Spatial and temporal trends in sport fish mercury concentrations in the St. Lawrence River (Cornwall) Area of Concern (AOC)

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Objectives

Fish mercury data from the St. Lawrence River in blocks 12, 13, 14, 15 and 16 (Fig. 1) were analyzed in order to address three main objectives: a) examine long-term temporal trends in mercury concentrations from each river block; b) assess differences in mercury concentrations among river blocks both historically (1975-1979) and recently (2000-2008); and c) compare between historical and recent mercury concentrations in anthropogenically-impacted block 15.

Methods

Species with data covering a broad range of years were chosen in order to assess temporal trends in mercury concentrations. Based on data availability and temporal extent of sampling, long-term temporal trends (1975-2008) for Northern Pike and Yellow Perch were assessed for St. Lawrence River blocks 12, 13, 14 and 15. In addition, temporal trends for Smallmouth Bass (1977-2006) were assessed for blocks 13 and 14, and Walleye (1976-2006) was assessed for blocks 14, 15 and 16.

As relationships between log-transformed values of fish length and mercury concentrations were not consistently linear and statistically significant across years, a restricted size range for each species was used to account for any correlation between fish length and mercury concentration. The restricted size range was selected based on previous studies as well as the grand mean fish length across all years for each species/block combination. The selected size ranges were: Northern Pike – 55-65 cm, Smallmouth Bass – 32-42 cm, Walleye – 45-55 cm, and Yellow Perch – 15-25 cm.

Long-term temporal trends in mercury concentrations were assessed using linear regression and Mann-Kendall tests. Linear regression is a parametric analysis, which assumes data are normally distributed, while Mann-Kendall test for trend and Sen's slope estimates aims to detect and estimate trends in a time series of annual values. This analysis first tests for the presence of a monotonic increasing or decreasing trend by comparing the calculated Mann-Kendall statistic (*Z*) to a critical value. The slope of that trend is calculated with Sen's slope estimate (Salmi et al. 2002).

Comparisons between river blocks using historical and recent mercury concentrations were examined using ANOVA or Kruskal-Wallis One-Way Analysis with Ranks, followed by multiple comparison tests. Comparison of historical and recent mercury values in block 15 for Northern Pike, Smallmouth Bass, Walleye and Yellow Perch were assessed using t-test and Mann-Whitney test.

Results

Temporal trends

Mercury concentrations in Yellow Perch have significantly ($p<0.05$) declined in river blocks 12, 13, 14 and 15, based on both linear regression and Mann-Kendall tests (Table 1, Figs. 2b, 3b, 4d and 5d). Northern Pike mercury concentrations have also significantly ($p<0.05$) declined over time in block 12 (Fig. 2a), and Walleye mercury concentrations exhibited marginally insignificant ($p>0.05$) declines in block 15 (Fig. 5c). All other species/block combinations show insignificant ($p>0.05$) declining trends, or constant trends through time (Figs. 2-6).

Comparisons between river blocks

Historical (1975-1979) Yellow Perch mercury concentrations for river block 14 were significantly lower than values for blocks 15 and 13 (Kruskal-Wallis One Way Analysis with Ranks with Dunn's test, $p<0.05$) (Fig. 7). Recent (2000-2008) mercury concentrations in block 15 were significantly higher ($p<0.05$) than blocks 12 and 14 (Fig. 7). All other river blocks showed no significant difference ($p>0.05$) in recent mercury concentrations (Fig. 7).

Historical (1975-1979) Northern Pike mercury concentrations for river block 12 were significantly higher than blocks 13 and 14 (ANOVA with Tukey's test, $p<0.05$) (Fig. 8). Block 15 concentrations were also significantly higher than values for blocks 13 and 14 (ANOVA with Tukey's test, $p<0.05$) (Fig. 8). Recent (2000-2008) Northern Pike mercury concentrations in block 15 were significantly higher than the concentrations in block 14 (Kruskal-Wallis One Way Analysis with Ranks with Dunn's test, $p<0.05$) (Fig. 8). All other river blocks showed no significant difference ($p>0.05$) in recent mercury concentrations ($p>0.05$).

Historical mercury concentrations for Walleye in block 15 were significantly higher than block 14 (Mann-Whitney test, $p<0.05$), but there were no statistically significant ($p>0.05$) differences between recent values (Fig. 9a). Historical (1975-1979) and recent (2000-2008) concentrations in Smallmouth Bass were significantly higher in block 15 than block 14 (Mann-Whitney test, $p>0.05$) (Fig. 9b).

Block 15 comparisons

Historical (1975-1979) mercury concentrations were significantly higher than recent (2000-2008) concentrations in Northern Pike (t-test, $p<0.001$), Yellow Perch (Mann-Whitney test, $p<0.001$), Smallmouth Bass (Mann-Whitney test, $p=0.002$), and Walleye (Mann-Whitney test, $p=0.003$) (Fig. 10).

Conclusions

Mercury concentrations for Yellow Perch have declined in all sampled blocks of the St. Lawrence River, including block 15, which encompasses the St. Lawrence River (Cornwall) Area of Concern (AOC). Average 2006 mercury concentrations for 15-25 cm Yellow Perch (0.195 μg/g) in this area fall below the 0.26 μg/g fish consumption advisory guideline for unrestricted (8 meals/month) for the sensitive population. In addition, recent mercury concentrations for Walleye in block 15 show no significant differences from the upstream block 14. However, recent mercury concentrations for Northern Pike and Smallmouth Bass and Walleye in block 15 are significantly higher than values for block 14.

This analysis suggests that there has been some degree of recovery from mercury contamination in the St. Lawrence River (Cornwall) AOC, particularly in Yellow Perch populations. However, while the historical concentrations in block 15 for Northern Pike, Smallmouth Bass and Walleye were statistically significantly higher than the recent concentrations, none of these species have shown statistically significant declines over time in the AOC. In addition, mean mercury concentrations for the most recent year of sampling for each species (Northern Pike, 2006 – 0.67 μg/g; Smallmouth Bass, 2006 – 0.35 μg/g; Walleye, 2006 – 0.5 μg/g) suggest that consumption restrictions for the sensitive population would still be appropriate for these species. Therefore, the data suggests that recovery is still ongoing in this AOC, and that appropriate care should still be applied when consuming fish from this section of the St. Lawrence River.

References

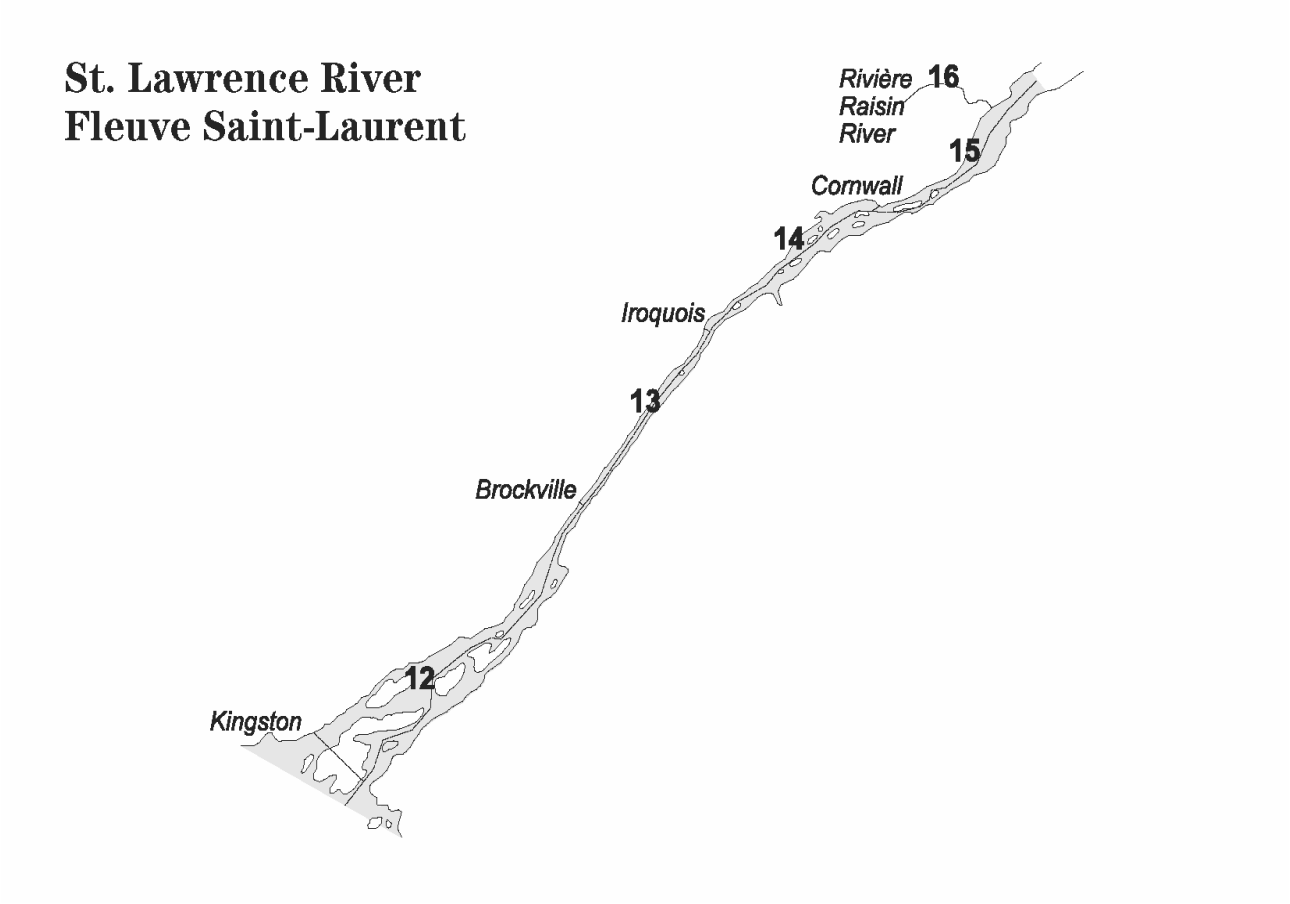
Salmi, T., A. Maatta, P. Anttila, T. Ruoho-Airola and T. Amnell. 2002. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates – the Excel template application MAKESENS. Finnish Meteorological Institute, publications on Air Quality No. 31, report code FMI-AQ-31.

TABLES

Table 1. Summary of the relationship between the log of Hg concentrations and time, with linear regression and Mann-Kendall test (*Z* statistic). Results are for each species/block combination. Asterisks (*) denote significant relationships. Plus signs (+) indicate trends significant at p<0.1. For the Mann-Kendall Z statistic, large negative values indicate negative trends in mercury concentrations over time. Note: for Block 16 Walleye, the sample size was insufficient for the Mann-Kendall test (n<10), and so the *S* statistic, which is interpreted in the same manner, is presented instead.

		Data range		Linear regression				Mann-Kendall test	
Block	Species	Start	End	Trend	Slope	R^2	p-value	*Z*	p-value
	Northern Pike	1976	2007	Declining	-0.0168	0.5281	0.001*	-2.51	<0.05*
12	Yellow Perch	1976	2007	Declining	-0.0229	0.3369	0.0233*	-2.18	<0.05*
	Northern Pike	1975	2008	None	-0.0020	0.0084	0.8009	-0.18	>0.05
13	Yellow Perch	1975	2008	Declining	-0.0218	0.3966	0.0378	-2.65	<0.01*
	Northern Pike	1977	2002	None	-0.0095	0.1660	0.2135	-0.78	>0.1
	Smallmouth Bass	1977	2002	None+	-0.0202	0.3971	0.0508+	-1.43	>0.1
	Walleye	1981	2002	None	0.0015	0.0012	0.9185	-0.47	n/a
14	Yellow Perch	1977	2006	Declining	-0.0200	0.3547	0.0317*	-2.14	<0.05*
	Northern Pike	1977	2006	None+	-0.0142	0.2739	0.0548+	-1.09	>0.1
	Smallmouth Bass	1981	2006	None	-0.0133	0.1900	0.1803	-1.09	>0.1
	Walleye	1976	2006	None+	-0.0162	0.2715	0.0678+	-1.89	<0.1
15	Yellow Perch	1977	2006	Declining	-0.0185	0.4059	0.0059*	-2.27	<0.05*
16	Walleye	1978	2000	None	-0.0119	0.0437	0.6529	-3 (S test)	n/a

FIGURES



12. Thousand Islands area – St. Lawrence River from east of Kingston to Brockville
13. Middle Corridor – St. Lawrence River from east of Brockville to Iroquois
14. Lake St. Lawrence – St. Lawrence River from east of Iroquois to the Moses Saunders Dam
15. Lake St. Francis – St. Lawrence River from downstream of the Moses Saunders Dam to Quebec border
16. Raisin River – spawning run in the river including offshore area to 10 metre depth

Figure 1. Sport fish consumption advisory blocks for the St. Lawrence River.

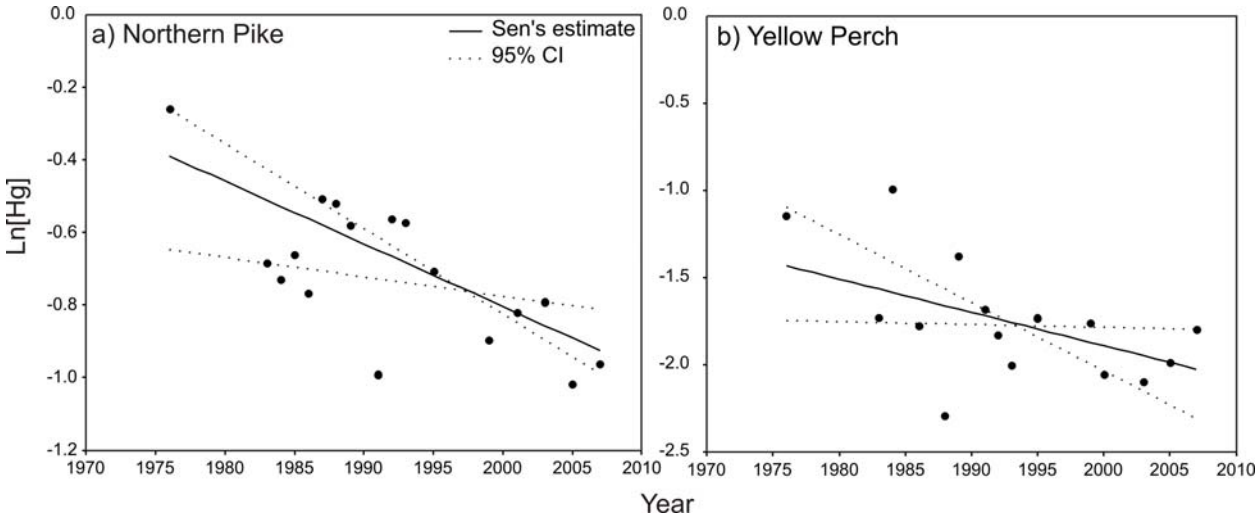


Figure 2. Plots of Hg concentrations over time for a) Northern Pike and b) Yellow Perch for Block 12. Solid line indicates Sen's slope estimate and dashed lines indicate 95% confidence intervals. Mercury concentrations have significantly declined in both Northern Pike and Yellow Perch over the sampled time period in this river block (Mann-Kendall test, $p<0.05$ – see Table 1).

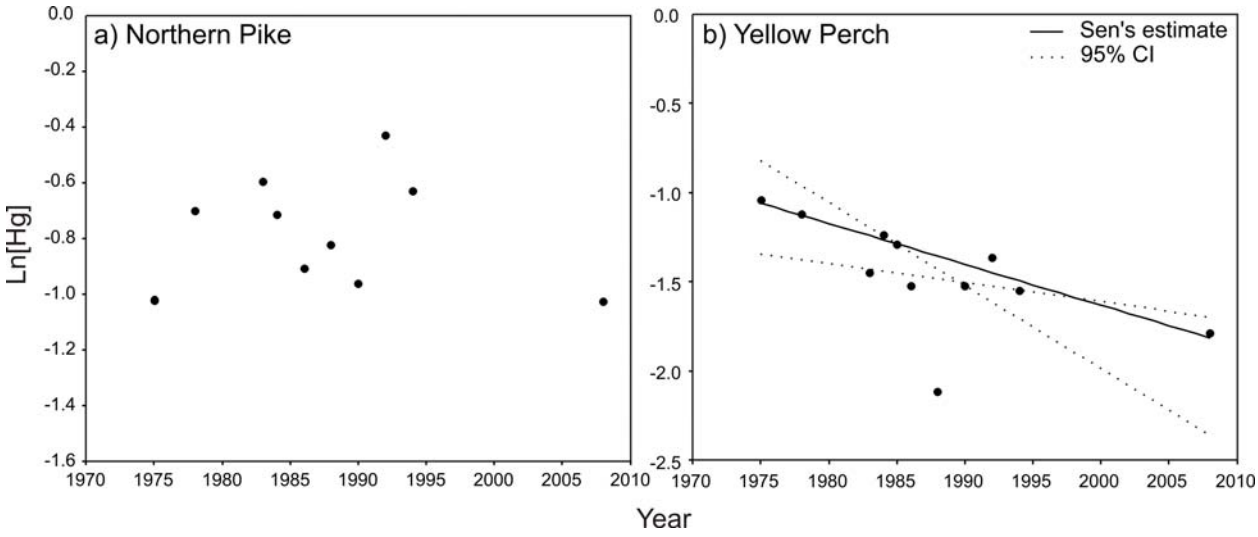


Figure 3. Plots of Hg concentrations over time with for a) Northern Pike and b) Yellow Perch for Block 13. Solid line indicates Sen's slope estimate and dashed lines indicate 95% confidence intervals. Mercury concentrations have significantly declined in Yellow Perch over the sampled time period in this river block (Mann-Kendall test, $p<0.05$ – see Table 1).

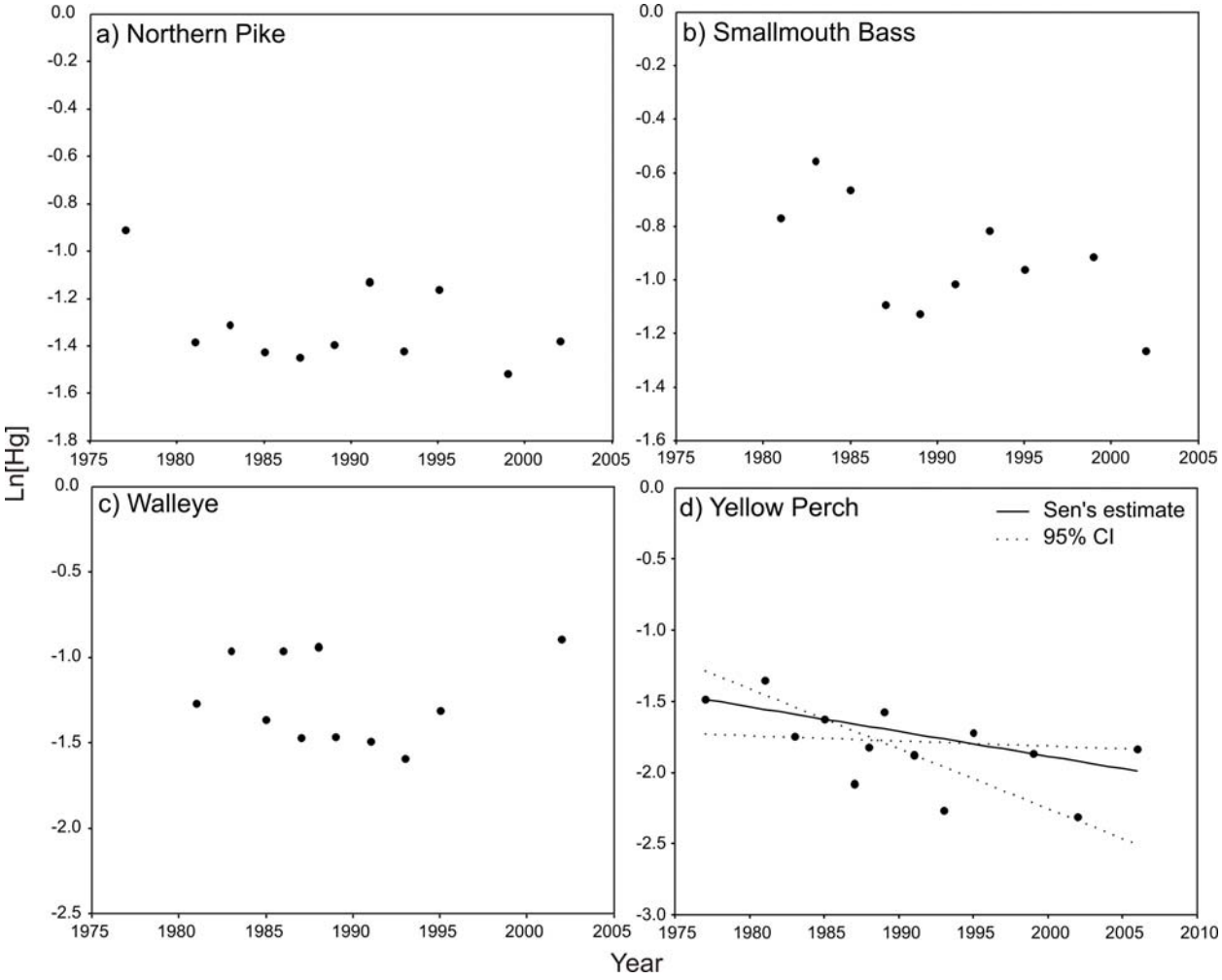


Figure 4. Plots of Hg concentrations over time for a) Northern Pike, b) Smallmouth Bass, c) Walleye and d) Yellow Perch for Block 14. Solid line indicates Sen's slope estimate and dashed lines indicate 95% confidence intervals. Mercury concentrations have significantly declined in Yellow Perch over the sampled time period in this river block (Mann-Kendall test, $p<0.05$ – see Table 1).

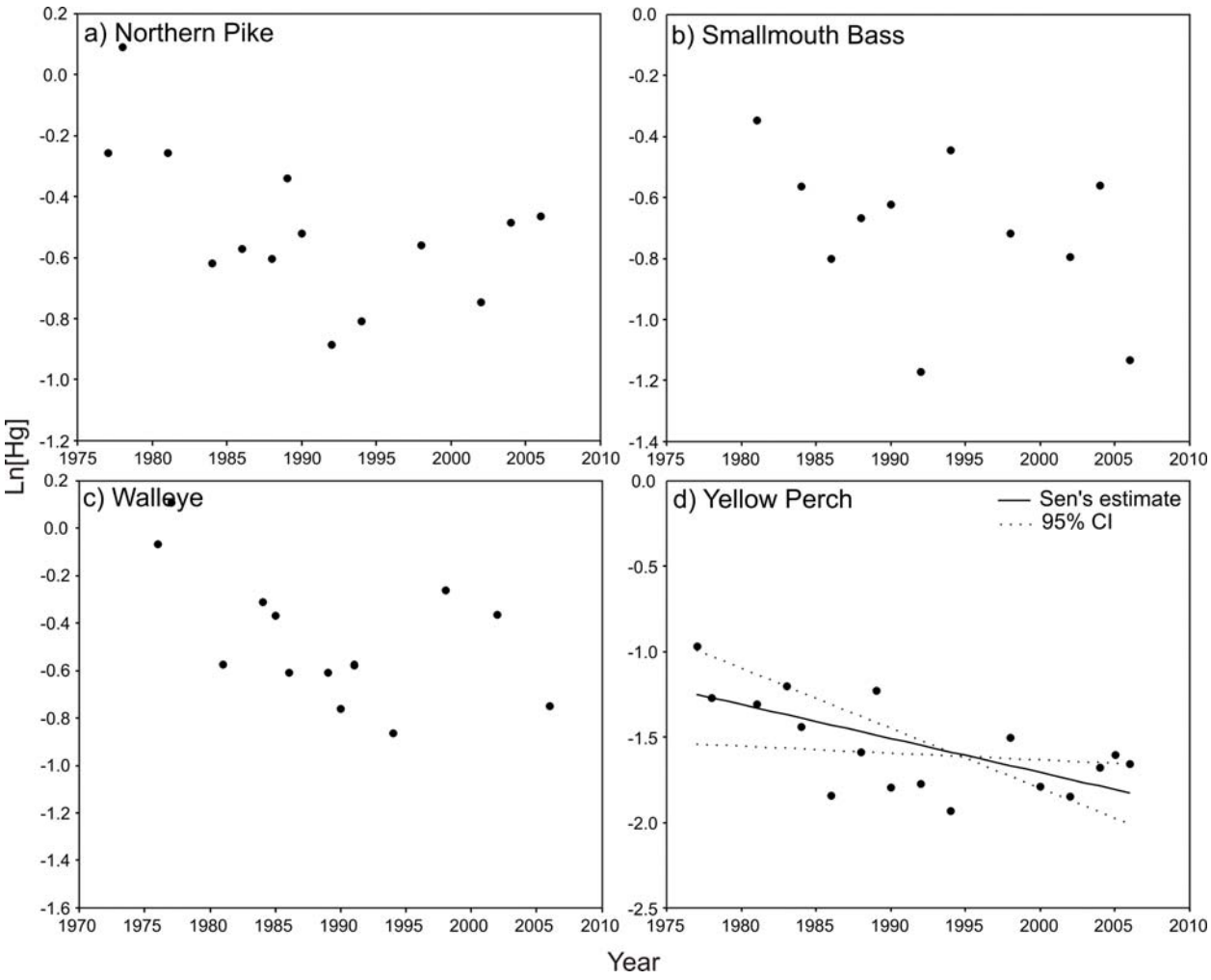


Figure 5. Plots of Hg concentrations over time for a) Northern Pike and b) Smallmouth Bass, c) Walleye and d) Yellow Perch for Block 15. Solid line indicates Sen's slope estimate and dashed lines indicate 95% confidence intervals. Mercury concentrations have significantly declined in Yellow Perch over the sampled time period in this river block (Mann-Kendall test, $p<0.05$ – see Table 1).

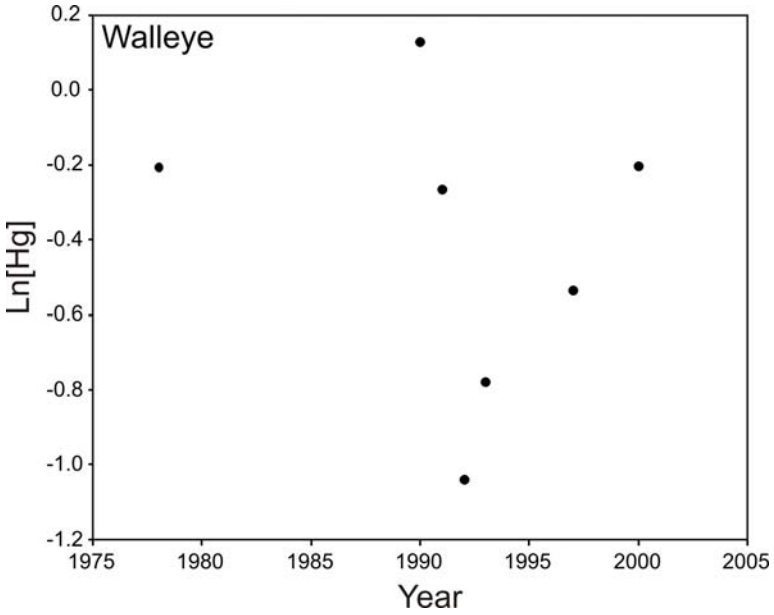


Figure 6. Plot of Hg concentrations over time with for Block 16 Walleye. There was no significant trend in mercury concentrations (Table 1).

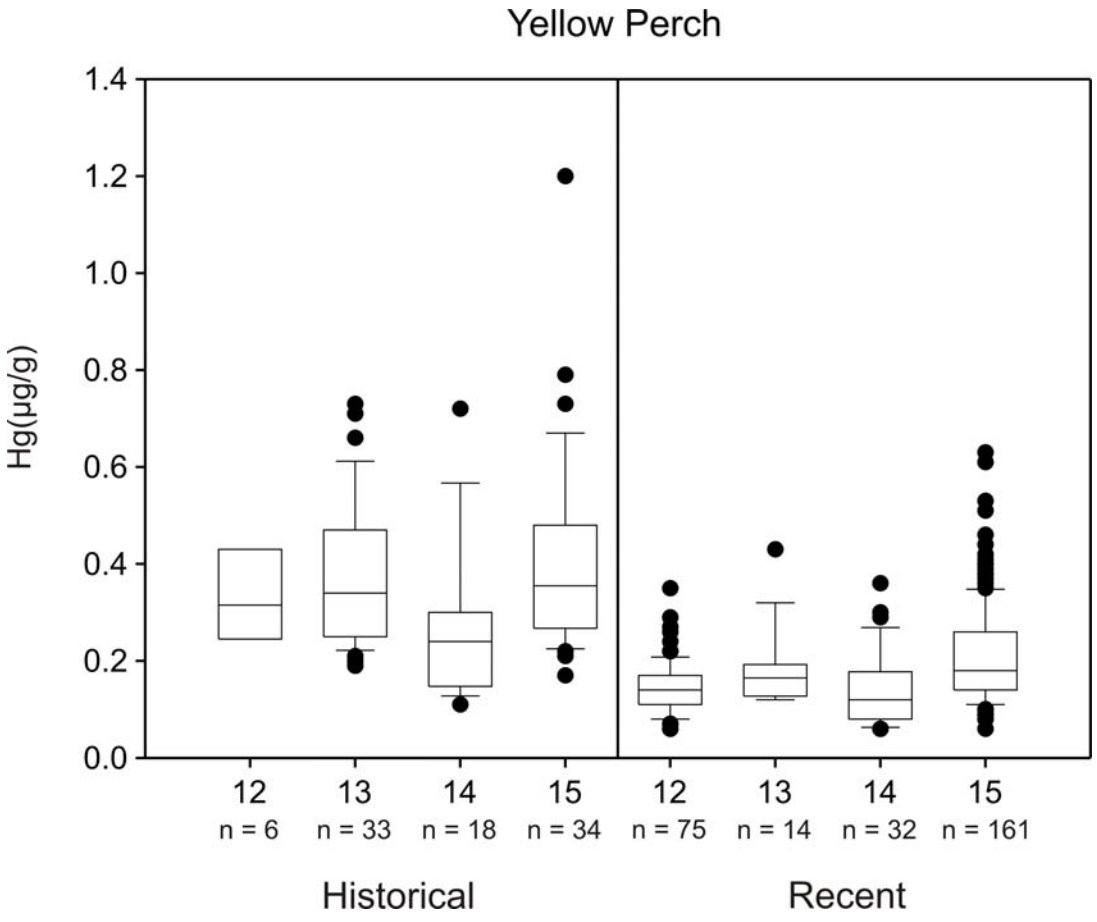


Figure 7. Box plots of historical and recent mercury concentrations for Yellow Perch in St. Lawrence River blocks 12-15. The line in each box represents the median, the box indicates the 25th and 75th quartile values, and the whiskers indicate upper and lower values not classified as outliers. Historical concentrations for blocks 15 and 13 were significantly higher than block 14, while recent concentrations for block 15 are significantly higher than blocks 12 and 14.

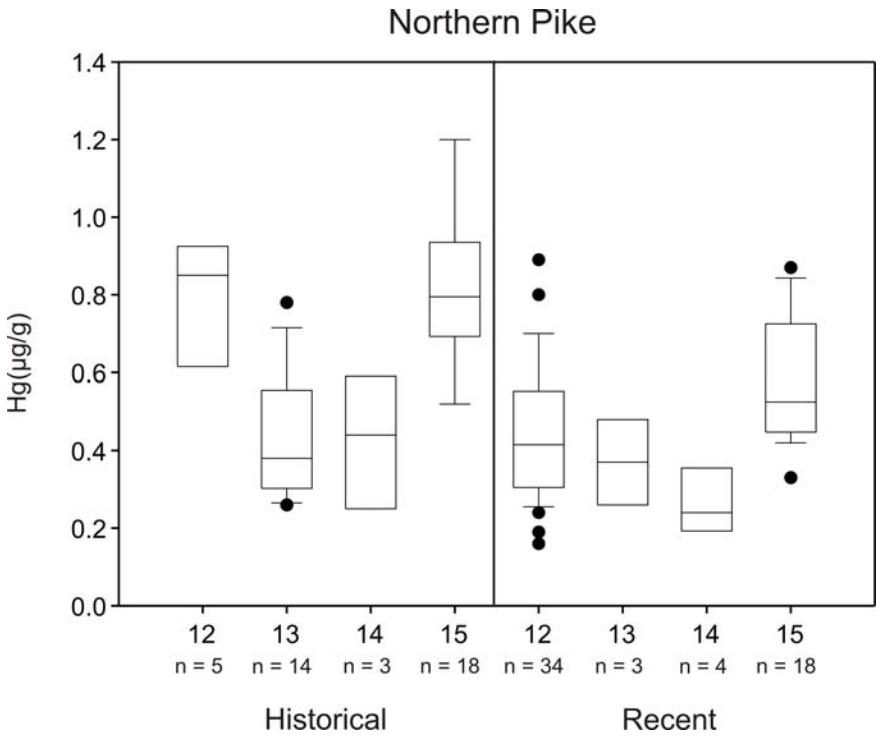


Figure 8. Box plots of historical and recent mercury concentrations for Northern Pike in St. Lawrence River blocks 12-15. The line in each box represents the median, the box indicates the 25th and 75th quartile values, and the whiskers indicate upper and lower values not classified as outliers. Historical concentrations for block 15 were significantly higher than blocks 13 and 14, and recent concentrations for block 15 were significantly higher than block 14.

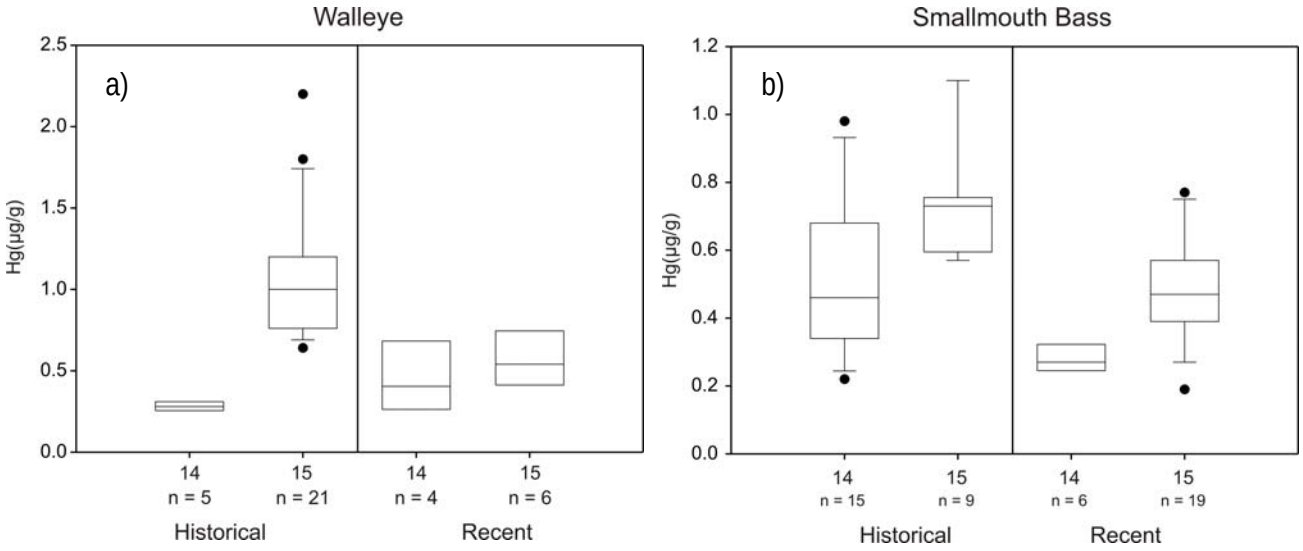


Figure 9. Box plots of historical and recent mercury concentrations for a) Walleye and b) Smallmouth Bass in St. Lawrence River blocks 14 and 15. The line in each box represents the median, the box indicates the 25th and 75th quartile values, and the whiskers indicate upper and lower values not classified as outliers. Historical Walleye mercury concentrations in block 15 were significantly higher than block 14 concentrations, but not for recent values. There were no significant differences in mercury concentrations between blocks 14 and 15 for Smallmouth Bass historically or recently.

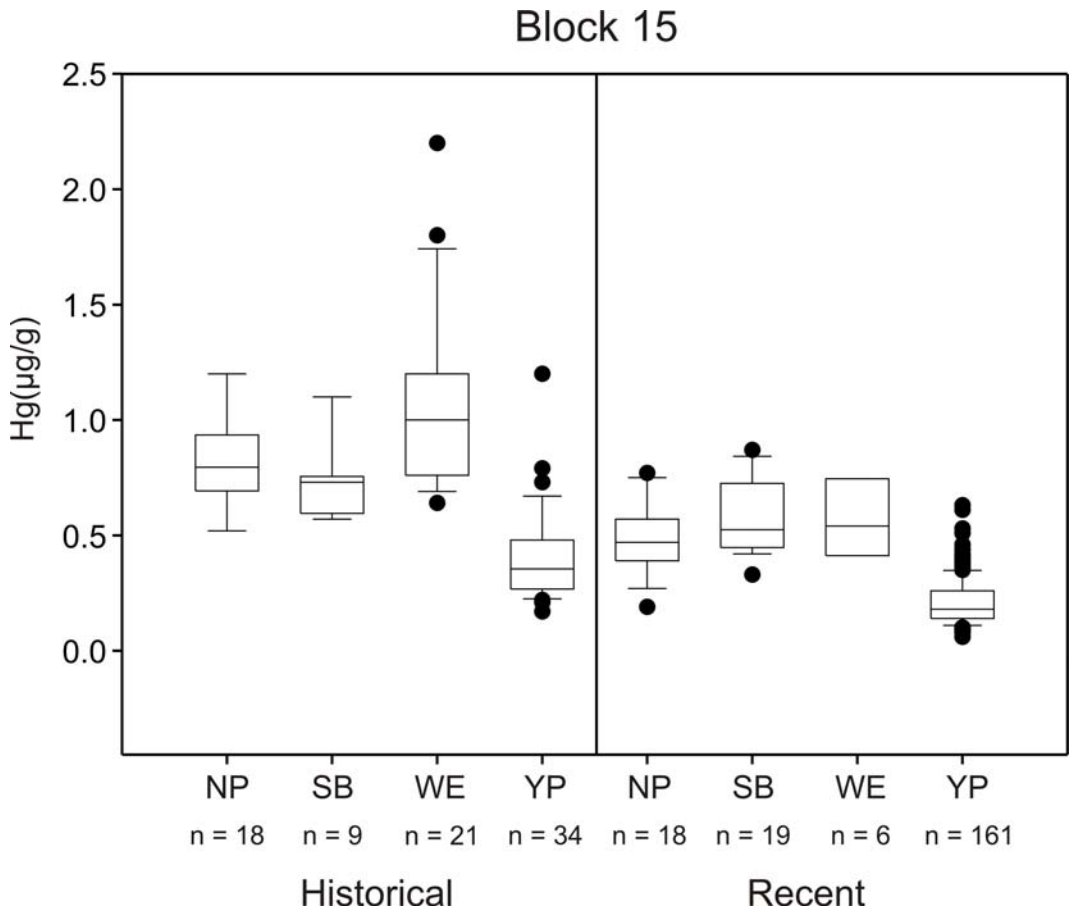


Figure 10. Box plots of historical and recent mercury concentrations for Northern Pike (NP), Smallmouth Bass (SB), Walleye (WE) and Yellow Perch (YP) in St. Lawrence River block 15. The line in each box represents the median, the box indicates the 25th and 75th quartile values, and the whiskers indicate upper and lower values not classified as outliers.