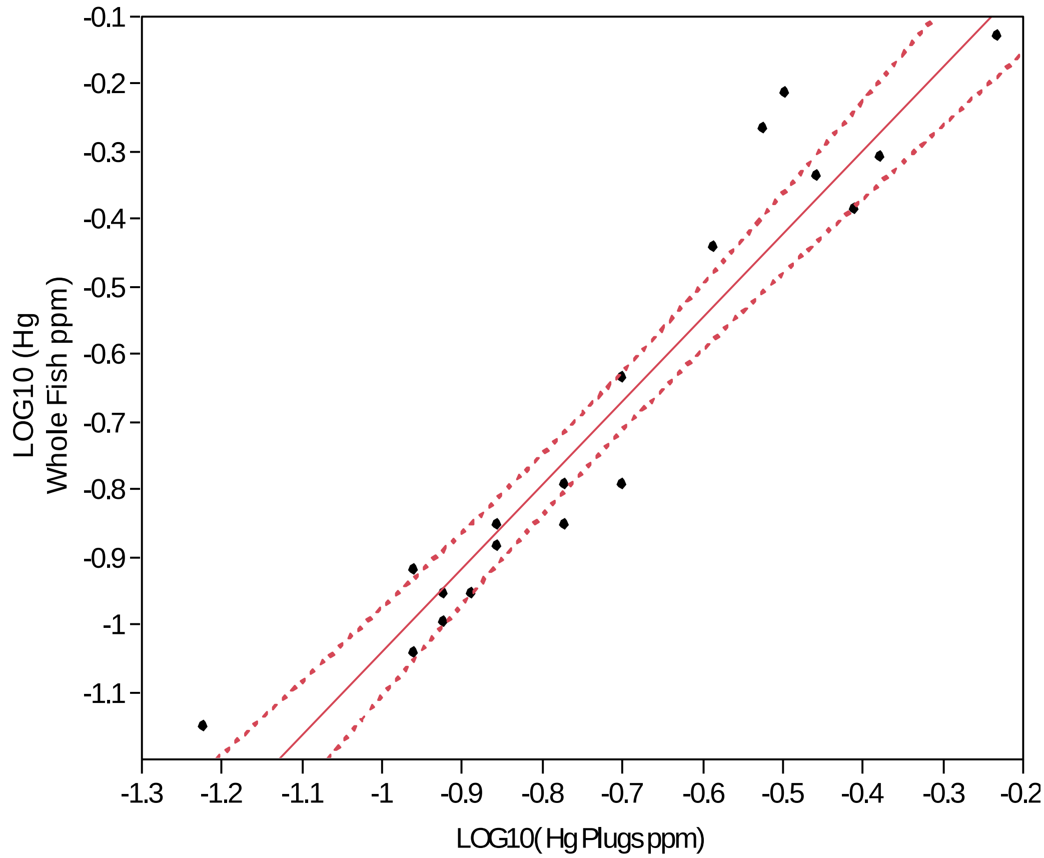

FIGURE 3: RELATIONSHIP BETWEEN HG VALUES OBTAINED FROM BIOPSY PLUGS AND WHOLE FISH FILLETS(YELLOW PERCH, LAKE TROUT, WALLEYE). DASHED LINES REPRESENT THE 95% CONFIDENCE INTERVAL AROUND THE REGRESSION LINE (LOG_{10} HG WHOLE FISH PPM = 0.198 + 1.2386 * LOG_{10} HG PLUGS PPM)

Correlations were run on blood Hg and plug Hg with varying levels of correlation. White perch (r^2 = 0.82, p = <0.0001;Figure 4) and smallmouth bass (r^2 = 0.72,p<0.0001; Figure 6) had the strongest correlations. Lake trout had a moderate correlation, however the relationship was not significant (r^2 = 0.43,p=0.2220; Figure 7). Yellow perch had a very low correlation but still retained a statistically significant positive relationship (r^2 = 0.08,p=0.0182, Figure 5).

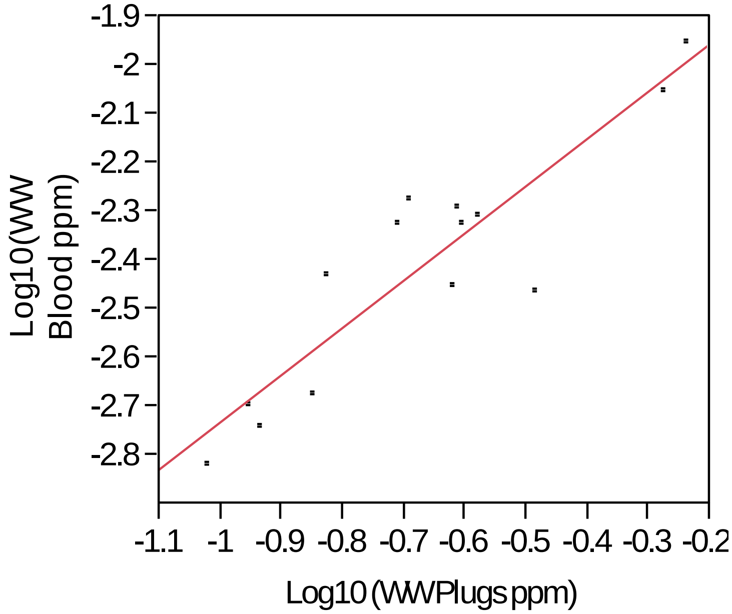

FIGURE 4: CORRELATION OF LOG TRANSFORMED BLOOD HG TO LOG TRANSFORMED PLUG HG IN WHITE PERCH. R^2 = 0.82. P = <0.0001.

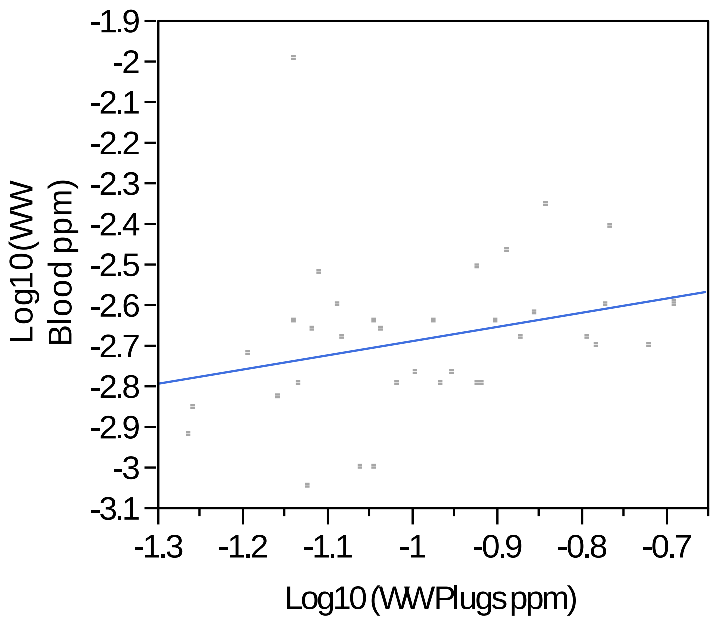

FIGURE 5 : CORRELATION OF LOG TRANSFORMED BLOOD HG TO LOG TRANSFORMED PLUG HG IN YELLOW PERCH. R^2 = 0.08. P = 0.0182.

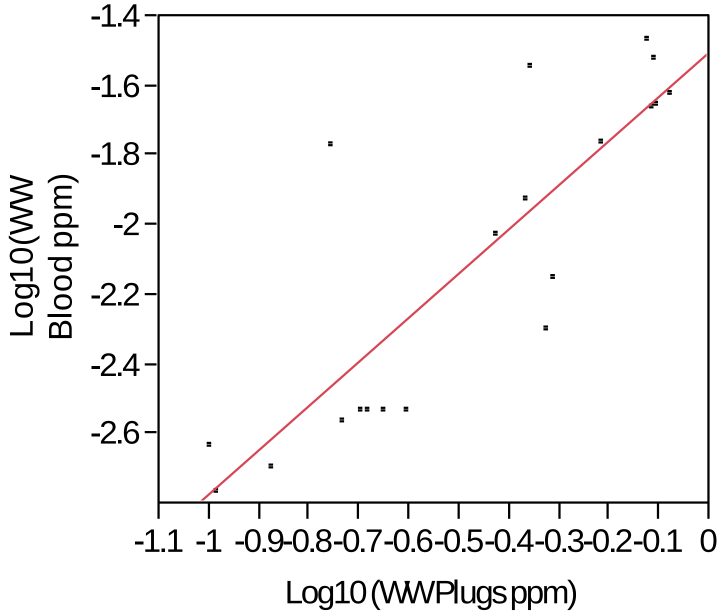

FIGURE 6 : CORRELATION OF LOG TRANSFORMED BLOOD HG TO LOG TRANSFORMED PLUG HG IN SMALLMOUTH BASS. R^2 = 0.72. P <0.0001.

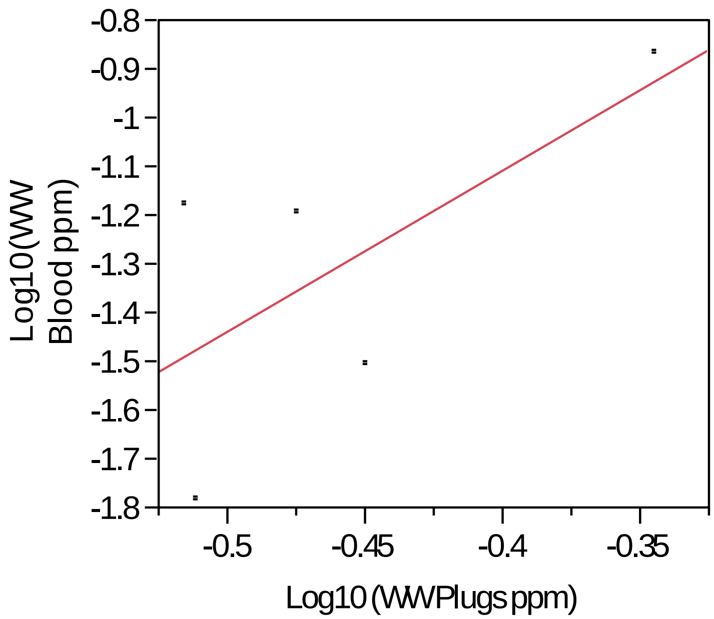

FIGURE 7 : CORRELATION OF LOG TRANSFORMED BLOOD HG TO LOG TRANSFORMED PLUG HG IN LAKE TROUT. R^2 = 0.43. P = 0.2220.

CORRELATIONS BETWEEN FISH LENGTH AND AGE

Fish age was correlated to the length of each fish in yellow perch, white perch and smallmouth bass; walleye and northern pike were excluded from the analysis because of limited sample sizes. Lake trout were also excluded from analysis of length vs. age because this species is not aged consistently with scales after 15 years; many of our larger fish have the potential to be older than 15 years.

In total, 78 white perch samples were aged. The mean age of white perch sampled was 5.5 years ± 1.7. There was a strong positive relationship between fish length and age as determined by scale characteristics (Figure 8;linear regression; $F_{1,76}$= 90.53, p < 0.0001; r^2=0.544).

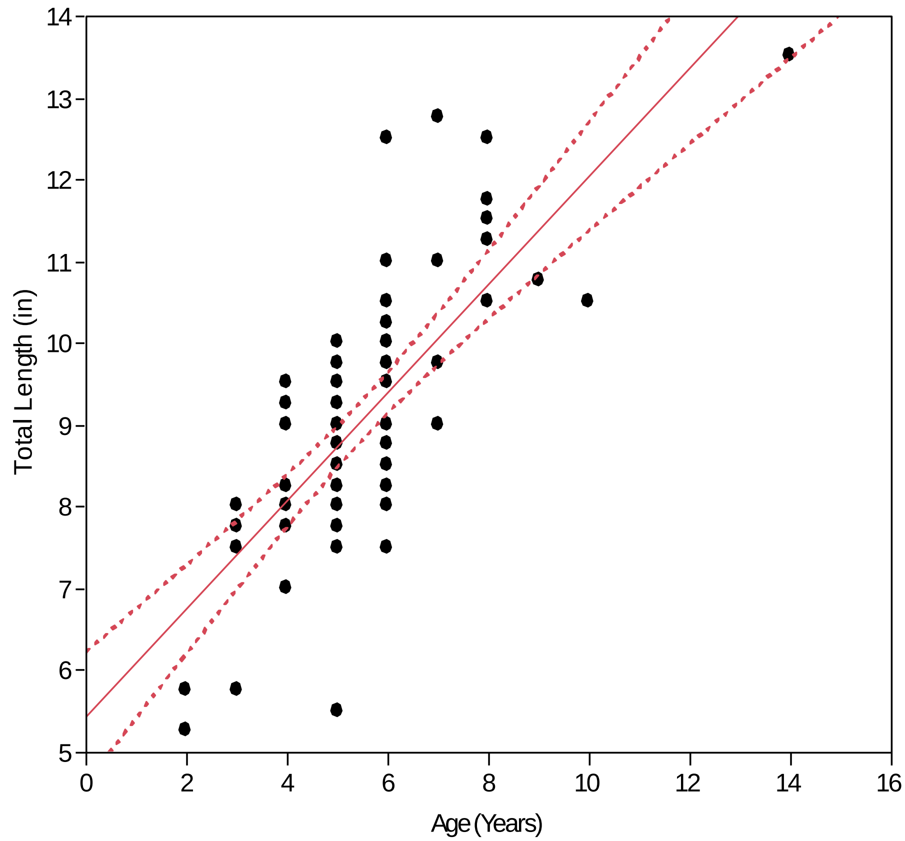

FIGURE 8 : CORRELATION OF AGE AND LENGTH IN WHITE PERCH. POINTS ARE OVERLAPPING HENCE THE NUMBER OF VISIBLE POINTS DOES NOT REFLECT THE TOTAL SAMPLE SIZE (78). DASHED LINES REPRESENT THE 95% CONFIDENCE INTERVAL AROUND THE REGRESION LINE (LENGTH = 5.442 + 0.661 * AGE)

In total, 103 yellow perch samples were aged. These results were correlated against the length of the fish. There was a strong positive relationship between fish length and age as determined by scale characteristics (Figure 9;linear regression; $F_{1,101}$= 84.86, $p < 0.0001$; r^2=0.457). The mean age of yellow perch sampled was 5.6 years ± 2.1.

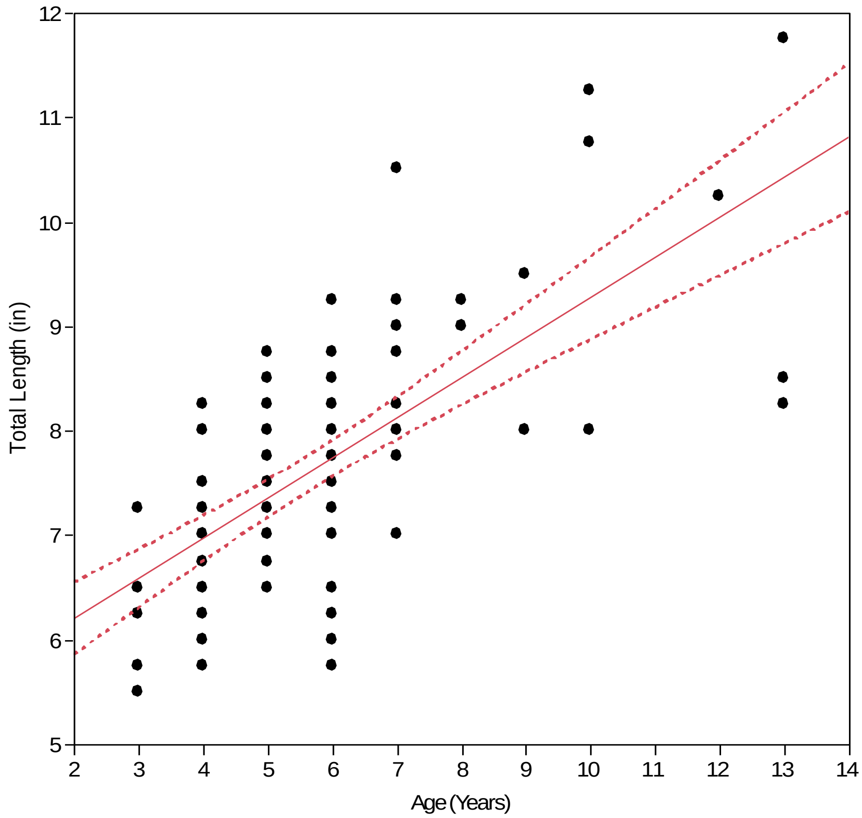

FIGURE 9 : CORRELATION OF AGE OF YELLOW PERCH AND LENGTH. POINTS ARE OVERLAPPING, HENCE THE NUMBER OF VISIBLE POINTS DOES NOT REPRESENT THE SAMPLE SIZE (103). DASHED LINES REPRESENT THE 95% CONFIDENCE INTERVAL AROUND THE REGRESSION LINE. LENGTH = 5.44 + 0.384*AGE

In total, 68 smallmouth bass samples were aged. They had an average age of 8.35 years ± 2.94. There was a strong positive relationship between fish length and age as determined by scale characteristics (Figure 10; linear regression; $F_{1,64}$= 117.99, $p < 0.0001$; r^2=0.648).

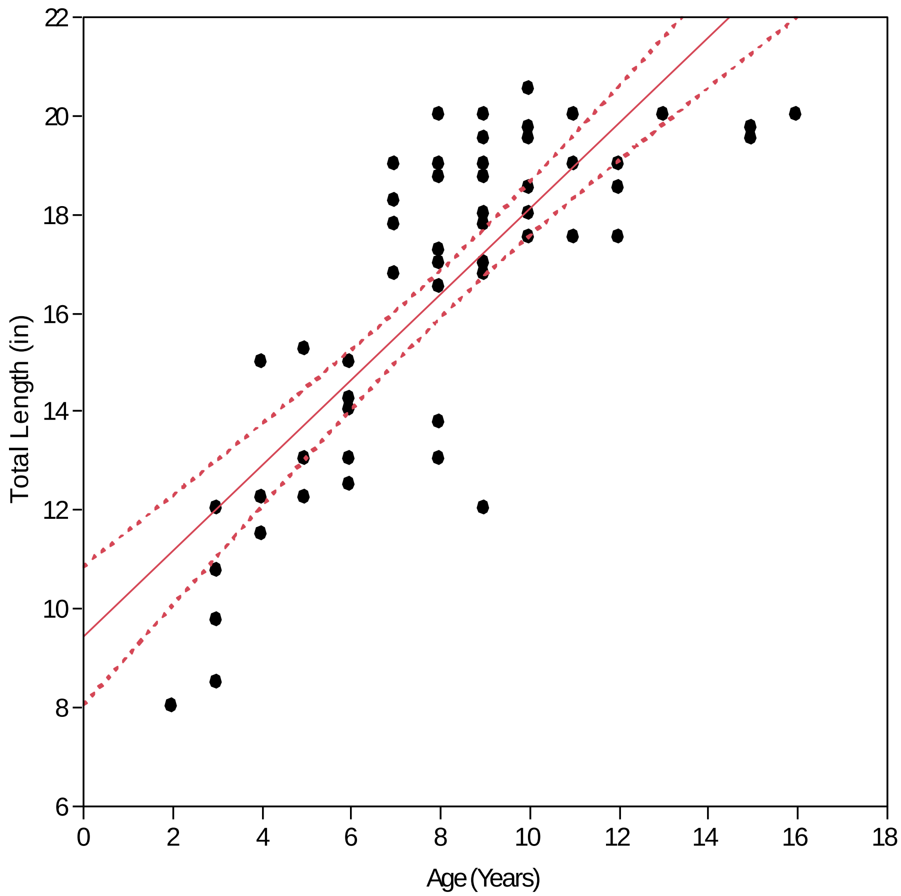

FIGURE 10:CORRELATION OF AGE OF SMALLMOUTH BASS AND LENGTH. POINTS ARE OVERLAPPING, HENCE THE NUMBER OF VISIBLE POINTS DOES NOT REPRESENT THE SAMPLE SIZE (68). DASHED LINES REPRESENT THE 95% CONFIDENCE INTERVAL AROUND THE REGRESSION LINE. LENGTH = 9.46 + 0.866*AGE

DIFFERENCE BETWEEN LAKE SEGMENTS BY SPECIES

An analysis of covariance (ANCOVA) by species was used to examine differences in Hg levels based on plug samples among the 7 sections of Lake Champlain. Because Hg bioaccumulates as a fish ages and our best representation of age is the length of the fish, the influence of length on Hg levels was removed by including fish length as a covariate. Sections of Lake Champlain were excluded from analysis where a particular species was represented by < 3 specimens (sections 1 and 7 -- smallmouth bass; sections 1, 4, 5, 6 and 7 -- lake trout).

After controlling for the effects length, there were significant ($p < 0.0001$) among-section differences in Hg levels of white perch and yellow perch (Figure 11). Similarly, differences in Hg levels exhibited by smallmouth bass among 5 sections also approached statistical significance ($p = 0.070$). Lake trout, which were only represented by samples from segments 2 and 3, did not show a significant difference in Hg levels after the effects of fish age (length) were removed.

TABLE 1 : SUMMARY OF TARGET SPECIES MEAN PPM HG, STANDARD DEVIATION AND SAMPLE SIZE BY LAKE SEGMENT

	mean ppm Hg(SD,n)			
Segment (#)	Lake Trout	Smallmouth Bass	White Perch	Yellow Perch
South Lake (1)	.	.	0.274 (0.09,15)	0.099 (0.03,25)
South Main Lake (2)	0.328 (0.08,6)	0.531 (0.27,11)	0.396 (0.3,8)	0.15 (0.06,5)
Main Lake (3)	0.357 (0.15,18)	0.538 (0.32,15)	0.148 (0.14,6)	0.087 (0.07,17)
Mallett's Bay (4)	.	0.26 (0.17,13)	0.268 (0.13,15)	0.165 (0.07,15)
Northeast Arm (5)	.	0.558 (0.27,16)	0.27 (0.15,8)	0.114 (0.11,17)
North Main Lake (6)	0.669 (0.07,3)	0.799 (0.29,12)	0.151 (0.06,12)	0.086 (0.04,14)
Missisquoi Bay (7)	.	0.201 (n=1)	0.122 (0.05,15)	0.105 (0.05,10)
All	0.373 (0.15,27)	0.533 (0.31,69)	0.228 (0.16,79)	0.11 (0.07,103)

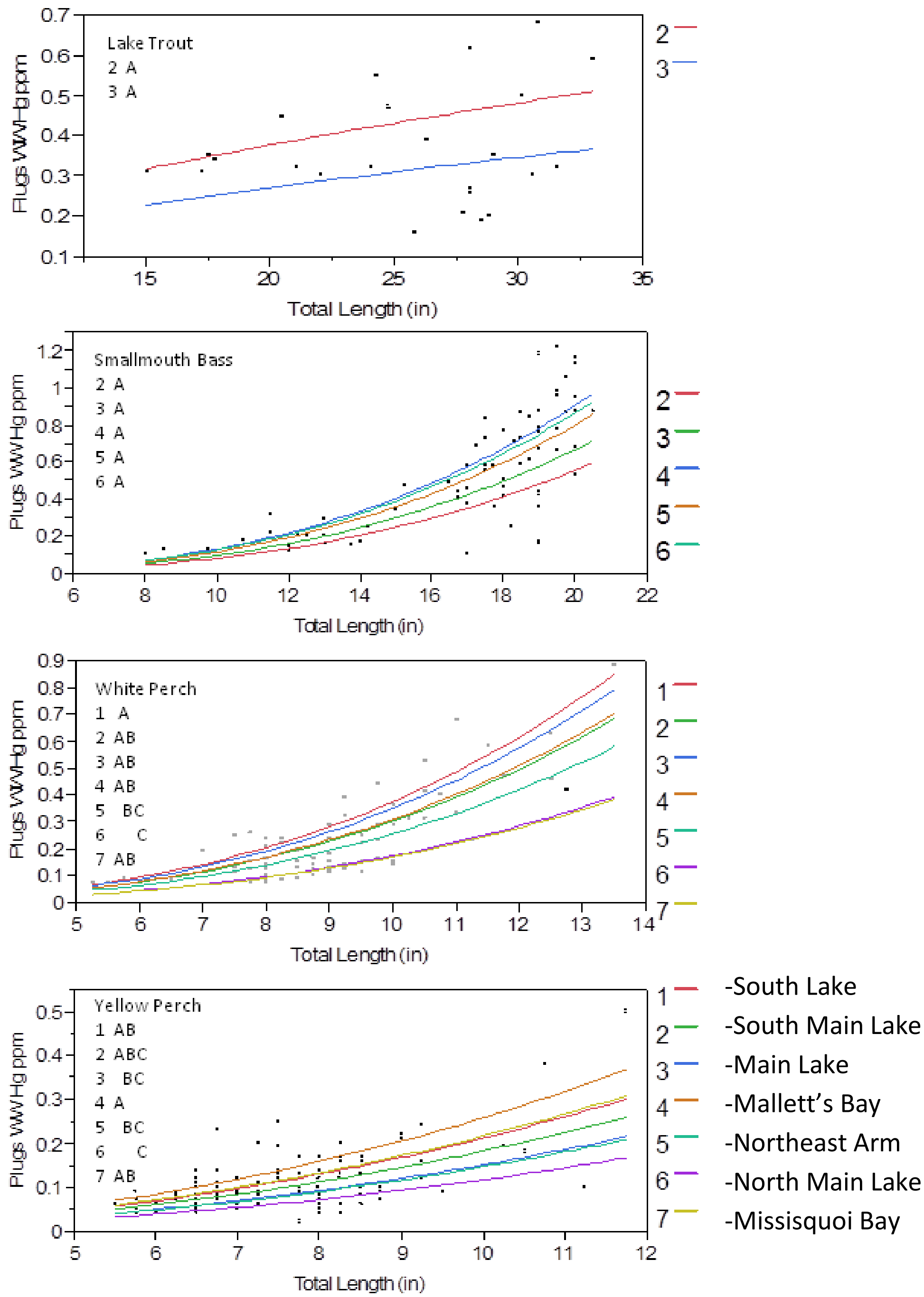

FIGURE 11 : COMPARISON OF HG LEVELS (PLUGS) AMONG GEOGRAPHICALLY-DELINEATED SECTIONS OF LAKE CHAMPLAIN IN FOUR FISH SPECIES (SEGMENTS WHERE n<3 HAVE BEEN EXCLUDED FROM ANALYSIS). LINES REPRESENT RELATIONSHIP BETWEEN HG LEVELS AND FISH LENGTH. AFTER CONTROLLING FOR THE EFFECTS OF FISH LENGTH (AGE) ON HG LEVELS, THE CONNECTING LINES REPORT (UPPER LEFT CORNER OF EACH PLOT) SHOWS SECTIONS OF THE LAKE THAT ARE SIGNIFICANTLY (α= 0.05) DIFFERENT; SECTIONS NOT CONNECTED BY THE SAME LETTER ARE SIGNIFICANTLY DIFFERENT. ANCOVA ANALYSIS WAS DONE ON LOG10 TRANSFORMED DATA AND BACK-TRANSFORMED FOR GRAPHING

To compare Hg levels between lake segments an ANCOVA model was created that used the effect of length and segment to predict Hg. The model was run on the primary target species.

TABLE 2 : TABLE OF SIGNIFICANCE VALUES FOR ANCOVA MODEL

Species	Significance of Length (p-value)	Significance of Segment (p-value)	R^2
Lake Trout	0.3970	0.3732	0.04
Smallmouth Bass	<0.0001	0.0697	0.65
White Perch	<0.0001	<0.0001	0.84
Yellow Perch	<0.0001	<0.0001	0.48

SPATIAL DISTRIBUTION OF SAMPLES AND MEANS

Spatial distributions of Hg levels found in each target species were compared on the same ppm scale across the lake. The EPA action level guideline was considered when creating scale, and if a mean concentration for a segment was ≤ 0.3 ppm it was shown as blue; green, yellow, orange and red sections indicate areas where the mean Hg level exceeds the 0.3 ppm EPA action level. Although length was not considered when creating these means, they can show a general pattern across the lake for a species. The label is formatted as mean Hg (standard deviation, n). Segments with no sample taken from them for a particular species are blank, if only one sample was taken from the segment no standard deviation will appear in the label.

For white perch, in only one segment was the mean Hg concentration above the EPA action level (Figure 14). Yellow perch were entirely under the EPA action level (Figure 15). Smallmouth bass had the highest mean concentrations overall, but showed levels under the EPA action level in Missisquoi Bay and Mallett's bay (Figure 13). Lake trout did not have any mean concentrations that were below the EPA action level (Figure 12).

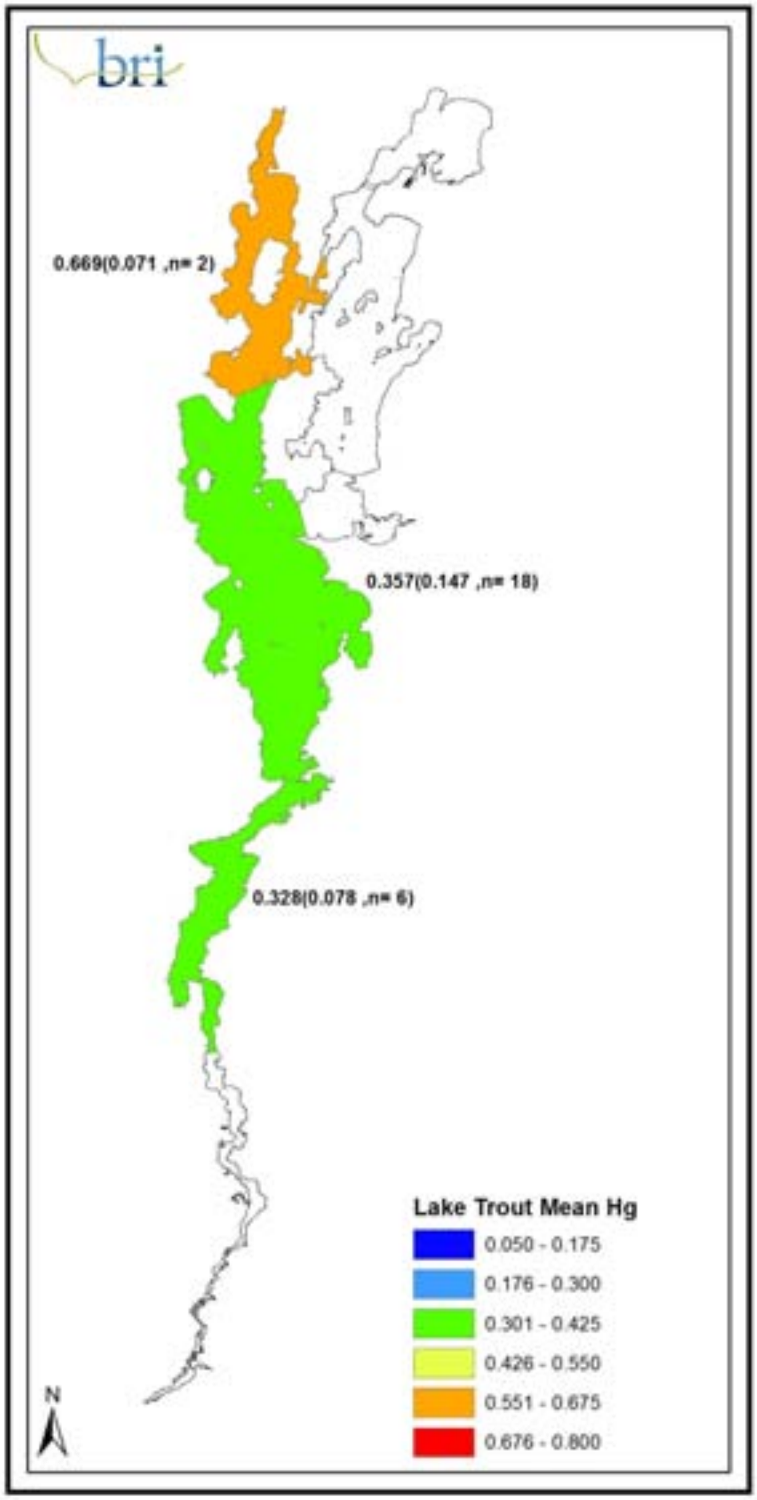

FIGURE 12: LAKE TROUT MEAN CONCENTRATION BY LAKE SEGMENT. SCALE REPRESENTS LIMIT UP TO EPA ACTION LEVEL (0.3 PPM) AND THEN BEYOND AT EQUAL INTERVALS. SAMPLES NOT COLLECTED FROM SOUTH LAKE, MALLETT'S BAY, NORTHEAST ARM, OR MISSISQUOI BAY.

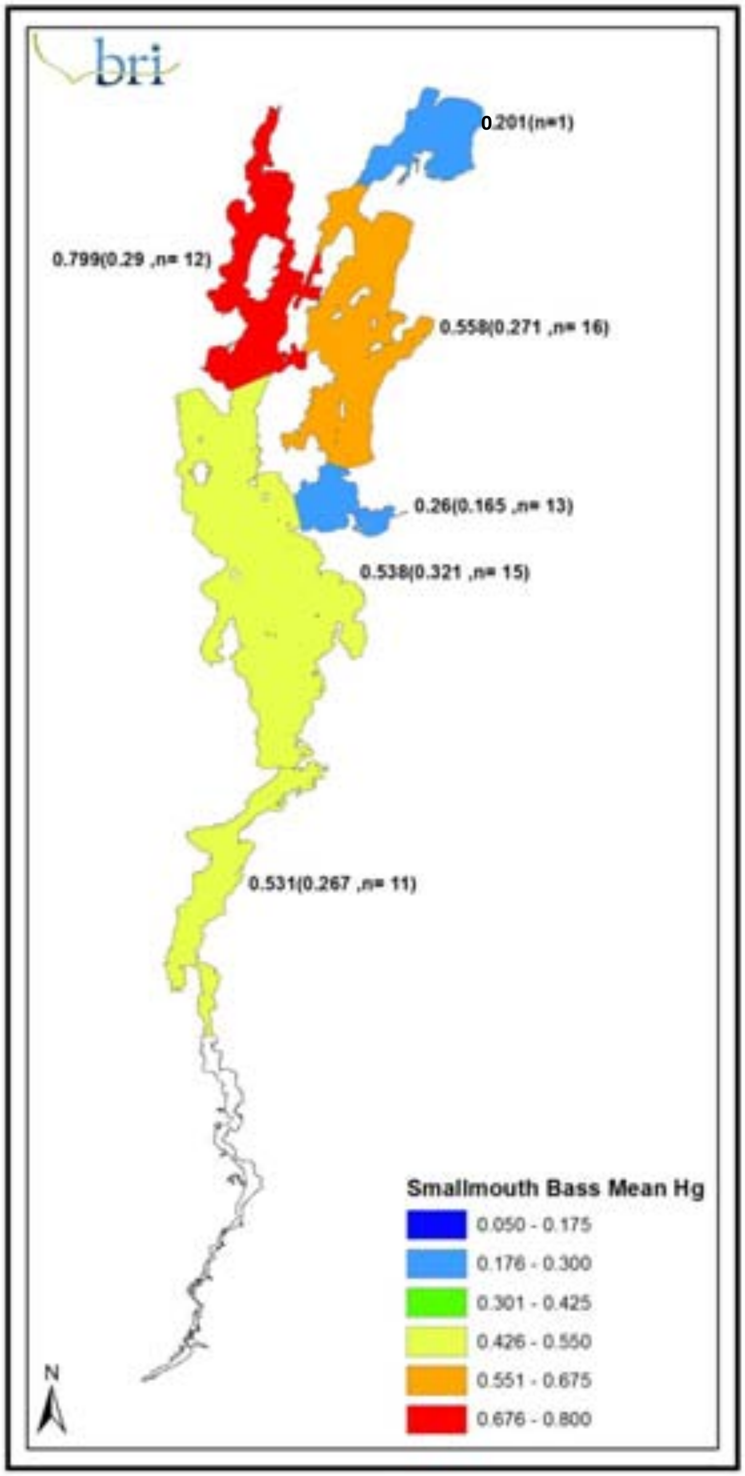

FIGURE 13 : SMALLMOUTH BASS MEAN HG CONCENTRATION BY LAKE SEGMENT. SCALE REPRESENTS LIMIT UP TO EPA ACTION LEVEL (0.3 PPM) AND THEN BEYOND AT EQUAL INTERVALS. NO SAMPLES WERE COLLECTED FROM THE SOUTH LAKE

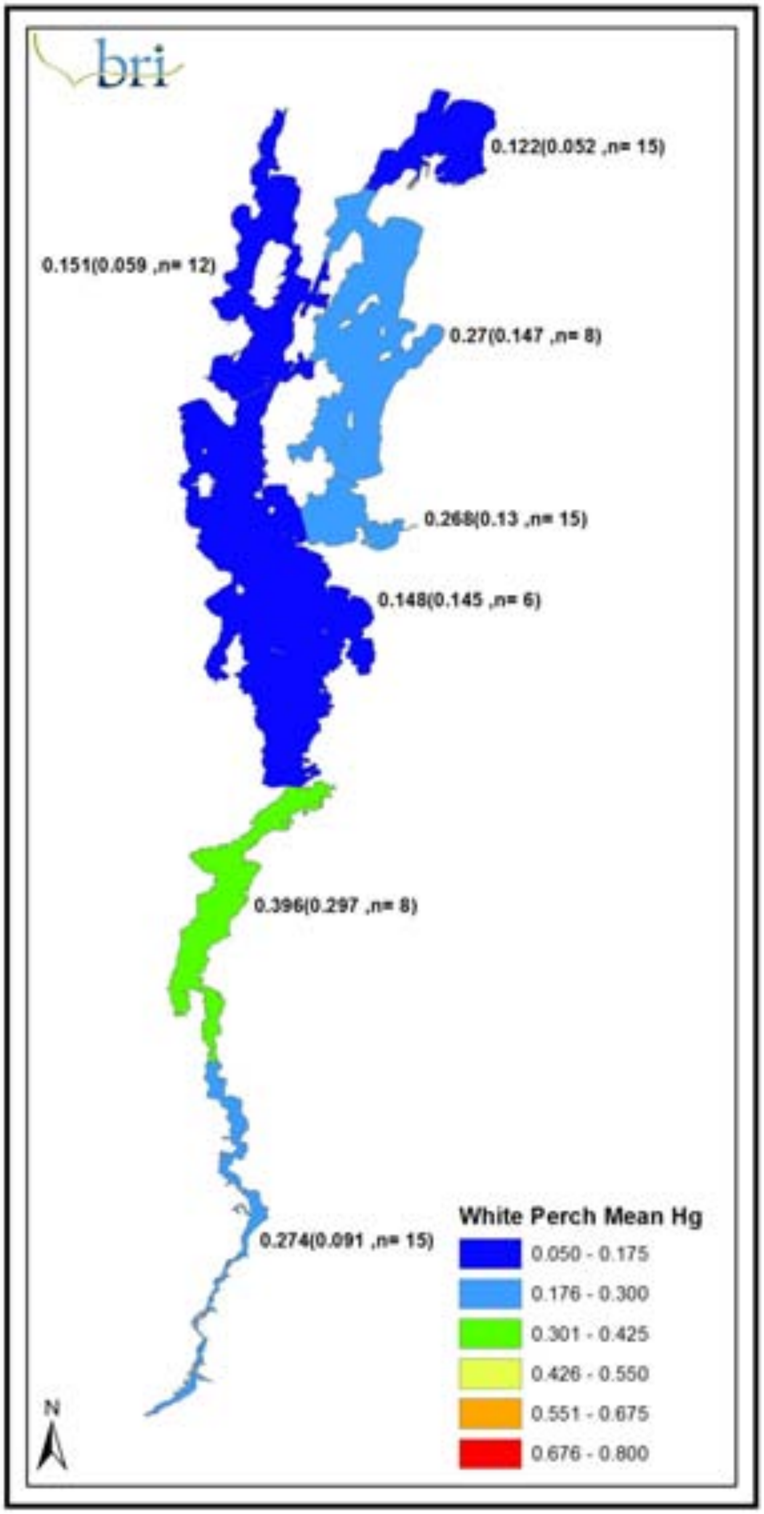

FIGURE 14: WHITE PERCH MEAN HG CONCENTRATION BY LAKE SEGMENT. SCALE REPRESENTS LIMIT UP TO EPA ACTION LEVEL (0.3 PPM) AND THEN BEYOND AT EQUAL INTERVALS.

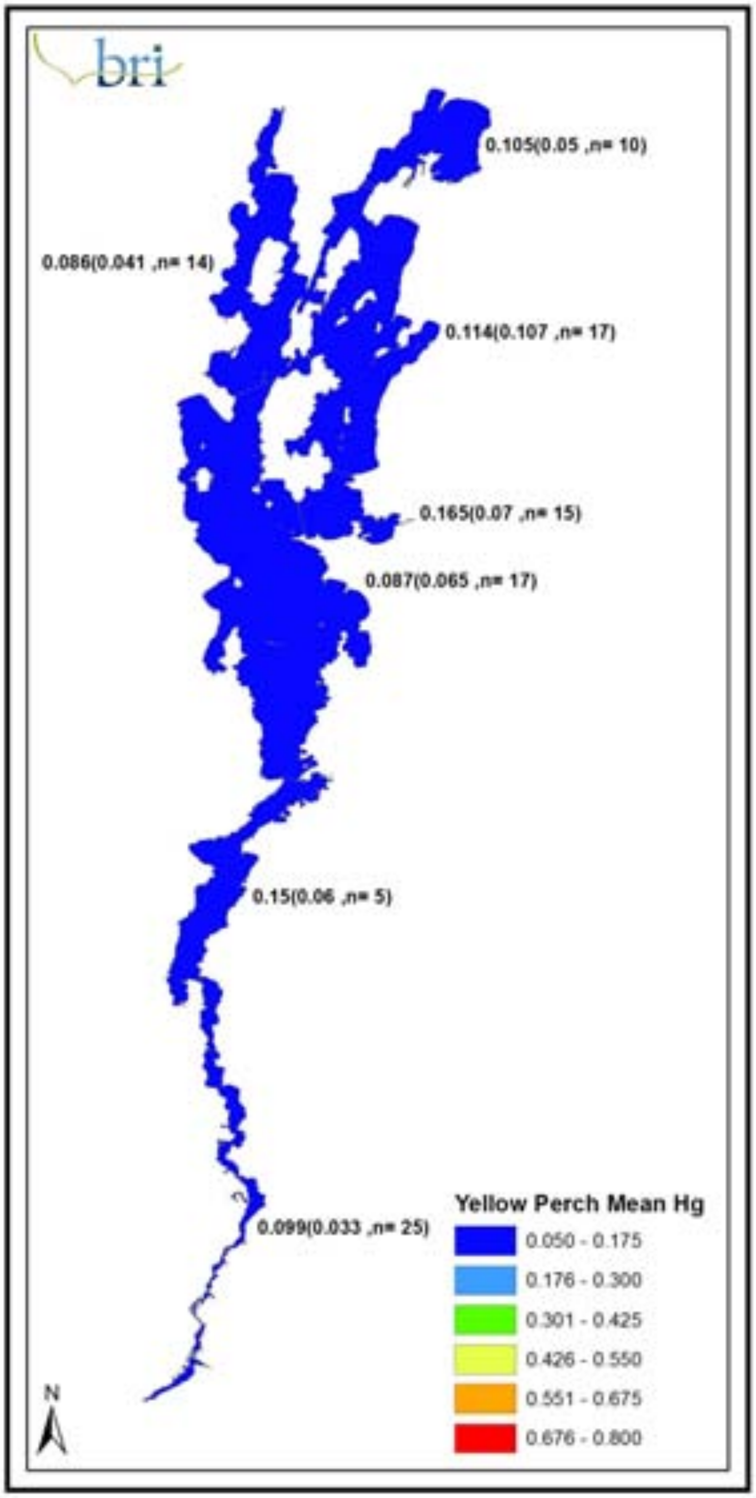

FIGURE 15: YELLOW PERCH MEAN HG CONCENTRATION BY LAKE SEGMENT. SCALE REPRESENTS LIMIT UP TO EPA ACTION LEVEL (0.3 PPM) AND THEN BEYOND AT EQUAL INTERVALS

DIFFERENCE AMONG SPECIES

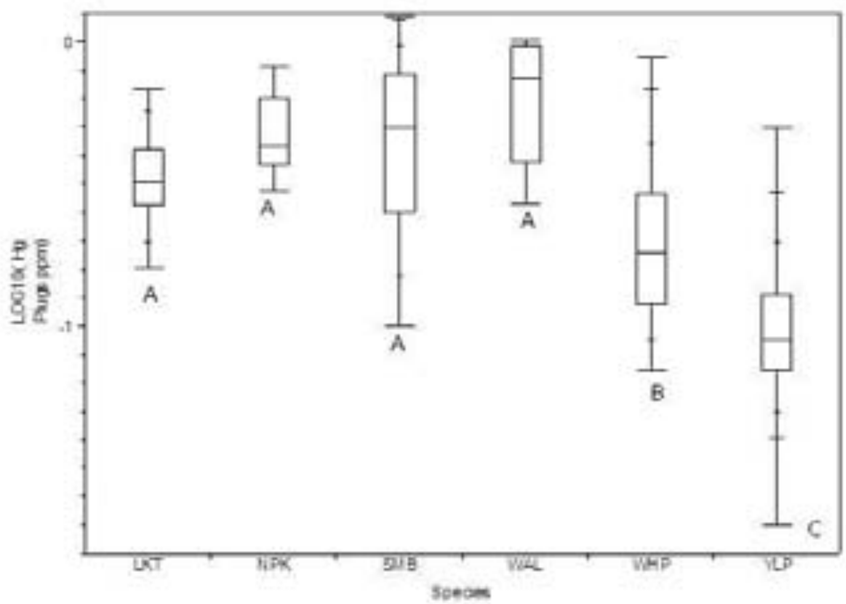

FIGURE 16: COMPARISON OF MEANS AMONG SPECIES. MEANS ARE SURROUNDED BY QUANTILE BOX PLOTS.RESULTS WERE ANALYZED FOR DIFFERENCE WITH TUKEY TEST AND SIGNIFICANT DIFFERENCES ARE REPRESENTED BY LETTERS

When comparing the mean Hg concentration among all species (Figure 16) walleye, northern pike, smallmouth bass and lake trout show no evidence for difference. White perch are significantly different than all other species and yellow perch are significantly different than all other species. Of the target species yellow perch had the lowest overall mean at 0.11 ppm Hg and smallmouth bass had the highest mean of 0.53 ppm Hg.

HISTORICAL VERSUS CURRENT DATA TRENDS

The data from this project were compared to Lake Champlain data collected in 2003 to 2004. An ANCOVA model was run on log transformed total length and Hg concentration data for each of the species collected during sampling. The model created looked at the effects of data collection period and length to explain Hg concentrations. Results of the ANCOVA are summarized in Table 4 for each species.

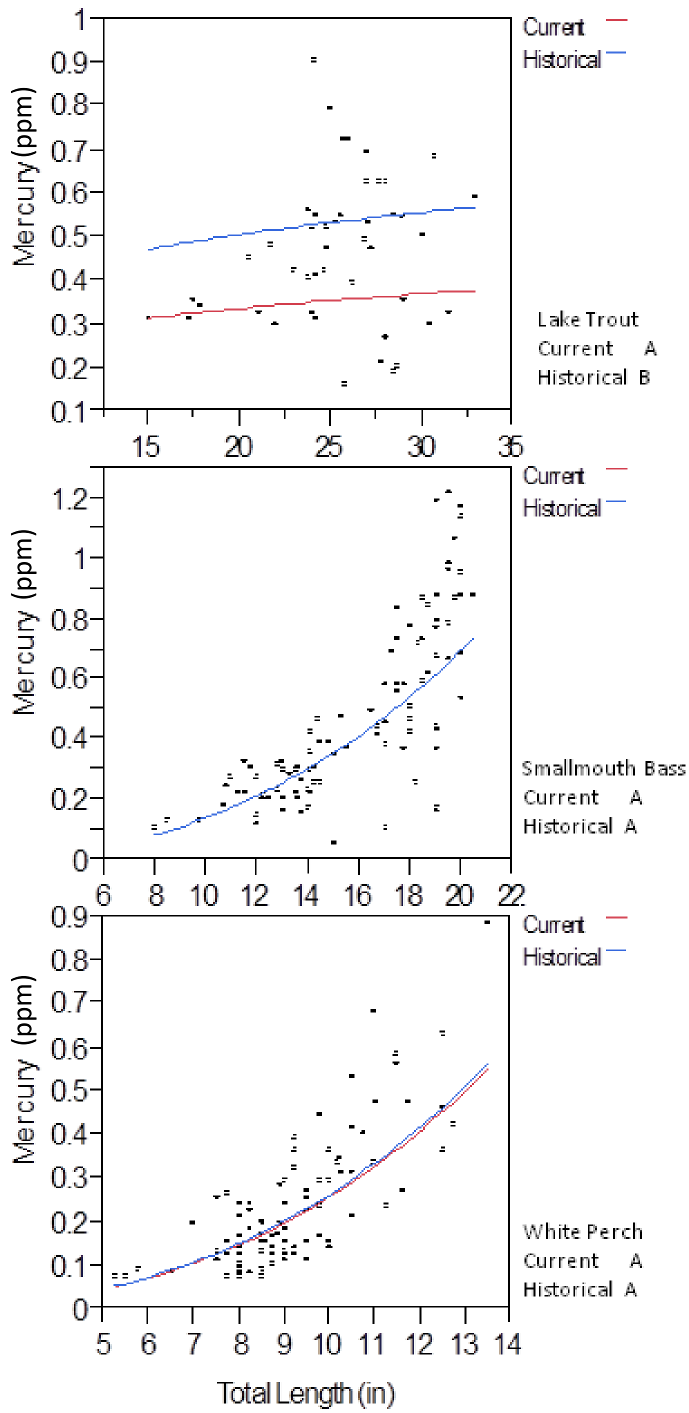

FIGURE 17 : COMPARISON OF HG LEVELS (PLUGS) AMONG HISTORICAL (2003 – 2004) AND CURRENT DATA. LINES REPRESENT RELATIONSHIP BETWEEN HG LEVELS AND FISH LENGTH. AFTER CONTROLLING FOR THE EFFECTS OF FISH LENGTH (AGE) ON HG LEVELS, THE CONNECTING LINES REPORT (LOWER RIGHT CORNER OF REPORT) SHOWS TIME PERIODS THAT ARE SIGNIFICANTLY ($\alpha = 0.05$) DIFFERENT; TIME PERIODS NOT CONNECTED BY THE SAME LETTER ARE SIGNIFICANTLY DIFFERENT. ANCOVA ANALYSIS WAS DONE ON LOG_{10} TRANSFORMED DATA AND BACK-TRANSFORMED FOR GRAPHING.

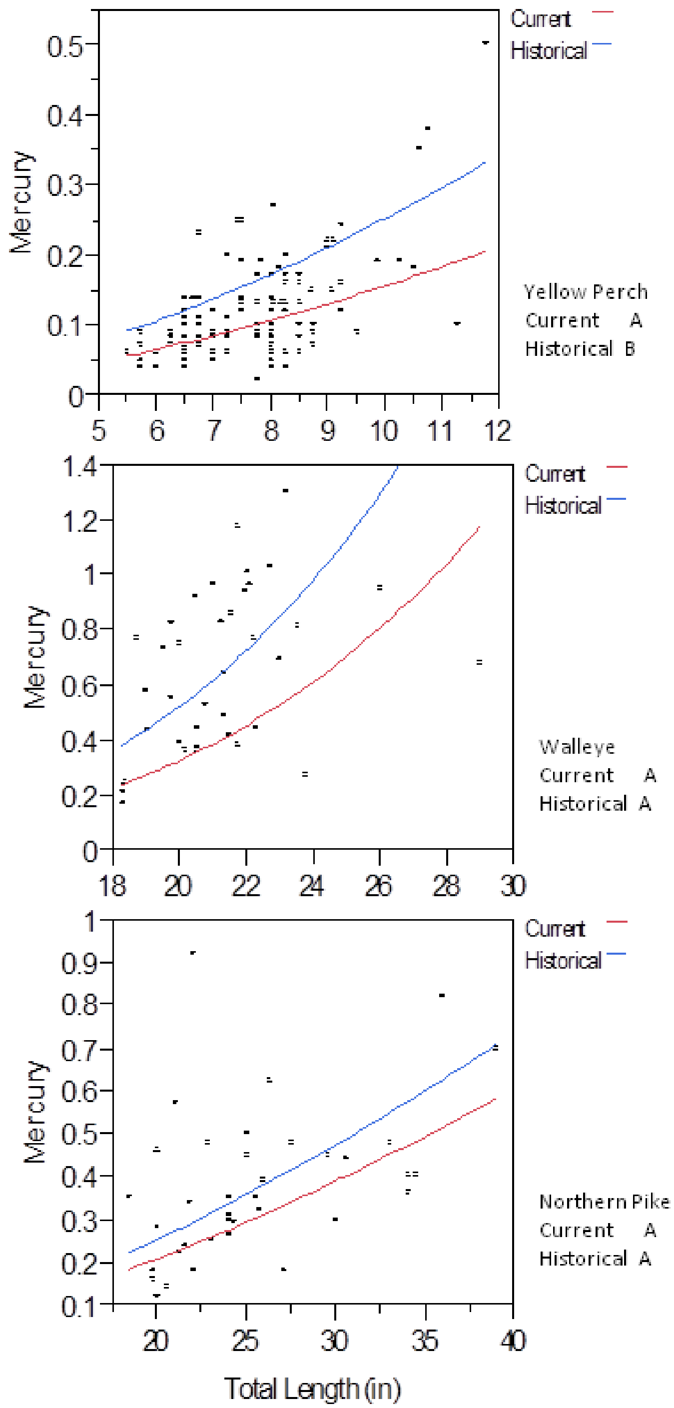

FIGURE 18: COMPARSON OF HG LEVELS (PLUGS) AMONG HISTORICAL (2003- 2004) AND CURRENT DATA. LINES REPRESENT RELATIONSHIP BETWEEN LEVELS AND FISH LENGTH. AFTER CONTROLLING FOR THE EFFECTS OF FISH LENGTH (AGE) ON HG LEVELS, THE CONNECTING LINES REPORT (LOWER RIGHT CORNER OF REPORT) SHOWS TIME PERIODS OF THE LAKE THAT ARE SIGNIFICANTLY (α = 0.05) DIFFERENT; TIME PERIODS NOT CONNECTED BY THE SAME LETTER ARE SIGNIFICANTLY DIFFERENT. ANCOVA ANALYSIS WAS DONE ON LOG_{10} TRANSFORMED DATA AND BACK-TRANSFORMED FOR GRAPHING.

TABLE 3: SAMPLE SIZE BY SPECIES FROM HISTORICAL AND CURRENT SAMPLING

Sampling Period	Lake Trout	Northern Pike	Smallmouth Bass	Walleye	White Perch	Yellow Perch
Current	27	8	69	6	79	103
Historical	22	29	26	32	15	13

LAKE TROUT

The ANCOVA model of the effects of length and sampling period on Hg concentration explained 29% of the variability of Hg (r^2=0.29,Table 4).When comparing the datasets sampling period was significant in predicting Hg concentration while holding length constant; there was significant difference between current and historical levels of Hg. Current data had a least square mean (LSM) of 0.35 ppm and the historical dataset had an LSM of 0.530 ppm. This demonstrates a decline in Hg concentration between the two datasets.

YELLOW PERCH

The ANCOVA model of the effect of length and sampling period on Hg concentration explained 36% of the variability of Hg (r^2= .36,Table 4). When comparing the datasets sampling period was significant in predicting Hg concentration while holding length constant (p= 0.0004); there was a significant difference between current and historical levels of Hg. Current data had an LSM of 0.098 ppm and historical data had an LSM of 0.159 ppm. This represents a decline in Hg concentration between the two datasets.

WHITE PERCH

The ANCOVA model of the effect of length and sampling period on Hg concentration explained 57% of the variability of Hg (r^2 = 0.57,Table 4). When comparing the datasets sampling period was not significant in predicting Hg concentration while holding length constant (p = 0.8548); there was no significant difference in Hg between current and historical datasets. In the historical dataset the LSM was 0.200ppm and in the current dataset it was 0.195 ppm.

SMALLMOUTH BASS

Smallmouth bass had a historical sample size of 26 and a current sample size of 69. The ANCOVA model of the effect of length and sampling period on Hg concentration explained 55% of the variability of Hg (r^2 = 0.55,Table 4). When comparing the datasets sampling period was not significant in predicting Hg concentrations while holding length constant (p = 0.9962); there was no significant difference in Hg concentration between current and historical datasets. In the historical dataset the LSM was 0.380 ppm and in the current dataset it was also 0.380 ppm.

NORTHERN PIKE

Northern pike had a historical sample size of 29 and a current sample size of 8. The ANCOVA model of the effect of length and sampling period on Hg concentration explained 25% of the variability of Hg (r^2 = 0.25,Table 4). When comparing the datasets sampling period was not significant in predicting Hg concentrations while holding length constant (p = 0.4985). In the historical dataset the LSM was 0.356 ppm and in the current dataset it was 0.292 ppm.

WALLEYE

In the historical dataset walleye had a sample size of 32 and in the current dataset the sample size was 6. The ANCOVA model of the effect of length and sampling period on Hg concentration explained 26% of the variability of Hg (r^2 = 0.26,Table 4). When comparing the datasets sampling period was nearly significant when predicting Hg concentration (p = 0.0699); although the data did not meet the a 95% significance, this significance will be examined further in the discussion section. The LSM of the current Hg concentrations was 0.395 ppm and in the historical data it was 0.633 ppm.

TABLE 4 : TABLE OF SIGNIFICANCE VALUES FROM ANCOVA MODEL TO USE LENGTH AND SAMPLING PERIOD AS PREDICTORS OF HG.

Species	Significance of Length (p-value)	Significance of Sampling Period (p-value)	R^2
Lake Trout	0.4379	0.0001	0.29
Smallmouth Bass	<0.0001	0.9962	0.55
White Perch	<0.0001	0.8548	0.57
Yellow Perch	<0.0001	0.0004	0.36
Northern Pike	0.0161	0.4985	0.25
Walleye	0.0013	0.0699	0.26

PCB RESULTS

The bodies of fish equilibrate with PCBs that are dissolved in the water around them. Because PCBs tend to be absorbed into the lipids of a fish, individuals caught in the same area but with different fat contents can exhibit dramatically different PCB levels. Because of this it is useful to report the observed PCB value by normalizing with the lipid percentage. This standardization process provides a unit that is more constant for all fish and can be compared between multiple datasets.

PCB analysis was run on 15 lake trout obtained during the current study; the individual results for each sample are listed in Appendix IV. These data were combined with historical PCB lake trout data collected between 1987 and 2004 (n=27). The combined PCB results were normalized by percent lipid values ([WW PCB ppm/ % lipid)*100) and then $\log_{10}$ transformed; the data were had a strong right tail before transformation and were much more normal after transformation.

An ANCOVA process was used to examine whether PCB levels in lake trout differed between historic (1987 and 2004) and current samples. After removing the effects of fish length on PCB levels, there was a significant difference in PCB levels between the two time periods ($F = 50.134$, $P < 0.0001$).A Least Square Means Student's t test resulted in a historical LSM of 1.38 and a current LSM of 0.62.

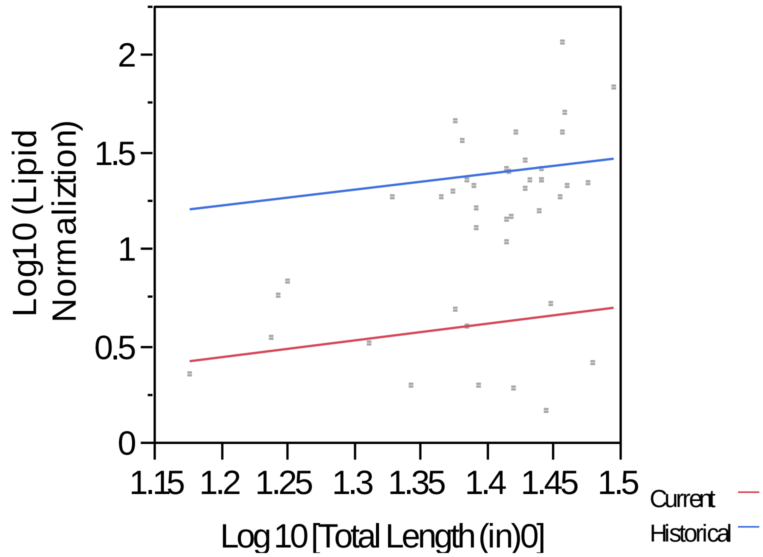

FIGURE 19: ANCOVA MODEL OF LENGTH AND SAMPLING PERIOD IN RELATION TO LOG TRANSFORMED LIPID NORMALIZATION. R^2 = 0.72. CURRENT PCBS ARE STATISTICALLY BELOW HISTORICAL LEVELS WHILE KEEPING LENGTH CONSTANT.

DISCUSSION

In comparing literature on Hg concentrations of fish species in the northeastern U.S. (Kamman et. al 2005), lake trout were reported to have 0.60 ppm Hg, yellow perch 0.44 ppm Hg, white perch 0.71 ppm, and smallmouth bass 0.58 ppm Hg. Our results show lower concentrations of Hg in these fish species than reported in previous studies for the northeastern U.S.

White and yellow perch exhibit the lowest concentrations of Hg, followed by lake trout, northern pike, smallmouth bass and walleye. This pattern may be related to the trophic position of the fish. One of the values of this study was to determine if there were spatial trends in Hg concentrations. While there were no consistent spatial trends shown across the lake by all species, the data do suggest that shallower areas in the lake may have higher levels of Hg compared to other sections (Figures 12-15). Although there are many variables that can affect the bioavailability of Hg, these shallower areas may have greater methylation of Hg.

In order to aid the goals of the EPA's TMDL, the results from this study were compared to Lake Champlain fish Hg levels measured in 2003 and 2004. Historical data were obtained from Neil Kamman at the Department of Environmental Conservation, Vermont. The datasets showed a variety of different sample size between the current and historical samplings (Table 3). An ANCOVA model was designed to account for sampling period and length of the fish in predicting Hg values. The model explained a large range of variability in Hg. In some cases the model explained up to 57% of variability, however it also explained as little as 25%.

Both lake trout and yellow perch show a decrease in Hg concentration between the two sampling periods; for the other species there was no significant difference in Hg levels. Walleye were close to having a significant drop in Hg between current and historical levels, and from a human health viewpoint these results could be considered important.

Fish caught in different segments of the lake may also exhibit different levels of Hg contamination. Among-section differences in smallmouth bass were nearly significant; the South Main Lake and North Main Lake differed from each other, while others did not. Although top predator species like northern pike, walleye and smallmouth bass have not declined significantly in Hg, it is likely that Hg concentrations will start to decline in the coming years because yellow perch, an important food source, are seeing a decrease; lower Hg concentrations in yellow perch should have an important effect on the upper trophic species.

Fish grow at different rates based on a plethora of environmental factors; consequently, there is a large amount variance of age and length. Although Hg levels have traditionally been correlated to length (Grieb et al. 1990), the age of the fish may be a better predictor of how much Hg is present. By using age as a predictor of Hg it may increase the amount of variability explained by a model. It is recommended that further studies including aging of specimens, if possible, to increase the understanding of Hg pollution and effects in these fish species.

Along with the variation of age and length in Hg concentration, gender may play a role in Hg accumulation. Adult females often accumulate more Hg than males because of the energy requirements needed for egg production (Trudel M. et al. 2000). A majority of the Hg gained through feeding for egg production is not transferred to the eggs during spawning (Nicoletto et al. 1988). Within a lake there are multiple abiotic factors affecting the assimilation of methyl-mercury, including pH, water temperature and Hg availability (deposition) (Greenfield B.K. et a.l 2001, Simonin H.A. et al. 1994, Grieb T.M. et al. 1990,Suns K et al. 1990). In a lake as large as Lake Champlain, any of these factors can change on a gradient throughout the lake and result in different concentrations throughout the lake. Based on the factors that can influence Hg levels in fish, further studies that include aging fish would allow for cross-comparison with this study's dataset. Also, because sex can be a confounding factor influencing Hg acquisition, sexing the fish may provide useful; however, non-lethal determination of sex would require sampling in the spring or fall, depending on species, before spawning. Although sexing the fish may yield interesting information regarding Hg in the lake, there would be many considerations in the design of the study to complete it successfully. An effective way to collect Hg samples of known sex fish may be to work with the hatcheries of Lake Champlain.

Inclusion of trophy fish collected at the derby did not significantly affect the results. The ANCOVA model controlled for the effect of length. Only about 150 of our 292 samples came from the derby. To help offset the effects of length on Hg concentration an ANCOVA model was created to include length and sampling period as predictors of Hg. The model was used to compare historical sampling that was conducted by standard means (i.e. not at a fishing derby) to our sampling efforts. Smallmouth bass, northern pike and walleye were the only fish sampled during the derby. Yellow perch and white perch were sampled during the effort leading up to the derby. This evidence suggests that although length is a predictor in smallmouth bass, the trophy fish that were registered at the derby did not skew our results significantly. Through sampling at the LCI fishing derby BRI conducted outreach as well as efficient and effective sampling.

PCBs analysis demonstrated a decline in the PCB levels found in lake trout. This could be attributed to the Wilcox Dock remediation, considering that the greatest reduction of PCBs occurred in the Wilcox Dock region as reported in the Earth Tech 2007 report. However, other factors may be involved. Sampling period may affect PCBs found within fish as they move from spawning grounds to summer areas. Because PCBs equilibrate with a fish's surrounding PCB levels these migrations may remove or add PCBs to the lipid tissue. In the Earth Tech 2007 report there were significant differences in PCBs in yellow perch collected during the spring and fall. Although the PCB results give good insight into PCBS within the lake, a more comprehensive sampling throughout the lake could help in determining whether the decline is evident lake wide.

Biopsy plugs were an effective, non-lethal way to sample fish and are an accurate predictor of whole fillet Hg concentration. Additionally, correlations of blood Hg levels and the plugs was strong, in white perch and smallmouth bass; yellow perch had a low blood and plug level correlation. There was a small blood sample size for lake trout which mostly likely accounted for the moderate correlation between blood and plug concentrations. The blood/plug correlation could be used during further sampling of Lake Champlain fishes. At the very least the data can be used as a measure of QA/QC in fish plug samples. Bloods samples are quick to take and require less storage space and sampling supplies.

In summary, BRI found some larger sport fish species have Hg levels that are above the EPA limit, while Hg levels found in yellow and white perch were below the limit. Overall, the Hg concentrations measured were below levels reported in the literature, but there was not a consistent pattern with historical data from Lake Champlain. Similarly, there were no consistent spatial patterns within the lake. Sampling at the Derby was a success as well as using non-lethal sampling techniques.

QUALITY ASSURANCE TASKS COMPLETED

1. Storage of digital data
    a. All data was entered into an Access database. The database is stored on a server which has redundancies. It will be maintained there for a minimum of three years. All datasheets were scanned and the originals have been archived.
2. Analysis of data using DMA
    a. Samples were placed into nickel sample boats, weighed, and analyzed for total Hg using thermal decomposition technique with an automated direct Hg analyzer (DMA 80, Milestone Incorporated, USA) using the US EPA Method 7473 (US EPA 2007). Before and after every set of 30 samples we included one sample each of two standard reference materials (Dorm-3 and Dolt-4), two methods blanks, and one sample blank. Every 20 sample a duplicate was run. Hg results were reported on a wet weight, parts per million basis.
3. Field collection
    a. Strict data collection measures were taken to ensure there was no cross contamination when sampling. A new pair of Nitrile gloves was worn for each specimen and a new hypodermics and biopsy punch was used for each specimen. When measuring the specimen a new sheet of plastic wrap was placed onto the measuring board to ensure that no contamination occurred while measuring the fish. Data records were complete for each fish. Sample integrity was maintained and samples were bagged before placing them onto dry ice. Samples were transported to UVM and stored in their freezer until transport back to BRI facilities.
4. Shipment of samples
    a. All samples shipped to the Texas laboratory for PCB analysis were accompanied by a COC form that included specimen type, collection date, date sent and a signature of relinquishment of the sample. The COC was scanned and will be kept here on the server (see storage of digital data) and also as an original archive.
5. Training of Field Staff
    a. Each field technician was trained and demonstrated the techniques to collected the samples before the derby.
6. Quarterly Reports

a. Quarterly reports were submitted to Eric Howe and outlined the status of the project.

DELIVERABLES COMPLETED:

1. QAPP
   a. The QAPP was approved prior to field sampling in June.
2. Quarterly Report 1
   a. Quarterly report 1 was submitted on June 30, 2011
3. Quarterly Report 2
   a. Quarterly report 2 was submitted on September 30, 2011
4. Quarterly Report 3
   a. Quarterly report 3 was submitted on December 31, 2011
5. Database
   a. The database of sampling data will be submitted to LCBP with the completion of this report.

ACKNOWLEDGEMENTS

Collaboration with Lake Champlain International (LCI) was crucial to the timely completion of sampling. Through collaboration with them and the LCI Father's Day Fishing Derby we collected almost 150 samples from approximately 80 anglers. Thank you LCI! During sampling in June Bill Lowell (University of Vermont), gave us access to their freezer, which provided ample space for us to store our samples and helped us maintain our sample integrity. Francis Brautigam and Brian Lewis at Maine Inland Fisheries and Wildlife were a tremendous help in giving resources and tips for aging fish scales; they gave us access to their jeweler's press, projector and pre-aged scales for practice. Juan Ramirez (B & B Laboratory) was very flexible for the timeline associated with analyzing these samples; they delivered an excellent product for the PCB portion of this work. We worked with Captain Mickey Maynard to obtain the last lake trout samples. Captain Mick went above and beyond the call of duty to obtain samples for us on his own time. We are very grateful! Last, thank-you to Brian Lang who worked as the fisheries technician for this position. He aided in sampling, sample storage, and scale aging.

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APPENDED DOCUMENTS:

APPENDIX I: INDIVIDUAL RESULTS OF HG ANALYSIS

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
LKT	29	9.45	-99999	-99999	0.35	
SMB	19	3.2	-99999	-99999	0.79	
WHP	7	0.143	43.85515	-73.37672	0.19	1
WHP	8	0.264	43.85515	-73.37672	0.21	1
WHP	8.5	0.275	43.85515	-73.37672	0.20	1
WHP	10.25	0.539	43.85515	-73.37672	0.31	1
WHP	8.5	0.297	43.85515	-73.37672	0.19	1
WHP	8.25	0.308	43.85515	-73.37672	0.22	1
WHP	10	0.55	43.85515	-73.37672	0.29	1
WHP	10.5	0.484	43.85515	-73.37672	0.41	1
WHP	7.75	0.242	43.85515	-73.37672	0.26	1
WHP	8.25	0.275	43.85515	-73.37672	0.24	1
WHP	8	0.275	43.85515	-73.37672	0.24	1
WHP	7.5	0.209	43.85515	-73.37672	0.25	1
WHP	10.5	0.627	43.85515	-73.37672	0.53	1
WHP	9	0.363	43.85515	-73.37672	0.24	1
WHP	10.5	0.594	43.85515	-73.37672	0.31	1
YLP	6.5	0.1122	43.91648	-73.39426	0.08	1
YLP	6.5	0.1188	43.85515	-73.37672	0.11	1
YLP	7	0.1452	43.85515	-73.37672	0.08	1
YLP	7	0.1408	43.85515	-73.37672	0.08	1
YLP	8.25	0.2596	43.91648	-73.39426	0.20	1
YLP	6.75	0.1232	43.91648	-73.39426	0.11	1
YLP	6.5	0.1232	43.85515	-73.37672	0.10	1
YLP	7.5	0.1936	43.91648	-73.39426	0.13	1
YLP	6.25	0.1122	43.91648	-73.39426	0.08	1
YLP	6.25	0.0902	43.91648	-73.39426	0.09	1
YLP	6.75	0.1342	43.91648	-73.39426	0.08	1
YLP	7.25	0.1826	43.91648	-73.39426	0.11	1
YLP	6.5	0.1166	43.91648	-73.39426	0.14	1
YLP	7.75	0.1408	43.91648	-73.39426	0.09	1
YLP	6.25	0.0968	43.91648	-73.39426	0.07	1

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
YLP	7.75	0.1188	43.91648	-73.39426	0.08	1
YLP	8.25	0.2332	43.91648	-73.39426	0.17	1
YLP	7	0.1386	43.91648	-73.39426	0.08	1
YLP	7.25	0.1716	43.85515	-73.37672	0.08	1
YLP	7	0.165	43.85515	-73.37672	0.12	1
YLP	6.75	0.1276	43.85515	-73.37672	0.07	1
YLP	6	0.1056	43.85515	-73.37672	0.06	1
YLP	7.75	0.2002	43.85515	-73.37672	0.08	1
YLP	6.75	0.1364	43.91648	-73.39426	0.10	1
YLP	6.25	0.1232	43.85515	-73.37672	0.08	1
LKT	17.75	1.56	44.25317	-73.325997	0.34	2
LKT	15	0.99	44.25317	-73.320323	0.31	2
LKT	17.5	1.41	44.26657	-73.3195	0.35	2
LKT	17.25	1.21	44.27075	-73.32113	0.31	2
LKT		8.88	44.235989	-73.334271	0.21	2
LKT	20.5	24.9	44.26757	-73.31892	0.45	2
SMB	20	3.53	44.133111	-73.389085	0.95	2
SMB	18	2.96	44.133111	-73.389085	0.42	2
SMB	19	3.46	44.219272	-73.319135	0.87	2
SMB	17.75	2.73	44.219272	-73.319135	0.58	2
SMB	19	3.35	44.133111	-73.389085	0.67	2
SMB	20	3.85	44.133111	-73.389085	0.53	2
SMB	19	3.35	44.133111	-73.389085	0.17	2
SMB	17	2.44	44.264395	-73.297506	0.10	2
SMB	17	2.22	44.235978	-73.283981	0.38	2
SMB	19	3.41	44.233408	-73.318422	0.43	2
SMB	18.5	3.11	44.133111	-73.389085	0.73	2
WHP	8.5	0.27	44.273223	-73.285065	0.13	2
WHP	7.75		44.273223	-73.285065	0.15	2
WHP	13.5	1.33	44.133111	-73.389085	0.88	2
WHP	12.5	0.94	44.273223	-73.285065	0.63	2
WHP	9	0.36	44.273223	-73.285065	0.18	2
WHP	10	0.51	44.273223	-73.285065	0.14	2
WHP	11	0.8	44.273223	-73.285065	0.68	2
WHP	9.25		44.273223	-73.285065	0.39	2
YLP	8.75	0.28	44.273223	-73.285065	0.10	2
YLP	9.25	0.42	44.273223	-73.285065	0.24	2

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
YLP	10.25	0.46	44.273223	-73.285065	0.19	2
YLP	8.25	0.21	44.273223	-73.285065	0.12	2
YLP	8	0.21	44.273223	-73.285065	0.10	2
LKT	22	3.81	44.495931	-73.274213	0.30	3
LKT	21		44.443352	-73.250388	0.32	3
LKT			44.443521	-73.27564	0.39	3
LKT	24.75	5.57	44.460487	-73.313193	0.47	3
LKT	28	9.43	44.395989	-73.33601	0.27	3
LKT	26.25	6.37	44.460318	-73.301547	0.39	3
LKT	31.5	9.75	44.456077	-73.297744	0.32	3
LKT	30.75	10.63	44.445694	-73.260287	0.68	3
LKT	30.5	11.2	44.270522	-73.323889	0.30	3
LKT	30.1	9.36	44.460487	-73.313193	0.50	3
LKT	25.75	6.2	44.52949	-73.277779	0.16	3
LKT	24	5.03	44.436903	-73.283483	0.32	3
LKT	24.25	5.06	44.443521	-73.27564	0.55	3
LKT	28.75	9.27	44.392762	-73.301309	0.20	3
LKT	33	11.95	44.420099	-73.271599	0.59	3
LKT	28	8.14	44.4916	-73.3764	0.26	3
LKT	28.5	8	44.502532	-73.342362	0.19	3
LKT	27.75	7.6	44.471174	-73.256387	0.21	3
SMB	17.5	2.88	44.73974	-73.33414	0.73	3
SMB	19	3.49	44.4349	-73.248	0.36	3
SMB	19		44.4349	-73.248	0.16	3
SMB	19.5	4.8	44.294344	-73.299408	0.66	3
SMB	16.75	2.28	44.73974	-73.33414	0.44	3
SMB	19	3.04	44.502532	-73.342362	0.76	3
SMB	15	1.8942	44.56503	-73.31125	0.34	3
SMB	18.31	2.58	44.502532	-73.342362	0.71	3
SMB	18.75	3.2	44.502532	-73.342362	0.61	3
SMB	19.75	3.15	44.73974	-73.33414	1.06	3
SMB	12.5	1.9382	44.56503	-73.31125	0.20	3
SMB	16.75	2.4332	44.56503	-73.31125	0.41	3
SMB	18.25	3.4	44.4482	-73.2763	0.25	3
SMB	19.5	3.55	44.333629	-73.285384	1.22	3
SMB	13	1.0384	44.56503	-73.31125	0.16	3
WAL	29	8.59	44.272394	-73.337436	0.68	3

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
WHP	9.75	0.45	44.5307	-73.2735	0.44	3
WHP	5.25	0.0638	44.5307	-73.2735	0.07	3
WHP	5.75	0.0836	44.5307	-73.2735	0.09	3
WHP	5.5	0.0759	44.5307	-73.2735	0.07	3
WHP	6.5	0.11682	44.4349	-73.248	0.08	3
WHP	8	0.2288	44.5307	-73.2735	0.14	3
YLP	6	0.10032	44.5307	-73.2735	0.04	3
YLP	8.25	0.31	44.5307	-73.2735	0.06	3
YLP	7	0.13904	44.5307	-73.2735	0.06	3
YLP	6.5	0.1089	44.4349	-73.248	0.06	3
YLP	7	0.12276	44.4349	-73.248	0.08	3
YLP	7	0.16	44.4349	-73.248	0.05	3
YLP	7.5	0.1628	44.4349	-73.248	0.13	3
YLP	6.5	0.16412	44.4349	-73.248	0.05	3
YLP	8	0.19492	44.4349	-73.248	0.04	3
YLP	7.75	0.20944	44.4349	-73.248	0.02	3
YLP	7	0.10098	44.4349	-73.248	0.05	3
YLP	7.25	0.15884	44.4349	-73.248	0.09	3
YLP	6.75	0.1408	44.4349	-73.248	0.23	3
YLP	6.75	0.1045	44.4349	-73.248	0.14	3
YLP	7.5	0.16544	44.4349	-73.248	0.25	3
YLP	6.5	0.0869	44.4349	-73.248	0.08	3
YLP	7	0.14344	44.4349	-73.248	0.05	3
NPK	39	10.5	44.614487	-73.249257	0.70	4
SMB	15.25	1.584	44.57519	-73.21317	0.47	4
SMB	15	1.463	44.54773	-73.20493	0.34	4
SMB	11.5	0.6842	44.55874	-73.22086	0.32	4
SMB	12.25	0.7612	44.55874	-73.22086	0.20	4
SMB	14.25	0.99	44.55874	-73.22086	0.25	4
SMB	10.75	0.528	44.55874	-73.22086	0.18	4
SMB	12.25	0.836	44.55874	-73.22086	0.21	4
SMB	8	0.1914	44.55874	-73.22086	0.10	4
SMB	12	0.7876	44.54773	-73.20493	0.14	4
SMB	17.25	2.5432	44.54773	-73.20493	0.69	4
SMB	11.5	0.6754	44.54773	-73.20493	0.22	4
SMB	8.5	0.2838	44.57519	-73.21317	0.13	4
SMB	12	0.539	44.54773	-73.20493	0.12	4

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
WHP	11.75	0.8228	44.54773	-73.20493	0.47	4
WHP	8.5	0.3212	44.54773	-73.20493	0.19	4
WHP	10	0.4972	44.54773	-73.20493	0.36	4
WHP	8.75	0.3212	44.54773	-73.20493	0.14	4
WHP	8.25	0.2376	44.54773	-73.20493	0.18	4
WHP	9.5	0.4224	44.54773	-73.20493	0.27	4
WHP	9.5	0.4004	44.54773	-73.20493	0.25	4
WHP	9	0.374	44.54773	-73.20493	0.29	4
WHP	7.5	0.2332	44.54773	-73.20493	0.11	4
WHP	9.5	0.451	44.54773	-73.20493	0.25	4
WHP	9.75	0.4026	44.54773	-73.20493	0.29	4
WHP	9.5	0.4642	44.54773	-73.20493	0.22	4
WHP	5.75	0.0418	44.54773	-73.20493	0.09	4
WHP	11.5	0.7458	44.54773	-73.20493	0.58	4
WHP	9.25	0.33	44.54773	-73.20493	0.32	4
YLP	7.5	0.176	44.57519	-73.21317	0.12	4
YLP	7.5	0.1804	44.57519	-73.21317	0.14	4
YLP	8.5	0.319	44.57519	-73.21317	0.13	4
YLP	7.5	0.2376	44.57519	-73.21317	0.19	4
YLP	7	0.1408	44.54773	-73.20493	0.09	4
YLP	8.25	0.264	44.57519	-73.21317	0.13	4
YLP	7.75	0.22	44.57519	-73.21317	0.17	4
YLP	8	0.2112	44.57519	-73.21317	0.12	4
YLP	8.25	0.2442	44.54773	-73.20493	0.16	4
YLP	9	0.341	44.57519	-73.21317	0.22	4
YLP	8	0.1914	44.57519	-73.21317	0.17	4
YLP	7.75	0.1804	44.54773	-73.20493	0.13	4
YLP	6.5	0.0968	44.57519	-73.21317	0.12	4
YLP	7.25	0.1584	44.54773	-73.20493	0.20	4
YLP	10.75	0.418	44.54773	-73.20493	0.38	4
NPK	34.5	8.73	44.8073	-73.14658	0.40	5
NPK	34	8.26	44.821145	-73.348472	0.36	5
NPK	36	10.49	44.86843	-73.22841	0.82	5
SMB	13.75	1.4762	44.63093	-73.23172	0.15	5
SMB	13	0.8778	44.63093	-73.23172	0.29	5
SMB	9.75	0.341	44.67039	-73.21236	0.13	5
SMB	18.5	3.12	44.83606	-73.23685	0.59	5

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
SMB	17	2.56	44.81102	-73.17652	0.45	5
SMB	19	3.02	44.86843	-73.22841	0.44	5
SMB	18.75	3.61	44.86843	-73.22841	0.84	5
SMB	16.5	2.03	44.86843	-73.22841	0.49	5
SMB	20	3.84	44.92155	-73.21323	1.13	5
SMB	17	2.32	44.79285	-73.16187	0.58	5
SMB	17.5	2.55	44.78144	-73.16208	0.55	5
SMB	19.5	3.49	44.83606	-73.23685	0.98	5
SMB	18	2.84	44.81102	-73.17652	0.50	5
SMB	17.5	2.54	44.88085	-73.18034	0.58	5
SMB	18	2.98	44.81102	-73.17652	0.46	5
SMB	18	2.15	44.79992	-73.19106	0.77	5
WAL	23.75	5.04	44.92633	-73.22221	0.27	5
WAL	26	6.55	44.63867	-73.261854	0.95	5
WAL	21.5	3.57	44.86843	-73.22841	0.42	5
WAL	23.5	5.72	44.979142	-73.342049	0.81	5
WHP	7.5	0.2068	44.8103	-73.1512	0.13	5
WHP	10.75	0.583	44.8103	-73.1512	0.40	5
WHP	12.5	0.86	44.87303	-73.28316	0.46	5
WHP	7.75	0.2332	44.8103	-73.1512	0.12	5
WHP	8	0.2332	44.8103	-73.1512	0.16	5
WHP	9	0.36	44.87303	-73.28316	0.15	5
WHP	11	0.72	44.87303	-73.28316	0.33	5
WHP	12.75	0.95	44.90387	-73.27332	0.42	5
YLP	8.5	0.2926	44.63093	-73.23172	0.10	5
YLP	8.5	0.242	44.63093	-73.23172	0.16	5
YLP	11.75	0.75	44.92633	-73.22221	0.50	5
YLP	11.25	0.69	44.92633	-73.22221	0.10	5
YLP	7	0.154	44.63093	-73.23172	0.06	5
YLP	7.75	0.1826	44.63093	-73.23172	0.10	5
YLP	7	0.1276	44.63093	-73.23172	0.08	5
YLP	8.5	0.242	44.63093	-73.23172	0.08	5
YLP	9	0.363	44.67039	-73.21236	0.21	5
YLP	8.5	0.2684	44.63093	-73.23172	0.10	5
YLP	8.5	0.2486	44.67039	-73.21236	0.08	5
YLP	6.5	0.099	44.63093	-73.23172	0.04	5
YLP	8.5	0.231	44.67039	-73.21236	0.06	5

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
YLP	5.75	0.0726	44.63093	-73.23172	0.04	5
YLP	7.75	0.1848	44.63093	-73.23172	0.09	5
YLP	7.75	0.176	44.63093	-73.23172	0.09	5
YLP	7	0.132	44.63093	-73.23172	0.06	5
LKT	28	6.96	44.82651	-73.342	0.62	6
LKT	26	7.63	44.7967	-73.31335	0.72	6
NPK	29.5	6.44	44.833747	-73.396336	0.45	6
NPK	33	8.5	45.0069	-73.34012	0.48	6
NPK	30	5.36	45.0069	-73.34012	0.30	6
NPK	34	8.96	44.94696	-73.37144	0.40	6
SMB	17.5	2.71	44.83002	-73.29719	0.83	6
SMB	18.5	2.87	44.83699	-73.3307	0.86	6
SMB	20	4.34	44.97837	-73.34301	0.87	6
SMB	19.75	3.06	44.8622	-73.28293	0.86	6
SMB	20	3.33	44.98254	-73.34033	0.68	6
SMB	14	1.2672	44.82576	-73.300834	0.17	6
SMB	19	3.15	44.83107	-73.28454	1.18	6
SMB	20.5	4.04	44.93953	-73.37316	0.87	6
SMB	19.5	3.52	44.8159	-73.31619	0.96	6
SMB	20	3.13	44.98254	-73.34033	1.17	6
SMB	19.5	3.5	44.8782	-73.31843	0.78	6
SMB	17.75	2.76	44.94986	-73.31053	0.36	6
WAL	22	3.57	44.84333	-73.30129	1.01	6
WHP	9	0.308	44.83589	-73.30125	0.15	6
WHP	9.75	0.5632	44.83589	-73.30125	0.16	6
WHP	11	0.7084	44.83589	-73.30125	0.33	6
WHP	10	0.4994	44.83589	-73.30125	0.15	6
WHP	9	0.41	44.8622	-73.28293	0.13	6
WHP	8.75	0.33	44.83589	-73.30125	0.10	6
WHP	8.75	0.363	44.83589	-73.30125	0.14	6
WHP	9.5	0.4466	44.83589	-73.30125	0.15	6
WHP	9	0.396	44.83589	-73.30125	0.11	6
WHP	9.25	0.4268	44.83589	-73.30125	0.12	6
WHP	9.25	0.3784	44.83589	-73.30125	0.14	6
WHP	9.5	0.4642	44.83589	-73.30125	0.15	6
YLP	7	0.1518	44.83589	-73.30125	0.06	6
YLP	9.5	0.44	44.83589	-73.30125	0.09	6

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
YLP	8.75	0.286	44.83589	-73.30125	0.09	6
YLP	8.25	0.2486	44.83589	-73.30125	0.04	6
YLP	8	0.2156	44.83589	-73.30125	0.07	6
YLP	8	0.2156	44.83589	-73.30125	0.06	6
YLP	8	0.2178	44.83589	-73.30125	0.05	6
YLP	8.75	0.3036	44.83589	-73.30125	0.07	6
YLP	7.25	0.1848	44.83589	-73.30125	0.06	6
YLP	9.25	0.3432	44.83589	-73.30125	0.16	6
YLP	8	0.198	44.83589	-73.30125	0.08	6
YLP	7.75	0.2024	44.83589	-73.30125	0.09	6
YLP	10.5	0.55	44.8622	-73.28293	0.18	6
YLP	9.25	0.3652	44.83589	-73.30125	0.12	6
SMB	13	0.902	44.97039	-73.21076	0.20	7
WHP	8.5	0.3102	45.0019	-73.1181	0.09	7
WHP	8	0.2706	45.0019	-73.1181	0.12	7
WHP	7.75	0.2596	45.0019	-73.1181	0.07	7
WHP	8.25	0.319	45.0019	-73.1181	0.08	7
WHP	11.25	0.7634	45.0019	-73.1181	0.23	7
WHP	8.75	0.3014	45.0019	-73.1181	0.12	7
WHP	9	0.3652	45.0019	-73.1181	0.12	7
WHP	8	0.2596	45.0019	-73.1181	0.07	7
WHP	8.5	0.286	45.0019	-73.1181	0.15	7
WHP	8	0.2596	45.0019	-73.1181	0.10	7
WHP	9.5	0.4796	45.0019	-73.1181	0.11	7
WHP	8.75	0.3234	45.0019	-73.1181	0.16	7
WHP	9.75	0.4466	45.0019	-73.1181	0.23	7
WHP	8	0.2464	45.0019	-73.1181	0.09	7
WHP	8	0.2706	45.0019	-73.1181	0.08	7
YLP	8.25	0.3542	45.0019	-73.1181	0.20	7
YLP	8	0.2068	44.97039	-73.21076	0.09	7
YLP	6.5	0.1166	44.97039	-73.21076	0.07	7
YLP	5.75	0.0748	45.0019	-73.1181	0.09	7
YLP	5.75	0.0858	45.0019	-73.1181	0.07	7
YLP	8.5	0.2618	45.0019	-73.1181	0.17	7
YLP	7	0.165	45.0019	-73.1181	0.09	7
YLP	8	0.22	45.0019	-73.1181	0.14	7
YLP	5.75	0.0792	44.97039	-73.21076	0.05	7

Species	Total Length (in)	Weight (lbs)	Latitude Captured	Longitude Captured	WW Hg Plugs ppm	Segment Number
YLP	5.5	0.0704	45.0019	-73.1181	0.06	7

APPENDIX II : TABLE OF JUST PLUG AND CORRESPONDING WHOLE FISH SAMPLE INDIVIDUAL RESULTS

Species	Total Length(in)	Plug Hg ppm	Whole Fish Hg ppm
Lake Trout		0.39	0.41
Yellow Perch	8	0.14	0.14
Lake Trout	33	0.59	0.74
Lake Trout	28	0.26	0.36
Lake Trout	31.5	0.32	0.61
Yellow Perch	8.5	0.17	0.16
Yellow Perch	8.25	0.20	0.23
Lake Trout	29	0.35	0.46
Walleye	21.5	0.42	0.49
Yellow Perch	7.5	0.12	0.10
Lake Trout	30.5	0.30	0.46
Yellow Perch	7.5	0.13	0.11
Yellow Perch	5.5	0.06	0.07
Yellow Perch	7.25	0.11	0.12
Yellow Perch	8.25	0.17	0.16
Yellow Perch	8	0.12	0.11
Yellow Perch	8	0.17	0.14
Yellow Perch	7.5	0.14	0.13
Yellow Perch	8.25	0.13	0.11
Yellow Perch	6.75	0.11	0.09
Yellow Perch	8.25	0.20	0.16
Lake Trout	30.5	0.30	0.54
Yellow Perch	6.75	0.11	0.09

APPENDIX III: SUMMARY OF NON-TARGET SPECIES RESULTS

	Northern Pike	Walleye
Segment	mean Hg ppm(STDev, n)	
South Lake	.	.
South Main Lake	.	.
Main Lake	.	0.677(1)
Mallett's Bay	0.7(1)	.
Northeast Arm	0.527(0.252,3)	0.614(0.318,4)
North Maine Lake	0.407(0.078,4)	1.007(1)
Missisquoi Bay	.	.
ALL	0.488(0.178,8)	0.69(0.292,6)

APPENDIX IV: TABLE OF PCB DATA WITH LIPID NORMALIZATION

Sampling Period	Species	Total PCB	Total Length (in)	% Lipid	Lipid Normalization Value
Current	Lake Trout	0.239	20.50	7.54	3.17
Current	Lake Trout	0.3	27.75	20.86	1.44
Current	Lake Trout	0.268	22.00	13.79	1.94
Current	Lake Trout	0.31	26.25	16.26	1.91
Current	Lake Trout	0.392	24.75	19.99	1.96
Current	Lake Trout	0.473	30.10	18.73	2.53
Current	Lake Trout	0.762	28.00	15.07	5.06
Current	Lake Trout	1.059	26.00	9.95	10.64
Current	Lake Trout	0.212	17.50	3.74	5.67
Current	Lake Trout	0.138	15.00	6.11	2.26
Current	Lake Trout	0.229	17.75	3.38	6.78
Current	Lake Trout	0.467	23.75	9.81	4.76
Current	Lake Trout	1.114	29.85	5.07	21.97
Current	Lake Trout	0.357	24.25	9.00	3.97
Current	Lake Trout	0.19	17.25	5.55	3.42
Historical	Lake Trout	2.6	26.42	6.68	38.92
Historical	Lake Trout	5.15	31.18	7.60	67.76
Historical	Lake Trout	4.22	28.58	3.70	114.05
Historical	Lake Trout	4	28.54	10.20	39.22
Historical	Lake Trout	3.6	28.74	7.28	49.45
Historical	Lake Trout	2	26.81	9.83	20.35
Historical	Lake Trout	2.9	25.91	11.30	25.66
Historical	Lake Trout	1.9	28.82	9.16	20.74
Historical	Lake Trout	2.52	27.52	11.40	22.11
Historical	Lake Trout	2.5	26.10	10.00	25.00
Historical	Lake Trout	2.4	26.97	10.70	22.43
Historical	Lake Trout	2.37	23.74	5.20	45.58
Historical	Lake Trout	2.3	26.81	8.18	28.12
Historical	Lake Trout	2.3	24.09	6.40	35.94
Historical	Lake Trout	2.1	27.56	9.23	22.75
Historical	Lake Trout	1.01	21.34	5.50	18.36
Historical	Lake Trout	1.36	24.61	8.37	16.25
Historical	Lake Trout	1.4	24.21	6.31	22.19
Historical	Lake Trout	1.4	23.23	7.70	18.18
Historical	Lake Trout	2.1	27.56	8.31	25.27
Historical	Lake Trout	1.5	23.66	7.61	19.71

Sampling Period	Species	Total PCB	Total Length (in)	% Lipid	Lipid Normalization Value
Historical	Lake Trout	1.3	24.61	10.20	12.75
Historical	Lake Trout	1.63	27.44	10.50	15.52
Historical	Lake Trout	1.7	26.18	11.60	14.66
Historical	Lake Trout	1.7	25.98	12.10	14.05
Historical	Lake Trout	1.8	28.43	9.86	18.26
Historical	Lake Trout	1.5	24.49	7.24	20.72